

## POSTER

**1032-1 Myocardial Contrast Echocardiography: Clinical Experience**

Sunday, March 12, 2000, Noon–2:00 p.m.  
 Anaheim Convention Center, Hall A  
 Presentation Hour: Noon–1:00 p.m.

**1032-2 Adenosine Contrast Echocardiography in 936 Consecutive Patients With Suspected Coronary Artery Disease: Experience of a Single Center**

Fernando Morcerf, Alvaro Moraes, Marcia Carrinho, Flavia Salek, Antonio C. Nogueira, Flavio C. Palheiro, Hans Dohmann. *Hospital Pro-Cardiaco and ECOR, Rio de Janeiro, Brazil*

**Background:** We have previously shown that myocardial perfusion is accurately assessed by Adenosine Contrast Echocardiography (ACE) following PESDA infusion in a relatively small group of pts with stable coronary artery disease (CAD). The aim of this study was to assess the safety and tolerance of this protocol in the clinical scenario of CAD.

**Methods:** 936 consecutive pts (660 male, 12 to 91 years) were submitted to the ACE protocol to investigate myocardial perfusion using continuous infusion of PESDA (1–2 ml/m), associated with triggered (fixed 1:1) 2<sup>nd</sup> harmonic imaging technology, at rest and after a bolus injection of Adenosine (ADN – at least 1 ampoule of 2 ml/6 mg was used for each echocardiographic view). Images were obtained at the standard apical 4-chamber and 2-chamber views. Myocardial perfusion was visually analyzed (2 independent investigators) in the territory of LAD, RCA and Cx arteries.

**Results:** PESDA infusion produced myocardial contrast and ADN bolus injection enhanced it further in at least 1 LV segment wall in all pts. 580 pts (62%) required 1 amp of ADN per view to achieve further increment of the wall contrast. 300 pts (32%) and 56 pts (6%) required 2 and 3 amp respectively to obtain the same result. A transient, asymptomatic 3<sup>rd</sup> degree AV block lasting less than 10 s was noted in 84 pts – 9% (19, 27 and 38 pts who had 1, 2 or 3 amp of ADN respectively). 122 pts (13%) complained of lightheadedness, 66 pts (7%) of headache, and, 47 pts (5%) of non-angina chest discomfort. All patients developed tachypnea. Symptoms lasted less than 30 s and did not required therapy or precluded further ADN injection is needed.

**Conclusion:** ACE protocol with PESDA infusion is safe and very well tolerated by pts with suspected CAD.

**1032-3 Temporal Change of Myocardial Capillary Flow After Attempted Reperfusion in Acute Myocardial Infarction**

Jeong Kee Seo, Jun Kwan, Hyo Jung Lee, Seong Wook Cho, Keum Soo Park, Woo Hyung Lee. *Inha University, Incheon, South Korea*

**Background:** Microvascular function after reperfusion of infarct myocardium can be changed in convalescent stage for several possible mechanisms such as hyperemia and microvascular stunning. Therefore, myocardial contrast echocardiography (MCE) performed early stage after reperfusion may cause over or underestimation of the extent of myocardial necrosis. The aims of the study were to demonstrate the temporal change of microvascular perfusion after reperfusion and to explore its association with the validity of MCE for the prediction of contractile recovery.

**Methods:** MCE was performed 5–7 days after the attack of acute myocardial infarction (AMI) in 21 patients (M:F = 17:4, age: 58 ± 12 yrs) who underwent successful restoration of infarct related artery (IRA). MCE was graded by semiquantitative score (0, 0.5, 1) by 16 segment model. Every patient underwent 1 month follow up 2D echocardiography and MCE. Improvement of wall motion score more than 1 at follow up was considered to have contractile recovery.

**Results:** Thirty-one of 71 initially akinetic segments were scored as 1, 30 as 0.5 and 10 as 0 after attempted reperfusion. Twelve of 30 segments with score of 0.5 and 5 of 10 segments with score of 0 showed late improvement to score of 1 and 0.5. Only 1 of 30 segments with score of 0.5 got worse to score of 0. Every segment with late improvement from 0.5 to 1 showed contractile recovery, whereas none of 5 segments with late improvement from 0 to 0.5 showed contractile recovery. There was no significant difference of sensitivity 100 vs 100% and specificity 35 vs 59% between early and late MCE ( $p > 0.05$  by Fisher's exact test).

**Conclusion:** Temporal change of myocardial perfusion from 1 week to 1 month in AMI was mainly of late improvement probably due to recovery of microvascular function from stunning. However, it may not significantly affect the validity of MCE in predicting contractile recovery.

**1032-3 Regional Heterogeneity in Adenosine-Augmented Videointensity in Myocardial Contrast Echocardiographic Images in Normal Humans**

Jiefen Yao, H. Joachim Nesser, Wolfgang Tkalec, Christian Ebner, Regina Steringer-Mascherbauer, Fernando Morcerf, Natesa Pandian. *St. Elisabethinen Hospital, Linz, Austria; Tufts – New England Medical Center, Boston, MA, USA*

It is known that there is significant heterogeneity in myocardial blood flow in a normal heart; it is also known that contrast enhanced 2DE images display differences in regional signal intensity. Interpretation of myocardial contrast echocardiographic (MCE) images following vasodilator such as adenosine relies on presence or absence of videointensity (VI) increase related to coronary blood flow reserve. *Whether there are regional differences in VI augmentation in MCE images following adenosine in a normal heart is not clear.*

**Methods:** To address this, baseline 2DE images and MCE images during intravenous infusion of Optison before and after bolus adenosine administration (6 mg) were obtained in a digital format, using 3 apical views at 1:1 triggering, in 10 healthy volunteers. Each view was divided into 5 segments and the mean VI was measured in each segment. Subtraction of baseline 2DE images from MCE images yielded VI caused by contrast alone, and with further augmentation by adenosine.

**Results** (mean ± SD): The VI of baseline 2DE images ranged from 8.5 to 20.5 (13 ± 4) dB among regions. The VI of MCE images was 9.4 to 23.4 (17 ± 5) dB before and 15.3 to 29.2 (22 ± 5) dB after adenosine among regions. After 2DE image subtraction, VI caused by contrast alone was 0.7 to 6.3 (3 ± 2) dB and following adenosine was 2 to 9 (6 ± 2) dB. *The magnitude of adenosine-induced increase in VI was 283 ± 312%, but ranged from as low as 0.3 folds (32%) in the basal inferior segment to as high as 13 folds (1300%) in the basal lateral segment.*

**Conclusions:** 1) There is significant regional variability in VI between segments of normal myocardium in 2DE and MCE images; 2) Following adenosine administration, there was consistent increase in VI in all segments but with significant regional differences. This implies that in the interpretation of adenosine MCE images, consideration should be given to the regional variability in VI augmentation that occurs even in normal myocardium.

**1032-4 Quantitative Myocardial Perfusion Studies: Comparison of Pulse Inversion Technique, Harmonic Power Doppler and Second Harmonic Imaging With Simultaneous Technetium SPECT Studies**

Helene von Bibra, Urban Niklasson, Dianna Bone, Mats Fröman, Flemming Larsen. *Dept. of Clinical Physiology, Karolinska Hospital, Stockholm, Sweden*

**Objective:** Three modern imaging modalities have been designed to detect specific bubble signature in myocardial perfusion studies: Pulse inversion technique (PI), harmonic power Doppler (PD) and second harmonic imaging (SH). A comparative, quantitative evaluation, however, has not yet been performed, nor has the clinical utility been evaluated by comparison to simultaneous scintigraphic perfusion studies (SPECT).

**Methods:** Dipyridamole (0.84 mg/kg) stress tests were performed in 23 patients with suspected ischemic heart disease, followed by i.v. injection of the radioactive tracer (Tc-tetrofosmin) and three doses of Optison® (0.3 ml). Triggered (0.5 Hz) ultrasound images were acquired using an ATL HDI 5000 system before and during the contrast injection in SH, PD and PI mode at rest and during stress. The digital data were analysed for myocardial signal intensity (SI) in the basal and apical segments, using dedicated software (HDI lab). Tomographic image acquisition was performed using a dual headed gamma camera (SMV). The LV section corresponding to the echocardiographic 4-chamber view was reconstructed and analysed in the corresponding 4 regions of interest (ROI).

**Results:** In a total of 92 ROIs, SI increase was 5.0 ± 3.3 dB in PI, 4.9 ± 2.7 dB in PD and 3.6 ± 2.3 dB in SH ( $p < 0.002$  vs PI) at rest and 4.8 ± 3.0, 6.1 ± 3.3 and 4.7 ± 2.6 dB at stress. Normal tracer uptake was measured in 9 patients and a reversible perfusion defect in 14 patients by SPECT. Concordant microbubble uptake was observed in 19 patients by PI and in 17 patients both by HI and PD mode. Image resolution was best with PI. PD was limited by attenuation artifacts in 4 patients.

**Conclusion:** These results indicate, that the information obtained by the new technique pulse inversion technique is in closer agreement with SPECT data than are second harmonic and power Doppler imaging.

### 1032-5 Fate of Collateral Circulation After Successful Coronary Angioplasty of Chronic Total Occlusion Assessed by Coronary Angiography and Myocardial Contrast Echocardiography

Jong-Won Ha, Seung-Yun Cho, Dong-Hoon Choi, Yangsoo Jang, Won-Heum Shim, Byung-Joo Choi, Se-Joong Rim, Namsik Chung, Sung-Soon Kim. *Yonsei University College of Medicine, Seoul, Korea*

**Background:** A well-developed collateral circulation (CC) is frequently observed in patients with total coronary occlusion. However, the fate of CC after successful coronary angioplasty (PTCA) is not clearly defined. The purpose of this study was to assess the temporal change of CC after successful PTCA of a chronically occluded artery using coronary angiography (CA) and myocardial contrast echocardiography (MCE).

**Methods:** The study group comprised 18 consecutive patients (14 male, mean age 53 years) who underwent elective PTCA for chronic total occlusion. CA and MCE were performed before, immediately after and 24 hrs after PTCA. MCE was performed by intracoronary injection of sonicated radiographic contrast medium. According to the 3 as follows: 0 = no visible filling; 1 = collateral filling of side branches; 2 = partial collateral filling of the epicardial artery; 3 = complete filling of the epicardial artery. On MCE, myocardial perfusion by CC was assessed by scoring the contrast pattern of collateral-dependent myocardial segments as follows: 0, none; 0.5, patchy or epicardial; or 1, homogenous.

**Results:** Left anterior descending artery was occluded in 11 patients and right coronary artery in 7 patient. CA collateral grade before PTCA was grade 2 in 6 patients and grade 3 in 12. PTCA with stenting was successfully performed in all patients without significant residual stenosis. CA showed CC disappeared after PTCA in all patients. However, residual collateral perfusion was observed in 6 patients by MCE performed immediately after PTCA (score 1 in 3 patients; score 0.5 in 3 patients). This residual collateral perfusion could be demonstrated even 24 hrs after PTCA by MCE in 2 patients.

**Conclusion:** Although angiographically not visible, coronary CC may persist after successful PTCA of a chronically occluded artery. MCE is a useful clinical tool in the evaluation of temporal change of CC after PTCA.

### 1032-6 Comparison of Adenosine Infusion and Adenosine Bolus in Myocardial Contrast Echocardiography (Optison) for Detection of Coronary Artery Disease Using Nuclear Imaging as the Independent Standard

H. Joachim Nesser, Jiefen Yao, Wolfgang Tkalec, Christian Ebner, Regina Steringer-Mascherbauer, C. Ng, Bernhard Markt, Fernando Morcerf, Natesa Pandian. *St. Elisabethinen Hospital, Linz, Austria; Tufts – New England Medical Center, Boston, MA, USA*

Adenosine infusion (AI) is an established method for detection of coronary artery disease (CAD) in nuclear imaging. In myocardial contrast echocardiography (MCE), adenosine bolus (AB) has been shown to be useful. *The diagnostic accuracy of AI for unmasking perfusion abnormalities by MCE is not yet known.*

**Methods:** 64 pts (64 ± 12 yrs, 35 M, 29 F) referred to the nuclear laboratory for evaluation of CAD underwent Dipyridamole Thallium SPECT and, within a week, MCE with AB (6±12 mg) and AI (140 µg/kg/min for 6 min) in a randomized sequence employing i.v. infusion of Optison. MCE images were acquired in 3 apical views with 1:1 triggering with AB, and 1:1 and 1:4 triggering during AI. A blinded observer interpreted these images and noted the presence/absence of reversible and fixed perfusion abnormalities. MCE results were compared to SPECT findings.

**Results:** Of 64 pts, good quality MCE images were available in 56 pts. SPECT showed reversible or fixed defects in 25 pts and normal scans in 131. AI and AB had comparable accuracy in the detection of CAD and in the identification of abnormal territories (table). Only one pt had prolonged ischemia following AI that required aminophylline. No pt had major complications.

	Detection of CAD		Identification of Abnormal Territory	
	AI	AB	AI	AB
Sensitivity	77%	81%	66%	61%
Specificity	87%	90%	95%	92%
+Predictive Value	83%	88%	81%	70%
–Predictive Value	81%	84%	91%	89%
Overall Accuracy	82%	86%	89%	85%

**Conclusions:** 1) both adenosine infusion and adenosine bolus protocols are accurate in the detection of CAD by MCE, 2) they appear to have similar diagnostic accuracy in the identification of the territory involved, and 3) both protocols are practical and safe for performing MCE in humans.

### 1032-7 Improvement in Myocardial Contrast Opacification Patterns After Myocardial Infarction: Their Relation to Myocardial Viability

Hajime Kihara, Hitoshi Takahashi, Ayumi Ono, Masatoshi Fukunishi, Yasuhiko Ibaragi, Takao Tanaka, Ai Murakami, Hirohumi Kawamata<sup>1</sup>, Hiroshi Takahashi<sup>1</sup>. *Kihara Cardiovascular Hospital, Asahikawa, Hokkaido; <sup>1</sup>The 2nd. Internal Medicine, Nihon University Tokyo, Japan*

**Purpose:** To analyze the relations between the early changes of the degree of contrast opacification of the risk area and their contractile reserve and regional systolic functional recovery in patients with reperfused acute myocardial infarction (AMI)

**Methods:** 19 patients (15 men, 4 women; 63.5 ± 7.8 years old) who underwent coronary revascularization within 6 hours of the onset, were analyzed. The infarct-related coronary arteries consists of 12 LAD, 4 LCX, and 3 RCA. We performed intracoronary MCE immediately after successful reflow and 14 days later. 3 ml of sonicated loxaglate was injected into the infarct related coronary artery. During these procedures, the apical 4 ch. view and 2 ch. view of 2 dimensional echo images were recorded on videotape. Contrast opacification patterns of the risk area were classified into 3 levels; homogenous opacification, patchy opacification, and no opacification. We compared the contrast opacification patterns of the risk area between the immediately after revascularization and 14 days later in each patient.

Comparing the contrast opacification patterns between 2 periods, we divided 19 patients into 3 groups; group A (homogenous→homogenous), group B (patchy→homogenous, no opacification→patchy) and group C (patchy→patchy, no opacification→no opacification) Low dose dobutamine (5–10 µg/kg/min) stress echocardiography was also performed 10 days after the onset of acute myocardial infarction. During dobutamine infusion, apical 4 ch. view and 2 ch. view were recorded. We defined contractile reserve positive (+) as a risk area which showed improvement in wall motion as a result of dobutamine infusion.

Furthermore quantitative computer analyses were also made by dividing LV into 6 equiangular segments to evaluate the regional LV systolic function of the risk area [seg. FAC (%)] The difference of seg. FAC (%) immediately after revascularization and 6 weeks after the onset was expressed as Δseg FAC (%)

**Results:** The relationship between the early change of contrast opacification patterns and contractile reserve and systolic functional recovery of the risk area

	Contractile reserve	ΔSeg. FAC (%)
Group A (n: 5)	(+)	20% (mean)
Group B (n: 10)	(+)	27% (mean)
Group C (n: 4)	(–)	3% (mean)

**Conclusion:** Early improvement in contrast opacification patterns of the risk area suggests the existence of contractile reserve and late systolic functional recovery.

### 1032-8 Improved Power Doppler Imaging of Normal Myocardial Contrast Using a New Dual-Frame Trigger Harmonic Angio Algorithm

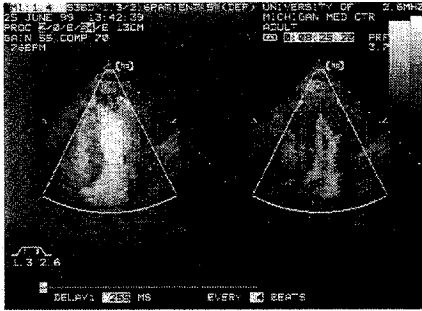
Peng Li, Thippeswamy H. Murthy, Cheryl Baisch, William Armstrong, Mani Vannan, Patrick Rafer. *University of Michigan, Ann Arbor, Michigan; Hewlett-Packard, Andover, Massachusetts, USA*

**Background:** Non-uniform regional myocardial signal intensities and artifacts in the reference frame (second frame) of the dual-frame trigger are among the limitations of Doppler imaging of myocardial contrast. We used a newer system (Hewlett-Packard) with 1) a lower transmit frequency of 1.3 MHz 2) smaller number of ultrasound pulses (five) and 3) an efficient filter setting to better eliminate artifacts in the reference frame in the dual-frame trigger method.

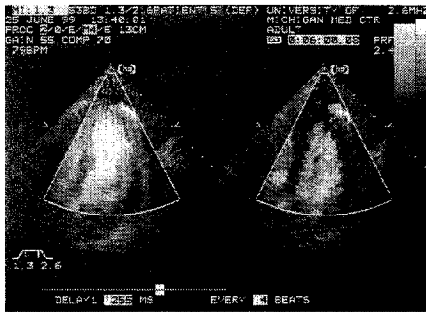
**Methods:** We performed dual-frame trigger, myocardial contrast echocardiography (MCE) with IV Optison™ infusion (26 individuals – 16 normal volunteers and 10 patients with normal SPECT) and Definity infusion (12 normal volunteers) in subjects selected for good acoustic windows.

**Results:** The figures show representative examples with Definity™ and Optison™ MCE. Focus was set at the upper one-third of the sector and there was uniform filling of the myocardium in normals. The destruction frame was almost completely clear of myocardial contrast. There was excellent correlation between nuclear perfusion and Power Doppler MCE in the subgroup of 10 patients with SPECT.

**Conclusion:** A more uniform power in the ultrasound field using lower transmit frequency enhances Power Doppler detection of myocardial microbubble signals and improves the utility of the dual-frame trigger method.



Definity™ MCE



Optison™ MCE

POSTER

**1033 Computed Tomography/Magnetic Resonance Imaging: Coronary Imaging**

Sunday, March 12, 2000, Noon–2:00 p.m.  
 Anaheim Convention Center, Hall A  
 Presentation Hour: Noon–1:00 p.m.

**1033-25 Detection of High-Grade Restenosis After Coronary Angioplasty Using Noninvasive Contrast-Enhanced Magnetic Resonance Imaging and Electron Beam Computed Tomography in 105 Patients**

Dieter Ropers, Stephan Achenbach, Susanne Birke, Matthias Regenfus, Werner G. Daniel, Werner Moshage. *Department of Cardiology, University of Erlangen-Nürnberg, Germany*

**Background:** Magnetic resonance imaging (MRI) and electron beam computed tomography (EBCT) both have been shown to permit noninvasive coronary angiography. We compared the accuracy of contrast-enhanced MRI and EBCT to detect high-grade restenosis after balloon angioplasty (PTCA).

**Methods:** Contrast-enhanced MRI and was performed in 105 patients (81 men, 24 women, age 38 to 87 years) after PTCA of high-grade coronary artery stenoses (mean interval of 36 months after angioplasty). By EBCT, 50 axial images (3 mm slice thickness, 1 mm overlap, 100 ms acquisition time) of the coronary arteries were acquired during intravenous injection of contrast agent (160 ml iopromide at 4 ml/s). MRI was performed using navigator-echo-based respiratory gated sequences (24–48 axial cross-sections, 2 mm slice thickness, TE 2.7 ms, TR 7.4 ms, 1.17 × 1.17 mm<sup>2</sup> in-plane resolution, 20 ml gadolinium i.v.). EBCT and MR images were independently evaluated concerning high-grade restenosis (>=75%) or occlusion at the former PTCA segment. All results were validated against invasive, quantitative coronary angiography performed within 3 days after EBCT and MRI.

**Results:** In MRI, 30 patients (29%) and in EBCT, 25 patients (24%) were unevaluable due to reduced image quality and therefore excluded from further evaluation. In the remaining patients, MRI demonstrated 67% sensitivity and

49% specificity for detection of high-grade restenosis or occlusion. EBCT showed 93% sensitivity and 65% specificity (see table).

**Conclusion:** In a direct comparison, contrast-enhanced EBCT demonstrated higher accuracy than navigator-echo MRI for the detection of high-grade restenosis after PTCA.

**1033-26 Noninvasive Coronary Angiography Using Contrast-Enhanced Magnetic Resonance Imaging and Electron Beam Computed Tomography: Comparison of the Contrast-To-noise Ratio**

Dieter Ropers, Stephan Achenbach, Matthias Regenfus, Susanne Birke, Werner G. Daniel, Werner Moshage. *Department of Cardiology, University of Erlangen-Nürnberg, Germany*

**Background:** Magnetic resonance imaging (MRI) and electron beam computed tomography (EBCT) both have been shown to permit noninvasive coronary angiography. Since the contrast-to-noise-ratio (CNR) heavily influences image quality and diagnostic accuracy, we compared the CNR in current protocols for contrast enhanced coronary imaging by MRI and EBCT.

**Methods:** 73 patients were studied by EBCT (40 axial cross-sections, 3 mm slice thickness, 160 ml iopromide) and respiratory gated MRI (navigator-echo three-dimensional gradient-echo sequence, 2 mm slice thickness, 20 ml gadolinium). Both in EBCT and MRI CNR (defined as the difference between the signal intensity in the vessel and the surrounding tissue, divided by the standard deviation of the signal intensity measured in the aortic root) was determined for the left main (LM), left anterior descending (LAD), left circumflex (LCX), right coronary artery (RCA) and for the great cardiac vein.

**Results:** For all coronary arteries combined and in every single coronary vessel, CNR was significantly higher in EBCT than in MRI (see table). The difference in CNR between arteries and veins was significantly higher in EBCT than in MRI (see table).

Mean CNR	All arteries	LM	LAD	LCX	RCA	Veins
EBCT	12.97 ±3.35	13.68 ±2.55	12.78 ±3.45	11.91 ±2.95	13.56 ±3.98	8.43 ±2.48
MRI	6.69 ±2.99	6.47 ±2.50	6.34 ±2.63	6.51 ±2.90	7.41 ±3.54	4.39 ±2.30
P value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

**Conclusion:** Non-invasive contrast-enhanced coronary angiography by electron beam CT yields a higher contrast-to-noise-ratio than current magnetic resonance imaging protocols.

**1033-27 Coronary Calcifications as a Cause of False Positive and False Negative Results of Noninvasive Angiography With EBCT**

Ralph Haberl, Olaf Muehling, Alexander Becker, Alexander Leber, Andreas Knez, Christoph Becker<sup>1</sup>, Anja Maass, Roland Bruening<sup>1</sup>, Maximilian Reiser<sup>1</sup>. *Medical Hospital I, <sup>1</sup>Department of Radiology, University of Munich, Munich, Germany*

Contrast enhanced angiography with electron beam computed tomography (EBCT) allows visualization of the proximal part of coronary arteries accurately enough to detect or to exclude coronary stenoses. One major cause of pitfall are calcified plaques. We therefore studied the impact of calcifications on the results of CT angiography (CTA) in 160 patients, 84 of whom had significant coronary stenoses ≥ 75% with conventional angiography requiring intervention. CTA used 40 slices of 3 mm thickness, scan time was 100 msec. Shaded surface display, maximum intensity projection and volume rendering were applied. Calcifications were measured by calculating the volume score. We found a total of 224 calcified plaques > 12 mm<sup>2</sup> with a predominance in the LAD, depending on age and extent of coronary disease. 70% of the calcified plaques were located in the proximal 4–5 cm of the coronary arteries, 78% of significant stenoses in conventional angiography were located also in this area. In 56/92 (61%) stenoses there was a calcified plaque > 12 mm<sup>2</sup> in the target region of coronary intervention. In 35/92 cases CTA failed to detect stenoses, because significant calcification made adequate analysis impossible. Plaque density was very similar to contrast enhancement in 17 cases of CTA thereby masking stenoses. In 13 cases false positive stenoses were diagnosed with CTA due to contrast extinction in the vicinity of coronary calcification.

Thus, coronary calcifications may mask or mimic coronary stenoses in a significant number of cases making CTA with EBCT an unreliable tool for routine screening of coronary stenoses.

	Evaluation Possible	Sensitivity	Specificity	Predictive value	
				Positive	Negative
MRI	71% (75/105)	67% (8/12)	49% (31/63)	20% (8/40)	89% (31/35)
EBCT	76% (80/105)	93% (14/15)	65% (42/65)	38% (14/37)	98% (42/43)

### 1033-28 Diagnostic Value of 2- and 3-Dimensional Image Reconstruction Techniques for the Detection of Coronary Artery Stenoses by Contrast-Enhanced Electron-Beam CT

Stephan Achenbach, Dieter Ropers, Matthias Regenfus, Gerd Muschiol, Werner G. Daniel, Werner Moshage. *Department of Cardiology, University of Erlangen-Nürnberg, Germany*

**Background:** Electron-beam CT (EBCT) permits visualization of the coronary arteries and detection of stenoses after intravenous injection of contrast agent. Various 2- and 3-dimensional forms of image reconstruction have been applied to evaluate the data sets. We compared 4 methods of image evaluation concerning their accuracy to visualize coronary stenoses.

**Methods:** In 50 patients, 40–50 axial images of the heart were acquired by EBCT after i.v. injection of contrast agent (3 mm slice thickness, 1 mm overlap, ECG trigger at 40% of the cardiac cycle). Next to evaluation of the cross-sectional source images, maximum intensity projections (MIP), curved multiplanar reconstructions (MPR), and 3-dimensional shaded surface display reconstructions were independently assessed concerning the presence of high-grade coronary artery stenoses and occlusions in the proximal and mid segments of coronary arteries. Results were compared to invasive coronary angiography in a blinded fashion.

**Results:** A total of 200 arteries were assessed (left main, left anterior descending, left circumflex, and right coronary artery in 50 patients). In the evaluable arteries, source images and MIP reconstructions yielded highest accuracy (sensitivity 89% and 93%, specificity 90% and 87%, respectively). Joint evaluation of all forms of reconstruction yielded 93% sensitivity and 88% specificity (see table).

	Evaluable	Sensitivity	Specificity
Source Images	83% (166/200)	89% (22/27)	90% (126/139)
MIP	84% (168/200)	93% (25/27)	87% (122/141)
MPR	82% (163/200)	76% (19/25)	86% (118/138)
SSD	82% (164/200)	52% (13/25)	92% (128/139)
Joint Evaluation	84% (167/200)	93% (26/28)	88% (123/139)

**Conclusion:** Analysis of the unprocessed source images is sufficient for the detection of high-grade stenoses and occlusions in contrast-enhanced data sets of the coronary arteries. Of the investigated image reconstruction methods, MIP was most accurate.

## POSTER

### 1034 Stress Myocardial Perfusion Imaging: Diagnosis and Prognosis

Sunday, March 12, 2000, Noon–2:00 p.m.  
Anaheim Convention Center, Hall A  
Presentation Hour: Noon–1:00 p.m.

### 1034-29 Prognostic Significance of Transient Ischemic Dilatation of the Left Ventricle in Normal Dual-Isotope Myocardial Perfusion SPECT

Shay Livschitz, Daniel S. Berman, Raluca Agafitei, Xingping Kang, Naoya Matsumoto, Ishac Cohen, Sean W. Hayes, John Friedman, Howard C. Lewin, Guido Germano. *Cedars-Sinai Medical Center, Los Angeles, CA, USA*

**Background:** Transient ischemic dilatation (TID) of the left ventricle on stress myocardial perfusion SPECT (MPS) has been shown to be a useful marker for detecting severe and extensive coronary artery disease (Mazzanti et al: JACC 1996). However, the prognostic significance of TID in the presence of normal perfusion has not been evaluated.

**Methods:** We assessed 2892 consecutive pts who underwent rest/stress dual-isotope MPS and were followed for  $\geq 1$  year (average  $20 \pm 4$  months) for hard events (HE: cardiac death and myocardial infarction) as well as soft events (SE: catheterization or revascularization). Pts with early revascularization were censored from prognostic analysis. Two expert readers interpreted MPS using a 20 segment analysis and a 5 point scale (0 = normal, 4 = no uptake). TID was assessed automatically using commercially available software (QGS). A summed stress score (SSS)  $< 4$  and a TID ratio  $\leq 1.22$  were considered normal. Patient groups with TID above and below normal were compared with respect to HE and SE.

**Results:** We identified 1405 (48.6%) pts with a normal SSS, 52% male, aged  $65 \pm 10$  years. TID ratio  $> 1.22$  was present in 213 (15.2%) pts and  $\leq 1.22$  in 1192 pts (84.8%). A total of 16 (1.1%) HE and 151 (10.7%) SE occurred, 99 (7%) catheterizations and 52 (3.7%) revascularization. No

significant differences were observed between pts with and without TID regarding HE and SE ( $p = 0.27$  and  $0.11$  respectively).

**Conclusion:** The presence of TID in pts with normal rest/stress MPS does not appear to have clinical prognostic significance.

### 1034-30 Prediction of Outcomes in Patients With Suspected or Known Coronary Artery Disease (CAD) by Tc-99m Tetrofosmin Stress Myocardial Perfusion Imaging Studies

Salvador Borges-Neto, Linda K. Shaw, Gregory C. Ravizzini, Steven Mast, R.E. Coleman. *Duke University Medical Center, Durham, NC, USA*

**Background:** Despite the well established prognostic value of myocardial perfusion scintigraphy, limited information is available regarding the tracer Tc-99m Tetrofosmin. The purpose of this investigation was to evaluate the relative contribution and potential incremental prognostic value, of this newest clinically available stress perfusion imaging agent, in patients with suspected or known CAD.

**Methods:** We studied 479 consecutive patients that underwent stress myocardial perfusion imaging with Tc-99m Tetrofosmin that were followed for a maximum of 3 years and an average of 113 days. Sum stress score (SSS) and sum reversibility score (SRS) were calculated to estimate the severity and extent of stress induced perfusion abnormalities. Cox proportional hazard models were used to assess the relationship between independent predictors and the composite end-point of hard events (16 death and non-fatal MI) and revascularization procedures (62 events).

**Results:** Univariable models demonstrated that all variables were significant predictors of the composite endpoint: clinical index:  $\chi^2 = 25.5$ ,  $p = < 0.001$ ; SSS:  $\chi^2 = 4.9$ ,  $p = 0.03$ ; SRS:  $\chi^2 = 18.8$ ,  $p = < 0.001$ . Using multivariable models, stress perfusion imaging (SRS) provided incremental prognostic information after adjusting for significant clinical predictors (Table).

	Chi-square	p-value
Clinical	25.5	<0.001
Clinical + SSS	27.4	<0.001
Clinical + SRS	36.0*	<0.001

\*  $p = 0.001$  incremental contribution of stress imaging

**Conclusions:** Tc-99m Tetrofosmin stress perfusion imaging studies are strong predictors of events in patients with suspected or known CAD, and provide incremental prognostic information to that provided by clinical variables alone.

### 1034-31 Time-Varying Hazard Rates in Diabetic and Non-Diabetic Patients With Normal Dipyridamole Stress Myocardial SPECT in Suspected Coronary Artery Disease

Dong Soo Lee, Gi Jeong Cheon, Myoung Jin Jang, Keon Wook Kang, Jeong Seok Yeo, Myoung Mook Lee, June-Key Chung, Myoung Chul Lee. *Seoul National University College of Medicine, Seoul, Korea*

**Background:** Normal findings on stress myocardial SPECT could predict good prognosis in patients with suspected coronary artery disease (CAD). However, long term follow-up revealed hazard rates changed with time. This study aimed at finding the change points of hazard rates in patients with normal SPECT according to diabetes (DM) and pretest likelihood.

**Methods:** We followed up 522 patients (M:F = 260:262, age =  $58 \pm 10$ , DM:non-DM = 147:375) in whom dipyridamole stress myocardial SPECT was performed with the suspicion of CAD (follow-up period: 2 months – 8.6 years, mean: 3.6 years). They had no prior history of revascularization. Cardiac events were defined as evolution of cardiac death, acute myocardial infarction, congestive heart failure, or revascularization treatment after two months. Change points of hazard rates in event-free survival curves were examined using likelihood ratio method of Siegmund.

**Results:** There were 7 cardiac events in 147 DM patients and 10 cardiac events in 375 non-DM patients. Annual cardiac event rates of DM and non-DM patients with normal SPECT were 1.22% and 0.76%, respectively. In DM patients, hazard rate increased significantly after 4.8 years regardless of the pretest likelihood. In non-DM patients, hazard rate did not change, however, hazard rate increased significantly in a subgroup of these non-DM patients with high pretest likelihood ( $n = 120$ ) after 4.4 years.

**Conclusion:** Hazard rate increased after a certain period in diabetic patients regardless of pretest likelihood and also in non-diabetic patients with high pre-test likelihood, who showed normal stress myocardial perfusion SPECT. Though normal SPECT predicted benign prognosis, diabetic patients need re-evaluation later within 4 years regardless of their pretest likelihood.

**1034-32 Description of a Cost Analysis Model for Performance of Myocardial Perfusion SPECT Imaging**

Timothy M. Bateman, James A. Case, Manuel D. Cerqueira, Khaldoon Alaswad. *Cardiovascular Consultants, P.C. Kansas City, MO; Georgetown University Medical Center, Washington, D.C., USA*

**Introduction:** Congress recently mandated HCFA to change the reimbursement structure for services to Medicare patients to reflect actual costs incurred by the provider. Because such data does not currently exist for SPECT myocardial perfusion imaging, we developed an analysis model to identify and measure the associated costs.

**Methods:** Expense categories included personnel, equipment, facility-associated, supplies, and pharmaceuticals. Data were derived from surveys conducted by the American College of Cardiology, Abt Associates through Clinical Practice Expert Panels (CPEPs), and time and motion studies performed at 3 outpatient and 3 hospital-based labs. Personnel, equipment and supplies expenses; useful life estimates; and amortization schedules were derived from HCFA supplied data. Cost/test was calculated for 2 hypothetical "typical" labs: one performing 3 studies/day using a single-detector camera (A), and the other 4-studies/day (B).

**Results:** Personnel, facility and equipment costs (all relatively "fixed") accounted for 52% and 62% of the expense structure of labs A & B, respectively. Cost/test was markedly volume driven being 20% higher in Lab A. HCFA data did not capture such substantive costs as those associated with NRC licensure, hot lab set up and maintenance, equipment service/maintenance, QA routines, physics consultants, radiation safety, delivery charges, and management.

**Conclusions:** Detailed analysis of costs for individual medical procedures is achievable, providing important insight into cost structure. This data can be used to compare costs between labs, evaluate efficiencies, and track the impact of changes in lab structure and function. Furthermore, employing a standardized template may provide useful information for deriving appropriate reimbursements.

**1034-33 Strategies for Selecting Patients for Stress Testing to Avoid Unnecessary Myocardial Imaging**

Andrew M. Barnstein, Tina M. Sias, Denny D. Watson, George A. Beller. *University of Virginia, Charlottesville, VA, USA*

We examined strategies to eliminate unnecessary SPECT in 48 patients with normal resting ECG referred for combined graded exercise test (GXT) and SPECT. A pretest questionnaire was developed to provide a 0-5 level symptomatic classification. Conditional probability analysis (Bayes) was used to rule out CAD whenever probability of CAD was <5%. ROC analysis of the chest pain score showed excellent predictive accuracy for normal patients (pts) with area of 0.88 under the ROC curve ( $p < 0.0001$ ). The first strategy was to perform GXT alone on all patients with chest pain scores of 0 or 1 and without prior CABG or MI. This strategy would have selected 16/48 (33%) for initial GXT only. Nine of 16 would have required a second GXT with SPECT because GXT and Bayes left post GXT probability of CAD > 5%. All of these were reduced to  $p < 5\%$  after SPECT. This reduced the number of SPECT procedures by 7 and increased the number of GXT by 9 for a net cost reduction. A 2nd strategy was to use pre GXT Bayes and not perform SPECT if pre GXT  $p < 5\%$ . This would have eliminated all double testing but eliminates unnecessary SPECT in only 5/48 pts. Using GXT without SPECT in patients with chest pain score of 2 or 3 would have identified only 1 of 20 in this classification to have  $p < 5\%$  after GXT alone. This would have eliminated only 1 SPECT and resulted in 19 double GXT tests for a net increase in cost.

This pilot study shows that we can reduce overall cost without significant compromise in predictive accuracy to rule out CAD in patients with normal baseline ECG. However, careful and sophisticated selection strategies are necessary in order to avoid excessive double testing of patients who cannot be definitively diagnosed after clinical evaluation and GXT alone.

**1034-34 Utility of Dipyridamole Tc-99m Sestamibi SPECT Myocardial Perfusion Imaging to Predict Short-Term Cardiac Events Following Primary Angioplasty**

Abdul M. Alkeylani, Darshak H. Karia, Domenic Marini, Deborah Katten, Dakshina R. Murthy, Satyendra Giri, Ross Prpic, Jeffrey J. Popma, David D. Waters, Gary V. Heller. *Hartford Hospital, Hartford, CT, USA*

**Background:** Primary percutaneous transluminal coronary angioplasty (1<sup>o</sup> PTCA) is a proven first line treatment for acute myocardial infarction (AMI) with few short term cardiac events in this population. The relationship between cardiac events and dipyridamole Tc-99m sestamibi SPECT imaging (DIP-MIBI) following 1<sup>o</sup> PTCA is unknown.

**Methods:** 29 patients who had 1<sup>o</sup> PTCA for AMI underwent DIP-MIBI (0.56 mg/kg over 4 minutes) at 48-96 hours (early) and at 6 weeks (late) following 1<sup>o</sup> PTCA. Blinded images were interpreted by a consensus of 3 experienced readers using a standard 17-segment model and 5-point scoring system. Summed stress scores (SSS), summed rest scores (SRS), and summed difference (SSS-SRS) scores (SDS) were calculated. Post procedure computerized quantitation of coronary dimensions and residual stenoses were determined by independent interventionalists blinded to clinical information. Patients were followed  $\geq 6$  months for cardiac events (unstable angina with or without subsequent revascularization, MI, or cardiac death). Patients were categorized by the occurrence of a cardiac event (CE) and no cardiac event (No-CE). Differences between early and late SSS and SRS with DIP-MIBI were examined.

**Results:** Quantitative post procedure coronary dimensions and residual stenoses were similar between groups ( $p = NS$ ). Late SSS and SRS improved significantly in the No-CE group, but were unchanged in the CE group. The degree of ischemia (SDS) was low in both groups with both early and late imaging.

Group	Early-SSS	Late-SSS	Early-SRS	Late-SRS
No-CE (n = 20)	12.5 ± 8	*9.4 ± 7.6	9.7 ± 7.1	†6.7 ± 6.6
CE (n = 9)	13.1 ± 5.8	11.9 ± 5.7	9.9 ± 4.3	8.9 ± 5.4

\* $p < 0.05$  versus Early-SSS; † $p < 0.01$  versus Early-SRS

**Conclusion:** Patients free of cardiac events following 1<sup>o</sup> PTCA are associated with an improvement in myocardial perfusion defect severity. The lack of improvement may be associated with short-term cardiac events. The significance of these findings should be prospectively evaluated.

**1034-35 Diagnostic Accuracy of Simultaneous Acquisition Dual Isotope (Rest Tl-201/Stress Sestamibi) ECG-gated Myocardial Perfusion SPECT**

Timothy M. Bateman, A. Iain McGhie, James H. O'Keefe, Jr., S. James Cullom, Kelly L. Moutray, Will E. Gainey, Khaldoon Alaswad, James A. Case. *Cardiovascular Consultants, P.C., Kansas City, MO, USA*

**Introduction:** A recently described simultaneous (SIM) acquisition (rest Tl-201/stress Tc-99m sestamibi) SPECT imaging protocol has demonstrated high concordance with sequential dual isotope SPECT. This study examines dual SIM SPECT diagnostic accuracy in 23 consecutive patients who subsequently underwent coronary angiography (CORS).

**Methods:** Images were acquired using the following parameters: (1) LEGP collimation, (2) 4.5 mCi Tl-201 at rest, (3) 9 mCi sestamibi at peak stress, (4) energy windows for Tl-201 at 72 keV ± 10% and 167 keV ± 20%, for Tc-99m at 140 keV ± 20% and for downscatter correction at 86 keV ± 10%, and (5) simultaneous ECG-gated SPECT data acquisition 30 minutes post-stress using a Picker Prism 3000XP. The dual SIM images were interpreted by consensus of 2 experienced readers, blinded to patient name or the results of CORS. Scans were interpreted as normal or abnormal overall and for each coronary territory. CORS results were derived from clinical reports, with stenoses  $\geq 70\%$  defined as significant.

**Results:** 20 Patients had CAD and 3 did not. Overall accuracy for CAD was 96% (22/23); sensitivity was 100% and specificity 67%. There were 39/69 (57%) diseased coronaries: 10 LAD, 18 RCA, and 11 LCX. 17 (74%) of the patients were male. Results for each coronary artery:

	LAD	RCA	LCX
Accuracy	78%	91%	91%
Sensitivity	80%	94%	82%
Specificity	77%	80%	100%

**Conclusion:** These data offer encouragement that dual simultaneous SPECT imaging may provide high and comparable diagnostic value to that previously reported for traditional dual sequential SPECT, when coronary angiography is used as a gold standard for CAD.

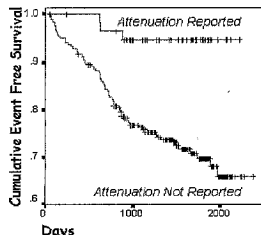
**1034-36 Outcome Validation of a Stepwise Visual Approach for Distinction of Attenuation Artifacts From Perfusion Defects on Spect Perfusion Imaging**

Kim A. Williams, Candace M. Schneider. *University of Chicago, Chicago, IL, USA*

**Background:** Attenuation artifacts have been a major source of reduced accuracy of myocardial perfusion SPECT. A stepwise visual approach to identification of these artifacts may help to distinguish low risk from high risk patients with coronary artery disease (CAD).

**Methods:** Data from 324 patients who underwent rest and exercise Tc-99m-Sestamibi SPECT were analyzed at a mean interval of 4 years (range 2–7 years), during which there were 70 cardiac events (cardiac death, infarction, revascularization, hospitalization for unstable angina or heart failure). "Pseudodeficits" attributable to overlying breast or chest wall attenuation were distinguished from CAD by the presence of 1) a large shadow over the myocardium on rotating cine display of raw projection images, 2) decreased extrathoracic counts adjacent to the affected myocardium, 3) no substantive change from rest to stress SPECT, and 4) normal wall motion on gated SPECT.

**Results:** Attenuation artifacts reported by the interpreter was a strong univariate predictor of outcome by Cox regression analysis (Chi-square 12.1,  $p = 0.005$ ). The annualized event rate (*figure*) was 0.8% vs. 6.0% (38% overall) in the patients in whom attenuation was not cited. Multivariate analysis showed that this variable was independent of height, weight, or gender or body surface area.



**Conclusion:** Visual recognition of attenuation artifacts on myocardial perfusion SPECT, using a stepwise combination of raw projections, SPECT slices and gated images, identifies a low-event rate group, most likely by excluding patients with perfusion defects due to significant left anterior descending CAD.

#### 1034-37 Stress Modality for Myocardial Perfusion Imaging in Patients With Left Bundle Branch Block. Exercise or Vasodilator Stress?

Ahmad Salloum, Jamal Ahmed, Domenic Marini, Alan W. Ahlberg, David Waters, Gary V. Heller. *Hartford Hospital, Hartford, CT, USA*

**Background:** In selected series of patients with left bundle branch (LBBB) reversible septal perfusion abnormalities are less frequent with vasodilator stress (VAS) than exercise (EX). As a clinical tool, EX is preferred over pharmacologic stress. There are no data comparing the incidence of reversible perfusion defects between VAS and EX stress in an unselected series of patients.

**Methods:** We evaluated 166 consecutive symptomatic patients with LBBB who underwent stress (EX or VAS) Tc-99m sestamibi SPECT imaging. Stress modality was based on the ability of a patient to exercise, not the presence of LBBB. Patients were categorized into EX (EX alone ( $n = 70$ ) or EX with dipyridamole ( $n = 23$ ) or VAS (adenosine ( $n = 11$ ) or dipyridamole ( $n = 66$ )). Imaging results were classified as LBBB-only (reversible anteroapical and/or anteroseptal defect), non-LBBB (all other distributions, fixed or reversible), both (LBBB-only and Non-LBBB in the same study), or normal.

**Results:** The incidence of isolated LBBB reversible perfusion defects were low (6%) and did not differ between EX and VAS stress.

	Normal	Non LBBB	LBBB Alone	Both
Exercise ( $n = 93$ )	30 (32%)	57 (61%)	2 (2%)	4 (4%)
Vasodilator ( $n = 73$ )	28 (38%)	34 (47%)	8 (11%)	3 (4%)
<i>p</i> values	0.413	0.295	0.108	0.951

**Conclusion:** In a clinical laboratory setting of consecutive patients with complete left bundle branch block, the incidence of reversible septal defects was low and not increased with exercise in comparison with vasodilator stress using Tc-99m sestamibi SPECT imaging. The choice of stress modality should be made based upon the ability of a patient to exercise, not the presence of left bundle branch block.

#### 1034-38 Myocardial Blood Flow Induced by Dobutamine in Patients With Stable Coronary Artery Disease Demonstrates Good Long Term Reproducibility

Rohan Jagathesan, Philipp Kaufmann, Rodney A. Foale, Paolo G. Camici. *MRC Cyclotron Unit, Imperial College School of Medicine, Hammersmith and St Mary's Hospitals, London, UK*

Dobutamine (Dob) is widely used as a pharmacological stressor in the as-

essment of patients with coronary artery disease (CAD). It is recognized that Dob exerts its effects via increasing rate pressure product (RPP) and thus cardiac workload, with a corresponding increase in myocardial blood flow (MBF). However, little data exist regarding the long-term reproducibility of this stressor on MBF and coronary flow reserve (CFR = MBF-Dob/MBF-rest).

**Methods:** Sixteen patients with chronic stable angina (14 male, age  $64 \pm 6$  yrs) and angiographically proven CAD ( $>70\%$  stenosis in at least one major coronary artery) underwent symptom-limited exercise testing (ETT) and Dob stress positron emission tomography (PET) with  $H_2O^{15}$  at baseline ( $T = 0$ ) and after 6 months ( $T = 6$ ). MBF-rest and MBF-Dob were calculated for the whole left ventricle (Wh) and the region subtended by the most stenotic artery (Isc). MBF-rest was corrected for rate pressure product (RPP) and CFR was calculated as MBF-Dob/MBF-rest. Reproducibility was assessed by regression analysis ( $r$ ) and using the Bland-Altman repeatability coefficient (BA), also expressed as a percent of the mean value of the two measurements (BA%).

**Results:** No patients reported deterioration in symptoms over the study period. Mean Canadian functional class score of 2.3 remained unchanged. Total exercise time (sec) was greater at  $T = 6$  compared to  $T = 0$  ( $534 \pm 128$  vs  $485 \pm 107$ ;  $p < 0.01$ ), possibly reflecting an effect of training. Maximum ST depression (mm) during ETT was comparable at  $T = 0$  and  $T = 6$  ( $2.8 \pm 1.2$  vs  $2.9 \pm 1.2$ ;  $p = ns$ ). During PET, mean Dob dose ( $30 \pm 11$  vs  $31 \pm 11$   $\mu g/kg/min$ ) and peak Dob RPP ( $20092 \pm 4095$  vs  $19425 \pm 3845$ ) at  $T = 6$  and  $T = 0$  were not statistically different.

	T = 0	T = 6	BA	BA %	r	p
Wh-MBF rest	$1.06 \pm 0.21$	$1.09 \pm 0.21$	0.33	30	0.83	0.0001
Wh-MBF Dob	$2.02 \pm 0.43$	$2.01 \pm 0.60$	0.74	37	0.84	0.0001
Wh-CFR	$1.93 \pm 0.40$	$1.84 \pm 0.47$	0.62	33	0.84	0.0001
Isc-MBF rest	$1.08 \pm 0.25$	$1.08 \pm 0.26$	0.39	22	0.80	0.0001
Isc-MBF Dob	$1.72 \pm 0.52$	$1.75 \pm 0.64$	0.59	33	0.90	0.0001
Isc-CFR	$1.59 \pm 0.42$	$1.61 \pm 0.49$	0.44	27	0.92	0.0001

**Conclusion:** In patients with clinically stable CAD, Dob stress induces reproducible changes in both global and regional MBF over a 6 month period.

#### 1034-39 The Effect of Pravastatin on Myocardial Blood Flow in Young Healthy Adults

Tuula Helle, Reijo Laaksonen, Risto Vesalainen, Olli Raitakari, Terho Lehtimäki, P. Pirjo Nuutila, Juhani Knuuti. *Turku PET Centre, Turku and University of Tampere, Tampere, Finland*

**Background:** Intensive lipid-lowering therapy has been shown to improve endothelium-mediated vasodilatation in middle-aged men with angina pectoris and hypercholesterolemia. The purpose of this study was to investigate the effect of lipid lowering therapy on myocardial perfusion and perfusion reserve in young hypercholesterolemic men without any signs of CAD.

**Methods:** We randomly assigned 51 men (age  $35 \pm 4$  years) with mild to moderate hypercholesterolemia (total cholesterol  $5.6 \pm 0.8$  mmol/l) to receive pravastatin 40 mg/day or placebo for six months. Myocardial blood flow was measured at rest and during adenosine-induced hyperemia by means of positron emission tomography (PET) and oxygen-15-labeled water before and after treatment.

**Results:** Seven subjects were excluded from the analysis mainly because of technical problems during the study. Pravastatin treatment decreased serum total cholesterol and LDL-cholesterol concentrations by  $-21\%$  and  $-33\%$ , respectively. At baseline the groups had similar and in the normal range basal and induced flow values as well as coronary flow reserve (CFR) and flow resistance values. No significant change was seen in resting or adenosine-induced blood flow values in either group during treatment. Consequently, no significant change in CFR or flow resistance was seen. For further analysis the patients from the pravastatin group with adenosine-induced flow below 4.0 ml/min/g (the long term normal average in our PET centre) (15 subjects) were compared with matched subjects from the placebo group. The resting blood flow values did not differ between the two subgroups at baseline and they did not change during treatment. A 27% increase in adenosine-induced blood flow was seen in the pravastatin subgroup ( $p < 0.02$ ), while no change was seen in the placebo subgroup. This resulted in a 26% increase in CFR ( $p = 0.14$ ) and  $-15\%$  decrease in flow resistance ( $p < 0.05$ ) in the pravastatin subgroup.

**Conclusions:** The results provide evidence that cholesterol-lowering therapy with pravastatin can improve coronary vasodilator capacity even in young men with no signs of CAD and fairly low cholesterol levels.

**1034-40 Insulin-Induced Increment of Coronary Flow Reserve is Not Abolished by Dexamethasone in Healthy Young Men**

Hanna Laine, Pirjo Nuutila, Matti Luotolahti, Christian Meyer, Tapani Rönnemaa, Juhani Knuti. *Turku PET Centre and Departments of Medicine and Clinical Physiology of Turku University, Turku, Finland*

**Background:** Hyperinsulinemia is a risk factor for coronary artery disease and insulin increases cardiac sympathetic nerve activity. We examined whether physiological hyperinsulinemia affects myocardial blood flow and flow reserve in healthy subjects. Additionally, the role of sympathetic nervous system in regulating insulin's effects on coronary perfusion was tested.

**Methods:** We quantitated myocardial blood flow and coronary flow reserve in 16 healthy nonobese men (age  $34 \pm 4$  yrs, RR118  $\pm 10/65 \pm 8$  mmHg) at rest and during euglycemic hyperinsulinemic clamp ( $1 \text{ mU}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$  for 80 minutes) using positron emission tomography and oxygen-15-labelled water. To study the role of sympathetic nervous system each subject was studied twice, once after administration of dexamethasone (dexa+) for two days (2 mg per day) and once without previous medication (dexa-).

**Results:** Adenosine infusion ( $140 \mu\text{g}/\text{kg}$  per min for 5 minutes i.v.) induced a significant increase in resting myocardial blood flow both in the basal state ( $p < 0.001$ ) and during hyperinsulinemia ( $p < 0.001$ ). Insulin stimulation increased both the adenosine stimulated flow (from  $3.38 \pm 0.97$  to  $4.28 \pm 1.57 \text{ mL}\cdot\text{g}^{-1}\cdot\text{min}^{-1}$ , basal vs hyperinsulinemic,  $p < 0.01$ ) and the coronary flow reserve (from  $4.55 \pm 1.19$  to  $5.78 \pm 1.90$ , respectively,  $p < 0.05$ ). Pretreatment with dexamethasone did not significantly change the resting blood flow ( $0.72 \pm 0.22$  vs  $0.76 \pm 0.19 \text{ mL}\cdot\text{g}^{-1}\cdot\text{min}^{-1}$ , dexa+ vs dexa-, NS), the adenosine stimulated flow ( $3.56 \pm 1.49$  vs  $3.38 \pm 0.97 \text{ mL}\cdot\text{g}^{-1}\cdot\text{min}^{-1}$ , respectively, NS) or the insulin and adenosine stimulated blood flow ( $4.68 \pm 1.74$  vs  $4.28 \pm 1.57 \text{ mL}\cdot\text{g}^{-1}\cdot\text{min}^{-1}$ , respectively, NS). Coronary flow reserves in the basal state ( $5.3 \pm 2.7$  vs  $4.6 \pm 1.2 \text{ mL}\cdot\text{g}^{-1}\cdot\text{min}^{-1}$ , dexa+ vs dexa-, NS) and during hyperinsulinemia ( $6.8 \pm 2.9$  vs  $5.8 \pm 1.9 \text{ mL}\cdot\text{g}^{-1}\cdot\text{min}^{-1}$ , respectively, NS) tended to be, but were not significantly higher after dexamethasone treatment.

**Conclusions:** Insulin acts as a vasodilatory hormone also in the coronary vasculature. As the insulin induced increment of myocardial flow reserve remained unchanged by dexamethasone pretreatment, centrally mediated sympathetic activation appears not to play a major role in regulating insulin action on myocardial perfusion in healthy subjects.

POSTER

**1054 Echo-Doppler Assessment of Myocardial Function and Viability**

Sunday, March 12, 2000, 4:00 p.m.–6:00 p.m.  
Anaheim Convention Center, Hall A  
Presentation Hour: 4:00 p.m.–5:00 p.m.

**1054-1 A Rapid, Bedside Test for Brain Natriuretic Peptide Accurately Predicts Cardiac Function in Patients Referred for Echocardiography**

Jen Koon, Judy Hope Alex Garcia, Radmila Kasanegra, Nancy Gardetto, Anthony DeMaria, Alan S. Maisel. *VAMC and UCSD, La Jolla, CA, USA*

**Background:** While echocardiography is an important test for making the diagnosis of left ventricular (LV) dysfunction, the cost of this procedure often precludes its use as a routine screening tool for this purpose. Brain natriuretic peptide (BNP) accurately reflects ventricular stretch, and in preliminary studies we have found it to be both highly sensitive and highly specific in diagnosing congestive heart failure in the emergency room setting. We hypothesized that BNP might therefore be useful as a screening tool prior to performing echocardiography in patients with possible left ventricular dysfunction.

**Methods:** Subjects included those patients referred for echocardiography in order to evaluate the presence or absence of left ventricular dysfunction. Patients with previously known left ventricular dysfunction were excluded from analysis. BNP was measured by a point of care immunoassay (Biosite Diagnostics, La Jolla, CA). The results of BNP levels were blinded from cardiologists making the assessment of LV function.

**Results:** Seventy six patients with unknown left ventricular function were studied. In the 43 patients (56%) whose ventricular function was subsequently determined to be normal by echocardiography, BNP levels averaged  $38 \pm 4 \text{ pg}/\text{ml}$ . This was significantly less than those patients with either ultimate diastolic dysfunction (BNP =  $416 \pm 31 \text{ pg}/\text{ml}$ ) or systolic dysfunction (BNP =  $480 \pm 48 \text{ pg}/\text{ml}$ )  $P < 0.001$ . ROC curve analysis revealed that a BNP level of  $100 \text{ pg}/\text{ml}$  was 91% sensitive and 100% specific for detecting

the presence or absence of left ventricular dysfunction using echocardiography.

**Conclusions:** An easy, rapid test for BNP, which can be performed at the bedside or in the cardiology clinic, can reliably predict the presence or absence of left ventricular dysfunction on echocardiography. We believe that BNP might be an excellent screening tool for left ventricular dysfunction, and may, in fact, preclude the need for expensive echocardiography testing in many patients.

**1054-2 New Index of Combined Systolic and Diastolic Myocardial Performance – Diagnostic Value in Patients With Coronary Artery Disease and Systemic Hypertension**

Christian Bruch, Daniela Marin, Stephanie Kuntz, Thomas Band, Raimund Erbel. *Dept. of Cardiology, University Essen, Germany*

**Background:** The index "isovolumic contraction time and isovolumic relaxation time divided by ejection time" (ICT + IRT/ET) according to Tei is a well established measure of global cardiac function in patients (pts.) with dilated cardiomyopathy and amyloidosis. An index  $\geq 0.48$  has been reported to be abnormal. The diagnostic value in heart failure pts. with coronary artery disease (CAD) and long-term systemic hypertension (HTN) is unclear.

**Methods & Results:** Study pts. consisted of 90 subjects: 10 asymptomatic control subjects (7 male/3 female, age  $66 \pm 4$  y.), 46 CAD pts. (37 m/9 f,  $68 \pm 6$  y.) and 35 pts. with HTN (27 m/8 f,  $62 \pm 6$  y.). All pts. underwent left heart catheterization for measurement of left ventricular enddiastolic pressure (LVEDP) and peak +dP/dT. Ejection fraction (EF), deceleration time (DT) and mitral E/A ratio were derived from two-dimensional and pulsed Doppler echocardiography. Pulsed Doppler recordings of mitral inflow and aortic outflow were used to assess "ICT + IRT/ET".

Group	NYHA class.	E/A	DT (msec)	EF (%)	+dP/dT (mmHg/s)	LVEDP (mmHg)	ICT + IRT /ET
CON (n = 10)	1*†	0.9	198†	54*	2132*	10*†	0.42†
		$\pm 0.24$	$\pm 33$	$\pm 9$	$\pm 460$	$\pm 5$	$\pm 0.17$
CAD (n = 46)	2.4	0.81	206	46‡	1624	17	0.55‡
	$\pm 0.5$	$\pm 0.43$	$\pm 42$	$\pm 11$	$\pm 543$	$\pm 7$	$\pm 0.18$
HTN (n = 35)	2.5	0.84	228	54	1836	19	0.41
	$\pm 0.5$	$\pm 0.42$	$\pm 35$	$\pm 10$	$\pm 634$	$\pm 9$	$\pm 0.15$

$p < 0.05$  \*Control (CON) vs. CAD; †CON vs. HTN; ‡CAD vs. HTN.

**Conclusion:** "ICT + IRT/ET" reliably detects global cardiac dysfunction in heart failure pts. with underlying CAD, but not in subjects with long-term HTN and primary diastolic dysfunction. These findings may be mainly attributed to shortening of ICT in HTN pts.

**1054-3 Diagnosis of Right Ventricular Infarction by Doppler Total Ejection Isovolum Index**

Shiro Yoshifuku, Yutaka Otsuji, Akira Kisanuki, Kouichi Toyonaga<sup>1</sup>, Hitoshi Toda<sup>1</sup>, Takashi Murayama<sup>1</sup>, Kazuaki Kiyonaga<sup>1</sup>, Chuwa Tei. *Kagoshima University, <sup>1</sup>Kagoshima CCU network, Kagoshima, Japan*

**Background:** Diagnosis of right ventricular (RV) infarction is not always feasible due to its complicated geometry. Recently proposed total ejection isovolume index (TEI index), allows simple and noninvasive estimation of global RV function independent of its geometry. Therefore, the purpose of this study is to investigate whether diagnosis of RV infarction by TEI index is feasible or not.

**Methods:** We measured RV TEI index [(isovolumetric contraction time + isovolumetric relaxation time)/ejection time] in 19 consecutive patients with acute inferior myocardial infarction, 10 with and 9 without RV infarction, and 20 normal controls as  $a-b/b$ , where  $a$  is the interval between cessation and onset of transtricuspid Doppler flow and  $b$  is the interval of pulmonary ejection flow. RV infarction was confirmed by catheterization [1] mean right atrial pressure  $> 10 \text{ mmHg}$  or 2) the ratio of mean right atrial pressure to pulmonary artery wedge pressure  $> 0.8$ ].

**Results:** 1) TEI index was significantly increased in patients with RV infarction compared to those without RV infarction and normal controls ( $0.64 \pm 0.12$  vs.  $0.41 \pm 0.14$  vs.  $0.24 \pm 0.09$ , RV infarction (+) vs. RV infarction (-) vs. control;  $p < 0.001$ ). 2) When the RV index  $\geq 0.52$  was used for the criteria, the sensitivity, specificity, and overall accuracy to diagnose RV infarction was 90%, 89%, and 89% respectively.

	RV Infarction	
	(-)	(+)
TEI index $< 0.52$	8	1
TEI index $\geq 0.52$	1	9

**Conclusions:** TEI index is a simple and noninvasive measure to diagnose RV infarction in patients with acute myocardial infarction.

**1054-4 Implications of Measuring Coronary Blood Flow With Trans-Thoracic Doppler in Patients With Acute Myocardial Infarction: Its Relation to Stunned Myocardium**

Yasunori Shintani, Hiroshi Ito, Katsuomi Iwakura, Ken Sugimoto, Kouichi Yamamoto, Kazuo Tem, Yorihiro Higashino, Kenshi Fujii. *Sakurabashi Watanabe Hospital, Osaka, Japan*

The goal of this study was to investigate clinical implications of coronary blood flow of the infarct-related artery with trans thoracic doppler (TTD) at day-2 of reperfusion in AMI.

**Methods:** The study population was consisted of 25 patients with anterior wall AMI undergoing successful PTCA and/or stent. We recorded coronary flow velocity of the LAD at day-2 of AMI with TTD and calculated time velocity integral in diastole (TVI, cm). At day-2, we also recorded real time integrated backscatter (IBS) images of short-axis view with SONGS 5500. We measured IBS in the center of infarct zone to reconstruct its cyclic variation (CV). To assess the intrinsic contractile performance of the infarct segment, we expressed the magnitude of CV as positive and negative values (phase-corrected magnitude, PCM (dB)), when it showed synchronous and asynchronous contraction, respectively. We performed 2-D echo at days-1, 2 and 21 and determined wall motion score index (WMSI, average of wall motion score (normal = 0 to dyskinesia = 3) of the infarct segments) and divided the study patients into two groups based on the magnitude of WMSI reduction, Good Recovery (GR (n = 8) =  $\Delta$ WMSI (1d-21d)  $\geq$  1) and No Recovery (NR (n = 17) = others).

**Results:** There were no differences in WMSI at days-1 and 2 and between GR and NR. TVI at day-2, however, was significantly higher in GR than in NR ( $10 \pm 1.9$  vs  $5.1 \pm 0.4$ ,  $p < 0.05$ ). PCM at day-2 was also significantly higher in GR than NR ( $2.6 \pm 1.1$  vs.  $-0.8 \pm 0.7$ , dB,  $p < 0.05$ ).

**Conclusion:** The higher coronary blood flow of infarct-related artery is associated with better intrinsic contractile performance, that implies the presence of stunned myocardium, and thus, is associated with better functional outcomes. LAD flow measurements in anterior AMI using TTD is the noninvasive and promising method to assessing the functional outcomes.

**1054-5 Deceleration Time of Diastolic Coronary Blood Flow Velocity in Patients With Acute Anterior Myocardial Infarction Can Predict Regional Left Ventricular Wall Motion Recovery: Assessment by Transthoracic Doppler Echocardiography**

Yosiaki Ueda, Takashi Akasaka, Takeshi Hozumi, Tsutomu Takagi, Atsushi Yamamuro, Koichi Tamita, Kenji Yamabe, Shigefumi Morioka. *Kobe General Hospital, Kobe, Japan*

**Background:** A recent study has demonstrated that coronary blood flow velocity pattern with a rapid deceleration time of diastolic flow velocity (DDT) implies the poor recovery of regional left ventricular function in patients (pts) with acute myocardial infarction (AMI). Recent advancement in transthoracic Doppler echocardiography (TIDE) with a high-frequency transducer provided accurate measurement of coronary flow velocity in the left anterior descending coronary artery (LAD). However, relation between regional wall motion recovery and DDT of coronary blood flow velocity measured by TIDE has not been investigated. The aim of this study was to determine whether DDT of coronary blood flow velocity measured by TTDE can predict regional wall motion recovery in pts with AMI.

**Methods:** The study population consisted of 20 pts with a first anterior AMI successfully treated with direct coronary angioplasty. Using transthoracic Doppler echocardiography (Logic 500, GE Yokogawa Medical, 3.5-8 MHz), we measured coronary blood flow velocity in the LAD in 20 pts at  $1.2 \pm 0.8$  days after onset of AMI. Pts were divided in two groups according to the DDT: Group 1, 9 pts with DDT  $> 600$  ms and Group 2, 7 pts with DDT  $\leq 600$  ms. Regional wall motion was analyzed to estimate anterior wall motion score index (AWMSI) by transthoracic echocardiography before recanalization and 1 month after the onset of AMI.

**Results:** DDT measurement was possible in 16 of 20 pts. AWMSI in Group 2 was significantly greater than that in Group 1 at 1 month after the onset of AMI (AWMSI:  $2.64 \pm 0.2$  vs  $1.91 \pm 0.33$ ,  $p < 0.001$ , respectively). A significant inverse correlation was found between DDT and 1-month AWMSI ( $r = -0.75$ ;  $p < 0.001$ ).

**Conclusions:** DDT of coronary blood flow measured by TTDE provides an accurate mean to predict regional left ventricular wall motion recovery in pts with AMI.

**1054-6 Lack of Remote Hyperkinesis Predicts Multivessel Disease in Acute Myocardial Infarction: A Prospective Echocardiographic Study**

David W. Leibowitz, Doron Zahger, Fanny Ben-Ibgi, A. Teddy Weiss. *Hadassah University Hospital, Jerusalem, Israel*

**Background:** Compensatory hyperkinesis of noninfarcted myocardium in acute myocardial infarction (MI) has been well documented and failure of this response may suggest the presence of multivessel disease. No study has assessed remote hyperkinesis acutely before reperfusion therapy when hemodynamic stress is most severe. The objective of this study was to prospectively examine the correlation between failure of remote hyperkinesis as assessed acutely by echocardiography and the presence of multivessel coronary disease on angiography.

**Methods:** The patient population consisted of 31 patients admitted with chest pain of more than 30 minutes duration and ST-elevation in two or more contiguous leads. Patients with previous history of MI or cardiogenic shock were excluded. All patients underwent 2-D echocardiography immediately on arrival to the intensive care unit before administration of thrombolytic agents and wall motion was graded on a five-point scale. Regional hyperkinesis was defined as exaggerated systolic motion of at least two non-infarcted segments. 25 patients underwent coronary angiography based on clinical criteria without regard to the presence of regional hyperkinesis on the echo study and they form the study group.

**Results:** Of the 25 patients, 19 presented with an anterior infarct, 5 with an inferior infarct and 1 with a lateral infarct. 19 patients (76%) had single-vessel disease (SVD) and 6 (24%) had multivessel disease (MVD) on angiography. Regional hyperkinesis was noted acutely by echocardiography in 17 of 19 patients with single-vessel disease and only 1 of 6 patients with multivessel disease ( $p < 0.02$ ).

**Conclusions:** Regional hyperkinesis occurs frequently in patients presenting with a first myocardial infarction. Failure of compensatory hyperkinesis as assessed acutely at the bedside by 2-D echocardiography is predictive of the presence of multivessel disease and may be facilitate risk stratification in these patients.

**1054-7 Hyperkinesis of Non-Infarcted Myocardial Regions by Echocardiography: Relation to Coronary Artery Stenosis**

H. Mehrdad Sadeghi, Ajit Raisinghani, Daniel Blanchard, Anthony N. DeMaria. *UCSD Medical Center, San Diego, CA, USA*

**Background:** Although compensatory hyperkinesis (HYP) of non-infarcted myocardium occurs frequently, uncertainty persists regarding its relationship to additional coronary artery stenosis. Therefore, we analyzed the 2-D echocardiograms of 19 consecutive patients having a first myocardial infarction (15 Q, 4 non-Q), and compared the findings to coronary angiography.

**Methods:** Two-D echo recordings were obtained in all standard views within 48 hours of the infarct and coronary angiography, and myocardial regions were classified according to coronary perfusion bed (BED): LAD = anterior, septal, apical, RCA = inferior, posterior, and LCx = lateral. HYP was defined as  $\geq 33\%$  increase in myocardial wall thickening compared to normal; a stenosis was  $\geq 70\%$  diameter reduction.

**Results:** MI location was anterior in 7, inferior in 11, and lateral in 1 pt. Compensatory HYP was observed in 20 of 38 (53%) non-infarct BEDs, and mean group EF was 53%. The distribution of coronary stenosis and HYP BED is shown in the Figure.

Hyperkinesis

	2 BEDS	1 BED	No BED
$\leq 1$ -v CAD	7	1	0
2-v CAD	1	3	3
3-v CAD	0	0	4

HYP was not seen in any BED in pts with disease in all three coronaries (n = 4). HYP was seen in 4 of 7 patients with two-vessel disease, including 3 regions perfused by significantly-stenosed vessels. In addition, HYP was observed in all 8 patients with single-vessel disease, and 7 of 8 patients with HYP of 2 different regions had single-vessel disease.

**Conclusion:** Thus, 2-D echo reveals compensatory HYP in 63% of post-MI patients suffering a first infarct. Although HYP did not exclude a stenosis in the respective coronary artery, HYP was observed in all 8 patients with single-vessel disease and in no patients with obstructions in all three coronary vessels. HYP on 2-D echo can be of value in predicting the presence of additional coronary artery stenosis in post-infarct patients.



### 1054-8 Low Negative Predictive Value of "Global Hypokinesia" in Two-Dimensional Echocardiography for Coronary Artery Disease

A.F. Osman, L. Orejarena, S. Solis, A. Grant, Y. Gilliland, M.D. Cassidy, C.J. Lavie, J.A. Bernal, R.V. Milani. *Ochsner Medical Foundation, New Orleans, Louisiana, USA*

**Introduction:** The term "global hypokinesia" is often used in echocardiography to denote depressed left ventricular systolic function without obvious regional wall motion abnormalities, and to imply a non-ischemic etiology. We sought to determine the clinical significance of this finding.

**Methods:** More than 18,000 echocardiography reports performed at the Ochsner Medical Foundation between October 1997 and August 1999 were reviewed for the use of the term "global hypokinesia." Of the resulting 2,450 studies, 464 patients had diagnostic or interventional coronary catheterizations. The presence (or absence) of coronary artery disease (CAD) was determined according to the number of significant stenoses [70% or more by visual estimation, Quantitative Coronary Angiography (QCA) or intravascular ultrasound] in any of the three major epicardial coronary arteries. Severe valvular disease without critical CAD, felt to be the cause of left ventricular dysfunction, was classified separately.

**Results:** The distribution of coronary artery disease is shown in the Table:

Normal or nonobstructive CAD	125	27%
1-vessel CAD	70	15%
2-vessel CAD	63	14%
3-vessel CAD	191	41%
Severe Valvular Disease	15	3%
Total	464	100%

The negative predictive value for coronary artery disease is 30% for the whole group and 26% for patients with an ejection fraction <30%. However, the presence of global hypokinesia was accurate in predicting 3-vessel CAD or a non-ischemic etiology in 71% of the patients.

**Conclusion:** Contrary to popular belief, the presence of global hypokinesia is not specific to exclude CAD, but rather 'suggests' the presence of either 3-vessel CAD or non-ischemic myocardial dysfunction.

## POSTER

### 1055 Stress Echo: Perfusion and Functional Correlates

Sunday, March 12, 2000, 4:00 p.m.–6:00 p.m.  
Anaheim Convention Center, Hall A  
Presentation Hour: 4:00 p.m.–5:00 p.m.

### 1055-25 Comparison of Dobutamine Stress Echocardiography and <sup>99m</sup>Tc-Sestamibi SPECT Imaging for the Diagnosis of Single Vessel Coronary Artery Disease

Abdou Elhendy, Ron T. van Domburg, Jaroslaw D. Kasprzak, Jos R.T.C. Roelandt, Peter R. Nierop, Jeroen J. Bax, Don Poldermans, Fabiola Sozzi, Roelf Valkema. *Thoraxcenter, Rotterdam, The Netherlands*

**Background:** Stress myocardial perfusion scintigraphy is thought to be more sensitive than echocardiography in patients with single vessel coronary artery disease (CAD). However, recent experimental studies have shown that <sup>99m</sup>Tc methoxyisobutyl isonitrile (MIBI) underestimates flow heterogeneity induced by dobutamine and this might have an impact on the sensitivity in patients with single vessel CAD. This study compares the accuracy of dobutamine MIBI SPECT and simultaneous echocardiography in the diagnosis of single vessel CAD.

**Methods:** Ninety one patients (age = 57 ± 12 years) with single vessel CAD or without significant CAD were studied with dobutamine (up to 40 µg/kg/min)-atropine (up to 1 mg) stress echocardiography (DSE) and simultaneous MIBI SPECT imaging. CAD was predicted on basis of myocardial ischemia (transient wall motion abnormalities by DSE and reversible perfusion defects by MIBI).

**Results:** Ischemia was detected by DSE in 30 patients with and in 6 patients without significant CAD (sensitivity of DSE = 56%, CI 45–66, specificity = 84% CI 76–91, accuracy = 67%, CI 57–77). Ischemia was detected by MIBI in 30 of the 54 patients with and in 10 of the 37 patients without single vessel CAD (sensitivity = 56%, CI 45–66, specificity = 73% CI 64–82, accuracy = 63%, CI 53–73, p = NS vs DSE). For both imaging methods, sensitivity was significantly higher in patients with left anterior descending (LAD) than in patients with left circumflex (LCx) or right coronary artery (RCA) stenosis

(75% vs 40%, p < 0.05). The addition of MIBI to echocardiography did not improve the accuracy (68% CI 59–78, p = NS vs DSE or MIBI alone).

**Conclusions:** DSE and MIBI SPECT have similar moderate sensitivity for the diagnosis of single vessel CAD. Sensitivity of each of these techniques is higher in patients with LAD than in patients with LCx or RCA stenosis. There is no improvement of accuracy by using the combination of both techniques.

### 1055-26 Comparison of Non-Invasively Assessed Coronary Flow Reserve With Myocardial Scintigraphy in Patients With Suspected Coronary Artery Disease

Carlo Caiati, Giovanni Cioglia, Norma Zedda, Cristiana Montaldo, Lijun Chen, Alessandro Bina, Roberta Montisci, Sabino Illiceto. *Inst. of Card, Univ. of Cagliari and "S. Maugeri" Foundation, Cassano, Italy*

**Background:** Base-adenosine contrast-enhanced transthoracic echo Doppler in harmonic mode is a novel non-invasive method to assess coronary flow reserve that has never been validated versus myocardial perfusion imaging.

**Methods:** Thirty-five patients (pts) undergoing coronary angiography were submitted to absolute coronary flow reserve (CFR) in the left anterior descending coronary artery by a novel non-invasive method (base-adenosine contrast-enhanced transthoracic echo Doppler in harmonic mode) and simultaneously, to <sup>99m</sup>Tc-sestamibi myocardial perfusion imaging (SPECT).

**Results:** CFR categorized as normal (≥2.0) or abnormal (<2.0) was in agreement with SPECT in 30 studies (86%)(K = 0.52, p < 0.02) (see table).

			Spect	
			normal	abnormal
LAD Ang				
No stenosis	CFR	normal	13	1
>40% ≤75%	CFR	normal	9	
		abnormal	1	2
>75%	CFR	normal	3	1
		abnormal	2	3

numbers indicate number of patients; angio, LAD stenosis categories by angio

Absolute CFR added to SPECT in the discordant studies: in the subgroup, in fact, with CFR abnormal and SPECT normal (4 pts), 3 pts had balanced hypoperfusion since severe multivessel coronary artery disease (CAD) was present and 1 had severe left ventricular hypertrophy. In the subgroup with CFR normal and SPECT abnormal (2 pt), 1 pt had left branch bundle block and normal coronaries.

**Conclusion:** CFR gives concordant results with SPECT. An integrated approach, combining SPECT and non-invasive absolute CFR in the LAD, may improve understanding of pathophysiology and detection of CAD.

### 1055-27 Non-Invasive Prediction of Angiographic Progression of Coronary Artery Disease by Dipyridamole Stress Echocardiography

Olaf S. Rodríguez, Silvio Fedele, Imre Ungi, Alberto Genovesi-Ebert, Martha Morelos, Patrizia Landi, Mario Marzilli, Eugenio Picano. *Institute of Clinical Physiology, Pisa, Italy*

**Background:** Extent and severity of angiographically assessed coronary artery disease (CAD) are mirrored by stress reduced wall motion abnormalities during dipyridamole stress echocardiography (DSE).

**Aim:** To assess whether variations in serial DSE match variations in angiographically assessed CAD.

**Methods:** From the data bank of our institution encompassing 15 years (1983–1998) we selected 60 patients meeting the inclusion criteria of 2 repeat coronary angiography and DSE. each test performed and interpreted independently and within one week. The second angiographic-stress echocardiographic assessment was repeated 45 ± 30 months after the initial one. Angiographic progressors were defined a priori, according to Kaski, as patients with any stenosis progressing to occlusion and/or any significant stenosis with >20% stenosis progression. Stress echocardiography progressors were defined as patients either with a previously negative test becoming positive or with a persistently positive test with increase in peak wall motion score index > 0.12 (1 = normal to 4 = dyskinetic in a 16 segment model) at repeat testing.

**Results:** Of the 60 patients, 44 were angiographic "progressors" and 16 "non progressors". Stress echo response was concordant with angiographic identification in 39/44 progressors and 15/16 non-progressors, with an overall concordance of 90%. The greatest rate of concordance was achieved with an initially positive DSE response becoming negative at repeat testing (4/4, 100% concordance with angiographic "non progressors") and with an initially negative DSE becoming positive at repeat testing (18/19, 95% concordance with angiographic progressors).

**Conclusion:** Angiographic progressors and non progressors can be non-invasively identified by serial changes in dipyridamole stress echo response.

**1055-28 Correlation of Myocardial Perfusion and Wall Thickening Abnormalities Detected With Intravenous Optison and Low Mechanical Index Harmonic Imaging With Radionuclide SPECT During Exercise Stress**

Thomas Porter, Feng Xie, Rebecca Oster, Mary Silver, David Kricsfeld, Lisa Gobar. *University of Nebraska Medical Center, Omaha, Nebraska, USA*

**Background:** Myocardial perfusion (MP) can be assessed at real time frame rates (10–20 hertz) when using a low mechanical index (MI) and harmonic imaging following intravenous (IV) perfluorocarbon ultrasound contrast (UC). This permits the detection of MP with UC during exercise stress echo (ESE). The sensitivity and specificity of this in a prospective series of patients is unknown.

**Methods:** Fifty consecutive patients (mean age  $58 \pm 11$ ) with intermediate probability of coronary artery disease (CAD) on clinical criteria had resting and exercise stress echocardiograms performed using a symptom-limited Bruce Protocol. IV Optison was given while imaging at an MI of 0.3 and a frame rate of 10–12 hertz (resting) and 20 hertz (peak exercise). All patients underwent a rest thallium and exercise Tc-99 sestamibi study (SPECT) on the same day. Six regions per patient were assigned a diagnosis of either normal (nl), fixed (fix), or inducible (ind) MP or wall motion (WM) abnormality by a blinded reviewer who had no knowledge of clinical history. Regional WM was assessed in the presence and absence of UC. MP assessed by SPECT was considered the gold standard.

**Results:** Eighteen regions could not be compared because of attenuation or technical factors. The table demonstrates the results in the remaining 282 regions (IOA = % agreement):

		MP-Echo			WM-Echo		
		nl	ind	fix	nl	ind	fix
SPECT	nl	239	12	3	249	4	1
	ind	9	12	3	11	9	4
	fix	2	2	0	3	1	0
kappa		0.52			0.56		
IOA		91%			93%		

In 18 of 50 patients (36%), endocardial borders could not be visualized in at least one region unless UC was present. The regional sensitivity and specificity of MP using low MI imaging was 61 and 94%, compared to 50 and 98% for WM.

**Conclusion:** Low MI imaging with IV Optison has significant potential for assessing MP in real time during ESE. Both wall motion and perfusion using low MI imaging compare favorably to radionuclide SPECT in detecting significant CAD.

**1055-29 Mechanism of Myocardial Dysfunction in the Presence of Chronic Coronary Stenosis and Normal Resting Myocardial Blood Flow**

Pelberg Robert, Spotnitz William, Bin Jian-Ping, Le Elizabeth, Goodman Craig, Kaul Sanjiv. *University of Virginia, Charlottesville, VA, USA*

In chronic coronary artery disease, resting myocardial dysfunction can exist in the presence of normal resting transmural myocardial blood flow (MBF). We hypothesized that this phenomenon occurs because of diminished endocardial MBF reserve. MBF (radiolabeled microspheres) and wall thickening (WT) were measured (at rest and during dobutamine) in 7 dogs after the development of severe LV dysfunction caused by placement of ameroid constrictors on the left anterior descending (LAD) and left circumflex (LCx) coronary arteries. These data were again measured 3 weeks after selective bypass surgery to the LAD. Prior to surgery, the mean transmural MBF at rest and at the peak dobutamine was  $1.1 \pm 0.5$  and  $3.0 \pm 1.5$  mL·min<sup>-1</sup>·g<sup>-1</sup>, respectively, and were not significantly changed after LAD bypass. The resting endocardial/epicardial MBF ratio (EER) at peak dobutamine was markedly diminished in the LAD bed prior to surgery ( $0.7 \pm 0.3$ ) and improved significantly ( $1.3 \pm 0.8$ ,  $p < 0.01$ ) after surgery. After selective LAD bypass, resting WT in the LAD bed improved to normal levels ( $36 \pm 4$  vs  $13 \pm 6\%$ ,  $p = 0.0001$ ) compared to pre-bypass and no longer demonstrated a biphasic response to dobutamine. In comparison, the non-bypassed LCx bed continued to show reduced resting WT ( $12 \pm 6$  vs  $13 \pm 9\%$ ) with a persistent biphasic response to dobutamine. The EER ( $0.6 \pm 0.3$ ) during dobutamine also remained abnormal. We conclude that persistent myocardial dysfunction in the presence of normal resting transmural MBF can occur as a result of diminished endocardial MBF reserve, with transmural MBF reserve remaining normal.

**1055-30 The Effect of Systemic Endothelial Dysfunction and Coronary Artery Disease on Electrocardiographic and Functional Signs of Ischemia During Stress**

Albert Varga, Martha Morelos, Emilia Fabian, Olaf Rodriguez, Lorenza Pratali, Eugenio Picano. *Institute of Clinical Physiology, Pisa, Italy*

**Background:** Stress induced ST segment depression may be all "anatomic lie" (occur with normal coronary arteries) but a "physiologic truth" (correctly identifying systemic endothelial dysfunction).

**Objective:** To assess the effects of systemic endothelial dysfunction on stress-induced electrocardiographic and echocardiographic signs of ischemia.

**Methods:** Forty-six patients with chest pain syndrome were studied – on different days, in random order, and within 1 week – by stress testing with simultaneous ECG and echo monitoring (exercise in 12; dipyridamole in 32; dobutamine in 2); coronary angiography (with semiquantitative assessment with Duke score, from 0 = no disease to 100 = most severe disease); and systemic endothelial function evaluation (by brachial artery, vascular ultrasound).

**Results:** By multivariate analysis, endothelial dysfunction (<5% of post-ischemic dilation) was best predicted by ST segment changes (>0.15 mV from baseline) during stress ( $p = 0.04$ , OR:8.9). Coronary artery disease was best predicted by stress echo positivity ( $p = 0.0045$ , OR:22.6) There was no correlation between endothelium-dependent vasodilation (%) and angiographic Duke score ( $r = 0.169$ ,  $p = ns$ ).

**Conclusions:** Systemic endothelial dysfunction predicts electrocardiographic, not echocardiographic, positivity during stress testing for noninvasive detection of coronary artery disease. Presence and severity of angiographically assessed coronary artery disease are linked to echocardiographic positivity, which is dissociated from systemic endothelial dysfunction. Different markers of ischemia during stress testing are affected by different anatomic and physiological variables.

**1055-31 Significance of ST Elevation With Dobutamine Stress**

Himadri Dasgupta, James E. Knight, John Costello, Timothy R. McConnell, James C. Blankenship. *Geisinger Medical Center, Danville, Pennsylvania, USA*

**Background:** Significance of ST elevation during dobutamine stress echocardiography (DSE) remains unknown. In patients with previous myocardial infarction, dyskinesia of infarcted segments or acute ischemia of jeopardized myocardium are the postulated mechanisms. Few studies have been done or mechanisms proposed in those without prior myocardial infarction.

**Methods:** All DSEs done between 1/92 and 2/99 with >1 mm ST elevations in at least 2 leads were identified and those with cardiac catheterization within 8 months of DSE were selected. Historical, DSE and cath data were compared.

**Results:** Of a total 3187 tests, 55 (1.7%) had dobutamine induced ST elevation. Twenty two met the inclusion criteria. Only 13 (59%) had angina with ST elevation. Sixteen (73%) had ST elevation involving the inferior (INF) leads. Six (27%) had predominantly antero-septal (AS) ST elevation. Fourteen (64%) had dobutamine induced wall motion abnormality (WMA) matching the segment predicted by ST elevation. One had WMA in a different segment. Six (27%) had no inducible WMA. All patients had at least 1 stenosis that was 70% or more in a culprit artery corresponding to the ST elevation. The culprit lesion was found most often on the RCA (88%) in those with INF ST elevation and on the LAD (100%) with AS ST elevation.

The following table shows the relation of ST elevation to number of arteries with >50% disease, location of lesion in culprit artery (proximal or mid) and patients with >90% stenosis in culprit artery: (all figures are in percentages)

	3V	2V	1V	Proximal	Mid	≥90% stenosis
Any ST ↑	73	18	9	45	32	82
INF ST ↑	75	19	6	44	31	88
AS ST ↑	66	17	17	50	33	67

1V/2V/3V = 1 vessel/2 vessel/3 vessel

**Conclusions:** ST elevation during DSE predicts significant (>70%) and often severe (>90%), proximal and multivessel coronary disease in patients with or without prior myocardial infarction even in absence of dobutamine induced WMA. Leads showing ST elevation usually suggest the anatomical location of stenoses.

**1055-32 Right Ventricular Dysfunction During Dobutamine-Atropine Stress Echocardiography Correlates With Global Left Ventricular Dysfunction and Multivessel Coronary Artery Disease**

Steven C. Smart<sup>1</sup>, Kiran B. Sagar<sup>2</sup>. <sup>1</sup>Gundersen Lutheran, La Crosse, WI; <sup>2</sup>The Medical College of Wisconsin, Milwaukee, WI, USA

**Background:** Right ventricular dysfunction (RVD) during dobutamine-atropine stress echocardiography (DASE) may be indicative of coronary artery disease, but it is unclear whether it is a consequence of right ventricular ischemia due to right coronary artery disease (RCA) or global left ventricular dysfunction.

**Methods:** To investigate the hypothesis that RVD results from global left ventricular dysfunction, 387 patients (age 60 ± 12 yrs, 242 men/145 women) underwent DASE and coronary angiography within 2 months of each other. Atropine was used in 191 patients. Echocardiographic measurements were done and LV mass and meridional (M) and circumferential (C) wall stress calculated.

**Results:** Peak heart rate was 128 ± 16 bpm. DASE was normal in 155 patients. Left ventricular wall motion abnormalities (WMA) were detected in 1 vascular territory (1VT) in 111 patients and multiple VT in 121. RVD was detected in 110 patients. Angiography revealed no (<50% luminal diameter stenosis) coronary artery disease (CAD) in 137 patients, single vessel (1V) CAD in 94, 2V CAD in 90, and 3V CAD in 66. The sensitivity and specificity WMA by DASE for CAD were 87% (218/250) and 90% (123/137), respectively. The distribution of CAD in patients with RVD was RCA in 77, LAD in 80, and LCX in 77 (p = NS).

Table 1. DASE and angiographic findings in patients with and without RVD

Finding	RVD (n = 110) no	RVD (n = 277)	Univariate X <sup>2</sup>	Multivariate X <sup>2</sup>
Rest WMSI	2.25 ± 0.70	1.26 ± 0.43	176.8	NS
Peak WMSI	2.35 ± 0.66	1.29 ± 0.41	210.7	122.5
Wall Stress (C)	403 ± 200	182 ± 90	154.3	16.4
Wall Stress (M)	142 ± 64	69 ± 33	147.0	NS
Multiple WMA	75% (82)	14% (39)	151.3	NS
Multivessel CAD	75% (82)	27% (74)	91.9	91.9
Rest LVEF (%)	34 ± 13	56 ± 12	162.3	NS

**Conclusion:** RVD during DASE correlates with multivessel CAD and global left ventricular dysfunction rather than CAD in the right coronary artery.

POSTER

**1056 Tissue Doppler Imaging**

Sunday, March 12, 2000, 4:00 p.m.–6:00 p.m.  
Anaheim Convention Center, Hall A  
Presentation Hour: 4:00 p.m.–5:00 p.m.

**1056-33 Feasibility of 4-Dimensional Myocardial Doppler Tissue Velocity Imaging for Full-Thickness Myocardial Mapping**

Ryan D. Packer, Michael R. Wahl, Sam Asirvatham, Javier Roman-Gonzalez, Jon J. Camp, Susan B. Johnson, Richard A. Robb, Douglas L. Packer. *Mayo Foundation, Rochester, MN, USA*

**Background:** Currently available catheter utilities limit mapping to endocardial and epicardial regions. Mid-myocardial activation, as potentially present in ventricular tachycardia, has not been accessible to a catheter based approach. To determine the feasibility of 4D myocardial doppler tissue velocity imaging as a surrogate reflection of local myocardial activation, 4 dogs underwent evaluation.

**Methods:** A 10 Fr, 7.5 MHz phased-array intracardiac ultrasound catheter inserted via a carotid artery was utilized to acquire global ultrasound (US) images. A 4-dimensional toroidal volume was created in parallel from B-mode toroids of colorized doppler tissue velocity (DTV) volumes derived from full thickness myocardial time sequences.

**Results:** Images were created by US acquisition during rotation of the catheter around 360 degrees, as controlled by a computerized stepper motor. At each 3-degree rotational step, a 12 frame movie was captured, with emphasis on the first 200 ms of the cardiac cycle. The site of earliest activation during ventricular pacing was identified as the earliest site of doppler tissue velocity perturbations. These DTV volumes qualitatively displayed the fluid spread of effective activation throughout the heart.

**Conclusion:** This information demonstrates that 4-dimensional doppler tissue velocity imaging is feasible and could provide a surrogate indicator of

local activation. This may have far reaching implications for the analysis of cardiac electrical and mechanical activation and propagation not accessible by endocardial or epicardial catheters. These methods could be developed into a more comprehensive technique for complete, full-thickness cardiac wall activation assessment.

**1056-34 Abnormal Strain Throughout the Base of the Left Ventricle in Hypertrophic Cardiomyopathy**

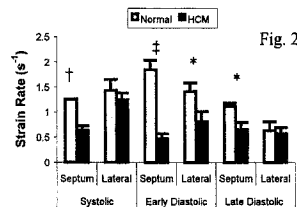
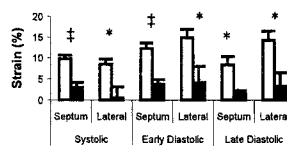
Peter L. Castro, Neil L. Greenberg, Michael S. Firstenberg, Jeannie Drinko, Harry M. Lever, Mario J. Garcia, James D. Thomas. *Department of Cardiology, The Cleveland Clinic Foundation, Cleveland, Ohio, USA*

**Background:** In hypertrophic cardiomyopathy (HCM) the septum is pathologically hypertrophied and the lateral wall is assumed to be normal. We hypothesized that patients with HCM would have derangement of the lateral wall in addition to the septum when evaluating myocardial strain.

**Methods:** Nine patients with HCM and ten normal subjects were imaged using the echocardiographic strain rate imaging (SRI) modality (System V, GE Vingmed). From an apical 4-chamber view, peak strain rate was determined and integrated to yield strain in the basal region of the septum and the lateral wall of the LV.

**Results:** The strain of both the lateral wall and the septum in the base of the LV are decreased in HCM patients when compared to normals (Fig. 1). In systole and diastole, the strain rate in the basal septum of the HCM patients is significantly lower than normals (Fig. 2). Interestingly, strain rate is not different in systole and late diastole when comparing the basal lateral wall of HCM patients to normals, but is significantly lower in early diastole. Resting LVOT gradient ranged from 4–170 mmHg but had no association with strain or strain rate abnormality.

\* p<0.05 † p<0.01 ‡ p<0.001 Fig. 1



**Conclusions:** There is abnormally low strain throughout the base of the LV during the entire cardiac cycle in patients with HCM. The lack association of strain or strain rate abnormality with LVOT obstruction suggests that the lateral wall abnormality is due to primary myocardial disease and not secondary LV hypertrophy.

**1056-35 Strain Rate Imaging: An In Vitro "Validation" Study Using a Physiologic Balloon Model Mimicking the Left Ventricle**

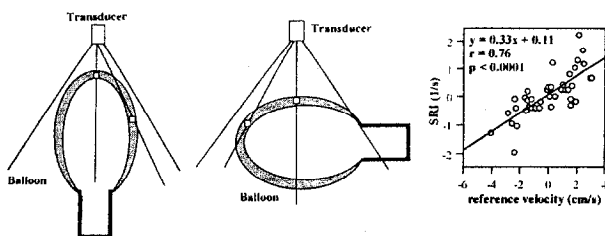
Ikuo Hashimoto, Yoshiki Mori, Ying Wu, Xiaokui Li, Suthep Wanitkun, Rosemary A. Rusk, Fukiko Ichida, David J. Sahn. *Oregon Health Sciences University, Portland, OR, USA*

**Background:** Strain rate imaging (SRI) implemented from digital ultrasound image loops is computed as an auto-correlation solution of the varying distance between intramyocardial targets. It should have better resolution for wall segments imaged along individual ultrasound scanlines, and thus have advantages for lateral wall evaluation where tissue Doppler (TDI) data is reduced by the angle dependency of Doppler. We studied SRI results in a quantifiable left ventricle (LV) phantom.

**Methods:** We used a new "left ventricular" double balloon model with a tissue-mimicking gel between the walls. Mounted in a water bath and connected to a pulsatile flow pump at 4 stroke volumes (30–50 ml/beat), high frame rate digital multipulse 2D/tissue/TDI loops of balloon wall motion were recorded using a GE/Vingmed System Five (3.5 MHz transducer) with the model scanned longitudinally from the apex. The SR was measured both at the apex and lateral wall using an off-line measurement program, and mean SR values for every 100 msec were calculated by averaging 3 determinations at each point. The excursions of apex and lateral wall were also directly measured by high speed digital video imaging and consecutive

velocity profiles were calculated every 100 msec. A total of 40 data points for 5 stroke volumes were analyzed.

**Results:** While our balloon model had enough gel targets between the walls to produce a good mimic of myocardial speckle with walls that thickened and thinned, samples immediately across the apex varied substantially and apex SR values (Hz) had no relation to video velocities. In contrast, systematic reproducible signals could be obtained from lines  $>15^\circ$  from true apex, crossing a longer length of "myocardium." As such, at the lateral wall there was close correlation between video velocities and SRI as well as a close overlap of the phasic patterns. When the same model was imaged from the side, the apex results improved.



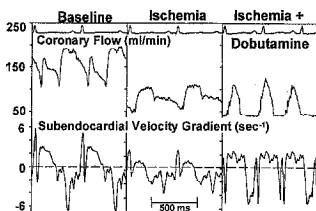
**Conclusion:** SRI produces more reliable data from wall segments parallel to scanlines, and with enough tissue pathway, it is reproducible and angle independent. Thinned apical areas could give spurious results.

#### 1056-37 Quantification of Regional Subendocardial Function During Ischemia and Low Dose Dobutamine Using Tissue Doppler Subendocardial Velocity Gradient

John Gorcsan III, Michael Dishart, Hao Wang, Donald Severyn, Michael R. Pinsky. *University of Pittsburgh, Pittsburgh, PA, USA*

**Background:** Difficulties exist with quantitative echo assessment of subendocardial function in ischemic heart disease. The aim was to test the hypothesis that subendocardial velocity gradient (SVG) can quantify effects of ischemia on regional LV function and the effects of dobutamine on ischemic myocardium.

**Methods:** Seven open-chest dogs had flow probes and variable occluders placed on the left anterior descending coronary artery. Anteroseptal subendocardium was analyzed for SVG from color tissue Doppler images (Toshiba 7000) using a customized computer at baseline, during ischemia (50% decrease in coronary flow, and addition of dobutamine (5  $\mu\text{g}/\text{kg}/\text{min}$ ) during controlled ischemia.



**Results:** Peak systolic and diastolic SVG decreased with ischemia from  $2.7 \pm 1.1$  to  $1.8 \pm 0.7 \text{ sec}^{-1}$  and  $4.9 \pm 1.7$  to  $3.3 \pm 1.2 \text{ sec}^{-1}$ , respectively (\* $p < 0.05$  vs. baseline). Addition of dobutamine during controlled ischemia increased systolic and diastolic SVG to  $2.9 \pm 0.6 \text{ sec}^{-1}$  and  $5.0 \pm 1.3 \text{ sec}^{-1}$ , respectively ( $\#p < 0.05$  vs. ischemia alone).

**Conclusions:** SVG quantified alterations in subendocardial function reduced by ischemia and enhanced by low dose dobutamine during ischemia. Tissue Doppler SVG appears to be a promising method to quantify subendocardial function in ischemic heart disease.

#### 1056-38 Noninvasive Visualization of Right Ventricular Function by Tissue Locus Imaging: Prediction of Right Ventricular Ejection Fraction From Systolic Shift of the Tricuspid Leaflets

Shim Yoshifuku, Yutaka Otsuji, Koichi Kihara, Toshiro Kumano, Keiko Matsukida, Won-Ho Kim, Akira Kisanuki, Chuwa Tei. *Kagoshima University School of Medicine, Kagoshima, Japan*

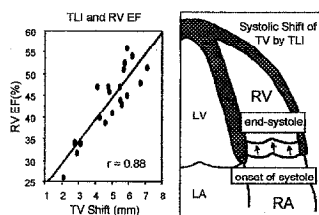
**Background:** Visualization of Right ventricular (RV) function requires moving or series of pictures to estimate RV wall or bicuspid leaflet and annular motion. Newly developed echocardiographic technique called "Tissue Locus Imaging (TLI)" can visualize series of pictures by keeping the display of previous pictures with shading function. Because it can display whole systolic shift of

the tricuspid leaflets towards the apex in a single picture, it can potentially visualize useful information of RV function. We therefore investigated whether systolic shift of tricuspid leaflets visualized by TLI is a good predictor of RV ejection fraction or not.

**Methods:** We measured systolic shift of the tricuspid leaflets using TLI in an RV apical 4 chamber view and RV ejection fraction from TC-99m human serum albumin pool scintigraphy (first pass method) in 21 patients with possible RV dysfunction (16 with ischemic heart disease, 2 with biventricular dysfunction, 2 with interstitial pneumonia, and 1 with mitral stenosis).

**Results:** 1) Systolic shift of the tricuspid leaflets was visualized in all the 21 pts in the single end-systolic TLI image.

2) Systolic shift of tricuspid leaflets towards the apex visualized and measured by TLI correlated well with RV ejection fraction ( $r = 0.88$ ,  $\text{SEE} = 0.6 \text{ mm}$ ,  $p < 0.0001$ ).



**Conclusion:** Prediction of RV ejection fraction from systolic shift of the tricuspid leaflets visualized and estimated by TLI is feasible, therefore, TLI allows noninvasive visualization of RV function in a single picture.

#### 1056-39 Right Ventricle Strain Rate: A New Way of Characterising Right Ventricular Myocardium

Rocio Garcia, Miguel A. Garcia-Fernandez, Pablo Puertas, Mar Moreno, Javier Bermejo, M. Jesus Ledesma<sup>1</sup>, Norberto Malpica<sup>1</sup>, Manuel Desco<sup>1</sup>. *Dept of Cardiology; <sup>1</sup>Dept of Biomedical Engineering, Gregorio Maranon, Madrid, Spain*

Strain rate imaging is a new method for the analysis of myocardial velocities that measures regional velocity gradients, and reflects local compression and expansion rates not affected by overall heart translation, or regional deformation during the cardiac cycle. Right ventricle walls contraction and characteristics are quite often difficult to evaluate. Measurement of the regional strain could help in the differentiation of different pathologies.

**Purpose:** In this study, we sought to determine the normal values of strain rate for the right ventricle (RV) and analyse whether strain rate is more uniformly distributed than myocardial Doppler velocity (MDV) during myocardial contraction and relaxation.

**Methods:** An Acuson Sequoia ultrasound scanner with a 3.5 MHz phased array transducer was used to collect colour 2D images from the apical acoustic window and they were analysed off-line using dedicated software. Peak systolic (sys) and early (D1) and late (D2) peak diastolic fibre velocities (V) and strains (ST) of the basal and medial regions of lateral and inferior walls of the right ventricle, were determined.

**Results:** 34 lateral and 22 inferior right walls were collected from patients without any reason or evidence of right ventricular alteration. Medial and basal segments from both walls were analysed.

	Sys ST	D1 ST	D2 ST	Sys Vel	D1 Vel	D2 Vel
RV lat. medial	-1.2	1.1	0.7	3.9	-4.1	-3.2
RV lat. basal	-1.4	1.1	0.6	4.6	-4.1	-3.2
RV inf. medial	-1.08	1.06	0.57	3.7	-3.7	-1.9
RV inf. basal	-1.1	1.01	0.6	4.9	-4.1	-2.4

1. Strain rate showed repeatedly a broad systolic compression peak and two shorter expansion diastolic peaks. 2. We did not find any medial-basal gradient of systolic, early diastolic or late diastolic maximum strain. 3. There was a medial-basal gradient for systolic velocity.

**Conclusions:** Strain rate is more homogeneously distributed than MDV in the right ventricle, so it is not necessary to define segment specific ranges for it, as for MDV. It might be a tool for the detection and differentiation of pathologies that modify the elastic and deformation properties of right ventricular myocardium.

POSTER

**1077 Myocardial Contrast Echocardiography**

Monday, March 13, 2000, 9:00 a.m.–11:00 a.m.  
 Anaheim Convention Center, Hall A  
 Presentation Hour: 9:00 a.m.–10:00 a.m.

**1077-1 Phase Analysis of Echocardiographic Contrast Images for Objective Identification of Myocardial Perfusion Defects**

Raffi Bekeredjian, Alexander Hanson, Andreas Benz, Joerg Zehelein, Nelson B. Schiller<sup>1</sup>, Elias H. Botvinick<sup>1</sup>, Elyse Foster<sup>1</sup>, Helmut F. Kuecherer. *University of Heidelberg, Heidelberg, Germany; <sup>1</sup>University of California San Francisco, San Francisco, CA, USA*

**Background:** Reliable objective methods for measuring myocardial perfusion with contrast echocardiography are not yet widely available.

**Aim:** We investigated the application of phase analysis of myocardial contrast echocardiograms in the identification of myocardial perfusion defects.

**Methods:** Harmonic Power-Doppler contrast (Levovist™) echocardiograms were performed in 19 patients (age 69 ± 9 years) undergoing TI-201-SPECT and in 11 controls (age 48 ± 14 years). Power-Doppler images were transformed using a first harmonic Fourier algorithm to obtain phase images displaying color coded sequence of myocardial intensity changes. Means and standard deviations (SD) of phase angle histograms and peak intensities were measured in septal, apical and lateral regions from apical 4-chamber views to estimate temporal and spatial heterogeneity of myocardial opacification.

**Results:** In normals, phase angles were delayed in apical regions (relative phase angles 25 ± 14° vs. 12 ± 11° in septal and 14 ± 11° in lateral regions, p < 0.05) but homogeneously distributed within regions (SD 26 ± 14°). Magnitudes were lower in lateral (61 ± 50, p < 0.001) than in septal (126 ± 61) and apical (86 ± 42) regions. Phase imaging and intensity analysis showed focal areas with marked phase shifts (106 ± 90°), heterogenous distribution of phase angles (SD 66 ± 17°) and low intensities (30 ± 20), correctly identifying 13/14 perfusion defects (5 apical, 6 septal, 2 lateral), missing an apical defect (sensitivity 93%) and misinterpreting one normal septal region as abnormal (specificity 98%).

**Conclusion:** Phase imaging reliably detects myocardial perfusion defects displaying dynamics of myocardial opacification in a simple color coded format.

**1077-2 Continuous Echo Contrast Infusion is Superior to Bolus Injection During Dobutamine Stress Echocardiography for Simultaneous Wall Motion – Myocardial Perfusion Analysis**

Toni L. Bransford, Lisa Pyatt, LaTish McKinney, Melda Dolan, Kathleen Habermehl, Jeannette St. Vrain, Carrie Totta, Arthur J. Labovitz. *Saint Louis University, St. Louis, Missouri, USA*

Numerous investigators have validated myocardial contrast echocardiography to assess wall motion in technically difficult subjects and myocardial perfusion data in a sequential echo analysis. We sought to evaluate continuous echo contrast infusion vs. bolus injection as a means of obtaining simultaneous wall motion analysis and myocardial perfusion during dobutamine stress echo.

**Method:** 19 patients were evaluated with either bolus injection (n = 9) or continuous infusion (n = 10) with harmonic mode echo. 3 ml Optison was infused at a rate of 0.15–0.25 ml/minute. Real time echo images were obtained at each stage for wall motion analysis followed by intermittent gated imaging (every 4th–5th beat). Images were evaluated for left ventricular cavity opacification (LVCO), myocardial opacification (MO), endocardial border detection (EBD), and attenuation artifact. Each category was scored as 1 (absent)–5 (maximal).

**Results:** LVCO was not consistently achieved during continuous infusion and was better with bolus injection (p < 0.05). LVCO improved by starting contrast infusion one minute prior to dobutamine echo. Despite this, there was no distinction between either protocol for EBD. Continuous infusion was preferred over bolus injection for MO and was obtained in 85% of dobutamine stress-continuous infusion stages vs. 53% with bolus injection (Chi square

	LVCO*	MO*	EBD CA*	
Continuous	3.3	4.51	4.66	0.02
Bolus	4.53	4.00	4.53	0.15

\*P = 0.05

test = 8.4, p < 0.05). Cavity (CA) attenuation artifacts were reduced with continuous echo contrast infusion (p = 0.08, p < 0.05).

**Conclusion:** Continuous echo contrast infusion was superior to bolus injection with improved image quality during the study without loss of endocardial visualization for simultaneous wall motion and perfusion analysis.

**1077-3 Correlation Between Myocardial Perfusion Abnormalities Detected With Intermittent Imaging Using Intravenous Perfluorocarbon Microbubbles and Radioisotope Imaging During High Dose Dipyridamole Stress Echo**

Ricardo Ronderos, Mario Boskis, Namsik Chung, Diomedes Corneli, Eduardo Escudero, J. Ha, Carlos Charlante, S. Rim, K. Kwon, Marcelo Portis, Nora Fabris, Jorge Camilletti, Anibal Mele, Fernando Otero, H. Kim, Thomas R. Porter. *Instituto de Cardiologia La Plata; Cardiotest Buenos Aires, Argentina*

**Purpose:** The purpose of this paper was to prospectively determine the correlation between wall motion (WM), myocardial perfusion (MP) assessed with intermittent harmonic imaging (IHI), and MP determined by sestamibi (Mibi) single photon emission computed tomography (SPECT) during high dose dipyridamole (DYP) stress.

**Methods:** In 68 consecutive non-selected patients (46 males; age range 43–83 years) from three separate institutions, a DYP stress echo was performed. Continuous intravenous (IV) infusion of 20 ml of perfluorocarbon containing microbubbles (PESDA) at 2–5 milliliters/min was administered for resting MP using triggering at end systole (apical 2, 3 and 4 chambers) and real time digitized imaging for WM. DYP was then injected in 2 steps: A) 0.56 mg/kg (3 min); and B) 0.28 mg/kg (1 min) if step A was negative for an ischemic WM response. Echo and SPECT images at rest and during DYP infusion were analyzed separately by blinded observers using a standardized 16 segment model. SPECT perfusion defects were considered true positive defects.

**Results:** Patient by patient results are shown in the Table. A total of 168 segmental defects were observed by SPECT in 35 patients; 132 (79%) of these were seen with IHI.

SPECT	+		–	
	MP	Echo	WM	Echo
MP	+32	1	+22	1
Echo	–3	32	–13	32

	N = 68	N = 68
Sensitivity	94%	66%
Specificity	94%	97%
+Predictive value	94%	66%
–Predictive value	94%	73%
Cohen's Kappa	0.76	0.60

**Conclusions:** Contrast defects observed with IHI during DYP stress echo are in excellent agreement with Mibi SPECT. Compared to WM alone, MP assessment with IV contrast improves the accuracy of echo in detecting significant coronary artery disease during DYP stress.

**1077-4 Intraprocedural Myocardial Contrast Echocardiography: A Routine Procedure in Catheter Treatment for Hypertrophic Obstructive Cardiomyopathy**

Lothar Faber, Hubert Seggewiss, Peer Ziemssen, Axel Meissner, Werner Meyners. *Dept. of Cardiology, Heart Center NRW, Ruhr-University Bochum, Bad Oeynhausen, Germany*

**Background:** Catheter treatment (PTSMA) for HOCM requires the exact definition of the septal myocardium to be ablated. We compared the predictive value of myocardial contrast echocardiography (MCE) and probatory balloon occlusion (PBO) of the presumed target vessel (TV) in 168 patients (pts.) in whom both approaches were used.

**Methods and Results:** A satisfactory reduction of the left ventricular outflow gradient (LVOTG) was achieved in 148 of these pts. (88%; from 59 ± 32 to 15 ± 19 mm Hg; p < 0.0001). LVOTG with PBO was 43 ± 33 mm Hg (p < 0.001). There was only a weak correlation between the LVOTG with PBO and the LVOTG after 3 months (See figure).

PBO-induced LVOTG reduction was >30% in 96 pts. (57%) and >50% in only 67 pts. (40%). In 21 pts. (13%) the TV had to be changed according to the MCE result; in 13 pts. (8%) PTSMA was terminated despite an insignificant acute LVOTG reduction in view of a correct MCE effect.

**Conclusion:** In case of a positive intraprocedural MCE study, PBO adds little information. Furthermore, MCE is able to exclude alcohol necrotization

NONINVASIVE IMAGING

of myocardium remote from the septal target area, and should therefore be considered the method of choice for TV selection.

#### 1077-5 Assessment of Myocardial Perfusion by Intravenous Administration of Levovist: A Comparison With $^{201}\text{Tl}$ Single Photon Emission Computed Tomography

Takashi Muro, Masakazu Teragaki, Hiroyuki Yamagishi, Hiroyuki Watanabe, Keiji Ujino, Kumiko Hirata, Ryo Otsuka, Masao Daimon, Kazuhide Takeuchi, Junichi Yoshikawa. *The First Department of Internal Medicine, Osaka City University, Osaka, Japan*

**Objectives:** The purpose of this study was to assess myocardial perfusion by myocardial contrast echocardiography (MCE) with intravenous injection of Levovist. Results were compared with those obtained by  $^{201}\text{Tl}$  single photon emission computed tomography (SPECT).

**Methods:** Twelve patients with myocardial infarction (MI) underwent MCE with intravenous injection of Levovist (Schering, Germany) using the intermittent harmonic power Doppler imaging method. Images were obtained from the apical two-, four-chamber and long-axis views and parasternal long- and short-axis views. The left ventricle was divided into 16 segments according to the recommendations of the American Society of Echocardiography and myocardial opacification was scored as good (2), fair (1) or poor (0) in each segment. SPECT was then performed with reinjection of  $^{201}\text{Tl}$  and myocardial perfusion was scored as normal (2), mildly reduced (1) or severely reduced (0) in each segment.

**Results:** Of the 192 segments, adequate image quality was obtained for 178 segments and graded for MCE and SPECT, and the results were compared. Under MCE, 96 out of 178 segments were judged as good, 42 as fair and 40 as poor. Under SPECT, 112 segments were judged normal, 30 as mildly reduced and 36 as severely reduced. When comparing the segmental scores for the two methods, the concordance rate was 83% for the score 2 segments, 38% for the score 1 segments, 85% for the score 0 segments and 73% for all segments. Good or fair opacification by MCE predicts normal or mildly reduced uptake by SPECT with a sensitivity of 90%, specificity of 94% and accuracy of 91%.

**Conclusions:** Although the concordance between fair opacification by MCE and mildly reduced uptake by SPECT was not ideal, the identification of perfusion abnormalities under MCE is similar to that provided by SPECT. MCE with intravenous injection of Levovist is suitable for the assessment of myocardial perfusion and viability in the clinical setting.

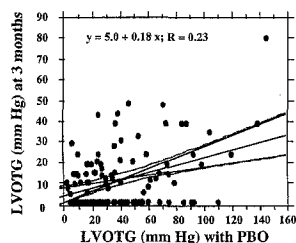
#### 1077-6 Is Adenosine Contrast Echocardiography Useful in the Assessment of the Culprit Artery Patency in Patients With Acute Myocardial Infarction?

Alvaro Moraes, Fernando Morcerf, Marcia Carrinho, Flavia Salek, Antonio C. Nogueira, Flavio C. Palheiro, Hans Dohmann. *Hospital Pro-Cardiaco and ECOR, Rio de Janeiro, Brazil*

We have previously shown that myocardial perfusion is accurately assessed by Adenosine Contrast Echocardiography (ACE) following PESDA infusion in pts with stable coronary artery disease (CAD). The aim was to assess the ability of ACE to identify perfusion defects in pts with 1<sup>st</sup> AMI and to correlate with the patency of culprit coronary artery.

**Methods:** In 21 pts (18 male,  $64 \pm 11$  years) with 1<sup>st</sup> Q-wave AMI (inferior in 16 pts) submitted to coronary angiography (ANG) to investigate the extension of CAD, ACE with PESDA was visually assessed (2 independent investigators), at rest and after IV bolus injection of 6–18 mg of adenosine (ADN) using triggered (1:1) 2<sup>nd</sup> harmonic imaging. ANG (within 15 days from ACE) showed single-vessel disease in 9 pts, 2 vessels in 8 pts and 3 vessels in 4 pts. For each pt 3 LV territories (LAD, RCA and CX arteries) were considered.

**Results:** 63 territories were analyzed being 21 related to AMI, 16 to other coronary artery with obstruction  $\geq 75\%$ , and 26 to a normal (or obstruction  $< 75\%$ ) coronary artery. A marked and homogeneous contrast enhancement (normal perfusion) was obtained with ACE in all territories supplied by arteries



with obstruction  $< 75\%$ . Absence or heterogeneous enhancement in the walls (perfusion defect) was observed in all noninfarcted territories perfused by arteries with obstruction  $\geq 75\%$ . In the AMI territories, there were 2 different types of findings: Type A (myocardial enhancement by 2<sup>nd</sup> harmonic only even before PESDA and no variation with ADN); Type B (normal aspect with 2<sup>nd</sup> harmonic only, decrease of myocardial contrast with PESDA and no enhancement with ADN). Type A was seen in 9/10 territories with a completely obstructed artery and Type B in 11/11 territories related to a reperfused artery.

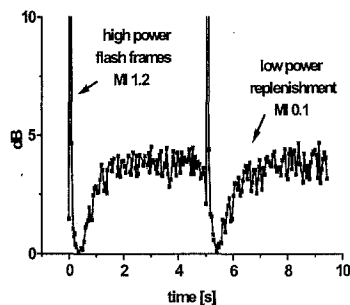
**Conclusion:** ACE is a safe and accurate method to study myocardial perfusion in humans with evolving AMI, and may be important to evaluate patency of the culprit artery after 1<sup>st</sup> Q-wave AMI.

#### 1077-7 Real-time Assessment of Tissue Perfusion Following Bubble Destruction at Low Emission Power – First Experimental Results Using Power Pulse Inversion Imaging

Klaus Tiemann, Harald Becher, Stefan Lohmeier, Jörg Köster, Stefanie Kuntz, Berndt Lüderitz, Michalakis Averkiou<sup>1</sup>, Dan Skyba<sup>1</sup>, Matthew Bruce<sup>1</sup>, Jeff E. Powers. *Dept. of Cardiology, University of Bonn, Bonn, Germany; <sup>1</sup>ATL-Ultrasound, Bothell, USA*

**Background:** Replenishment curves following bubble destruction have been found to correlate well with blood flow. However, high emission power is necessary to obtain contrast images with current techniques and a considerable amount of contrast agent is destroyed, thus restricting assessment of replenishment curves to intermittent imaging techniques. The aim of this study was to evaluate, whether replenishment curves could be obtained in *real time* using Power Pulse Inversion (PPI).

**Methods:** Replenishment kinetics were studied in a flow phantom mimicking tissue perfusion at variable volumetric flow rates ( $\dot{V}$ , 0 to 45 ml/min). Definity<sup>TM</sup> (DuPont Pharmaceuticals Company, North Billerica, MA) was continuously infused at 0.001 ml/min. Following a high power destruction burst at a mechanical index (MI) of 1.2, replenishment of echocontrast was assessed at low power (MI 0.1, 34 Hz frame rate) using an HDI 5000 (ATL Ultrasound) equipped with a prototype version for PPI. Replenishment kinetics were evaluated off-line applying the fitting function  $f(t) = c + a \cdot e^{(-\beta t)}$  with parameter  $\beta$  describing the replenishment rate ( $n = 180$ ). The extent of bubble destruction during low power PPI imaging was assessed downstream of the insonation area by means of a second transducer.



**Results:**  $\beta$  correlated well with  $\dot{V}$  ( $r = 0.98$ ,  $p < 0.01$ ). No significant decrease in signal intensity was observed downstream of the registration area during PPI imaging at MI = 0.1. At MI = 0.3 bubble destruction was  $65\% \pm 15.8\%$ , at MI = 0.8 bubbles were completely destroyed ( $99\% \pm 2.1\%$ ).

**Conclusion:** Assessment of replenishment curves using real time Power Pulse Inversion Imaging is feasible at very low emission power opening the possibility for real time perfusion imaging in clinical settings.

#### 1077-8 An Experimental Study of Prediction of the Coronary Bypass Stenosis by Intravenous Myocardial Contrast Echocardiography: Delay of Opacification of Coronary Bypass Region Depends on Bypass Flow

Fuminobu Ishikura, Haruka Kobayashi, Keisuke Matsushita, Toshiaki Hamada, Hiroaki Ueda, Shintaro Beppu. *School of Allied Health Sciences, Osaka University, Osaka, Japan*

**Background:** There were few reports about myocardial opacification using intravenous myocardial contrast echocardiography (MCE) in a patient of aorto-coronary bypass, while it has been revealed that iv MCE is useful for diagnosing the stenosis of the native coronary artery.

**Purpose:** The aim of this study is to clarify the characteristic of the myocardial opacification via the coronary bypass graft.

**Methods:** The subjects were 11 beagles, whose left circumflex artery was bypassed from the carotid artery. The bypass flow was measured by the electromagnetic flow meter attached to the bypass tube with 2 ml net volume. MCE was performed with 0.1 mg iv Optison (MBI) during short axis view recording using ECG-triggered mode at end-systole and harmonic (2.5/5.0 MHz) mode. Background-subtracted videointensity at the lateral wall (perfused area by the bypass) and the septal wall (perfused area by the native coronary artery) was measured over 50 cardiac beats, and calculated their peak intensity (PI).

**Results:** The time of PI of the lateral wall (Peak2) was delayed from that of the PI of the septal wall (Peak1) due to longer pathway of bypass tract as expected. PI of the septal wall at Peak 1 was higher than PI of lateral wall at Peak2 (71 ± 15 vs. 48 ± 12, p < 0.01). In the range of bypass flow from 12 to 38 ml/min (22.6 ± 7.0 ml/min), the time delay of PI between the lateral wall and the septal wall ranged from 2.6 to 8.0 sec (5.9 ± 1.4 sec), indicating a good reverse correlation between the bypass flow volume and the time delay. The calculated time delay (2 ml × 60 sec/bypass flow) well correlated with the time delay from MCE (r = 0.72, p < 0.05).

**Conclusion:** In the coronary bypass model, the myocardial opacification of bypass territory was delayed, correlating inversely with the bypass flow volume. This study indicates the iv MCE is useful for diagnosing the bypass stenosis.

POSTER

1078 **Cardiac Magnetic Resonance Imaging: Left Ventricular Size and Function**

Monday, March 13, 2000, 9:00 a.m.–11:00 a.m.  
 Anaheim Convention Center, Hall A  
 Presentation Hour: 9:00 a.m.–10:00 a.m.

1078-25 **Comparison of Left Ventricular Functional Analysis in Heart Failure by Echocardiography, Radionuclide Ventriculography and Magnetic Resonance; Implications for Research and Clinical Practice**

Nicholas G. Bellenger<sup>1</sup>, Malcolm I. Burgess<sup>2</sup>, Simon G. Ray<sup>2</sup>, Dudley J. Pennell<sup>1</sup>. <sup>1</sup>Cardiovascular MR Unit, Royal Brompton Hospital, National Heart and Lung Institute, Imperial College, London; <sup>2</sup>Northwest Regional Cardiac Centre, Wythenshawe Hospital, Manchester, UK

**Background:** Cardiovascular Magnetic resonance (CMR) is increasingly used in clinical practice and therapeutic trials. Studies have not assessed how rapid CMR functional analysis in heart failure compares with echocardiography and radionuclide ventriculography (RNV).

**Methods:** Fifty two patients with chronic stable heart failure underwent M-mode echo, 2D echo, RNV and CMR within 4 weeks. The scans were analysed independently in blinded fashion by a single investigator at three core laboratories.

**Results:** Of the echocardiograms, 86% had sufficient image quality to obtain left ventricular EF by M-mode cube method, but only 69% by Simpson's bi-plane analysis. All 52 patients tolerated the RNV and CMR, and all these scans were analysable. The mean LV EF by M-mode was 39 ± 16%, by the echo Simpson's bi-plane was 31 ± 10%, by RNV was 24 ± 9% and by CMR was 30 ± 11%. All the mean LV EFs by each technique were significantly different from all other techniques (p < 0.001), except for CMR EF and echo EF by Simpson's rule (p = 0.23). The Bland-Altman limits of agreement encompassing 4 standard deviations was widest for CMR vs cube echo at 66%, and was 58% for RNV vs cube echo, 44% for CMR vs Simpson's echo, 39% for RNV vs Simpson's echo, and smallest at 31% for CMR vs RNV.

**Conclusion:** These results suggest that EF measurements by various techniques are not interchangeable. In addition, there are very wide variations between techniques, which are most marked in comparisons using echocardiography. The conclusions and recommendations of research studies in heart failure should therefore be interpreted in the context of locally available techniques.

1078-26 **Cardiovascular Magnetic Resonance Only Requires Small Sample Sizes in the Study of Heart Failure**

Nicholas G. Bellenger, L. Ceri Davies, Jane M. Francis, Dudley J. Pennell. Cardiovascular MR Unit, Royal Brompton Hospital, National Heart and Lung Institute, Imperial College, London, UK

**Background:** Despite increased use, the reproducibility of fast Cardiovas-

cular Magnetic Resonance (CMR) techniques for the assessment of cardiac volumes, function and mass has not been tested outside the normal population. This reproducibility determines the sample size required to show a clinical change.

**Methods:** Breath hold CMR was performed on 15 patients with heart failure and 15 normal subjects. Intra-observer, inter-observer and inter-study reproducibility of end diastolic and end systolic volumes, ejection fraction and mass were analysed. The total standard deviation of the difference (SD, where SD = √ [Intra-observer + interobserver + inter-study SD]) was used to calculate the sample size.

**Results:** The percentage variability of the measured parameters in the HF group of intra-observer (2.0–7.4%), inter-observer (3.3–7.7%) and inter-study (2.5–4.8%) measurements was slightly larger than for the normal group (1.6–6.6%, 1.6–7.3% and 2.0–7.3% respectively), but remained comparable with previous studies using both conventional cine and breath-hold techniques in the normal population. The sample size required to show a 20 ml difference in EDV, a 10 ml difference in ESV, a 5% difference in EF and a 10 g difference in mass were 2, 5, 7 and 5 patients respectively. This compares with 30, 53, 37 and 279 using 2D echocardiography<sup>1</sup>.

**Conclusion:** Breathhold CMR provides a reproducible assessment of failing as well as normal ventricles. The fast acquisition times availability on most current MR scanners, makes this an ideal technique for assessment and follow up of patients and for reducing the sample size required to show the results of an intervention in research studies.

[1] Otterstad JE, Froeland G, St John Sutton M, Holme I. Accuracy and reproducibility of biplane two-dimensional echocardiographic measurements of left ventricular dimensions and function. *Eur Heart J* 1997; 18: 507–13

1078-27 **Cardiovascular Function in the Obese: Insights From Cardiac Magnetic Resonance Imaging**

Peter G. Danias, Nicholas A. Tritos, Kraig V. Kissinger, Warren J. Manning. Beth Israel Deaconess Medical Center and Harvard Medical School, Boston, Massachusetts, USA

**Background:** For obese individuals, magnetic resonance imaging has potential advantages for evaluation of the cardiovascular system, as other noninvasive technologies are limited by body habitus.

**Methods:** Using a 1.5 T scanner (Gyrosan NT/ACS, Philips Medical Systems) we studied 30 healthy adult men, 18 obese (body mass index 35 ± 3 kg/m<sup>2</sup>; 28 ± 7 years) and 12 lean (body mass index 23 ± 2 kg/m<sup>2</sup>; 29 ± 5 years) and measured left ventricular (LV) mass, end-diastolic and end-systolic volumes (EDV and ESV, respectively) and ejection fraction. Arterial blood pressure was noninvasively measured and indices of aortic elasticity including compliance, stiffness index (β) and pressure-strain elastic modulus (Ep) were obtained at the abdominal aorta, just proximal to the renal arteries. Images were acquired with a breathhold hybrid gradient echo – echoplanar cine sequence. LV EDV and ESV epicardial and endocardial borders were manually traced for determination of mass, volumes and ejection fraction. Aortic cross-sectional areas were manually segmented.

**Results:** LV mass and EDV (absolute and indexed for height) were both increased in obese subjects (Table). LV ejection fraction was similar (71 ± 6% vs. 70 ± 5%, obese vs. lean, respectively, p > 0.05). Abdominal aortic elasticity was decreased in obese subjects (Table).

Table (values are mean ± standard deviation):

Subject Group	LV mass (g)	LV mass index (g/m)	LV EDV (ml)	LV EDV index (ml/m)	Compliance (mm <sup>2</sup> /kPa)	β	Ep (kPa)
Obese	215 ± 38	118 ± 18	184 ± 24	102 ± 12	0.16 ± 0.06	9 ± 3	106 ± 44
Lean	164 ± 25	95 ± 13	145 ± 20	83 ± 10	0.25 ± 0.11	7 ± 2	73 ± 22
P value	<0.001	<0.001	<0.001	<0.001	<0.05	0.07	<0.05

**Conclusions:** Obese individuals have increased LV mass and EDV, and decreased abdominal aortic elasticity. Cardiac magnetic resonance is uniquely suited for evaluation of cardiovascular function in obesity.

1078-28 **Magnetic Resonance Real Time Imaging of Left Ventricular Function: Comparison With Conventional Magnetic Resonance Imaging and Echocardiography**

Simon Schalla, Eike Nagel, Hans Lehmkuhl, Christoph Klein, Ingo Paetsch, Axel Bornstedt, Bernhard Schnackenburg<sup>1</sup>, Eckhard Fleck. *Internal Medicine/Cardiology, Charité Campus Virchow, HU & German Heart Institute Berlin; <sup>1</sup>Philips Medical Systems, Hamburg, Germany*

**Background:** Magnetic resonance (MR) gradient echo imaging has been shown to be highly accurate and reproducible for the determination of left

NONINVASIVE IMAGING

ventricular muscle mass (LVM) and volumes and is regarded as the reference standard. The development of new ultrafast gradient systems and hybrid sequences make the acquisition of a complete image within 65 milliseconds possible. Purpose of this study was to analyse if a new real time magnetic resonance imaging technique is as accurate as the reference standard for the determination of left ventricular enddiastolic volume (EDV), end-systolic volume (ESV), ejection fraction (EF) and LVM within minimal measurement time and to compare these parameters with echocardiography.

**Methods:** In 34 patients EDV, ESV, EF and LVM were determined by MR with standard turbo gradient echo and a new real time technique. EDV, ESV and EF were additionally obtained by digital echocardiography.

**Results:** A close correlation was found between the results of real time and turbo gradient echo MR imaging for EF, EDV and ESV ( $r > 0.95$ ) with a lower correlation for LVM ( $r = 0.81$ ). Correlations in comparison with echocardiography were lower for all parameters.

	% error real time	% error echo
EF	7.7 ± 7.1	19.6 ± 15.9
EDV	12.0 ± 13.8	23.3 ± 18.7
ESV	14.9 ± 18.3	39.0 ± 28.9
LVM	17.3 ± 17.2	-

**Conclusion:** MR real time imaging allows to acquire a three-dimensional data set covering the entire heart in minimal measurement time without ECG-triggering or breath holding. Thus, patient set up and scan time can be reduced considerably without a significant loss of image quality. Differences between echocardiography and MR can be explained by the different approaches as complete cardiac volumes are obtained with MR whereas geometric assumptions are needed to determine EF with echocardiography. Using MR real time imaging it will be possible to examine patients with atrial fibrillation or frequent extrasystoles.

## POSTER

### 1079 Radionuclide Assessment of Myocardial Viability

Monday, March 13, 2000, 9:00 a.m.–11:00 a.m.  
Anaheim Convention Center, Hall A  
Presentation Hour: 9:00 a.m.–10:00 a.m.

### 1079-29 Oxidative Metabolism, Glucose Utilization, Perfusion and Contractile Reserve in Patients With Chronic Ischemic Left Ventricular Dysfunction

Jeroen J. Bax, Gerrit W. Sloof, Don Poldermans, Frans C. Visser, Abdou Elhendy, Arthur van Lingen, Paolo M. Fioretti, Cees A. Visser. *Leiden University Hospital, Leiden; Amsterdam; Rotterdam, Netherlands; Udine, Italy*

Nuclear tracers can be used to assess free fatty acid utilization (oxidative metabolism by I-123-iodophenyl-b-methylpentadecanoic acid, BMIPP), glucose utilization (by F18-fluorodeoxyglucose, FDG) and perfusion (by TI-201, imaged immediately following tracer injection at rest), while low-dose dobutamine echocardiography (LDDE) can be used to detect contractile reserve (CR). All these features can be observed in viable tissue, albeit with a different frequency.

**Methods:** We evaluated the incidence of these different features in 14 patients with chronic ischemic LV dysfunction (LVEF 35 ± 12%). Only segments with akinesia (assessed by resting 2D echo) were evaluated. Perfusion, glucose utilization and oxidative metabolism were considered preserved when respectively TI-201, FDG or BMIPP uptake exceeded 70% of maximum. CR was considered present when wall motion improved during low-dose dobutamine infusion.

**Results:** 64 (35%) of 182 segments were akinetic. The nuclear and LDDE results were as follows:

	BMIPP+	FDG+	TI-201+
CR+ n = 21	19	21	16
CR- n = 43	19	17	17

Hence, preserved oxidative metabolism and glucose utilization were observed in 59% of the akinetic segments, intact perfusion in 52% and CR in 33% ( $P < 0.01$ ).

**Conclusion:** The data suggest that oxidative metabolism, glucose utilization and perfusion are more frequently preserved in patients with ischemic LV dysfunction as compared to CR.

### 1079-30 Effects of Left Bundle Branch Block on Myocardial Fluorodeoxyglucose Positron Emission Tomography Imaging in Subjects With Healthy Coronary Arteries

Pierluigi Zanco, Gianni Mobilia, Giovanni M. Boffa<sup>1</sup>, Alessandro Desideri, Serena Cargnel, Elisa Milan, Leopoldo Celegon, Riccardo Buchberger, Giorgio Ferlin. *Nuclear Medicine and Cardiology Depts. ULSS 8, Castelfranco Veneto – Montebelluna; <sup>1</sup>Cardiology Dept., Padua University, Italy*

**Background:** Cardiac positron emission tomography (PET) studies in patients affected by left bundle branch block (LBBB) are limited in number and the results are conflicting. In particular, even if a reduced uptake of F18-fluorodeoxyglucose (FDG) is reported, confirmation in a large group of patients and exact understanding of the underlying cause are lacking.

**Methods:** Among the patients submitted to FDG and N13-ammonia (NH3) PET in our center, 29 consecutive patients affected by complete LBBB and presenting no significant stenosis at the coronary angiography were selected. A semiquantitative analysis of the PET images by ROI was also performed calculating the septum/lateral uptake ratio (S/L). Wall motion was evaluated using B-mode echocardiography. A group of 10 subjects without coronary stenosis and LBBB was considered as control.

**Results:** In all the LBBB patients a reverse mismatch in the septum was present, defined as a reduced uptake of FDG in comparison with NH3, extending to anterior and inferior wall in 17 patients. The mean S/L was 0.57 ± 0.11 for FDG (range 0.28–0.76) and 0.99 ± 0.12 for NH3 (range 0.75–1.18), with a p value < 0.0001. On the contrary no significant differences in the uptake was present in the control group, that presented a S/L equal to 0.95 ± 0.13 for FDG (range 0.78–1.15, with p < 0.01 respect to LBBB patients) and 0.94 ± 0.11 (range 0.85–1.20) for NH3.

**Conclusion:** Our study suggests that in LBBB patients with healthy coronary arteries a change in the FDG uptake in the septum without correlated damage in perfusion is present. This phenomenon could cause an artifactual diagnosis of necrosis in the LAD territory and this is mostly relevant in view of the rapid increase in sites utilizing SPECT systems for viability imaging with FDG.

### 1079-31 The Extent of Ischemic and Non-Ischemic Viable Tissue Predicts the Degree of Recovery of LV Dysfunction Post-Revascularization

Rob Beanlands, Terrence D. Ruddy, Robert deKemp, Paul Hendry, Roy Masters, Geoffrey Coates, Robert Burns, R. Mark Iwanochko, Graham Nichol, Claude Nahmias, Michael Freeman, Lynda Mickleborough, Andrew Lamy, William Kostuk, Ernest Fallen. *The PARR Investigators; University of Ottawa, Ottawa; McMaster University, Hamilton, Canada*

**Background:** F-18-fluorodeoxyglucose (FDG) PET imaging can be used to identify high risk patients with hibernating myocardium and LV dysfunction. However, in patients with severe LV dysfunction, it is unclear what amount of viable myocardium is needed to predict a certain degree of recovery after revascularization (REV).

**Methods:** 41 patients with severe coronary disease and EF ≥ 35% (age = 61 ± 9 yrs) underwent FDG PET and perfusion imaging prior to revascularization (REV). FDG PET and perfusion images were divided into 9 segments and scored on a 0–4 scale (absent to normal uptake). For each patient, the total extent of viable tissue (FDG index (FDG-I)) and a perfusion index were obtained from the sum of segmental FDG and perfusion scores respectively (maximum FDG-I value = 36). A hibernating myocardium (mismatch) index (M/M) was defined as the sum of segment differences in FDG – perfusion.

**Results:** Patients were divided into tertiles according to their FDG-I values: low (17.6 ± 2.6, n = 14); moderate (22.7 ± 1.3, n = 15); high (28.0 ± 1.9, n = 12) ( $p < 0.001$ ). Baseline and 3 month post-REV LV function were compared (\* p < 0.02 vs baseline and vs low):

	low	Moderate	high
EF (baseline)	27.5 ± 5.6	25.0 ± 8.3	28.9 ± 7.0
EF (follow-up)	26.7 ± 5.0	27.4 ± 12.0	35.0 ± 8.9*

For predicting EF increase ≥ 5%, ROC analysis showed that FDG-I ≥ 24 yielded sensitivity (SN) = 75% and specificity (SP) = 76%. The additional consideration of a M/M index ≥ 5, in patients with moderate range FDG-I, further improved SN to 92%.

**Conclusion:** In patients with severe LV dysfunction, both the total extent of viable myocardium and the amount of ischemic viable hibernating tissue are important for accurate prediction of the extent of recovery of LV function with REV. In addition to hibernating tissue, determination of the total extent of viable myocardium should be considered, in order to optimize appropriate therapy selection in this difficult population.



**1079-32 Coronary Bypass Surgery in Patients With a Prolonged History of Medically Treated Ischemic Heart Disease, Decreased Left Ventricular Function and Relatively Low Extent of Myocardial Viability by Positron Emission Tomography (PET) and RevAscularisation: The PETREA Study)**

Klaus F. Kofoed, Regitze B. Petersen, Alan Rabøl, Jens D. Hove, Steen Carstensen, Søren Holm, Mikael Jensen, Jesper H. Svendsen, Peter R. Hansen, Henrik Arendrup, Stig Haunsø, Birger Hesse, Henning Kelbæk. *Rigshospitalet, University of Copenhagen, Denmark*

**Background:** In most patients with a prolonged history of ischemic heart disease and decreased left ventricular ejection fraction (LVEF), the global extent of myocardial viability by positron emission tomography (PET) is relatively low. The effect of coronary bypass surgery (CABG) in such patients was studied.

**Methods:** Forty-six consecutive patients with a prolonged history of medically treated ischemic heart disease (average 9 ± 7 years), LVEF < 45% and multivessel disease were included in the study. Myocardial viability was assessed with F-18 fluorodeoxyglucose, N-13 ammonia and PET. Before and 6 months after CABG cardiac event rate, LVEF, angina pectoris, anti-anginal medication and exercise-capacity (Ex-cap) were assessed. Cardiac survival rate was recorded at a median of 3 years post-CABG.

**Results:** In 95% of the patients the extent of myocardial viability by PET in the left ventricle was ≤25%. The post-CABG event rate (6 months) was 24%.

	Pre CABG	Post CABG*	p
LVEF (%)	32 ± 7	26 ± 8	<0.005
Pts with angina pectoris (%)	87	7	<0.001
Pts on anti-anginal medication (%)	91	18	<0.001
Ex-cap (Mets)	5.2 ± 1.2	5.7 ± 1.2	<0.03

\*Eventfree patients. The 3-year cardiac survival rate was 82%.

**Conclusion:** Patients with a prolonged history of ischemic heart disease, a decreased left ventricular ejection fraction and a relatively low extent of myocardial viability seem to benefit from CABG by relief of angina, a reduction in use of anti-anginal medication, increased exercise-capacity and a fairly good longterm survival, despite a postoperative decrease in left ventricular function.

**1079-33 <sup>13</sup>N-Ammonia Myocardial Uptake but Not Blood Flow Identifies Regions With Positive Contractile Reserve to Low-Dose Dobutamine**

Anastasia N. Kitsiou, Stephen L. Bacharach, Claiborne Miller-Davis, Andrew E. Arai, Vasken Dilisizian. *NHLBI, NIH, Bethesda, Maryland, USA*

**Background:** In patients with chronic CAD, the relation between regional myocardial blood flow (MBF) and regional contractile response to low-dose dobutamine (LDD) is complex. Recently we showed that beyond its value as a MBF tracer, late <sup>13</sup>N-ammonia uptake (metabolic trapping) provides useful information regarding functional recovery after revascularization. In the present study, we determine whether late <sup>13</sup>N-ammonia uptake may identify regional contractile response to LDD.

**Methods:** 29 pts (mean age 58 ± 10 yrs) with chronic CAD and LV dysfunction (mean LVEF = 27 ± 8%) underwent rest and LDD <sup>13</sup>N-ammonia PET and cardiac MRI. Rest and LDD short-axis PET and MRI slices (4 slices/patient) were matched and MBF and contractile function were assessed in 8 regions/slice. Absolute MBF was measured from the first ~3.0 min after <sup>13</sup>N-ammonia injection, using a 2-compartment model, while late <sup>13</sup>N-ammonia uptake was measured from the last 10–15 min of image acquisition.

**Results:** In asynergic regions with abnormal (<0.75) and normal (≥0.75) MBF at rest, changes in MBF and late <sup>13</sup>N-ammonia uptake in relation to positive (+) or negative (-) contractile response (CR) to LDD are shown:

	MBF (ml/min/g)		Late <sup>13</sup> N-ammonia Uptake	
	Rest	LDD	Rest	LDD
<i>Rest MBF &lt; 0.75</i>				
+CR (n = 159)	0.46 ± 0.18	0.69 ± 0.27	87 ± 20%	p < 0.001 86 ± 20% p < 0.001
-CR (n = 313)	0.49 ± 0.17	0.65 ± 0.30	78 ± 23%	77 ± 22%
<i>Rest MBF ≥ 0.75</i>				
+CR (n = 52)	0.94 ± 0.18	0.92 ± 0.35	95 ± 19%	p < 0.05 90 ± 20%
-CR (n = 99)	0.96 ± 0.22	0.93 ± 0.46	87 ± 23%	87 ± 28%

MBF does not differentiate +CR from -CR regions but late <sup>13</sup>N-ammonia uptake does. Thus, improvement in contractile function with LDD cannot be explained by the potential of that region to augment MBF. On the other hand, late <sup>13</sup>N-ammonia uptake is significantly higher in regions with +CR compared to -CR.

**Conclusion:** These data suggest that improved contractile response to catecholamine is, in part, dependent on the metabolic status of the myocardium.

**1079-34 Enhanced Diagnostic Accuracy to Predict Improvement of LVEF Post-Revascularization by Sequential Thallium-201 Imaging and Dobutamine Echocardiography**

Jeroen J. Bax, Jamshid Maddahi, Don Poldermans, Jan H. Cornel, Abdou Elhendy, Paolo M. Fioretti. *Leiden Univ. Medical Center, Leiden; Rotterdam, The Netherlands; Los Angeles, USA; Udine, Italy*

Thallium-201 (TI-201) imaging and low-dose dobutamine echo (LDDE) can identify viable myocardium. Prediction of functional outcome after revascularization (REV) remains suboptimal with either technique due to relatively low specificity of TI-201 and low sensitivity of LDDE. This study was undertaken to develop an optimal testing strategy for prediction of post-REV functional outcome.

**Methods:** 66 patients (LVEF 33 ± 8%) underwent LDDE and TI-201 SPECT (rest-redistribution) prior to REV. Dysfunctional segments (Segs) with TI-201 activity ≥50% or with contractile reserve were considered viable. LVEF was assessed before and 3 months post-REV.

**Results:** ROC analysis showed that the optimum criteria to predict improvement (≥5%) in LVEF after REV were ≥6 viable dysfunctional Segs (in a 16-Segs model) on TI-201 and ≥4 Segs on LDDE. Sensitivity and specificity for TI-201 were 83% (24/29) and 65% (24/37) and for LDDE 69% (20/29) and 84% (31/37). Change of TI-201 criteria to improve specificity to 78% (≥8 Segs) yielded a low sensitivity of 41% and change of LDDE criteria to improve sensitivity to 83% (≥2 Segs) lowered specificity to 57%. To achieve optimal sensitivities and specificities, 2 sequential testing strategies were explored. In strategy#1, 27/66 (41%) patients with an intermediate (58%) likelihood of viability by TI-201 (5–8 viable Segs) underwent LDDE study. In strategy#2, 26/66 (39%) patients with an intermediate (42%) likelihood of viability by LDDE (2–4 viable Segs) underwent TI-201 study. Sensitivity and specificity for strategy#1 were 88% (21/24) and 81% (34/42) and for strategy#2 79% (22/28) and 82% (31/38).

**Conclusion:** Sequential testing by TI-201 and LDDE in a subgroup of patients with an intermediate likelihood of viability by either test enhances prediction of post-REV improvement of LVEF.

**1079-35 Absolute Myocardial Blood Flow to Stunned Myocardium is Normal in Patients With Coronary Artery Disease**

Edward Barnes, David P. Dutka, Roger J.C. Hall, Paolo G. Camici. *MRC Cyclotron Unit and Department of Cardiology, Hammersmith Hospital, Imperial College School of Medicine, London, UK*

**Background:** In patients with coronary artery disease (CAD) and normal left ventricular (LV) function, we have shown previously that dobutamine (DOB)-induced ischaemia leads to prolonged LV systolic dysfunction, presumed to be due to myocardial stunning as seen following exercise. The present study was designed to assess absolute myocardial blood flow (MBF) in this condition using positron emission tomography (PET).

**Methods:** 10 patients (aged 61 ± 8 years) with angiographically proven CAD (mean 2.5 VD) and normal LV function (ejection fraction [EF] 65 ± 1.6%) underwent DOB stress. Quantitative transthoracic echocardiographic assessment of global (EF) and regional (shortening fraction [SF]) systolic function was performed at rest and regular intervals after DOB. Regions with greater than a 20% reduction in SF 30 minutes (mins) after DOB were defined as stunned. MBF was assessed at rest and after peak stress just prior to the 30 mins echo data acquisition, using PET and the flow tracer H<sub>2</sub><sup>15</sup>O.

**Results:** Thirty mins after stress, EF and SF were both significantly reduced by 10 ± 2.1% and 39 ± 2.4% respectively, compared to baseline (both p < 0.01), but had recovered by 60 mins and 120 mins respectively. MBF to impaired regions was 0.91 ± 0.22 ml/min/gm prior to and 1.13 ± 0.49 ml/min/gm after DOB stress (p < 0.05) when LV function was globally and regionally depressed. When corrected for rate pressure product, flow was 1.05 ± 2.6 ml/min/gm prior to and 1.02 ± 3.1 ml/min/gm after DOB (NS).

**Conclusions:** Absolute MBF to regions of reversible post-ischaemic LV dysfunction is not reduced compared to baseline (flow-function mismatch). Therefore this condition represents myocardial stunning.

### 1079-36 Myocardial Salvage in Patients With Non-ST Elevation Myocardial Infarction: Results Using Technetium-99m Sestamibi Myocardial Perfusion Imaging

Michael C. Kontos, Karen A. Kurdziel, Joseph P. Ornato, Robert L. Jesse, James L. Tatum. *MCV/VCU, Richmond, VA, USA*

**Background:** Technetium-99m sestamibi can be used to delineate both myocardium at risk and final infarct size in patient (pts) with ST-elevation myocardial infarction (MI). Serial myocardial perfusion imaging (MPI) in pts with non-ST elevation MI has not been described previously.

**Methods:** Pts with non-ST elevation MI who had MPI at the time of Emergency Department (ED) presentation were included. Percent defect size was quantitated using a 50% threshold derived from a phantom ( $r = 0.99$ ) using multiple short axis slices. Myocardial risk area was defined as the initial defect size; infarct area as the defect size on repeat imaging; and myocardial salvage as the difference between the two.

**Results:** There were 45 pts who had acute ED MPI diagnosed with MI who underwent repeat MPI a median 5 days later. Revascularization was performed in 33 pts (73%) (only 2 within 12 hours of presentation). Variation in both mean peak CK ( $810 \pm 1480$  U/L, median 325 U/L, range 88 to 3196 U/L) and area at risk ( $21 \pm 12\%$ , median 20%, range 2–50% of the left ventricle) was high. Mean final infarct size,  $12 \pm 8\%$  (median 11%, range 0–36%) of the left ventricle, was significantly smaller ( $p < 0.001$ ), and was only 57% of the initial risk area. Significant salvage (initial risk area-final infarct size  $> 10\%$ ) occurred in most pts (74%), with 44% of pts having  $> 50\%$  salvage. In the subgroup of pts without prior MI ( $N = 30$ ), final infarct size had a higher correlation with mean peak CK ( $r = 0.49$ ) than did initial defect size ( $r = 0.17$ ).

**Conclusions:** The ischemic risk area in pts with non-ST elevation MI can be large. Significant myocardial salvage is common and is not limited to those that have early revascularization.

### 1079-37 Accuracy and Feasibility of Technetium-99m Tetrofosmin Myocardial Perfusion Imaging to Detect of Spontaneous Recanalization in Patients With Acute Anterior Myocardial Infarction

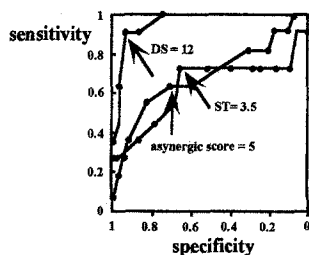
Shinichi Hamada, Seishi Nakamura, Takashi Nishiue, Junko Watanabe, Kengo Hatada, Yoshihiro Kudo, Masayoshi Fukui, Toshinori Fujimoto, Masato Baden, Tetsuro Sugiura<sup>1</sup>, Toshiji Iwasaka. *Cardiovascular Center, Kansai Medical University, Osaka;* <sup>1</sup>*Kochi Medical University, Kochi, Japan*

**Background:** To avoid the hemorrhagic risk of unnecessary thrombolysis in acute myocardial infarction (AMI), early and precise diagnosis of spontaneous recanalization (SR) of the infarct-related artery is required. The aim of this study was to clarify the accuracy and feasibility of technetium-99m tetrofosmin myocardial perfusion imaging to detect SR in pts with anterior AMI on an emergency department.

**Methods:** Electrocardiographic (ECG), echocardiographic (UCG) and semiquantitative tetrofosmin SPECT imaging were performed in 43 pts with anterior AMI before emergency coronary angiography (CAO) (time from admission to CAG =  $38 \pm 15$  min). Left ventricle of the SPECT image was divided into 13 segments and defect score (DS) was calculated as the sum of perfusion defect of each segment: from 3 (complete defect) to 0 (normal perfusion). UCG asynergic score was defined as the number of severe hypokinetic or akinetic segments corresponding to the nuclear images. The greatest ST elevation of the 12-lead ECG on admission was measured.

**Results:** SR was defined as TIMI 3 flow on emergency CAG ( $G1 = 11$  pts). Primary PTCA was performed in 32 pts with TIMI 0–2 flow ( $G2$ ). There were no significant differences between the 2 groups in elapsed time to CAG, collateral grade, asynergic score ( $G1 = 4 \pm 2$ ,  $G2 = 5 \pm 2$ ) and degree of ST elevation ( $G1 = 4.6 \pm 4.3$ ,  $G2 = 5.1 \pm 2.7$  mm) between the 2 groups, whereas DS in  $G1$  ( $9 \pm 4$ ) was significantly smaller than that in  $G2$  ( $19 \pm 5$ ) ( $p < 0.01$ ).

From the receiver operating characteristic curves, the optimal cut-off point of DS, asynergic score, and ST elevation for detecting SR was 12 and 5 and 3.5, respectively. Sensitivity and specificity of DS (91% and 94%) were



significantly higher compared with UCG (55% and 81%) and ECG (72% and 65%).

**Conclusions:** Tetrofosmin myocardial perfusion imaging on admission is a very accurate method in detecting SR in pts with anterior AMI.

### 1079-38 Assessing Myocardial Viability Using NOGA Left Ventricular Mapping System in a Chronic Ischemic Porcine Model: A Correlation With Histology and Thallium Scintigraphy

Sukumaran T. Thambar, Valerie B. Popkin, Lynne L. Johnson, Lorraine Schofield, Barry L. Sharaf, David O. Williams. *Rhode Island Hospital, Providence, Rhode Island, USA*

**Background:** Left ventricular (LV) R wave voltage endocardial mapping is an emerging technique for assessing myocardial viability. The aim of this study was to compare unipolar voltage (UPV) scores with thallium uptake and myocardial fibrosis in a chronic ischemic porcine model.

**Methods:** Six domestic swine (wt 36–43 kg) had ameroid constrictors placed on epicardial coronary arteries (3 LAD, 3 LCX). Once wall motion abnormalities (WMA) were documented on follow up echocardiograms (range 2–7 weeks post surgery) the animals were anesthetized and underwent rest thallium scanning, dobutamine echocardiography, and UPV mapping. LV cross sections were stained with trichrome and percentage fibrosis (PF) calculated using a color recognition program and then compared with corresponding thallium and UPV segments. Each heart was divided into 12 segments. PF, thallium uptake (% peak counts), and UPV values for all segments were dichotomized using cut-off value of 2SD of mean for normal segments. The cut-off value for PF was 12%, for thallium 70% (0.70) uptake and for UPV 6.5 mV.

**Results:** UPV and thallium were concordant in 44/49 segments ( $p < 0.0001$ ). UPV and PF were concordant in 35/41 segments ( $p < 0.0001$ ). Thallium was concordant with PF in 45/48 segments ( $p < 0.0001$ ). The segments that had low thallium and low PF were the same segments with low UPV and PF. That these 5 segments were hypokinetic and improved with dobutamine was indicative of ischemia/viability (hibernation). When the individual UPV scores were correlated with thallium uptake  $r^2 = 0.409$  ( $p, 0.001$ ).

**Conclusion:** UPV agrees with thallium in detecting normal, scarred, or hibernating myocardium.

### 1079-39 Segmental Motility and Regional FDG-Uptake With Severe Coronary Heart Disease

Hans Martin Hoffmeister<sup>1</sup>, Uwe Helber<sup>1</sup>, Andreas Franow<sup>1</sup>, Jörg Logemann<sup>2</sup>, Hans Jörg Machulla<sup>2</sup>, Wolfgang Müller-Schauenburg<sup>2</sup>, Roland Bares<sup>2</sup>. <sup>1</sup>*Med. Dept. III;* <sup>2</sup>*Dept. Nuclear Med., Univ. Tübingen, Germany*

**Background:** FDG-positron emission tomography (PET) is clinically used to identify vital myocardium in patients with coronary heart disease and severely compromised LV-function. Nevertheless, not all FDG positive akinetic segments improve function after revascularization, probably due to the commonly used artificial 50% uptake limit to discriminate vital and non-vital.

**Methods:** With a new ECG-triggered PET technique we determined not only FDG-uptake but also regional function of 45 LVs vs. biplane cineventriculography (total 1620 segments). Pat. were restudied post revascularization. Segments were graded as normokinetic (NORM), hypokinetic (HYPO) and akinetic (AKIN) and FDG-uptake was quantified in % of a normally perfused region (identified with perfusion imaging).

**Results:**

Uptake	NORM	HYPO	AKIN
$\leq 40\%$	0%	0%	54.7%
40–49%	0%	8.4%	27.0%
50–59%	2.5%	19.0%	10.8%
$\geq 60\%$	97.5%	72.6%	7.5%

After the baseline study we stimulated the LV with low-dose dobutamine. In akinetic segments with  $< 40\%$  FDG no functional response was observed. 10% of the hypokinetic (vital) segments had 40–50% FDG-uptake. In contrast 15% of segments with a FDG-uptake of 50–60% could not be stimulated with dobutamine and did not improve post revascularization.

**Conclusion:** On a segmental base a 50% FDG-uptake does not always correctly discriminate vital/non-vital myocardium. In segments with 40–50% FDG-uptake inotropic stimulation can be helpful to identify residual vital myocardium (also in according to our postop. data), while below 40% FDG-uptake no evidence for viability was found.

**1079-40 Stress Technetium-99m Sestamibi Gated SPECT Imaging Can Differentiate Non-Ischemic, Ischemic, or Combined Origins of Dilated Cardiomyopathy**

Domenic Marini, Mary C. deGroot, Alan W. Ahlberg, Giselle M. Cyr, April Mann, Gary V. Heller. *Hartford Hospital, Hartford, CT, USA*

**Background:** A study of preselected patients has shown that exercise Tc-99m sestamibi gated SPECT imaging (GS-MIBI) can differentiate non-ischemic (NI) from ischemic (I) dilated cardiomyopathy (Danias et al *Am J Cardiol* 1998; 82: 1253-8). The ability of GS-MIBI to differentiate NI, I, or combined (C) origins of dilated cardiomyopathy in unselected patients is unknown.

**Methods:** One-hundred nineteen consecutive patients with dilated cardiomyopathy and LV ejection fraction (EF) <40% who underwent both coronary angiography with contrast ventriculography (CATH) and exercise or pharmacologic stress and rest GS-MIBI within 12 weeks were studied. Three angiographers, unaware of GS-MIBI results, assessed OATH by consensus and classified patients as either NI (n = 22), C (n = 11), or I (n = 86). Three nuclear cardiologists, unaware of CATH results, interpreted GS-MIBI images by consensus using a standard 17-segment model and 5-point scale for myocardial perfusion (0 = normal to 4 = absent activity) and 6-point scale for LV wall motion (0 = normal to 5 = dyskinetic). For each image, summed stress scores (SSS), summed rest scores (SRS), summed difference (SSS-SRS) scores (SDS), segmental wall motion variance (SWMV), and LVEF were calculated.

**Results:** SSS and SDS were lower in the NI group when compared to the C and I groups. There were no differences in SSS, SRS, and SDS between the C and I groups. SWMV was lower in the NI and C groups when compared to the I group. There were no differences in SWMV between the NI and C groups. LVEF was lower in the NI group when compared to the I group. There were no differences in LVEF between NI and C groups.

	SSS	SRS	SDS	SWMV	LVEF (%)
NI	*17.8 ± 6.7	†6.5 ± 6.6	*11.3 ± 1.5	‡0.47 ± 0.46	*26 ± 8
C	16.4 ± 6.5	10.2 ± 4.7	6.2 ± 6.2	‡0.64 ± 0.55	25 ± 8
I	20.5 ± 8.9	16.2 ± 9.2	4.3 ± 4.7	1.43 ± 0.98	31 ± 8

\* p < 0.05 NI vs C or I; † p < 0.001 NI vs I; ‡ p < 0.05 C vs I

**Conclusion:** In patients with dilated cardiomyopathy, stress myocardial perfusion data are similar between ischemic and combined origins while left ventricular segmental wall motion variance is similar between non-ischemic and combined origins. Thus, a combined assessment of myocardial perfusion and left ventricular function using stress Tc-99m sestamibi gated SPECT imaging can differentiate non-ischemic, ischemic, or combined origins of dilated cardiomyopathy.

ORAL

**829** **Stress Echo: Advances in Quantitation**

Monday, March 13, 2000, 9:15 a.m.–10:30 a.m.  
Hilton Anaheim, Pacific C

9:15 a.m.

**829-1 Tissue Doppler vs Myocardial Strain Rate for Quantitative Assessment of Dobutamine Echo: Feasibility and Comparison With Angiography**

Peter Cain, Leanne Short, Jared Dart, Danielle Spicer, Paul Garrayh, Tom Marwick. *University of Queensland, Brisbane, Australia*

**Background:** Systolic myocardial Doppler velocity (MDV) may be a sensitive quantitative index of ischemia during dobutamine echo (DbE). Strain rate imaging (SRI, derived from MDV) may be less influenced by translation and tethering but is not suitable in many segts due to image orientation. We sought to assess clinical feasibility and diagnostic accuracy of MDV and derived SRI during DbE.

**Methods:** We studied 34 patients (normalcy group) with low pretest risk for CAD, and 106 patients with coronary angiography. Digital tissue Doppler images optimized for MDV (1000 Hz) were acquired in 3 apical views (GE-Vingmed System FiVe) during DbE. MDV and SRI were analyzed offline, and normal ranges (derived from the normalcy group) were used to define segts as normal or abnormal. Wall motion (WM) analysis was assessed independently by an experienced observer; segts with abnormal WM at rest or stress were identified as abnormal. Significant CAD was defined by >50% stenosis by quantitative angiography. Interobserver concordance between 2 readers of MDV and SRI was measured using Cronbach's alpha test.

**Results:** Normal reference ranges of MDV but not SRI varied according to location (basal vs midwall, septal vs free wall). Cutoffs were designated to give a specificity of 80%;

Site	Basal/paraseptal		Basal/free wall		Mid/paraseptal		Mid/freewall	
	M ± SD	Cutoff	M ± SD	Cutoff	M ± SD	Cutoff	M ± SD	Cutoff
MDV	8.3 ± 3.0	6.0	7.7 ± 3.7	5.0	6.6 ± 2.5	4.0	6.3 ± 4.2	3.0
SRI	-1.3 ± 0.4	-1.0	-1.2 ± 0.4	-0.9	-1.3 ± 0.4	-1.0	-1.3 ± 0.4	-1.0

Concordance (Cronbach's alpha) between observers was 0.8 for MDV and 0.22 for SRI. MDV but not SRI accurately predicted significant coronary artery disease and approached the diagnostic accuracy of expert wall motion analysis;

	LAD	LCX	RCA	ANY CAD
WM analysis	74%	72%	72%	87%
MDV	68%	70%	64%	73%
SRI	53%	68%	56%	53%

**Conclusions:** SRI derived from MDV is non-reproducible and accuracy is limited by setup for MDV; further technical refinement may improve performance of SRI. However, MDV accurately predicts significant CAD during DbE.

9:30 a.m.

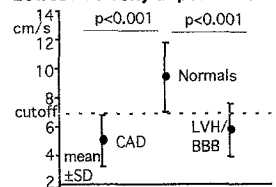
**829-2 Objective and Quantitative Stress Echo Analysis to Diagnose Coronary Disease Using Model-Based Image Processing**

Patrick Hunziker, Dinghua Yuan, Lukas Schöb, Hans Bosch, Matthias Pfisterer, Peter Buser. *University Hospital, Basel, Switzerland*

**Study Purpose:** To study the feasibility of quantitative stress echo analysis, to describe quantitatively the behaviour of normal & of ischemic wall segments during stress, & to find objective diagnostic criteria for diagnosing coronary disease, we applied model-based image analysis to 105 consecutive patients undergoing standard dobutamine-atropine stress echo (DASE). Patients were classified as coronary disease (CAD), normal (NL), and left ventricular hypertrophy & conduction defects (LVH/BBB) by angiogram, echo & Bayesian analysis. Coronaries were classified as stenosed (>50%) or open. The endocardial motion tracking algorithm was based on a mathematical heart model combined with grayscale echo information. A 16 segment model was used for segmental analysis & perfusion territories.

**Results:** At baseline, peak systolic endocardial velocity was 3.3 ± 1.6 cm/s. At peak stress (92% predicted heart rate), average peak velocities were 12 ± 3.6 cm/s in normals, 7.0 ± 3.1 cm/s in CAD (p < 0.001 vs NL), and 7.6 ± 2.7 cm/s in LVH/BBB (p < 0.001 vs NL). Notably, in patients with CAD, endocardial velocities were significantly lower than in normals even in perfusion territories of nonstenosed vessels, pointing to additional mechanisms for impaired contractile reserve. When the lowest endocardial velocity in any perfusion territory at peak stress was used for diagnosis of ischemia, with a cutoff of 7.2 cm/s, patients with CAD could be discriminated from normals with a sensitivity of 93% and a specificity of 77%.

**Lowest velocity at peak stress**



**We conclude** that quantitative analysis of stress echo is feasible using model-based digital image analysis and allows diagnosis of CAD based on objective criteria with a good sensitivity and specificity. This reduces dependence of stress echo results from reader expertise and has the potential to improve diagnostic accuracy.

9:45 a.m.

**829-3 Tissue Doppler During Dobutamine Echo Facilitates Accurate Quantification of Extent of Ischemia and Prediction of Multivessel Disease by Novice Readers**

Peter Cain, Terri Baglin, Colin Case, Tom Marwick. *University of Queensland, Brisbane, Australia*

**Background:** Extent of myocardial ischemia is prognostically important but wall motion scoring is subjective and reproducibility may be problematic.

Systolic myocardial Doppler velocity (MDV) may be a sensitive quantitative index of ischemia during dobutamine echo (DbE). We sought to compare extent of ischemia assessed by expert wall motion analysis with that assessed by novice readers of stress echo using MDV.

**Methods:** We studied 109 pts, 34 with low pretest risk for CAD, and 75 with coronary angiography (39 single, 36 multivessel, 35 with history of prior infarction). Digital tissue Doppler images were acquired in 3 apical views (GE-Vingmed System FiVe) during DbE. MDV was analyzed offline by a novice reader, and normal ranges (derived from the normalcy group) were used to define segts as normal or abnormal. Wall motion (WM) was assessed independently by an experienced observer. Significant CAD was defined by quantitative angiography as >50% stenosis. Correct recognition of multivessel disease was defined by abnormal segt in >1 coronary territory with significant CAD. Percent myocardium composed of abnormal segts by MDV and WM were compared.

**Results:** Accuracy for diagnosis of multivessel disease was similar in pts without prior infarction (WMS 80% vs MDV 78%  $p = 0.82$ ) and in all pts (WMS 75% vs MDV 75%  $p = 0.98$ ). In pts without infarction, extent of ischemia by WMS was  $20 \pm 25\%$  vs  $19 \pm 25\%$  with MDV ( $p = 0.89$ ). In pts without infarction MDV and WM identified ischemia in a similar proportion of the vascular territories except in the RCA territory;

% ischemic LV with;	LAD		LCX		RCA	
	WMS	MDV	WMS	MDV	WMS	MDV
Single vessel disease	23%	27%	75%	34%	98%	2%
Multivessel disease	43%	47%	44%	47%	39%	50%
Any coronary disease	33%	38%	48%	46%	60%	30%
p (MDV vs WMS)		0.58		0.90		0.003
Correlation (Spearman)		0.52		0.23		0.04

Thus, WMS was less accurate at diagnosing extent of ischemia in multivessel disease, and MDV demonstrated improved accuracy in the multivessel group.

**Conclusions:** MDV accurately identifies extent of myocardial ischemia during DbE and may improve detection extent of ischemia by novice echocardiographers.

10:00 a.m.

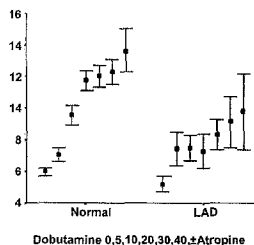
#### 829-4 Quantitative Stress Echocardiography Using Tissue Doppler for the Diagnosis of Coronary Artery Disease

Alan G. Fraser, Ursula Wilkenschoff, Birgitta Janerot-Sjoberg, Raphael Rosenhek, Nicola Payne, Lars-Ake Brodin. *University of Wales College of Medicine, Cardiff, UK*

**Background:** Stress echocardiography using grey-scale imaging has sub-optimal sensitivity and specificity particularly for identifying single vessel disease. Tissue Doppler echocardiography is a very sensitive technique for quantifying regional myocardial ischemia, which can be performed 'off-line' on spectral data acquired as digital loops during stress (Vingmed System V). In MYDISE (Myocardial Doppler in Stress Echocardiography) we investigated if this could discriminate between normal subjects and those with 1VD (LAD).

**Methods:** 30 subjects investigated for chest pain underwent dobutamine stress by a standard protocol (5–40 mcg/kg/min  $\pm$  Atropine) with simultaneous acquisition of TDE digital data. 20 subjects were normal by ECG stress-testing and angiography, and 10 age-matched subjects all had >50% diameter stenosis of the LAD. 5 parameters were measured 'off-line' in 11 left ventricular myocardial segments: peak systolic velocity (V), time to V (TTP), systolic velocity-time integral normalised for heart rate (NVTI), and peak E and A diastolic velocities.

**Results:** Heart rate increased from  $69 \pm 11$  to  $141 \pm 14$  bpm and  $70 \pm 10$  to  $130 \pm 14$  bpm in normal and LAD groups respectively. V increased less in LAD pts than in controls (basal anterior segment (A2C), V cm/s, figure) ( $p < 0.05$ ). Also TTP shortened less, and NVTI increased less, in LAD patients ( $p < 0.05$ );



**Conclusion:** Stress echo quantification by off-line TDE may be a useful technique for diagnosing ischemia.

10:15 a.m.

#### 829-5 Subendocardial Ischemia Detected by Reduction of Backscatter Cyclic Variations Correlates With the Degree of Coronary Artery Stenosis

Paolo Colonna, Roberta Montisci, Christian Cadeddu, Lijun Chen, Luigi Meloni, Sabino Iliceto. *Institute of Cardiology, Cagliari University, Italy*

Integrated backscatter cyclic variations (CVBS) are related to contractile activity and are reversibly blunted during temporary ischemia. In the presence of progressive coronary artery stenosis stress induced ischemia affects subendocardium (*subendo*) and can result in wall motion abnormalities. We hypothesized that, during atrial pacing stress test, only *subendo* contractility and not subepicardial (*subepi*) one (as expressed by CVBS) is blunted in CAD segments.

**Method:** Thirty-seven pts undergoing coronary angiography were studied with multipane transesophageal echocardiography and simultaneous atrial pacing. The Acoustic Densitometry package (Hewlett-Packard 5500) was used to acquire and analyse densitometric images. In each pt a transgastric two-chamber view was acquired at rest and at 150 beats/m<sup>2</sup> peak-pacing. We analyzed the transmural myocardial thickening (TH) and the CVBS separately in the *subendo* and in the subepicardium (*subepi*) at rest and at peak pacing stress. Then we computed the normalized stress induced changes as: (rest TH - stress TH)/rest TH, and similarly for *subendo* and *subepi* CVBS.

**Results:** Twenty five pts had CAD (>50% stenosis of at least 1 major coronary vessel) and 12 had no CAD; 42 segments were unequivocally supplied by a non stenotic coronary artery and 53 segments by a coronary artery with a significant stenosis. The degree of coronary stenosis showed a weak, but not significant, correlation with the normalized stress induced changes in TH. Conversely, the coronary stenosis correlated significantly with stress induced CVBS changes in *subendo* ( $p < 0.01$   $r = 0.42$ ) and not in the *subepi* ( $p = ns$ ).

**Conclusion:** Due to the early *subendo* ischemia, the coronary stenosis is directly correlated with the reduction in *subendo* CVBS and not with the *subepi* ones. CVBS changes in the different layers can add important information to the noninvasive diagnosis.

ORAL

#### 830 Computed Tomography/Magnetic Resonance Imaging: Imaging Atherosclerosis

Monday, March 13, 2000, 9:15 a.m.–10:30 a.m.  
Hilton Anaheim, Pacific D

9:15 a.m.

#### 830-1 Serial Noninvasive In Vivo MRI Monitors Progression and Regression of Individual Atherosclerotic Lesions in a Rabbit Model

Stephen G. Worthley, Gérard Helft, Valentin Fuster, Zahi A. Fayad, Azfar G. Zaman, John T. Fallon, Juan J. Badimon. *Mount Sinai School of Medicine, New York, New York, USA*

**Background:** *In vivo* MRI is able to document noninvasively atherosclerotic lesion size and composition, although to date, true serial data on changes in an individual plaque over time are yet to be published. The ability to monitor serially and noninvasively atherosclerotic plaque size and composition could provide insight into mechanisms of plaque stabilization and help direct future therapies. We report the ability of MRI to monitor changes in individual aortic atherosclerotic lesions under conditions of atherosclerotic regression and progression in a rabbit model.

**Methods:** Aortic atherosclerosis was induced in New Zealand White rabbits ( $n = 15$ ) by a combination of atherogenic diet (0.2% chol.) and double balloon denudation. MRI of the abdominal aorta was performed using a standard phased array surface coil in a clinical 1.5 T system. Fast spin echo sequences were performed with both proton density and T2 weighting and an in-plane resolution of  $350 \mu$  with slice thickness of 3 mm. MRI was performed at baseline, 9 months and 15 months post diet initiation. A subgroup of rabbits ( $n = 5$ , atherosclerosis induction group) were sacrificed at the 9 month time point for correlation of MRI with histopathology. The remaining rabbits were randomized into atherosclerosis progression (0.2% chol.,  $n = 5$ ) and regression (regular chow,  $n = 5$ ) groups. The third MRI was thus performed 6 months following randomization.

**Results:** Comparison between MR images from the 9 and 15 month time points of the same atherosclerotic segments of rabbits in the progression group revealed a significant ( $p < 0.0001$ ) increase in vessel wall area (mean  $7.41 \pm 1.85 \text{ mm}^2$  to  $9.75 \pm 2.13 \text{ mm}^2$ ), with outward vascular remodeling as evidenced by a small but significant increase in the total vessel wall area

(mean  $12.44 \pm 2.81 \text{ mm}^2$  to  $13.25 \pm 2.93 \text{ mm}^2$ ). The same comparisons in the regression group identified a small but significant decrease in vessel wall area (mean  $7.71 \pm 2.36 \text{ mm}^2$  to  $6.21 \pm 1.49 \text{ mm}^2$ ), and inward vascular remodeling with a decrease in the total vessel wall area (mean  $16.28 \pm 3.48 \text{ mm}^2$  to  $13.84 \pm 3.68 \text{ mm}^2$ ).

**Conclusions:** MRI provides serial data on atherosclerotic burden and vascular remodeling and thus has the potential to noninvasively monitor atherosclerotic lesions in humans.

9:30 a.m.

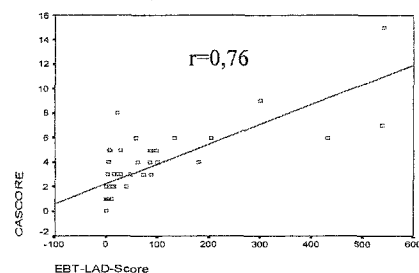
### 830-2 Frequency and Magnitude of Coronary Calcification in Patients With Early Plaque Formation After Heart Transplantation. Comparison Between Intracoronary Ultrasound and Electron Beam Computed Tomography

W. Bocksch, F. Knollmann, W. Klimek, E. Wellnhofer, M. Schartl, E. Fleck. *Dep. Cardiology/Radiology, Charité-Campus Virchow, Humboldt Universitaet; Deutsches Herzzentrum Berlin, Germany*

Non-invasive early detection of transplant vasculopathy (TVP) is a major clinical challenge after heart transplantation (HTX). The aim of this prospective study is the evaluation of frequency and magnitude of coronary calcification by intracoronary ultrasound (ICUS) and electron beam computed tomography (EBT) in post-HTX patients without angiographic evidence of CAD.

In 98 patients in aver.  $4.6 \pm 2.7$  years after HTX EBT and ICUS (30 MHz, Endosonics) of the left main coronary artery (LMCA) and the entire LAD was performed within 1 week. An ICUS calcification score between 0 (no calcification) and 16 (complete calcification of all cross-sectional quadrants of the LMCA and all LAD segments) was correlated to the LAD-EBT-score (Agatston).

90/98 patients had early plaque formation detected by ICUS. Only 45 of these pts (50%) had coronary calcification (av. ICUS-score  $3.5 \pm 2.7$ ). Sensitivity of EBT for detection of coronary calcification was 82.2%, specificity 88.9%. Correlation between ICUS- and EBT-score is shown below.



**Conclusion:** Although correlation between ICUS and EBT is acceptable for detection of coronary calcium, EBT could not be recommended for early detection of TVP after HTX, because coronary calcification is not a unique phenomenon after HTX.

9:45 a.m.

### 830-3 Coronary Calcifications in Postmenopausal Women With Estrogen Substitution

Alexander Becker, Christoph Becker<sup>1</sup>, Andreas Knez, Alexander Leber, Anja Maass, Roland Bruening<sup>1</sup>, Maximilian Reiser<sup>1</sup>, Ralph Haberl. *Medical Hospital I; <sup>1</sup>Department of Radiology, Univ. of Munich, Munich, Germany*

**Background:** Coronary calcification has proven to be a highly sensitive marker for the risk of cardiovascular diseases. We determined coronary calcification in 76 postmenopausal women with estrogen substitution and compared the coronary calcium score determined by electron beam computed tomography with the scores of 76 postmenopausal women without estrogen substitution.

**Patients:** We examined two groups of 76 postmenopausal women without CAD. There was no significant difference in age, group I  $62.4 \pm 6.9$  years, group II  $61.1 \pm 5.4$  years, or risk factor distribution, group I 24 women with hypertension, 16 women with hypercholesterolemia, group II 26 women with hypertension, 17 women with hypercholesterolemia. Time after menopause was  $7.6 \pm 1.4$  years in group I and  $7.8 \pm 1.6$  years in group II, n.s.. In group I a substitution with estrogen 0.6 mg/d in combination with gestagen took place for at least the last 4 years.

**Methods:** We acquired 40 slices with the Imatron C-150 EBCT (acquisition time = 100 ms, slice thickness 3 mm) in the high resolution mode beginning 1 cm below the carina. Examination was carried out in breath-hold inspiration and prospective ECG-gating at 80% of the RR-interval. The calcium score was calculated using the Agatston method.

### 830-4 Progression of Coronary and Aortic Calcification in Middle-Aged Women as Measured by Electron Beam Tomography

Daniel Edmundowicz, Kim Sutton-Tyrrell, Lewis H. Kuller, Adam H. Feldman, Richard Holubkov, Lori Givens, Karen A. Mathews. *University of Pittsburgh Cardiovascular Institute and Graduate School of Public Health, Pittsburgh, PA, USA*

**Background:** Electron Beam Tomography (EBT) permits quantification of coronary calcification (CC) and aortic calcification (AC) as markers of atherosclerosis, both of which are related to premenopausal cardiovascular risk factors in middle aged women. There is controversy regarding the reproducibility and implications of EBT detected calcium progression over time.

**Methods:** 541 premenopausal women aged 42–50 yrs were followed through menopause. At 8 yrs postmenopause, 52 underwent serial EBT of the coronaries and aorta separated by 16 months. Duplicate readings were obtained to evaluate the effect of reader variation on the results.

**Results:** At baseline, the median CC score was 0 and AC score was 86. Average changes in CC score (+14) and AC score (+104) were significantly different from zero ( $P = 0.002$  and  $<0.001$ ). The correlation between baseline and follow-up CC score was 0.93 and AC score was 0.97. Reader variability did not contribute significantly to the variation in scores. Extent of CC was associated with progression of AC ( $P = 0.057$ ). Both CC and AC were associated with premenopausal risk factors. Increase in CC was associated with lower HDL-C levels ( $P = 0.002$ ), higher triglycerides ( $P = 0.003$ ), greater waist circumference ( $P = 0.006$ ) and cigarette smoking ( $P = 0.053$ ) while increase in AC was associated with pulse pressure ( $P = 0.041$ ), total cholesterol ( $P = 0.007$ ) and LDL cholesterol ( $P = 0.003$ ). There was no association with hormone replacement therapy use at the eighth postmenopausal visit and progression of either CC or AC.

**Conclusion:** Measurement of both CC and AC using EBT is reproducible and progression can be observed over a short time in healthy middle aged women. These measures may be useful in evaluating the efficacy of risk factor modification when atherosclerosis is in its early stages.

10:15 a.m.

### 830-5 Comparison of Electron Beam- and Multidetector Helical Computed Tomography in the Noninvasive Assessment of Coronary Arteries

Alexander Leber, Christoph Becker<sup>1</sup>, Andreas Knez, Alexander Becker, Roland Bruening<sup>1</sup>, Maximilian Reiser<sup>1</sup>, Ralph Haberl. *Medical Hospital I; <sup>1</sup>Department of Radiology, University of Munich, Munich, Germany*

**Background:** Contrast enhanced Electron Beam Tomography (EBCT) has emerged as a noninvasive method that allows visualisation of coronary arteries. The recent introduction of multidetector helical computed tomography (MDCT) promises to permit the acquisition of nearly motionfree cardiac images with high spatial and temporal resolution. The aim of this study was to compare the diagnostic accuracy of noninvasive EBCT- and MDCT-coronary-angiography.

**Methods:** In order to get comparable patient-selections our study population consisted of 23 matched male patient-pairs (age  $56 \pm 5$  y) with suspected coronary artery disease (CAD), who were age-, gender-, body index- and calcium-score-adjusted. In one patient from each pair EBCT- in the other MDCT-angiography was performed and compared to conventional angiography. After intravenous application of contrast medium 55 axial slices of the heart (slice thickness = 3 mm, overlap = 1 mm, acquisition time = 100 ms, ECG-trigger) were acquired with EBCT (Imatron C-150 XP). For MDCT-studies (Somatom Plus4VZ, Siemens) the whole heart was covered within  $35 \pm 3$  s, with acquisition of 4 axial slices simultaneously. Using retrospective ECG-gating the raw data were reconstructed in 215 axial slices (thickness = 1.25 mm) acquired in diastole (overlap = 0.75 mm, effective acquisition-time = 250 ms/slice). Data-sets of EBCT and MDCT studies were 3D-reconstructed and analyzed on an Insight-workstation (Neomimery, USA).

**Results:** In comparison to conventional angiography in the EBCT group 18/25 coronary stenosis > 50% could be correctly identified (Sensitivity 72%) and in the MDCT-group 16/22 stenoses were visualized (Sensitivity 73%).

Stenoses > 50% were correctly ruled out in 35/48 vessels (Specificity 73%) with EBCT and in 38/50 vessels (Specificity 76%) with MDCT.

**Conclusion:** Contrast enhanced EBCT- and MDCT-angiography are equal accurate in the diagnosis of CAD and thus are both promising noninvasive cardiac imaging methods.

## ORAL

### 840 Transesophageal Echocardiography: Assessment of Left Atrial Structure and Function

Monday, March 13, 2000, 11:00 a.m.–12:15 p.m.  
Hilton Anaheim, Pacific D

11:00 a.m.

### 840-1 Long-Term Prognosis After Paradoxical Embolism

Dirk Hausmann, Rajja Keil, Arndt Schaefer, Gerd P. Meyer, Helmut Drexler. *Division of Cardiology and Angiology, Hannover Medical School, Hannover, Germany*

**Background:** Paradoxical embolism through a patent foramen ovale (PFO) may cause arterial ischemic events. Therapeutic strategies range from no treatment, anticoagulation to surgical/interventional closure; however, long-term prognosis is unknown.

**Methods:** Among ~5,000 TEE studies performed between '88 and '97 for cardiac source of embolism, 97 pts. (38 m, 59 f; age  $42 \pm 13$  yrs.) with PFO (Valsalva with right-to-left atrial shunt during contrast TEE) were identified. Arterial ischemic events were 56 stroke, 4 PRIND, 32 TIA, 5 peripheral embolism; 33 (34%) patients had a previous ischemic event. All definite/probable cardiac or extracardiac sources of embolism other than PFO were excluded; 70 (72%) pts. were <50 yrs. Initial therapy included interventional (n = 2) or surgical (n = 3) closure, cava filter (n = 5), coumarin (n = 13), platelet inhibitors (n = 73). Follow-up was available in 53 pts. for  $5.2 \pm 2.9$  yrs. (0.5–11.6).

**Results:** During follow-up, 12 (23%) pts. (including 7 pts. <50 yrs.) had 15 recurrent ischemic events (13 TIA, 1 stroke, 1 peripheral embolism) after  $2.7 \pm 2.0$  yrs. (0.3–8.0). Events occurred under platelet inhibitors (n = 10), coumarin (n = 2), or no (n = 3) therapy. Pts. with and without recurrent events showed no differences in baseline data (demographic profile, risk factors, previous ischemic events, presence of atrial septal aneurysm) or treatment. Large PFO size (>50% of left atrium filled with contrast and/or PFO opening > 5 mm) was present in 11 (92%) pts. with compared to 20 (49%) pts. without recurrent events ( $p < 0.05$ ).

**Conclusions:** Paradoxical embolism is a rare cause for ischemic events (2% in referral populations); these pts., however, are often young. Without PFO closure, recurrent events are frequent despite medical therapy and occur mostly in pts. with large PFO. These data indicate that closure should be considered in large PFOs.

11:15 a.m.

### 840-2 Integrated Backscatter Provides a Highly Sensitive and Specific Tool for Quantification of Left Atrial Appendage Spontaneous Echo Contrast: A Transesophageal Echocardiography Study

Mohammad Bashir, Kevin G. Schaefer, R. Daniel Murray, Richard A. Grimm, Rohit Gupta, Joseph Salloum, Todd Coffey, Carolyn Apperson-Hansen, Susan E. Jasper, Ariel S. Goodman, Craig R. Asher, Allan L. Klein. *The Cleveland Clinic Foundation, Cleveland, Ohio, USA*

**Background:** The intensity of the integrated backscatter (IBS) signal in the left atrial (LA) cavity has been shown to correlate with the qualitative grade of spontaneous echo contrast (SEC) by transesophageal echocardiography (TEE). However, the relationship between LA appendage (LAA) SEC intensity and IBS in patients with atrial arrhythmia (AA) has not been explored. We sought to study this relationship between LAA SEC, LAA mean velocities and IBS.

**Methods:** We performed TEE evaluation in 53 patients (36 male, age  $64 \pm 12$  years) with AA (48 with atrial fibrillation) and acquired on-line IBS data of the LAA, LA cavity, left ventricle and interatrial septum using the acoustic densitometry software (Hewlett Packard). Mean IBS data over 3 seconds, mean LAA emptying (EV) and filling velocity (FV), pulmonary vein (PV) flow velocities, LAA area and the presence of thrombus or SEC were determined.

**Results:** Of the 53 patients, 32 had severe, 11 had mild and 10 had no SEC in the LAA by qualitative grading. A higher mean IBS intensity was noted in patients with mild and severe SEC as compared to those with no

SEC ( $p < 0.0001$ ). A cutoff value of 11.1 dB (IBS) predicted the presence of LAA SEC, while a value of 16.3 dB differentiated severe from mild LAA SEC, both with 100% sensitivity and specificity. The mean IBS intensity of the LAA was inversely related to the LAA mean EV ( $r = -0.74$ ;  $p < 0.0001$ ) and FV ( $r = -0.71$ ;  $p < 0.0001$ ), PV systolic velocity ( $r = -0.33$ ;  $p < 0.016$ ) and positively correlated with LAA area ( $r = 0.33$ ;  $p < 0.017$ ). Patients with LAA thrombus (n = 8) had a higher IBS intensity than those without ( $18.9 \pm 4.4$  dB vs.  $15.6 \pm 4.5$  dB,  $p < 0.05$ ). There was a good correlation between LA cavity and LAA IBS intensity measurements ( $r = 0.69$ ,  $p < 0.0001$ ).

**Conclusions:** 1). Integrated Backscatter provides a highly sensitive and specific (100%) tool for quantification of left atrial appendage spontaneous echo contrast. 2). LAA IBS values are significantly higher in patients with LAA thrombi. Prospective studies are needed to evaluate role of IBS in predicting future embolic events.

11:30 a.m.

### 840-3 Is Transesophageal Echocardiography Indicated to Detect Left Atrial Thrombi in Patients With Sinus Rhythm? Experience From 20,643 Consecutive Transesophageal Studies

Yoram Agmon, Bijoy K. Khandheria, Federico Gentile, James B. Seward. *Mayo Clinic and Mayo Foundation, Rochester, Minnesota, USA*

**Background:** Transesophageal echocardiography (TEE) is frequently performed to detect left atrial (LA) thrombi. However, the diagnostic yield of TEE for LA thrombus detection in the presence of sinus rhythm (SR) is extremely low. The aim of this study was to characterize the clinical and echocardiographic profile of patients with SR and LA thrombus, in order to define a high-risk group in which TEE is indicated.

**Methods:** A total of 20,643 TEE studies were performed at the Mayo Clinic between 1988–1998. Of these, all studies with LA and/or left atrial appendage (LAA) thrombi were identified using the Echocardiographic Laboratory database. Of these, all TEEs in patients with SR during the echocardiographic study were reviewed and the presence of SR and LA/LAA thrombus was confirmed.

**Results:** LA and/or LAA thrombi were detected in 380 studies (1.8% of all TEEs) in 314 patients. SR was present during 23 studies (6.1% of all thrombi, 0.1% of all TEEs) in 20 patients (age:  $69 \pm 13$ ; 9 [45%] men). The relevant echocardiographic findings in these patients (2 patients with >1 finding) are summarized in the Table:

	n	(%)
Left ventricular (LV) systolic dysfunction (ejection fraction < 40%)	6	(30)
Restrictive LV filling*	1	(5)
Mitral valve prosthesis or repair†	6	(30)
Mitral stenosis (moderate to severe)	2	(10)
Mitral regurgitation (severe)	1	(5)
Aortic valve prosthesis‡	2	(10)
Aortic regurgitation (severe)	1	(5)

\*Preserved LV systolic function, mitral E/A ratio > 2, pulmonary vein systolic < diastolic velocities, and  $\geq$  moderate LA enlargement; †mechanical prosthesis in 4, bioprosthesis in 1, and mitral annuloplasty in 1; ‡ bioprosthesis in 2 patients.

Three patients (15%) had none of the above echocardiographic findings. Atrial fibrillation (AF) was previously documented in 2 of them.

**Conclusions:** LA thrombus is an extremely rare echocardiographic finding in patients with SR. These patients are characterized by cardiac pathologies potentially detectable by transthoracic echocardiography (TTE) and/or a history of AF. Thus, TEE may be reserved for high-risk patients with TTE-detected pathology and/or a prior history of AF.

11:45 a.m.

### 840-4 Echocardiographic and Clinical Features of Mixed Constriction/Restriction

Steve Zelin, Jeffrey A. Skiles, Allan L. Klein. *The Cleveland Clinic Foundation, Cleveland, OH, USA*

**Background:** Constrictive pericarditis (CP) and restrictive cardiomyopathy (RC) share similar clinical features yet possess identifiable 2D and Doppler echocardiographic findings. Recently, patients with qualities of both constriction and restriction (mixed disease) have been described and bear further characterization.

**Methods:** Twenty-nine patients (8F, 21 M) with characteristics of both CP and RC were evaluated with transesophageal echocardiography. Pulsed wave Doppler of the left or right pulmonary veins and mitral inflow was performed. Pulmonary venous systolic and diastolic flow velocities and the systolic/diastolic flow ratio during expiration and inspiration were recorded. The percent change in Doppler flow velocity of the E wave was calculated from expiration to inspiration (%E) and the deceleration time of the

E wave was recorded. Localization of pericardial thickening was identified by TEE and confirmed by MRI. Mortality rates over an approximate 5 year period were determined through the Social Security Death Index and were compared between patients treated surgically and those treated medically.

**Results:** Mean %E for pulmonary vein diastolic flow and left ventricular inflow peak E wave were 14 and 12 percent, respectively. Pulmonary venous systolic-to-diastolic flow ratios were blunted (0.76). The mean deceleration time of the E wave was shortened (111 msec). Pericardial thickening was localized primarily on the right side of the heart with 52% of patients presenting with left-sided thickening as well. Etiologies included radiation therapy (12), CABG (8), heart transplant (3), idiopathic (3), CAD-s/pMI (2) and valvular repair (1). There was an overall mortality rate of 50% with the prognosis of patients who underwent surgical treatment similar to those without.

**Conclusions:** Mixed constriction/restriction is a definable entity characterized by pericardial thickening without significant respiratory variation of transmittal or pulmonary venous flow. The all-cause mortality rate of approximately 10% per year portends a poor prognosis for this patient group which is unaffected by surgical intervention.

Noon

**840-5 Three-Dimensional Echo Atrial Septal Defect Diameters That Account for Septum Primum Tissue Exceed Standard Two-Dimensional Echo Measurements: Possible Utility in Device Closure**

Megan C. Sherwood, Craig E. Fleishman, Jacqueline Kreutzer, Gerald R. Marx. *Children's Hospital, Harvard Medical School, Boston, MA, USA*

Controversy persists regarding the importance of recognition and measurement of septum primum (SP) in device closure of secundum ASDs. Appreciation of SP has been difficult by 2-dimensional echo (2DE). 3DE permits unique left and right atrial en face and oblique views, which allows more precise delineation of SP. Our purpose was to measure ASD size by 3DE with and without accounting for SP, and compare with blinded 2DE measurements of maximal (max) ASD diameter.

**Methods:** 3DE of ASDs in 10 pts, median age 17 yrs (range 2.7–65) undergoing assessment for device closure. 2DE sequential rotational acquisitions at 3° performed with transesophageal (n = 9) or transthoracic (n = 1) omniplane probe placement, with digital processing and off-line 3D rendering. The max ASD size by 2DE was compared to the max size by 3DE, and to the 3DE size accounting for SP, limits of agreement (LOA, mean difference ± SD), correlation coefficient (r).

**Results:** 3DE clearly distinguished the size, shape and position of thin SP tissue from the thicker, less mobile septum secundum, which was less well appreciated by 2DE. ASD max size by 2DE was median 10 mm (range 5–15) and by 3DE was median 11 mm (4–16), LOA = 0.2 ± 1.4, r = 0.90. However, max size by 3DE accounting for SP was median 20 mm (10–31), which exceeded the 2DE measurements of max size, LOA = 10.6 ± 6.8, r = 0.14. In 2 pts balloon stretched size was obtained (13 mm, 15 mm) and closely approximated 3DE max size that accounted for SP (10 mm, 15 mm).

**Conclusions:** While 2DE and 3DE max ASD sizes compare closely, 3DE measurements accounting for SP are significantly greater than max ASD size measurements. We hypothesize 3DE max size accounting for SP may more closely approximate stretched diameter measurement than standard 2DE measurements. 3DE ASD size accounting for SP should be a consideration in assessment for ASD device closure.

POSTER

**1100 New Applications of Three-Dimensional Echocardiography and Doppler Imaging**

Monday, March 13, 2000, Noon–2:00 p.m.  
Anaheim Convention Center, Hall A  
Presentation Hour: Noon–1:00 p.m.

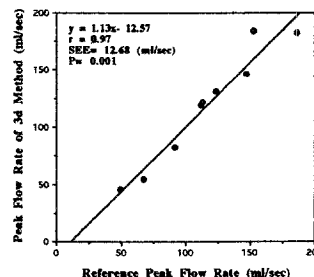
**1100-1 Semiautomated Computation of Multiple Dynamic Orifices From Digital 3D Reconstruction Color Doppler of the Flow Convergence Region: An In Vitro Model Mimicking Mitral Valve Regurgitation**

Shannon Hicks, Xiaokui Li, Xiang-Ning Li, Suthep Wanitkun, Yoshiki Mori, Ikuro Hashimoto, Rosemary A. Rusk, David J. Sahn. *Oregon Health Sciences University, Portland, OR; ATL Ultrasound, Bothell, WA, USA*

**Background:** Digital color images produced by 3D reconstruction allow us to visualize the isovelocity surface areas within the flow convergence regions of regurgitant jets. The aim of this study was to assess the accuracy of a new 3D: digital color Doppler method for quantifying regurgitant flow rates in a model with a dynamically changing orifice mimicking mitral regurgitation.

**Methods:** We have developed a new method wherein a digital 3D dataset is acquired using digital color Doppler velocity values from images in the flow convergence region. Scanline data are directly transferred from an ATL HDI 5000 ultrasound system to a Silicon Graphics workstation to develop a multithreshold method for computation of 3D flow convergence surface areas directly. We studied pulsatile flows at 9 stroke volumes (15–55 ml/beat) through a flow phantom. The unique dynamically changing orifice area in the model simulated mitral valve regurgitation. Reconstruction of the digital dataset allows computer development of an object occupying the spatial location of a chosen velocity threshold. Multiple direct 3D surface area measurements were made within the flow convergence zone.

**Results:** Data was computed at aliasing velocities of 14.4–48.1 cm/sec. Peak regurgitant flow rate obtained by the new 3D method agreed well with the reference flow meter flows (r = 0.97; SEE = 12.68; p = 0.001; mean = -2.58).



**Conclusion:** This digital color Doppler 3D reconstruction method of flow convergence can provide an accurate estimation of regurgitant flow rate in a dynamic orifice model simulating mitral regurgitation.

**1100-2 The Effect of Dynamic Inlet Geometry on the Accuracy of Digital 3D Flow Convergence Measurements: A Study of Dynamic Inlet Geometries in an In Vitro Model Mimicking Mitral Valve Regurgitation**

Davy M. Merrick, Xiaokui Li, Rosemary A. Rusk, Gordon Mack, Yoshiki Mori, David J. Sahn. *Oregon Health Sciences University, Portland, OR, USA*

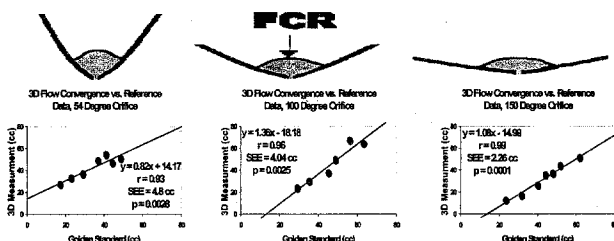
**Background:** It has been shown that valve inlet geometry affects the contraction coefficient, and that 2D flow convergence (FC) calculations need to be corrected for inlet angle. We assessed the accuracy of a 3D flow convergence measurement method yielding direct isovelocity surface area measurements in 3 models which had both dynamic inlet geometries and orifices mimicking mitral regurgitation.

**Methods:** Three clay models with differing angles approaching the orifice were constructed. Liquid latex was poured over the models and a 1 cm × 2 mm slit was cut in the base in order to fashion three dynamic phantoms with time averaged inlet angles of approximately 54°, 100°, and 150°. The orifice size and inlet geometries were verified to change dynamically by digital video imaging. Imaging was performed with a 7 MHz multiplane TEE probe running on an ATL HDI 5000 system. Data for 180° rotational color Doppler scans were acquired for each of 8 pulsatile stroke volumes (15–50 ml/beat),

NONINVASIVE IMAGING

and transferred as scanline data to a SGI workstation for 3D reconstruction. A new digital 3D color Doppler method was used to trace surface area at aliasing velocities 9–28 cm/sec at 20 points in the heart cycle and calculate regurgitant stroke volumes for comparison to reference data.

**Results:** The computed stroke volumes correlated well for the medium angle orifice (mean difference –1.3 cc,  $r = 0.96$ ), but underestimated for the large angle (mean difference –11.5 cc,  $r = 0.99$ ), and slightly overestimated for the small angle (mean difference 8.0 cc,  $r = 0.93$ ). 3D results were made worse by  $1 - \cos\theta$  angle correction, but were still more accurate than angle-corrected 2D FC calculation.



**Conclusion:** This study demonstrates that even 3D flow convergence measurement is affected by the orifice inlet geometry. While surface area is computed directly by 3D, some isovelocity surface is lost in zones where flow is at a significant angle to Doppler interrogation.

### 1100-3 In-Vivo Visualization of the Three-Dimensional Shape of the Proximal Flow Convergence Zone and the Vena Contracta: A Qualitative Study Using Three-Dimensional Color Doppler Echocardiography

Harald P. Kühl, Andreas Franke, Ole A. Breithardt, Matthias Ploch, Rainer Hoffmann, Peter Hanrath. *Medical Clinic I, University Hospital Aachen, Germany*

**Background:** Quantification of mitral regurgitation (MR) severity by the proximal flow convergence (PISA) method and vena contracta (VC) width using 2D echo is based on geometrical assumptions. The aim of this study was to assess the three-dimensional (3D) shape of the PISA zone and the correct cross-section of the vena contracta (VC) in patients (pts) with different degrees of MR using 3D gray scale and color Doppler echocardiography.

**Methods:** 15 pts ( $56 \pm 21$  years, 7 females) were investigated by transesophageal color Doppler echo and 3D reconstruction. For data acquisition a standard equipment was used (HP Sonos 5500, 3° increments). Analysis of 3D reconstructed gray scale and color Doppler data was performed using a novel software (MedCom, Darmstadt, Germany).

**Results:** MR was graded mild in 2 pts, moderate in 3 pts and severe in 10 pts based on 2D color Doppler. The pathomechanism included leaflet prolapse in 11 pts., annular dilatation in 2 pts. and restricted leaflet motion in 2 pts. 3D color Doppler reconstruction was feasible in all pts. Visualization of PISA and VC required simultaneous display of 3D reconstructed gray scale and color Doppler data. In 3 pts with complex valvular lesions 3D color Doppler helped to clarify the underlying pathomorphology and mechanism of MR. In the majority of pts (12/15) the PISA zone did not correspond to an hemisphere or hemielipse. Due to its complex 3D shape a clear delineation of the VC was difficult in all pts with eccentric jets and could not be adequately described by conventional 1D or 2D measurements.

**Conclusion:** 3D color Doppler echo demonstrates the complex three-dimensional shape of PISA and VC which cannot be adequately described by a simple mathematical formula. Moreover, it may contribute to clarify the mechanism of regurgitation in patients with complex valvular lesions.

### 1100-4 Quantitation of Valvular Regurgitation With Proximal Flow Confinement: In Vitro Studies Using a New On-Board 3D Color Doppler Acquisition and Reconstruction Method

Tamara Y. Chang, Xiaokui Li, Timothy Irvine, Mushtaq Hussain, David J. Sahn. *Oregon Health Sciences University, Portland, OR, USA; GE/VingMed, Horten, Norway*

**Background:** We evaluated 3 methods for the quantitation of confined flow convergence region (FCR), such as might occur in moderate aortic regurgitation by imaging an *in vitro* model: a standard hemispheric FCR (HS) method; a 2D segment of a sphere (SS) method [surface area =  $\pi p^2$  where  $p$  is the chord from the zenith of the SS to the circumference at the base]; and a new "on-board" digital 3D FCR method (3D).

**Method:** 8 flow states with pulsatile stroke volumes (5–50 ml) were studied across each of 3 orifices (circular, oval and triangular, 0.24 cm<sup>2</sup> each) surrounded by a tapered 1.5 cm diameter tube to produce confinement of proximal flow. Imaging was performed using a 5 MHz probe and a VingMed System 5 ultrasound system (55 cm/sec Nyquist) with a new on-board 3D acquisition, reconstruction and review feature which incorporates both structural and color Doppler data into the 3D dataset. After a 180° probe rotation, the program allowed for direct 3D FCR surface area measurement. For each method, regurgitant stroke volume (RSV) was calculated using the maximum color Doppler FCR surface area combined with the ratio of the CW Doppler velocity-time integral/peak velocity and compared to RSV by ultrasonic flow meter.

**Results:** All 3 methods correlated well with actual RSVs. The 3D PISA method ( $r = 0.93$ , mean difference =  $0.03 \text{ ml} \pm 1.54$ ) was superior to both 2D methods for the calculation of RSV, though SS ( $r = 0.90$ , mean difference =  $3.36 \text{ ml} \pm 2.43$ ) was significantly better ( $p < 0.01$ ) than HS ( $r = 0.88$ , mean difference =  $14.5 \text{ ml} \pm 6.36$ ).

**Conclusion:** This new digital on-board 3D acquisition and reconstruction capability for structure and flow on board a clinical ultrasound system should facilitate the applicability of 3D FC flow quantification.

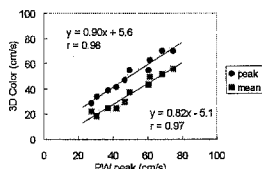
### 1100-5 Estimation of the Spatial Mean and Peak Flow Velocities Using Real-time 3D (RT3D) Color Doppler Echocardiography: An In Vitro Experiment

Hiroyuki Tsujino, Takahiro Shiota, Jian Xin Qin, Fabrice Bauer, Agnese Travaglini, Neil L. Greenberg, James D. Thomas. *The Cleveland Clinic Foundation, Cleveland, OH, USA*

**Background:** The aim of this study was to determine the feasibility of flow velocity estimation using the real-time 3D color Doppler with an *in vitro* experiment under rigidly controlled hemodynamic conditions.

**Methods:** An *in vitro* flow model (EchoCal CD10, Dynatek Laboratories, Inc) was used to produce pulsatile flows with relatively flat velocity profiles across a 1.0-cm tube. By using RT3D, the cross-sectional color images of the flow tract at peak systole were derived and digitally transferred to a PC to quantify spatial velocity distributions. Conventional pulsed wave (PW) Doppler was performed as a reference standard. Peak velocities of the PW Doppler were compared with spatial mean and peak velocities derived from the peak color flow images.

**Results:** Peak velocity by reference PW ranged from 27.5 to 74.8 cm/s. There was an excellent linear relationship between peak velocity obtained by PW (x) and that by RT3D color Doppler (y):  $y = 0.90x + 5.6$ ,  $r = 0.98$ , mean difference =  $1.9 \pm 6.5\%$ . The spatial mean velocity by 3D color also showed an excellent linear relationship with PW peak velocity, but with an anticipated underestimation ( $y = 0.82x - 5.1$ ,  $r = 0.97$ , mean difference =  $-29.1 \pm 8.0\%$ ) due to the non-flat velocity profile. The ratio between spatial mean and peak velocities from 3D color was  $0.70 \pm 0.09$ , indicating the relatively blunt velocity distribution in the flow tract.



**Conclusion:** Real-time, color 3D echocardiography was capable of quantifying velocities accurately, permitting the calculating of flow volume without any geometrical assumptions of the flow distribution.

### 1100-6 Real-time 3D Color Doppler Echocardiography for Analysis of the Spatial Velocity Distribution in the Left Ventricular Outflow Tract

Hiroyuki Tsujino, Michael Jones<sup>1</sup>, Takahiro Shiota, Jian Xin Qin, Lisa A. Cardon, Annitta J. Morehead, Arthur D. Zetts<sup>1</sup>, Fabrice Bauer, Agnese Travaglini, Neil L. Greenberg, Julio A. Panza<sup>1</sup>, James D. Thomas. *Cleveland Clinic Foundation, Cleveland, OH; <sup>1</sup>NIH, Bethesda, MD, USA*

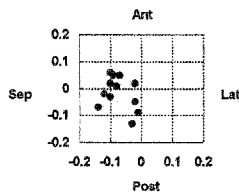
**Background:** Calculation of stroke volumes with PW Doppler assumes a "flat" velocity profile in the left ventricular outflow tract (LVOT), which observation refutes. The present study was undertaken to quantitatively determine the two-dimensional spatial velocity profile in the LVOT short axis planes using real-time 3D (RT3D) color Doppler.

**Methods:** A total of twelve different hemodynamic conditions were created in 4 sheep. RT3D color Doppler data were obtained epicardially using apical views. From the volumetric data, the brightest (highest velocities) color images of the LVOT during systole were digitally transferred to a PC. By using custom software, color-encoded velocity information was decoded into short



axis two-dimensional velocity data points  $v(x,y)$  to visualize and quantify the spatial velocity distribution.

**Results:** Non-uniform, skewed profiles were consistently observed with the velocity centroid located 0.01 to 0.14 (mean  $0.07 \pm 0.04$ ) LVOT radii septally from the center of the LVOT (Figure). For the twelve hemodynamic conditions, the spatial mean and peak velocities by RT3D color were  $26.2 \pm 7.4$  cm/s and  $51.0 \pm 11.3$  cm/s, respectively. The ratio between spatial mean and peak velocities was  $0.51 \pm 0.08$ , reflecting the non-uniform velocity distribution in the LVOT.



**Conclusions:** Using the short axis, cross-sectional images of the LVOT, RT3D color Doppler revealed the non-uniform velocity distributions, showing the importance of considering the spatial velocity distribution when quantifying flow.

**1100-7 3D Intracardiac Ultrasound Toroidal Reconstructions in the Beating Heart**

Michael R. Wahl, Sam Asirvatham, Susan B. Johnson, Javier Roman-Gonzalez, Ryan D. Packer, Jon J. Camp, Richard A. Robb, James B. Seward, Douglas L. Packer. *Mayo Foundation, Rochester, MN, USA*

**Background:** The ability to acquire and reconstruct three-dimensional (3D) images from intracardiac ultrasound (US) applied in the intact beating heart has been limited. This dynamic process is impeded by US catheter positioning, cardiac motion, and the rotational measurements of this system. To test whether an accurate 3D myocardial representation from a beating heart could be reproduced from rotational, phased array intracardiac US, five dogs were studied.

**Methods:** A 10 Fr, 64 element, 7.5 MHz intracardiac US catheter was inserted through the carotid artery or jugular vein into the ventricles of the heart. This US catheter was rotated in 3 degree increments using a stepper motor and sequential images acquired during normal sinus rhythm or pacing. The triggered live heart US acquisitions were reconstructed into a 3D toroidal cardiac representation.

**Results:** Continuously acquired US images had an average translational movement between each sequential B-mode slice of 2.2 mm in the end-diastolic toroid. Actively triggered B-mode images could be reproduce into a toroid with 1.6 mm of translational motion. These toroidal reconstructions could be processed in an average of 28 seconds providing a field depth of 80 mm (diameter of 160 mm), also encompassing the right ventricle and epicardial border. Each section detailed 2.3 cm of endocardium and 6.2 cm of epicardial border with exquisitely detailed anatomy and tissue characterization.

**Conclusion:** Triggered intracardiac US images produced seamless reproductions of the true 3D myocardium anatomy from beating hearts. These 3D reconstructions will facilitate the fusion of real-time imaging with multidimensional physiologic parameters allowing analysis of cardiac wall motion, cardiac tissue velocity, and even cardiac electrical activation during interventional procedures.

**1100-8 Left Atrial Volume Measurement by Real-Time 3D Echocardiography**

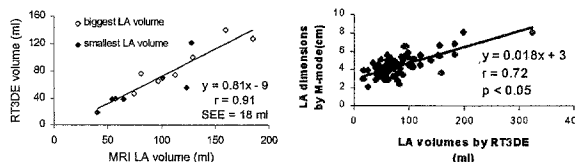
Fabrice Bauer, Takahiro Shiota, Richard White, Jian Xin Qin, Agnese Travaglini, Hirooyuki Tsujino, James D. Thomas. *Cleveland Clinic Foundation, Cleveland, OH, USA*

**Background:** Assessment of left atrial (LA) size has been performed by 2D techniques, which have been limited due to requirement of geometrical assumption.

**Aim of the Study:** 1 – to assess the accuracy of real-time 3D echocardiography (RT3DE) with MRI. 2 – to compare M-mode LA volume to RT3DE LA volume.

**Methods:** RT3DE was used for LA volume measurement in 8 patients, using 7 parallel planes from the apical-4 chamber view. The smallest and the largest LA volumes, including the appendage were measured at the onset of the QRS and at the end of the T wave, respectively. LA volumes were compared to MRI. Then, 100 human LA (15 normal, 15 mitral valve disease, 23 aortic valve disease, 17 hypertrophic cardiomyopathy, 15 dilated cardiomyopathy and 15 heart transplantation) were studied. For each patient, LA diameter was measured by conventional M-mode from the parasternal long axis view and compared to the largest LA volume.

**Results:** 1 – There was an excellent correlation between the RT3DE LA volume and MRI LA volume (figure 1) with significant underestimation by RT3DE (27%). 2 – The correlation between LA dimensions by M-mode and the largest LA volume by RT3DE was moderately good (figure 2).



**Conclusion:** LA volume can be estimated by RT3DE with underestimation. A moderately good correlation between LA volumes determined by RT3DE and LA dimensions by conventional M-mode was found.

POSTER

**1101 Stress Echo: Impact on Prognosis**

Monday, March 13, 2000, Noon–2:00 p.m.  
Anaheim Convention Center, Hall A  
Presentation Hour: Noon–1:00 p.m.

**1101-25 Treadmill Exercise Stress Echocardiography in Patients With Left Bundle Branch Block: Is There Prognostic Value?**

Andrew J. Rainbird, Chung Y. Lee, Jae K. Oh, Veronique L. Roger, Douglas M. Mahoney, James B. Seward, Patricia A. Pellikka. *Mayo Clinic, Rochester, MN, USA*

**Background:** The most common association of left bundle branch block (LBBB) is atherosclerotic heart disease. The interpretation of stress tests may be difficult in the presence of LBBB and the coincident wall motion abnormalities.

**Method:** To determine the prognostic value of treadmill exercise stress echocardiography (TSE) in patients with LBBB, 275 consecutive patients with LBBB, who underwent TSE for the evaluation of known or suspected coronary artery disease, were followed. Hard events (HE) (cardiac death or non-fatal myocardial infarct) and all events (AE) (hard events, cardiac transplantation, cardiac arrest or coronary revascularization) were determined. Cox proportional hazards regression analysis was used.

**Results:** Follow up ( $3 \pm 2$  yrs) was complete in 266 (97%). There were 147 males and 119 females, mean age  $66 \pm 10$  yrs. There were 44 AE (17%), including 22 HE (8%). Exercise echocardiography was interpreted as normal in 78 (29%) patients, infarction in 63 (24%), ischemia in 51 (19%) and infarction and ischemia 74 (28%). The 1, 2 and 3 year event rates were 2%, 7% and 12% for HE and 6%, 13% and 22% for AE. The only clinical multivariate variable predictive of AE was history of coronary artery disease (RR 5.5  $p = 0.0001$ ). When forced into the clinical model, the TSE variables predictive of AE were rest wall motion score index (RR 2.3;  $p = 0.005$ ) and peak systolic blood pressure (RR 0.99;  $p = 0.01$ ). The only clinical multivariate variable predictive of HE was history of previous myocardial infarction (RR 6.1;  $p = 0.0001$ ). The TSE variables predictive of HE were peak systolic blood pressure (RR 0.98;  $p = 0.008$ ) and rest wall motion score index (RR 3.1;  $p = 0.005$ ). Age, exercise wall motion score index, ischemia by echocardiography, workload, percent of age predicted heart rate and ejection fraction were not predictive of HE or SE.

**Conclusions:** In patients with LBBB and known or suspected coronary artery disease, the 1 year event rate was 6%. Exercise echocardiograms were abnormal in 188 (71%). The best predictors of events were history of coronary artery disease, previous myocardial infarct, rest wall motion score index and peak systolic blood pressure. TSE was not suitably predictive in this subset of patients.

**1101-26 Prognostic Value of Exercise Echocardiography: Is There a Gender Effect?**

Adelaide M. Arruda, Eldyn M. Juracan, Timothy E. Paterick, Douglas W. Mahoney, Veronique L. Roger, Patricia A. Pellikka. *Mayo Clinic, Rochester, MN, USA*

**Background:** Limited information exists regarding gender differences in prognostic value of exercise echocardiography (ex-Echo).

**Methods:** To determine the effect of gender on the prognostic value of ex-Echo we obtained follow-up ( $3.0 \pm 1.7$  yrs) in 5,798 pts who had ex-Echo for evaluation of known or suspected coronary artery disease.

NONINVASIVE IMAGING

**Results:** There were 3,322 males (M) and 2,476 females (F), age 62 ± 12 yrs. M were more likely to have angina, prior myocardial infarction and prior coronary revascularization ( $p < 0.05$ ). In M, rest ejection fraction was lower ( $56 \pm 9\%$  vs  $59 \pm 7\%$ ,  $p < 0.0001$ ), resting wall motion abnormalities were more frequent ( $20\%$  vs  $8\%$ ,  $p = 0.001$ ) and workload achieved was higher ( $9 \pm 3$  METs vs  $8 \pm 2$  METs,  $p < 0.0001$ ). New or worsening wall motion abnormalities developed with exercise in 35% M and 25% F ( $p = 0.001$ ). Cardiac events (CE) including cardiac death (107 pts) and nonfatal myocardial infarction (148 pts) occurred in 5.3% M and 3.1% F ( $p = 0.001$ ). The best clinical model for prediction of CE included age, sex, diabetes mellitus, history of angina, prior myocardial infarction and rest ejection fraction. Addition of ex-ECG variables to the clinical model provided incremental information in predicting CE in both M ( $X^2 = 123$ ;  $p = 0.001$ ) and F ( $X^2 = 81$ ;  $p = 0.04$ ). The best exercise electrocardiographic (ex-ECG) variable was METs. Addition of ex-Echo variables further improved both models (M:  $X^2 = 169$ ;  $p < 0.0001$ ) (F:  $X^2 = 89$ ;  $p = 0.03$ ). The best ex-Echo predictor of cardiac events was exercise ejection fraction. Lower exercise ejection fraction was an independent predictor of CE for both genders (M-RR: 1.2/95%CI: 0.9–1.4) (F-RR: 1.3/95%CI: 0.9–1.5). Failure of left ventricular end systolic volume to decrease with exercise was a predictor in M (RR: 1.8/95%CI: 1.2–2.7) but not in F (RR: 1.6/95%CI: 0.9–2.9). There was no significant interaction effect of ex-ECG ( $p = 0.20$ ) or ex-Echo ( $p = 0.64$ ) with gender.

**Conclusions:** Ex-Echo provides independent prognostic information for both M and F, incremental to clinical, rest echocardiographic and ex-ECG data. Of all ex-ECG and ex-Echo variables, METs and exercise ejection fraction had the strongest association with outcome.

#### 1101-27 Prognostic Value of Pharmacological Stress Echocardiography in Patients with Left Bundle Branch Block

Lauro Cortigiani, Carlo Vigna, Egidio Mariotti, Riccardo Bigi, Fabio Lattanzi, Albert Varga, Eugenio Picano. *On behalf of the EPIC (Echo Persantine International Cooperative)-EDIC (Echo Dobutamine International Cooperative) study groups; Institute of Clinical Physiology, Pisa, Italy*

**Background:** Patients with left bundle branch block (LBBB) have an increased risk for cardiac death, especially when underlying coronary artery disease is present.

**Methods:** To evaluate the prognostic value of stress echocardiography in this setting we analyzed 387 patients with LBBB (231 males, mean age  $64 \pm 9$  years) submitted to high dose dipyridamole (170 patients) or dobutamine (217 patients) stress echocardiography in 7 echo labs quality-controlled for stress echo reading.

**Results:** Stress echo was positive for myocardial ischemia in 10 g patients. During a follow-up period of  $29 \pm 26$  months, overall 105 cardiac events occurred (21 deaths, 20 acute myocardial infarctions, 63 revascularization procedures, and 1 cardiac transplantation). Cardiac events were significantly more frequent in the patients with positive when compared to those with negative test (61/109 vs 44/278, respectively: 56% vs 16%;  $p < 0.0001$ ). The relative risk for hard cardiac events (cardiac death and myocardial infarction) was 3.7 higher (CI 2.0–7.0) in patients with evidence of stress-induced ischemia. The four-years survival free from spontaneous hard cardiac events was significantly lower for patients with positive when compared with those with negative stress echocardiography (60% vs 89%, respectively;  $p < 0.0001$ ). By Cox analysis for cardiac death, peak stress Wall Motion Score Index was the strongest predictor (OR = 10.1, CI = 3.6–28.7,  $p < 0.00001$ ) at univariate analysis. At multivariate analysis, resting wall motion (OR = 8.6), previous myocardial infarction (OR = 3.7) and rest-stress variation in wall motion score index (OR = 3.0,  $p < 0.05$ ) were independent predictors of death.

**In conclusion,** pharmacological stress echocardiography is effective in prognostic stratification of patients with resting LBBB.

#### 1101-28 Wall Motion Abnormalities in Multiple Vessel Territories on Exercise Stress Echocardiography Predict All-Cause Mortality

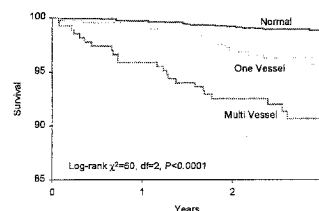
Maran Thamilarasan, Michael S. Lauer, Curtis M. Rimmerman, James D. Thomas, Imran Afridi. *Cleveland Clinic Foundation, Cleveland, OH, USA*

**Background:** Although exercise echocardiography has been shown to be predictive of cardiac events, its ability to predict all-cause mortality has not been well explored.

**Methods:** Consecutive patients undergoing exercise echocardiography during 1994 and 1995 (N = 2291, mean age 57, 62% male, mean ejection fraction 52%, known CAD in 34%) were followed for 3 years. Stress echocardiograms were classified according to presence of scar and/or ischemia and according to vascular territories (LAD, LCx, RCA).

**Results:** Abnormalities were present in 677 patients (30%) with ischemia in 330 (14%), scar in 523 (23%), single vessel abnormalities in 410 (18%), and multi-vessel abnormalities in 267 (12%). Among patients with multi-vessel involvement, ischemia was present and defined multi-vessel abnormalities in 146 (55%).

There were 71 deaths. Any scar was predictive of death (8% vs. 2%, unadjusted relative risk [RR] 4.92, 95% CI 3.01–7.88,  $P < 0.0001$ ), but any ischemia was less predictive (RR 1.55, 95% CI 0.86–2.77,  $P = 0.15$ ). Single vessel abnormalities predicted death (4% vs. 2%, RR 2.81, 95% CI 1.55–5.11,  $P = 0.0007$ ), whereas multi-vessel abnormalities [Figure] were associated with higher risk (10% vs. 2%, RR 4.91, 95% CI 3.03–7.96,  $P < 0.0001$ ). After adjusting for age, gender, exercise capacity, diabetes, smoking, and hypertension, multi-vessel abnormalities remained predictive of death (adjusted RR 2.42, 95% CI 1.37–4.25,  $P = 0.002$ ), while single vessel abnormalities did not (adjusted RR 1.38, 95% CI 0.75–2.55,  $P = 0.30$ ).



**Conclusions:** Presence of wall motion abnormalities on stress echocardiography, particularly if multiple vascular territories are involved, is strongly and independently predictive of all-cause mortality.

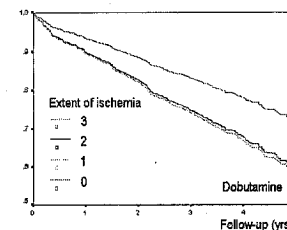
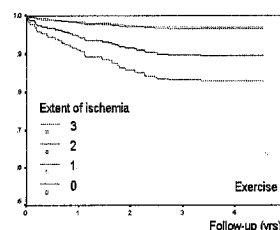
#### 1101-29 Do Exercise and Dobutamine Echo Convey Equivalent Information About Risk of Death?

Tom Marwick, Colin Case, Charles Vasey, Pat Brennehan, Susan Allen, Stephen Sawada. *University of Queensland, Brisbane, Australia; Asheville Cardiology Assoc, NC; Indiana University, Indianapolis, IN, USA*

**Background:** Exercise (ExE) and dobutamine echo (DbE) have similar accuracy but their relative prognostic value is not well defined. Previous studies have shown both tests to predict composite endpoints but have not been powered to examine prediction of mortality. We sought to compare prediction of death by DbE and ExE in a multicenter follow-up study of 8369 pts at 3 large-volume laboratories.

**Methods:** Standard ExE (n = 5213) and DbE (n = 3156) protocols were performed in pts (age  $63 \pm 12$  y, 57% men) with known or suspected CAD. Pts were classified by expert observers as having normal findings, ischemia or scar. Survival curves were generated over 9 years follow-up (mean  $5 \pm 2$  for Ex and  $4 \pm 2$  for Db). Cox models were used to analyze effect of ischemia, independent of other determinants of death.

**Results:** Pts were stressed maximally to  $9 \pm 3$  METs and 84% completed the Db protocol; heart-rate increased to  $90 \pm 23\%$  predicted maximum with exercise vs  $86 \pm 12\%$  with Db. ISC was identified in 2429 (77%). Total mortality was 18% for Db and 7% for ExE over 9 yr follow-up. Pts with normal ExE had a total mortality of <1%/year, while a normal DbE was associated with a total mortality of 8%/yr and cardiac mortality 1%/yr. In both ExE and DbE, ischemia was an independent predictor of death together with age and heart failure.



**Conclusion:** Normal ExE and DbE predicts low risk. Risk of death increases with extent of ischemia, and appears higher in DbE related to higher risk for these pts.

### 1101-30 Clinical Importance of ST Segment Elevation During Dobutamine Stress Echocardiography in Patients With an Old Myocardial Infarction

E. Adamopoulou, C. Evdoridis, E. Zouridakis, M. Calachanis, P. Nihoyannopoulos. *Clinical Cardiology Unit, Hammersmith Hospital, Imperial College London, UK*

**Background:** Exercise-induced ST segment elevation (ST $\uparrow$ ) in the presence of an old Q wave myocardial infarction (MI) could be attributed to either extensive ischemia, myocardial scar or represent viable tissue. The aim of this study was to investigate which of the above mechanisms underlies the development of ST $\uparrow$  in patients with previous MI, undergoing dobutamine stress echocardiography (DSE).

**Methods and Results:** We analysed the electrocardiographic findings of 193 patients (pts) with myocardial dysfunction who underwent DSE. ST changes were defined as  $\geq 1$  mm change at 80 msec from the J point. ST $\uparrow$  occurred in 29 pts (25 men, age  $64 \pm 8$  yrs) whilst 164 pts (134 men, age  $60 \pm 9$  yrs) had no significant ST segment changes. Wall motion score index (WMSI) was assessed using a 16 segments-3 grade score model. The number of akinetic segments at rest (ASrest), of viable segments (VS) and of new akinetic segments at peak stress (ASpeak) were measured. The extent of myocardial ischemia was assessed by calculating the difference between WMSI at rest and peak stress (WMSIdiff). Values are presented as median (interquartile range). At rest, there was no difference in ASrest between groups [4 (2.5–6) vs 5 (3–8),  $p = \text{NS}$ ], signifying that the extent of myocardial scar was similar in pts with and without ST $\uparrow$ . There was also no significant difference in the number of VS between the two groups [1 (0–3) vs 1 (0–3),  $p = \text{NS}$ ]. However, pts with ST $\uparrow$  had significantly higher WMSIdiff [0.06 (0–0.28) vs 0 (–0.06–0.09),  $p = 0.006$ ] and ASpeak [1 (0–3) vs 0 (0–1),  $p = 0.009$ ] indicating more extensive ischemia.

**Conclusion:** Our findings suggest that the mechanism for the stress induced ST $\uparrow$  in the presence of old Q wave MI might not be related to the extent of myocardial scar nor viable tissue but is associated with severe residual ischemia.

### 1101-31 Optimization of Regional Wall Motion Assessment in Stress Echocardiography: Is 5-Grade Scale Reproducible Enough?

Jaroslaw D. Kasprzak<sup>1</sup>, Bernard Paelinck, Guido Rocchi, Wim B. Vletter, Rene Frowijn, Lubov Koroleva, Abdou Elhendy, Jos R.T.C. Roelandt, Folkert J. Ten Cate. *Heart Centre, Rotterdam, The Netherlands; <sup>1</sup>Medical University of Łódź, Poland*

**Purpose:** Subjective visual assessment of regional wall motion remains a standard for the evaluation of stress echocardiogram. A 5 grade scale has been replacing 4-grade scale with expectations to improve the precision of scoring. We studied the reproducibility of both regimens at different experience and image quality levels.

**Methods:** 48 image sequences originating from 12 dobutamine-atropine stress echo, fundamental (FI) and harmonic (HI), baseline and peak recordings were randomly arranged on videotape and scored independently by a physician with expert (EX), intermediate (IM) and beginner (BG) interpretation experience. Scores were assigned in 4-grade (normokinesis/hypokinesis/akinesis/dyskinesis) and in 5 grade scale (additional separation of mild and severe hypokinesis). Reproducibility was analyzed using percent agreement in score values.

**Results:** The HI images presented with significantly better quality than FI images. The agreement in 4-grade scale was significantly better at all experience levels: 87% vs. 74%, 77% vs. 62% and 80% vs. 62% for EX/IM, EX/BG and IM/BG, respectively. The main source of variability were, surprisingly, baseline images (agreement 70% EX/IM and below 50% in IM/BG and EX/BG). Peak images were significantly more reproducible due to reduction in most ambiguous, mildly hypokinetic segments. The same trends were seen in higher quality HI as in FI recordings. Reproducibility of the more experienced scorers was significantly better.

**Conclusions:** Visual 5-grade scale of left ventricular wall motion is not sufficiently reproducible for routine clinical use even when image quality is improved by the application of harmonic imaging. The use of simpler, 4-grade scoring supported by reader's expertise should be recommended to improve the agreement in stress echo interpretation in both routine studies and multicenter research projects.

### 1101-32 Usefulness of Hypotension During Dobutamine Echocardiography in Predicting Perioperative Cardiac Events

Sharlene M. Day, John G. Younger, David S. Bach, William F. Armstrong, Kim A. Eagle. *University of Michigan Medical Center, Ann Arbor, Michigan, USA*

**Background:** This study was undertaken to determine the prognostic significance of hypotension induced during preoperative dobutamine stress echocardiography (DSE) prior to vascular and non-cardiac thoracic surgery. Wall motion abnormality during DSE predicts perioperative risk. Although hypotension during DSE has not been shown to correlate with the presence or severity of coronary artery disease, its significance in perioperative risk assessment is unknown.

**Methods:** We retrospectively studied 300 patients who had DSE within 6 months of noncardiac surgery. A hypotensive response was defined as a decrease in systolic blood pressure  $\geq 20$  mm Hg from the peak pressure during the infusion protocol or an absolute systolic blood pressure  $\leq 80$  mm Hg. Perioperative events, including death, myocardial infarction, ischemia, and arrhythmias were recorded. Odds ratios (OR) with 95% confidence intervals (CI) were used to examine the association between clinical and echocardiographic variables and perioperative events.

**Results:** A hypotensive response during DSE was seen in 85 patients (28%). Forty eight patients (16%) had 54 perioperative complications including 4 cardiac related deaths, 10 myocardial infarctions, 12 myocardial ischemic events, and 28 arrhythmias. Hypotension during DSE was predictive of the combined end point of perioperative cardiac mortality, myocardial infarction and ischemia (OR 4.04, 95% CI 1.72–9.51), independent of wall motion abnormalities, in a multivariate logistic regression model, hypotension during DSE remained a significant predictor (OR 4.10,  $p < 0.01$ ). Variables associated with a hypotensive response included older age, female gender, a history of coronary artery disease and left ventricular hypertrophy ( $p < 0.05$  for each).

**Conclusion:** DSE related hypotension was predictive of perioperative cardiac events and therefore may have a role in risk stratification prior to vascular or non-cardiac thoracic surgery.

## POSTER

### 1102 New Doppler Techniques

Monday, March 13, 2000, Noon–2:00 p.m.  
Anaheim Convention Center, Hall A  
Presentation Hour: Noon–1:00 p.m.

### 1102-33 Pulse Inversion Harmonic Imaging: Does It Improve the Endocardial Border Definition?

Anne-Claire Vancon, Chi-Ming Chow, Ervin R. Fox, Jeffrey Hill, Michael H. Picard, Marielle Scherrer-Crosbie. *Massachusetts General Hospital, Boston, Massachusetts, USA*

**Background:** Harmonic Imaging (HI), which detects non linear responses to insonification, significantly improves the Endocardial Border Definition (EBD). Pulse Inversion Harmonic Imaging (PIHI), a new imaging modality, increases harmonic responses. Although PIHI improves contrast agent detection, it has never been assessed for tissue definition.

**Method:** Transthoracic echocardiography was performed in 50 consecutive patients (20 males, 30 females,  $62 \pm 19$  years, 17 with technically difficult studies) using 3 different modalities: fundamental mode (FM), HI and PIHI. Apical 4 and 2 chamber views were digitally acquired. The left ventricle was divided in 6 segments for each view and endocardial visualization was scored by 2 readers as followed: 0 if the endocardium was not seen, 1 if partially visualized (1 to 50% of the length), 2 if partially visualized (51 to 99% of the length) or totally seen with poor quality, 3 if the visualization was complete and excellent. Interobserver variability was assessed by measuring the standard deviation of the ratio: (reader 1 score – reader 2 score)  $\times$  100 / score average.

**Results:** The global and the segmental Endocardial Visualization Scores (EVS) measured with FM were all significantly improved by using either HI or PIHI (global score, FM:  $16.02 \pm 7.02$ , HI:  $21.60 \pm 7.11$ , PIHI:  $22.72 \pm 6.98$ ,  $p < 0.01$ ). The improvement of the global score compared to baseline was higher using PIHI ( $6.72 \pm 0.03$ ) than HI ( $5.73 \pm 0.09$ ,  $p = 0.035$ ). This occurred globally without any differences between selected segments. The interobserver variability decreased equally when using PIHI and HI compared with FM (standard deviation, FM: 30%, HI: 17%, PIHI: 18%). There was no linear relationship between the FM score and the improvement brought by HI or PIHI.

**Conclusion:** PIHI, a promising new modality for detection of myocardial contrast, can also successfully be used for EBD. It sharpens significantly fundamental EBD and provides a mild global improvement relative to conventional HI.

#### 1102-34 How Much Does Harmonic Imaging Affect Cardiac Dimensions?

Chi-Ming Chow, Anne-Claire Vancon, Marc J. Roy, Marielle Scherrer-Crosbie, Michael H. Picard. *Massachusetts General Hospital, Boston, MA, USA*

**Background:** Although it is clinically recognized that cardiac structures appear thicker with harmonic (HA) than with fundamental (FU) imaging, the magnitude of the difference is not known. Furthermore, the interaction between these 2 imaging modes might depend on the gain settings. We performed in vitro and in vivo studies to investigate these issues.

**Methods:** We imaged a 12 mm circular solid structure (area 113 mm<sup>2</sup>) at a depth of 40 mm in a tissue phantom using a 3.5 MHz probe. Transmission gain was increased from -20 dB to 20 dB at 4 dB increments. Compression, depth, receiving gain and focus remained constant. In five healthy volunteers (3 M, 2 F), parasternal long axis view of the mitral valve was digitally acquired across all gain settings and the mid anterior mitral leaflet thickness was measured at end diastole. All measurements were an average of those obtained by two independent observers.

**Results:** For the phantom, while one setting in FU measured phantom size accurately, all settings in HA overestimated the area (124 ± 8 mm<sup>2</sup> with FU and 143 ± 13 mm<sup>2</sup> by HA (p < 0.001). The overestimation was greater in the horizontal than in the vertical axis (16% vs 9% for HA, p < 0.001) and persisted across all gain settings. The differences between HA and FU measurements increased linearly with the increase in gain both in the horizontal (r = 0.82, p = 0.002) and vertical (r = 0.96, p < 0.0001) dimensions. In vivo, with optimal machine settings, mitral leaflet thickness (measured in near vertical axis) was 1.74 ± 0.6 mm with FU and 2.03 ± 0.6 mm with HA. The mean difference across all gains between FU and HA was 30 ± 20.7% (p < 0.001). The relative differences in thickness of leaflets noted between the two modalities did not change as a function of the gain settings (r = 0.38, p = 0.25).

**Conclusions:** HA consistently overestimates structure size across all gains with a more exaggerated increase in the horizontal compared to vertical axis. These overestimations increase with increasing gain. Thus particularly for larger structures and especially when horizontal measurements are made caution should be exercised in interpreting harmonic images.

#### 1102-35 Quantification of Shunt Fraction in Ventricular Septal Defects of Adults Using an Automated Color Doppler Method for Flow Volume Evaluation

Karl Dennig, Ullrich H. Haase, Albert Schömig. *Deutsches Herzzentrum and 1. Medizinische Klinik, TU Muenchen, Munich, Germany*

**Background:** Doppler echocardiographic assessment of VSD's is frequently limited in adults since adequate imaging of RV outflow for flow volume comparison can not be obtained. We sought to examine whether a color Doppler method (ACM) for automated determination of flow volumes may contribute to the quantification of perimembraneous VSD's.

**Methods:** Color Doppler imaging was carried out in 23 patients with a VSD prior to cardiac catheterization as well as in 12 healthy volunteers. From an apical transducer position the left ventricular outflow tract with adjacent aorta ascendens were visualized. The sampling box of the ACM method was located across the LVOT proximal to the septal defect as well as across the aorta 2 cm distal of the valve. From both sampling positions flow volumes were determined using the automated Doppler algorithm for the identical systolic interval. Shunt fraction (SF) was determined as the difference of the proximal and the distal measurements divided by the proximal flow volume expressed in %.

**Results:** In healthy persons, a close agreement of proximal and distal flow volumes was found with a mean difference of 5%. In contrast, in patients with a VSD proximal measurements revealed significantly higher flow volumes, 71 ± 24 ml, compared with distal measurements, 54 ± 17 ml. Accordingly, calculated SF's for the entire patient group were 23 ± 10%. The comparison with invasively determined SF's showed a close correlation (r = 0.87, SEE = 6%).

**Conclusion:** With an automated color Doppler method accurate quantification of shunt fraction in perimembraneous VSD of adults can be achieved without the need of RV outflow imaging.

#### 1102-36 Quantification of Dobutamine Echo With Tissue Doppler Offers an Objective Means of Following Responses to Therapy and Progression of Coronary Artery Disease

Peter Cain, Terri Baglin, Colin Case, Tom Marwick. *University of Queensland, Brisbane, Australia*

**Background:** Extent of myocardial ischemia is related to outcome, and quantification with nuclear techniques has recently been used to select pts for therapy. Combination of dobutamine echo (DbE) with tissue Doppler measurement of myocardial Doppler velocity (MDV) has been shown to objectify DbE. We sought to explore the test-retest concordance of DbE-TDI and its ability to follow response to therapy.

**Methods:** 44 pts were enrolled for study; 23 with chronic CAD (cCAD), 5 with low pretest clinical risk of CAD, and 16 before revascularization (RVS). Repeat DbE was performed on all patients (3.2 ± 2 months between tests). All images were acquired in digital cine-loop format (Vingmed system FiVe) at all stages of stress. Wall motion analysis was performed the same independent expert reader and MDV analysis was performed by a novice reader. Both were blinded to other test results. Retest concordance was assessed using Cronbach's alpha (concordant tests indicated by value > 0.8).

**Results:** A high level of MDV test-retest concordance existed in normal segments on followup DbE (alpha = 0.83 for cCAD, 0.76 RVS, 0.91 normal). Ischemic segments post-RVS had a marked improvement in MDV compared to unaffected segments. Pts treated medically for chronic IHD with a stable clinical course showed little difference on followup MDV.

Test 1-Test 2 MDV (cm/sec)

Territory	RVS		RVS		cCAD		cCAD	
	Normal segt	Abnormal segt	Normal segt	Abnormal segt	Normal segt	Abnormal segt	Normal segt	Abnormal segt
LAD	8.00	8.45	5.8	9.2	7.6	8.0	6.0	6.4
LCX	7.4	7.9	4.9	7.1	7.5	7.8	4.3	4.0
RCA	7.0	7.1	7.5	9.4	7.5	7.0	7.3	7.5
ALL	7.5	7.8	6.0	9.0	7.5	7.7	6.0	6.1
Sign.	p = 0.410		p < 0.0001		p = 0.556		p = 0.876	

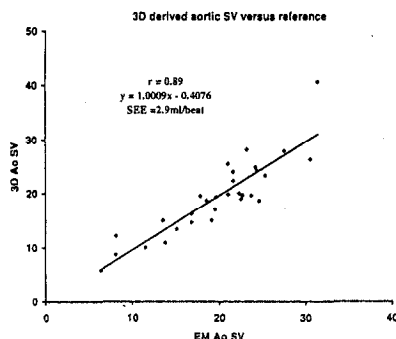
**Conclusions:** MDV is reproducible at rest and leak stress in normal segts. Segmental myocardial function improved in RVS territories. Medical therapy produced similar results of MDV in this population.

#### 1102-37 A Validation Study of Aortic Stroke Volume Using Dynamic 4D Color Doppler: An In Vivo Study

Rosemary A. Rusk, Yoshiki Mori, Xiang-Ning Li, Michael Jones, Timothy Irvine, Petra S. Mehwald, Antoinette Kenny, David J. Sahn. *Oregon Health Sciences University, Portland, OR; LAMS-NHLBI, Bethesda, MD, USA*

**Background:** Traditional methods for flow quantification require geometric assumptions on flow area and flow profiles. Accurate quantification of flow across the aortic valve is clinically important as a means of estimating cardiac output. To explore the feasibility of directly quantifying transaortic volume with a newly developed dynamic 4D Doppler technique, an in vivo study was performed.

**Methods:** Eight open chest sheep were scanned with epicardial placement of a 7 MHz multiplane TEE probe scanning parallel to aortic flow and running on an ATL HDI 5000 system. An electromagnetic (EM) flow meter implanted on the ascending aorta was used as reference. Thirty different hemodynamic conditions were achieved by administration of blood, angiotensin and sodium nitroprusside. ECG gated digital 3D velocity data were acquired for each of the 30 steady states. The aortic stroke volumes were computed by temporal and spatial integration of flow areas and actual velocities across a spherical surface perpendicular to the direction of flow, at a level just below the aortic valve.



**Results:** There was close correlation between these calculated aortic stroke volumes and the EM data ( $r = 0.89$ ,  $y = 1.0009x - 0.41$ ,  $SEE = 2.9$  ml/beat) (Figure).

**Conclusion:** This study suggests that this 4D digital color Doppler method provides an accurate geometry independent method of calculating flow across the aortic valve and is, therefore, a potential noninvasive means of determining cardiac output.

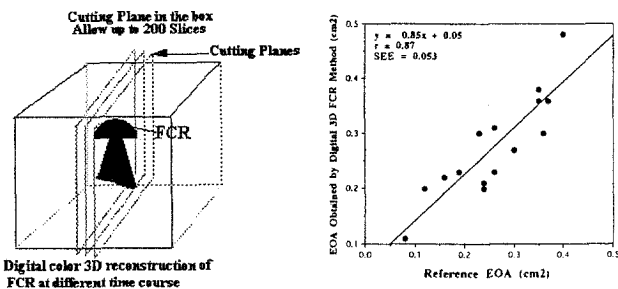
**1102-38 A Geometry Independent 3D Digital Color Doppler Method Which Allows Accurate Calculation of Instantaneous Flow Rate Can Be Used to Accurately Define Dynamically Changing Effective Orifice Area: An In Vitro Study**

Xiaokui Li, Suthep Wanitkun, Ikuo Hashimoto, Yoshiki Mori, Rosemary A. Rusk, Xiang-Ning Li, David J. Sahn. *Oregon Health Sciences University, Portland, OR; ATL Ultrasound, Bothell, WA, USA*

**Background:** We have reported a 3D digital Doppler method for quantifying the flow convergence region (FCR) which, since all raw velocity data is available, variable Nyquist limits can be selected for computation of flow rate without any shape assumptions. This study tested the 3D flow FCR method in a unique new in vitro model of "mitral" regurgitation which has a dynamically changing orifice during the heart cycle.

**Methods:** 3D flow convergence surface computation was performed on parallel slices through the 3D data set at aliasing velocities (14–48 cm/sec) selected to maximize the regularity and minimize lateral drop out of the visualized 3D FC at 4 points in every cardiac cycle. Using CW velocities for that period, FCR EOA was compared to EOA determined using flow rates from a reference ultrasonic flow meter and CW velocities. Simultaneous digital video images defined the actual orifice size.

**Results:** Over a range of 8 pulsatile flow states with stroke volumes 15–50 ml and maximum flow rates 66–72 ml/sec, FC EOAs (0.12–0.48 cm<sup>2</sup>) correlated extremely well with reference EOA ( $r = 0.87$ ,  $Y = 0.85X + 0.05$ ,  $SEE = 0.053$  cm<sup>2</sup>) and they were also correlated with digital video actual orifices at the same time ( $r = 0.86$ ), although they were consistently smaller, as expected by the contraction coefficient.



**Conclusion:** The digital 3D FC method can accurately predict flow rate and thus EOA (in conjunction with CW Doppler) because it allows direct FC surface measurement despite temporal variability of FC shape.

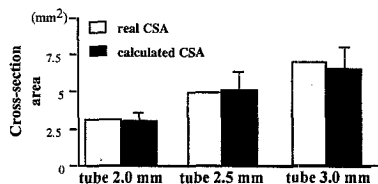
**1102-39 Vessel Cross-Section Area Can Be Measured by Doppler Flow Wire Using Doppler Signal Power**

Lazar Mandinov, Andre Linka, Rolf Jenni. *Echocardiography, Division of Cardiology, University Hospital Zurich, Switzerland*

**Background:** Measurement of coronary artery cross-sectional area (CSA) is traditionally performed by quantitative coronary angiography (QCA). For estimation of coronary blood flow, however, QCA has to be combined with blood flow velocity measurement. Particularly in patients undergoing coronary intervention, Doppler guide wire is often routinely used. Therefore, we studied the ability of a new Doppler power-based method to calculate CSA, when Doppler flow wire is applied alone.

**Method:** An in vitro pulsatile flow model with serially connected silicon tubes of known lumen diameters (2.0, 2.5 and 3.0 mm) and changing blood flow was employed. A 0.014 inch Doppler Flow Wire was coupled to a commercially available Doppler system (FloMap, Cardiometrics). The following power-based parameters were calculated on line by the Doppler system: M1 = first Doppler moment, M0 = zeroth Doppler moment; M1/M0 = mean flow velocity. Two different groups of sample volumes (different gate depths) were used to evaluate the effect of scattering and attenuation on Doppler power: 1) sample volumes, lying in the vessel (proximal gates), and 2) those, intersecting the vessel lumen (distal gates). Power-based parameters obtained at the distal gates were then corrected for scattering and attenuation by the data obtained at the proximal gates. Finally, corrected power-based parameters were used for calculation of vessel CSA of each silicon tube during different flow rates.

**Results:** The calculated CSA did not differ from the real CSA of the individual tubes (fig.). Mean paired differences between the two CSA were as follows: +0.15 mm<sup>2</sup> in the 2.0 mm-tube; -0.16 mm<sup>2</sup> in the 2.5 mm-tube, and +0.6 mm<sup>2</sup> in the tube sizing 3.0 mm (all ns). A good correlation between real and calculated cross-sectional areas was found ( $r = 0.80$ ,  $p < 0.0001$ ).



**Conclusion:** Vessel CSA can be measured by Doppler flow wire using Doppler signal power. This method can improve further application of Doppler guide wire for measurement of coronary artery size and coronary volumetric flow as well.

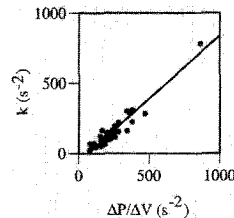
**1102-40 Invasive Validation of Left Ventricular Chamber Stiffness Predicted From Model-Based Image Processed Doppler E-Waves**

Jennifer B. Lisauskas, Jasvindhar Singh, Mark W. Sessoms, Sándor J. Kovács. *Cardiovascular Biophysics Laboratory, Washington University, St. Louis, MO, USA*

**Background:** Determination of left ventricular chamber stiffness ( $K_{LV} = \Delta P/\Delta V$ ), an index of diastolic function, requires invasive pressure-volume measurements. Noninvasive determination of  $K_{LV}$  in dogs by Little et al used the E-wave deceleration time and included invasive validation. Based on a suction-pump model of filling, we have previously shown that  $K_{LV}$  and the model stiffness parameter  $k$  are linearly related. In humans, validation of non-invasively predicted chamber stiffness has not been previously performed.

**Methods:** Micromanometric (Millar) left ventricular pressures (LVP) and simultaneous transmitral Doppler images were recorded in 45 patients during cardiac catheterization.  $\Delta P$  was defined as the change in pressure from minimum LVP to LVEDP (as per Little).  $\Delta V$  was computed as the sum of the E and A wave time-velocity integrals, starting at minimum LVP, multiplied by the 2-D echocardiographic mitral valve area. A previously validated, automated, model-based image processing (MBIP) method of E-wave analysis was used to determine  $k$ .

**Results:** Figure depicts the observed relationship of the echocardiographically determined stiffness  $k$  to catheterization determined  $\Delta P/\Delta V$ . Linear least-squares fit yields  $k = \Delta P/\Delta V - 57$ . Excellent correlation ( $r = 0.95$ ) was observed.



**Conclusion:** The Doppler E-wave derived stiffness parameter  $k$  determined by MBIP is linearly proportional to the invasively determined LV chamber stiffness  $\Delta P/\Delta V$  as predicted. Determination of  $k$  by MBIP permits quantitative diastolic function assessment in physiologic terms directly from transmitral flow and eliminates the need for E-wave contour attribute measurement by-eye. Application in selected pathologic clinical subsets is in progress.

**1102-177 Relation of Tissue Doppler Derived Myocardial Velocities to Myocardial Structure and Beta-Adrenergic Receptor Density in Man**

Kesavan Shan, Roger J. Bick<sup>1</sup>, Brian J. Poindexter<sup>1</sup>, Sarah Shimoni, George V. Letsou, Michael J. Reardon, Jimmy F. Howell, William A. Zoghbi, Sherif F. Nagueh. *Baylor College of Medicine; <sup>1</sup>University of Texas Medical School, Houston, Texas, USA*

**Background:** The systolic ( $S_m$ ) and early diastolic ( $E_m$ ) myocardial velocities acquired by tissue Doppler (TD) are promising new indices of left ventricular function. However, their structural and functional correlates in man are still unknown.

**Methods:** Accordingly, 10 patients with known coronary artery disease underwent echocardiographic examination including (TD) imaging, along

with transmural endomyocardial biopsy at the time of coronary bypass surgery (2 biopsies per patient for a total of 20 specimens). The specimens were analyzed for percent interstitial fibrosis (Mallory's trichrome stain) and  $\beta$ -adrenoceptor density (fluorescent analog of the  $\beta$ -adrenoceptor agonist CGP 12177).

**Results:** Normal segments ( $n = 8$ ) had a higher  $\beta$ -adrenoceptor density ( $2280 \pm 738$  vs  $1373 \pm 460$  per  $60 \times 60 \mu\text{m}$  tissue slices,  $p = 0.03$ ), and a lower amount of interstitial fibrosis ( $13 \pm 3.3\%$  vs  $28 \pm 11.5\%$ ,  $p = 0.002$ ) than dysfunctional segments ( $n = 12$ ). Sm ( $9.5 \pm 2.7$  vs  $5.9 \pm 1.8$  cm/s,  $p = 0.025$ ) and Em ( $11.3 \pm 2.8$  vs  $6.4 \pm 2.1$  cm/s,  $p = 0.002$ ) were significantly higher in normal segments. A significant relation was present between Em and the  $\beta$ -adrenergic receptor density ( $r = 0.76$ ,  $p < 0.001$ ) and percent interstitial fibrosis ( $r = -0.7$ ,  $p = 0.0026$ ) which together accounted for 81% of the variance observed in Em. Likewise, a significant relation was present between Sm and the  $\beta$ -adrenergic receptor density ( $r = 0.68$ ,  $p < 0.001$ ) and percent interstitial fibrosis ( $r = -0.66$ ,  $p = 0.004$ ) that together accounted for 62% of the variance observed in Sm.

**Conclusions:** Sm and Em are strongly dependent on the number of myocytes and on the myocardial  $\beta$ -adrenergic receptor density.

#### 1102-178 Hemodynamic Determinants of the Mitral Annulus Early Diastolic Velocity

Sherif F. Nagueh, Huabin Sun, Helen A. Kopelen, Dirar S. Khoury. *Baylor College of Medicine, Houston, Texas, USA*

**Background:** Early diastolic mitral annulus velocity (Ea) acquired by tissue Doppler imaging of the mitral valve is a promising new index of left ventricular (LV) diastolic function. However, there is a paucity of data on its hemodynamic determinants.

**Methods:** Catheters (5F, Millar) were inserted in the left atrium (LA) and LV of 6 adult mongrel dogs (19–28 kg) to record LA and LV pressures. Epicardial echocardiographic imaging was performed and Ea was measured from the same cardiac cycles used for hemodynamic measurements (average of 15 beats). LV preload was altered through saline infusion and inferior vena caval compression. LV relaxation was augmented with dobutamine (5  $\mu\text{g/kg/min}$ ) and depressed with esmolol (0.5 mg/kg).

**Results:** With caval occlusion, filling pressures decreased (LA v wave pressure:  $6 \pm 2.5$  to  $3 \pm 2$  mmHg; LA mean pressure:  $4.5 \pm 2.6$  to  $2.8 \pm 2$  mmHg; LV end-diastolic pressure:  $5 \pm 2$  to  $1 \pm 0.7$  mmHg; all  $p < 0.01$ ). However, Ea changed minimally ( $5.1 \pm 1.9$  to  $4.7 \pm 2$  cm/s,  $p = 0.08$ ). With dobutamine infusion, LV relaxation increased (tau:  $51 \pm 10$  to  $37 \pm 5$  ms,  $-dP/dt$ :  $2815 \pm 678$  to  $4604 \pm 1000$  mmHg/ms; both  $p < 0.001$ ). Esmolol resulted in prolongation of tau ( $51 \pm 10$  to  $91.5 \pm 9$  ms,  $p < 0.001$ ) and decrease in  $-dP/dt$  ( $2815 \pm 678$  to  $1119 \pm 367$  mmHg/ms,  $p < 0.001$ ). Along with these hemodynamic changes, Ea increased with dobutamine ( $5.1 \pm 1.9$  to  $7.7 \pm 0.85$  cm/s,  $p < 0.001$ ) and decreased with esmolol ( $5.1 \pm 1.9$  to  $3.7 \pm 0.8$  cm/s,  $p < 0.001$ ). Overall a strong relation was present between Ea and the parameters of LV relaxation (tau:  $r = -0.91$ ;  $-dP/dt$ :  $r = 0.84$ , both  $p < 0.001$ ) whereas a weak relation was noted with the transmitral pressure gradient ( $r = 0.53$ ,  $p = 0.06$ ).

**Conclusions:** These observations support the strong and direct relation of Ea to LV relaxation and suggest a relatively minor effect of preload on this velocity.

#### ORAL

#### 849 Novel Applications of Three-Dimensional Echocardiography

Monday, March 13, 2000, 2:00 p.m.–3:30 p.m.  
Hilton Anaheim, Pacific C

2:00 p.m.

#### 849-1 Regression of Left Ventricular Mass One Year After Valve Replacement for Severe Aortic Stenosis is Dependent on Prosthetic Valve Size: A Three-Dimensional Echocardiographic Study

Harald P. Kühl, David Puschmann, Rainer Hoffmann, Friedrich Schöndube<sup>1</sup>, Andreas Franke, Peter Hanrath. *Medical Clinic I and <sup>1</sup>Department of Cardiothoracic Surgery, University Hospital Aachen, Germany*

**Background:** Conflicting data exist concerning the influence of valve size on the regression of left ventricular mass (LVM) in patients undergoing valve replacement therapy for severe aortic stenosis. We hypothesized that three-dimensional echocardiography (3DE) may be more sensitive than M-mode to assess differences of LVM changes in patients with small versus large prosthetic valves.

**Methods:** In 26 patients (mean age  $64 \pm 9$  years) without concomitant coronary artery disease, hypertension or diabetes mellitus LVM was measured using transeophageal 3DE and M-mode according to ASE standards  $2 \pm 1$  days before and  $14 \pm 2$  months after aortic valve replacement. Results of LVM regression were compared for patients with a small prosthetic valve size (23 mm; group I = 13 pts) to those with a valve size of  $>23$  mm (range 25 to 31 mm; group II = 13 pts.). 3DE image acquisition was performed in 3° increments using ECG and respiratory gating (HP Sonos 5500). LVM was measured using a previously validated software (Echo-View, TomTec).

**Results:** Preoperative mean valve area was  $0.7 \text{ cm}^2$  in both groups. Before surgery LVM by 3DE averaged  $181 \pm 23$  g in group I and  $284 \pm 53$  g in group II ( $p < 0.001$ ). With M-mode preoperative mass values were significantly larger compared to 3DE ( $209 \pm 54$  g for group I and  $310 \pm 62$  g for group II;  $p < 0.05$  versus 3DE). At follow-up there was a similar regression of LVM with both echocardiographic techniques (for 3DE  $57 \pm 34$  g, for M-mode  $56 \pm 35$  g;  $p = \text{ns}$ ). A significant difference in the regression of LVM between groups I and II could be demonstrated for 3DE ( $34 \pm 11$  g or 19% in group I vs.  $80 \pm 35$  g or 28% in group II;  $p < 0.001$ ) but not for M-mode ( $44 \pm 25$  g or 20% in group I vs.  $69 \pm 41$  g or 21% in group II;  $p = \text{ns}$ ). Multivariate regression analysis using 3DE data revealed that the preoperative LVM ( $r^2 = 0.61$ ;  $p < 0.001$ ) as well as prosthetic valve size ( $r^2 = 0.29$ ;  $p < 0.01$ ) were predictors of absolute and relative LVM regression.

**Conclusion:** 1) In pure aortic stenosis the regression of LVM as assessed by 3DE is dependent on valve size and lower for small prosthetic valves as compared to large valves one year after surgery. 2) M-mode may be insensitive to detect differences of mass changes in patients with small versus large prosthetic valves.

2:15 p.m.

#### 849-2 Real-time 3D Pulsed Wave (PW) Doppler Echocardiography for Quantification of the Left Ventricular Stroke Volume

Jian Xin Qin, Michael Jones<sup>1</sup>, Takahiro Shiota, Hiroyuki Tsujino, Agnese Travaglini, Arthur D. Zetts<sup>1</sup>, Lisa A. Cardon, Annitta J. Morehead, Fabrice Bauer, James D. Thomas. *The Cleveland Clinic Foundation; <sup>1</sup>LAMS, NHLBI, Bethesda, MD, USA*

Real-time PW 3-dimensional echocardiography (RT3DPW), recently developed, has the potential ability to quantify left ventricular (LV) stroke volume (SV) non-invasively. The aim of this study was to determine the feasibility and accuracy of RT3DPW for LV SV measurement in an animal model.

**Methods:** Seven sheep (2 normal, 4 with chronic coronary occlusion and 1 with chronic aortic regurgitation) were studied. RT3DPW images were acquired epicardially during 28 hemodynamic conditions. The velocity time integral (VTI) of pulsed wave (PW) Doppler was multiplied by the cross-sectional area (CSA) of 3D color Doppler flow in the LV outflow tract (LVOT) to determine LVSV. The CSA was selected at the level of the PW sample volume, orthogonal to the PW interrogation. VTI and LVOT area by the conventional 2D-PW method were also used to calculate LVSV. LVSV obtained by the electromagnetic flow meter (EM) served as a reference standard.

**Results** (table): Good correlations between RT3DC and EM and between 2D-PW and EM for LVSV measurement were found. However, the agreement of RT3DC with EM was better than that of 2D-PW with EM. The 2D-PW method significantly overestimated the LVSV measured by EM.

	LVSV (ml)	r-value vs EM	Difference (ml)
EM	$25.1 \pm 10.1$		
RT3DC	$24.8 \pm 10.3$	0.88	$0.3 \pm 4.9$
2D-PW	$36.7 \pm 16.1^{\#}$	0.89	$10.9 \pm 8.3^*$

\*. Compare with RT3DC,  $p < 0.0001$ . #. Compare with the others,  $p < 0.001$ .

**Conclusion:** Real-time color Doppler 3DE can provide cross-sectional flow area, which is orthogonal to PW Doppler interrogation. The RT3DC method provided better agreement with the referenced LV stroke volume than did the conventional 2D-PW method.

2:30 p.m.

#### 849-3 New Observations in Comparison of Real-Time 3-D Dobutamine Stress Echocardiography With Conventional 2-D Dobutamine Stress Echocardiography

Tianrong Xie, Raul Heredia, Masood Ahmad. *University of Texas Medical Branch at Galveston, Galveston, Texas, USA*

**Background:** Our recent observations suggest Real-time 3-D dobutamine stress echocardiography (RT-3D DSE) is sensitive in detection of ischemia and offers advantages in ease of use, rapid imaging and measurement of volumes. Comparisons of RT-3D and 2-D DSE LV wall motion abnormalities

by region and the interobserver agreements for each method have not been reported.

**Methods:** Two hundred and fifty three patients (pts) had RT-3D images within a minute of 2-D acquisitions at baseline and at peak DSE. All images were evaluated by two independent observers. In pts with DSE positive for ischemia, comparisons of ischemic segments between RT-3D and 2-D were performed in anterior, posteroinferior, lateral, and apical regions.

**Results:** At baseline 62 of 253 pts had abnormal LV wall motion by RT-3D compared to 72 of 253 by 2-D (84.2% concordance); at peak DSE, 77 of 253 had new wall motion abnormalities by RT-3D compared to 58 of 253 by 2-D (89.3% concordance). The interobserver agreements for the overall presence or absence of LV wall motion abnormalities at baseline and at peak DSE were 89.4% and 92.2% for RT-3D, and 82% and 84.9% for 2-D ( $p < 0.05$ ). In 77 pts with DSE positive for ischemia, comparisons by the region of abnormality between RT-3D and 2-D at peak DSE showed a concordance of 74% in anterior, 74% in inferoposterior, 93.5% in lateral, and 87% in apical regions. In 90 pts with coronary angiographic data, the sensitivity of RT-3D in detection of ischemia was 85.7% compared to 78.8% by 2-D. In 49 pts with coronary artery disease, comparisons of regions of ischemia at peak DSE showed significantly increased number of ischemic segments detected by RT-3D in inferoposterior and apical regions ( $p < 0.05$ ).

**Conclusions:** 1) There was good agreement between RT-3D and 2-D in detection of abnormal LV wall motion during DSE. 2) The interobserver agreement for assessment of abnormal LV wall motion was excellent for RT-3D and superior to 2D. 3) The increased sensitivity of RT-3D, when compared to 2-D, appeared to be related to improved detection of ischemia in apical and inferoposterior regions.

2:45 p.m.

**849-4 Effect of Remodeling Following Myocardial Infarction on Left Ventricular Size and Function: A Real-Time 3-Dimensional Echocardiographic Study**

Gustavo Camarano, Michael Jones, Takahiro Shiota<sup>1</sup>, Inez Ernst, Arthur D. Zetts, James D. Thomas<sup>1</sup>, Julio A. Panza. *National Institutes of Health, Bethesda, Maryland; <sup>1</sup>The Cleveland Clinic Foundation, Cleveland, Ohio, USA*

**Background:** Remodeling following acute myocardial infarction (MI) is an adaptive mechanism that changes the geometry of the left ventricular (LV) chamber. The present study was designed to determine how this process affects LV size and function and their response to hemodynamic changes.

**Methods:** MI was created in 23 adult sheep by arterial ligation on the anterior or posterior coronary circulation. Animals were studied either 24 hours (group I; n = 10) or 6 months (group II; n = 13) later. Similar coronary occlusion procedures were followed in both groups to achieve equivalent size of MI. In each study, real-time 3-dimensional echocardiographic (RT3D echo) images were obtained in the open-chest anesthetized animals at baseline, during angiotensin II and sodium nitroprusside (SNP) infusion, and during partial ligation of the inferior vena cava. LV volumes were measured off-line from RT3D echo images using an interactive tracing technique based on a Silicon Graphics workstation.

**Results:** Baseline LV end-diastolic (EDV), end-systolic (ESV) and stroke (SV) volumes, and ejection fraction (EF) were as follows:

	EDV (ml)	ESV (ml)	SV (ml)	EF (%)
Group I	44.4 ± 6.9	15.6 ± 3.3	28.8 ± 4.9	65 ± 5
Group II	64.7 ± 6.6	35.0 ± 4.9	29.7 ± 4.3	46 ± 5
P value	<0.0001	<0.0001	0.67	<0.0001

There was no difference between the two groups in the response to angiotensin II administration or inferior vena cava ligation. However, SNP induced an increase in SV only in group I ( $P = 0.005$ ); consequently, SV measured during SNP infusion was significantly greater in group I compared to group II animals ( $33.2 ± 2.1$  vs.  $27.6 ± 2.6$  ml;  $P = 0.01$ ).

**Conclusion:** Remodeling following MI leads to LV dilation and reduced global function without changing SV. Afterload reduction positively affects LV function only during the early phases of MI and therefore is more likely to be beneficial at this stage than after the remodeling process has been completed.

3:00 p.m.

**849-5 Quantitative Three-Dimensional Left Ventricular Shape Changes Associated With Acute Myocardial Infarction: Clinical Correlation of Shape Change and Function at Outcome**

Kazuaki Tanabe, Marek Belohlavek, James B. Seward. *Mayo Clinic, Rochester, MN, USA*

**Background:** A clinically feasible systematic study of three-dimensional (3D) echocardiographic assessment of left ventricular (LV) shape changes in patients with acute myocardial infarction (AMI) has not been done. The purpose of this study was to prospectively follow patients after AMI and quantitatively assess LV shape changes to correlate these findings with subsequent changes in the LV ejection fraction.

**Methods:** We studied 16 AMI patients using the Volumetrics real-time 3D echocardiographic system in acute phase (5 days after AMI), 1 month (1 M) and 6 months (6 M) after AMI. We reconstructed LV computer casts using 9 equally incremented apical long-axis tomograms from the volumetric data. To express the shape numerically for comparison of changes, we used radial distances from the rotational axis of the LV cast. An 18-segment model of the LV was used to express the shape locally as the mean distances of the radii in each segment. We compared regional and global radial distance-based LV shape changes after AMI with measurements of LV volume and ejection fraction (EF).

**Results:** Patients with greater LV expansion (global positive end-systolic shape change) from acute phase to 1 M demonstrated the greatest subsequent decline in LV EF from 1 M to 6 M ( $y = -1.78x + 12.67$ ,  $r = -0.71$ ,  $p = 0.003$ ).

**Conclusions:** LV remodeling based on quantitative regional and global shape changes and volume analysis after AMI can be assessed. End-systolic LV shape change from acute phase to 1 M is predictive of subsequent changes in LV systolic function at 6 M after AMI.

3:15 p.m.

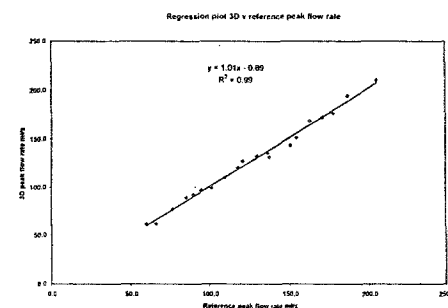
**849-6 An Automatic Volume Flow Method Based on 4D Digital Color Doppler: A Computer Algorithm Tested on an In Vitro Flow Model**

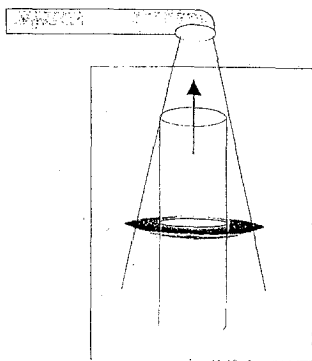
Timothy Irvine, Xiang-Ning Li, Yoshiki Mori, Suthep Wanitkun, Xiaokui Li, Paul R. Detmer, Roy W. Martin, Annette Pope, Gary A. Schwartz, Rosemary A. Rusk, Antoinette Kenny, David J. Sahn. *Oregon Health Sciences University, Portland, OR; ATL Ultrasound, Bothell, WA, USA*

**Background:** Conventional 2D Doppler methods for the quantitation of laminar flows in large vessels are prone to inaccuracy. 3D volume imaging provides the opportunity to make cross-sectional flow calculations through digital spatiotemporal integration of flow velocity, area and profile.

**Methods:** A new digital 3D color Doppler reconstruction method was used to generate radially acquired flow datasets. Raw scanline data with digital velocity assignments obtained by scanning parallel to flow were transferred from a specially programmed but otherwise conventional ATL HDI 5000 ultrasound system controlling a multiplane transesophageal probe to a computer workstation via an ethernet link for assimilation into color 3D datasets. This configuration was used to study 20 pulsatile laminar flows (stroke volumes 30–70 ml and peak flow rates 65–205 ml/sec) in a curved tube model with an oval cross-sectional geometry. After generation of the color 3D dataset flow velocity values from cross-sections perpendicular to the robes were analyzed to compute flow rate and stroke volume.

**Results:** The flows from 3D digital velocity profiles showed close correlation to peak instantaneous flow rates ( $r = 0.99$ ,  $y = 1.01x - 0.9$ , SEE 4.1 ml/sec). When interpolated with pulsed wave Doppler data obtained through the cardiac cycle they also allowed computation of stroke volume ( $r = 0.98$ ,  $y = 1.44x - 2.5$ , SEE 3.8 ml).





**Conclusion:** The ability to compute laminar flows from 3D digital datasets obtained parallel to the direction of flow and without the need for geometric assumptions represents an important opportunity for and advantage of 3D color Doppler echocardiography.

## ORAL

### 850 Myocardial Contrast Echocardiography: Experimental Observations

Monday, March 13, 2000, 2:00 p.m.–3:30 p.m.  
Hilton Anaheim, Pacific D

2:00 p.m.

### 850-1 Non-Invasive Assessment of Inflammation Using Ultrasound Detection of Phagocytosed Microbubbles

Jonathan R. Lindner, Ji Song, Matthew P. Coggins, Fang Xu, Sanjiv Kaul.  
*University of Virginia, Charlottesville, VA, USA*

We have previously shown that microbubbles attach to leukocytes adhered to the venular wall in regions of inflammation. We hypothesized that microbubbles that are eventually phagocytosed remain acoustically active and can be detected by ultrasound (US) imaging of inflamed tissue. Fluorescein-labeled albumin or lipid microbubbles were administered by intravenous bolus during simultaneous US imaging and intravital microscopy of the cremaster muscle in 6 mice. Three mice were pretreated with intrascrotal TNF- $\alpha$  to produce inflammation and the remainder served as controls. The extent of leukocyte adhesion in venules was 7-fold greater in TNF- $\alpha$ -treated compared to control animals which resulted in a 7-fold increase ( $p < 0.01$ ) in the number of microbubbles attaching to leukocytes early (0–2 min) after their injection. Fifteen min after their injection, most microbubbles associated with leukocytes appeared to be phagocytosed and few freely circulating microbubbles were observed. At this time point, upon initiation of US imaging, background-subtracted video intensity (VI) in the cremaster muscle was much greater ( $p < 0.01$ ) in TNF- $\alpha$ -treated compared to control animals for both albumin ( $25 \pm 7$  vs  $5 \pm 3$  units) and lipid ( $23 \pm 9$  vs  $5 \pm 4$  units) microbubbles. The VI on a second frame 0.5 s later was similar to pre-contrast baseline values, indicating almost complete destruction of all microbubbles by the first US pulse. The VI in frames subsequently obtained at a pulsing interval of 30 s, which represents signal from freely circulating microbubbles, was very low ( $\leq 5$  units) in all mice and not significantly different from the baseline VI. We conclude that microbubbles phagocytosed by leukocytes *in vivo* remain acoustically active and can be detected by US imaging in regions of inflammation after sufficient time is allowed for clearance of freely circulating microbubbles.

2:15 p.m.

### 850-2 Targeted Gene Delivery to the Left Ventricular Myocardium Using Ultrasound-Triggered Microbubble Destruction

Ralph Shohet, Shuyuan Chen, Yan-Ting Zhou, Zhouwei Wang, Robert S. Meidell, Roger Unger, Paul A. Grayburn. *UT Southwestern and VA Medical Centers, Dallas, Texas, USA*

**Background:** Ultrasound-triggered microbubble destruction (UTMD) has been proposed as a means of targeting gene therapy to specific organs. However, successful gene expression using this approach has not been reported until now. This study was done to test the hypothesis that albumin microbubbles containing an adenovirus with a beta-galactosidase gene un-

der a CMV promoter (AdCMV- $\beta$ gal) could be used to express the gene in rat hearts after UTMD.

**Methods:** Perfluoropropane-filled microbubbles with AdCMV- $\beta$ gal attached to their surface were prepared in our laboratory. Mean microbubble diameter was  $3.0 \pm 1.2 \mu\text{m}$  with a concentration of  $1.6 \pm 0.2 \times 10^9$  bubbles/mL. Each mL of microbubble suspension contained  $5 \times 10^9$  pfu of AdCMV- $\beta$ gal. In vitro experiments showed that the viral titer of the microbubble suspension was not affected by ultrasound at multiple frequencies. Microbubbles containing AdCMV- $\beta$ gal (1 mL) were injected intravenously into 6 rats, 3 during continuous harmonic ultrasound at maximal acoustic power and 3 without ultrasound. Additional controls included 3 rats undergoing ultrasound with albumin microspheres that did not contain AdCMV- $\beta$ gal, 3 rats receiving AdCMV- $\beta$ gal, and 3 rats receiving AdCMV- $\beta$ gal and ultrasound. All rats were sacrificed 4 days after the experiment and the hearts, livers (positive control), and hindlimb skeletal muscle (negative control) were harvested and stained with X-gal for evidence of expression of the  $\beta$ -gal transgene.

**Results:** As expected, the liver stained blue in all rats; there was no staining of skeletal muscle. The hearts of all 3 rats that underwent UTMD of microbubbles containing AdCMV- $\beta$ gal showed intense blue staining with X-gal, indicating expression of the transgene. Expression was predominant in the anterior wall where up to 50% of cardiomyocytes were transduced. In the posterior wall, <10% of cardiomyocytes showed gene expression. In contrast, none of the hearts in the control groups showed expression of the  $\beta$ -gal transgene.

**Conclusions:** Ultrasound-triggered destruction of albumin-coated microbubbles containing a viral transgene is a promising method for gene delivery to the anterior myocardium. This is the first study to show successful expression of a reporter gene *in vivo* using this new technique.

2:30 p.m.

### 850-3 A Bilayer Microbubble Designed Specifically for Power Doppler Imaging Provides a Method for Detecting Coronary Stenoses

Flordeliza S. Villanueva, Edward W. Gertz, Greg Pulido, Melissa Black, David Fischer. *University of Pittsburgh, Pittsburgh, PA; POINT Biomedical Corp, San Carlos, CA; University of Pittsburgh, Pittsburgh, PA, USA*

**Background:** The visual detection and quantification of coronary stenoses (STN) with B-mode harmonic myocardial contrast echocardiography can be complicated by tissue noise and requirements for background subtraction. Since power Doppler imaging (PDI) theoretically displays signals deriving uniquely from ultrasound-induced bubble destruction, it may have advantages over B-mode. Because maximal variance ensues when bubble destruction is rapid and complete, we theorized that the ideal bubble for PDI should be robust *in vivo*, yet instantaneously disappear in response to ultrasound energy. Accordingly, the bilayer shell of a microbubble (PB127, POINT Biomedical) has been engineered to disrupt rapidly in an ultrasound field, allowing the nitrogen gas in its core to quickly dissolve in blood. We tested the hypothesis that PB127 used with PDI can detect graded STN.

**Methods:** The left anterior descending (LAD) was instrumented with a variable occluder and flow probe in 6 dogs. PB127 was infused *i.v.* during gated multi-triggered PDI at increasing pulsing intervals, with real time split screen display of pre- and post-contrast images. Two non-flow- and 1 flow-limiting STN were created and PDI and radiolabeled microsphere data were collected with and without *i.v.* adenosine (ADN). LAD and LCX bed videointensity (VI) were measured at a pulsing interval of 6.

**Results:** With non-flow limiting STN at rest, LAD and LCX VI were similar. With STN + ADN, visually obvious perfusion defects appeared that paralleled the wide range of STN (gradients 10 to 60 mmHg): LAD/LCX VI and LAD/LCX transmurular flow were linearly related ( $r = 0.88$ ,  $p < 0.0001$ ). STN severity with ADN was quantifiable (STN gradient vs. LAD/LCX VI,  $r = -0.71$ ,  $p < 0.001$ ), and endo/epi ratios were discernible and quantifiable. Data were no different even when background subtraction was not performed.

**Conclusion:** PB127 used with PDI can quantify a spectrum of coronary STN. Minimization of tissue signal, combined with potent Doppler signals arising from rapid decay of PB127, may facilitate quantification, obviate the need for background subtraction, delineate transmural distribution of flow, and improve the accuracy of qualitative visual assessments of STN.

2:45 p.m.

### 850-4 Prediction of Ultimate Infarct Size Despite Persistent Total Coronary Occlusion: A Study Using Myocardial Contrast Echocardiography

Matthew Coggins, D. Elizabeth Le, Kevin Wei, Jonathan R. Lindner, Sanjiv Kaul. *University of Virginia, Charlottesville, VA, USA*

**Background:** In the presence of acute coronary occlusion, although risk area (RA) can be measured using several imaging techniques, there is no method



that can accurately predict the ultimate infarct size (IS). We hypothesized that by detecting regions with adequate collateral myocardial blood flow, myocardial contrast echocardiography (MCE) could be used to predict the ultimate IS even if the infarct-related artery remained permanently occluded.

**Methods:** Coronary occlusion was performed for 6 hr in 15 dogs. RA was measured with aortic root injections of microbubbles. MCE was performed at pulsing intervals (PI) of 1, 5, 10, and 20 cardiac cycles during an intravenous infusion of microbubbles. MBF was measured with radiolabeled microspheres and post-mortem tissue staining was done to determine IS.

**Results:** MCE-defined perfusion defects varied with the PI. They were the largest at short PIs, where they corresponded well with RA ( $r = 0.89$ ) and were the smallest at longer PIs, where they corresponded well with IS ( $r = 0.87$ ). Because of marked variability in collateral-derived MBF, there was no correlation between RA and IS. MBF was the lowest with necrosis, which could be identified as having both the lowest myocardial blood volume (A) and the lowest microbubble velocity ( $\beta$ ). There was a good relation between radiolabeled microsphere-derived MBF and the product  $A\beta$  ( $r = 0.77$ ). Eighty-eight percent of myocardial segments with normalized  $A\beta$  of  $<0.25$  showed myocardial necrosis.

**Conclusion:** By defining temporal and spatial MBF characteristics, MCE can define both RA and IS despite total persistent coronary occlusion. The prediction of IS is based on detecting collateral-derived residual MBF within the RA. Thus MCE could be used to identify patients with acute infarction who may not need urgent reperfusion.

3:00 p.m.

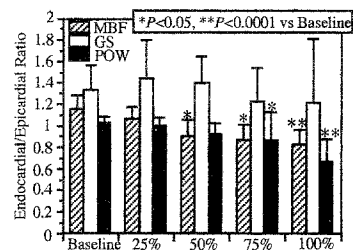
**850-5 Quantitative Assessment of the Transmural Distribution of Myocardial Perfusion by Contrast Echocardiography During Graded Coronary Stenosis**

Hisashi Masugata, Bruno Cotter, Barry Peters, Oi Ling Kwan, G. Monet Strachan, Anthony N. DeMaria. *University of California at San Diego, San Diego, CA, USA*

**Background:** Controversy exists regarding the ability of myocardial contrast echo (MCE) to determine the ratio of endocardial/epicardial (endo/epi) myocardial blood flow (MBF). In this study, we compared the ability of MCE to assess transmural distribution of MBF with conventional gray scale tissue (GS) and power Doppler (POW) imaging.

**Methods:** In 9 open-chest dogs, we created four grades of left anterior descending (LAD) stenoses. All stenoses were flow limiting at rest, and produced a reduction of 25%, 50%, 75%, and 100% of baseline flow (confirmed by a flow probe). MCE was performed with GS and POW at varying ECG gated pulsing intervals (PI) ranging from 1:1 to 1:10 cardiac cycles during intravenous Optison infusion (0.2 cc/min). The LAD perfusion bed was identified as unopacified region during LAD occlusion, was bisected into endo and epicardial halves, and was examined for background subtracted videointensity (VI) (256 gray levels). MBF was measured using fluorescent microspheres.

**Results:** The endo/epi MBF ratio correlated significantly with VI ratio by POW at all PI ( $r = 0.50$  or greater,  $p < 0.005$ ), but did not correlate as well with VI ratio by GS at any PI ( $r = 0.26$  or less,  $p = NS$ ). Correlation of MBF and POW was closest at PI of 1:4 ( $r = 0.57$ ) (shown in Figure), and the endo/epi VI ratio was significantly less than baseline with 75 and 100% lesion by POW at all PI, but not by GS.



**Conclusion:** These data demonstrate that the transmural distribution of MBF is altered by flow limiting stenosis, and that the endo/epi VI ratio by POW correlates with measurements by microspheres. POW yields endo/epi VI ratios which are significantly reduced from baseline with stenoses which reduce resting flow 75 and 100%.

3:15 p.m.

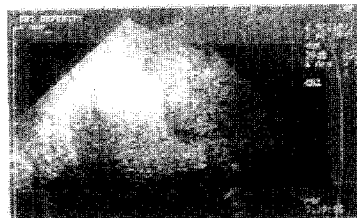
**850-6 Receiving Frequencies Lower Rather Than Higher Than the Transmittal Frequencies Could Yield Improved Results for Contrast Imaging: An In Vivo Study in Closed Chest Dogs**

Rosemary A. Rusk, Yoshiki Mori, Xiaokui Li, Petra S. Mehwald, Suthep Wanitkun, Zuhua Mao, Peng Jiang, Anita Chambers, David J. Sahn. *Oregon Health Sciences University, Portland OR; Siemens Ultrasound, Issaquah, WA, USA*

**Background:** Ultrasonic imaging methods of receiving at higher frequencies which are multiples of the transmitting frequencies, are well established as a means of improving myocardial perfusion visualization in association with intravenous contrast administration. This study examined the effect of using receive frequencies which are lower than transmit frequency ( $RX < TX$ ), while imaging closed chest dogs using an Ensemble™ wideband phase inversion contrast program on a modified Siemens Elegra™ scanner.

**Methods:** Intravenous bolus injections of 0.75 ml Definity® (DuPont Pharmaceuticals) and 1 ml Qw 7437 (Sonos Pharmaceuticals) were administered to six 38–55 kg anaesthetized dogs. Intermittent contrast imaging was performed using a 2.5 MHz transducer sending at 1.6–1.8 MHz and receiving at frequencies  $> 2.6$  MHz, and also with a 6.5 Mhz transducer, receiving at  $<4.5$  MHz. Contrast enhancement was measured by videodensitometry, sampling mid cavity and within the myocardium before and after injection. The changes in videodensity from control to peak after injection were calculated for each method.

**Results:** Using Definity®, the change in cavity enhancement was greater using  $RX < YX$  (mean, 178 vs 148 videodensity units [VDU]). Using QW7437, there was no appreciable difference in the cavity density achieved; but for both agents the change in myocardial density was greater using  $RX < TX$  than  $RX > TX$  (78 vs 37 VDU for QW7437 and 85 vs 73 VDU for Definity®). Cavity opacification was present for at least 3 minutes using both imaging modalities. However, the "myocardial" blush seemed to remain longer when receiving at  $RX < TX$  (mean for both agents 144 seconds compared with 100 seconds for  $RX > TX$ ).



**Conclusion:** Delivering sound energy at a slightly higher frequency and receiving at lower than the transmit frequency may be an advantageous method of enhancing myocardial perfusion signals during intravenous contrast echo.

NONINVASIVE IMAGING

## MODERATED POSTER SESSION

1006

**Myocardial Ischemia and Viability: Clinical Studies**Monday, March 13, 2000, 3:00 p.m.–5:00 p.m.  
Anaheim Convention Center, Hall A

3:00 p.m.

1006-167

**Regional Left Ventricular Response to Low-Dose Dobutamine Infusion During ECG-Gated Tc-99m Sestamibi SPECT Image Acquisition Accurately Predicts Global Left Ventricular Function After Revascularization in Patients With Coronary Artery Disease and Left Ventricular Dysfunction**Brett H. Duncan, Alan W. Ahlberg, Domenic Marini, Carol C. McGill, Michael P. White, Jeffrey F. Mather, David D. Waters, Gary V. Heller. *Hartford Hospital, Hartford, CT, USA***Background:** Electrocardiographic (ECG)-gated SPECT imaging allows assessment of left ventricular (LV) function. This study evaluated the ability of low-dose dobutamine (LDD) infusion during ECG-gated SPECT image acquisition to predict global LV function after revascularization in patients with coronary artery disease (CAD) and LV dysfunction.**Methods:** Sixteen patients with CAD and LV ejection fraction (EF)  $\leq$  45% scheduled for revascularization underwent ECG-gated Tc-99m sestamibi SPECT imaging at rest and during LDD infusion (5–7.5 mcg/kg/min) before revascularization, as well as at rest 1 and/or 6 weeks after revascularization. Blinded images were interpreted by a consensus of 3 experienced readers for wall motion (WM) using a 17-segment model and 6-point scoring system (0 = normal to 5 = dyskinetic). Severely dysfunctional territories (summed WM score  $\geq$  14 for left anterior descending and  $\geq$  10 for both left circumflex and right coronary artery territories) were examined for improvement with LDD. Patients were classified as responders (n = 9) if they had at least one territory that improved by  $\geq$  30% with LDD and non-responders (n = 7) if all territories improved by  $<$  30% with LDD.**Results:** There were no significant differences in baseline LVEF between responders and non-responders. Responders had a significant improvement in LVEF with LDD as well as after revascularization while non-responders had no improvement. Furthermore, there was a significant correlation between the LVEF with LDD and the resting LVEF after revascularization in all patients (r = 0.896, p < 0.001).

	Baseline LVEF (%)	LDD LVEF (%)	Post-Revasc LVEF (%)
Responders	33 $\pm$ 8	*42 $\pm$ 9	*46 $\pm$ 13
Non-responders	27 $\pm$ 11	29 $\pm$ 10	31 $\pm$ 15

\* p &lt; 0.001 versus Baseline LVEF

**Conclusion:** In patients with CAD and LV dysfunction, the regional response to LDD infusion during ECG-gated Tc-99m sestamibi SPECT image acquisition accurately predicts global LV function after revascularization.

3:12 p.m.

1006-168

**Correlation of OPTISON<sup>®</sup> Myocardial Contrast Echocardiography (MCE) and Single Photon Emission Computed Tomography (SPECT) Sestamibi to Coronary Anatomy in Patients With Recent MI**Mani Nannan, Sharon Mulvagh, Vera Rigolin, Peter Hagan, Arthur Labovitz, Ramon Castello, Flordeliza Villanueva, Denise Bruns, Lisa Leonetti, Jeff Miller. *University of Michigan Health System; Mayo Clinic, Rochester; Northwestern University Hospital; Molecular Biosystems, Inc., San Diego, CA, USA***Objective:** Agreement between OPTISON MCE and SPECT for detection of infarction and ischemia was determined in patients with recent ( $\leq$  15 d) MI. The agreement between each of these modalities and coronary anatomy by Coronary Angiography (CA) was also studied.**Methods:** Patients (37) were enrolled in a Phase 2 multi-center controlled and randomized trial. All patients underwent Dipyridamole OPTISON MCE (Power Doppler, Pulse Inversion, or Second Harmonic) and SPECT imaging studies. OPTISON (3.0 mL) was infused (20–30 mL/hr) continuously with NaCl at rest and again during Dipyridamole stress for MCE imaging. Images were semi-quantitatively graded for perfusion (normal/reduced/absent) with 1, 3, and 5 cardiac cycle intermittent imaging and wall motion with continuous imaging. For MCE, if either perfusion or wall motion was abnormal in the Left Anterior Descending (LAD), Left Circumflex (LCx), or Right Coronary (RCA) territory, the composite score was abnormal. MCE and SPECT gradeswere determined by consensus review (2/3). A subgroup of 29 patients also underwent CA prior to the stress procedure; stenoses  $\geq$  70% were considered abnormal.**Results:** Normal coronary anatomy was found in 71% of the patients, due in a large part to coronary interventions. MCE agreement with SPECT was highest in the LAD and LCx territories and lowest in the RCA territory. MCE agreement with CA was higher in all three territories than SPECT agreement with CA. Overall agreement (by patient) between MCE and CA was 61%, MCE and SPECT was 31%, and SPECT and CA was 33%.

	Agreement (%)				N
	LAD	LCx	RCA	Overall	
MCE vs. SPECT	66	66	34	31	35
MCE vs. CA ( $\geq$ 70% = abn)	70	76	79	61	26
SPECT vs. CA ( $\geq$ 70% = abn)	38	62	36	33	26

**Conclusion:** In patients with recent MI, OPTISON MCE perfusion imaging accurately characterizes coronary anatomy. MCE may be more specific than SPECT for the assessment of myocardial microvascular perfusion in MI patients undergoing coronary intervention.

3:24 p.m.

1006-169

**Improved Detection of Microvascular Integrity by Delayed Compared to Early Intermittent Myocardial Contrast Echocardiography Early After Acute Myocardial Infarction**Jonathan Swinburn, Avijit Lahiri, Roxy Senior. *Northwick Park Hospital, Harrow, UK***Background:** Microvascular integrity (MI) in the dysynergic segments has been shown to be a prerequisite for the presence of contractile reserve (CR) and hence myocardial viability following acute myocardial infarction (AMI). Myocardial contrast echocardiography (MCE) accurately assesses MI. However, the presence of severe flow limiting infarct related artery may preclude adequate replenishment of contrast in the myocardium during 1:1 cardiac cycle intermittent MCE and hence may underestimate CR. We have hypothesized that delayed (1:5 or 1:10 cardiac cycle) MCE may enhance detection of contrast in the dysynergic segments by increasing the transit time.**Methods:** Accordingly 47 consecutive patients underwent rest MCE followed by low dose Dobutamine echocardiography (LDDE) early after AMI. Early 1:10 and delayed (1:5 and 1:10) intermittent pulse inversion MCE was performed during intravenous injection of slow bolus of Optison in the apical views. MI was considered to be present when contrast was seen homogeneously in the dysynergic segments while CR was defined as contractile improvement of the dysynergic segments using a 16 segment LV model.**Results:** Delayed MCE showed significantly more number of segments with MI compared to early MCE (47% vs 23% p < 0.01). CR was present in only 24% of segments showing absence of microvascular integrity during delayed MCE compared to 36% (p < 0.01) with early MCE. Agreement between CR and MI during delayed MCE (kappa = 0.40) was significantly (p < 0.01) higher than during early MCE (kappa = 0.17).**Conclusion:** Delayed MCE results in enhanced detection of microvascular integrity compared to early MCE in patients early after AMI.

3:36 p.m.

1006-170

**Prediction of Myocardial Viability in Patients With Acute Myocardial Infarction From Coronary Flow Velocity Patterns With Trans-Thoracic Doppler: Retrospective and Prospective Studies**Yasunori Shintani, Hiroshi Ito, Katsuomi Iwakura, Ken Sugimoto, Kouichi Yamamoto, Kazuo Terai, Yorihiro Higashino, Kenshi Fujii. *Sakurabashi Watanabe Hospital, Osaka, Japan***Backgrounds:** Using Doppler guidewire in AMI, we reported that substantial no reflow phenomenon alters the coronary flow velocity pattern, that is characterized by the systolic reverse flow and the rapid deceleration of diastolic flow velocity. In this study, we examined whether we can noninvasively predict the functional outcomes from coronary flow velocity pattern of the left anterior descending artery (LAD) recorded with trans-thoracic Doppler (TTD) technique in patients with anterior AMI.**Methods and Results:** The study population was consisted of 40 patients with reperfused anterior AMI. We recorded LAD flow velocity at day-2 of reperfusion with SONOS 5500. We measured deceleration half time of diastolic flow velocity (DHT, msec) as the interval between peak diastolic velocity and 1/2 of peak velocity. We recorded 2-D echo at day-1 and 21 to calculate wall motion score index (WMSI, average of segmental scores (normal = 0 to dys/akinesis = 3) of the infarct segments). In the retrospective study, DHT was

compared between those with poor ( $\Delta$  WMSI (1 d–21 d)  $< 1.0$ ,  $n = 8$ ) and good (others,  $n = 14$ ) functional outcomes. DHT was much shorter in those with poor outcomes than in those with better outcomes ( $130 \pm 77$  msec vs.  $390 \pm 110$  msec,  $p < 0.05$ ). ROC analysis documented that 300 msec for DT is the suitable cut-off point to predict good functional outcomes (sensitivity = 88%, specificity = 100%). Then, we prospectively studied consecutive 18 patients. DHT at day-2 was significantly correlated with  $\Delta$  WMSI (1 d–21 d) ( $r = 0.72$ ,  $p < 0.001$ ). The improvement of wall motion was worse in patients with DHT 300 msec ( $n = 11$ ) than in others (DHT  $\geq 300$  msec,  $n = 7$ ) ( $\Delta$  WMSI (1 d–21 d)  $0.3 \pm 0.2$  vs.  $1.5 \pm 0.3$ ,  $p < 0.001$ ).

**Conclusion:** The patients with the shorter DHT of diastolic flow in the infarct-related artery are associated with poorer functional outcomes in AMI. To measure DHT of LAD flow with TTD provides a noninvasive and useful estimate of myocardial viability in the patients with anterior AMI.

3:48 p.m.

**1006-171 Value of Resting Wall Motion Abnormalities in 2-Dimensional Echocardiography for the Prediction of an Ischemic Response During Stress in Patients Without Previous Myocardial Infarction**

Abdou Elhendy, Ron T. van Domburg, Jeroen Bax, Marcel L. Geleijnse, Jaroslav D. Kasprzak, Youssef F.M. Nosir, Don Poldermans, Peter R. Nierop, Jos R.T.C. Roelandt. *Thoraxcenter, Rotterdam, The Netherlands*

**Background:** Resting wall motion abnormalities (WMA) may be encountered in patients (pts) without known coronary artery disease (CAD) referred for stress echocardiography. However, the significance of resting WMA has not been evaluated by an independent technique. The aim of this study is to assess the value of resting WMA in the prediction of an ischemic response during dobutamine stress test.

**Methods:** We studied 116 pts (mean age  $57 \pm 13$  years, 50 men) without known CAD or previous infarction by dobutamine (up to  $40 \mu\text{g/kg/min}$ ) – atropine (up to 1 mg) stress echocardiography and simultaneous stress and rest sestamibi SPECT. Ischemia was defined as new or worsening WMA and reversible perfusion defects respectively.

**Results:** Resting WMA were detected in 24 pts (21%). Pts with resting WMA had a higher prevalence of abnormal perfusion (75% vs 25%,  $p < 0.001$ ) and a higher prevalence of ischemia by SPECT (50% vs 24%,  $p < 0.05$ ) and by echocardiography (42% vs 9%,  $p < 0.001$ ) compared to pts without resting WMA. Stress myocardial perfusion defect score was higher in pts with than those without rest WMA ( $3.25 \pm 2.67$  vs  $0.88 \pm 1.77$ ,  $p < 0.0001$ ). Independent predictors of the occurrence of ischemia by echocardiography were the presence of resting WMA ( $p < 0.01$ ,  $\text{Chi}^2 = 6.7$ ), ST segment depression ( $p < 0.005$ ,  $\text{Chi}^2 = 11.3$ ) and angina during the test ( $p < 0.05$ ,  $\text{Chi}^2 = 5.3$ ). The presence of resting WMA was the only predictor of abnormal perfusion ( $p < 0.0001$ ,  $\text{Chi}^2 = 20$ ).

**Conclusions:** 1) The presence of resting WMA in pts without known CAD referred for pharmacologic stress testing is highly predictive of abnormal myocardial perfusion. 2) Resting WMA are powerful predictors of an ischemic response during dobutamine stress test.

4:00 p.m.

**1006-172 Dipyridamole-Echocardiography Versus Thallium-Exercise Scintigraphy for the Diagnosis of Coronary Artery Disease in Hypertensives With Positive Exercise-Electrocardiography Test**

Costantino Astarita, Emanuele Nicolai, Erminio Liguori, Salvatore Gambardella, Salvatore Rumolo, Francesco S. Maresca, Albert Varga, Eugenio Picano. *Regional Hospital of Sorrento and Institute of Clinical Physiology, Pisa, Italy*

**Background:** A positive exercise-electrocardiography test has a low diagnostic specificity in hypertensive patients, and warrants a confirmatory imaging test to include the diagnosis of coronary artery disease (CAD).

**Aim:** To compare, head to head, the diagnostic value of dipyridamole-atropine echocardiography test (DET) vs Thallium-exercise scintigraphy test (TET) in hypertensive patients with positive exercise-electrocardiography test (EET).

**Methods:** Forty-two consecutive hypertensive patients (22 males, mean age  $59 \pm 10$  years) with positive EET ( $>0.15$  mV of ST segment depression), no previous myocardial infarction and no previous revascularization underwent – on different days and in random order – DET and SPECT-TET. All patients underwent coronary angiography afterwards and independently of imaging test results.

**Results:** At angiography 25 patients had no CAD, and 17 had significant ( $\geq 50\%$  diameter reduction) CAD, with 1, 2, and 3 vessel/left main disease in

5,3 and 9 patients, respectively. Sensitivity was similar (DET = 88% vs TET = 100%,  $p = \text{ns}$ ). Specificity was higher for echo (DET = 100% vs TET = 48%,  $p < 0.01$ ). Diagnostic accuracy was also higher for echo (DET = 95% vs TET = 69%,  $p < 0.01$ ).

**Conclusions:** In hypertensive patients with exercise-induced ST segment depression, TET shows a higher sensitivity than DET, but DET has a better accuracy due to a substantially higher specificity.

4:12 p.m.

**1006-173 Nitrate-Enhanced Tc-99m Sestamibi SPECT is Comparable to TI-201 for Detection of Myocardial Viability and for Predicting Outcome in Patients With Heart Failure**

Roxy Senior, Sanjiv Kaul, Avijit Lahiri. *Northwick Park Hospital, Harrow, UK; University of Virginia Health Sciences, USA*

**Background:** Nitrate enhanced MIBI SPECT was shown to be comparable to thallium-201 imaging for the detection of viable myocardium in pts with ischaemic cardiomyopathy. However, the relative value of these techniques to predict outcome after revascularisation in this group of patients is unknown.

**Methods:** Accordingly, 49 pts with symptomatic (NYHA II–IV) heart failure (LVEF =  $25 \pm 8\%$ ) demonstrating retained myocardial contractile reserve indicating viability by low dose dobutamine echocardiography underwent nitrate enhanced MIBI and TI-201 SPECT on separate days. Myocardial viability (MV) by both MIBI and TI-201 were defined as  $<$ grade 3 tracer uptake (grade 0 = normal, grade 1 and 2 = mild to moderately reduced uptake, grade 3 = severe reduction) in at least 5 myocardial segments (12 segment LV model). Mean tracer uptake was also calculated in severely dysynergic segments. Twenty-three patients underwent revascularisation at  $12 \pm 4$  weeks after imaging. All pts were followed-up for  $40 \pm 18$  months for cardiac mortality.

**Results:** Of the 49 pts, MIBI and TI-201 detected MV in 48 and 43 pts respectively.

	Mortality		
	Revascularisation	Medical Therapy	p value
MIBI (n = 48)	2/23 (9%)	7/25 (28%)	$<0.01$
TI-201 (n = 43)	2/20 (10%)	7/23 (30%)	$<0.01$

$p = \text{NS}$  (mortality between TI-201 and MIBI Group)

Baseline pt characteristics (age, gender, previous MI, number of pts with angina, NYHA class, number of CAD vessels, jeopardy score, LVEF and number of viable segments) were similar between MIBI and TI-201 and between the revascularisation and medical therapy groups. Mean tracer-uptake by both imaging modalities in the severely dysynergic segments were also similar in these groups ( $p = \text{NS}$ ).

**Conclusion:** Thus, both nitrate enhanced MIBI and TI-201 SPECT similarly predicted improved survival when revascularisation was performed compared to medical therapy in patients with ischaemic cardiomyopathy and myocardial viability.

4:24 p.m.

**1006-174 Exercise Thallium Testing Predicts Significant Coronary Disease on Angiography in Asymptomatic Siblings of Persons With Premature Heart Disease**

Roger S. Blumenthal, John A. Bellan, Diane M. Becker, Raphael M. Yook, Taryn F. Moy, Thomas A. Aversano, Vicki J. Coombs, Lewis C. Becker. *Johns Hopkins Medical Institutions, Baltimore, Maryland, USA*

**Background:** Siblings (SIBS) of persons with premature coronary artery disease (CAD) have a marked excess risk of coronary events. This study was done to determine if functional stress testing could identify high risk asymptomatic persons with hemodynamically significant CAD (sigCAD) ( $\geq 50\%$  left main and/or  $\geq 70\%$  major epicardial artery diameter stenosis).

**Methods:** We performed exercise thallium tomography and coronary angiography in 114 asymptomatic apparently healthy siblings of persons with documented CAD  $< 60$  years of age (91 males, 23 females).

**Results:** SIBS were classified on the basis of their exercise test (ETT) and thallium scan (Table).

	-ETT/-Thallium (n = 18)	+ETT Only (n = 20)	+Thallium Only (n = 51)	+ETT/+Thallium (n = 25)
sigCAD (%)	0	10	10	48

A positive ETT and positive thallium scan together (double positive) occurred in 12/19 SIBS with sigCAD. No SIBS with a normal ETT and thallium

scan (double negative) had sigCAD. A multiple logistic regression analysis indicated that SIBS with a double positive were 14 times more likely (95% CI = 3.8–50.7) to have sigCAD, independent of age, race, gender, LDL, smoking, obesity, and hypertension, none of which were significant.

**Conclusion:** Convergence of an abnormal exercise test and thallium heart scan is strongly and independently associated with hemodynamically significant CAD in an asymptomatic high risk population. Stress thallium testing may be useful in the risk stratification of asymptomatic adults with a family history of premature CAD and may serve as a stimulus for more aggressive prevention regimens.

4:36 p.m.

**1006-175 Value of Combined Myocardial Perfusion and Functional Analysis in Magnetic Resonance Imaging for the Detection of Regional Myocardial Ischemia**

Tareq Ibrahim<sup>1</sup>, Stephan Nekolla<sup>1</sup>, Carmen Weniger<sup>1</sup>, Karin Schreiber<sup>1</sup>, Stefan Volz<sup>2</sup>, Martin Güthlin<sup>2</sup>, Wolfram Delius<sup>2</sup>, Markus Schwaiger<sup>1</sup>.

<sup>1</sup>Nuklearmedizinische Klinik der TU München; <sup>2</sup>Krankenhaus München Bogenhausen, Germany

**Background:** MRI provides morphological and functional assessment of the left ventricle (LV). The purpose of this study was to investigate the feasibility of a combined MRI myocardial perfusion and wall motion analysis during the same adenosine stress and to determine the diagnostic value in comparison to coronary angiography.

**Methods:** We examined 16 patients (Pts) with angiographically proven coronary artery disease (Philips 1.5T). All Pts underwent both a 3 short axis slice ECG-gated cine-gradient echo sequence (12 phases) as well as a corresponding dynamic contrast enhanced fast gradient echo sequence (Gd-DTPA bolus 0.05 mmol/kg). Both techniques were performed successively at rest and during the same adenosine induced stress (140 µg/kg/min) of 6 min. duration. Maximal upslope ratio (USR) was calculated from MRI-time intensity curves by dividing stress/rest. LV-ejection fraction (EF) and quantitative regional wall motion was calculated from cine-MRI. All parameters were analyzed in 3 vascular territories and compared to a normal database consisted of 17 healthy volunteers (VOL) and to angiographic findings.

**Results:** In Pts and VOL, EF did not significantly change under stress condition. Coronary artery stenoses ≥ 75% were detected with sensitivity and specificity of 64% and 82%, respectively, by MRI wall motion analysis and with 77% and 94%, respectively, by MRI perfusion analysis. Combination of both MRI techniques increased sensitivity to 93% while specificity decreased to 79%.

**Conclusion:** MRI allows near simultaneous assessment of myocardial perfusion and function at rest and during stress which can increase the diagnostic accuracy.

4:48 p.m.

**1006-176 Determination of Coronary Calcium With Helical-, Multidetector Helical- and Electron Beam Computed Tomography: A Comparative Study**

Andreas Knez, Christoph Becker<sup>1</sup>, Alexander Becker, Alexander Leber, Anja Maass, Roland Bruening<sup>1</sup>, Maximilian Reiser<sup>1</sup>, Ralph Haberl. *Medical Hospital I, <sup>1</sup>Department of Radiology, Univ. of Munich, Munich, Germany*

**Background:** Electron beam computed tomography (EBCT) is the gold standard in the assessment of coronary calcium. The aim of this study was to determine the diagnostic accuracy of Helical- and Multidetector helical computed tomography (HCT, MDCT) in the quantification of coronary calcium.

**Methods:** In 110 male patients, age 54 ± 3 y, EBCT- (Imatron C150XP) and HCT studies (Somatom Plus 4, Siemens) were acquired within one hour (group A). In 54 male patients, age 60 ± 10 y, EBCT- and MDCT studies (Somatom Plus4VZ, Siemens) also were acquired within one hour (group B). In group A the Agatston score (AS) and the volumetric calcium score (VCS) were calculated using an external workstation (Neomagery, Insight, USA). In group B the Agatston score was not applied due to different slice thicknesses (3 mm versus 2.5 mm) and therefore the volumetric score was determined.

**Results:** In group A (calcium score range 0–5300) Pearson's correlation coefficient was calculated as 0.97 (p = 0.01) for the Agatston score and 0.97 (p = 0.01) for the VCS. Mean difference for the Agatston score was 136 ± 248 (n.s.) and 113 ± 179 (n.s.) for VCS. Using an ECG-triggered sequence mode for HCT even in the low range score < 100 (n = 45) the Agatston score (p = 0.06) and VCS (p = 0.11) were not significantly different. In group B (calcium score range 0–5000) for VCS Pearson's correlation coefficient was calculated as 0.99. p = 0.01. Mean difference was 97 ± 115 and statistically not significant. The mean difference in the low score range (n = 26) was also statistically not significant (p = 0.12).

**Conclusions:** Coronary calcium can be determined, using the Agatston and/or volumetric score method, with Helical- and Multidetector Helical computed tomography with high accuracy in comparison to Electron beam CT. Therefore both imaging modalities can be applied in the assessment of coronary calcium, even in the low range scores.

## POSTER

**1121 Novel Approaches to Ultrasonic Imaging**

Monday, March 13, 2000, 3:00 p.m.–5:00 p.m.

Anaheim Convention Center, Hall A

Presentation Hour: 3:00 p.m.–4:00 p.m.

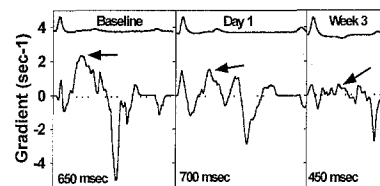
**1121-1 Detection of Progressive Alterations in Regional Myocardial Function by Tissue Doppler Velocity Gradient in a Rapid Pacing Model of Heart Failure**

John Gorcsan III, Arthur M. Feldman, Wang Hao, Donald Severyn, Geoffrey E. Moore. *University of Pittsburgh, Pittsburgh, PA, USA*

**Background:** Although assessing the progression of LV dysfunction in heart failure (CHF) is important, noninvasive quantification of regional LV function is difficult.

**Methods:** To test the hypothesis that tissue Doppler myocardial velocity gradient (MVG) can quantify temporal alterations in regional LV function in CHF, a rapid pacing canine model was used. Five dogs were studied at baseline and after 1 day, 1 week and 3 weeks of pacing at 250 min<sup>-1</sup>. Transthoracic color-coded tissue Doppler images (Toshiba 7000) were digitally analyzed for posterior wall MVG using a customized computer.

**Results:** Significant decreases in peak systolic MVG were detected after only 1 day of rapid pacing from 3.6 ± 0.8 to 1.9 ± 0.5\* sec<sup>-1</sup>, \*p < 0.001 vs. baseline. Further progression of LV dysfunction was detected after 3 weeks with peak systolic SVG declining to 1.3 ± 0.3\*\* sec<sup>-1</sup>, \*\*p < 0.001 vs. 1 day and baseline. The clinical onset of CHF, manifest as dyspnea, fatigue and ascites, did not begin until after 3–4 weeks of rapid pacing.



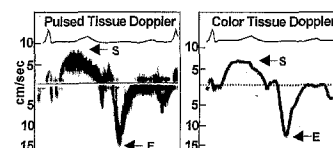
**Conclusions:** Tissue Doppler MVG quantified progressive alterations in regional LV function in this model of CHF. Detection of regional LV dysfunction was immediate and preceded the onset of clinical CHF in these animals. MVG appears to be promising to monitor changes in regional LV dysfunction in human CHF.

**1121-2 Comparison of Spectral Tissue Doppler With Color Tissue Doppler to Quantitatively Assess Left Ventricular Function**

Hao Wang, William A. Mandarino, John Gorcsan III. *University of Pittsburgh, Pittsburgh, PA, USA*

**Background:** Spectral pulsed tissue Doppler (P-TD) and color tissue Doppler (C-TD) are alternative evolving approaches to quantify LV function. However, P-TD and C-TD differ in signal processing and velocity display.

**Methods:** To evaluate the clinical impact of these differences on quantitative velocity values, 43 subjects, aged 48 ± 13 yrs (25 with cardiac disease; 18 normal controls) had both P-TD and C-TD studies of the mitral annulus (apical views) and posterior wall (parasternal view) (Toshiba 7000). A customized computer digitally analyzed C-TD data. Peak systolic (S) and early diastolic (E) values were assessed (examples shown). Mean values for S and E by P-TD were calculated as (maximum – minimum)/2 + minimum.



**Results:** Both peak and mean P-TD values correlated significantly with C-TD (r = 0.89 and r = 0.90 respectively). However, peak P-TD values were higher than C-TD: 10.4 ± 5.0\* vs. 5.7 ± 2.3 cm/sec for the mitral annulus

and  $10.6 \pm 4.8^*$  vs.  $5.3 \pm 2.8$  cm/sec for the posterior wall ( $*p < 0.001$  vs. C-TD). Bland-Altman analysis revealed a bias of +5.2 cm/sec for peak P-TD measures. Comparing mean P-TD values with C-TD eliminated bias.

**Conclusions:** Myocardial velocity by P-TD and C-TD are closely correlated. However, peak spectral P-TD values are significantly higher than C-TD with mean P-TD values more closely in agreement. These differences are important for clinical applications of tissue Doppler to assess LV function.

#### 1121-3 Automatic Border Detection: A New Ultrasonic Approach for the Evaluation of Left Ventricular Performance of the Athlete's Heart. Comparison With the Hypertensive Cardiopathy

Vitantonio Di Bello, Alessio Bertini, Davide Giorgi, Enrica Talini, Giosu  Valentini, Marco Pallini, Sergio Precisi, Maria T. Caputo, Costantino Giusti, Roberto Pedrinelli, Giulia Dell'Orto. *Department of Internal Medicine, University of Pisa; Department of Cardiology, University of Pisa, Italy*

**Background:** Automatic Border Detection (ABD) allows the real-time measurements of the areas of the cardiac chambers during the cycle, differentiating ultrasonic backscatter characteristics of the blood by those of the myocardium, in a R.O.I. placed by the operator. Some studies with equilibrium radioisotopic ventriculography have showed that in the hypertensive cardiopathy are present abnormalities of diastolic filling: both the Peak Filling Rate (PFR) and the Time to Peak Filling Rate (TPFR).

**Methods:** We have studied three groups of 10 subjects, all males of mean age ( $31.6 \pm 3.5$ ), with comparable weight and height: athlete's group (A) (all cyclist of a good competition level); hypertensive group (I) and control group (C). Hypertensives are selected on the basis of ambulatory blood pressure monitoring results, according to ISH-WHO guidelines. All subjects have performed 2D-color Doppler echocardiography with a digital echograph HP Sonos 5500, for the conventional analysis of left ventricular mass and function. With ABD we have analyzed in real-time both end-diastolic (EDV) and end-systolic volumes (ESV) and the relative ejection fraction (EF); we have obtained, by the study of  $dV/dt$  of the volumetric curve, the following parameters: Peak Filling Rate (PFR), Time to Peak Filling Rate (TPFR) and the Peak Ejection Rate (PER).

**Results:** Left ventricular mass is comparable between the A and I groups and significantly higher in comparison with group C (LVMBs: A:  $154.5 \pm 18.7$ ; I:  $146.8 \pm 25.5$ ; C:  $101.4 \pm 12.4$ ;  $p < 0.001$ ). Athlete's heart and hypertensive cardiopathy are different for the following parameters: EDV is significantly higher in athletes ( $140.5 \pm 20.4$  ml) in comparison with hypertensives ( $116.1 \pm 17.3$  ml) and controls ( $102.0 \pm 15.5$  ml) ( $p < 0.01$ ). PFR is significantly lower in hypertensives ( $3.07 \pm 0.28$ ) in comparison with athletes ( $3.92 \pm 0.29$ ) and controls ( $3.83 \pm 0.33$ ) ( $p < 0.03$ ). TPFR is significantly higher in hypertensives ( $146.1 \pm 14.6$ ) in comparison with athletes ( $109.7 \pm 16.7$ ) and controls ( $103.2 \pm 16.7$ ) ( $p < 0.05$ ).

**Conclusion:** ABD allows the differentiation between the two models of left ventricular hypertrophy; the athlete's heart doesn't show any difference with control group, while hypertensive cardiopathy shows early abnormalities of the left ventricular diastolic filling.

#### 1121-4 Assessment of Dynamic LV Eccentricity Using Signal-Averaged High Frame Rate Acoustic Quantification

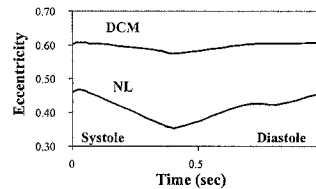
Kirk T. Spencer, Lynn Weinert, Victor Mor-Avi, David Prater, Roberto M. Lang. *University of Chicago, Chicago IL; Hewlett Packard, Andover, MA, USA*

**Background:** The cardiac cycle is associated with dynamic changes in LV shape, which can be characterized by the eccentricity, defined as the ratio of the short axis diameter to long axis length. Eccentricity of 1 represents a circular chamber, while elongated ventricles are represented by low eccentricities. Noninvasive measurement of eccentricity involves tedious hand tracing of ventricular dimensions and is therefore usually only measured at end-systole and end-diastole. Acoustic quantification (AQ) allows continuous identification of endocardial borders, which could then be used to calculate eccentricity throughout the cardiac cycle. Our aim was to test the feasibility of calculating eccentricity dynamically throughout the cardiac cycle using AQ.

**Methods:** Eight normal subjects (NL, EF  $50 \pm 12\%$ ) and in 8 subjects with dilated cardiomyopathy (DCM, EF  $21 \pm 6\%$ ) were studied. Signal-averaged LV area and volume waveforms were acquired simultaneously using prototype AQ software (HP 5500) in the apical four-chamber view. These waveforms were used to generate continuous LV eccentricity time-curves.

**Results:** The ventricles were more spherical in DCM patients at end-diastole ( $0.60 \pm 0.04$  vs  $0.46 \pm 0.08$ ) and end-systole ( $0.58 \pm 0.06$  vs  $0.37 \pm 0.09$ ) as well as throughout the cardiac cycle (figure). In the normal subjects, there was a 23% reduction in eccentricity during ejection (LV becomes

more elliptical), with 65% of this decrease restored during rapid filling. In DCM patients, the changes in eccentricity throughout the cardiac cycle were minimal.



**Conclusions:** AQ allows assessment of continuous LV eccentricity throughout the cardiac cycle. Normal subjects and DCM patients have different patterns of dynamic eccentricity.

#### 1121-5 Image Digitization and File Compression Using the Motion Picture Expert's Group (MPEG) Algorithm Does Not Affect Quantitative Echo Measurements in a Pediatric Population

Brian G. Sinclair, Jane M. Loughheed. *Children's Hospital of Eastern Ontario, University of Ottawa, Ottawa, Ontario, Canada*

**Background:** Digital archiving of echocardiographic images is prohibitive due to large memory requirements. Digital compression algorithms have been shown to have variable effects upon image quality. The MPEG algorithm is a specific video syntax, designed to digitize and compress video signal in real time using a dynamic multiple image frame comparison process. The degree of data compression varies: 150–200:1 at a data stream of 1.8 Mbits/s.

**Method:** To assess effects of this process upon quantitative echocardiographic data, 28 children (age 2–11) undergoing cardiac function monitoring for anthracycline toxicity were assessed. During each study, the analog sVHS output of the ultrasound system (Hewlett-Packard 2500) was split. Concurrent with video tape recording, the signal was digitized and compressed using a personal computer with MPEG encoding. Studies were archived on magnetic optical disc. Frames of M-mode, 2D and Doppler were identified. At independent blinded sessions, corresponding frames from each medium were viewed, calibrated and measured using HP2500 software. Measurements required either point differentiation or planimetry.

**Results:** There was no subjective difference in image characteristics. Highly significant correlations between video and digital measurements were found (all  $P < 0.001$ ). Measurements and respective  $r$  values:

LVED: 0.99	AoAnnulus: 0.98	Ao Pk: 0.99	MV E: 0.98
LVES: 0.94	MV Annulus: 0.99	AoVTI: 0.97	MV A: 0.99
SF: 0.94		Ao Mean: 0.95	

**Conclusion:** MPEG digitization and compression does not affect quantitative echo measurements at a data stream rate used in standard applications of this technology. In a clinical setting MPEG based digital archiving will not compromise assessment of cardiac function in children.

#### 1121-6 Effects of MPEG Compression of Echocardiographic Images on Endocardial Visualization and Wall Motion Assessment

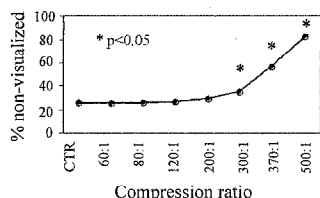
Lawrence Solomon, Kirk T. Spencer, Lynn Weinert, Kathie Dean, Beth Balasia, Thomas Pionke, Lawrence Sieb, Victor Mor-Avi, Roberto M. Lang. *University of Chicago, Chicago, IL, USA*

**Background:** The compression of echocardiographic images is essential for minimizing storage space and maximizing transmission rates of digital studies. The optimal compression ratio of MPEG-1 digital loops that maintains diagnostic accuracy remains unknown. The aim of this study was to determine the threshold level of MPEG-1 compression that impairs the ability to adequately visualize the endocardium and detect regional wall motion abnormalities (RWMA).

**Methods:** Digital loops were acquired in 40 patients in the SAX and A4C views using harmonic imaging (HP 5500), without compression (CTR) and at 7 different MPEG-1 compression ratios (60:1, 80:1, 120:1, 200:1, 300:1, 370:1 and 500:1). Two experienced readers, blinded to compression ratios, reviewed the loops in random order. Each view was divided into 6 segments. All segments (N = 3360) were scored for: (1) endocardial visualization, and (2) presence of RWMA.

**Results:** At the lowest four compression ratios (60:1, 80:1, 120:1 and 200:1), endocardial visualization remained unchanged. At ratios  $> 200:1$ , a progressive increase in the number of non-visualized segments (figure) was

noted. Compared to control, only 5% of the RWMA were not detected at 60:1, whereas at 500:1 compression, 78% of RWMA were missed.



**Conclusion:** MPEG-1 compression of digital echocardiographic loops at ratios up to 200:1 allows adequate endocardial visualization and detection of regional wall motion abnormalities without compromising diagnostic content.

**1121-7 Influence of Respiration on Left Ventricular Diastolic Velocities in Longitudinal Axis as Assessed by Doppler Tissue Imaging in Normal Subjects**

Antonio Pazin-Filho, Minna M. Dias, André Schmidt, Oswaldo C. Almeida-Filho, José A. Marin-Neto, Lourenço Gallo-Júnior, Benedito C. Maciel. *Division of Cardiology, Medical School of Ribeirão Preto, University of São Paulo, Brazil*

**Background:** Diastolic velocities of mitral annulus (MVA) as measured by Doppler tissue imaging (DTI), reflecting lengthening of the myocardial fibers along a longitudinal plane, can provide valuable information for the study of left ventricular (LV) diastolic function. The potential effects of tidal volume (TV) and respiratory rate (RR) on these velocities has not been quantitatively evaluated.

**Methods:** We evaluated 12 normal male volunteers aging 20 to 26 years (mean: 22.8). Using DTI, we measured peak early ( $E_a$ ) and late ( $A_a$ ) velocities of longitudinal axis expansion at lateral and medial MVA, in apical 4 chamber view. Respiratory cycles were simultaneously recorded with a commercially available monitoring system at RR of 9, 12, 15 e 18 cycles/min and TV of 600 e 900 ml during respiration (RESP).

**Results:**

TV/RR	MVA Lateral (LAT)				MVA Medial (MED)			
	$E_a$		$A_a$		$E_a$		$A_a$	
	INS	EXP	INS	EXP	INS	EXP	INS	EXP
600/9	21 ± 4	21 ± 4	10 ± 2	10 ± 2	15 ± 3	14 ± 2*	10 ± 2	12 ± 2*
600/12	21 ± 3	20 ± 3	10 ± 2	10 ± 2	14 ± 2	13 ± 2*	10 ± 2	11 ± 3*
600/15	20 ± 4	20 ± 4	11 ± 4	10 ± 4*	15 ± 2	14 ± 3	10 ± 3	10 ± 2
600/18	21 ± 3	21 ± 3	10 ± 2	10 ± 2	15 ± 2	14 ± 3*	9 ± 2	11 ± 2*
900/9	20 ± 3	18 ± 3	12 ± 3	10 ± 1*	15 ± 2	13 ± 2*	9 ± 2	11 ± 2*
900/12	20 ± 3	18 ± 3	10 ± 2	10 ± 2	16 ± 3	14 ± 2*	9 ± 1	11 ± 2*
900/15	20 ± 4	20 ± 4	10 ± 2	10 ± 2	15 ± 2	14 ± 3*	9 ± 1	11 ± 2*
900/18	19 ± 4	19 ± 4	11 ± 2	10 ± 2*	15 ± 3	14 ± 2	9 ± 1	11 ± 2*

\* ( $p < 0.05$  comparing inspiration-ins vs expiration-exp) (cm/s)

**Conclusions:** 1) Lateral MVA  $E_a$  and  $A_a$  velocities were slightly influenced by RESP; 2) A significant increase of  $E_a$  at medial MVA was documented during INS; 3) A significant decrease of  $A_a$  at medial MVA was observed during INSP; 4) RR and TV did not influence MVA velocities in normal young males, in the conditions of the current protocol; 5) The more consistent effects of RESP in medial as compared to lateral MVA velocities are probably related to a more important influence of RESP on right than on left ventricular filling.

**1121-8 Intracardiac Echocardiography Can Identify Pericardial Effusion/Tamponade and Monitor Pericardiocentesis: Experimental Studies**

Craig Clark, L. Ray Davis, Richard E. Kerber. *University of Iowa, Iowa City, IA, USA*

**Background:** Cardiac perforation with pericardial effusion/tamponade is a major complication in the cardiac catheterization and electrophysiology (EP) laboratories. Emergency transthoracic echocardiography is difficult to perform in the catheterization and EP laboratory because of limited space, the inability to properly position patients, and need to maintain a sterile field. Intracardiac echocardiography (ICE) however can be readily accomplished. Our purpose was to evaluate the ability of ICE to identify pericardial effusion/tamponade and to monitor fluid withdrawal by pericardiocentesis.

**Methods:** In seven anesthetized, ventilated dogs a 9 Fr, 9 MHz ICE catheter was placed in the left ventricle. A pigtail catheter was then inserted into the pericardial space and saline injected in increments to 240 ml. Heart rate and arterial pressure were continuously monitored. The fluid was then

withdrawn. The ability of ICE to identify the presence of pericardial fluid and to monitor accumulation and withdrawal was evaluated.

**Results:** ICE correctly identified the presence or absence of pericardial fluid in all 7 animals. The smallest amount of pericardial fluid that was visualized was 30 ml. The largest epicardial-pericardial separation seen by ICE was 12 mm which was associated with marked LV compression. The maximal arterial pressure fall was 100 mmHg.

**Conclusion:** ICE readily identifies the presence of pericardial fluid and is an excellent tool to monitor pericardiocentesis. ICE can be readily accomplished in the catheterization and EP laboratory where patients already have vascular access; ICE should be a valuable adjunct in diagnosing pericardial effusion/tamponade and monitoring pericardiocentesis.

POSTER

**1122 Transesophageal Echo: New Clinical Insights**

Monday, March 13, 2000, 3:00 p.m.–5:00 p.m.  
Anaheim Convention Center, Hall A  
Presentation Hour: 3:00 p.m.–4:00 p.m.

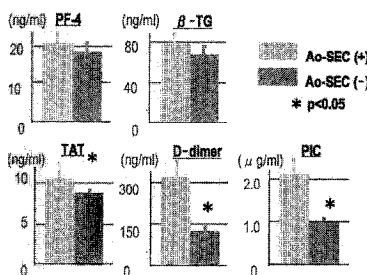
**1122-25 Clinical Importance of Aortic Spontaneous Echocardiographic Contrast as a Marker for Abnormalities of Hypercoagulability in Patients With Atrial Fibrillation**

Keiko Nakagawa, Tadakazu Hirai, Yoshiko Uchiyama, Tomoki Kameyama, Noriko Shinokawa, Syutarō Takashima, Takashi Nozawa, Hidetsugu Asanoi, Hiroshi Inoue. *Toyama Medical and Pharmaceutical University, Toyama, Japan*

**Background:** Transesophageal echocardiography (TEE) has improved the ability to detect spontaneous echocardiographic contrast (SEC) in the thoracic aorta. SEC in the aorta, as in the left atrium, may be associated with a hypercoagulable or prothrombotic state in patients with atrial fibrillation (AF) who have an increased stroke risk.

**Methods:** The plasma levels of molecular markers for platelet activity (platelet factor (PF-4) and  $\beta$ -thromboglobulin ( $\beta$ -TG)), the thrombotic status (thrombin-antithrombin III complex (TAT)) and fibrinolytic status (D-dimer and plasmin- $\alpha$  2-plasmin inhibitor complex (PIC)) were measured in 62 non-rheumatic AF patients (40 males, mean age 68 years) who underwent transesophageal echocardiography.

**Results:** Aortic SEC was prevalent in patients with severe aortic atherosclerosis and was associated with less distensible aortic wall (% change of aortic diameter;  $4.2 \pm 0.7\%$  in SEC(+) vs  $6.4 \pm 0.8\%$  in SEC(-),  $p < 0.05$ ). Plasma levels of TAT, PIC and D-dimer were significantly higher in patients with aortic SEC than in those without aortic SEC, while plasma levels of PF-4 and  $\beta$ -TG did not differ significantly between patients with and without aortic SEC (Figure).



**Conclusion:** Patients with aortic SEC appears to have activated coagulation system, suggesting an increased risk of thromboembolism in these patients.

**1122-26 Spontaneous Echocardiographic Contrast in the Thoracic Aorta: Prognostic Significance After Three-Year Clinical Follow-up**

Constantina Aggeli, Alexandra Frogoudaki, Spyros Lambrou, John Barbetseas, Christos Pitsavos, Angelos Rigopoulos, Christodoulos Stefanadis, Pavlos Toutouzas. *Department of Cardiology of the University of Athens, Hippokraton Hospital, Athens, Greece*

**Background:** It has been suggested that spontaneous echocardiographic contrast in the thoracic aorta (SEC) is associated with an increased risk of future cardiovascular events.

**Methods:** To further elucidate this issue, the transesophageal echocardiograms (TEE) of 717 consecutive patients (pts) who were examined in our laboratory between January, 1995 and December 1996 were reviewed for the presence of SEC. Pts in whom the finding was confirmed were reexamined clinically or their attending physicians were contacted by telephone and information were collected regarding the occurrence of the following events: Cardiac death, noncardiac death, stroke, peripheral embolic events and acute myocardial infarction (AMI).

**Results:** SEC was confirmed in 58 (8.1%) of the reviewed cases, none of whom regarded aortic dissection or thoracic aortic aneurysm. Follow-up information were collected in 45 of these pts (33 men, 12 women, aged 70 ± 10 years). The time elapsed between the index TEE and the follow-up was 38 ± 6 months (range, 25–48 months). During this period, 20 pts (45%) died, 11 of whom due to cardiac causes (6 by sudden cardiac death, 1 because of congestive heart failure, and 4 because of an AMI), 3 due to a cerebrovascular accident, and 4 due to non cardiac causes. The cause of death was not defined in 2 cases. Furthermore, 2 pts experienced a non-fatal stroke during follow-up, while no non-fatal myocardial infarctions or peripheral embolic events were reported. Five of the pts with SEC consented to undergo repeat TEE at follow-up. Four of them who underwent repeat TEE had coronary artery disease and one had chronic atrial fibrillation. All 5 pts had been receiving chronic aspirin therapy (160–325 mg o.d.), whereas no one received oral anticoagulants. Thoracic aortic SEC was shown to persist in all cases.

**Conclusions:** The data of the present report support the suggestion that thoracic aortic SEC is associated with considerable cardiovascular morbidity and mortality. Conventional-dose aspirin was shown not to influence the presence of SEC over a 3-year period in a small group of patients.

#### 1122-27 Complex Plaque of the Ascending Aorta and Arch Predicts Cardiovascular Events

Bradley J. Artel, Aman M. Amanullah, Linda B. Grossman, Umesh V. Katdare, Andrey Espinoza, Farooq A. Chaudhry. *MCP Hahnemann School of Medicine, Philadelphia, PA, USA*

**Background:** Transesophageal echocardiography (TEE) is used to identify the presence of complex and mobile aortic plaque. However, its prognostic impact in predicting cardiovascular events are not well defined.

**Methods:** The findings of TEE were correlated with clinical variables in 127 consecutive patients (age 68 ± 12 years; male/female 76/51) for the prediction of cardiovascular events (CVE).

**Results:** During a mean follow up of 13 ± 3 months, 19 patients had hard CVE (HE) (cardiac death or embolic stroke) and 26 soft CVE (coronary revascularization or carotid endarterectomy). HE rate was 26% (15/57) in patients with complex plaque of the ascending aorta or arch (protuberant ≥ 4 mm in thickness or a mobile plaque) and 6% (4/70) in patients without a complex plaque ( $p < 0.002$ ). Among clinical and TEE variables, univariate predictors ( $p < 0.05$ ) of CVE were age, hypertension, history of heart failure, presence of coronary artery disease and a complex plaque. Multivariable Cox model, after adjustment for age, demonstrated complex plaque as the most predictive variable for CVE ( $X^2 = 8.9$ ;  $p < 0.02$ ).

**Conclusions:** Complex plaque of ascending aorta and arch is a powerful marker of not only of stroke but also of cardiac death and coronary events.

#### 1122-28 Correlation of Multiple Transesophageal Echocardiography and Nonfluoroscopic Electromechanical ("NOGA") Left Ventricular Mapping in the Assessment of Left Ventricular Function in Patients With Refractory Angina Pectoris Undergoing Direct Myocardial Gene Transfer of Vascular Endothelial Growth Factor

D.D. Esakof, M. Maysky, D.W. Losordo, P.R. Vale, J.O. Pastore, J.F. Symes, J.M. Isner. *St. Elizabeth's Medical Center, Boston, MA, USA*

**Background:** Direct myocardial gene transfer of DNA encoding vascular endothelial growth factor (VEGF) has emerged as a novel therapy for patients with angina pectoris refractory to maximal medical therapy and not amenable to standard surgical or percutaneous revascularization.

**Methods:** Nonfluoroscopic electromechanical ("NOGA") left ventricular (LV) mapping was performed in 13 patients undergoing diagnostic coronary artery catheterization prior to direct myocardial VEGF gene transfer via a limited lateral thoracotomy. Mapping produced a three-dimensional depiction of the LV cavity with a color-coded mechanical map of linear log shortening (LLS) and electrical maps of maximum unipolar and bipolar voltage (UV and BV), each in 12 myocardial segments. Subsequently multiplane transesophageal echocardiography (MPTEE) was performed continuously for guidance of DNA injection during surgical gene transfer. MPTEE 16-segment LV wall motion scores adapted from the American Society of Echocar-

diography were converted to a 12-segment LV scheme for direct correlation with corresponding electromechanical data. LV segments were categorized further as normal (normal contractility) or abnormal (hypokinetic or akinetic wall motion).

**Results:** LLS in 116 LV segments with normal echocardiographic wall motion ( $12.56 \pm 0.54\%$ , mean ± SEM) was greater than the LLS in 26 abnormal LV segments ( $9.93 \pm 0.1.26\%$ ,  $p < 0.001$ ). UV and BV also were greater in normal than in abnormal myocardium defined by ultrasound ( $12.04 \pm 0.50$  mV vs.  $7.62 \pm 0.85$  mV, and  $3.68 \pm 0.24$  mV vs.  $1.58 \pm 0.23$  mV, respectively, both  $p < 0.001$ ).

**Conclusion:** Nonfluoroscopic electromechanical LV mapping correlates well with the assessment of regional LV wall motion by echocardiography. This mapping technique therefore may offer functional LV data useful in guiding new techniques for catheter-based myocardial gene transfer.

#### 1122-29 Biplane, Omniplane and Paraplane Analysis for Accurate Right Ventricular Volume Measurement: A Comparison With Magnetic Resonance Imaging

Youssef F.M. Nosir, Maarten H. Lequin, Anita Dall'Agata, Jaroslaw D. Kasprzak, Abdou Elhendy, Folkert J. Ten Cate, Silja E.C. Spitaels, Jos R.T.C. Roelandt. *Thoraxcenter, Erasmus University, Rotterdam, The Netherlands; Cardiology Department, Al-Azhar University, Cairo, Egypt*

Right ventricular volume (RVV) measurement remains a challenge in clinical practice because of RV complex geometry. Our aim was to study both the feasibility and accuracy of three-dimensional echocardiography (3DE) for RVV calculation, as compared with magnetic resonance imaging (MRI).

**Subjects:** 12 patients were examined {2 with an atrial septal defect, 8 with ischaemic heart disease and 2 normal volunteers}. Precordial 3DE acquisition of RV was performed at 2-degree rotational intervals with ECG and respiratory gating algorithm. MRI was performed at 0.5 T. MRI measurements of end-diastolic (ED) and end-systolic (ES) RVV and ejection fraction (EF) were computed by Simpson's rule at 9-mm slice intervals. RVV and EF were calculated from 3DE data sets by (a) biplane modified Simpson's method (BMS) with two orthogonal RV long axis views, (b) omniplane method (OMN) with 8 RV long axis views obtained at 22.5° of rotational intervals and by (c) paraplane (Simpson's) method (3DS) with 8 parallel equidistant RV short axis slices.

**Results:** The mean ± SD of ED- and ES-RVV (ml) and EF (%) from MRI were ( $143 \pm 70$  and  $85 \pm 40$  and  $40 \pm 11$ ), from 3DS were ( $141 \pm 72$  and  $86 \pm 44$  and  $40 \pm 12$ ), from OMN were ( $141 \pm 74$  and  $87 \pm 46$  and  $38 \pm 11$ ) and those from BMS were ( $140 \pm 74$ ,  $84 \pm 45$  and  $41 \pm 12$ ) respectively. There were no significant differences between measurements of RVV and EF obtained from MRI and the 3DE methods. However, there were closer limits of agreement between MRI measurements and both 3DS and OMN methods ( $\pm 16$ ,  $\pm 16$  and  $\pm 6.6$ ) and ( $\pm 18$ ,  $\pm 18$  and  $\pm 6.6$ ) than with BMS ( $\pm 24$ ,  $\pm 21$  and  $\pm 11.8$ ) for ED- and ES RVV (ml) and EF (%) respectively. The interobserver standard error of the estimate (SEE) for ED-RVV, ES-RVV and EF were (4.9, 3.6 and 2.2), (5.1, 3.5 and 2.3) and (7.3, 6.2 and 3.4), for 3DS, OMN and BMS respectively ( $p = NS$ ).

**Conclusions:** 3DE rotational acquisition for RV is feasible. 3DE using both the paraplane and omniplane analysis provides more accurate and reproducible measurements of RVV and EF than the BMS method when compared with MRI.

#### 1122-30 Is Noninvasive Detection of Non-Proximal Coronary Lesions Possible by Transesophageal Doppler Echocardiography? The Importance of Diastolic Acceleration Time of Proximal Coronary Flow

Jaroslaw D. Kasprzak, Jaroslaw Drozd, Michał Plewka, Marcin Zwierzak, Michał Ciesielczyk, Michał Borkowski, Maria Krzemińska-Pakuła. *Department of Cardiology IMW, Medical University of Łódź, Poland*

**Purpose:** Transesophageal Doppler echocardiography (TEE) can detect proximal coronary disease by visualization of the luminal narrowing and detection of accelerated stenotic flow. We studied the proximal coronary flow (PCF) to determine if distal coronary lesions can be predicted by noninvasive coronary Doppler parameters.

**Methods:** PCF was studied with pulsed Doppler in 210 TEE examinations and compared with coronary angiography.

**Results:** PCF was recorded in LMCA in 88%, LAD in 85%, CX in 58% and RCA in 65% of studies (at least 5 good quality beats were averaged). The only PFC abnormality found in patients with LAD stenosis > 70% was a significant prolongation of diastolic acceleration of coronary flow velocity (DA):  $141 \pm 41$  ms vs  $125 \pm 39$  ms ( $P = 0.033$ ) in controls. The calculation of acceleration slope, correction by heart rate and duration of diastolic coronary flow did not alter the findings. ANOVA revealed significant differences of

DA in patients with LAD occlusion, stenosis 71–99%, stenosis 50–70% and no stenosis:  $131 \pm 36$  ms,  $144 \pm 42$  ms,  $124 \pm 33$  ms and  $125 \pm 41$  ms, resp. DA was not correlated with ejection fraction and global E/A ratio. Similar trends were observed in proximal RCA flow without reaching statistical significance.

**Conclusions:** Significant coronary artery stenosis is reflected by prolonged diastolic acceleration period of proximal coronary flow. The possible explanation is that impaired relaxation due to coronary disease delays the diastolic peak of velocity in proximal coronary arteries. This finding contributes to understanding of pathophysiology in diastolic heart failure.

### 1122-31 Is Echocardiography Cost Effective in the Diagnosis and Treatment of Endocarditis?

Stamatios P. Lerakis, Stephen D. Clements, Randolph P. Martin, William S. Weintraub, Rachel A. Willette. *Emory University, Atlanta, GA; University of Texas Medical Branch, Galveston, TX, USA*

**Background:** The roles of transthoracic (TTE) and transesophageal (TEE) echocardiography in the management of endocarditis have been controversial. Accordingly, we evaluated the cost effectiveness of TTE and TEE by selecting patients with suspicion of infectious endocarditis (IE) for antibiotic therapy.

**Methods:** Using a decision analytic model, we compared the quality adjusted life years (QALYs) and costs of 1) TTE guided, 2) TEE guided selection of patients for antibiotic therapy (A) versus 3) treating all patients with suspected IE with A. Using the Duke criteria, models were developed for patients with high (80%), medium (50%), and low (20%) suspected probability of IE.

**Results:** TEE guided is the least expensive alternative, saving the most hospital days, and offers comparable QALYS to treating all patients with A. This model was not intended to evaluate the use of echocardiography in the diagnosis or management of complications of IE. These benefits could only improve the cost-effectiveness of TEE if baseline echocardiography also reveals such complications as an abscess, severe valvular regurgitation, or a large or mobile mass.

	Treat All	TTE Guided	TEE Guided
Low Probability Cost	\$43,700	\$15,435	\$10,814
QALYs	19	17	19
Medium Probability Cost	\$43,700	\$41,109	\$21,975
QALYs	18	19	17
High Probability Cost	\$43,700	\$42,072	\$33,101
QALYs	17	17	16

**Conclusions:** TEE guided therapy is cost effective in guiding the diagnosis and treatment of IE. In addition, TEE is both essential and cost effective for the management of complications of IE.

### 1122-32 Quantitative Assessment of Mechanical Prosthetic Valve Area With 3 Dimensional Transesophageal Echocardiography

Herman Mannaerts, Yue Li, Otto Kamp, Sara Rippa, Jana Hrudova, Cees Visser. *University Hospital VU, Amsterdam, The Netherlands*

**Background:** The currently used methods for prosthetic effective orifice area (EOA) assessment based on transthoracic Doppler pressure half time and continuity equation (EOA-Doppler) have their own known limitations. A new method of direct 3 D planimetry for EOA (EOA-3 D) is compared with EOA-Doppler and with the EOA's provided by Doppler literature (EOA-L) and with the manufacturer's values (EOA-M) for the corresponding valve types and sizes.

**Methods:** With a HP 2500 multiplane transesophageal echocardiography (TEE) probe rotational acquisition was performed with ECG and respiratory gating. The images were processed off-line with Tom-Tec 4.1 EchoView. From 2 perpendicular long axes of the prosthesis short axis anyplane images with the EOA at maximal valve opening were generated. Twenty four normal functioning mechanical valve prostheses were studied in 22 patients (pts): 13 pts after mitral valve replacement (MVR); (10 St Jude and 3 Medtronic Hall, sizes 27 to 33) and 11 after aortic valve replacement (AVR); (8 St Jude, 1 Carbomedics, 1 Medtronic Hall, 1 Bjork Shiley ABP, sizes 19 to 27).

**Results:** 3 D planimetry was possible in all 24 cases. The means ( $\pm$  SD) of EOA's after MVR, AVR and the total group for EOA-3 D, EOA-Doppler, EOA-L and EOA-M are shown in the table. Only EOA-M was significantly larger in comparison with the other methods ( $P < 0.01$ ; ANOVA). Correlations between EOA-3D and EOA-M were 0.83 (AVR), and 0.77 (MVR). EOA-Doppler showed good correlation with EOA-M and EOA-3D after AVR only and not after MVR. Intraobserver and interobserver variabilities for EOA-3D were 11 and 21%.

EOA (cm <sup>2</sup> )	N	EOA-3D	EOA-Doppler	EOA-L	EOA-M
MVR	13	$3.1 \pm 0.6$	$2.7 \pm 0.7$	$3.1 \pm 0.1$	$4.3 \pm 0.7$
AVR	11	$2.2 \pm 0.4$	$1.7 \pm 1.0$	$1.5 \pm 0.5$	$2.6 \pm 0.8$
Total	24	$2.6 \pm 0.7$	$2.3 \pm 0.9$	$2.4 \pm 0.9$	$3.6 \pm 1.1$

**Conclusions:** 3 D TEE planimetry (EOA-3D) is feasible, and independent of any physiological variables. It shows excellent correlation with EOA-M; and good correlation with EOA-Doppler only after AVR, indicating that pressure half time cannot be used for accurate EOA assessment after MVR. EOA-3D assessment is complementary to EOA-Doppler and possibly superior in case of significant prosthetic regurgitation, low cardiac output states or patient valve mismatch.

## POSTER

### 1123 Magnetic Resonance Imaging: Valvular, Ischemic, and Hypertensive Heart Disease

Monday, March 13, 2000, 3:00 p.m.–5:00 p.m.  
Anaheim Convention Center, Hall A  
Presentation Hour: 3:00 p.m.–4:00 p.m.

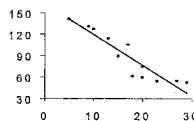
### 1123-33 Regional Myocardial Infarct Related Edema is Visualized by STIR Magnetic Resonance Imaging and Correlates With Circumferential Strain in Anterior Myocardial Infarction

Aernout M. Beek, Marco J.W. Götte, J. Tim Marcus, Albert C.v. Rossum. *University Hospital Vrije Universiteit, Amsterdam, The Netherlands*

**Background:** In acute myocardial infarction (AMI) regional edema formation at the infarcted area leads to prolongation of MRI relaxation times T1 and T2. The Short  $\tau$  Inversion Recovery (STIR) sequence was adapted for cardiac imaging to overcome the shortcomings of earlier T2-weighted spin-echo techniques by combining blood nulling, fat suppression and predominant T2-weighting in a single breath hold sequence. STIR is presumed to be sensitive to infarct related edema and requires no contrast agent.

**Methods:** To assess the clinical value of this technique we prospectively studied 31 patients (25 males, age  $58 \pm 9.3$  years) with first AMI (18 anterior, 13 inferior/posterolateral, 15 thrombolysis (TL), 11 primary PTCA, peak CK  $1482 \pm 966$ ) 5 days (4–14) after admission. The MRI protocol (1.5 T) included also myocardial tagging (SPAMM, 7 mm grid). A short axis slice at midventricular level was divided in 12 equiangular segments, starting at the anterior septal insertion of the right ventricle. In each segment mean STIR signal intensity (SI) was compared to circumferential strain ('shortening',  $\epsilon_c$ ).

**Results:** In 27 pts qualitative assessment of the STIR images readily identified infarct site as a well demarcated area of high SI. In 4 pts (2 inferior, 2 anterior) STIR was negative. In patients with anterior MI (216 segments) an excellent correlation was found between mean segmental SI and  $\epsilon_c$  ( $r = 0.930$ ,  $p < 0.001$ , see figure). In patients with inferior MI no such correlation existed. This might be explained by the considerably smaller inferior infarct size ( $979 \pm 371$  vs  $1795 \pm 1918$ ,  $p < 0.001$ ) and partly by the gradual decrease in SI from antero-septal to posterolateral region due to differences in distance to surface coil.



X: Mean segmental circumferential strain (%); Y: Mean segmental STIR SI (a.u.); Each point represents a single short axis segment with averaged SI and  $\epsilon_c$

**Conclusion:** Unenhanced STIR MRI visualizes infarct related edema. STIR SI is correlated with circumferential strain only in anterior MI.

### 1123-34 Cardiac High Energy Phosphates in Human Ischemic Preconditioning Assessed by Magnetic Resonance Spectroscopy

R. Kalil, J.C. Nicolau, A.M.B.P. Leme, R.G. Weiss<sup>1</sup>, Cicero Piva de Albuquerque, C.V. Serrano Jr., R.R.C.V. Giraldez, J.A.F. Ramires. *Heart Institute (InCor), University of São Paulo Medical School, Brazil; Johns Hopkins Hospital, Baltimore, MD, USA*

Ischemic preconditioning (IP) limits myocardial infarct size in animals but the pathophysiology is unknown. A paradigm of IP in humans involves the evaluation of patients with episodes of chest pain a day or two prior to



infarction. We studied 21 patients after anterior myocardial infarction (MI) with successful thrombolytic treatment within six hours of onset. The patients were divided in two groups: patients that presented with prior chest pain less than 48 hours before MI (IP group, n = 11, mean age 56) and 10 patients with no pain before MI (NIP, mean age 59). Myocardial creatine phosphate to ATP (PCr/ATP) ratios were measured at rest with spatially-localized <sup>31</sup>P NMR spectroscopy (ISIS). Cardiac PCr/ATP ratios were corrected for partial saturation and blood contamination and regional function was evaluated with cine MRI early (avg. 4 days, n = 21) and late (avg. 39 days, n = 21) after presentation. Contractility scored from 0 (hyperkinesis) to 6 (dyskinesis). There were no differences in the LV function between the groups in the early study (2.12 ± 0.73 vs 2.38 vs ±0.61) however in late phase the LV function was better in IP group (1.16 ± 0.03 vs 1.72 ± 0.53, p = 0.02). The IP group presented with higher PCr/ATP ratios than NIP group in the early (1.61 ± 0.11 vs 1.40 ± 0.14, p = 0.001) and late studies (1.64 ± 0.10 vs 1.38 ± 0.12, p = 0.008). These findings suggests that chest pain prior to infarction, as a model of human ischemic preconditioning, delays high-energy depletion and improves metabolic and functional recovery in humans.

**1123-35 Tagged Magnetic Resonance Imaging Can Quantify Regional Functional Variation During Dobutamine Stress in Subjects With Coronary Stenoses**

Craig H. Scott, Kevin Duffy, Bert Ivey, Yevgeniy Batkov, Steven Hao, Leon Axel, Martin G. St. John Sutton, Victor Ferrari. *University of Pennsylvania, Philadelphia, PA, USA*

**Background:** Coronary artery disease (CAD) can be qualitatively assessed by examination of regional wall motion during dobutamine infusion. We sought to determine whether magnetic resonance imaging (MRI) stress testing could provide a quantitative evaluation of the wall motion heterogeneity in patients with CAD during inotropic stimulation.

**Methods:** We studied 8 normal subjects and 11 patients with documented 1 or 2 vessel CAD using dobutamine stress testing with tagged MRI. All CAD patients had normal global function without infarction. We performed homogenous strain analysis using the maximum and minimum principal strains, E1 and E2 and compared the global mean strain for the normal and CAD groups. The heart was divided into 4 regions for MRI analysis. Cardiac catheterization identified regions at risk and remote from coronary stenoses in the CAD group.

**Results:** Regions remote from coronary stenoses responded similarly to the normal group: strain increased from baseline to 10 µg/kg/min dobutamine infusion. At risk myocardial regions did not show a significant increase in strain with dobutamine stress. Dobutamine doses above 10 µg/kg/min did not further increase strain in either the normal or CAD groups.

	Normal		CAD Patients			
	E1	E2	E1 at risk	E1 remote	E2 at risk	E2 remote
Baselin	0.33±0.02	-0.19±0.02	0.28±0.06	0.30±0.05	-0.19±0.03	-0.19±0.03
Dob 10	0.52±0.1*	-0.24±0.01*	0.34±0.09	0.41±0.05*	0.22±0.04	-0.25±0.03*
Dob 20	0.44±0.1*	-0.24±0.02*	0.32±0.06	0.37±0.07	-0.19±0.02	-0.19±0.02

\*p < 0.05 vs. baseline

**Conclusions:** Myocardial strain measurements calculated from tagged MRI images quantitate the heterogeneity of regional cardiac function induced during dobutamine stress testing in patients with CAD.

**1123-36 Relations Between Echocardiographic and Magnetic Resonance Imaging in Hypertensive Patients With Electrocardiographic Left Ventricular Hypertrophy: The LIFE Study**

Kristian Wachtell, Christian Tuxen, Kirstine L. Hermann, Thomas F. Hansen, Michael H. Olsen, Vittorio Palmieri, Per Hildebrandt, Vasilios Papademetriou, Jonathan N. Bella, Jens Rokkedal, Richard B. Devereux. *Glostrup University Hospital, Denmark and Frederiksberg Hospital, Denmark*

**Background:** The reproducibility of left ventricular (LV) mass is known to be better with magnetic resonance imaging (MRI) than by echocardiogram (ECHO). However, the difference in measuring LV mass<sub>ECHO</sub> compared to LV mass<sub>MRI</sub> in patients with or without LV hypertrophy is unclear. Furthermore, there exist no partition values for LV hypertrophy when LV mass is measured by MRI.

**Methods:** ECHO and MRI measures of LV dimensions were compared in 51 unmedicated patients (66 ± 7 years) with stage I-III hypertension and LV hypertrophy determined by electrocardiogram (Cornell voltage duration criteria > 2,440 mm × msec or Sokolow-Lyon voltage criteria SV1 + V5/RV6 > 38 mm).

**Results:** Nineteen patients (37%) had normal LV mass by ECHO. The 32 (63%) that had LV hypertrophy on ECHO had higher LVMI<sub>MRI</sub> than compared to those with normal LVMI<sub>ECHO</sub> (p < 0.05). In a Bland-Altman plot limits of agreement was the absolute 15 g/m<sup>2</sup> (95% CI: -30 to 74 g/m<sup>2</sup>) and relative 16% (95% CI: -5 to 47%) difference between LVMI<sub>ECHO</sub> and LVMI<sub>MRI</sub> were independent of the mean LVMI-ECHO-MRI. In univariate regression analysis the regression coefficient was 0.44 with an intercept of 54 g/m<sup>2</sup>. Furthermore the absolute and relative differences between LVMI<sub>ECHO</sub> and LVMI<sub>MRI</sub> were both independent of relative wall thickness<sub>ECHO</sub>, gender and body mass index. Using the ECHO-LVH 116/104 g/m<sup>2</sup> partition values for men and women we suggest partition values for MRI-LV hypertrophy are 105 g/m<sup>2</sup> (95% CI: 103-108 g/m<sup>2</sup>) for men and 100 g/m<sup>2</sup> (95% CI: 95-105 g/m<sup>2</sup>) for women, respectively.

**Conclusions:** LV mass is measured higher with ECHO than with MRI. However, the difference is independent of relative wall thickness, gender and body size. Partition values for LV hypertrophy measured by MRI are suggested.

**1123-37 Evaluation of Aortic Valve Stenosis by Magnetic Resonance Imaging Compared to Results From Transesophageal Echocardiography and Cardiac Catheterization**

Anna John, Thorsten Dill, Udo Sprengel, Clemens Müller, Ali Rad, Thomas Dambacher, Wolfgang Ricken, Christian W. Hamm. *Kerckhoff-Klinik, Bad Nauheim, Germany*

**Background:** Assessment of the severity of aortic stenosis frequently involves invasive or semi-invasive techniques such as cardiac catheterization (CC) and transesophageal echocardiography (TEE). The aim of this pilot study was to show that estimation of the aortic valve area (AVA) by magnetic resonance imaging (MRI) is feasible as well as sufficiently correlating with the results of TEE and cardiac catheterization (CC).

**Methods:** 22 patients (14 male) underwent cardiac catheterization and TEE for aortic stenosis. MRI was performed on an 1.5 T Magnetom Vision (Siemens Medical Systems, Erlangen, Germany) using a cine-gradient echo sequence with a temporal resolution of 30-40 ms and a spatial resolution of 1.24-2.91 × 1.17-1.56 mm, slice thickness 4 mm. Imaging planes for planimetry were chosen perpendicular to the aortic jet as deduced from the area of signal loss due to turbulent flow at valve orifice level. Planimetry of the aortic valve was performed independently by three observers blinded to the results of transesophageal echocardiography and cardiac catheterization and was repeated two months later to determine intraobserver variability.

**Results:** Mean AVA was 0.78 ± 0.16 qcm for MRI, 0.95 ± 0.26 qcm for TEE and 0.7 ± 0.26 qcm for CC. MRI results correlated well with TEE and CC results (p < 0.008 and p < 0.001, respectively). Interobserver variability was 0.054 ± 0.058. Intraobserver variability was 0.055 ± 0.042.

**Conclusion:** TEE results showed a tendency towards systematic over-estimation of the AVA compared to MRI and catheter data. Evaluation of aortic valve stenosis by MRI is feasible and of excellent reproducibility. It is a promising alternative to current invasive and semi-invasive techniques.

**1123-38 Evaluation of Valvular Regurgitation: Real-Time Color Flow Magnetic Resonance Imaging Compared to Echo**

Pedro A. Rivas, Krishna S. Nayak, Adam B. Kerr, Michael V. McConnell, Phillip C. Yang, John M. Pauly, Dwight G. Nishimura, Bob S. Hu. *Department of Electrical Engineering and Division of Cardiovascular Medicine, Stanford University, Stanford, CA, USA*

Doppler Color Flow Mapping has become the gold standard in the assessment of valvular heart disease. Despite this, however, it is constrained by limitations specific to Ultrasound. Real-Time Interactive Color Flow MRI has been developed to address these limitations and in this study we compared the system to Echocardiography in the semi-quantitative assessment of valvular regurgitation. 31 patients were studied. Echo and MRI regurgitation scores were graded as None, Mild, Moderate, or Severe by two independent and blinded observers. System parameters have been previously described. Total patient exam time was under 30 minutes. Inter-observer agreement was higher for MRI than Echo (88 vs. 72%, p = 0.01) with a trend toward less suboptimal MRI scans for endocardial border definition (16 vs 38%, p = 0.088). Correlations are as follows. Aortic: N = 28, R = Spearman's Rank Correlation Coefficient = 0.842, p < 0.0001; Mitral: N = 24, R = 0.768, p = 0.0002; Pulmonic: N = 6, R = 0.949, p = 0.0339; and Tricuspid: N = 19, R = 0.651, p = 0.0057. Moderate and Severe Regurgitation was seen in 100% of Aortic Insufficiency and in 83% of Mitral Insufficiency. Color Flow MRI has been shown to have diagnostic accuracy in the assessment of Aortic and Mitral Insufficiency with greater inter-observer agreement due to a trend toward improved image quality. Ongoing studies include through-plane flow

comparisons, congenital heart disease assessment, and right-sided valve regurgitation.

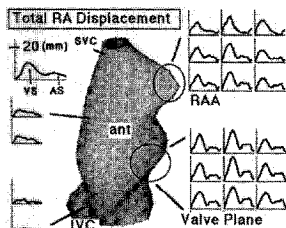
#### 1123-39 Analysis of Atrial Motion Using Magnetic Resonance Imaging

Cenghizan Öztürk, Luis F. Gutiérrez, Jérôme Declerck, Guy Shechter, Elliot R. McVeigh. *Johns Hopkins University, Baltimore, Maryland, USA*

**Background:** Atrial shape and motion can be altered in many cardiac pathologies. We present a method for the full 3D-motion analysis of the right and left atrium (RA, LA).

**Methods:** Cardiac gated FSE and cine FGRE MRI images (up to 90 phases) were acquired from healthy human subjects. Using surface templates generated using high contrast FSE images, cine images of atria were segmented using interactive template based segmentation. The corresponding points on the resulting surfaces at different time frames were found by a four-dimensional surface based registration algorithm.

**Results:** For both RA and LA, the displacement values show high spatial variability. During ventricular systole (VS in Figure) the RA appendage (RAA), anterior wall and valve plane show the most displacement. Significant through-plane motion is present in axial slices for RA. LA motion is less complex, occurring mostly in the anterior and inferior walls. A time resolution of 50 ms is found to be adequate to capture the full atrial dynamics including atrial systole (AS in Figure).



**Conclusion:** The fast MR imaging techniques, in conjunction with our surface fitting and registration methods can describe the complex 3D motion of both atria.

#### 1123-40 Quantification of Flow Velocity and Volume With Real Time Cardiovascular Magnetic Resonance

Christoph Klein, Eike Nagel, Simon Schalla, Hans Lehmkühl, Bernhard Schnackenburg<sup>1</sup>, Axel Bornstedt, Eckart Fleck. *Internal Medicine/Cardiology, Charité, Campus Virchow, HU & German Heart Institute Berlin; <sup>1</sup> Philips Medical Systems, Hamburg, Germany*

The quantification of peak blood flow velocity (Vmax) and flow volume (VOL) with cardiovascular magnetic resonance has been shown to be highly accurate. Problems of current standard techniques are their long acquisition duration, the necessity of ECG-triggering and the non diagnostic image quality in patients with arrhythmias. We developed a new technique capable of measuring flow in real time which is independent of ECG-triggering. Aim of the study was to compare the new real time technique with a standard technique.

In 36 large vessels (aorta), 33 medium sized vessels (common carotid and iliac artery) and through 12 valves (mitral and aortic) Vmax and VOL were measured with a 1.5 Tesla tomograph (ACS NT, Philips) using a gradient echo sequence (retrospective triggering, temporal resolution 32 ms, scan duration app. 2 min) and the real time technique (no triggering, temporal resolution 120 ms).

In all examined vessels and valves flow measurements could be successfully performed. A good correlation between the standard and the real time technique was found for Vmax in large and medium sized arteries as well as in valves ( $r = 0.88, 0.81$  and  $0.88$  respectively). In contrast, the determination of VOL was only satisfactory for the larger vessels ( $r = 0.87$ ).

The new real time technique allows for a quantification of peak flow velocity in large and medium sized vessels as well as through valves without ECG triggering in minimal measurement time. In large vessels the determination of volume flow is also possible with real time imaging. This new technique it is a step towards a integrative examination of the cardiovascular system with MR and will allow to examine patients with atrial fibrillation and frequent premature beats.

ORAL

#### 858 Nuclear Cardiology: Stress Perfusion Imaging and Prognosis

Monday, March 13, 2000, 4:00 p.m.–5:30 p.m.  
Hilton Anaheim, Pacific D

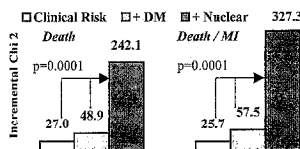
4:00 p.m.

#### 858-1 What is the Incremental Contribution of Stress Myocardial Perfusion Imaging Over Clinical Data in Risk Stratification for Future Cardiac Events in Diabetic Patients?

Satyendra Giri, Leslee J. Shaw, Mark I. Travin, D. Douglas Miller, S. Borges-Neto, Rory Hachamovitch, Daniel S. Berman, David D. Waters, Gary V. Heller. *Hartford Hospital, Hartford, CT, USA*

**Background:** Despite recent therapeutic advances, diabetic (DM) patients continue to have higher coronary disease (CAD) event rates that are not explained by CAD risk factors alone. The value of stress myocardial perfusion imaging (MPI) in relation to clinical risk factors for risk stratification in DM patients is unknown.

**Methods:** We evaluated stress MPI in a large, prospective, multicenter study of symptomatic pts undergoing stress MPI from five centers for the 3-year occurrence of cardiac death and MI. Stress MPI results were classified as normal or abnormal (fixed or ischemic defects; 1, 2 or 3 vessel distribution). After adjusting for clinical risk, the independent contribution of each variable predicting subsequent cardiac events was analyzed by calculating the difference in the model likelihood ratio  $\chi^2$  statistic (Cox's model) from the overall model with and without each of the variables (see figure).



**Results:** Of 4,755 pts, 929 (19.5%) were diabetic. DM pts had 80 (8.6%) cardiac events (39 deaths & 41 MI) compared to 172 (4.5%) cardiac events (69 deaths & 103 MI) in the non-DM ( $p < 0.01$ ). DM pts with ischemic defects had increased cardiac events ( $p < 0.001$ ) with highest MI rate (17.1%) with 3-vessel ischemia. A multivessel fixed defect was associated with the highest rate of cardiac death (13.6%) in DM pts. The unadjusted 3-year cardiac survival was lower for DM pts (91% vs 97%,  $p < 0.001$ ), but became comparable once adjusted for the clinical risk and stress MPI results. In multivariable Cox analysis, stress MPI was the largest contributor to the overall model.

**Conclusions:** Stress myocardial perfusion imaging successfully identifies diabetic patients at high risk for future cardiac events. Use of stress MPI in conjunction with clinical risk assessment can significantly improve risk stratification in diabetics.

4:15 p.m.

#### 858-2 Prognostic Value of Stress Technetium-99m-Sestamibi Myocardial Perfusion Imaging in Asymptomatic Diabetics

Andrea De Lorenzo, Aurora Issa, Claudio Baldi, Eduardo Cwajg, Elizabeth Costa, Márcia Sales, Ronaldo L. Lima, Maurício Pantoja. *Universidade Federal do Rio de Janeiro, Rio de Janeiro; Cintilab, Rio de Janeiro, Brazil*

**Background:** Coronary artery disease (CAD) is a common cause of death among diabetics. Silent CAD is also more frequent in these patients, and its adverse prognosis cannot be underestimated. The predictive value of exercise thallium-201 imaging has already been demonstrated, but to date no studies have assessed the use of technetium-99m-labeled myocardial perfusion tracers to evaluate outcome in this population.

**Methods:** We identified 114 consecutive asymptomatic diabetic patients who had been referred for cardiac single photon emission computed tomography (SPECT) to investigate the presence of CAD. They were subjected to a separate-day, stress-rest technetium-99m-sestamibi SPECT. The patients underwent a symptom-limited maximal Bruce treadmill protocol; for those unable to exercise, pharmacologic stress with dipyridamole was used. Follow-up was performed by telephone interview with the patient or assistant physician.

**Results:** The population consisted of 13.3% type I and 86.7% type II diabetics, 47.4% men, age  $63.2 \pm 10.2$  years. 75 (65.8%) patients had nor-

mal scans, 23 (20.2%) showed completely reversible defects, 8 (7.0%) had partially reversible defects and 8 (7.0%) had irreversible ones. There were 25 cardiac events over 31.9 ± 18.9 months of follow-up. Cardiac death occurred in 6 (5.3%) patients, nonfatal acute myocardial infarction (AMI) in 4 (3.5%), and 15 (13.1%) underwent late (more than 1 month after SPECT) myocardial revascularization (7 by percutaneous transluminal coronary angioplasty -PTCA- and 8 by coronary artery bypass grafting -CABG). Three patients (2.6%) died of noncardiac causes. An abnormal cardiac SPECT increased the risk of combined events (cardiac death, nonfatal AMI, CABG and PTCA), with an OR of 3.08 (p = 0.01). On univariate analysis, the presence of reversible defects was predictive of CABG (p = 0.02) and PTCA (p = 0.003), and the finding of partially reversible defects was associated with a greater incidence of AMI (p = 0.03).

**Conclusion:** The presence of abnormalities in cardiac perfusion imaging was significantly related to adverse outcomes. Completely or partially reversible defects were predictors of myocardial revascularization and AMI, respectively. Thus, technetium-99m-sestamibi SPECT can provide useful prognostic information in asymptomatic diabetics.

4:30 p.m.

**858-3 Prognostic Significance of Rest <sup>201</sup>Tl/Stress <sup>99m</sup>Tc-Sestamibi Dual-Isotope Myocardial Perfusion SPECT in Very Elderly Patients**

Sean W. Hayes, Howard C. Lewin, John Friedman, Guido Germano, Daniel S. Berman. *Cedars-Sinai Medical Center, Los Angeles, California, USA*

**Background:** Although myocardial perfusion SPECT (MPS) is valuable for risk stratification in the general population, little is known about the prognostic value of MPS in very elderly patients.

**Methods:** We identified 1,848 consecutive patients ≥ age 80 who underwent rest <sup>201</sup>Tl/stress <sup>99m</sup>Tc-sestamibi dual-isotope MPS. 51 patients (2.8%) were lost to follow-up and 170 patients were censored for early revascularization (within 60 days of SPECT). The remaining 1,627 patients were followed for 20.5 ± 8.2 months; all patients were followed for ≥ 1 yr. Mean age = 83.4 ± 3.1; 51% female, 63% adenosine stress. Summed stress perfusion scores (SSS) were calculated by adding 20 visually assessed segment scores using a 5-point scale (0 = normal to 4 = no uptake) and were subdivided using a previously defined classification. Hard events were categorized as nonfatal myocardial infarction (MI, n = 39) or cardiac death (CD, n = 110); total events (TE, n = 243) included MI, CD or late revascularization (>60 days post SPECT).  $\chi^2$  test was used to evaluate differences in event rates on follow-up based on SSS category. Cox proportional hazards method was used to assess cardiac risk factors and perfusion data for significance in predicting MI or CD.

**Results:** Using Cox proportional hazards method, SSS ( $\chi^2 = 66.6$ , p < 0.001), age ( $\chi^2 = 28.3$ , p < 0.001), and pharmacologic stress ( $\chi^2 = 10.6$ , p = 0.001) were significant predictors of CD, but only SSS ( $\chi^2 = 30.4$ , p < 0.001) was a predictor for MI.

	Annualized event rate				p
	Normal (SSS = 0-3) (n = 722)	Mild (SSS = 4-8) (n = 328)	Moderate (SSS = 9-13) (n = 176)	Severe (SSS ≥ 13) (n = 401)	
MI	0.4%	1.4%	1.4%	3.4%	<0.001
CD	1.9%	2.4%	4.1%	9.3%	<0.001
TE	3.8%	7.7%	10.6%	18.5%	<0.001

**Conclusions:** Very elderly patients are effectively risk stratified for CD or MI by MPS. Although patients in this group with normal MPS have an annual CD rate > 1%, this is far lower than that of the age matched U.S. population (age 75-84: 1.9%, age ≥ 85: 6.2%).

4:45 p.m.

**858-4 Prevalence and Significance of Exercise-Induced Left Ventricular Dysfunction Determined From ECG-Gated SPECT Myocardial Perfusion Scintigraphy**

A. Iain McGhie, Timothy M. Bateman, Will E. Gainey, Kelly L. Moutray, James A. Case, S. James Cullom, Khaldoon Alaswad, James H. O'Keefe Jr. *Mid-America Heart Institute, Cardiovascular Consultants PC, Kansas City, Missouri, USA*

**Introduction:** Exercise inducible left ventricular dysfunction, a transient phenomenon presumably reflecting myocardial stunning and/or hibernation, is a prognostically important marker in patients with coronary artery disease (CAD). It has been noted using ECG-gating of both post-stress and rest myocardial perfusion SPECT acquisitions, but its prevalence and significance require further study. The aims of this investigation were 1) determine

the prevalence of exercise-induced LV dysfunction in a large cohort of patients with known or suspected CAD, 2) determine its relation to severity of ischemia as evaluated by the summed difference score (SDS), and 3) determine whether its detection was dependent on the time interval between termination of exercise and onset of imaging.

**Methods and Results:** Gated myocardial perfusion SPECT studies in 1738 patients with known or suspected CAD were evaluated. A fall of ≥ 10 ejection fraction (EF) units (2.5 SD) was observed in 111 (6.4%) pts. A drop in EF correlated with the severity of ischemia: it occurred in 20/761 (2.6%) pts. with SDS ≤ 3; in 18/436 (4.1%) pts. with SDS of 4-8; and in 73/541 (13.5%) pts. with SDS ≥ 9 (p = 0.05). SPECT was performed using a standard exercise TI-201 protocol in 1167 (67%) where the time interval between termination of exercise and onset of imaging was 10-15 minutes. In the remaining pts a dual isotope protocol (rest TI-201/stress Sestamibi) was utilized with a 30-45 minute time interval between termination of exercise and onset of imaging. The prevalence of exercise-induced LV dysfunction was significantly lower in pts studied using the dual isotope technique, 3% vs. 8% (p = 0.001), with fewer pts demonstrating a fall in EF using dual isotope this within each ischemic category: 2.7% vs. 4.9% for SSS 4-8, and 9.7% vs. 14.5% for SSS ≥ 9 (p < 0.05).

**Conclusion:** This study demonstrates that transient LV dysfunction post-exercise can be diagnosed by ECG-gated myocardial perfusion SPECT when performed both post-stress and at rest, using TI/Tl and TI/MIBI protocols. Its prevalence correlates with a semiquantitative measurement of ischemic extent and severity, and with earlier post-stress imaging.

5:00 p.m.

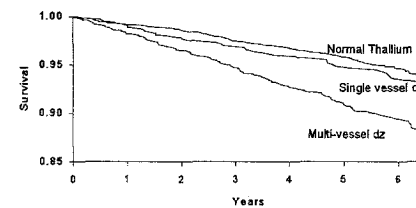
**858-5 Perfusion Defects of Multiple Vessel Territories on Exercise SPECT Thallium Imaging Predict Long-Term All-Cause Mortality**

Lazaro A. Diaz, Claire E. Snader, Eugene H. Blackstone, Frederic J. Pashkow, Michael S. Lauer. *Cleveland Clinic Foundation, Cleveland, OH, USA*

**Background:** Abnormalities on thallium imaging have been shown to be associated with short-term cardiovascular risk. However, the association between perfusion abnormalities and long-term all-cause mortality has not been well studied.

**Methods:** Consecutive patients undergoing SPECT thallium testing who did not have heart failure or valve disease (N = 7172, mean age 60, 75% male, 56% with known coronary disease) were followed for 5.5 years. Thallium defects were classified according to vascular territory (LAD, LCX, RCA) and by size. Fixed or reversible abnormalities were noted.

**Results:** Defects were present in 2735 (38%) patients. There were 467 deaths, of which 219 (5%) occurred in patients with normal scans and 248 (9%) in patients with perfusion defects (Unadjusted relative risk [RR] 1.88, 95% CI 1.57-2.26, P < 0.0001). Among 849 patients (12%) with only single vessel territory defects (fixed and/or reversible), only 49 (6%) died (RR 1.17, 95% CI 0.87-1.59). Among these patients, neither size nor location of defect predicted risk, including LAD perfusion defects (RR = 1.06, 95% CI 0.71-1.59). In contrast, two or three vessel territory involvement, whether fixed and/or reversible, was associated with increased mortality (RR 2.21, 95% CI 1.83-2.68, P < 0.0001). After adjusting for age, gender, exercise capacity, and standard risk factors, multi-vessel territory defects remained associated with a higher risk of death (adjusted RR 1.52, 95% CI 1.23-1.86, P < 0.0001), while single vessel territory defects were not predictive of mortality (adjusted RR 1.02, 95% CI 0.74-1.39, P = 0.92).



**Conclusions:** In this large single-center cohort, multi-vessel territory defects were independently associated with an increased risk in all-cause mortality, even over a period exceeding five years. In contrast, single vessel territory defects were not associated with a higher risk of death.

5:15 p.m.

**858-6 Cardiac Mortality of Patients With Left Bundle-Branch Block Following Rest <sup>201</sup>Tl/<sup>99m</sup>Tc-Sestamibi Dual-Isotope Myocardial Perfusion**

Howard C. Lewin, Trevor Thompson, Sean W. Hayes, John Friedman, Guido Germano, Daniel S. Berman. *Cedars-Sinai Medical Center, Los Angeles, California, USA*

**Background:** Although there have been a few reports on the prognosis of patients with left bundle-branch block (LBBB) following myocardial perfusion SPECT (MPS), these studies have included a limited number of patients and have not explicitly addressed the end-point of cardiac death (CD).

**Methods:** We identified 509 consecutive patients with LBBB pattern on rest ECG who underwent rest <sup>201</sup>Tl/stress <sup>99m</sup>Tc-sestamibi dual-isotope MPS. Two expert readers interpreted MPS using a 20-segment, 5-point scoring system (0 = normal, 4 = no uptake). The summed stress score (SSS) was defined as the sum of the 20 stress segments. All pts were followed for  $\geq 1$  year, average  $22.1 \pm 9.1$  months. Patients undergoing revascularization (n = 74) were censored from the analysis at the time of revascularization. The end-point of 18-month (18 m) CD was used. Univariate predictors of 18 m CD were identified and used to develop a multivariable Cox proportional hazards model (COX) and 18 m Kaplan-Meier (KM) survival estimates were calculated.

**Results:** The population was  $72 \pm 9.0$  years old and 54% male, with 64% undergoing adenosine stress. Overall, there were 23 CD, 5.3% 18 m KM estimate of CD. There was significant risk-stratification of 18 m CD by SSS (see table). A COX was developed to determine the predictors of 18 m CD. This model revealed that age, diabetes and history of MI were all independent predictors (PR) of 18 m CD. After adjusting for all of these, the SSS remained an independent PR of 18 m CD ( $p < 0.03$ ,  $\chi^2 = 5.2$ ). KM CD rates for exercise vs. adenosine are 1.9% vs. 7.1% respectively,  $p = 0.02$ . After adjusting for the baseline differences, this was no longer significant although a trend remains,  $p = 0.082$ , likely due to small sample size.

	18-Month Cardiac Death				p
	Normal (SSS = 0-3)	Mild (SSS = 4-8)	Moderate (SSS = 9-12)	Severe (SSS $\geq$ 13)	
CD	0.7%	4.2%	5.6%	10.3%	= 0.008
N	(n = 138)	(n = 106)	(n = 83)	(n = 182)	

**Conclusions:** Patients with LBBB have a higher rate of CD than the general population. However, their risk can be stratified by MPS, and those with normal scans are at low risk for CD (<1.0%)

## ORAL

**867 Myocardial Contrast Echocardiography in Humans**

Tuesday, March 14, 2000, 8:30 a.m.–10:00 a.m.  
Hilton Anaheim, Pacific D

8:30 a.m.

**867-1 Myocardial Contrast Echocardiography With Continuous Infusion of Optison and Variable Pulsing Intervals: Experience With First 200 Cases Undergoing <sup>99m</sup>Tc-Sestamibi-SPECT**

John M. Dent, Jerrell Thorpe, Amanda Doss, Sally Moos, Denny Watson, Sanjiv Kaul. *University of Virginia, Charlottesville, VA, USA*

**Background:** Myocardial Contrast Echocardiography (MCE) can be performed with a continuous infusion of microbubbles. When steady-state is achieved, the pulsing interval (PI) can be changed in order to allow for greater filling of the ultrasound beam. In this manner, regions with lower flows can be identified.

**Methods:** We recruited 200 patients referred for pharmacological stress testing with <sup>99m</sup>Tc-sestamibi SPECT. The median age was 64 years; 52% were men, 38% each had previous infarction and lipid disorders; 37% had diabetes, 75% were hypertensive, and 63% were smokers. Optison (Mallinckrodt) infusion was started right after injection of sestamibi both at rest and after  $0.56 \text{ mg} \cdot \text{kg}^{-1}$  of dipyridamole. Intermittent harmonic imaging was performed at end-systole at PI of 1,3,5, and 8 cardiac cycles using HDI 5000 (ATL). Images were read in gray-scale and each of 14 segments was scored as either normal (N) or (AB). The latter were scored as either fixed (FD) or reversible (RD) defect. Comparisons were performed with color-coded quantitative SPECT.

**Results:** Agreement between MCE and SPECT regarding N vs AB was 86%, 82%, and 82% on segmental, territorial, and patient basis ( $\kappa = 0.60$ ), respectively. When both read a segment as AB, there was 77% agreement between FD and RD.

**Conclusion:** MCE, with continuous infusion of Optison and varying PI, has good agreement with quantitative color-coded SPECT. It needs to be determined whether the concordance could be improved if MCE data were also quantified and color-coded.

8:45 a.m.

**867-2 Assessment of Myocardial Perfusion by Power Doppler Harmonic Imaging at Rest and During Adenosine Stress**

Sheila K. Heinle, Jennifer Noblin, Pam Goree-Best, Ana Mello, Guy Ravad, Stephanie Mull, Pradeep Mammen, Paul A. Grayburn. *University of Texas Southwestern and VA Medical Centers, Dallas, Texas, USA*

**Background:** Although experimental studies have shown that myocardial contrast echocardiography accurately predicts infarct size, myocardial area at risk, and the extent of salvage after reperfusion after IV contrast agents, clinical studies have been disappointing. The recent development of harmonic power Doppler imaging (HPDI) has enabled detection of resting perfusion defects in man. The purpose of this study is to compare myocardial perfusion by HPDI to that obtained simultaneously by <sup>99m</sup>Tc-sestamibi single-photon emission computed tomography (SPECT) during rest and pharmacological stress with adenosine.

**Methods:** HPDI was performed on 123 patients who were referred for SPECT imaging for known or suspected CAD. Images were obtained during Optison infusion (3 ml) both at baseline and during adenosine stress ( $0.14 \text{ mg/kg/min} \times 6 \text{ min}$ ) in each of three apical views. HPDI was done at maximal acoustic power using dual-triggered "flash" imaging at end-systole. Myocardial perfusion by HPDI was graded for each coronary territory as absent, patchy or full. The persistence of absent or patchy myocardial perfusion by HPDI between rest and adenosine was interpreted as a fixed defect, whereas any decrease in perfusion grade was interpreted as a reversible defect. HPDI and SPECT images were analyzed independently and in blinded fashion.

**Results:** Overall concordance between the two techniques was 80% for normal perfusion and reversible or fixed defects. Agreement between the two methods for each of the three coronary territories was 81% ( $k = 0.6$ ) for the left anterior descending artery, 76% ( $k = 0.5$ ) for the right coronary artery, and 72% ( $k = 0.4$ ) for the left circumflex (LCX) artery. A significant difference between the two techniques was evident in the LCX territory where fixed defects were observed in 33% by HPDI but only 14% by SPECT ( $\chi^2 = 15.8$ ,  $p = 0.0001$ ).

**Conclusions:** This study demonstrates HPDI can reliably detect myocardial perfusion abnormalities during pharmacologic stress, although there is a significantly higher number of falsely abnormal results in the LCX region compared to SPECT imaging.

9:00 a.m.

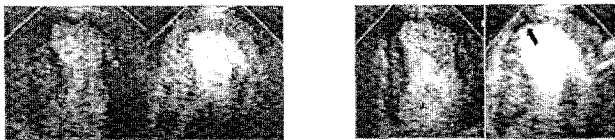
**867-3 Real Time Myocardial Perfusion in Humans Using Low Mechanical Index Power Pulse Inversion Imaging and Intravenous Optison During Dobutamine Stress Echocardiography**

Thomas Porter, Feng Xie, Rebecca Oster, Mary Silver, Curtis LeBleu, Michalakis Averkiou, Jeffrey Powers, David Kricsfeld. *University of Nebraska Medical Center, Omaha, Nebraska, USA*

**Background:** Power Pulse Inversion (PPI) is a new concept which involves sending multiple pulses of alternating opposite polarity into tissue at a very low mechanical index (MI) following intravenous (IV) perfluorocarbon containing microbubble injections. At this MI, tissue harmonic activity is suppressed and only non-linear bubble behavior is detected. This may prevent the need for any off-line background subtraction and permit frame rates which allow for real time perfusion imaging.

**Methods:** This concept was tested in 16 patients during dobutamine stress echocardiography (DSE). A prototype harmonic transducer (HDI 5000; Advanced Technology Laboratories) was used which delivered multiple pulses of alternating polarity followed by unique signal processing to image apical four, two, and three chamber views at an MI of 0.1 and a frame rate of 11–18 hertz. IV Optison (Op) was given in 0.3 cc doses for each view.

**Results:** Background activity was absent in the myocardium prior to each injection, creating a black image around a contrast filled cavity (Figure). Bright myocardial contrast enhancement was observed following IV Op in all 16 patients, with some attenuation of basal segments. Regional contrast defects observed during DSE (Figure) correlated with the location of  $>50\%$  diameter stenosis at quantitative angiography ( $\kappa = 0.83$ , 92% agreement). An inducible apical perfusion defect during DSE is shown (arrow).



**Conclusion:** PPI imaging successfully produces myocardial opacification using extraordinarily low mechanical indices, and allows the real time assessment of myocardial perfusion without the need for off-line background suppression of tissue harmonic activity.

9:15 a.m.

**867-4 Is Power Doppler Equivalent to Digital Subtraction With Color Coding for Interpretation of Myocardial Contrast Echo? Comparison With Dipyridamole Stress Perfusion Scintigraphy**

Brian Haluska, Michelle Jenkins, John Anderson, Tom Marwick. *Princess Alexandra Hospital and University of Queensland, Brisbane, Australia*

**Background:** Specificity of contrast defects is the greatest limitation of myocardial contrast echo (MCE), as variance in baseline myocardial brightness at influences recognition of contrast enhancement using gray scale. Subtraction and color coding (SC) may overcome this problem, but is time consuming. Triggered harmonic power Doppler (HPD) offers on-line imaging of bubble destruction independent of underlying image brightness, and may be comparable to SC.

**Methods:** We sought to compare the ability of SC and HPD to avoid false positive MCE due to baseline image heterogeneity in 29 pts ( $61 \pm 11$  y) with low probability of CAD. Pts were studied with simultaneous MCE and SPECT after standard dipyridamole stress. MCE was performed during infusion of 2 mls/min Levovist (Schering Germany) and standard echo equipment using a harmonic transducer (1.7 MHz). Images were obtained in grey scale (GS) at baseline and during infusion, using end-systolic triggering at 1:4 and 1:6. These images were subtracted and color-coded off-line using MCE software (Univ Virginia). HPD was performed with a pulse-repetition frequency >2000. SPECT was performed with a standard 180 degree acquisition using Tc99m tetrafosmin. Only the apical 4 chamber view was interpreted; SPECT and MCE-GS, SC and HPD in basal, mid and apical segts were scored by 2 expert observers as 0 (absent), 1 (incomplete) or 2 (complete).

**Results:** Of the 174 segts, MCE defects were reported by GS in 116 (66%), SC in 92 (53%) and HPD in 89 (51%). Among 134 segts with normal SPECT perfusion, the specificity of GS (67%) was less than SC (77%) and HPD (88%,  $p < 0.001$ ). HPD was more specific than SC ( $p = 0.006$ ). In 37 segts with abnormal SPECT results, the sensitivity of GS, HPD and SC were comparable (41%, 38%, 47%).

**Conclusion:** HPD appears to improve specificity of GS images to a comparable degree to SCC. As it is available on-line and no post-processing is needed, this technique appears promising for clinical application of MCE.

9:30 a.m.

**867-5 Real-Time Myocardial Perfusion Imaging During Intravenous Contrast: Echocardiography – First Clinical Results Using the New Contrast Specific Imaging Modality Power-Pulse-Inversion**

Klaus Tiemann, Harald Becher, Stefanie Kuntz, Alexa Heinemann, Peter N. Burns, Berndt Lüderitz, Michalakis Averkiou, Jeffrey E. Powers, Matthew Bruce. *Dept. of Cardiology, University of Bonn, Bonn, Germany; ATL-Ultrasound, Bothell, USA*

**Background:** The assessment of myocardial perfusion following intravenous application of echocontrast agents has been limited to triggered imaging since a considerable amount of echocontrast is destroyed during insonification. This study was designed to evaluate whether the new imaging modality Power Pulse Inversion Imaging (PPI) allows the assessment of wall motion and perfusion simultaneously at very low emission power to minimize bubble destruction.

**Methods:** Apical four chamber views were obtained consecutively in PPI mode in 18 healthy volunteers using an HDI 5000 (ATL-Ultrasound) during a constant infusion of Optison (Mallinckrodt, St. Louis, USA; 0.6 ml/min). Frame rate was 12 Hz, emission Power was set to the lowest available value (MI 0.1). Baseline settings were optimized to avoid non-contrast PPI signals within the myocardium. Signal enhancement for contrast PPI was evaluated in standard myocardial segments in 10 consecutive endsystolic frames both quantitatively using a calibrated software tool and visually by means of a 4 point score (0 = no, 1 = weak, 2 = moderate, 3 = strong contrast)

Endocardial border definition (EBD) scores were defined for all segments in 10 consecutive cardiac cycles and compared to baseline Tissue Harmonic Imaging recordings (0 = no, 1 = poor, 2 = moderate, 3 = excellent delineation).

**Results:** Real time perfusion imaging was feasible in all subjects. Wall motion could be assessed in 92 out of 108 segments during contrast PPI. In 12 segments myocardial signal enhancement equaled cavity signals impeding a proper visual wall motion analysis.

	S1	S2	S3	S4	S5	S6	Cavity
PPImax (dB)	$8.8 \pm 3.3$	$9.3 \pm 3$	$6.0 \pm 2$	$5.8 \pm 2.1$	$6.8 \pm 3.4$	$4.1 \pm 2.7$	$15.5 \pm 6.3$
PPI score	$2.4 \pm 0.6$	$2.7 \pm 0.5$	$2.0 \pm 0.6$	$1.9 \pm 0.6$	$1.7 \pm 0.7$	$1.2 \pm 0.6$	–
EBD	$2.7 \pm 0.5$	$3.0 \pm 0$	$3.0 \pm 0$	$2.9 \pm 0.3$	$2.8 \pm 0.4$	$2.2 \pm$	–

**Conclusion:** Simultaneous assessment of wall motion and perfusion is feasible using real-time PPI. Thus, perfusion imaging during stress echocardiography is no longer limited to intermittent imaging techniques.

9:45 a.m.

**867-6 Venous Myocardial Contrast Echocardiography and SPECT Imaging in Patients With Coronary Disease: Quantitative Comparison of Signals at Rest and During Stress**

Christian Firsche, Martina Reeg, Martin Lampen, Rudolf Blasini, Ulrich Schricke, Albert Schömig, Kenichi Odaka, Stephan Nekolla, Jody Neverve, Markus Schwaiger. *Deutsches Herzzentrum, Technische Universität, München; Nuklearmedizinische Klinik, Technische Universität, München, Germany*

**Background:** In the experimental setting of myocardial infarction and coronary artery stenosis, the magnitude of video intensity mismatch on venous myocardial contrast echocardiography (VMCE) has been demonstrated to closely correlate with the magnitude of myocardial flow mismatch by radio-labeled microspheres at rest and during coronary hyperemia. We therefore hypothesized there is a correlation between the signals of VMCE and a clinical myocardial flow marker, Tc 99m Sestamibi SPECT imaging (SI) in patients with known coronary disease at rest and during stress.

**Methods:** 45 patients underwent both VMCE (venous infusion of 8g of Levovist at rest and during 140 µg/kg/min of Adenosine over 6 minutes, intermittent harmonic imaging with a pulsing interval of 7 cardiac cycles, digital off-line processing with background subtraction, grey scale expansion and color coding) and SI (300 MBq of Tc 99m Sestamibi at rest and 700 MBq during bicycle exercise). Mean videointensities and radionuclide activities were measured in the basal and mid septal, lateral, anterior and inferior segments and of the apex of the left ventricle.

**Results:** Mean videointensities and radionuclide activities of each segment were normalized to the value of the segment with the maximum mean videointensity and radionuclide activity, respectively. There was a fair correlation between normalized mean videointensities and radionuclide activities at rest ( $y = 0.29 + 0.67x$ ,  $r = 0.52$ ,  $p < 0.0001$ , SEE = 0.14) and during stress ( $y = 0.17 + 0.80x$ ,  $r = 0.66$ ,  $p < 0.0001$ , SEE = 0.13).

**Conclusion:** Videointensity signal on VMCE can be used to evaluate myocardial perfusion in the clinical setting of coronary disease at rest and during stress similar to the radionuclide activity of Tc 99m Sestamibi on SPECT imaging.

NONINVASIVE IMAGING

POSTER

**1143 Ventricular Filling and Atrial Function: New Doppler Insights**

Tuesday, March 14, 2000, 9:00 a.m.–11:00 a.m.  
Anaheim Convention Center, Hall A  
Presentation Hour: 9:00 a.m.–10:00 a.m.

**1143-1 Noninvasive Assessment of Hemodynamic Subsets in Patients With Acute Myocardial Infarction Using Pulmonary Venous Flow Analysis With Transthoracic Echocardiography**

Atsushi Yamamuro, Takashi Akasaka, Takeshi Hozumi, Tsutomu Takagi, Koichi Tamita, Kenji Yamabe, Shigefumi Morioka. *Kobe General Hospital, Kobe, Japan*

**Background:** Hemodynamic subsets (HS) have been evaluated both cardiac index (CI) and pulmonary capillary wedge pressure (PCWP) using a Swan-Ganz catheter (S-G) in patients (pts) with acute myocardial infarction (AMI), the use of which is not without risks. Recent studies have suggested

that there is a correlation between CI and peak systolic velocity (PSV) in pulmonary venous flow (PVF) as well as a correlation between PCWP and PVF deceleration time (PV-DT). Thus, we evaluated whether only PVF analysis can be applied to noninvasive assessment of HS in pts with AMI.

**Methods:** We attempted to classify HS from both noninvasive (PVF analysis) with transthoracic echocardiography (TTE) and invasive methods with S-G in 150 pts with AMI as follow: HS I: CI > 2.2 (l/min/m<sup>2</sup>), PCWP ≤ 18 (mmHg), HS II: CI > 2.2, PCWP > 18, HS III: CI ≤ 2.2, PCWP ≤ 18, HS IV: CI ≤ 2.2, PCWP > 18.

**Results:** PVF analysis was possible in 124 of 150 pts. CI from PSV correlated with that from S-G ( $r = 0.64$ ). There was a good correlation between the PV-DT and PCWP from S-G ( $r = -0.82$ ). When we determine the value of 0.35 m/s in PSV as the cutoff point in predicting >2.2 in CI and the value of 160 ms in PV-DT as the cutoff point in predicting ≤18 in PCWP, there was 88% (110 of 124 pts) agreement between noninvasive and invasive HS.

#### Transthoracic echocardiography

S-G	I	II	III	IV
I	66	1	6	0
II	0	13	0	2
III	4	0	25	0
IV	0	0	1	6

**Conclusion:** PVF analysis with TTE provides a simple method for the noninvasive assessment of hemodynamic subsets in pts with AMI.

### 1143-2 Effect of Changes in Preload on Transmitral Flow Velocity Patterns in Patients With Atrial Fibrillation

Hideaki Okubo, Hideyuki Takaoka, Katsuya Hata, Hiroya Kawai, Toshiro Shinke, Tomoo Inoue, Mitsuhiro Yokoyama. *Rokko Island Hospital, Kobe University Hospital, Kobe, Japan*

**Background:** Transmitral flow velocity patterns (TMF) are influenced by changes in preload in patients with sinus rhythm. However, in patients with atrial fibrillation (Af) the effect of changes in preload on TMF has not been fully elucidated.

**Methods:** In 16 patients with Af, we simultaneously measured mean pulmonary wedge pressure (PWP), early filling acceleration time (ACT), deceleration time (DCT), peak early flow velocity (E) and its time velocity integral (VTI<sub>E</sub>) and acceleration rate (E/ACT) by right-sided cardiac catheterization and echocardiography. Measurements were averaged over 5 cardiac cycles. In patients with normal PWP (<18 mmHg) ( $n = 8$ ), we infused dextrose to increase PWP (8 to 14 mmHg). In patients with elevated PWP ( $n = 7$ ), we infused diuretics to decrease PWP (27 to 11 mmHg).

**Results:** As PWP increased, E (64 to 75 cm/sec), VTI<sub>E</sub> (9 to 10 cm) and E/ACT (0.67 to 0.90) increased and ACT (96 to 84) and DCT (143 to 131 msec) shortened significantly. Inverse change was observed with decrease in PWP. Changes in these Doppler indices correlated significantly with changes in PWP by simple linear regression analysis. The good relations were observed with the E/ACT ( $r = 0.92$ ,  $p < 0.0001$ ), E ( $r = 0.85$ ,  $p < 0.0001$ ), ACT ( $r = -0.84$ ,  $p < 0.0001$ ) and DCT ( $r = -0.82$ ,  $p < 0.0001$ ). Results of the multiple stepwise linear regression analysis revealed that combination of the changes in E/ACT and DCT showed strongest association with the changes in PWP ( $R^2 = 0.89$ ,  $p < 0.0001$ ).

**Conclusion:** Even in patients with Af, PWP affected E, ACT and DCT as in patients with sinus rhythm. Changes in E/ACT and DCT reflect changes in PWP most sensitively.

### 1143-3 The Role of Mitral Regurgitation and Ventricular Function on Pulmonary Venous Waves in Patients With Atrial Fibrillation

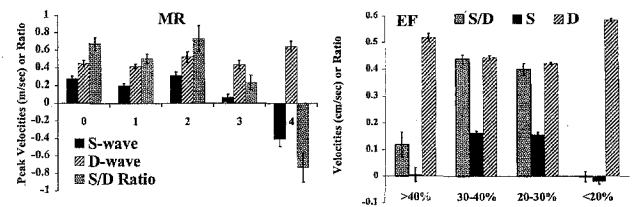
Michael S. Firstenberg, Maran Thamilarasan, David L. Prior, Rohit Gupta, Mohammad Bashir, James D. Thomas, Allan L. Klein. *The Department of Cardiology, The Cleveland Clinic Foundation, USA*

In patients with sinus rhythm, pulmonary venous (PV) flow patterns are a function of LA and LV systolic and diastolic properties. In atrial fibrillation, the determinants of PV flow are poorly defined.

**Methods:** Ethos in 111 patients (age:  $65.1 \pm 11.8$  years, 84 males) in atrial fibrillation were performed. Peak systolic (S-wave) and diastolic (D-wave) PV velocities and the S/D ratio were compared with LV end-systolic (ESV), end-diastolic (EDV) and LA dimensions, ejection fraction (EF), and degree of mitral regurgitation (0 to 4+ MR) with analysis of variance (ANOVA)

**Results:** With increasing MR the S/D ratio decreased reflecting an increasing D-wave that is partially offset by a decreasing S-wave (figures show averages  $\pm$ SEM, all  $p < 0.05$ ). When stratified by MR, no correlation was observed between D-wave or the S/D ratio and LV or LA dimensions. In

17 pts with 4+ MR, S-wave reversal occurred and correlated with EDV ( $r = 0.62$ ,  $p < 0.01$ ) otherwise pts with EF < 40 ( $n = 73$ ) had significantly greater S-waves than pts ( $n = 38$ ) with EF > 40 ( $0.12 \pm 0.03$  vs  $0.01 \pm 0.001$ ,  $p < 0.05$  respectively)



**Conclusion:** In patients in atrial fibrillation, PV S and D waves, and the S/D ratio are determined by the degree of MR. While influenced primarily by MR, poor LV function was associated with elevated S-waves and only when associated severe MR did S-waves directly correlate with EDV.

### 1143-4 The Composite Index of Left Atrial Function: A Noninvasive Tool for Quantitating Left Atrial Function

Lisa A. Hourigan, Nelson B. Schiller. *University of California, San Francisco, San Francisco, California, USA*

**Background:** Left atrial dilatation and fibrillation are associated with adverse outcomes. Based on the presumption that left atrial dysfunction may form the substrate for these maladaptive conditions, we have devised a tool for quantitation of atrial function, the *Composite Index of Left Atrial Function*. This index incorporates analogues of cardiac output, atrial reservoir function and atrial end systolic size. We hypothesize that patients with chronic maladaptive or reduced atrial function have a smaller cardiac output, poorer atrial reservoir function and a larger atrial end systolic volume, thereby producing a smaller index when compared with normal subjects.

**Methods:** 24 patients in chronic atrial fibrillation (AF) and 15 patients in sinus rhythm with a history paroxysmal atrial fibrillation (PAF) were retrospectively identified from our laboratory database and compared with age and sex matched controls in sinus rhythm with no historical or echocardiographic evidence of heart disease. Apart from the arrhythmia, the chronic AF and PAF groups had no other cardiac history or structural abnormality demonstrable on transthoracic echocardiogram. The mean age was 66.3 years (SD 18) (median 73 years; range 27–90 years). The following measurements were collected from transthoracic studies: left ventricular outflow tract velocity time integral (VII LVOT) and biplane planimetered left atrial volumes to calculate an indexed left atrial end systolic volume (LAESVI) and a left atrial ejection fraction (LAEF). The composite index was calculated using the formula: (VTI LVOT) (LAEF) (100)/(LAESVI).

**Results:** The mean index for each group was: chronic AF = 15.8 (SD 9.6); PAF = 35.8 (SD 22.9); controls = 54.78 (SD 19.6). Unpaired t tests showed highly significant differences between each group (chronic AF vs. PAF  $p = 0.0005$ ; AF vs. control  $p < 0.0001$ ; PAF vs. control  $p = 0.0037$ ).

**Conclusion:** The Composite Index of Left Atrial Function separates subjects with normal atrial function from those with malfunctioning atria. Furthermore, the index was effective at segregating subgroups within the sinus rhythm group (controls and PAF) and within the group with atrial malfunction (PAF and chronic AF). Based on these preliminary observations, the Composite Index of Left Atrial Function merits further investigation as a means of quantitating atrial function, predicting arrhythmias and monitoring interventions.

### 1143-5 Left Atrial Contractile Function During Left Ventricular Ischemia With and Without Left Atrial Ischemia

Fabrice Bauer, Michael Jones, Takahiro Shiota<sup>1</sup>, Jian Xin Qin, Hiroyuki Tsujino, Annieta J. Morehead, Lisa A. Cardon, Agnese Travaglini, Arthur D. Zetts, Julio A. Panza<sup>1</sup>, James D. Thomas<sup>1</sup>. *The Cleveland Clinic Foundation, Cleveland, OH; <sup>1</sup>NHLBI, Bethesda, MD, USA*

**Background:** During left ventricular (LV) ischemia, left atrial (LA) contractile function is enhanced to compensate for LV dysfunction; however, in the presence of LA ischemia, it may be unable to do so.

**Aim of the Study:** To assess the LA pump function in a model of acute LV ischemia with [proximal left circumflex artery occlusion (LCX<sub>o</sub>)] or without [proximal left anterior descending artery occlusion (LAD<sub>o</sub>)] LA ischemia.

**Methods:** LV ischemia was produced in 9 sheep (LCX<sub>o</sub> = 3, LAD<sub>o</sub> = 6). LA volumes were measured epicardially by real-time 3D echocardiography and LA pressure was recorded with a high fidelity pressure catheter. Pulsed Doppler was used to quantify the mitral inflow velocity. LA pressure volume

loops were traced off-line during one cardiac beat. For each sheep, the following parameters were measured before and after coronary occlusion: atrial stroke volume (A-SV), atrial ejection fraction (A-EF), transmitral A-wave Doppler peak velocity (A-D), a-wave pressure (A-P) and atrial stroke work (A-SW) from the LA pressure-volume loop.

**Results:** A-D decreased in the two groups, but was significantly lower during LCx<sub>o</sub> (36.5 ± 9 cm.s<sup>-1</sup> vs 29.7 ± 5 cm.s<sup>-1</sup> in LAD<sub>o</sub> group, ns and 60.7 ± 12.8 cm.s<sup>-1</sup> before vs 29.4 ± 12.2 cm.s<sup>-1</sup> after in LCx<sub>o</sub> group, p < 0.05). A-P was higher during LAD<sub>o</sub> (6.7 ± 3.6 mm Hg before vs 11.9 ± 5.5 mm Hg after, p < 0.05) and was unchanged during LCx<sub>o</sub> (12.0 ± 2.6 mm Hg before vs 11.8 ± 1.4 mm Hg after, ns). LA pump function is given in the table.

	LAD <sub>o</sub>			LCx <sub>o</sub>		
	A-SV (ml)	A-EF (%)	A-SW (mmHg.ml)	A-SV (ml)	A-EF (%)	A-SW (mmHg.ml)
Before	4.2 ± 2.7	22 ± 9	13.7 ± 4.9	4.8 ± 2.8	26 ± 16	6.2 ± 3.1
After	8.5 ± 3.2	29 ± 9	17.8 ± 7.9	1.8 ± 0.8	5 ± 3	3.0 ± 2.9
p	0.05	ns	0.05	ns	0.05	ns

**Conclusion:** During LAD<sub>o</sub>, LA pump function increased while with LCx<sub>o</sub>, the LA was unable to compensate LV dysfunction.

**1143-6 How Should Left Atrial Size Be Reported? Comparative Assessment With Use of Multiple Echocardiographic Methods**

Banthit Khankirawatana, Ping Lu, Leng Jiang. *University of Nebraska Medical Center, Omaha, NE, USA*

**Background:** Determination of left atrial (LA) size is important in clinical decision-making. The LA antero-posterior dimension (APD) has been routinely reported as LA size assessment. Early studies indicated that the APD may have limited accuracy in quantification. Three-dimensional reconstruction (3DR) of the LA has been validated. However, its process is time consuming and not applicable for daily practice. To explore an accurate and practical approach, we compared different echo measurements with conventional 3DR in 14 patients with different LA sizes.

**Methods:** LA size was measured with: 1) Cubic equation with APD on parasternal long axis view (Cub); 2) Ellipsoidal formula (Ellip) (LA volume = 4/3π\*APD/2\*length/2\*medio-lateral dimension/2); 3) Biplane modified Simpson's rule (Biplane); 4) Simplified 3DR from 3 standard apical views with B spline interpolation (3VR). 3DR was also obtained with an transthoracic apical rotational approach.

**Results:** (Table) Compared to 3DR, biplane and 3VR provided comparable accuracy in LA volume measurement, while the Cub and Ellip calculation were less accurate with significant underestimation (P < 0.001).

LA volume	y	r	SEE (ml)	Mean Difference (%)
Cub	0.61x + 33.4	0.73	17.0	24.3
Ellip	0.79x + 2.1	0.77	11.3	22.3
Biplane	1.05x - 3.2	0.97	5.4	5.3
3VR	1.02x - 0.2	0.98	4.4	5.1

**Conclusion:** LA single dimension is not accurate for LA size measurement. Biplane Simpson's rule provides accurate LA volume assessment and is comparable to 3D methods. It is readily available with current echo equipment and should be routinely applied in clinical practice.

**1143-7 Noninvasive Estimation of Pulmonary Vascular Resistance in Patients With Chronic Heart Failure**

Francesco Scapellato, Pier L. Temporelli, Ugo Corrà, Ermanno Eleuteri, Pantaleo Giannuzzi. *"S. Maugeri" Foundation - IRCCS, Division of Cardiology, Veruno, Italy*

**Background:** Pulmonary vascular resistance (PVR) is of important clinical and prognostic value in patients (pts) with chronic heart failure (CHF), particularly for possible candidates to heart transplantation. Therefore, a noninvasive estimation is desirable. Accordingly, we hypothesized a strict correlation between Doppler systolic pulmonary flow (PF) and PVR.

**Methods:** 50 consecutive pts with CHF (39 males, 57 ± 3 yrs, EF 22 ± 4%, NYHA class II-IV) underwent simultaneous hemodynamic monitoring (Swan-Ganz cath.) and echo-Doppler study. The following Doppler parameters were evaluated on PF: pre-ejection period (PEP), acceleration time (ACT), ejection time (EjT), total systolic time (Tt) and peak flow velocity (Vmax).

**Results:** Mean hemodynamic PVR value was 2.8 ± 2.1 Wood (range 0.5 to 9.4). At univariate analysis, all variables, except Vmax, showed a significant, although weak, correlation with PVR. The best correlation found was with AcT (r = -0.68). By multivariate analysis, only PEP, AcT and Tt resulted

independent predictors of PVR. The analysis led to the final equation: PVR = 5.8 + (-42.1 ACT) + (58.7 PEP) + (-11.2 Tt) (r = 0.87). However, PEP to AcT ratio, normalized for Tt showed a greater correlation with PVR (r = 0.95). Furthermore, a group of 10 pts underwent simultaneous hemodynamic and echo-Doppler evaluations at baseline and after Nitroprusside infusion. The correlation between predicted (by Doppler echocardiography) and estimated (by right heart catheterization) PVR was r = 0.97.

**Conclusion:** Although PVR is a complex parameter resulting from the interaction of several hemodynamic variables, Doppler systolic pulmonary flow signal is strictly related to PVR. PEP to AcT ratio, normalized for Tt of pulmonary systolic flow represents a reliable tool for predicting PVR in pts with CHF. This finding strongly support the contention that most CHF pts can be noninvasively investigated by echo-Doppler examination to accurately predict PVR.

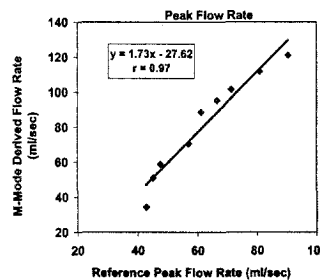
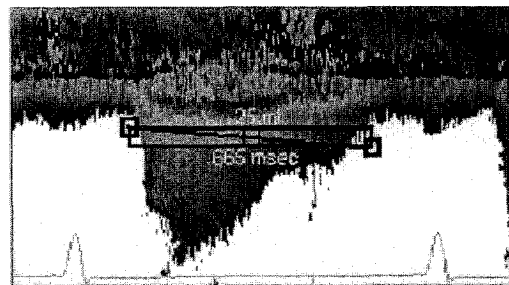
**1143-8 Quantification of Regurgitant Flow Rate From Doppler Color M-Mode Imaging: An In Vitro Study**

Xiaokui Li, Xiang-Ning Li, Damien Dolimier, Gordon Mack, Andrew Rosenthal, Susan L. Martin, Rosemary Rusk, David J. Sahn. *Oregon Health Sciences University, Portland, OR; ATL Ultrasound, Bothell, WA, USA*

**Background:** The poor temporal resolution of 2D color Doppler imaging may hinder its use for quantifying the instantaneous flow rate in valvular regurgitation. The objective of this study was to determine the accuracy of a modified flow convergence method that uses digital processing of color M-mode Doppler to estimate regurgitant flow rate.

**Methods:** Pulsatile flows (regurgitant volumes 8-35 ml) were applied through two new dynamic orifice regurgitant flow models wherein the orifice's size and location were changing dynamically in response to the pressure. To avoid having to directly identify the orifice center and aliasing boundaries, the method we have developed calculated the flow rate from digital velocities at two locations differing in depth by a known distance along a color M-mode scan line digitally transferred from an ATL HDI 5000 to an SGI workstation. Instantaneous flow rates were measured at 5 temporal points for each regurgitation period from color M-mode imaging in comparison with flow curves from an acoustic flow meter.

**Results:** The flow rates at both beginning and end of regurgitation correlated more closely with reference values than those at peak regurgitation. At peak regurgitation, our method overestimated the regurgitant flow rates by average of 27%. However, only a slight overestimation (4%) of the integrated total regurgitant volume occurred.



**Conclusion:** With the high temporal resolution of color M-mode Doppler, our method produces a better delineation of the temporal variations of flow events in the flow convergence region. Our computer algorithm can be adjusted to track varying sampling field locations during the heart cycle such that it tracks flow field motion and the method could allow simplicity of assessment in valvular regurgitation with reduced clinical examination time.

NONINVASIVE IMAGING

## POSTER

1144 **New Techniques in Ultrasound: Miscellaneous I**

Tuesday, March 14, 2000, 9:00 a.m.–11:00 a.m.  
Anaheim Convention Center, Hall A  
Presentation Hour: 9:00 a.m.–10:00 a.m.

1144-25 **Can Heterogeneity of Myocardial Velocities of Long-Axis Left Ventricular Contraction Differentiate Between Hypertrophic Cardiomyopathy and Left Ventricular Hypertrophy Due to Arterial Hypertension?**

Dragos Vinereanu, Ann Tweddel, Nicolae Florescu, Michael R. Stephens, Alan G. Fraser. *University Hospital of Wales, Cardiff, UK*

Echocardiographic differentiation between hypertrophic non-obstructive cardiomyopathy (HCM) and LVH due to arterial hypertension (HT) may be difficult. Reduced myocardial velocity gradients in LVH are associated with subendocardial dysfunction which is likely to alter longitudinal function; this can be assessed by measuring long-axis velocities.

**Methods:** We studied long-axis function in 10 pts with HCM (maximal resting LVOT gradient  $23 \pm 14$  mm Hg) (G1), 10 pts with HT (G2) and 10 normal subjects (G3), by measuring the peak systolic velocities of mitral annular motion by tissue Doppler echocardiography, at four sites: lateral L, medial – M, anterior – A, inferior – I, 4-site average – Av. We calculated the heterogeneity index of mitral annular velocities by the formula:  $Het = (|L - Av| + |M - Av| + |A - Av| + |I - Av|)/4$ .

**Results:** There were no differences between HCM and HT patients for age, global EF, and LV mass index. Although mitral annular velocities were lower in HCM and HT patients in comparison with the normal subjects, they were not different between the two groups (see table). The heterogeneity index was the only echo parameter significantly different ( $p < 0.05$ ) between the HCM and HT patients: an index less than 0.60 differentiated well (sensitivity 80%, specificity 100%) between HCM and LVH due to HT.

G	L (cm/s)	M (cm/s)	A (cm/s)	I (cm/s)	Av (cm/s)	Het
1	8.8 (2)	7.3 (2)*	7.5 (2)*	8.2 (2)	7.9 (2)*	1.04 (0.56)
2	8.2 (2) <sup>#</sup>	7.6 (1) <sup>#</sup>	7.9 (2) <sup>#</sup>	7.8 (1) <sup>#</sup>	7.9 (1) <sup>#</sup>	0.52 (0.46)
3	10.3 (1)	9.6 (1)	10.2 (1)	9.8 (1)	10.0 (1)	0.66 (0.24)

\* $p < 0.05$ : HCM vs Normals; <sup>#</sup> $p < 0.05$  AHT vs Normals.

**Conclusion:** Patients with AHT have low mitral annular velocities but no heterogeneity, probably related to diffuse subendocardial dysfunction. Patients with HCM have also low mitral annular velocities, however they have a high heterogeneity, suggesting rather localized subendocardial dysfunction. This heterogeneity index merits further evaluation as a possible index of differentiation between HCM and LVH in AHT.

1144-26 **Three Dimensional Echocardiographic Quantification of Left Ventricular Remodeling After Acute Myocardial Infarction**

Bobbi Hoppe, Michal Hubka, John McDonald, Edward Bolson, Karen Coady, Florence Sheehan. *University of Washington, Seattle, WA, USA*

**Background:** Left ventricular (LV) remodeling occurs early after myocardial infarction (MI) and is associated with a poor prognosis. Previous two dimensional echocardiography studies have provided limited information regarding changes in regional LV shape.

**Methods:** We measured location and magnitude of regional shape change in 5 patients (pts) from freehand three dimensional echocardiograms (3D echo) acquired 48 hours after first acute MI and 7–10 days later. Each LV endocardium in end-diastole was reconstructed as a triangulated surface from traced borders using a piecewise subdivision method. A robust fitting method was used to align each pt's pair of LV surfaces along the regions of similar shape. The CenterSurface method was used to measure the local orthogonal distance between the two aligned LV surfaces. Remodeling was assessed as change in regional shape between the early and follow up LV surfaces. The location and magnitude of the maximum distance between the surfaces was measured.

**Results:** In the two pts with anterior MI's, the maximal outward dilatation was 5.1 mm in the basal anterior region and 12.0 mm in the posterior apical region. In the three pts with posterior MI's, the maximum outward dilatation was: 5.1 mm in the posterior lateral region, 7.4 mm in posterior basal and 6.4 mm in the mid-anterior region, and 4.1 mm in the inferior apical region, respectively. In 4 of the 5 pts who underwent coronary angiography, location of the regional shape abnormalities corresponded to coronary pathology.

**Conclusion:** Quantitative analysis of the location, size, and severity of regional LV shape abnormalities can be performed from our 3D echo reconstruction method. This novel tool is useful for detecting LV dilatation associated with early remodeling following acute MI.

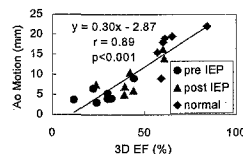
1144-27 **Assessment of Aortic Annular Motion in Patients With Ischemic Cardiomyopathy by Real-Time 3D Echocardiography (RT3DE) Before and After the Infarct Exclusion Procedure**

Peggy Han, Takahiro Shiota, Hiroyuki Tsujino, Patrick M. McCarthy, Jianxin Qin, Fabrice Bauer, Agnese Travaglini, Michael Firstenberg, James D. Thomas. *The Cleveland Clinic Foundation, Cleveland, OH, USA*

**Background:** Patients with ischemic cardiomyopathy have abnormal ventricular geometries hence complicating the routine assessment of left ventricular (LV) function, particularly following interventions such as the infarct exclusion procedure (IEP). We propose that aortic annular motion can serve as a surrogate marker in evaluating LV function.

**Methods:** Intraoperative epicardial RT3DE was performed in 7 patients pre and post IEP. Reconstruction of the aortic annulus in end-diastolic and end-systolic phases was performed by identifying the leaflet hinge points as spatial coordinates in 9 rotational apical planes (angle increment =  $20^\circ$ ). The annular area, circumference, and motion along the aortic long axis were automatically calculated. LV volumes and ejection fractions (EF) were also determined by RT3DE. Transthoracic RT3DE was performed in 6 healthy volunteers for comparison.

**Results:** A strong correlation between the aortic annular motion from end-diastole to end-systole and EF was observed ( $r = 0.89$ ,  $p < 0.001$ , figure). Ischemic cardiomyopathy patients showed improvement in EF ( $p < 0.01$ ) and aortic annular motion ( $p < 0.02$ ) after IEP. A significant difference between normal and ischemic patients was found in annular motion ( $17 \pm 5$  mm vs  $6 \pm 2$  mm,  $p < 0.0001$ ), but not change in area ( $18 \pm 9\%$  vs  $12 \pm 9\%$ ,  $p > 0.20$ ) or circumference ( $10 \pm 5\%$  vs  $7 \pm 5\%$ ,  $p > 0.25$ ).



**Conclusions:** Resultant aortic annular motion along the aortic long axis can serve as an alternate measure for evaluating LV function, particularly in patients with complex LV geometry. The IEP significantly improved both annular motion and EF.

1144-28 **Simulated Real-Time Myocardial Contrast Echocardiography at a Low Mechanical Index Using Intravenous Definity™**

Thippeswamy H. Murthy, Peng Li, Cheryl Baisch, Paul Widner, William F. Armstrong, Mani Vannan, Sriram Krishnan, Greg Holley. *University of Michigan, Ann Arbor, Michigan; Acuson Corporation, Mountain View, California, USA*

**Background:** Triggered B-Mode harmonic imaging (BHI) using a high mechanical index (MI) is the current standard in myocardial contrast echocardiography (MCE); but tissue harmonic response (THR) confounds detection of microbubble signals, requiring post-processing. With lower MI's, although there is little THR, microbubble harmonic signals are diminished. We used a proprietary non-linear imaging technique (NLIT) to enhance microbubble signals using low MI's with Definity™, an investigational perfluoropropane microbubble (DuPont Pharmaceuticals).

**Methods:** Resting MCE was performed with an Acuson Sequoia ultrasound platform using intravenous Definity™ (3900  $\mu$ L in 25 mL 0.9 NS at 4 mL/min) in 18 healthy volunteers (ages 22–30) selected for good acoustic windows. Triggered NUT (NLIT-tr) was done with MI's of 0.5–0.6, and low frame rate (6–13 Hz) NLIT (NLIT-lfr) was done with MI's of 0.3–0.4 in the

Baseline NLIT-tr NLIT-lfr

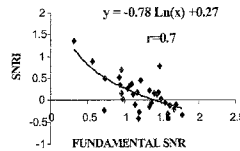




apical 4 C view. Myocardial opacification was quantified with both NLIT-tr and NLIT-lfr to assess the efficacy of Definity™ at a low MI. Average gain-compensated acoustic intensity was quantified on-line at baseline and post contrast using NLIT-lfr in the apical 4-C view at the apex and mid lateral wall.

**Results:** Both NLIT-tr and NLIT-lfr produced excellent myocardial opacification as shown in the representative figure below. Average acoustic density increased from 9.6 (apex) and 12.6 (mid lateral) pre-contrast to 41.6 (apex) and 41.6 (mid lateral) post-contrast (NLIT-lfr). These data correlated well with visual assessment of myocardial opacification.

**Conclusions:** Normal myocardial perfusion can be clearly delineated at low MI's using IV Definity™ with a novel algorithm to detect nonlinear microbubble signals. This approach affords an avenue for real-time MCE with Definity™ in humans.



**Conclusion:** Harmonic imaging improves SNR on the endocardial border, resulting in enhancement of endocardial border visualization. It is most beneficial for patients with poor echo images and low SNR, regardless of age, sex, and body build.

**1144-29 The Qualitative and Quantitative Advantage of Harmonic Contrast Echo**

Tamanna Nahar, Lori B. Croft, Robert Shapiro, Samantha Buckley, Milena Henzlova, Josef Machac, Joseph Diamond, Eric H. Stern, Martin E. Goldman. Mount Sinai Medical Center, NYC, USA

Harmonic (H) contrast (C) echo improves subjective LV endocardial border definition which should translate into better quantification (quant) of LV ejection fraction (EF). However, incorporating contrast requires additional time, expense and I.V. insertion. To determine the individual incremental benefit of H and C imaging we analyzed 2-D echo's obtained in four modes: (1) fundamental (F), (2) Harmonic each (3) with (C+) or (4) without (C-) Optison<sup>®</sup> boluses for 50 pts.. Each study was analyzed subjectively and visually categorized as good or poor (= ≥2 continuous segments poorly seen in 2 or 4 chamber view) and biplane 2-D EF was blindly quantified and compared to radionuclear (RNC) EF done within 12 hours. An accurate 2-D EF was defined as RNC EF ≤ ±5%.

**Results:** Subjective visual assessment of LV function and cavity was significantly better with addition of C and H imaging. Contrast improved Fundamental LV EF quantification (≤ ±5% to RNC) in 9 pts, while contrast added to Harmonic imaging improved quant in 12 pts. About 0.5 the benefit of H:C+ was from Harmonics alone. Importantly, no parameter studied: age, sex, height, weight, LV, EF, LV size, blood pressure, predicted who benefited from either H, C or both.

		F:C-	F:C+	H:C-	H:C+
Visual	Good	6	17	29	44
	Poor	44	33	21	6
Quant	RNC ≤ ±5%	22	22	24	36
	RNC ≥ ±5%	28	28	26	14

Thus, while the impact of contrast added to harmonics (H:C+) for quantification is less than the improvement in subjective reading, H:C+ significantly improves quant compared to F:C+ or H:C-. While previous reports based on subjective readings alone may have overestimated the relative value of contrast echo, accurate echo quantification requires contrast and harmonic imaging in difficult studies.

**1144-30 Who Will Get the Most Benefit From Harmonic Imaging? A Quantitative Analysis With Use of Signal-Noise Ratio Method**

Banithi Khankirawatana, Ping Lu, Leng Jiang. University of Nebraska Medical Center, Omaha, NE, USA

**Background:** Harmonic imaging (HI) has been reported to improve visual identification of endocardial border. However, the effects of these improvements have not been consistent, nor have the factors impacting border enhancement been extensively studied. Therefore, we obtained fundamental imaging (FI) and HI on 34 patients (22 females; mean age 53 years).

**Methods:** To quantitate endocardial border definition, we measured pixel videointensity (PVI) along the LV endocardial zone by mapping PVI of the subendocardial myocardium and its adjacent cavity, and calculated the endocardial signal-noise ratio (SNR). Border enhancement with HI was expressed as SNR increment (SNRI) and obtained as:  $SNRI = \text{mean SNR obtained by HI} - \text{mean SNR obtained by FI}$ . Multiple stepwise linear regression analysis was performed to related SNRI to factors of age, sex, body mass index, body fat, and fundamental SNR.

**Results:** The fundamental SNR was  $1.21 \pm 0.34$ . The SNRI ranged from -0.42 to 1.35. Multiple linear regression found that only the fundamental SNR made an independently significant contribution to the SNRI with HI ( $p < 0.001$ ). SNRI was negatively correlated with the fundamental SNR ( $p < 0.001$ ).

**1144-31 Doppler Tissue Velocity Improves the Sensitivity and Specificity of Wall Motion Analysis of the Basal Inferior Wall**

Tasneem Z. Naqvi, Greg Neyman, Anatoly Brody, Robert J. Siegel. Cedars-Sinai Medical Center/UCLA School of Medicine, Los Angeles, CA, USA

**Background:** Wall motion assessment of the basal inferior wall by 2D echocardiography is frequently problematic. Myocardial pulsed wave Doppler tissue imaging (DTI) velocity measurement of the basal inferior wall may improve this assessment.

**Methods:** We performed pulsed wave DTI using transthoracic echocardiography in 37 patients with a normal 2D echocardiograms, age  $56 \pm 17$  y, 26 patients with inferior myocardial infarction (MI), age  $71 \pm 13$  y, and no other regional wall motion or valvular abnormality, and 26 patients with left ventricular hypertrophy (LVH), age  $69 \pm 15$  y with normal wall motion and without valvular abnormality. Pulsed wave DTI velocities were obtained from basal inferior wall in apical 2 chamber view. Values are mean ± SD.

**Results:**

Variables	Normal	Inferior MI	LVH
Pulsed Wave DTI			
S (m/sec)	$0.096 \pm 0.02$	$0.076 \pm 0.01^{*†}$	$0.087 \pm 0.02$
E (m/sec)	$0.12 \pm 0.04$	$0.073 \pm 0.03^{*†}$	$0.085 \pm 0.03^{*}$
A (m/sec)	$0.11 \pm 0.03$	$0.09 \pm 0.02^{*†}$	$0.11 \pm 0.03$
2-D Echocardiographic			
LVEF (%)	$59 \pm 6$	$54 \pm 10^{*}$	$57 \pm 6$
LV mass (gms/BMI)	$5.9 \pm 1.8$	$8.6 \pm 2.6^{*}$	$10.2 \pm 3^{*}$

\*p < 0.05 vs. N, †p < 0.05 vs LVH.

The sum of DTI systolic (S) and diastolic (E+A) waves resulted in a sensitivity and specificity of 81% and 72% to detect MI vs normal and 65% and 68% to detect MI vs LVH. S, E and A waves were different among groups adjusting for age, LV ejection fraction and LV mass by ANCOVA.

**Conclusion:** Pulsed wave DTI by 2D echocardiography allows differentiation of hypokinetic basal inferior wall motion in patients thereby improving the sensitivity and specificity of wall motion analysis by transthoracic echocardiography.

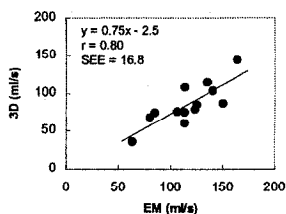
**1144-32 Quantification of the Volumetric Flow Rate Using Real-Time 3D (RT3D) Color Doppler Echocardiography: An Animal Study**

Hiroyuki Tsujino, Michael Jones<sup>1</sup>, Takahiro Shiota, Jian Xin Qin, Lisa A. Cardon, Annitta J. Morehead, Arthur D. Zetts<sup>1</sup>, Fabrice Bauer, Agnese Travaglini, Neil L. Greenberg, Julio A. Panza<sup>1</sup>, James D. Thomas. The Cleveland Clinic Foundation, Cleveland, OH; <sup>1</sup>NIH, Bethesda, MD, USA

**Background:** RT3D color Doppler allows one to obtain an entire cross-sectional velocity distribution (c-plane) of the left ventricular outflow tract (LVOT), which is not possible using conventional 2D echo. The aim of this study was therefore to determine the feasibility of flow quantification using the RT3D cross-sectional image of the LVOT.

**Methods:** A total of twelve different hemodynamic conditions were created in 4 sheep. By using RT3D color Doppler, the cross-sectional color images of the LVOT at peak systole were derived and digitally transferred to a PC to visualize and quantify spatial velocity distributions and peak flow rates. An electromagnetic (EM) flow probe was utilized to obtain reference LVOT flow rates.

**Results:** In the LVOT, markedly skewed profiles with higher velocities at the septum were consistently observed. There was a good linear relationship between EM (range, 63–163 ml/s) and 3D peak flow rates ( $r = 0.80$ ,  $y = 0.75x - 2.5$ ,  $p < 0.01$ ), but with an underestimation (mean difference =  $-28 \pm 14\%$ ), probably primarily due to low temporal resolution of 6–10 volumes per second.



**Conclusions:** Using the unique c-plane, RT3D color Doppler imaged the cross-sectional spatial velocity distributions in the LVOT. Estimations of peak flow rates were possible without any assumptions about flow velocity distribution, demonstrating the capability of this new method to provide better understanding and quantification of blood flow phenomena.

## POSTER

### 1145 Computed Tomography: Coronary Calcification, Myocardial Perfusion

Tuesday, March 14, 2000, 9:00 a.m.–11:00 a.m.  
Anaheim Convention Center, Hall A  
Presentation Hour: 9:00 a.m.–10:00 a.m.

### 1145-33 Prognostic Value of Coronary Calcification in a Chest Pain Population

Matthew J. Budoff, Eric S. Kaufer, Jay Han, Songshou Mao, Bruce H. Brundage. Harbor-UCLA Medical Center, Torrance, California, USA

To evaluate the prognostic power of coronary calcification, as measured by electron beam computed tomography (EBCT), in a population of 221 patients admitted to the emergency room with chest pain. We conducted a prospective, observational study of 221 patients admitted to the emergency department of a large tertiary care hospital for chest pain. Patients underwent EBCT scanning at the time of admission, and were followed for coronary events over the subsequent 7 years.

**Results:** Of the 221 patients, follow-up was obtained in 196 patients (89%). Average follow-up was  $37 \pm 10$  months (1 to 82 months). In the 192 patients with follow-up (124 males, 68 females), there were 22 (11.4%) hard events (10 cardiac deaths, 12 non-fatal myocardial infarctions) and 25 (14.8%) other cardiac events (8 bypass surgeries, 4 angioplasties and 10 hospitalizations for angina, and 3 ischemic strokes). In total, 41 subjects (21%) had 47 cardiovascular events, in which coronary calcium was detected (EBCT score  $>0$ ) in 39 patients (95%), with a mean score of  $459 \pm 631$ . Of the 151 patients without events, the mean score was  $191 \pm 370$ , significantly less than the event group ( $p < 0.001$ ). The median score in the total population was 4. Four patients with any cardiac event had a score  $<4$ , and 37 subjects had scores  $>4$  (9.25X increased risk, 95% CI 3.6–16.3,  $p < 0.001$ ). Of hard cardiac events, 2 had scores  $<4$ , and 18 persons had EBCT scores  $>4$  (0.5X increased risk, 95% CI 1.9–34.4,  $p < 0.001$ ). The likelihood of a coronary event increased with the total calcium score ( $p < 0.001$ ).

**Conclusion:** The presence of coronary calcification, as detected by electron beam computed tomography, is a strong predictor of future cardiovascular events.

### 1145-34 Impact of Age and Ethnicity on Coronary Calcification in the Women's Health Initiative Observational Study

Charan Khurana, Cynthia Archer, Barbara V. Howard, Lucile Adams-Campbell, Judith Hsia. George Washington University, Howard University and Medstar, Washington, DC, USA

**Background:** Coronary artery calcification, assessed by electron beam computed tomography (EBCT), predicts coronary risk. The goal of this study was to assess the impact of ethnicity on calcium scores in white and African-American (AA) women in the Observational Study (OS) of the Women's Health Initiative.

**Methods:** The OS is a large, population-based study of postmenopausal women 50–79 years of age. Participants provide data on a wide range of anthropometric and health variables. OS participants at the George Washington and Howard/Medstar clinics ( $n = 4435$ ) were invited for EBCT. Thirty contiguous 3-mm slices (100 ms/slice) were acquired during a single breath hold using an Imatron C-150 scanner. Total calcium score was determined using the Agatston method.

**Results:** EBCT was performed on 688 white and 111 AA women, mean age  $63 \pm 8$  years. AA women reported hypertension ( $p < 0.001$ ) and diabetes

( $p < 0.05$ ) more frequently than white women; family history of premature coronary disease, current smoking and hyperlipidemia were reported with similar frequency.

Calcium score (mean  $\pm$  SE)

Age, y	White	African-American	P value
50–59	$24 \pm 5$	$4 \pm 2$	$<0.0001$
60–69	$77 \pm 15$	$94 \pm 30$	NS
$\geq 70$	$179 \pm 26$	$251 \pm 133$	$<0.01$

In their 50's, white women were more likely to have moderate or significant calcification (10 vs 0%,  $p < 0.05$ ), whereas among women 60 and older, AA were more likely to have moderate/significant calcification (37 vs 27%,  $p < 0.01$ ). Thus, AA women in their 50's had lower calcium scores than white women, whereas AA women 70 years and older had higher calcium scores than white women. In multiple regression analysis, a significant interaction was apparent between age and ethnicity ( $p < 0.02$ ). While age was the most important independent determinant of calcium score for each ethnic group, the relationship between age and coronary calcium appeared to differ in white and AA women.

**Conclusion:** The time course of coronary calcification may differ in AA compared with white postmenopausal women.

### 1145-35 National Guidelines may not Accurately Reflect Atherosclerosis Risk in Women as Defined by Electron Beam Tomography

H. Robert Superko, Harvey S. Hecht. Berkeley HeartLab, University of California, Berkeley, California; Arizona Heart Institute, Phoenix, Arizona, USA

**Background:** National cholesterol guidelines are not gender specific and may not adequately predict CAD risk in women.

**Methods:** We examined whether National Cholesterol Education Program (NCEP) guidelines for determining CAD risk correlated with the presence of subclinical CAD as defined by Electron Beam Computerized Tomography (EBCT) in 364 consecutive asymptomatic female subjects who were screened to detect coronary calcium (EBCT+) or no coronary calcium (EBCT-). Fasting plasma lipid values were determined by enzymatic methods.

**Results:** EBCT+ women were older ( $62 \pm 11$  vs.  $53 \pm 10$  years,  $p < 0.0001$ ) than EBCT- women but there was no difference in BMI. In EBCT+ women total and LDLC were significantly higher compared to EBCT-women ( $226 \pm 42$  vs.  $211 \pm 43$ ,  $p < 0.002$ ;  $132 \pm 41$  vs.  $121 \pm 38$  mg/dl,  $p < 0.01$ ). There was no difference in HDLC or triglycerides. NCEP Low Risk women are classified as those who met NCEP recommendations of LDLC  $<130$  and HDLC  $>35$  mg/dl. Age adjusted calcium percentiles were significantly higher in the EBCT+ women  $\leq 55$  years compared to those  $>55$  years ( $83 \pm 15$  vs  $70 \pm 21$ ,  $p < 0.001$ ). The table illustrates differences in women  $\leq 55$  years of age or  $>55$  years old.

	EBCT+ $\leq 55$	EBCT- $\leq 55$	p	EBCT+ $>55$	EBCT- $>55$	p
N	41	129	113	81		
LDLC	$136 \pm 40$	$117 \pm 41$	0.01	$130 \pm 41$	$127 \pm 32$	0.54
HDLC	$62.3 \pm 15$	$65.2 \pm 21$	0.41	$66.8 \pm 20$	$66.9 \pm 16$	0.98
NCEP Low	46%	69%	50%	54%		

**Conclusion:** Total and LDLC values are related to coronary calcification in women  $\leq 55$  years but not those  $>55$  years. However, 46% of women  $\leq 55$  yrs were at low risk according to NCEP LDLC and HDLC guidelines, yet exhibited coronary calcification. NCEP LDLC and HDLC guidelines are not adequate to identify high CAD risk women of any age.

### 1145-36 Coronary Artery Calcification in Diabetes Mellitus

Judith Hsia, Pamela Walker, Joseph Frenkel, Richard J. Katz, Alan G. Wasserman. George Washington University, Washington, DC, USA

**Background:** Coronary heart disease (CHD) is the leading cause of death in patients with diabetes mellitus. Since ischemia in these patients is often silent, new CHD screening methods are needed. We assessed electron beam computed tomography (EBCT) as a screening strategy in this population.

**Methods:** Retrospective analysis of calcium scores (Agatston method) in 2382 subjects without known CHD undergoing EBCT.

**Results:** The analysis included 2214 subjects without diabetes and 168 with diabetes, 6% on insulin. Patients with diabetes were older ( $57 \pm 9$  vs  $54 \pm 11$  years,  $p = 0.0004$ ), more likely to report hyperlipidemia (26% vs 17%,  $p < 0.005$ ), family history of premature CHD (18% vs 9,  $p < 0.001$ ) and had higher body mass index for all ages (eg.  $31 \pm 6$  vs  $27 \pm 4$  kg/m<sup>2</sup>,  $p < 0.0001$  for ages 50–59). The two groups had similar proportions of women

(32% vs 41%), hypertensives (30% vs 28%) and current smokers (8% vs 5%). EBCT calcium scores were higher among patients of all ages with diabetes.

Coronary calcium scores in subjects with and without diabetes mellitus

Age, y	n	No DM	n	DM	p value
<50	617	33 ± 164	32	383 ± 989	<0.0001
50–59	956	88 ± 272	70	185 ± 671	0.013
60–69	438	158 ± 35	50	514 ± 738	0.0001
>70	180	332 ± 542	16	848 ± 1245	0.0019

In multivariate analysis, diabetes was a potent independent determinant of calcium score, second only to age. Calcium score was influenced less by gender and current smoking, and was not independently associated with hyperlipidemia, hypertension, family history or body mass index.

**Conclusion:** Diabetes mellitus is a potent independent determinant of EBCT coronary calcium score; EBCT is a potentially cost-effective approach to CHD screening in patients with diabetes mellitus.

**1145-37 Electron Beam CT-Determined Coronary Artery Calcium is Correlated With Parameters of the Insulin Resistance Syndrome**

Yadon Arad, David Newstein, Marguerite Roth, Alan D. Guerci. *St. Francis Hospital, Roslyn, New York, USA*

**Background:** The Insulin Resistance Syndrome is associated with higher risk of atherosclerosis. Coronary electron beam CT (EBCT)-derived calcium scores (CAC) accurately quantify the extent of coronary atherosclerosis and predicts the risk of future cardiovascular events even in asymptomatic subjects.

**Methods:** We measured parameters of the Insulin Resistance Syndrome (IRS) and coronary calcium in 1006 asymptomatic, men and women without history of diabetes, randomly selected from 5000 subjects screened for a population-based natural history study. We measured fasting total cholesterol, LDL, HDL, Triglycerides, blood pressure, glucose and insulin (fasting and 2-hour after 75 g of oral glucose), and indices of central obesity (COB): waist/hip ratio, abdominal height, intra-abdominal fat (by EBCT), as well as and abdominal subcutaneous fat).

**Results:** In univariate analysis, the strongest correlation of CAC was with COB ( $r = 0.20-0.32$ ,  $p < 0.0001$ ) followed by age ( $r = 0.23$ ,  $p < 0.0001$ ), total cholesterol/HDL ( $R = 0.21$ ,  $p < 0.0001$ ), HDL ( $r = -0.20$ ,  $p < 0.0001$ ), blood pressure total cholesterol ( $r = 0.18$ ,  $p < 0.0001$ ), triglycerides ( $r = 0.17$ ,  $p < 0.0001$ ), fasting glucose and insulin ( $r = 0.12$ ,  $0.13$ ,  $p < 0.0001$ ), 2-hour glucose and insulin ( $r = 0.09$ ,  $0.10$ ,  $p < 0.002$ ) and LDL ( $r = 0.07$ ,  $p = 0.017$ ) but not with subcutaneous fat. COB was strongly associated with blood pressure, total cholesterol, glucose, triglycerides and insulin ( $r = 0.26-0.53$ ,  $p < 0.0001$  for all). These correlations remained significant when the analysis was restricted to subjects with a fasting glucose  $<126$ . An increased number of IRS parameters (COB, HDL  $<35$ , glucose  $>126$  or insulin above the median, elevated blood pressure, increased total cholesterol, triglycerides  $>200$ ) correlated with progressively increased CAC ( $p$  for trend  $<0.0001$ ). In a stepwise multivariate regression analysis, abdominal height was the fourth strongest predictor of CAC, preceded by age, gender and a family history of premature CAD, and followed by LDL, current smoking and waist/hip ratio. The associations with HDL, blood pressure, total cholesterol, glucose and insulin were no longer significant.

**Conclusions:** IRS, and in particular COB, is a strongly associated with pre-clinical atherosclerosis (determined by EBCT) in asymptomatic, non-diabetic subjects.

**1145-38 Noninvasive Angiography With Multi-Detector Helical Computed Tomography for Evaluation of Coronary Artery Disease**

Andreas Knez, Christoph Becker<sup>1</sup>, Alexander Leber, Alexander Becker, Roland Bruening<sup>1</sup>, Maximilian Reiser<sup>1</sup>, Ralph Haberl. *Medical Hospital; <sup>1</sup>Department of Radiology, University of Munich, Munich, Germany*

**Background:** Contrast enhanced angiography of the coronary vessels with conventional computed tomography (CT) is limited by low spatial and temporal resolution and lack of ECG-trigger. The aim of this study was the determine the diagnostic accuracy of a new Multi-Detector Helical CT (= MDCT, Somatom Plus4VZ, Siemens) in the assessment of coronary artery stenosis.

**Methods:** In 60 patients with suspected coronary artery disease ( $m = 49$ ,  $f = 11$ ), age  $57 \pm 7$  y, MDCT scans and conventional angiography has been performed within  $2 \pm 1$  days. For MDCT scans, after injection of 140 ccm contrast media, the whole heart was covered within  $20 \pm 4$  sec, with acquisition of four axial slices simultaneously, in one single breathhold (slice

thickness = 1 mm, acquisition time = 250 msec) with registration of the ECG signal. This technique allows an individual retrospective ECG-gating to get nearly motion free cardiac images. For 3D-reconstruction (maximum intensity projection, volume rendering) all axial images were transferred and analyzed by two independent investigators on an external workstation (Insight, Neomagery, USA) recording the maximum percent stenosis in each vessel and then compared with conventional angiograms.

**Results:** With MDCT 25 vessels (RCA = 12, LAD = 2, RCx = 11) had to be excluded from analysis due to poor image quality. In by MDCT assessable vessels 51/59 stenosis  $>50\%$  were correctly diagnosed (Sensitivity = 86%) and MDCT correctly identified 95/106 angiographically nonobstructed vessels (Specificity = 90%). False negative results in five cases were caused by extensive calcification and in three cases by overlaying anatomic structures. False positive results were due to motion artifacts in five cases and in six cases due to insufficient opacification.

**Conclusion:** Multi-Detector Helical CT with retrospective ECG-gating allows to rule out and to determine coronary artery disease with high accuracy. Therefore MDCT is a promising, cost effective, imaging modality in the noninvasive diagnosis of coronary artery disease.

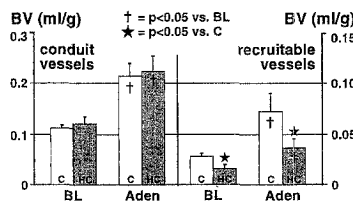
**1145-39 Quantitative Evaluation of Intramyocardial Microvascular Function in Hypercholesterolemic Pigs Using Electron Beam Computed Tomography**

Stefan Möhlenkamp<sup>1</sup>, Amir Lerman<sup>2</sup>, Lilach O. Lerman<sup>2</sup>, Patrick F. Sheedy<sup>3</sup>, Thomas R. Behrenbeck<sup>2</sup>, Erik L. Ritman<sup>1</sup>. *<sup>1</sup>Depts of Physiology; <sup>2</sup>Internal Medicine; <sup>3</sup>Radiology, Mayo Clinic, Rochester, MN, USA*

**Background:** Electron Beam CT (EBCT) based indicator dilution methods provide non-invasive quantitative estimates of intramyocardial blood volume (BV, ml/g) and perfusion (F, ml/g/min). The relationship  $BV = aF + b\sqrt{F}$  allows quantitation specifically of BV in recruitable (primarily terminal arterioles and capillaries) and non-recruitable (conduit) microvessels. Diet-induced experimental hypercholesterolemia (HC) induces functional impairment of the porcine coronary microvasculature. We sought to quantitate the response of the different microvascular components to adenosine in HC pigs.

**Methods:** In 12 HC- and 10 control (C) pigs, BV and F of the anterior cardiac wall were obtained in contrast-enhanced EBCT scans (IV iopamidol, 0.33 ml/kg over 2 sec) at baseline (BL) and after 5 min of continuous intracoronary (LAD) infusion of aden ( $100 \mu\text{g}/\text{kg}/\text{min}$ ).

**Results:** BV increased in recruitable and conduit vessels both in HC and control pigs (Fig). In recruitable vessels, BV was lower at baseline and after aden in HC pigs vs. controls (Fig). The increase in BV in recruitable vessels in response to aden was lower in HC pigs vs. controls (0.02 ml/g vs. 0.044 ml/g,  $p < 0.001$ ).



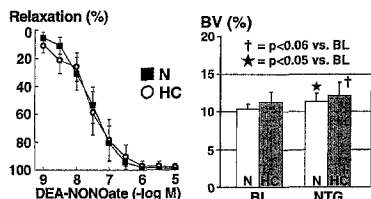
**Conclusion:** EBCT estimates of blood volume and perfusion allow non-invasive quantitative evaluation of functional components in the myocardial microvasculature. This study supports a role for EBCT as a non-invasive test for quantifying intramyocardial blood volume in pathophysiological states such as HC.

**1145-40 Comparison of In-Vivo With In-Vitro Assessment of Intramyocardial Resistance Vessel Function in Hypercholesterolemic Pigs**

Stefan Möhlenkamp<sup>1</sup>, Zvonimir S. Katusic<sup>2</sup>, Amir Lerman<sup>3</sup>, Leslie Smith<sup>2</sup>, Lilach O. Lerman<sup>3</sup>, Thomas R. Behrenbeck<sup>3</sup>, Patrick F. Sheedy<sup>4</sup>, Erik L. Ritman<sup>1</sup>. *<sup>1</sup>Depts of Physiology; <sup>2</sup>Anesthesia Research; <sup>3</sup>Internal Medicine; <sup>4</sup>Diagnostic Radiology, Mayo Clinic, Rochester, MN, USA*

**Background:** The function of intramyocardial microvessels plays an important role in the regulation of myocardial perfusion in normal and pathophysiological states. In-vivo fast-CT (EBCT)-based indicator-dilution methods provide an estimate of intramyocardial fractional blood volume (BV) and perfusion (F), which relate as  $BV = aF + b\sqrt{F}$ . From  $b\sqrt{F}$ , the BV in intramyocardial microvascular resistance vessels can be calculated. We sought to study the response of resistance vessels using EBCT in comparison to in-vitro videomicroscopy (VMS) in normal (N) and hypercholesterolemic (HC) pigs.

**Methods:** BY and F values were obtained from contrast enhanced EBCT studies (contrast agent: Iopamidol, 0.33 ml/kg iv over 2 sec) in 12 HC and 10 N pigs at baseline (BL, infusion of normal saline) and after 5 min of intracoronary infusion of nitroglycerine (NTG, 40  $\mu$ g/min, affecting primarily vessels with diameters  $>200 \mu$ m). In-vitro relaxation of harvested resistance vessels (diameter  $\approx 300 \mu$ m) in response to the Nitric-Oxide (NO) donor Diethylamine (DEA)-NONOate was studied 2 days later using VMS.



**Results:** We found a similar response to NO-donors in HC vs. normal pigs both as per relaxation in-vitro (Fig0.1) and as per BV in vivo (Fig0.2). This increase in BV was significant for normal pigs and showed a strong trend in HC pigs (Fig0.2).

**Conclusion:** EBCT allows non-invasive quantification of vasodilatation in intramyocardial resistance vessels as per changes in blood volume, which may be of diagnostic value in diseases that affect the coronary microcirculation.

## ORAL

### 806 Cardiac Magnetic Resonance Imaging: Left Ventricular Function, Myocardial Viability

Tuesday, March 14, 2000, 10:30 a.m.–Noon  
Hilton Anaheim, California A

10:30 a.m.

### 806-1 Fast Automated Assessment of Regional Left Ventricular Function From Tagged Cardiac Images by Harmonic Phase Magnetic Resonance Imaging

Jerome Garot, David A. Bluemke, Nael F. Osman, Carlos E. Rochitte, Elliot R. McVeigh, Elias A. Zerhouni, Jerry L. Prince, João A.C. Lima. *The Johns Hopkins Medical Institutions, Baltimore, MD, USA*

**Background:** On-line quantitative monitoring of regional LV function from tagged MRI during stress testing is unavailable due to the lack of fast analytical techniques. We evaluated the accuracy of harmonic phase (HARP) MRI, a novel method of fast automated myocardial strain analysis. In HARP images, the phase components extracted from isolated spectral peaks in the Fourier domain are linearly related to tag motion. They were used to construct myocardial strain fields during dobutamine (DOB) stress and in patients with wall motion abnormalities caused by myocardial ischemia.

**Methods:** We studied 10 healthy volunteers with SPAMM tagged MRI at baseline (BL) and during 5 and 20  $\mu$ g.kg<sup>-1</sup>.min<sup>-1</sup> DOB, and 9 post-infarct patients at rest. We compared 2D circumferential shortening (Ecc), maximal shortening (E<sub>2</sub>), and its angular orientation, as assessed transmurally in the entire LV by HARP and by the conventional motion tracking technique based on operator assisted delineation of border and tag contours.

**Results:** Full quantitative analysis of data was much faster by HARP (typically 3 min vs. 3 hours for a single patient). For the pooled data, correlations were  $r = 0.93, 0.93$  and  $0.93$ , for Ecc, E<sub>2</sub> and E<sub>2</sub> angle. For each strain, mean differences between both methods were not clinically relevant (<2%,  $p = \text{NS}$ ). In volunteers, strains augmented from BL to 5  $\mu$ g and peak DOB ( $-23 \pm 4$  to  $-25 \pm 5$  and to  $-30 \pm 4\%$  in subendocardium; and  $-17 \pm 4$  to  $-18 \pm 4$  and to  $-21 \pm 4\%$  in subepicardium, for E<sub>2</sub>  $p < 0.01$ ) by the two methods. E<sub>2</sub> angle shifted away from the circumferential direction at peak DOB vs. BL ( $18 \pm 6$  vs.  $12 \pm 5^\circ$ ,  $p < 0.01$ ). Strains increased similarly at peak DOB in subendo and subepi (22.4 and 21.6% for Ecc, 27.2 and 26.5% for E<sub>2</sub>), and greater in septum than in free wall (24.1 vs. 14.6%, and 27.6 vs. 16.1%,  $p < 0.01$ ). When using myocardial wall thickening from cine-MR images as a gold standard for assessment of regional LV function in patients, HARP-determined Ecc and E<sub>2</sub> were clearly reduced in the asynergic segments as compared to remote ( $-5.3 \pm 5.8$  vs.  $-18.2 \pm 4.8\%$ , and  $-11.8 \pm 5.5$  vs.  $-20.6 \pm 5.4\%$ , in subendo, respectively) and E<sub>2</sub> angle shifted further away from the circumferential direction ( $36.2 \pm 17.8$  vs.  $18.8 \pm 9.2^\circ$ ,  $p < 0.001$ ).

**Conclusions:** HARP MRI provides fast accurate measurements of 2D myocardial strain from tagged MR images, enabling on-line quantitative assessment of segmental LV function during stress testing.

### 806-2 LV Ejection Fraction Following Acute MI: Echo, MUGA and MRI-Preliminary Results From the MARRVEL Study

Nathaniel Reichel, Diane Vido, Leon Axel, Dudley Pennell, Antonello Zoni, Markus Jochims, Inder Anand, Albert C. van Rossum, Edward Shapiro, Yeon Heon Choe, Christine Lorenz. *For the MARRVEL Investigators; Allegheny General Hospital, MCP/Hahnemann School of Medicine, Pittsburgh, PA, USA*

LV ejection fraction (EF) is a major determinant of outcome after acute MI, but the performance of alternative imaging methods in this population with distorted LV geometry is not well defined. MARRVEL prospectively compares accuracy and utility of EF by 2D echo and MUGA to reference MRI EF in high-risk patients with acute MI and LV EF  $< 40\%$  on an initial clinical test. An interim analysis was performed in 34 patients: mean age  $59 \pm 13$  yrs; 30 male; 30 reperfused (15 thrombolysis, 15 PTCA); 12 anterior, 7 inferoposterior, 7 non-Q infarctions, 8 other. Interval from MI to MRI imaging was  $8.1 \pm 4.7$  days and mean follow-up 11.8 months. Short axis breath-hold cine MRI, apical biplane 2D echo (Simpson's rule) and LAO MUGA studies were analyzed at separate core laboratories in blinded fashion. Inter-test agreement and the ability of EF by each test to risk stratify patients for CHF and/or death were examined. The correlation between 2D echo EF and MRI EF was weak ( $r = 0.15$ ,  $p = \text{ns}$ ,  $n = 34$ ) and Bland Altman limits of agreement were very wide ( $\pm 25.5\%$ ). Overall, 10/34 (29.4%) patients were misclassified by 2D echo for EF  $< 30\%$ , including 9/10 with MRI EF  $< 30\%$ , while 12/34 (35%) were misclassified for EF  $< 40\%$ . MUGA and MRI correlated better ( $r = 0.77$ ,  $p < 0.001$ ,  $n = 25$ ), but the slope of the relationship was only 0.6 and the limits of agreement were  $\pm 14.8\%$ . MUGA misclassified for EF  $< 30\%$  in 4/25 patients (16%) and for EF  $< 40\%$  in 7/25 patients (28%). To date, 13 patients have experienced CHF or death within 1 year. Neither MUGA nor echo EF  $< 30\%$  altered the risk ratio for adverse outcomes, but MRI EF  $< 30\%$  was associated with a risk ratio of 2.1 (5 of 8 pts., 62.5%, had events) relative to EF  $> 30\%$  (7 of 24 pts., 29.2%, had events,  $p = 0.11$ ,  $n = 32$ ). Thus, the ability of 2D echo and MUGA to determine EF in post-MI patients is suboptimal when compared to an in vivo reference method. Improved EF determination may result in improved risk stratification for adverse outcomes.

11:00 a.m.

### 806-3 Complete Evaluation of Left Ventricular Volume and Mass in Less Than 5 Minutes With Real-Time Interactive Cardiac Magnetic Resonance Imaging System

Shuichiro Kaji, Phillip C. Yang, Adam B. Kerr, Craig H. Meyer, John M. Pauly, Bob S. Hu. *Division of Cardiovascular Medicine, Stanford University School of Medicine, Stanford, CA, USA*

**Background:** While magnetic resonance imaging (MRI) provides accurate assessment of left ventricular (LV) volume and function, most techniques have been relatively slow and required ECG gating to allow averaging of many heart beats. In contrast, a newly developed cardiac MRI system allows continuous real-time dynamic acquisition and display of any scan plane at up to 30 images/s without cardiac gating or breath-holding. The purpose of this study was to validate cardiac measurements derived from real-time cardiac MRI as compared with the well validated conventional cine MRI.

**Methods:** Eight healthy subjects underwent real-time cardiac MRI and cine MRI in the short axis orientation on a standard 1.5T MRI scanner. Non-breath-hold cine MRI were obtained with ECG gating and flow and respiratory compensation. Nine levels were obtained to encompass the entire LV. Measurements were obtained of end-diastolic volume (LVEDV), end-systolic volume (LVESV), ejection fraction (EF), and LV mass.

**Results:** The acquisition time for real-time cardiac MRI was significantly shorter than that for cine MRI ( $1 \pm 0$  versus  $13 \pm 2$  minutes,  $p < 0.001$ ). Both imaging techniques yielded good quality images allowing LV volumetrics. The measurements of LVEDV, LVESV, EF and LV mass obtained with real-time cardiac MRI showed close correlation with those obtained with conventional cine MRI (LVEDV:  $r = 0.98$ ,  $p < 0.001$ , LVESV:  $r = 0.96$ ,  $p < 0.001$ , EF:  $r = 0.76$ ,  $p < 0.05$ , LV mass:  $r = 0.91$ ,  $p < 0.001$ ).

**Conclusion:** Real-time cardiac MRI provides accurate measurements of LV function and mass in a time-efficient manner.

11:15 a.m.

ORAL

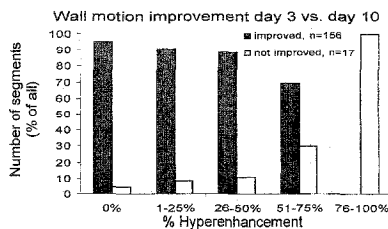
**806-4 Detection of Salvaged Myocardium by Contrast Enhanced Magnetic Resonance Imaging**

Hanns B. Hillenbrand, David S. Fieno, Raymond J. Kim, Francis J. Klocke, Robert M. Judd. *Feinberg Cardiovascular Research Institute, Northwestern University, Chicago, IL, USA*

**Background:** The determination of myocardial viability is an important question in clinical cardiology. Contrast enhanced MRI using Gd-DTPA (ceMRI) has been shown to delineate myocardial infarction (MI). We hypothesized that the recovery of wall motion in stunned versus infarcted myocardium can be predicted by the extent of hyperenhancement in ceMRI on a segmental basis.

**Methods:** MI was induced in six dogs by ligation of the LAD coronary artery for 45 min, 90 min or permanently. CeMRI and spatially matched cineMRI (same slice thickness) were performed on days 3, 10 and 28 post-infarction. For each dog the extent of MI was measured on day 3 post-infarction by ceMRI in 4 to 6 short axis slices, each divided into 12 sectors (n = 311). Corresponding wall motion was analyzed for each segment by two independent observers, blinded to the result of ceMRI on days 3, 10 and 28 post-infarction (n = 933).

**Results:** On day 3 wall motion was read abnormal in 173 segments. Of these, 90% had improved by day 10 and 95% had improved by day 28 post-infarction. The likelihood of segmental wall motion improvement decreased with increased transmural extent of the infarct (see graph).



**Conclusion:** Recovery of wall motion after coronary occlusion is related to the transmural extent of MI and can be predicted by ceMRI.

11:30 a.m.

**806-5 Delayed-Enhancement MRI for Fast and Accurate Assessment of Myocardial Viability: Comparison With Combined Cine, Tagging and First-Pass Perfusion Techniques in 102 Patients**

Paulo R. Schwartzman, Scott D. Flamm, Jane M. Kasper, Joan A. Weaver, Nancy A. Obuchowski, Orlando P. Simonetti, Richard D. White. *Cleveland Clinic Foundation, Cleveland, Ohio, USA*

**Background:** The delayed-enhanced (DE) MRI technique is able to differentiate viable myocardium (VM) from necrotic myocardium (NM) in patients with ischemic heart disease.

**Objective:** To compare accuracy of DE-MRI versus the combination of established MRI techniques for identification of VM and NM.

**Methods:** 102 patients (76 men; age 60.6 ± 11.9) with history of ischemic heart disease underwent a complete resting MRI (combined cine, tagging and first-pass perfusion). Three short-axis slices (10 mm thick, FOV 280, 128 × 256 matrix) from the left ventricle (basal, middle and apical) were acquired. Segmental NM was identified as an area of akinesia or dyskinesia (cine and tagging) along with a fixed perfusion defect (first-pass imaging during 0.2 mmol/kg Gd-DTPA administration). The DE-technique was an ECG triggered inversion-recovery segmented k-space FLASH sequence; images were acquired 30 minutes after GD-DTPA. NM was identified as area of hyperenhancement and VM as area of nulled signal. All studies were analyzed blindly using a 16-segment model.

**Results:** For the 1632 segments analyzed, results are tabulated below according to the relative amount of NM per segment on DE-MRI versus NM on combined MRI.

% NM/Segment	Sensitivity	Specificity
≥1%	100%	35%
≥25%	99%	70%
≥50%	88%	91%
≥75%	73%	98%
100%	32%	100%

**Conclusion:** The single DE-MRI sequence is a fast and accurate technique for evaluation of VM and NM. Potential advantages include direct visualization of patchy and subendocardial scar which may give the false appearance of complete necrosis on standard MRI techniques.

**876 Diastology: Novel Hemodynamic Insights**

Tuesday, March 14, 2000, 10:30 a.m.–Noon  
Hilton Anaheim, California B

10:30 a.m.

**876-1 Accuracy of Doppler Echocardiography for Estimation of Left Ventricular Filling Pressure: A Simultaneous Doppler-Catheterization Study**

Steve R. Ommen, Rick A. Nishimura, Christopher P. Appleton, Fletcher A. Miller, Jae K. Oh, Margaret M. Redfield, A. Jamil Tajik. *Mayo Clinic and Mayo Foundation, Rochester, MN; Mayo Clinic, Scottsdale, AZ, USA*

**Background:** Noninvasive assessment of diastolic filling by Doppler echocardiography provides diagnostic and prognostic information about the status of the left ventricle in selected subsets of patients. Tissue Doppler imaging (TDI) of the mitral annulus has been proposed as a new marker of diastolic performance. This study was designed to assess whether mitral annular velocities are associated with invasive measures of diastolic LV performance and whether additional information is gained over traditional Doppler variables.

**Methods:** 100 consecutive patients referred for cardiac catheterization underwent simultaneous Doppler interrogation. Invasive measurements of left ventricular pressures were obtained with micromanometer tipped catheters. Doppler signals from the mitral inflow, pulmonary venous inflow, and TDI of the mitral annulus were obtained.

**Results:** TDI and mitral inflow were adequately obtained in >90% of patients, compared with <80% for pulmonary veins and Valsalva maneuver. Isolated parameters of transmitral flow correlated with left atrial pressure (LAP) only in patients with EF < 50%. The ratio of mitral E to early diastolic velocity of the mitral annulus (E/E') showed a better correlation with LAP than did the change in the mitral flow velocity curve during preload reduction or combined data from the mitral and pulmonary venous flow for all levels of systolic function. E/E' < 8 accurately predicted normal LAP and E/E' > 15 identified patients with increased LAP. Wide variability was present in those with E/E' 8–15. A subset of those patients E/E' between 8–15 could be further defined using other two-dimensional and Doppler data.

**Conclusion:** The combination of tissue Doppler of the mitral annulus and mitral inflow velocity curves provide better estimates of LV filling pressures than other methods (pulmonary vein, preload reduction). However, accurate prediction of filling pressures for an individual patient with preserved systolic function requires a stepwise approach using all available data.

10:45 a.m.

**876-2 Influence of Left Ventricular Systolic Function on Flow Propagation During Early Diastolic Filling Assessed by Color M-Mode Doppler**

Karl Dennig, Ullrich H. Haase, Albert Schömig. *Deutsches Herzzentrum and 1. Medizinische Klinik, TU Muenchen, Munich, Germany*

**Background:** Several studies demonstrated an association between delayed LV relaxation and a reduced flow propagation velocity (v<sub>p</sub>) of early LV filling determined by color M-mode Doppler. We sought to assess whether relaxation abnormalities are invariably associated with a reduced v<sub>p</sub> or if other factors may insert critical influence on flow propagation.

**Methods:** We prospectively studied 47 patients with LV hypertrophy due to hypertension, a reduced mitral inflow E/A ratio < 1 and no valvular lesions. From PW Doppler LV filling profiles E, A, E/A, E deceleration slope (slope) as well as time (DT) were measured. Flow propagation v<sub>p</sub> was determined as the slope of the first aliasing velocity from color M-mode Doppler recordings oriented from the LV apex to the tips of the mitral leaflets.

**Results:** In the entire patient group with a LV filling pattern characteristic for relaxation abnormalities only 14/47 patients showed a v<sub>p</sub> < 45 cm/s. A weak or no significant correlation was present between diastolic PW Doppler indices and v<sub>p</sub>: E 56 ± 15 cm/s (r = 0.32), A 89 ± 19 cm/s (ns), E/A 0.63 ± 0.10 (r = 0.38), slope 239 ± 82 cm/s<sup>2</sup> (ns), DT 249 ± 57 ms (ns). In contrast, systolic M-mode parameters of the LV demonstrated a significant correlation with v<sub>p</sub>: fractional shortening (r = 0.64), endsystolic diameter (r = 0.67). All patients with a FS < 28% had a v<sub>p</sub> < 45 cm/s and only one patient with a v<sub>p</sub> < 45 cm/s had a FS > 28%.

**Conclusion:** 1) Flow propagation velocity of early LV filling is frequently normal in patients with a LV filling pattern characteristic for abnormal relaxation, 2) a reduced v<sub>p</sub> is mainly found in patients with systolic dysfunction suggesting that elastic recoil of the LV is a major determinant of this parameter.

NONINVASIVE IMAGING

11:00 a.m.

### 876-3 Striking Effect of Left Ventricular Systolic Performance on the Propagation of Left Ventricular Early Diastolic Filling Flow

Nobuyuki Ohle, Hitomi Narita, Takeshi Hashimoto, Sachie Akita, Kazuyuki Kurokawa, Genjiro Kimura. *Nagoya City University, Nagoya, Japan*

**Background:** Propagation velocity of the left ventricular (LV) early diastolic filling flow has been known as a useful parameter of LV diastolic performance. However, the effect of LV systolic performance on the LV propagation is not fully understood. Thus, we investigated this issue in 150 pts with coronary artery disease (CAD) who have wide range of combined systolic and diastolic LV dysfunction.

**Methods:** The propagation of LV peak early diastolic filling flow was visualized by changing the first aliasing limit of the color M-mode Doppler signals and the slopes of the peak velocity tracings were measured as a propagation velocity (PVE). In cardiac catheterization, mean pulmonary capillary wedge pressure (mPCWP), a time constant  $\tau$  of LV pressure decay, LV end-systolic volume index (ESVI), and LV ejection fraction (EF) were obtained in all pts. We assessed which clinical and hemodynamic parameters determine the PVE using regression analyses.

**Results:** In univariate regression analysis, the PVE significantly correlated with LVESVI ( $r = -0.69$ ,  $p < 0.001$ ), LVEF ( $r = 0.68$ ,  $p < 0.001$ ), time constant  $\tau$  ( $r = -0.52$ ,  $p < 0.001$ ), and heart rate ( $r = -0.20$ ,  $p < 0.05$ ). The PVE showed no significant relation with age, mean blood pressure, or mPCWP. In multivariate regression analysis, the PVE was regressed by the LVESVI,  $\tau$ , and mPCWP. The multiple correlation coefficient was  $r = 0.72$  ( $p < 0.001$ ). The contribution of each parameter to the regression model was 47%, 3%, and 2%, respectively.

**Conclusion:** These findings suggest that PVE is determined mainly by LV systolic performance and partly by both LV relaxation and LV filling pressure in pts with CAD. Elastic recoil of the left ventricle may play a key role to generate a much faster PVE.

11:15 a.m.

### 876-4 Validation of Six Non-Invasive Doppler Methods for the Assessment of Left Ventricular Filling Pressure

Ernst Lipp, Markus Schwerzmann, Bernhard Meier, Christian Seiler. *Swiss Cardiovascular Center, Bern; Cardiology, Univ. Hospital, Bern, Switzerland*

**Background:** There are several non-invasive Doppler methods to estimate left ventricular end-diastolic pressure (LVEDP). So far, it has not been evaluated which one most accurately determines LVEDP in an unselected patient population.

**Methods:** In 69 patients, transthoracic Doppler echocardiography was performed during ( $n = 20$ ) or within  $4 \pm 7$  hours before/after cardiac catheterization ( $n = 49$ ). LVEDP was estimated by the following methods (M): M1: by Doppler measurements of the mitral regurgitation (MR) peak gradient. M2: by the MR gradient at aortic valve opening. M3: by the end-diastolic gradient of aortic regurgitation. M1–M3 in combination with blood pressure measurements. M4: by the ratio of the early diastolic transmitral velocity ( $E_{TM}$ ) to E velocity of the mitral annulus ( $E_{DTI}$ ) as obtained by Doppler Tissue Imaging M5: by regression equations of transmitral inflow parameters. M6: by mitral A-wave and pulmonary vein A-wave duration. All estimates were compared with invasive LVEDP using linear regression analysis.

#### Results:

	M1	M2	M3	M4	M5	M6
n	22	18	9	25	55	55
r	0.71	0.85	0.81	0.63	0.27	0.14
p	0.0002	<0.0001	0.008	0.0008	0.051	0.29

r = regression coefficient; n = number of patients examined

**Conclusions:** Measurements of regurgitant jets allow best to estimate LVEDP. In patients without mitral or aortic regurgitation, the  $E_{TM}/E_{DTI}$ -ratio may be used to estimate LV filling pressure. The measurements of time intervals is probably more prone to errors than are velocities, which may, in part, explain the lack of correlation for method 5 and 6.

11:30 a.m.

### 876-5 Simple Noninvasive Differentiation of Pseudonormal From Normal Transmitral Flow by Doppler Total Ejection Isovolume Index

Hui Zhang, Yutaka Otsuji, Keiko Matsukida, Shuichi Hamasaki, Toshiro Kumano-hoso, Akira Kisanuki, Chuwa Tei. *Kagoshima University School of Medicine, Kagoshima, Japan*

**Background:** Differentiation of pseudonormal from normal transmitral flow

is important especially in young patients with congestive heart failure. Patients with pseudonormal flow usually have left ventricular (LV) dysfunction, which can be estimated by recently proposed combined systolic and diastolic Doppler index – total ejection isovolume (TEI) index. The purpose of this study is to investigate whether differentiation of pseudonormal from normal mitral flow by TEI index is feasible or not.

**Methods:** Subjects consisted of consecutive 33 patients with diagnostic cardiac catheterization study and transmitral Doppler flow  $E/A \geq 1.0$ . Based on the LV end diastolic pressure  $\geq 18$  mmHg or not, patients were divided into pseudonormal group (13 patients) and normal group (20 patients). TEI index was measured as  $(a - b)/a$ , where  $a$  is the interval between cessation and onset of transmitral Doppler flow and  $b$  is the aortic flow ejection time.

**Results:** 1) TEI index was significantly higher in the pseudonormal group compared to that of the normal group ( $0.71 \pm 0.17$  vs  $0.31 \pm 0.12$ ,  $p < 0.0001$ ). 2) By setting the upper limit of normal range of TEI index (0.49) as diagnostic criterion, the index differentiated pseudonormal from normal transmitral flow with an excellent sensitivity, specificity and overall accuracy (100%, 87%, and 94% respectively). 3) In 16 patients with age  $\pm 55$  years old, the sensitivity, specificity, and accuracy was 100%, 82%, and 89% respectively.

	TEI Index >0.49	TEI Index $\leq 0.49$
Pseudonormal (LVEDP $\geq 18$ mmHg)	13	0
Normal (LVEDP < 18 mmHg)	2	18

**Conclusion:** TEI index allows simple and noninvasive differentiation of pseudonormal from normal transmitral flow pattern.

11:45 a.m.

### 876-6 Are Left Atrial Appendage Contraction Velocities an Adequate Surrogate of Global Left Atrial Function? A Combined Transthoracic and Transeophageal Echocardiographic Study

Yoram Agmon, Bijoy K. Khandheria, Irene Meissner, Tanya M. Petterson, W. Michael O'Fallon, Brenda S. Moon, Jody L. Covalt, David O. Wiebers, James B. Seward. *Mayo Clinic and Mayo Foundation, Rochester, Minnesota, USA*

**Background:** Left atrial appendage (LAA) flow velocities are commonly used as surrogates of overall left atrial (LA) function. However, the validity of such an approach has not been adequately confirmed.

**Methods:** Transthoracic (TTE) and transeophageal (TEE) echocardiographic studies were performed in 359 subjects in sinus rhythm, participating in a population-based study SPARC (Stroke Prevention: Assessment of Risk in a Community). LA parameters were assessed by TTE. LA maximal (LAVol-max) and minimal (LAVol-min) volumes were measured by the area-length method in 2 orthogonal planes. Mitral inflow was measured by pulsed-Doppler at the levels of the mitral annulus (MAnn) and mitral leaflets tips. LAA contraction (late diastolic) velocities were measured by pulsed-Doppler interrogation of the LAA orifice during TEE.

**Results:** The correlation between LAA velocities and LA variables, and the sensitivity/specificity of low LAA contraction velocities (lower 10<sup>th</sup> percentile, velocities  $\leq 56$  cm/sec) to detect the lower 10<sup>th</sup> percentile of each LA variable are presented in the Table.

LA variable	r	P	10 <sup>th</sup> percentile	sensitivity	specificity
LA emptying volume*	-	0.53	17	0.10	0.89
LA emptying fraction**	0.16	0.005	37	0.31	0.91
LA contraction volume <sup>†</sup>	-	0.94	7	0.30	0.91
LA contraction fraction <sup>‡</sup>	0.11	0.05	28	0.27	0.91
Peak A velocities <sup>§</sup>	-	0.49	48	0.11	0.89
Peak A/peak E ratio	0.14	0.01	0.70	0.24	0.91

\*LA emptying volume (ml) = LAVol-max minus LAVol-min; \*\*LA emptying fraction (%) = LA emptying volume divided by LAVol-max. <sup>†</sup>LA contraction volume (ml) = time-velocity-integral (TVI) of atrial contraction (MAnn level) multiplied by MAnn area. <sup>‡</sup>LA contraction fraction (%) = atrial contraction TVI divided by the holodiastolic TVI (both TVIs – at MAnn level). <sup>§</sup>Peak mitral A and E velocities (cm/sec) measured at the level of the mitral leaflets tips.

**Conclusions:** In the current study of a non-selected population, LAA contraction velocities correlated poorly with various parameters of global LA function. Low LAA velocities were poorly sensitive, but highly specific in detecting low values of global LA parameters. Similar studies are necessary to assess the relation between LAA and global LA function in patients with various cardiac pathologies.

POSTER

**1167 Valvular Heart Disease: New Hemodynamic Insights**

Tuesday, March 14, 2000, Noon–2:00 p.m.  
 Anaheim Convention Center, Hall A  
 Presentation Hour: Noon–1:00 p.m.

**1167-1 Evidence That Mitral Valve Area Derived by Continuity Equation Method is Not Affected by Alterations in Cardiac Output**

Jagdish C. Mohan, Rajiv Passey, Dinesh Gupta, Ramesh Arora, Manoj Kumar, Ayan R. Patel, Natesa G. Pandian. *G.B. Pant Hospital, New Delhi, India; Tufts-New England Medical Center, Boston, MA, USA*

We have previously demonstrated that mitral valve area derived by planimetry and pressure half-time methods in mitral stenosis (MS) is not influenced by changes in cardiac output (CO). Whether continuity equation assessment of mitral valve area (CE MVA) based on Doppler flow velocity variables is affected by alterations in CO is not known. To evaluate the impact of changes in CO on CE MVA in MS, we performed dobutamine echocardiography (20 mcg/kg/min) on 49 patients with isolated MS (14 with mild or moderate MS, 35 with severe MS). Mitral valve area was also measured by two-dimensional planimetry in all patients. Severe MS was defined as CE MVA  $\leq 1$  cm<sup>2</sup> and mild-moderate MS was defined as CE MVA  $> 1$  cm<sup>2</sup>.

**Results** (mean  $\pm$  SEM): During Dobutamine infusion, heart rate (HR) increased by  $45 \pm 4\%$  and CO increased by  $54 \pm 4\%$ . Despite this increase in CO, mean CE MVA did not change ( $0.89 \pm 0.05$  baseline and after Dobutamine) and mean change in CE MVA was only  $16 \pm 2\%$ . Only 4 out of 49 patients (8%) developed a change in CE MVA of  $>20\%$  resulting in a change in classification of severity; all 4 patients had low baseline CO ( $\leq 3$  L/min). In these 4 patients, mitral valve area by planimetry was not altered by increase in CO. The remaining 8 patients with low CO did not develop a significant change in CE MVA. No patients with CO  $> 3$  L/min demonstrated significant change in CE MVA.

**Conclusion:** CE MVA is not influenced by changes in CO in patients with normal CO and in most patients with low CO. In patients with low CO, mitral valve planimetry can help to clarify severity of MS.

**1167-2 Echocardiographic Mitral Valve Area Using the Proximal Isovelocity Surface Area Method in Patients Undergoing Balloon Mitral Valvuloplasty**

Selwyn P. Wong, H. Arthur Coverdale, Sally C. Greaves, Malcolm E. Leggett. *Green Lane Hospital, Auckland, New Zealand*

**Background:** Standard echocardiographic measurement of the mitral valve area (MVA) by direct planimetry and the pressure-half time (PHT) methods following balloon mitral valvuloplasty (BMV) have limitations. This study aimed to compare echocardiographic MVA measured by those standard methods and the proximal isovelocity surface area (PISA) method to the corresponding peri-procedural MVA measured by the Gorlin equation during BMV.

**Methods:** Seventeen patients underwent transthoracic (TTE) and transesophageal echo (TEE) before, and TTE after, BMV. The PISA MVA was calculated by  $MVA = 2\pi r^2 \times \alpha/180^2 \times Vr/V_{peak}$ , where  $r$  = radius of PISA,  $Vr$  = aliasing velocity,  $V_{peak}$  = peak mitral inflow velocity, and  $\alpha$  = the angle subtended by the mitral leaflets. For each echo study, the PISA method was used in two planes with three separate aliasing velocities. MVA derived from each echo method was compared to the corresponding Gorlin MVA by linear regression correlation and Bland-Altman analysis (Difference of 2 methods).

**Results:**

Echo MVA*	Correlation coefficient		Bland Altman	
	R	SE	Mean	SD
Pre BMV				
Direct planimetry	0.69	0.22	0.06	0.22
PHT	0.22	0.35	0.09	0.44
PISA TTE 4-Chamber	0.77	0.23	0.29	0.20
PISA TEE (0–40°)	0.69	0.26	-0.08	0.56
Post BMV				
Direct planimetry	0.62	0.50	-0.24	0.52
PHT	0.22	0.60	0.19	0.74
PISA TIE 4-Chamber	0.63	0.53	-0.03	0.56

(\*PISA MVA measured at an aliasing velocity of 27 cm/s).

**Conclusion:** At an optimal aliasing velocity, the PISA method of MVA measurement is as good as direct planimetry and more accurate than the pressure half-time method particularly in patients immediately following BMV.

**1167-3 Reliability of Different Measures of Aortic Stenosis Severity in Patients With Decreased Cardiac Output**

Francesco Antonini-Canterin, Daniela Pavan, Flavio Ribichini<sup>1</sup>, Valeria Ferrero<sup>1</sup>, Pompilio Faggiano, Eugenio Cervesato, Gianluigi Nicolosi. *Cardiology Dept. ARC, Pordenone; <sup>1</sup> Cuneo, Italy*

**Background:** New simpler measures of aortic stenosis (AS) severity have been recently introduced in addition to the traditional "flow-corrected indexes" (continuity equation valve area; aortic valve resistance). These measures can be classified as "function-corrected indexes" (fractional shortening-velocity ratio = FS/4 Vmax<sup>2</sup>; ejection fraction-velocity ratio = EF/4 Vmax<sup>2</sup>) and "pressure-corrected indexes" (stroke work loss = mean gradient/LVsystolic pressure). Little information however is available about the reliability of each of these measures for identifying patients with severe AS in low flow states.

**Methods:** We analyzed 161 patients with AS (96 males, 65 females, aged  $68 \pm 9$  years) and low cardiac output (thermodilution cardiac index  $< 2.5$  l/min/m<sup>2</sup>). All pts underwent both cath. and echo. within 48 hours one of the other. Invasive Gorlin valve area was used as gold standard. Echo indexes were measured by an investigator unaware of hemodynamic findings.

**Results:** Mean Gorlin area was  $0.7 \pm 0.3$  cm<sup>2</sup>; cath. allowed to identify 129 patients with severe AS (Gorlin area  $\leq 0.8$  cm<sup>2</sup>) and 32 with mild-to-moderate AS. Respective values of sensitivity and specificity are reported for each echocardiographic index (using previously suggested cut-off severity values).

	Cut-off value	Sensitivity	Specificity
Mean Doppler Gradient	$\geq 50$ mmHg	55%	100%
Continuity Equation	$\leq 0.8$ cm <sup>2</sup>	83%	90%
Mean Aortic Valve Resistance	$>240$ d*s*cm <sup>-5</sup>	77%	97%
Percent Stroke Work Loss	$\geq 23\%$	84%	84%
Ejection Fraction-Velocity Ratio	$\leq 0.8$	87%	88%
Fract. Shortening-Velocity Ratio	$\leq 0.5$	88%	78%

**Conclusion:** Our study confirms the inadequate sensitivity of Doppler gradient alone in the assessment of AS severity in patients with decreased cardiac output. The simpler "function-corrected" and "pressure-corrected" indexes (in particular ejection fraction-velocity ratio and percent stroke work loss) provide a good diagnostic accuracy as well as "flow-corrected" indexes. The knowledge of these findings could be relevant in order to assess which index could be best applied in clinical practice.

**1167-4 Intravalvular and Supravalvular Energy Losses in Diseased Aortic Valves: An In Vivo Fluid Mechanic Study**

Michael D. VanAuker, Aung Hla, Jay S. Meisner, Jamshid Shirani, Joel A. Strom. *Brookdale University Hospital and Medical Center, Brooklyn, New York; Albert Einstein College of Medicine, Bronx, New York, USA*

**Background:** The hemodynamic impact of aortic valve stenosis and prosthetic valve replacement depends fundamentally on the total transvalvular energy loss, comprised of intravalvular losses and supravalvular losses downstream of the valve in the stenotic jet. Because energy loss is not measured by either Doppler or catheter techniques, we addressed the hypothesis that it could be calculated from data derived from these techniques, and that it would be related to other markers of stenosis severity, such as effective aortic valve area (AVA).

**Methods:** Simultaneous Doppler echocardiographic and catheter measurements were performed in 13 patients with aortic valve disease. AVA calculated by the continuity equation averaged  $1.02 \pm 0.85$  cm<sup>2</sup>. Intravalvular ( $\phi_i$ ) and supravalvular ( $\phi_s$ ) energy loss rates were calculated using  $\phi_i = \rho A_1 v_1 (v_2^2/2)(1/C_v^2 - 1)[1 - (A_2/A_1)^2]$  and  $\phi_s = A_1 v_1 [-\Delta P + (\rho v_2^2/2)(1 - (A_2/A_3)^2)]$ , where  $A_1$  and  $v_1$  are the area and mean velocity of the left ventricular outflow tract,  $A_2$  and  $v_2$  are the AVA and mean velocity through the aortic valve,  $A_3$  is the aortic root area,  $C_v$  is the velocity coefficient of the valve,  $\rho$  is the density of the blood, and  $\Delta P$  is the amount of pressure recovery distal to the valve. The total energy loss rate was assumed equal to the sum of  $\phi_i$  and  $\phi_s$ .

**Results:** Total energy loss rates correlated negatively with AVA ( $r = -0.64$ ,  $p = 0.02$ ). Total energy loss rates averaged 1.38 joules/sec for patients with AVA  $< 0.8$  cm<sup>2</sup> and 0.58 joules/sec for patients with AVA  $> 1.8$  cm<sup>2</sup>.  $\phi_s$  accounted for 95% of the total energy loss rate distal to stenotic valves and 92% of the total energy loss distal to nonstenotic valves.

**Conclusions:** Most of the energy lost across the aortic valve is due to supravalvular turbulence, even for nonstenotic valves. Reduction in turbulence is essential in the design and selection of prosthetic heart valves.

## POSTER

**1168 Measurement of Cardiac Structure and Function: New Three-Dimensional Echocardiography Approaches**

Tuesday, March 14, 2000, Noon–2:00 p.m.  
 Anaheim Convention Center, Hall A  
 Presentation Hour: Noon–1:00 p.m.

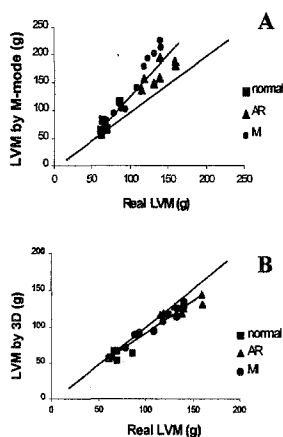
**1168-5 Measurement of Left Ventricular Mass (LVM) Using Real-Time 3D and 2D Echocardiography in Chronic Animal Model**

Agnese Travaglini, Michael Jones<sup>1</sup>, Takahiro Shiota, Jian Xin Qin, Fabrice Bauer, Hiroyuki Tsujino, Lisa A. Cardon, Annitta J. Morehead, Neil L. Greenberg, Julio A. Panza<sup>1</sup>, Arthur D. Zetts<sup>1</sup>, James D. Thomas. *The Cleveland Clinic, Cleveland, OH; <sup>1</sup>NHLBI, Bethesda, MD, USA*

**Background:** Conventional echo methods for determining LVM require geometric assumptions. It is hypothesized that real-time 3D echo (RT3DE) can reliably determine LVM without geometric assumptions. The aim of this study was to validate the use of RT3DE for determining LVM and to compare with conventional 2DE methods in normals and chronic animal models with myocardial infarction (MI) or aortic regurgitation (AR).

**Methods:** In 24 sheep (7 normal, 7 chronic AR and 10 chronic MI) RT3DE was used to acquire the entire LV with and without contrast enhancement. We also calculated LVM by M-mode echo using the D<sup>3</sup> formula and by 2DE using the Simpson's rule. Post mortem measured LVM was used as a reference standard.

**Results:** LVM by 2DE, M-mode, RT3DE and autopsy weight were 85 ± 25 g, 138 ± 52 g, 99 ± 30 g and 108 ± 32 g, respectively. Overestimation of LVM by M-mode ( $y = 1.50x - 25$ ,  $r = 0.92$ ) was found especially for chronic MI (Figure A). A stronger correlation existed between LVM and RT3DE mass without contrast ( $y = 0.89x + 2.6$ ,  $r = 0.97$ ) (Figure B) as compared to 2DE ( $y = 0.70x + 9$ ,  $r = 0.89$ ). However LV volume (LVV) with contrast enhancement overestimated LVV without contrast (mean difference 11 ± 5 ml) resulting further underestimation of LVM by contrast enhancement.



**Conclusions:** RT3DE without contrast provided an excellent technique to determine LVM as compared to conventional 2D and M-mode methods.

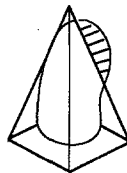
**1168-6 Use of the Apical Sound Window Involves Tangential Cuts of the Left Ventricle: Proof of the Hypothesis Using Real-Time 3-D Imaging and Volumetry**

Thomas Bartel<sup>1</sup>, Silvana Müller<sup>2</sup>, Marc A. Katz<sup>1</sup>, Raimund Erbel<sup>1</sup>.  
<sup>1</sup>University Essen, Germany; <sup>2</sup>University Innsbruck, Austria

**Background:** It was hypothesized that left ventricular volumes would be underestimated by tangential cuts of the left ventricle using standard transthoracic apical echocardiography.

**Methods:** In 35 patients (28 men, 7 women) 3 data sets were obtained by real-time 3-D echocardiography. The system uses a matrix phased array transducer (2.5 MHz, 512 elements) and a 16.1 receive/transmit parallel processing scheme to develop 4096 line scans interrogating all positions in a 60° pyramidal volume at 18 frames/s. The end-diastolic and end-systolic LV volumes (EDV, ESV) were measured in all 3 data sets and averaged. If a tangential cut was present the cut off plane was reconstructed and the cut off

area measured by manual tracing. To estimate the cut off volume the area was considered circular and a hemispherical volume calculated, which was then related to the mean EDV and ESV.



**Results:** The average EDV of the population was calculated to be of 127.1 ± 39.0 ml (mean ± SD) and the ESV of 57.3 ± 26.0 ml. In 20 subjects (57%) the left ventricular apex was found to be cut off in the end-diastole and in 9 individuals in the end-systole. The average end-diastolic cut off area was measured to be of 5.8 ± 3.1 cm<sup>2</sup> and the end-systolic area of 3.0 ± 0.4 cm<sup>2</sup>.

Calculated underestimation due to tangential cuts of the left ventricle

	n	Ventricular volume (ml)	Cut off volume (ml)	Underestimation (%)
EDV	20	129.3 ± 44.8	5.8 ± 4.8	4.3 ± 3.5
ESV	9	51.6 ± 16.8	2.0 ± 1.3	3.7 ± 1.9

**Conclusions:** In the majority of patients use of the apical sound window leads to tangential cuts of the left ventricle and to an underestimation of left ventricular volume parameters.

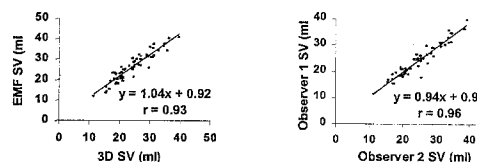
**1168-7 Volumetric Real-Time Three Dimensional Echocardiography Accurately Measures Stroke Volume Over a Wide Range of Hemodynamic Conditions**

John A. Mondelli, Silvia Di Luzio, Ashwin Nagaraj, Bonnie J. Kane, Alka V. Nagaraj, Rodney Greene, David D. McPherson, Vera H. Rigolin.  
*Northwestern University Medical School, Chicago, Illinois, USA*

**Background:** Real-time three dimensional echocardiography (3DE) is a novel methodology that provides instantaneous acquisition of left ventricular (LV) volumes. Validation of this technique for transthoracic imaging over a wide range of hemodynamic conditions has not been performed.

**Methods:** In ten mongrel dogs, an electromagnetic flow probe (EMF) was placed on the aorta and the thorax closed. To obtain a wide range of LV volumes and cardiac outputs, all dogs were evaluated during fluid bolus, dobutamine, nitroprusside, neosynephrine, and beta-blocker infusion. Transthoracic images were simultaneously acquired using a real-time Volumetric 3DE system with a 2.5 or 3.5 MHz transducer. Left ventricular volumes were manually traced off-line by two independent observers using an apical rotation method with TomTec Echoview Software.

**Results:** A wide range of stroke volumes (SV) by EMF (11.9 to 40.4 ml, average 26.5 ± 6.7 ml, n = 58) and ejection fractions by 3DE (27.5 to 94.6%, average 62.05 ± 14.23%, n = 58) were obtained. Excellent correlation was noted between SV measured by 3DE and EMF ( $r = 0.93$ ,  $y = 1.04x + 0.92$ , n = 58). Some variance was noted at higher volumes and lower ejection fractions (EF < 50%) when the ventricle was larger than the 3DE imaging plane ( $r = 0.88$ ,  $y = 1.00x + 0.93$ , n = 13). Inter-observer variability of calculated SV was excellent ( $r = 0.96$ ,  $y = 0.94x + 0.91$ , n = 58).



**Conclusion:** Real-time Volumetric echocardiography accurately and reproducibly measures left ventricular volume transthoracically over a wide range of hemodynamic conditions. This data provides validation for its use in various pathologic conditions including accurate timing for valve replacement.

**1168-8 Assessment of Ventricular Volumes and Ejection Fraction by Real-Time 3D-Echocardiography in Comparison With Gated SPECT Thallium**

Silvana Müller<sup>1</sup>, Thomas Bartel<sup>2</sup>, Elke Neubauer<sup>1</sup>, Marc Katz<sup>2</sup>, Daniela Marien<sup>2</sup>, R. Erbel<sup>2</sup>, O. Pachinger<sup>1</sup>. <sup>1</sup>Universities Innsbruck, Austria; <sup>2</sup>Essen, Germany

**Background:** We sought to evaluate the accuracy and interobserver vari-



ability in the determination of left ventricular volumes and ejection fraction (LVEF) using real-time 3D echocardiography (R3DE).

**Methods:** In 44 patients with coronary heart disease, R3DE was employed to measure end-diastolic and end-systolic left ventricular volumes (EDV, ESV). The system uses a matrix phased array transducer (2.5 MHz, 512 elements) and a 16.1 receive/transmit parallel processing scheme to develop a 4096 line scan interrogation of all positions in a 60° pyramidal volume at 18 frames/s. Volume determination was performed by summation of multiple discs obtained by manually tracing the endocardial border in 7 equally spaced and 0.9–1.2 thick short axis images. The interobserver variability was determined and in 10 patients the volume measurements compared with rest gated SPECT thallium within a 72-h period.

**Results:** R3DE and gated SPECT were shown to be in good agreement: The cardiac output (CO) was  $5.2 \pm 1.2$  vs  $5.1 \pm 0.8$  l/min;  $r = 0.72$ ,  $p < 0.05$ , and the LVEF  $53.3 \pm 18.3$  vs  $48.9 \pm 18.6$ ;  $r = 0.83$ ,  $p < 0.01$ . With respect to EDV and LVEF the interobserver differences were found to be not significant. In contrast, significant interobserver variability resulted in the determination of ESV.

Parameter	Difference between both observers		
	Mean $\pm$ SD (ml)	Variability (%)	p
EDV	$0.7 \pm 9.1$	0.5	0.62
ESV	$2.6 \pm 6.5$	4.3	0.01
LVEF	$2.0 \pm 6.6$ (%)	3.7	0.05

**Conclusions:** R3DE volumetry was demonstrated to be closely related to gated SPECT Thallium derived CO and LVEF data. R3DE is time saving and can be employed alternatively if there is no hemodynamic monitoring available.

**1168-25 Left Ventricular Volume Analysis in Pediatric Patients: A Comparison of Real Time Three Dimensional Echo With Cardiac MRI**

Ricardo H. Pignatelli, Giles W. Vick, Louis I. Bezold, Mark B. Lewin, Carolyn A. Altman, Nancy A. Ayres. *Texas Children's Hospital and Baylor College of Medicine, Houston, Texas, USA*

**Background:** Quantitative measurements of ventricular end diastolic and systolic volumes (EDV/ESV) with 2-D echocardiography are widely employed in the management of patients with congenital heart disease. However, volumetric measurements based on 2-D echo require geometrical assumptions, including symmetrical ventricular geometry. Real time three-dimensional echocardiography (RT3D) allows real time acquisition of the entire LV volumetric dataset without cardiac and respiratory gating. We compared RT3D to MRI ventricular volumes to correlate measurements between both techniques.

**Methods:** A total of 17 consecutive pts (3 mos–35 yrs, 5.9–83 kg) were analyzed. Patients with normal ventricular relationship (15/17) and 2 pts with L-TGA were evaluated. No pts were excluded because of poor echo quality. Regional wall motion abnormalities were seen in 2 pts. EDV/ESV were calculated by Sector Scan (SS), Parallel Scan (PS) and Long Axis Rotational Mode (LARM) using Simpson's method for volume calculations. Acquisition time for each segment was documented. MRI volumes were acquired with multiphasic, multiview gradient echo technique and EKG gated.

**Results:** Segment acquisition time averaged 6.1 min.

RT3D vs MRI Volume Correlation Coefficients	SS	PS	LARM (6*)	LARM (4*)
	EDV	0.89	0.83	0.92
ESV	0.72	0.60	0.85	0.83

\*number of planes around the axis

**Conclusions:** 1) RT3D is an accurate and rapid method for volume analysis independent of geometry and respiratory gating. 2) LARM provides the highest correlation with MRI volume analysis. 3) Using LARM, the performance of more than 4 planes appears unnecessary.

**1168-26 Assessment of Left Ventricular Function by Real-Time Three-Dimensional Echocardiography Compared With Conventional Noninvasive Methods**

Shin Takuma, Takahiro Ota, Takeshi Muro, Melissa Kazanowski, Rui Liu, Hideaki Yano, Ken Yoshiara, Clarito Dimayuga, Kengo Makita, Marco R. Di Tullio, Junichi Yoshikawa, Shunichi Homma. *Columbia University, New York, New York, USA*

**Background:** Quantitative assessment of LVEF is essential in cardiac evaluation. Reliable and reproducible noninvasive method would be desirable for

this purpose. Multigated radionuclide angiography (MUGA) and two-dimensional echocardiography (2DE) have been widely used as the accepted methods for the measurement of LVEF in spite of their well-recognized limitations. In this study, we compared LVEF assessed by newly developed real-time 3D echocardiography (RT3D) and conventional 2DE with that obtained by MUGA.

**Methods:** Forty-six patients (30 men and 16 female; mean age of 55  $\pm$  13 years) underwent the determination of LVEF by RT3D, 2DE, and MUGA. All three tests were performed on the same day. LVEF was determined by RT3D using sector plane-disks summation method (RT3D-S) and parallel plane-disks summation method (RT3D-P). For quantitative 2DE an apical biplane summation method was used. Standard methodology was used for MUGA. Comparison and interobserver variability (IV) of LVEF by RT3D and 2DE with MUGA were analyzed.

**Results:** \* <0.001

	r	SEE (%)	IV (%)
RT3D-S	0.90	2.9	4.3
RT3D-P	0.87	3.1	8.1
2DE	0.86	4.9*	10.1*

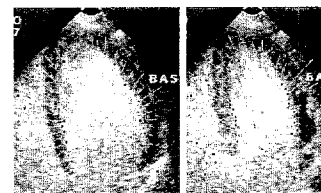
**Conclusions:** Determination of LVEF by RT3D has good correlation with MUGA and is significantly more reproducible than 2D echocardiographic method. Therefore, RT3D can be used for accurate serial quantification of LVEF as an alternative to MUGA and 2DE.

**1168-27 Preliminary Application of Simplified Three-Dimensional Echocardiography With Automatic Contour Tracking on Contrast Harmonic Imaging to Quantitate Left Ventricular Function: Comparison With Quantitated Gated SPECT**

Leng Jiang, Thomas Porter, Monique Kusler, Banthit Khankirawatana, Ping Lu, Lisa Gobar. *University of Nebraska Medical Center, Omaha, NE, USA*

We have developed a simplified three-dimensional reconstruction (S3DR) algorithm combined with an automated contour tracking technique (ACT), and validated it in patients with excellent echo imaging quality. To further explore its feasibility and ability in patients with suboptimal echo images, nine patients with known or suspected coronary heart disease who underwent simultaneous contrast harmonic (CH) echo and quantitative gated SPECT (QGS) were studied. CH images were obtained following venous boluses of Optison and recorded on 3 standard apical views. ACT was based on the enhanced endocardial contrast, using an energy minimization approach with weighted separability and capability for tracking modification. Left ventricular (LV) ejection fraction (EF) was automatically calculated after reconstruction of ACT-CH endocardial borders with B-spline interpolation. Comparison was made to LVEF quantitated by QGS with automatic 3D boundary detection.

**Results:** ACT was feasible for delineation of CH enhanced LV endocardial borders (Figure), with a need for tracking modification (5–30%). The LVEF obtained by S3DR-ACT ranged from 48 to 76% and correlated well with that obtained by QGS, with a slight trend of overestimation:  $y = 1.02x + 0.03$ ,  $r = 0.92$ ,  $SEE = 0.04\%$ ,  $p < 0.001$ , mean difference =  $0.04 \pm 0.036\%$ .



**Conclusions:** S3DR-ACT combined with CH is feasible for quantitative assessment of LVEF. This novel approach may enhance the ability of ACT in patients with poor imaging quality.

**1168-28 Fully Automated 3D Boundary Detection in Real-Time 3D Echocardiography**

Shin Takuma, Elsa D. Angelini, Ken Yoshiara, Rui Liu, Melissa Kazanowski, Clarito Dimayuga, Kengo Makita, Marco R. Di Tullio, Jeffrey W. Holmes, Andrew F. Laine, Shunichi Homma. *Columbia University, New York, New York, USA*

**Background:** Volumetric data acquisition of real-time 3D echocardiography (RT3D) obviates the need for slice registration and reconstruction. 3D automated boundary detection (3D-ABD) has been the only barrier for clinically applicable measurement of left ventricular volume. However, speckle noise

of the raw signal corrupts the data valance by introducing sharp changes in an image intensity profile, while the attenuation of intensity depends on its orientation with respect to the position of 3D ultrasound beam.

**Methods:** In this study, we used these properties to establish denoising and segmentation methods for 3D-ABD. Eight asynergic phantoms (29.5 to 87.5 ml) with sixty-four various intensities were tested using a matrix phased array transducer (2.5 MHz) of RT3D. The raw data consists of 300 slices,  $64 \times 64$  pixels per slice. Based on phase information, the automated multi-scale analysis was performed on the raw data by decomposing a signal into distinct patterns associated with a particular width and direction. For implementation, fast Fourier transform was applied for overcompleting framework of 3D-ABD. The threshold for segmentation was determined by mean level of spatial frequency within a signal. Manual tracing (MT) using the raw data for volume calculation was also performed. The volume of phantoms obtained by 3D-ABD and MT were compared with true volume.

**Results:** The threshold value in this study ranged from 0.85 to 1.25 of mean value of the coefficients for every slice. Correlation of 3D-ABD and MT with true volume are follows; 3D-ABD:  $y = 0.96x - 1.4$ ,  $r = 0.94$ . MT:  $y = 0.98x + 3.4$ ,  $r = 0.97$ .

**Conclusions:** 3D-ABD is possible for extracting the volume from 3D echocardiographic data set resulting in similar result as that from MT. This new method may improve accuracy and reduce observer variability in determination of the left ventricular volume from RT3D image.

#### 1168-29 A Single Intravenous Injection of Levovist With Real-Time Three-Dimensional Echocardiography Provides Endocardial Border Delineation of the Whole Left Ventricle

Keiji Ujino, Takashi Muro, Masakazu Teragaki, Ryo Otsuka, Kenichi Sugioka, Masao Daimon, Hiroyuki Watanabe, Takahiro Ota, Kazuhide Takeuchi, Junichi Yoshikawa. *First Department of Internal Medicine, Osaka City University Medical School, Osaka, Japan*

**Background:** Recently developed contrast agents can delineate the endocardial border of the left ventricle (LV). However, two-dimensional echocardiographic assessment of endocardial border delineation (EBD) needs multiple scan sets and repetitive injections of a contrast agent in order to assess the whole LV. Real-time three-dimensional (RT3D) echocardiography can provide volumetric imaging of cardiac structure and function.

**Purpose:** The purpose of this study was to assess the EBD of the whole LV by a single intravenous injection of Levovist and a single set of volumetric scans by RT3D.

**Methods:** Twelve patients (F/M 3/9, mean age  $53.8 \pm 19.8$  yrs) underwent RT3D imaging at baseline (BSL) and after a 4 ml (1.2 g) intravenous injection of Levovist (Schering AG, Germany). RT3D data was acquired from the apical position. Using the ASE 16-segment model, we rated the EBD of each segment as poor (0), fair (1) or good (2) and calculated the endocardial border score index, which was defined as the sum of segmental scores divided by the total number of segments.

**Results:** Out of the 192 segments, 58 segments were rated as good at BSL and 143 achieved that rating following Levovist injection. EBD was improved by Levovist injection in 100 out of the 134 (74.6%) segments that had been rated only fair or poor at BSL. The over all endocardial border score index was significantly higher after using Levovist injection than at BSL ( $1.07 \pm 0.46$  vs.  $1.69 \pm 0.42$ ,  $p < 0.003$ ).

**Conclusion:** A single intravenous injection of Levovist with a single set of volumetric scans can assess the whole LV.

#### 1168-30 Left Ventricular Volume Changes During Dobutamine Stress Echocardiography; Assessment by Real-Time 3-D Imaging

Tianrong Xie, Raul Heredia, Masood Ahmad. *University of Texas Medical Branch, Galveston, Texas, USA*

**Background:** LV volume changes during dobutamine stress echocardiography (DSE) have not been characterized and the impact of these changes on the interpretation of LV wall motion has not been reported. Real-time 3-D imaging (RT-3D, VOLUMETRICS) provides rapid measurement of LV volumes during DSE.

**Methods:** Sixty-six patients (pts), age range 37–86 yrs, with coronary cineangiograms had LV volumes (ml) measured by RT-3D during DSE using parallel planes-disks summation in both C-scans and orthogonal planes (Simpson's Formula). We have previously validated RT-3D LV volumes against biplane cineangiography in 9 pts with  $r = 0.77$  for end systolic (ESV) and  $r = 0.95$  for end diastolic (EDV) volumes.

**Results:** The mean  $\pm$  SD LV EDV and ESV for the group were  $106.6 \pm 33.7$ ,  $51 \pm 23.4$  at baseline and  $95.3 \pm 28.5$ ,  $36.1 \pm 18.4$  at peak DSE. We compared the EDV and the ESV changes from baseline to peak DSE in four

groups of pts, 29 pts with a true positive DSE, 20 pts with a true negative DSE, 12 pts with a false negative DSE and 5 pts with a false positive DSE. There were no significant differences in changes in the heart rate and blood pressure in the four groups. Pts with a true negative DSE had a significantly smaller ESV,  $39.9 \pm 15.4$  at baseline and  $27.9 \pm 12.2$  at peak DSE when compared to pts with a true positive DSE, baseline  $ESV 53.6 \pm 23.9$  and peak  $ESV 39.4 \pm 19.2$  ( $P < 0.05$ ). Pts with a false negative DSE had larger volumes with baseline EDV,  $120.5 \pm 37.1$ , and peak EDV,  $107.9 \pm 35.1$ , when compared to pts in the true negative group, baseline  $EDV, 93.5 \pm 26$ , peak  $EDV, 83.9 \pm 22.7$  ( $p < 0.05$ ). Although baseline ESV was significantly larger,  $59.3 \pm 26$ , in the false negative group compared to  $39.9 \pm 15.4$ , in the true negative group ( $p < 0.05$ ), the differences in the peak ESV were not significant. Overall there was a greater reduction in ESV,  $19.6 \pm 10.6$  at peak DSE in the false negative group compared to  $12.1 \pm 6.4$  in the true negative group ( $p < 0.05$ ).

**Conclusions:** 1) Pts with a true negative DSE have a significantly greater inotropic response, as demonstrated by the changes in ESV, when compared to pts with a true positive DSE. 2) A greater reduction in ESV in pts with a false negative DSE when compared to pts with a true negative DSE, suggests possible masking of segmental LV wall motion abnormality by the increased overall inotropic response.

#### 1168-31 Direct Measurement of Vena Contracta Cross-Sectional Area by 3D Digital Color Doppler: In Vitro Flow Computation Studies Facilitated by a New On-Board Acquisition and Reconstruction Method

Summer Lind, Timothy Irvine, Yoshiki Mori, Xiaokui Li, Antoinette Kenny, Sanjeev Sharma, Mushtaq Hussain, David J. Sahn. *Oregon Health Sciences University, Portland, OR, USA; Freeman Hospital, Newcastle-upon-Tyne, UK*

**Background:** Vena contracta (VC) cross-sectional area should theoretically provide an accurate estimate for regurgitant orifice area and allow regurgitant flow computation. VC imaging has however been limited by angle dependency in 2D color Doppler and the inability of current 3D echocardiographic systems to display true color Doppler data.

**Methods:** A new on-board 3D acquisition, reconstruction and review system incorporated into a Vingmed System 5 ultrasound scanner combines both structural and digital color Doppler data in the reconstructed 3D dataset. After image acquisition by a  $180^\circ$  probe rotation scanning parallel to flow, we used this system to image VCs generated by a variety of regurgitant orifices by sectioning and visualizing the VC cross-section perpendicular to flow. Three planar orifices (rectangular, triangular and oval, areas all  $0.24 \text{ cm}^2$ ) and two porcine aortic bioprosthetic valves surgically altered to produce regurgitation were examined in an in vitro pulsatile flow model at regurgitant stroke volumes (RSV) of 5–50 ml. For each orifice and RSV, the cross-section of the VC was identified in the 3D color Doppler dataset as the narrowest portion of the regurgitant jet at or just distal to the orifice. RSV was calculated as VC area  $\times$  velocity time integral measured by CW Doppler through the orifice.

**Results:** Measured VC areas showed good agreement with actual effective orifice area in all cases (all within  $0.04 \text{ cm}^2$ , including the larger valve orifices). VC derived RSVs also showed good correlation and agreement with actual flow values for both the regular orifices and the valves ( $r = 0.98$ ,  $SEE = 3.8 \text{ cc}$ ,  $y = 0.99$ ,  $x = 0.02$ ).

**Conclusion:** This new on-board digital 3D color Doppler flow reconstruction and quantitation system should facilitate clinical application of VC flow imaging.

#### 1168-32 New Quantitative Digital 3D Velocity Reconstruction of the Vena Contracta (VC) Area for Computation of Valvular Regurgitation: An In Vitro Study Using Dynamically Changing Orifices Mimicking Mitral Valve Regurgitation

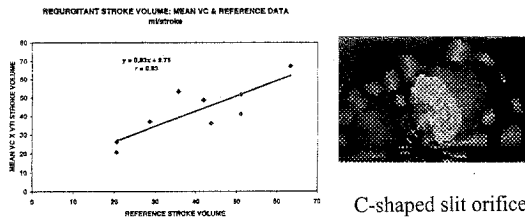
Andrew J. Rosenthal, Xiaokui Li, Shannon Hicks, Davy Merrick, Xiang-Ning Li, Yoshiki Mori, David J. Sahn. *Oregon Health Sciences University, Portland, OR; ATL Ultrasound, Bothell, WA, USA*

**Background:** Previous color echo Doppler studies using the VC area to assess regurgitation have been limited to two dimensions. We studied dynamically changing orifices and used 3D color Doppler, to evaluate the role of VC imaging.

**Methods:** Our study imaged proximal jet flows from 3 dynamically changing orifices (dual leaflet "z-shaped" balloon slit, straight silicon slit, and a triangular balloon slit). The orifices were mounted on a rigid surface within the model chamber, equidistant between the inlet and outlet. We used an ATL 5000 with a 7 MHz TEE multiplane probe with stepper function controlled

by the scanner and a connection allowing transfer of raw scanline digital velocity data to an SGI workstation. By interrogating 9 jet flow rates (15–55 ml/beat at heart rate 60 beat/minute) parallel to the direction of propagation and analyzing the images in a cross-section (perpendicular) selected for smallest diameter and flattest velocity profile, a high velocity core in the VC region could be identified. After identification, the VC area was measured at five points during the cardiac cycle, each with corresponding CW Doppler velocity data. Using the peak VC area, the peak flow rates were computed. The regurgitant volumes were calculated using peak and time averaged VC areas, multiplied by the VTI.

**Results:** The peak flow rate derived from peak VC area  $\times$  peak CW velocity had excellent correlation with reference data ( $r = 0.96$ ). The "peak VC"  $\times$  VTI overestimated regurgitant volume compared to reference data, but had an excellent correlation ( $r = 0.94$ , mean difference =  $27.9 \pm 15.8$  cc) with reference data. The "time averaged VC"  $\times$  VTI closely estimated regurgitant volume compared to reference data, had good agreement, and a correlation of  $r = 0.83$ , mean difference =  $3.84 \pm 6.9$  cc. The VC area during the 5 periods evaluated also correlated well with the reference EOA, showing dynamic change.



**Conclusion:** Digital color 3D reconstruction of dynamically changing VC areas yields accurate flow rate and regurgitant volume estimates.

POSTER

**1169 New Techniques in Ultrasound: Miscellaneous II**

Tuesday, March 14, 2000, Noon–2:00 p.m.  
Anaheim Convention Center, Hall A  
Presentation Hour: Noon–1:00 p.m.

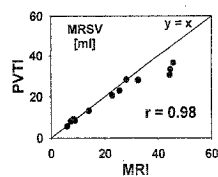
**1169-33 The Backscattered Doppler Power Times Velocity Integral at the Vena Contracta for Direct Quantification of Regurgitant Volume Flow: Clinical Validation Versus MRI**

Thomas Buck, Ron Mucci, J. Luis Guerrero, Godtfred Holmvang, Mark D. Handschumacher, Robert A. Levine. *Massachusetts General Hospital, Boston, MA, USA*

Noninvasive quantification of regurgitant flow has been limited because Doppler measures velocity, not volume. Since backscattered Doppler power reflects number of moving scatterers in laminar flow, it should be proportional to the sonified flow cross-sectional area (CSA), with power  $\times$  velocity proportional to volume flow rate. Previous experimental studies demonstrated that this power principle can be applied at the vena contracta where flow is laminar prior to entrainment, so that the power  $\times$  velocity integral (PVI) is linearly proportional to flow rate, as its time integral (PVTI) is to regurgitant stroke volume.

**Methods:** To validate this approach clinically, mitral regurgitant stroke volume (MRSV) by PVTI was compared with mitral inflow minus aortic outflow by MRI in 12 patients ( $52 \pm 17$  yrs) with mitral regurgitation with a range of severity and etiologies. Vena contracta power in the narrow high-velocity spectrum from a broad Doppler measuring beam encompassing the flow CSA was calibrated against that from a narrow reference beam of known area.

**Results:** MRSV by PVTI and MRI correlated well. MRSVs  $> 40$  ml were underestimated because available Doppler beams are not yet broad enough to encompass these severe CSAs.



**Conclusion:** The power-velocity integral at the vena contracta combined with a dual-beam calibration technique provides an accurate direct measurement of regurgitant flow, overcoming the limitations of existing Doppler techniques.

**1169-34 Assessment of Left Atrial End-Systolic Pressure Volume Relationship in an Animal Model: A Real-Time 3D Echocardiographic and Hemodynamic Study**

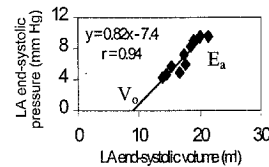
Fabrice Bauer, Michael Jones<sup>1</sup>, Takahiro Shiota, Jian Xin Qin, Hiroyuki Tsujino, Agnese Travaglini, Arthur D. Zetts<sup>1</sup>, Julio A. Panza<sup>1</sup>, James D. Thomas. *The Cleveland Clinic Foundation, Cleveland, OH;*  
<sup>1</sup>*NHLBI, Bethesda, MD, USA*

**Background:** The end-systolic pressure volume relationship is rarely used for the left atrium (LA) because of difficulty in measuring LA volumes. However, with real-time 3D echocardiography, it is now possible to measure LA volumes accurately and easily.

**Aim of the Study:** To assess the LA end-systolic pressure-volume relationship.

**Methods:** A LA pressure catheter was directly inserted via the left atrial appendage in 10 sheep. The LA was imaged epicardially from the left ventricular apex using real-time 3D echocardiography. LA end-systolic volumes were measured at the QRS wave (after atrial kick) using 7 parallel slices. After transient occlusion of the inferior vena cava, preload reduction provided multiple LA pressure-volume data points. For each sheep, the set of LA end-systolic pressure-volume points was submitted to a regression analysis. The slope  $E_a$ , the intercept on the X-axis  $V_0$  and the correlation coefficient  $r$  were determined from regression analysis (figure).

**Results:** Mean value of LA end-systolic pressure and volume were  $11 \pm 2.5$  mm Hg and  $17.4 \pm 5.1$  ml, respectively. There was linear relationship between LA end-systolic volume and LA end-systolic pressure for each animal (mean value of  $r = 0.92 \pm 0.03$ ). Mean value of  $E_a$  and  $V_0$  were  $0.72 \pm 0.19$  mm Hg/ml and  $9.9 \pm 2.7$  ml, respectively.



**Conclusion:** A linear end-systolic pressure-volume relationship was found for the left atrium.

**1169-35 Do Recent Advances in Ultrasound Imaging Improve the Accuracy of Left Ventricular Mass Measurements in Mice?**

Claudia Korcarz, Sanjeev G. Shroff, Keith A. Collins, Hua Lin, Richard C. Fentzke, Jeffrey M. Leiden, Roberto M. Lang. *The University of Chicago, Chicago, IL, USA*

**Background:** Transgenic and knockout mice with different cardiovascular phenotypes have created the need for accurate noninvasive measurements of LV mass. Recent technical advances (e.g., high frequency transducers, high frame rates) have yielded two-dimensional (2D) images adequate for calculation of LV mass based on the area-length method, which in humans is known to be more accurate than traditional M-mode based methods. The aim of this study was to compare the accuracy of M-mode and 2-D methods of LV mass calculations in mice over a wide range of LV sizes and weights (78–172 mg).

**Methods:** Forty-four mice (12 normal, 23 after 2 weeks of aortic banding, and 9 with inherited dilated cardiomyopathy) were imaged transthoracically with a 15 MHz linear transducer at a frame rate of 120 Hz. All measurements were made at end-diastole (2D-directed M-mode: short-axis LV diameter and wall thickness; 2D: short-axis LV muscle area and parasternal long-axis LV length). Standard M-mode and 2D (area-length) formulas were used to estimate LV mass. Using Bland-Altman and linear regression analyses, these echocardiographic estimates of LV mass were compared with true LV weights measured at autopsy.

	Bland-Altman		Linear Regression		
	Bias (%)	Error (%)	R <sup>2</sup>	Slope	Intercept (mg)
M-mode	32.1	$\pm 58.9$	0.32	$0.87 \pm 0.22$	$50 \pm 25$
2D	-1.4	$\pm 27.8$	0.67	$1.00 \pm 0.11$	$0.2 \pm 13.0$

**Results:** Similar to data in humans, in vivo measurements of LV mass in

mice using the 2D area-length method are more accurate than the M-mode method.

**Conclusions:** Both increased transducer frequency and high frame rate contribute to the improved image quality and the reduction in measurement bias and error.

**1169-36 Effect of Different Therapeutic Ultrasound Frequencies in Preventing Intimal Hyperplasia Following Balloon Injury in Pigs Treated with Intravenous Antisense Bound to Perfluorocarbon Albumin Microbubbles**

Thomas Porter, Feng Xie, Candice Montzingo, Edward O'Leary, David Kricksfeld, Patrick Iversen, Stanley Radio. *University of Nebraska Medical Center, Omaha, Nebraska, USA*

**Background:** Antisense oligonucleotides (AO) which inhibit intimal hyperplasia (IH) following vascular balloon injury bind avidly to perfluorocarbon exposed sonicated dextrose albumin microbubbles (PESDA). Therapeutic ultrasound (TU) has been used to improve the delivery of intravenous AO bound to PESDA to specific vascular targets, but the beneficial effect of this in preventing IH following balloon injury is unclear.

**Methods:** We tested two different TU frequencies (20 kilohertz [20 K] and 1 megahertz [1 M]) applied to the chest wall of 45 pigs following left anterior descending and left circumflex injury. Pigs were randomized to receive IV AO plus PESDA with or without TU at either frequency, as well as control (no injections) or reverse sequence (Sense) bound to PESDA. Histologic measurements of intimal area (IA), maximal intimal thickness (MIT), and intravascular ultrasound measurements of % area stenosis (% AS) were obtained 4 weeks following balloon injury.

**Results:** % AS, IA and MIT were the lowest in pigs who received AO bound to PESDA (PAO) without TU. 1 M TU had no additive effect, and 20 K TU had a detrimental effect (Table):

	PAO alone	1 M PAO	20 K PAO	Control	1 M Sense
% AS (IVUS)	23 ± 15	25 ± 14	41 ± 16	27 ± 6	29 ± 12
MIT (mm)	0.12 ± 0.07*	0.19 ± 0.16	0.45 ± 0.28	0.34 ± 0.29	0.28 ± 0.19
IA (mm <sup>2</sup> )	0.11 ± 0.08*	0.26 ± 0.36	0.56 ± 0.37	0.41 ± 0.46	0.34 ± 0.36

\*p < 0.05 ANOVA compared to 20 K PAS.

**Conclusion:** AO given bound to IV PESDA reduces the degree of IH produced by coronary BI in pigs. TU at different frequencies does not add to the beneficial effect of administering intravenous AO bound to PESDA, and may have a detrimental effect at lower frequencies.

**1169-37 The Impact of a Novel Imaging Transducer in the Assessment of a Pressure Overload Mouse Model of Cardiac Hypertrophy**

Sandra A. Witt, Jo El J. Schultz, Thomas C. Doestschman, Thomas R. Kimball. *University of Cincinnati College of Medicine, Cincinnati, OH, USA*

Echocardiography has become the tool of choice for noninvasive assessment of cardiac structures and function in mice. However, echo evaluation of hemodynamic indices remains somewhat limited and difficult because of suboptimal standard and color Doppler quality and the technical need for a standoff. The aim of this study was to determine the impact of a novel transducer on image and Doppler quality.

**Methods:** To evaluate a knockout model of fibroblast growth factor (FGF2, a protein implicated in cardiac hypertrophy), 12 mice (6 controls, 6 knockouts) with aortic arch banding producing pressure overload underwent echo using an ATL HDI 5000CV imaging system equipped with a 5–8 MHz broad band, tightly curved array scanhead (C8-5). This transducer is capable of faster frame rates and superior image quality. To monitor the effect of cardiac hypertrophy caused by this coarctation, 2D, M-mode, and color and continuous wave Doppler echo were performed pre-operatively and once a week for 10 weeks post-operatively. Indices included: LV end diastolic and systolic dimensions, shortening fraction, septal and posterior wall thicknesses and coarctation gradient. LV mass was calculated.

**Results:** Yield rate for all echo indices was 100% in both groups. Due to the architecture of the C8-5 transducer, a stand-off was not necessary in any instance. Despite initially similar LV mass and coarctation gradients, there was a significant difference in LV mass between groups at 10 weeks post banding (122 ± 20 in controls vs 89 ± 13 mg in knockouts, p < 0.05).

**Conclusion:** We conclude that this transducer provides improved image quality, eliminates stand-off need, and is sufficiently sensitive to quantitate hemodynamic, structural and functional changes in echo indices in transgenic mice models on a serial basis.

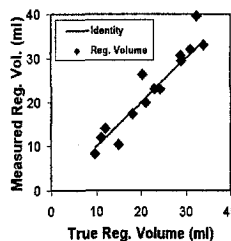
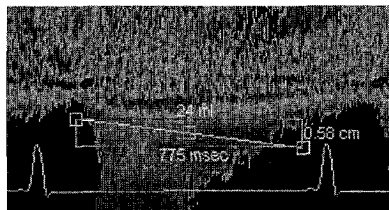
**1169-38 An Automated Quantification of Mitral Regurgitation Volume by Examination of Flow Acceleration Properties: In Vitro Validation**

Xiang-Ning Li, Xiaokui Li, Davy M. Merrick, David J. Sahn. *Oregon Health Sciences University, Portland, OR; ATL Ultrasound, Bothell, WA, USA*

**Background:** Difficulties such as identifying the center of an orifice when using flow convergence methods have limited their use for quantifying mitral regurgitation volume with Doppler echocardiography. To simplify the user interaction and minimize intra-observer variability, we have developed an automatic approach applied with digital color M-mode Doppler imaging for quantifying mitral regurgitant volume by analyzing flow acceleration in the flow convergence region (FCR).

**Methods:** Three dynamic mitral regurgitation orifices (both orifice size and location changing in response to pressure changes) were studied under pulsatile flow conditions (regurgitant volume 8–35 ml/sec, verified by an ultrasonic flow meter; n = 14). Digital color M-mode images were acquired using an ATL HDI 5000 ultrasound system with a P7-4 transducer. Digital velocity data were transferred from the scanner to a Windows computer and analyzed with custom-built software. A rectangular window was placed in the color M-mode FCR that was adjacent to the alias line and adjusted for temporal coverage of the entire regurgitation period. The velocity information within the defined window was analyzed for flow field acceleration rates to derive the instantaneous flow rates so that directly identifying the orifice center was unnecessary. The regurgitant volumes, integrated from the instantaneous flow rates and averaged over 5 beats for each flow condition, were compared against the reference values.

**Results:** The regurgitant stroke volumes measured by our method correlated well to the reference values ( $y = 1.1x - 1.7$ ,  $r = 0.96$ ,  $p < 0.05$ ), but slightly overestimated flow meter results by a mean of 4%.



**Conclusion:** Flow acceleration properties can be reproducibly quantified from digital color M-mode Doppler data with adequate accuracy to calculate regurgitant flow rate automatically.

**1169-39 Circumferential Profile Analysis for Quantitative Comparison of Simultaneous Pulse Inversion and SPECT Dipyridamole Stress Studies of Myocardial Perfusion**

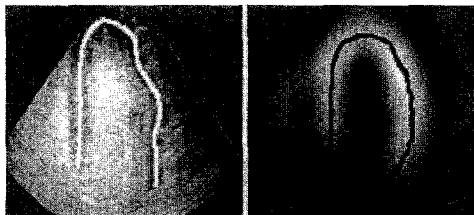
D. Bone, L. Eurenus, U. Niklasson, H. von Bibra. *Dept. of Clinical Physiology, Karolinska Hospital, Stockholm, Sweden*

**Objective:** The analysis of myocardial contrast echocardiography (MCE) by densitometry uses arbitrary regions of interest (ROIs). To take advantage of the improved resolution of the new imaging modality pulse inversion technique (PIT), a circumferential profile (CP) analysis for quantification of MCE and scintigraphic perfusion studies (SPECT) was developed. The two methods were compared in a simultaneous dipyridamole stress test in patients (pats) referred with suspected coronary heart disease.

**Methods:** Triggered (0.5 Hz) ultrasound images (4 chamber view) were acquired using an ATL HDI 5000 system before and during i.v. injection of 0.3 ml Optison® (Op) in PIT mode at rest and during Dipyridamole (0.84 mg/kg) stress tests. Technetium-99m tetrofosmin (Tc) was injected at the end of the dipyridamole infusion. SPECT acquisition was performed with a dual headed gamma camera. CPs were generated from the digital ultrasound images (in dB) and corresponding horizontal long axis SPECT images (in %) in order to evaluate myocardial uptake of Op/Tc with good spatial resolution. CPs were calculated by defining the centre of the myocardium on each image and

summing 5 pixels about the line (Figure). Normal vs pathologic uptake was defined from regional changes of uptake during stress and also by comparing stress vs rest Cps.

**Results:** In 10 pats, mean Op uptake was calculated from the profiles to be  $5.5 \pm 2.9$  dB at rest and  $5.7 \pm 3.3$  dB during stress. For Tc uptake the corresponding figures were  $77.2 \pm 18.6\%$  and  $76.4 \pm 18.3\%$ . In 8 patients (6 pathological) MCE and SPECT were in agreement.



**Conclusion:** The results indicate that CP analysis of PIT myocardial perfusion studies is feasible and preferable to arbitrary ROIs since it provides unequivocal local information.

**1169-40 Harmonic Transthoracic Echocardiography Allows the Exclusion of Left Atrial Appendage Thrombi Before Cardioversion of Atrial Fibrillation/Flutter**

Heyder Omran, Stefan Illien, Rainer Schimpf, Harald Schmidt, Giso von Recke, Rami Rabahieh, Werner Jung, Berndt Lüderitz. *Department of Cardiology, University of Bonn, Bonn, Germany*

**Background and Methods:** Recent studies show that harmonic echocardiography may allow transthoracic imaging of left atrial appendage (LAA) thrombi and assessment of LAA function. To compare the value of harmonic transthoracic echocardiography (TIE) and transesophageal echocardiography (TEE) for detecting LAA thrombi and assessing LAA function prior to cardioversion, 87 patients with atrial fibrillation (AF) and 32 patients with atrial flutter (AF1) were investigated prior to the procedure by two different investigators.

**Results:** Transthoracic imaging of the LAA was considered adequate in 75 of 87 patients with AF and in 28 of 32 cases with AF1. In patients with AF, TTE disclosed 5 thrombi in the LAA. In patients with AF1 thrombi were not detected. The transthoracic exclusion and detection of thrombi were confirmed by TEE in all cases with adequate transthoracic echogenicity. In patients with transthoracic exclusion of left atrial appendage thrombi, thromboembolic complications after cardioversion did not occur. Transthoracic recording of the flow velocity profile over the LAA was feasible in 69 patients with AF ( $0.36 \pm 0.16$  m/s) and in 27 patients with AF1 ( $0.48 \pm 0.12$  m/s).

**Conclusions:** If transthoracic echogenicity of patients is optimal, transthoracic echocardiography with harmonic imaging may allow the detection or exclusion of left atrial appendage thrombi with a high degree of confidence prior to cardioversion. Transesophageal examinations may therefore be limited to cases of suboptimal imaging or where there is clinical concern despite negative transthoracic results.

ORAL

**884 Stress Radionuclide Imaging and Detection of Coronary Artery Disease**

Tuesday, March 14, 2000, 2:00 p.m.–3:30 p.m.  
Hilton Anaheim, California A

2:00 p.m.

**884-1 Reversible Perfusion Defects on <sup>99m</sup>Tc Sestamibi Imaging are Not Due to Changes in Myocardial Blood Flow, but to Changes in Myocardial Blood Volume**

Kevin Wei, Ananda R. Jayaweera, Elizabeth Le, Matthew Coggins, Jiri Sklenar, Sanjiv Kaul. *University of Virginia, Charlottesville, VA, USA*

Despite the lack of a linear relation between <sup>99m</sup>Tc sestamibi (Tc) uptake and myocardial blood flow (MBF), reversible perfusion defects (RPDs) are seen during vasodilator-induced hyperemia. We have previously shown that RPDs on myocardial contrast echocardiography in this situation are due to a decrease in myocardial blood volume (MBV) distal to a stenosis. We, therefore, hypothesized that RPDs on Tc imaging are caused by the same mechanism. Accordingly, in Group I dogs (n = 8), the effect of regional increases in MBF by direct LAD infusions of adenosine on MBV and Tc

uptake was evaluated. In Group II dogs (n = 8), hyperemia was induced with left main infusions of adenosine in the presence of a non-critical stenosis on either the LAD or LCx. MBV was determined from myocardial video intensity measurements during continuous intravenous infusions of microbubbles. MBF was derived using radiolabeled microspheres and regional Tc uptake was measured with a well counter. In Group I dogs, no difference in MBV or Tc uptake was found between the LAD and LCx beds despite a 3-fold increase in MBF to the LAD with adenosine. In Group II dogs, MBV distal to the stenosis decreased during hyperemia on MCE, despite a MBF reserve of  $1.5 \pm 0.7$ . A good correlation ( $r = 0.89$ ,  $p = 0.003$ ) was found between the ratio of Tc uptake from the stenosed and normal beds versus the MBV ratio from those beds. We conclude that RPDs on Tc imaging during vasodilator administration are related to decreases in MBV distal to the stenosis. The decrease in capillary surface area causes reduced uptake of Tc with no increase in uptake in the normal bed. Therefore, contrary to current beliefs, RPDs are not due to heterogeneity of flow between beds, which may explain why RPDs are noted despite a flat relation between MBF and Tc uptake in the hyperemic range.

2:15 p.m.

**884-2 Clinical Performance of Simultaneous Acquisition of Rest TI-201 and Post Stress Tc-99m Sestamibi ECG-gated SPECT: Comparison With Dual Sequential Studies**

Timothy M. Bateman, James A. Case, James H. O'Keefe Jr., S. Kansas Cullom, Kelly L. Moutray, Khaldoon Alaswad, A. Iain McGhie. *Cardiovascular Consultants, P.C., Kansas City, MO, USA*

**Introduction:** Several recent investigations have reported the technical feasibility of simultaneous acquisition of rest TI-201 and post-stress Tc-99m-sestamibi ECG-gated SPECT studies. Diagnostic concordance with traditional dual sequential protocols has been shown in patient populations containing a high proportion of normal studies. This more critical analysis compares the information content of the dual simultaneous (SIM) studies with that of dual sequential (SEQ) studies in 74 consecutive patients with known CAD.

**Methods:** There were 52/74 (70%) males; 50%, 68% and 36% had prior MI, prior PTCA, and prior CABG, respectively. By dual SEQ or dual SIM, 656/1480 (44%) of scored segments were abnormal. The study protocol consisted of injection of 4.5 mCi of TI-201 at rest with ECG-gated SPECT imaging, followed by stress (exercise or adenosine) using a 9 mCi dosage of MIBI. Simultaneous post-stress imaging of both TI-201 and MIBI was performed utilizing energy windows at 72 keV  $\pm$  10% and 167 keV  $\pm$  10% for TI-201, 140 keV  $\pm$  20% for Tc-99m, and 86 keV  $\pm$  5% for downscatter correction. The SEQ and SIM images were interpreted blindly by consensus of 2 expert readers. Each study was scored overall and for each coronary territory as: normal; reversible PD; partially reversible PD; non-reversible PD. In addition, studies were rated as excellent, good, fair, or poor. Finally, interpretive confidence was rated as high, intermediate, or low.

**Results:** Overall concordance was noted for 88% of studies (65/74), with concordance within the vascular territories being 82%, 84%, and 85%, respectively, for the LAD, RCA, and LCX. 84% of the SEQ studies were rated as good or excellent versus 83% of the SIM studies. Interpretive confidence was intermediate-high for 90% of the SEQ studies and 91% of the SIM studies.

**Conclusion:** This study demonstrates that a dual simultaneous protocol provides results comparable to those of dual sequential imaging, in a more challenging group of patients than previously studied, including only patients with a history of known CAD and a high preponderance of abnormal findings. These results should encourage further evaluation of this technique as the simultaneous acquisition protocol can achieve significant time and cost savings in the nuclear cardiology laboratory.

2:30 p.m.

**884-3 Is Dobutamine Superior to Dipyridamole in Evaluating the Severity and Reversibility of Defects Using Tc-99m Sestamibi SPECT Imaging in Patients With Coronary Artery Disease?**

Mary C. deGroot, Alan W. Ahlberg, Domenic Marini, Carol C. McGill, Giselle M. Cyr, April Mann, Gary V. Heller. *Hartford Hospital, Hartford, CT, USA*

**Background:** Previous studies have questioned the diagnostic accuracy of dobutamine (DOB) SPECT imaging as well as the ability to induce reversible defects. Although one study showed similar sensitivities of DOB and dipyridamole (DIP) for detection of coronary artery disease (CAD) using Tc-99m sestamibi SPECT imaging (Santoro et al; *J Nucl Cardiol* 1998; 5: 19–27), there are no data evaluating the severity and reversibility of myocardial perfusion defects between both pharmacologic stress agents in patients (PTS) with CAD and stress-induced ischemia.

**Methods:** Thirteen patients with CAD underwent rest, DIP (0.56 mg/kg over 4 minutes), and DOB (5, 10, 20, 30, and 40  $\mu$ g/kg/minute each over 3 minutes) MIBI (25–30 mCi) SPECT imaging on separate days. With DOB, atropine (0.5–1.0 mg) was used in PTS ( $n = 6$ ) who failed to achieve  $\geq 85\%$  of the age predicted maximal heart rate. Blinded images were interpreted by a consensus of 3 experienced readers using a standard 17-segment model and 5-point scoring system (0 = normal photon activity to 4 = absent photon activity). Summed stress scores (SSS), summed rest scores (SRS), and summed difference (SSS-SRS) scores (SDS) were calculated.

**Results:** Peak heart rate and rate-pressure product were significantly higher with DOB. Although not statistically significant, SSS, a measure of defect severity, and SDS, a measure of defect reversibility, were larger with DOB.

	HRmax	%MPHR	SSS	SRS	SDS
DOB	140 $\pm$ 15	91 $\pm$ 7	16.9 $\pm$ 6.5	7.1 $\pm$ 6.5	9.8 $\pm$ 6.4
DIP	82 $\pm$ 15	56 $\pm$ 11	14 $\pm$ 5.7	7.4 $\pm$ 5.8	6.6 $\pm$ 5.8
p Value	0.009	0.009	0.057	0.633	0.084

**Conclusion:** Dobutamine, with the addition of atropine in patients who fail to achieve an adequate maximal heart rate, is an effective pharmacologic stressor which also may be superior to dipyridamole for evaluating the severity and reversibility of Tc-99m sestamibi myocardial perfusion defects in patients with coronary artery disease.

2:45 p.m.

#### 884-4 Judicious Use of Radionuclide Myocardial Perfusion Imaging in an Emergency Department Chest Pain Center Optimizes the Triage, of Patients With Chest Pain

Brian G. Abbott, Islam Abdel-Aziz, Edward P. Monico, Frans J. Th. Wackers. *Yale University, New Haven, Connecticut, USA*

**Background:** Emergency Department Chest Pain (CP) Centers (C) reduce admissions of patients (pts) with acute CP by improved triage prior to hospitalization. Presumably, pts admitted from the CPC represent a selected population at higher risk. We evaluated the prevalence of coronary artery disease (CAD) in pts admitted from our CPC and the role of myocardial perfusion imaging (MPI).

**Methods:** Over a 2-year period, 1,423 pts were evaluated in the Yale CPC. Acute myocardial infarction was ruled-out by serial enzymes or rest MPI, and the presence of CAD was excluded using exercise (Ex) ECG or stress MPI.

**Results:** Overall, 83% of CPC pts were discharged home and 17% ( $n = 246$ ) were admitted to the hospital. Reasons for admission were clinical changes: i.e. recurrent CP and/or rest ECG changes (40%), abnormal MPI (34%: rest 8%, stress 27%), abnormal Ex ECG (23%), and elevated enzymes (4%). At hospital discharge, only 4% of admitted CPC pts had acute myocardial infarction and only 30% had CAD on further testing. However, 66% of admitted CPC pts had no firm diagnosis at the time of discharge. Of 246 pts, 91 (37%) underwent coronary angiography. Only 49.5% had CAD. The yield to predict angiographic CAD was 100% for rest MPI, 80% for elevated enzymes, 66% for stress MPI, and only 37% for clinical changes, and 16% for abnormal Ex ECG.

**Conclusion:** Even after triaging in the CPC, and sending 83% of pts home, admitted pts from a CPC are at low risk. Of various reasons to admit pts, rest and stress MPI were the most effective diagnostic methods for identifying pts with CAD. Ex ECG, although excellent in identifying low-risk pts, was often falsely positive. Clinical assessment (recurrent CP, ECG changes) had a limited value in predicting angiographic CAD in the CPC population. Thus, judicious use of rest MPI in pts with clinical changes, and stress MPI in pts with abnormal Ex ECG, can optimize triage and reduce unnecessary hospital admissions.

3:00 p.m.

#### 884-5 Clinical and Economic Analysis of Myocardial Perfusion SPECT Scintigraphy in Patients With LBBB

Will E. Gainey, Timothy M. Bateman, A. Iain McGhie, James H. O'Keefe Jr., Kelly L. Moutray, James A. Case, S. James Cullom. *Cardiovascular Consultants, P.C., Kansas City, MO, USA*

**Background:** Left bundle branch block (LBBB), especially when associated with CAD, identifies patients at increased risk for cardiac death. Strategies for assessing patients with LBBB are not standardized, and LBBB is not a payable indication for SPECT in most Medicare regions. This study was designed to assess the potential value of SPECT in risk-stratifying such patients and the associated costs.

**Methods:** Of 361 patients with LBBB in absence of an RV pacemaker who underwent SPECT imaging in our lab between 1994–1998, 135 had no known CAD. Characteristics of these 135 patients were as follows – 41% male, mean age 67 yrs, 53% had anginal-like symptoms, 53% elevated blood pressure, 53% hyperlipidemia, 16% diabetes and 19% smokers. Images were scored using a 4 point (0 = normal, 3 = absent uptake), 20-segment model to determine a summed stress score (SSS) for each patient. Patients were subdivided by risk into low (0–3), intermediate (4–8), and high ( $\geq 9$ ) SSS categories, and followed for a mean of  $21 \pm 14$  months.

**Results:** 79/135 (59%) had a SSS  $\geq 3$ , suggesting CAD. Multivariable regression analysis identified sex and diabetes as weak correlates of an abnormal scan. Cardiac death occurred in 0/56 patients with SSS 0–3, 1/27 (3.7%) of those with SSS 4–8, and 6/52 (11.5%) of patients with SSS  $\geq 9$ . At a Medicare allowable for adenosine ECG-gated SPECT of approximately \$1000, the cost to identify each patient at high risk for cardiac death was \$2596 (\$135,000/52).

**Conclusion:** SPECT imaging would appear to be a clinically and economically effective strategy for risk stratifying patients with LBBB and no history of CAD.

3:15 p.m.

#### 884-6 Does Cardiologist Subspecialization Affect the Cost-Effective Management of Acute Myocardial Infarction Patients Undergoing Pre-Discharge SPECT?

Siu-Sun Yao, Mohammad Kamran, Kenneth Nichols, E. Gordon DePuey, Alan Rozanski. *St. Luke's-Roosevelt Hospital Center and Columbia University, New York, NY, USA*

**Background:** Whereas the impact of cardiologist subspecialization has been evaluated for its clinical influence on patient care, information regarding its impact on hospital costs is limited. An excellent paradigm for this assessment is comparison of cardiology subspecialists in use of myocardial perfusion SPECT for pre-discharge evaluation of patients with acute myocardial infarction (AMI).

**Methods:** We assessed differences between noninvasive (NIC) [ $n = 147$ ] and invasive (IC) [ $n = 59$ ] cardiologists in: days to SPECT following AMI, cardiac catheterization (CATH) and coronary revascularization (REV) rates, coronary care unit (CCU) days, length of hospital stay (LOHS), and total hospital costs (HCOST) among 206 patients ( $63 \pm 13$  years, 67% male) undergoing SPECT following AMI. One year followup (mean  $16 \pm 0.6$  years) for confirmed MI and cardiac death were obtained. SPECT studies were read using a 20-segment, 5-point scale of perfusion (0 = normal to 4 = no uptake). Global summed stress (SSS), summed reversibility (SRS), and summed fixed (SFS) scores were calculated.

**Results:** There were no differences among NIC vs IC in age, gender, cardiac risk factors, or SPECT results: SSS ( $24 \pm 12$  vs  $24 \pm 13$ ), SRS ( $5 \pm 6$  vs  $4 \pm 5$ ), and SFS ( $19 \pm 11$  vs  $20 \pm 14$ ) [all  $p = NS$ ].

	Days to SPECT	CATH	REV	CCU (days)	LOHS (days)	HCOST (x\$1000)	MI/Death
NIC	7.7 $\pm$ 4	35%	8.9%	4.4 $\pm$ 4	11.6 $\pm$ 5	20.5 $\pm$ 14	7.5%
IC	5.8 $\pm$ 3*	59%†	15.3%	6.2 $\pm$ 5*	11.0 $\pm$ 9	26.2 $\pm$ 15*	8.5%

\* $p < 0.05$  vs. NIC; † $p = 0.07$  vs. NIC.

Although IC used SPECT earlier following AMI, IC used significantly more CCU days, tended to refer more patients to CATH and REV, and incurred a significantly higher total HCOST. There was no difference in LOHS or adverse cardiac events among the two groups.

**Conclusions:** Despite no significant difference in baseline characteristics or SPECT study results among patients managed by NIC vs IC, NIC provided significantly better cost-effective AMI care.

ORAL

**885** **Ultrasound Detection of Myocardial Ischemia**

Tuesday, March 14, 2000, 2:00 p.m.–3:30 p.m.  
Hilton Anaheim, California B

2:00 p.m.

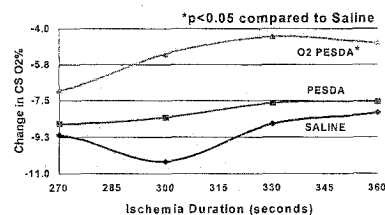
**885-1** **Reduction in Myocardial Ischemia During Acute Coronary Ischemia Using Intravenous Oxygenated Perfluorocarbon Exposed Sonicated Dextrose Albumin Microbubbles**

David Kricsfeld, Feng Xie, Candice Montzingo, Kurtis G. Cornish, John Lof, Thomas R. Porter. *University of Nebraska Medical Center, Omaha, NE, USA*

**Background:** The perfluorocarbon (PFC) within albumin coated microbubbles (MB) is a slowly permeating gas, while diffusible gases like oxygen (O<sub>2</sub>), carbon dioxide, and nitrogen freely pass across PFC containing MB membranes according to their concentration gradient. We hypothesized that PFC MB could transport O<sub>2</sub> from lungs to myocytes via the coronary microcirculation during ischemia.

**Methods:** Recurrent flow limiting stenoses were created in the left circumflex arteries of four dogs, followed by a randomized sequence of intravenous (IV) injections of either room air filled perfluorocarbon exposed sonicated dextrose albumin (PESDA) MB, PESDA sonicated in the presence of 100% oxygen (O<sub>2</sub> PESDA), or saline. After six minutes of ischemia, the stenosis was released. Coronary sinus (CS) oxygen saturation (CS O<sub>2</sub>%) and wall thickening (WT) within the risk area were measured both during ischemia and reperfusion (REP).

**Results:** CS O<sub>2</sub>% correlated closely with CS lactate levels ( $r = -0.97$ ). CS O<sub>2</sub>% was significantly higher throughout the ischemic period when O<sub>2</sub> PESDA was given (Graph). The improvement in WT immediately following PEP was significantly higher with O<sub>2</sub> PESDA ( $12 \pm 6\%$  saline versus  $22 \pm 8\%$  O<sub>2</sub> PESDA;  $p = 0.008$ ).



**Conclusion:** Intravenous O<sub>2</sub> PESDA reduces CS lactate production during acute ischemia due to flow limiting coronary stenoses, and may be an effective treatment in the early phases of acute coronary syndromes. O<sub>2</sub> PESDA also appears to reduce the duration of stunned myocardium following reperfusion.

2:15 p.m.

**885-2** **Altered Segmental Compression/Expansion Crossover: A Sensitive Indicator of Acute Myocardial Ischemia as Assessed by Non-Invasive Strain Rate Imaging**

Cristina Pislaru, Marek Belohlavek, Richard Y. Bae, Theodore P. Abraham, James B. Seward. *Mayo Clinic, Rochester, MN, USA*

**Background:** Acute myocardial ischemia results in impaired energetic metabolism and subsequent distortion in the regional contraction-relaxation sequence. Strain Rate Imaging (SRI), defined as the spatial gradient of local velocities, can differentiate vector components of myocardial fiber contraction and relaxation along the ultrasound beam. The aim of our study was to quantify temporal and spatial characteristics of myocardial compression/relaxation crossover, as measured by SRI, during acute myocardial ischemia.

**Methods:** SRI data were collected from 20 open-chest pigs, before and after LAD ligation (range: 7 to 90 min). 2D-cine-loops from single heartcycles (>55 frames/sec) were acquired in 3 apical views (4C, 2C, and LAX). Curved M-mode SRI reconstructed from the cine-loops were employed to analyze the segmental (apical, mid, basal) compression-relaxation sequence. Mean segmental compression duration (SCD = time from ECG R-top to end of compression on SRI M-mode) was measured for each segment, and corrected for heart rate [ $SCD_c = SCD/\sqrt{R-R}$ ]. The mean SCD<sub>c</sub> at baseline and ischemia, and differences between segments during ischemia, were compared. Excised hearts were stained for the area at risk, sliced (25 slices/ventricle), and 3D-reconstructed.

**Results:** Acute ischemia consistently resulted in significantly prolonged SCD<sub>c</sub> in all ischemic segments when compared with baseline [table: mean

$\pm$  SEE (ms); \* $p < 0.01$ ] or with normal segments. SRI mapping of the regions with prolonged SCD<sub>c</sub> matched or slightly overestimated (<10%) the anatomic mapping of the area at risk obtained from the same apical views in 3D-reconstructed stained hearts.

	Septal	Lateral	Inferior	Anterior	Posterior	Ant-septal
Basal	-3 ± 12	-2 ± 10	-6 ± 8	-4 ± 18	-6 ± 10	21 ± 12
Mid	42 ± 13	7 ± 12	11.1 ± 11.4	19 ± 11	7 ± 15	*72 ± 13
Apical	*129 ± 13	*83 ± 13	*94 ± 13	*96 ± 13	*59 ± 14	*105 ± 15

**Conclusions:** The measurement of the compression/relaxation crossover time, as calculated from curved M-mode SRI, is an accurate parameter for quantification of myocardial ischemia distribution. This regional parameter may be an estimator of impaired energetic metabolism.

2:30 p.m.

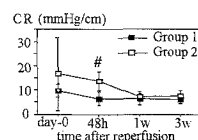
**885-3** **Early Changes of Coronary Resistance After Coronary Angioplasty Predicts Reversible Postischemic Dysfunction in Anterior Acute Myocardial Infarction: Serial Assessment With Transthoracic Coronary Doppler Echocardiography**

Yuichi Nohtomi, Hitoshi Kamiyama, Kouichi Kuwata, Isamu Matsuo, Tohru Yamawaki, Shoichi Kondo, Atsushi Sobashima, Kazushige Nagasawa, Akira Yamada, Shuichi Okamoto. *Iizuka Hospital, Fukuoka, Japan*

**Background:** Transthoracic coronary doppler echocardiography (TTCDE) has been used to measure flow velocity in left anterior descending coronary artery (LAD) noninvasively at bedside. Little is known about the relation between serial alteration of coronary hemodynamics in infarct-related artery and functional recovery of postischemic dysfunction in patients with acute myocardial infarction (AMI) after reperfusion.

**Method:** Thirty-three consecutive patients with anterior AMI after primary percutaneous transluminal coronary angioplasty (PTCA) were studied. Averaged regional wall motion score index of LAD segments (RWMSI: from 1 = normal to 4 = dyskinetic, for 9 segments) and distal LAD flow velocity were recorded by two-dimensional echocardiography and TTCDE (using 2–4 MHz and 5–12 MHz ultraband transducers, SONOS 5500, Hewlett-Packard). Data were obtained at immediately after PTCA (day-0), 48 hours, 1 and 3 weeks after AMI. The coronary resistance (CR; mmHg/cm) of LAD was defined as mean arterial pressure divided by the velocity time integral of distal LAD flow velocity.

**Result:** Serial recording of TTCDE was feasible in 30 patients (91%). 70% of the patients were stented. Nineteen patients manifested reversible dysfunction (defined as decrease of RWMSI > 0.22: Group 1). Remained 11 patients showed fixed dysfunction (Group 2). Baseline characteristics were similar between the two groups. Functional recovery was seen only at 3 weeks after PTCA in Group 1. CR was elevated significantly only at 48 hours after PTCA in Group 2 (vs. Group 1,  $p < 0.001$ ; #). CR at 48 hours was correlated significantly with decrease of RWMSI at 3 weeks ( $r^2 = 0.49$ ,  $P < 0.001$ ).



**Conclusion:** In anterior AMI, the patients with reduced CR at 48 hours after PTCA are associated with reversible dysfunction. Elevated CR at 48 hours after PTCA maybe a predictor for fixed dysfunction.

2:45 p.m.

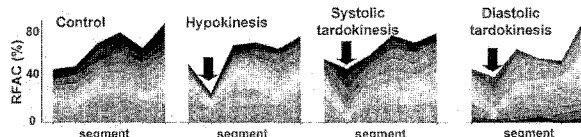
**885-4** **Objective Noninvasive Assessment of Regional LV Systolic and Diastolic Dysfunction During Acute Myocardial Ischemia**

Victor Mor-Avi, Claudia Korcarz, Keith A. Collins, Milind Shah, Kirk T. Spencer, Ted Feldman, Roberto M. Lang. *University of Chicago, Chicago, IL, USA*

**Background:** Echocardiographic diagnosis of acute ischemia is based on visualizing a regional decrease in systolic endocardial motion and myocardial thickening. Since ischemia may also cause temporal alterations in systolic and diastolic function, we developed a technique for objective evaluation of both the magnitude and timing of regional LV function, based on segmental analysis of color kinesis (CK) images. Our aim was to test the ability of this technique to noninvasively detect early changes in LV performance following coronary occlusion and reperfusion.

**Methods:** Thirteen PTCA balloon occlusions of the LAD were performed in 4 anesthetized pigs. Transthoracic short axis images were acquired at baseline, and then intermittently every 10 sec during 3 min of occlusion and during reperfusion. Systolic and diastolic endocardial motion was color-coded at 60 frames/sec using prototype high frame rate CK software (HP 5500). Regional fractional area change (RFAC) was displayed as stacked histograms wherein different layers represent consecutive time frames.

**Results:** All ischemic episodes caused changes in RFAC histograms which were detectable immediately after LAD occlusion and resolved during reperfusion. Three types of early response to occlusion were noted: (1) reduced magnitude of endocardial motion (hypokinesis), (2) delayed systolic motion with increased late contraction (systolic tardokinesis), and (3) delayed diastolic motion with augmented late filling (diastolic tardokinesis). The earliest sign of acute ischemia was: hypokinesis in 2 out of 13 occlusions, systolic tardokinesis in 5, and diastolic tardokinesis in 6.



**Conclusions:** Segmental analysis of high frame rate CK images allows objective detection of reversible changes in magnitude and timing of endocardial motion induced by acute ischemia. The ability to noninvasively detect changes in timing of LV regional contraction and filling is likely to improve the early echocardiographic diagnosis of acute ischemia.

3:00 p.m.

#### 885-5 Tissue Doppler Echo Tracking System Can Detect Subendocardial Ischemia Even at Rest

Yukihiro Kuwada, Katsu Takenaka, Fumiyoshi Watanabe, Makoto Sonoda, Weidong Yang, Susumu Sakurai, Tomiko Takahashi, Kazuno Sasaki, Yasuhiro Ito. *University of Tokyo, Tokyo, Japan*

**Backgrounds:** We developed a new automatic echo tracking system using tissue color-coded Doppler ultrasound and incorporated the system in the commercially available ultrasound machine (ALOKA SSD-2200). The system automatically tracks any designated point on M-mode echo by integrating the tissue Doppler velocity data over time.

**Objectives:** To assess if this new system can detect subendocardial ischemia even at rest.

**Methods:** This system was used in 42 normals (age  $57 \pm 14$  years) and 28 patients with coronary artery disease (CAD) (age  $67.4 \pm 6$  years) who had  $>75\%$  stenosis in both left circumflex coronary artery and right coronary artery on coronary angiograms, and showed normal or only mild hypokinesis of LV posterior wall on 2-D echo at rest. LV posterior wall at the level of the papillary muscle was recorded by M-mode tissue color Doppler with 2.5 MHz probe. At end-diastole, endocardium and epicardium was designated manually, and the midpoint of endocardium and epicardium was designated automatically. These 3 structures were tracked automatically from end-diastole to endsystole. Using these 3 tracked lines, we measured systolic thickenings of subendocardial layer ( $\Delta$ Endo), subepicardial layer ( $\Delta$ Epi), and whole wall ( $\Delta$ Total) of LV posterior wall, and calculated  $\Delta$ Endo/ $\Delta$ Epi.

**Results:** Results were shown in the table.

	Normals	p value	CAD
$\Delta$ Total	$0.57 \pm 0.20$	0.06	$0.50 \pm 0.13$
$\Delta$ Endo	$0.84 \pm 0.36$	$<0.001$	$0.47 \pm 0.29$
$\Delta$ Epi	$0.44 \pm 0.19$	$<0.005$	$0.64 \pm 0.35$
$\Delta$ Endo/ $\Delta$ Epi	$2.0 \pm 0.78$	$<0.0001$	$0.82 \pm 0.35$

In CAD group, even at rest, subendocardium showed decreased contraction and subepicardium showed "compensatory" hyperkinesis, making  $\Delta$ Endo/ $\Delta$ Epi a highly sensitive index for ischemia.

**Conclusions:** Tissue Doppler echo tracking system can detect subendocardial ischemia even at rest by evaluating subendocardium and subepicardium separately.

#### 885-6 Reduction in Myocardial Perfusion Defect Size During Acute Coronary Thrombosis With Transthoracic Therapeutic Ultrasound and Intravenous Perfluorocarbon Containing Microbubbles

Thomas Porter, Feng Xie, David Kricfeld. *University of Nebraska Medical Center, Omaha, Nebraska, USA*

**Background:** Transthoracic therapeutic ultrasound (TUS) and intravenous (IV) perfluorocarbon containing microbubbles (PESDA) have been used alone or in combination with fibrinolytic agents to recanalize thrombosed coronary and iliac arteries. Even without recanalization, treatment with TUS and IV PESDA has been shown to improve electrocardiographic and wall motion abnormalities. Because of this, we hypothesized that these improvements may be mediated by ultrasound-induced changes in collateral flow to the risk area.

**Methods:** We created coronary artery thromboses (CT) in 12 coronary arteries of 10 pigs (8 left anterior descending (LAD), 4 circumflex). Baseline measurements were then made of the spatial distribution (SD) of any contrast defect (CD) using diagnostic ultrasound and IV PESDA. TUS was then delivered (1 megahertz; 1.0 watts/cm<sup>2</sup>) while IV PESDA was given every three minutes up to 30 minutes. Angiography and SD measurements of CD size were made every 15 minutes. Pigs did not receive heparin or aspirin.

**Results:** Angiographic evidence of epicardial recanalization following TUS and IV PESDA was observed in five of the 12 CT (Group I) at 30 minutes, while the remaining 7 vessels had no or severely reduced epicardial flow (Group II). Myocardial CD size decreased in both Group I and II following TUS and PESDA ( $2.4 \pm 1.6$  cm<sup>2</sup> at time zero to  $0.4 \pm 0.6$  cm<sup>2</sup> at 30 minutes;  $p = 0.03$ ). The SD of the CD in Group II pigs consistently decreased along the lateral margins of the risk area in each pig (Figure).



LAD Thrombosis Before TUS/PESDA



Persistent LAD Thrombosis 30 minutes TUS/PESDA

A CD was no longer evident in 4 of the 7 vessels in Group II at 30 minutes.

**Conclusion:** TUS plus PESDA significantly reduces the size of the risk area even when epicardial reflow is not achieved. The pattern of risk area reduction is consistent with improved collateral flow from adjacent perfusion beds.

POSTER

#### 1189 Contrast Echocardiography: Left Ventricular Opacification

Tuesday, March 14, 2000, 3:00 p.m.–5:00 p.m.  
Anaheim Convention Center, Hall A  
Presentation Hour: 3:00 p.m.–4:00 p.m.

#### 1189-33 Contrast Echocardiography Improves the Accuracy and Reproducibility of Left Ventricular Remodeling Measurements: A Prospective, Randomized, Blinded Study

Arsene J. Basmadjian, Andrew J. Rainbird, Mehdi Razavi, Francesco Grigioni, Patricia A. Pellikka, Maurice E. Sarano. *Mayo Clinic, Rochester, MN, USA*

**Background:** Left ventricular (LV) remodeling is a precursor of LV dysfunction and predicts outcome. Echocardiographic assessment of LV remodeling is considered inaccurate and variable. Although contrast (C) imaging enhances endocardial border definition, improved reproducibility of LV remodeling measurements has yet to be demonstrated with this technique.

**Methods:** In an institution-funded study, fundamental (F), harmonics (H) and H + C (Optison™) digital biplane images of the LV were acquired prospectively in 32 patients with various degrees of LV remodeling. End diastolic volume (EDV), end systolic volume (ESV), stroke volume (SV) and ejection fraction (EF) were determined by Simpson's biplane method (SBM) in duplicate, in a randomized and blinded fashion by three observers for each imaging modality. SV was also assessed by 2 independent quantitative Doppler (QD) techniques.



**Results:**

	EDV		ESV		SV		EF	
	ABS	%	ABS	%	ABS	%	ABS	%
F	24	13	21	23	25	29	11	24
H	22	13	14	17	22	28	8	18
H + C	12	8	8	15	8	9	4	6
p (Anova)	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Interobserver variability (expressed as absolute (ABS) in mL and percentage (%)) was significantly reduced by H + C for EDV, ESV, SV and EF. Absolute intraobserver variability for EDV, ESV and SV and relative intraobserver variability for EDV, SV and EF were also reduced by H + C (all  $p < 0.02$ ). For SV determined by SBM, there were significant differences observed using F and H ( $p < 0.01$ ), as compared to QD, where as no difference was seen with H + C for all observers.

**Conclusions:** H + C imaging significantly reduces intra- and interobserver variability and improves accuracy of LV remodeling measurements by echocardiography. Harmonic imaging with contrast of LV should be recommended in patients in whom assessment of remodeling is required.

**1189-34 Echocardiographic Imaging of Technically Difficult Patients in the Intensive Care Unit: Use of Optison™ in Combination With Fundamental and Harmonic Imaging**

George K. Daniel, Stephen G. Sawada, Irmina Gradus-Pizlo, Harvey Feigenbaum, Douglas S. Segar. *Indiana University, Indianapolis, Indiana, USA*

**Background:** Previous studies of intravenous contrast agents have excluded patients in the intensive care unit. These patients remain the most technically difficult to image with ultrasound. We studied the effect of different imaging modalities with and without intravenous contrast Optison™ on endocardial border visualization (EBV) during echocardiography.

**Methods:** Patients in intensive care unit (n = 25, 17 males, 19 on mechanical ventilator, 7 with chest bandages, mean age 60.2 years, mean weight 193.4 pounds,) were considered to have technically difficult images based on non visualization on 2 of 6 segments with fundamental imaging on either of the apical views. Each patient was studied using fundamental (Fund), harmonic (Harm), Fund + Optison™ (Fund + Opt), and harm + Opt techniques, using standard long axis, short axis, apical 4 chamber, and 2 chamber views. Intravenous Optison™ (0.5–1.5 cc) was given before Fund + Opt and Harm + Opt imaging. There were no contrast related side effects noted. All images were stored digitally in a quad screen format. For each set of images, segments (n = 22) were given an EBV score of (0) if not visualized, (1) if visualized in either systole or diastole, and (2) if visualized in both.

**Results:** There was stepwise improvement in EBV with mean EBV score of  $0.91 \pm 0.86$  (Fund),  $1.07 \pm 0.84$  (Harm),  $1.41 \pm 0.68$  (Fund + Opt), and  $1.81 \pm 0.39$  (Harm + Opt). Using a Neuman-Keuls analysis there was a statistically significant difference between each group ( $p < 0.001$ ). The incremental benefit of Optison™ was greater with Harmonic imaging than with fundamental by two way repeated ANOVA ( $p < 0.001$ ).

**Conclusion:** The use of Optison™ is safe and effective and in combination with harmonic imaging provides maximal endocardial border delineation during echo imaging of technically difficult patients in the intensive care unit.

**1189-35 Accurate Quantitative Echocardiography Requires Harmonic Contrast Imaging**

Tamanna Nahar, Lori B. Croft, Robert Shapiro, Samantha Buckley, John Doucette, Josef Machac, Joseph Diamond, Milena Henzlova, Steve Fruchtman, Eric H. Stern, Martin E. Goldman. *Mount Sinai Medical Center, NYC, USA*

Quantitative LV ejection fraction (EF) measurement by 2-D echo is limited by subjective visual endocardial border detection. Both harmonic (H) imaging and precision contrast (C) echo provide improved LV wall and cavity definition. To determine the incremental benefit of the newer technologies, we calculated Simpson's biplane 2-D echo LV EF in 50 subjects, mean age =  $48 \pm 16$  yrs, by (1) fundamental (F) and (2) H imaging, (Acuson Sequoia & ATL HDI 5000 CV) each (3) with (C+), or (4) without (C-) Optison® contrast boluses. Of the 50 echo studies, 44 were considered technically difficult:  $\geq 2$  LV wall segments poorly visualized in apical 2 or 4 views. Radionuclear (RNC) gated LV EF's done within 12 hours of the echo ranged from 18–72%, mean =  $51 \pm 17\%$ , served as the gold standard. LV EF measurements were done blinded to RNC results, from digitally stored images by 3 independent readers (Readers<sub>1-3</sub>) and were correlated with RNC EF's. R values are listed:

	F:C-	F:C+	H:C-	H:C+
Reader 1	0.68	0.78	0.84	0.95
Reader 2	0.60	0.68	0.84	0.96
Reader 3	0.66	0.80	0.83	0.95
Mean	0.65	0.75	0.84	0.95
Bias $\pm$ S.D.	$3.4 \pm 15$	$5.0 \pm 11$	$2.8 \pm 9$	$-1.2 \pm 5$

Contrast provided a similar increment in accuracy for F and H imaging, though the correlation of H alone was significantly better than F alone. Harmonics alone provided roughly 0.5 the advantage gained by Contrast combined with Harmonic imaging. Harmonic and contrast had the best correlation with the smallest bias and standard deviation. Thus, quantitative echo is possible with newer imaging methods and is most accurate when harmonic imaging is performed with contrast.

**1189-36 Enhanced Detection of Patent Foramen Ovale by Transthoracic Contrast Echocardiography Using Harmonic Imaging**

Jong-Won Ha, Mi-Seung Shin, Seok-Min Kang, Kil-Jin Jang, Kihyun Byun, Se-Joong Rim, Namsik Chung, Seung-Yun Cho. *Yonsei University College of Medicine, Seoul, Korea*

**Background:** Paradoxical embolism through the patent foramen ovale (PFO) is a well-recognized mechanism for embolic stroke. Although transthoracic contrast echocardiography (TCE) has been used frequently for noninvasive diagnosis of PFO, its diagnostic accuracy appears limited, especially in patients with poor acoustic window. Since harmonic imaging (HI) can enhance the definition of contrast microbubbles, theoretical advantages of HI in the detection of PFO using microbubbles can be considered. The purpose of this study was to compare the diagnostic value of transthoracic HI in the detection of PFO in patients with stroke with that of fundamental imaging (FI).

**Methods:** One hundred twenty-one consecutive patients with stroke (70 male, mean age 59) underwent TCE in both HI and FI and transesophageal echocardiography (TEE) during rest and Valsalva maneuver with intravenous administration of agitated saline. PFO was judged to be present if microbubbles appeared in the left atrium within 3 cardiac cycles of their appearance in the right atrium. TEE was regarded as the gold standard for assessing the sensitivity of TCE.

**Results:** PFO was detected in 29 (24%) of 121 patients by TEE. FI of TCE detected PFO in only 6 (5%) of 121 patients. In contrast, HI detected PFO in 18 (14.9%) of 121 patients. The overall sensitivity and specificity of FI and HI for detection of PFO were 20.7, 62.1% ( $p < 0.05$ ) and 100, 100%, respectively. Valsalva maneuver during HI also significantly increased the detection rate of PFO (during rest in 8 and during Valsalva maneuver in 18,  $p < 0.05$ ).

**Conclusion:** HI with agitated saline injection significantly enhanced the detection of PFO in patients with stroke compared with FI by transthoracic approach.

**1189-37 Pulse Inversion and Second Harmonic Imaging Allows the Assessment of Left Ventricular Function Using Very Low Doses of Optison® Contrast Agent**

Sungwai Chiu, Hanna Akiki, Aylmer Tang, Michael D. VanAuker, David Z. Gunsburg, Joel A. Strom. *Brookdale University Hospital and Medical Center and S.U.N.Y. Health Science Center at Brooklyn, New York, USA*

**Background:** The use of echocardiographic contrast agents to opacify the left ventricle (LV) is becoming standard in technically difficult patients to assess ejection fraction (EF) and wall motion. We performed a dose ranging study using low doses of Optison® to determine the minimum amount needed for adequate LV opacification.

**Methods:** Echocardiograms were performed with Optison® on 43 patients. Serial doses ranging from 0.02 to 0.1 ml were administered. Apical two and four chamber views were acquired using standard second harmonic and pulse inversion imaging at a low mechanical index. LV walls imaged in these views were divided into 12 segments according to the American Society of Echocardiography standard. The number of assessable wall segments (AWS) was counted. EF and the volume-fraction (VF) of the LV that was opacified were determined by the area-length method. Adequate opacification was defined as  $VF \geq 70\%$ . Evaluations were made by 2 independent readers.

**Results:** The 0.1 ml dose was sufficient to consistently visualize wall motion ( $AWS > 11$ ). AWS seen at 0.1 ml was significantly higher than without contrast and for the lower doses (all  $p < 0.001$ ). Pulse inversion was slightly superior to standard second harmonic imaging, but differences were not statistically significant at any dose ( $p = NS$ ). There was no significant difference between independent evaluations. Adequate opacification was

achieved in some individuals at doses as low as 0.02 ml ( $0 \leq VF \leq 85\%$ ) and consistently at 0.1 ml.

**Conclusions:** A dose of 0.1 ml of Optison® combined with pulse inversion and second harmonic imaging allows for the adequate assessment of LVEF and wall motion. This finding indicates that the routine use of contrast echocardiography is economically feasible.

#### 1189-38 Optison® Enhanced Echocardiography: A Cost-Effective Approach to Non-Invasive Testing

Rollo P. Villareal, Andres Mesa, Antonieta Hernandez, Sue Maisey, Susan Wilansky. *St. Luke's Episcopal Hospital, Texas Heart Institute, Baylor College of Medicine, Houston, TX, USA*

**Background:** Optison®, a 2<sup>nd</sup> generation ultrasound contrast agent, significantly enhances endocardial definition and improves evaluation of regional and global left ventricular function. We prospectively compared the cost impact of performing contrast-enhanced echocardiography to that of another diagnostic test avoided.

**Methods:** From September 1998 to July 1999, 9256 inpatient 2-D echocardiograms with or without doppler and 119 dobutamine echocardiograms were performed at our institution. Of these, 109 were deemed technically suboptimal and enhanced with Optison®. Costs based on medicare reimbursement for the initial test with the use of Optison® were compared to incremental costs incurred for any follow-up tests avoided (i.e. MUGA, SPECT, TEE).

**Results:** Total costs for the Optison® group were \$57,223 (\$525 ± 6 per patient). Total costs of additional testing would have been \$80,243 (\$736 ± 188 per patient), not including charges for longer hospitalizations. Although Optison® increased the initial costs by \$90/patient, overall costs were 29% lower.

**Conclusion:** Optison® enhancement of technically suboptimal echocardiograms represents a cost-effective means of assessing regional and global left ventricular function.

#### 1189-39 Quantifying In Vivo Kinetics of Ultrasound Contrast Agents Using Peripheral Artery Doppler Power

James L. Januzzi, Charles C. Churchill<sup>1</sup>, Judith A. Gosselin, Andrea L. Zamejts, Robert C. Fetterman<sup>1</sup>, Richard C. Walovitch<sup>1</sup>, Michael H. Picard. *Massachusetts General Hospital; <sup>1</sup>Acusphere, Inc., Boston, MA, USA*

**Background:** Quantitative myocardial contrast imaging requires the delivery of an effective, reproducible concentration of contrast microbubbles. The use of cardiac contrast signal to quantify bubble concentration is hampered due to attenuation and on-going bubble destruction. We studied the feasibility of peripheral artery Doppler power (PADP) to monitor kinetics of echo contrast at several instrument settings compared to video intensity parameters of the LV cavity signal.

**Methods:** In five patients, following the IV injection of 1 cc of Optison, time-averaged spectral power was determined from Doppler flow signals of the radial artery, utilizing a PC-based CW Doppler power monitor device. Digital images at high (1.4–1.6) or low (0.5–0.6) mechanical index (MI), in continuous (frame rate [FR] = 30 Hz) or triggered (1:4), harmonic mode of the apical 4-chamber view were stored for off-line quantitation of LV cavity contrast intensity. Curves of average power vs. time were analyzed from first appearance to peak signal ( $t_{pk}$ ), area under the curve over 2 min (AUC2) and the ratio of AUC over the first 30 sec to that over the second half minute (AUC0.5/1.0), a measure of the rate at which microbubbles disappear from the blood.

**Results:** PADP parameters varied with expected influences on bubble stability (less concentration at high MI and FR); deviations in expected video intensity indices were noted due to LV cavity signal attenuation.

Imaging Mode	PADP			Video Densitometry		
	$t_{pk}$ sec, [n]	AUC2 dB-sec, [n]	AUC0.5/1.0 [n]	$t_{pk}$ sec, [n]	AUC2 dB-sec [n]	AUC0.5/1.0 [n]
Hi MI/30	5.6 [5]	630 [5]	4.7 [5]	24 [4]	780 [4]	1.5 [4]
Lo MI/30	8.4 [5]	974 [5]	2.2 [5]	31 [4]	582 [4]	1.2 [4]
Lo MI/1:4	8.7 [3]	1549 [3]	1.4 [3]	69 [3]	1206 [3]	0.5 [3]

**Conclusions:** Doppler power measured from peripheral arteries allows study of contrast echo kinetics and concentration, independent of attenuation. This technique may allow standardization of contrast effect through a better understanding of effective blood concentration for each dose of bubble as a function of different instrument settings, without the need for blood assays.

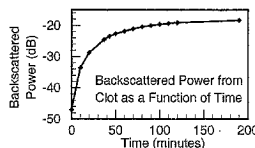
#### 1189-40 Kinetic Modeling of Ultrasonic Contrast Enhancement by Targeted Agents Using Acoustic Microscopy

Jon N. Marsh, Christopher S. Hall, Michael J. Scott, Ralph J. Fuhrhop, Patrick J. Gaffney, Samuel A. Wickline, Gregory M. Lanza. *Washington University School of Medicine, St. Louis, MO, USA*

**Background:** Molecular imaging with targeted contrast agents is emerging as an important technological advance for diagnostic ultrasound. In vivo, these agents must bind to and acoustically enhance their targets before the agents are cleared or destroyed. The present study describes the use of acoustic microscopy to dynamically assess the time-course of ultrasonic enhancement of plasma clots by a fibrin-targeted perfluorocarbon nanoparticulate emulsion.

**Methods:** Plasma clots were formed on nitrocellulose membranes, sequentially incubated with biotinylated antibody and avidin, then sealed inside a custom-designed recirculating flow chamber having an acoustic window made of polyethylene film. Ultrasonic scanning of the clot was performed using a single-element 25 MHz ultrasonic transducer mounted to a computer-controlled translating stage which allowed careful repositioning in three orthogonal directions. Clots were scanned at a spatial resolution of 100  $\mu$ m, and a complete backscattered radiofrequency waveform was stored off-line for each site. Each clot was scanned once every 10 minutes for 2 hours. Integrated backscatter analysis was performed to construct a time-lapse parametric representation of the interaction of the contrast agent with the clot.

**Results:** Backscattered power from large confluent regions of acoustic enhancement as a function of exposure time were used to estimate an effective time constant for the binding rate of particles to the clots. Scanning electron microscopy subsequently revealed that the targeted particles densely coated surface fibrin strands of each clot.



**Conclusion:** This combination of targeted contrast agent and dynamic acoustic microscopy system allows quantitative time-course assessments of backscatter changes to be measured, and may facilitate assessments of efficacy for emerging ultrasonic contrast agents to detect a variety of cardiovascular pathology.

#### POSTER

#### 1190 Magnetic Resonance Imaging: Imaging Atherosclerosis

Tuesday, March 14, 2000, 3:00 p.m.–5:00 p.m.  
Anaheim Convention Center, Hall A  
Presentation Hour: 3:00 p.m.–4:00 p.m.

#### 1190-1 In Vivo Quantification of Atherosclerotic Plaque Composition by Noninvasive High Resolution MRI in Rabbits: A Histopathological Correlation

Gérard Helft, Stephen G. Worthley, Valentin Fuster, Zahi A. Fayad, Julio I. Osende, Azfar G. Zaman, John Fallon, Juan J. Badimon. *Mount Sinai School of Medicine, New York, New York, USA*

**Background:** Atherosclerotic lesion composition is central to the process of plaque rupture and subsequent thrombogenicity. The ability to characterize and quantify atherosclerotic components noninvasively could permit risk stratification for plaque complications and allow serial studies of plaque progression and/or regression. We report the accurate quantification of atherosclerotic components by MRI in a rabbit model, which is hitherto unreported.

**Methods:** Thoracic and abdominal aortic atherosclerosis was induced in New Zealand white rabbits ( $n = 15$ ) by a combination of atherogenic diet for 9 months (0.2% chol.) and double balloon aortic denudation. MR images of the entire aorta were obtained in a clinical 1.5 T system (GE). Fast spin echo sequences were performed with an in-plane resolution of 0.35 mm and slice thickness of 3 mm. T2W (TR/TE 2300/60 msec) and PDW images (TR/TE 2300/15 msec) were acquired. Rabbits were sacrificed for histopathological correlation with matched MR images. Analysis with computer-assisted morphometry included quantification of lipidic and fibrotic areas and vessel wall area measurements by histology and MRI.

**Results:** At 9 months, MR imaging was able to distinguish between lipidic (low signal – dark) and fibrous (high signal – bright) areas on both PDW and T2W images. A significant correlation ( $p < 0.05$ ) between MR images and histology (using Oil red O staining) for analysis of lipidic areas was observed ( $r = 0.81$ ). Similarly, a significant correlation ( $p < 0.05$ ) between MR images and histology for analysis of fibrous areas was observed ( $r = 0.86$ ). T2W images demonstrated a significantly ( $p < 0.001$ ) greater contrast between fibrotic and lipidic areas compared with PDW images as demonstrated by the ratios of their signal intensities ( $1.83 \pm 0.26$  versus  $1.36 \pm 0.16$ ). Atherosclerotic burden, assessed by vessel wall area, showed a significant correlation ( $p < 0.001$ ) between MR imaging and histology ( $r = 0.78$ ) for the whole aorta. The correlation was still observed for the thoracic and upper part of the abdominal aorta, regions potentially more susceptible to respiratory motion artifacts ( $r = 0.77$ ).

**Conclusion:** *In vivo* noninvasive high resolution MRI accurately detects and quantifies lesion composition. The *in vivo* feasibility of this technique may allow the assessment of plaque vulnerability and the monitoring of atherosclerotic plaque stabilization.

**1190-2 High Resolution MRI in a Novel Porcine Model of Complex Atherosclerosis: T1W, T2W and PDW Characteristics of Atherosclerotic Plaque Components**

Stephen G. Worthley, Gérard Helft, Valentin Fuster, Zahi A. Fayad, Julio I. Osende, Azfar G. Zaman, John T. Fallon, Meir Shinnar, Juan J. Badimon. *Mount Sinai School of Medicine, New York, New York, USA*

**Background:** Acute coronary syndromes are the result of atherosclerotic plaque disruption and subsequent thrombosis. Atherosclerotic plaque composition is central in the pathogenesis of this process. We describe *ex vivo* MRI characterization of atherosclerotic lesions in a novel porcine model of complex atherosclerosis and validate this with histopathology.

**Methods:** Coronary and aortic atherosclerosis was induced in Yucatan mini-swine ( $n = 4$ ) by a combination of atherogenic diet (2% cholesterol) for 6 months and sequential balloon injury. All coronary arteries were imaged *ex vivo* on the intact heart, preserving the curvature of their course. The aortas also underwent MRI. The ability of MRI to identify fibrocellular, lipid rich, hemorrhagic and calcified components in those complex atherosclerotic lesions with 3 or more components ( $n = 13$ ) was analyzed using the criteria in the table, based on previous work.

MRI sequence	M.R.I. Fibrocellular	Signal Lipid Rich	Intensity Hematoma	Calcification
PDW	High	Intermediate	Intermediate	Nil
T1W	High	Intermediate	High	Nil
T2W	High	Low	Low	Nil

**Results:** The MR images were correlated with the matched histopathology sections for both the coronary arteries ( $n = 54$ ) and the aortas ( $n = 43$ ). Mean wall thickness for the coronary arteries ( $r = 0.94$ , slope = 0.81) and aortas ( $r = 0.94$ , slope = 0.81) was accurately determined by MR imaging ( $p < 0.0001$ ). MR imaging accurately characterized complex atherosclerotic lesions, able to identify dense fibro-cellular (13 of 13), lipid-rich (13 of 13) and calcified (13 of 13) regions. Intraplaque hematoma was only present in 3 specimens, however MRI was able to accurately document 2 of these (sensitivity 66%). One specimen was falsely characterized as having hematoma (92% specificity).

**Conclusions:** MRI accurately quantifies and characterizes coronary and aortic atherosclerotic lesions in this experimental porcine model of complex atherosclerosis. This model may be useful for future studies of MRI of complex atherosclerosis *in vivo*.

**1190-3 A New Non-Obstructive Intravascular MRI Probe for High Resolution *In Vivo* Imaging of Atherosclerotic Plaques**

Meir Shinnar, Stephen G. Worthley, Gérard Helft, Zahi A. Fayad, Lawrence A. Minkoff, Juan J. Badimon, Valentin Fuster. *Mount Sinai Medical Center, New York, New York; Magna Laboratories, New York, New York, USA*

**Background:** Magnetic resonance imaging (MRI) is being used to characterize the composition of atherosclerotic plaques. However, the resolution achievable using surface radio-frequency (RF) probes is limited by the signal to noise ratio. We are reporting the use of a new intravascular (IV) MRI probe for high resolution *in vivo* of atherosclerotic lesions.

**Methods:** The newly developed IV MRI probe is 1.3 mm in diameter, and can be positioned over a guide-wire. The probe is not balloon-mounted, and thus does not obstruct blood flow during image acquisition. It was tested in a 1.5 T clinical magnet in i) phantoms, ii) *ex vivo* aortas from rabbits, iii) *in vivo*

in the aortas of normal rabbits, and iv) *in vivo* in the abdominal aorta of a rabbit model of atherosclerosis.

**Results:** The probe gave excellent signal to noise to a distance of 1.2 cm from the center of the coil in phantoms. *Ex vivo*, we could distinguish the different components of the plaque with good resolution. We then tested the plaque *in vivo*. Images were obtained with 0.156 mm in plane resolution, with good signal to noise. No significant motion artifacts were noted, despite the continuation of arterial blood flow during image acquisition around the IV probe. Plaque components (lipid core, fibrous cap) were easily identified. An algorithm for signal intensity correction was developed for minimizing the high signal intensity immediately adjacent to the coil and improving the signal contrast.

**Conclusions:** The new non-obstructive design for this intravascular coil provides great promise for further work in the high resolution MRI characterization of atherosclerotic plaques *in vivo*. The ability to position the probe with a guide-wire allows for its placement under fluoroscopic or MRI guidance, while its size is compatible with human coronary arteries.

**1190-4 Advantages in Diagnostics of Using Magnetic Resonance Tomography and Color-Coded Duplex Ultrasound Prior to Carotid Desobliteration**

Wolfgang Ricken, Udo Sprengel, Niels Oesingmann, Anna John, Torsten Dill, Christian Hamm. *Kerckhoff-Klinik, Dept. of Cardiology, Bad Nauheim, Germany; Dept of Cardiovascular Magnetic Resonance Tomography, Germany*

**Aim of the Study:** Color-coded duplex ultrasound (CCDU) and magnetic resonance imaging (MRI) allow noninvasive assessment of carotid arteries disease. The question of our investigations has been if it can replace conventional angiography in the diagnostics for carotid desobliteration.

**Patients and Techniques:** From September 1996 until August 1999, in consecutive 338 patients between 39 and 87 years upon suspicion in directional doppler ultrasound of a higher-degree (>70%) carotid stenosis CCDU and MRT were performed. CCDU (HP Sonos 2500, 7.5 MHz transducer) was used to characterize the morphology and quantification (flow velocity, diameters) Morphologic characterization (e.g., of intramural hematomas, extravascular compressive processes) by MRI (Siemens Vision 1.5 T) included the performance of T1- and PD-T2-weighted sequences. Evaluation and quantification of extra- and intracranial vascular stenoses and malformations was done using 3D-time of flight (TOF) MRI.

**Results:** In 334 of 338 Patients combined CCDU and MRI techniques yielded sufficient diagnostic information in deciding if indication criteria for surgical intervention were fulfilled and to define the surgical strategy. The advances in contrast to the conventional angiography has been clearly the opportunity to define extravascular pathology. Only 4 patients required additional intraarterial digital subtraction angiography to clarify a possible subtotal stenosis or vascular occlusion.

**Conclusions:** The combined use of CCDU and MRI yields valid morphological and functional results for preoperative assessment and risk calculation prior to carotid desobliteration without the risk of invasive angiography or radiation exposure. We conclude that intraarterial or even selective angiography is necessary in only very few cases when MRI is available. Advanced fast-imaging techniques in MRI, now available will optimize the spatial and temporal resolution.

POSTER

**1191 Radionuclide Imaging of Flow and Metabolism**

Tuesday, March 14, 2000, 3:00 p.m.–5:00 p.m.  
Anaheim Convention Center, Hall A  
Presentation Hour: 3:00 p.m.–4:00 p.m.

**1191-5 Glucose Transport and GLUT-4 Content Within Chronically Ischemic Myocardium**

Edward O. McFalls, Douglas R. Baldwin, Jehi-San Liow, David Marx, Herbert B. Ward, Alex Lange, Howard C. Haspel, John C. Lobo. *VA Medical Center & University of MN, Minneapolis, MN; Henry Ford Hospital, Detroit MI, USA*

**Background:** Chronically ischemic myocardium demonstrates enhanced uptake of 2-[<sup>18</sup>F]fluoro-2-deoxy-D-glucose (FDG), possibly as a consequence of a recent supply-demand mismatch. The mechanism by which glucose uptake is increased may relate to increased glucose transporters, namely GLUT-4.

**Methods:** 12 pigs were instrumented with an external constrictor on the LAD artery. Serial measurements with ECHO and positron emission tomography (PET) were made of regional wall thickening, blood flow ( $^{13}\text{N}$ -ammonia) and FDG uptake.

**Results:** Within 1 week of surgery (Early Study), wall thickening and myocardial blood flows in the LAD and NonLAD regions were not dissimilar. At that time, an infusion of dobutamine ( $40 \mu\text{g}/\text{kg}/\text{min}$ ; iv) increased myocardial blood flow in the LAD and NonLAD regions to  $1.07 \pm 0.28 \text{ ml}/\text{min}/\text{g}$  and  $1.18 \pm 0.26 \text{ ml}/\text{min}/\text{g}$  respectively (NS). Post-stimulation, FDG uptake in the fasted state was  $0.044 \pm 0.043 \mu\text{mol}/\text{min}/\text{g}$  in the LAD region and  $0.046 \pm 0.046 \mu\text{mol}/\text{min}/\text{g}$  in the NonLAD region (NS). By ~2 months (Late Study), wall thickening in the LAD and NonLAD regions were  $20 \pm 7\%$  and  $36 \pm 6\%$  respectively ( $P < 0.05$ ). At that time, dobutamine increased myocardial blood flow in the LAD region to only  $0.92 \pm 0.16 \text{ ml}/\text{min}/\text{g}$  which was lower than that of the NonLAD region ( $1.17 \pm 0.20 \text{ ml}/\text{min}/\text{g}$ ;  $P < 0.05$ ). FDG uptake post-stimulation was higher in the ischemic LAD region compared with remote regions ( $0.085 \pm 0.053 \mu\text{mol}/\text{min}/\text{g}$  vs  $0.065 \pm 0.044 \mu\text{mol}/\text{min}/\text{g}$ ;  $P < 0.05$ ) and the magnitude of increase was inversely proportional to the relative impairment in dobutamine induced flow reserve ( $r^2 = 0.62$ ;  $P < 0.01$ ). Post-sacrifice immunoblots of GLUT-4 were 23% higher in the LAD relative to remote region ( $P < 0.05$ ) which is similar in magnitude to the regional differences in FDG uptake.

**Conclusions:** In this swine model of chronic ischemia, at a time that regional function is depressed, transmural blood flow can be recruited with dobutamine and the degree of abnormal flow response correlates with the relative enhancement in post-stress FDG uptake. GLUT-4 was increased and may provide one mechanism by which glucose uptake within chronically ischemic myocardium is enhanced, despite the inhibitory effects of high fatty acids in the fasted state.

#### 1191-6 Changes in Absolute Myocardial Blood Flow With Beta Blocker Therapy in Heart Failure

Susan K. Bennett, Mark F. Smith, Stephen G. Gottlieb, Michael L. Fisher, Stephen L. Bacharach, Vasken Dilisizian. *NIH, Bethesda, MD, USA*

**Background:** The addition of beta blockers (BB) to standard heart failure (CHF) therapy improves left ventricular ejection fraction (LVEF) and mortality. However, the underlying mechanism for the beneficial effects of BB in CHF is not well understood.

**Methods:** We compared changes in absolute myocardial blood flow (MBF) before and after the addition of 6 months of metoprolol to standard CHF therapy in 12 CHF patients with NYHA class  $\geq \text{II}$ ; 6 ischemic and 6 non-ischemic. All patients underwent pre- and post-BB N-13 ammonia PET and radionuclide angiography studies. Pre- and post-BB mid LV short-axis PET slices (2/patient) were matched and MBF was assessed in 4 regions/slice. MBF was computed from the dynamic N-13 ammonia data using a two-compartment model. Regional MBF of  $< 0.64 \text{ ml}/\text{min}/\text{g}$  was considered normal.

**Results:** Mean LVEF increased in the 12 patients from  $16 \pm 8\%$  pre to  $23 \pm 11\%$  post-BB ( $p < 0.005$ ). Changes in MBF pre- and post-BB in abnormal and normal regions as well as MBF normalized to rate-pressure product (RPP) are shown.

	MBF (ml/min/g)			MBF/RPP		
	Pre-	Post-BB	p	Pre-	Post-BB	p
Ischemic						
Abnormal	$0.40 \pm 0.18$	$0.54 \pm 0.18$	$< 0.01$	$0.55 \pm 0.29$	$0.79 \pm 0.28$	$< 0.001$
Normal	$0.88 \pm 0.31$	$0.61 \pm 0.15$	$< 0.01$	$1.23 \pm 0.54$	$0.94 \pm 0.23$	$< 0.05$
Non-ischemic						
Abnormal	$0.39 \pm 0.15$	$0.40 \pm 0.21$	NS	$0.45 \pm 0.19$	$0.54 \pm 0.28$	NS
Normal	$0.80 \pm 0.21$	$0.56 \pm 0.14$	$< 0.01$	$0.93 \pm 0.45$	$0.80 \pm 0.16$	NS

In regions with abnormal resting MBF, BB improves perfusion in ischemic but not in non-ischemic patients. Although MBF decreased post-BB in normal regions both in ischemic and non-ischemic patients, it decreased significantly only in the ischemic patients after normalization to RPP.

**Conclusion:** BB may increase MBF in abnormal regions in ischemic patients but its mechanism of action in non-ischemic patients appears different. Perhaps altered substrate utilization such as fatty acid and/or glucose may provide additional insight into the underlying mechanism for the salutary effects of BB in CHF.

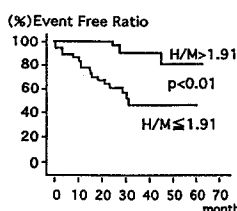
#### 1191-7 Comparison of the Prognostic Value of Cardiac I-123 Metaiodobenzylguanidine and Neurohumoral Factors in Patients With Congestive Heart Failure

Toshiki Matsui, Takayoshi Tsutamoto, Junya Kusunokawa, Takashi Tsutsui, Naoko Mabuchi, Keiko Maeda, Kenichi Mitsunami, Masahiko Kinoshita. *Shiga University of Medical Science, Otsu, Japan*

**Background:** Cardiac I-123 metaiodobenzylguanidine (MIBG) has been used to assess the severity of congestive heart failure (CHF). We assessed the usefulness of prognostic markers of CHF patients by MIBG and compared with neurohumoral factors.

**Methods:** The subjects were 77 patients with CHF who radionuclide left ventricular ejection fraction (EF) less than 45% and underwent MIBG. At the same time, we also measured plasma levels of atrial natriuretic peptide (ANP), brain natriuretic peptide (BNP), and norepinephrine (NE). The cardiac MIBG heart to mediastinal ratio (H/M) and washout rate (WR) were calculated from the chest anterior view, 15 and 180 min after isotope injection. Cox proportional hazard analysis was performed among H/M (delayed image) and WR in the MIBG, EF, age, gender, functional class, etiology, plasma levels of ANP, BNP, and NE.

**Results:** The H/M (delayed) was inversely correlated with BNP ( $r = -0.38$ ,  $p < 0.01$ ) and was not correlated with NE. The WR was correlated with BNP ( $r = 0.34$ ,  $p < 0.01$ ). Twenty-one patients had cardiac events [death ( $n = 11$ ), hospitalization ( $n = 10$ )] during a mean follow-up period of 2.5 years. Cox stepwise multivariate analysis revealed that H/M (delayed) ( $p = 0.0006$ ) and BNP ( $p = 0.0035$ ) were significant independent predictors of prognosis.



**Conclusion:** These findings suggest that H/M of MIBG is an important prognostic predictor independent of neurohumoral factors in patients with CHF.

#### 1191-8 New Assessment of Systemic Sympathetic Activity with Skeletal Muscle 123 I-Metaiodobenzylguanidine (MIBG) Scintigraphy in Patients of Chronic Heart Failure

Ichiro Kouhara, Yutaka Kimura, Seishi Nakamura, Kengo Hatada, Reisuke Yuyama, Jyunko Watanabe, Shinichi Hamada, Toshiji Iwasaka. *Kansai Medical University, Osaka, Japan*

**Background:** Measurement of 123 I-metaiodobenzylguanidine (MIBG) in heart is unique method to evaluate the sympathetic nervous activity, however, it would be affected by the cardiac ischemia, fibrosis and remodeling. Therefore we assessed MIBG uptake not only in heart but also in femoral muscle.

**Methods:** Thirty heart failure (HF) patients without diabetes (NYHA I:10, II:10, III:5, IV:5) and ten healthy control subjects underwent whole body, heart and femoral muscle scintigraphy at 20 minutes and 4 hours after injection of MIBG. The heart/mediastinum ratio-early (H/M-E) and H/M ratio-delay (H/M-D), the femoral muscle/mediastinum ratio-early (F/M-E) and F/M ratio-delay (F/M-D), the femoral muscle/whole body ratio-early (%FM-E) and %FM-delay (%FM-D) were calculated.

**Results:** HF patients had lower uptake than the control group not only in H/M-D but also in F/M-D ( $p < 0.005$ ,  $p < 0.005$ ). Similarly, %FM-E and %FM-D in HF patients were significantly lower than that in control group (%FM-E: 2.6% vs 3.6%,  $p < 0.005$ ; %FM-D: 2.4% vs 4.1%,  $p = 0.0006$ ). There were significant correlation between H/M-D and F/M-D ( $r = 0.43$ ,  $p < 0.05$ ) in the control group. However, there was no significant correlation between H/M-D and F/M-D in the HF patients.

**Conclusion:** These results suggest that patients with chronic heart failure had the abnormality of the autonomic nervous system not only myocardium but also skeletal muscle. Furthermore, assessment of 123 I-MIBG uptake of skeletal muscle might be more useful than that of heart, since skeletal muscle is less affected by cardiac ischemia, fibrosis and remodeling.

### 1191-25 The Myocardial Metabolic Response to Catecholamines is Dependent Upon the Substrate Environment

Pilar Herrero, Andrew M. Kates, Giridhar Vedela, Victor G. Davila-Roman, Robert J. Gropler. *Washington University School of Medicine, USA*

**Background:** Although catecholamines are administered routinely to study human myocardial bioenergetics, their impact on myocardial intermediary metabolism is unclear.

**Methods:** In 6 healthy young adults (average age  $26 \pm 6$  yrs; 5 males; no cardiac risk factors and normal rest-stress echocardiogram) measurements of myocardial perfusion (MBF), oxygen consumption (MVO<sub>2</sub>), fatty acid utilization (MFAU) and glucose utilization (MGU) were performed with PET using <sup>15</sup>O-water, <sup>11</sup>C-acetate, <sup>11</sup>C-palmitate and 1-<sup>11</sup>C-glucose, respectively. Subjects were studied either after an overnight fast (n = 3) or following a standard carbohydrate meal (n = 3), both at rest (R) and during the administration of dobutamine (D) (10 mg/kg/min).

**Results:** Results are shown in the following table.

	Plasma fatty acids $\mu\text{mol/ml}$	MBF $\text{ml/g/min}$	MVO <sub>2</sub>	MFAU $\mu\text{mol/g/min}$	MGU
Fast-R	$0.9 \pm 0.4$	$1.0 \pm 0.3$	$5.0 \pm 0.4$	$0.24 \pm 0.11$	$0.10 \pm 0.02$
Fed-R	$0.1 \pm 0.1^*$	$0.9 \pm 0.2$	$5.4 \pm 2.1$	$0.02 \pm 0.02^*$	$0.44^* \pm 0.05^*$
Fast-D	$1.8 \pm 0.3^{\#}$	$2.1 \pm 0.3^{\#}$	$11.3 \pm 2.1^{\#}$	$0.58 \pm 0.13^{\#}$	$0.200 \pm 0.03^{\#}$
Fed-D	$0.7 \pm 0.6^{\#}$	$2.0 \pm 0.7^{\#}$	$12.2 \pm 4.0^{\#}$	$0.21 \pm 0.12^{*\#}$	$0.54 \pm 0.34$

\*p < 0.05 Fast vs Fed, (R); #p < 0.05 Fast vs Fed, (D); #p < 0.05 R vs D (Fast or Fed)

As expected, plasma fatty acids, MBF, MVO<sub>2</sub>, and MFAU increased with D in both groups. However, if one assumes only fatty acids and glucose are being used as energy fuels, in the fasted group, MFAU provided similar contributions (R =  $71 \pm 5\%$  and D =  $70 \pm 4\%$ , p = ns) to substrate utilization. In contrast, in the fed group during D, MFAU now contributed  $26 \pm 3\%$  of the substrate being utilized compared to  $5 \pm 6\%$  at R, p < 0.001.

**Conclusion:** Thus, it appears that the impact of catecholamines on myocardial intermediary metabolism is dependent upon the substrate environment. Consequently, standardization of substrate environment may be necessary to better understand the bioenergetic impact of catecholamines on myocardium.

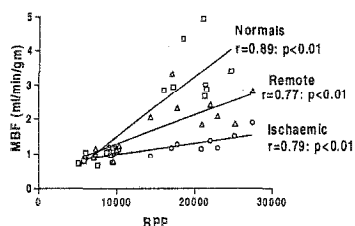
### 1191-26 Flow-Function Mismatch in Angiographically Normal Coronary Arteries Remote From Ischaemic Regions in Patients With Coronary Artery Disease

Edward Barnes, Rohan Jagathesan, Rodney A. Foale, Roger J. Hall, Paolo G. Camici. *MRC Cyclotron Unit and Dept of Cardiology Hammersmith Hospital, I.C.S.M. and Dept of Cardiology, St Mary's Hospital, London, UK*

**Background:** Under normal circumstances, a strong relation exists between myocardial oxygen consumption and blood flow (MBF). The mismatch of this relationship in patients with coronary artery disease (CAD) leads to ischaemia. Using dobutamine (DOB) stress, this study set out to assess the relationship between MBF and myocardial work in normal volunteers and in remote and ischaemic regions in patients with angiographically proven single vessel CAD.

**Methods:** 8 normal volunteers (aged  $45 \pm 5$  years) and 8 patients (aged  $62 \pm 5$  years), underwent DOB stress. MBF was assessed at rest and at peak stress using PET and H<sub>2</sub><sup>15</sup>O.

**Results:** RPP at rest was  $6863 \pm 1539$  and  $8887 \pm 1497$  (p = 0.01) and at peak stress was  $20174 \pm 2911$  and  $21018 \pm 4382$  (NS) in normals and patients respectively. Resting MBF (ml/min/gm) was lower in normals ( $0.86 \pm 0.16$ ) compared to both ischaemic and remote regions in patients ( $1.0 \pm 0.15$  and  $1.06 \pm 0.15$ ) although the difference fell short of statistical significance. Peak MBF was lower in the ischaemic compared with the remote regions ( $1.30 \pm 0.29$  vs.  $2.33 \pm 0.52$  p < 0.001). Peak MBF in normals was higher than remote regions ( $2.96 \pm 0.78$  vs.  $2.33 \pm 0.52$  p < 0.01). There was a strong correlation between RPP and MBF in all groups (fig). The regression line for normals was steeper than in ischaemic regions (p < 0.01) and was also significantly different from remote regions in patients (p = 0.02).



**Conclusions:** As expected there is a flow-function mismatch in ischaemic regions compared to normals. Moreover, myocardial regions subtended by angiographically normal coronary arteries remote from ischaemic regions in patients with CAD have a lower MBF as predicted by the RPP, also suggesting a flow-function mismatch.

### 1191-27 Combined Assessment of Myocardial Perfusion and Left Ventricular Function for the Evaluation of Patients With Breast Cancer Undergoing Radiation Therapy

Salvador Borges-Neto, Patricia Hardenbergh, Gregory C. Ravizzini, Steven Mast, R.E. Coleman. *Duke University Medical Center, Durham, NC, USA*

**Background:** Despite the indisputable benefits of post-operative radiation therapy to prevent local recurrence of early breast cancer, very limited data is available about the potential impact of this treatment in the myocardium and the optimal imaging modality to monitor these patients.

**Objectives:** The purpose of this investigation was to evaluate the effects of radiation to the myocardium, in patients undergoing therapy for left sided breast cancer, by combined assessment of myocardial perfusion and left ventricular (LV) function imaging studies using the gated perfusion SPECT (GSPECT) technique.

**Methods:** Resting GSPECT imaging was prospectively acquired in 16 patients before and within six months post radiation therapy. A semi-quantitative sum rest perfusion score (SRS) was performed to estimate the severity and extent of abnormalities using a twelve segment model and defects were score as: 0 = normal, 1 = mild, 2 = moderate, 3 = severe defect. Simultaneous measurements of total left ventricular perfusion abnormalities (TD) and ejection fraction (EF) was obtained using the Cedars-Sinai computerized program.

**Results:** Of the 14 patients with normal baseline perfusion study 7 developed new perfusion abnormalities on the follow-up scan (50%) and worsening of perfusion pattern was seen on the remaining two patients. The SRS and TD at baseline and six months were:  $0.6 \pm 0.4$  vs  $3.0 \pm 0.9$ , p = 0.005; and  $6.0 \pm 1.3$  vs  $13 \pm 2.1$ ; p = 0.004, respectively, ANOVA. However, left ventricular EF measurements did not change significantly:  $65\% \pm 2$  vs  $64\% \pm 2$ ; p = 0.57.

**Conclusions:** 1) Fifty percent of the patients developed new myocardial perfusion abnormalities as early as six months post radiation therapy for breast cancer, despite no significant changes in LV ejection fraction. 2) Optimal follow-up of these patients may require the combined assessment of myocardial perfusion and LV function imaging studies.

### 1191-28 Assessment of Ejection Fraction by 201-Thallium Gated Tomography in Extended Myocardial Infarction: Repeatability in a Rest-Redistribution Study and Accuracy Versus Planar Angiography

Emmanuel Itti, Pascal Damien, Jean Rosso, Michel Meignan, Serge Benayoun, Jean-Philippe Thirion. *H. Mondor Hospital, Créteil; INRIA/Focus Imaging, Nice, France*

**Background:** Viability and left ventricle ejection fraction (LVEF) are essential for prognosis of myocardial infarction. These two parameters may be evaluated simultaneously by 201-Tl single photon emission tomography (gSPECT), but repeatability and accuracy of measurements with this isotope remains controversial.

**Methods:** We studied 50 patients with history of myocardial infarction. Each patient underwent a rest (20 min) + redistribution (4 h) 201-Tl gSPECT viability protocol, the last acquisition being followed immediately by a 99m-Tc pyrophosphate equilibrium radionuclide angiography (ERNA). On gSPECT slices, count statistics were calculated and perfusion was quantified by Cardiomatch™, which provided both size and depth of defects. Rest and redistribution LVEF were determined from gSPECT by Germano's algorithm, while LVEF from planar ERNA was derived from the manufacturer's software.

**Results:** Mean LVEF values calculated from rest gSPECT, redistribution gSPECT, and planar ERNA were respectively  $31 \pm 13\%$ ,  $30 \pm 13\%$ , and  $32 \pm 14\%$ . Variance analysis did not show any significant difference between repeated experiences within each patient. Correlation factors were high between 20 min and 4 h acquisitions (r = 0.88), as well as between gSPECT and ERNA (r respectively 0.85 and 0.91 for 20 min and 4 h images). Additionally, Bland-Altman plot showed close agreement between gSPECT and ERNA. Finally, neither the perfusion alteration (size, depth), nor the technical conditions (count density) interfered with LVEF assessment by Germano's algorithm.

**Conclusion:** Thallium gSPECT is a repeatable method when assessing LVEF within the same patient at 3.5 hours interval, even with a substantial count decay, and gives accurate results, compared to planar ERNA, even in case of large perfusion defects.

### 1191-29 Exercise Perfusion Scintigraphy Positivity is Associated With Peripheral Vascular Endothelial Dysfunction in Patients With Normal Coronary Arteries

Emilia Fabian<sup>1</sup>, Albert Varga, Edoarda Pacetti<sup>2</sup>, Lorenza Pratali, Martha Morelos, Pier Carlo Rossi<sup>2</sup>, Imre Stock<sup>1</sup>, Eugenio Picano. <sup>1</sup>Institute of Clinical Physiology, Pisa, Regional Hospital, Fivizzano, Italy; <sup>2</sup>BM Korhaz Budapest, Hungary

**Background:** Patients with chest pain and angiographically normal coronary arteries often have a positive thallium-201 myocardial perfusion scintigraphy, hypothetically linked to coronary, microvascular disease and endothelial dysfunction. High resolution brachial ultrasound provides a noninvasive assessment of systemic endothelial function.

**Aim:** To determine the endothelium dependent vasodilator function in the brachial artery of patients with chest pain, angiographically normal coronary arteries and different response during thallium-201 perfusion scintigraphy.

**Methods:** Forty-two patients (33 males, mean age: 59 ± 8 years) with chest pain syndrome and angiographically normal coronary arteries underwent exercise stress thallium-201 scintigraphy. The scintigraphy was considered positive in case of a transient perfusion defect. Endothelium dependent vasodilation was assessed by measuring the change in brachial artery diameter in response to hyperemic flow by vascular ultrasound.

**Results:** On the basis of the associated scintigraphic response, 2 groups were identified; I. (n = 14) with negative and II. (n = 28) with positive perfusion scintigraphy. Brachial artery flow mediated vasodilation was decreased in patients with positive thallium-201 scintigraphy (I. = 11.4 ± 5.9% vs II. = 5.9 ± 5.4%, p < 0.01).

**Conclusion:** In patients with angiographically normal coronary arteries, a stress induced perfusion defect is an "anatomic lie" ("false-positive" versus the angiographic standard) but a "physiologic truth" (true positive versus the physiologic assessment of systemic endothelial function).

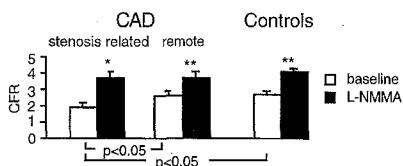
### 1191-30 Nitric Oxide Synthase Inhibition Improves Coronary Microcirculatory Function in Patients With Coronary Artery Disease

Pilipp A. Kaufmann, Tomaso Gnechchi-Ruscone, P.G. Camici. *Cardiology, University Hospital, Zürich, Switzerland; Hammersmith Hospital, ICSM, London, UK*

**Background:** Nitric oxide (NO) release in response to shear stress modulates coronary artery diameter. However, its impact on the coronary microcirculation and coronary flow reserve (CFR) particularly in patients with coronary artery disease (CAD) is unclear.

**Methods:** O-15 labeled water and positron emission tomography was used to measure myocardial blood flow (MBF) before and after iv adenosine in 10 controls and 10 CAD patients. This was repeated after infusion of 10 mg/kg L-NMMA. MBF rest was corrected for RPP. CFR was calculated as MBF-adenosine/MBF-rest.

**Results:** Hemodynamics were similar in all groups at baseline. Mean arterial pressure (MAP) increased (+10%) and heart rate decreased (-10%) in controls and CAD patients (both p < 0.05) during L-NMMA. During L-NMMA CFR increased significantly in stenosis related (n = 17) as well as in remote segments (n = 23) of CAD patients reaching similar values as in normal controls. (\*p < 0.01, \*\*p < 0.001 both vs. baseline)



**Conclusions:** L-NMMA increases CFR as assessed with PET. Although the mechanisms remain unclear, this study proves that a further reserve is available on top of that achieved with standard doses of adenosine in controls and in CAD patients.

### 1191-31 <sup>18</sup>FDG-PET, <sup>201</sup>Tl-SPECT Findings and Histopathological Characteristics of Syndrome X

Kazuhiro Masuyama, Osamichi Satake, Noboru Takekoshi, Shinobu Matsui, Hirokazu Tsugawa, Seiyu Kanemitsu, Michihiko Kitayama, Shinji Okubo, Takayoshi Asaji, Toshio Yamagata, Shougo Miura, Hironobu Akao, Hiraku Arisaka, Shogo Katsuda, Yoshimaro Ishikawa. *Kanazawa Medical University, Ishikawa, Japan*

**Purpose:** To clarify the myocardial metabolism and morphological characteristics in patients with syndrome X, <sup>18</sup>FDG-PET and <sup>201</sup>Tl-SPECT and right ventricular myocardium biopsy were done.

**Methods:** 1) 17 patients with syndrome X were studied. The diagnosis was done as follows; i) Existence of typical or atypical attacks of chest pain demonstrated in treadmill exercise tests with marked ischemic ST segment depression of extensive areas, ii) Normal coronary imaging and no coronary spasm when acetylcholine and ergonovine were injected into the coronary artery. The patients with hypertensive heart diseases, valvular heart diseases, idiopathic cardiomyopathy (hypertrophic type and dilated type), endocrine and metabolic diseases or collagen disease were excluded 2) the presence or absence of ischemia was evaluated with <sup>201</sup>Tl-SPECT and <sup>18</sup>FDG-PET. With right ventricular myocardium biopsy, morphological abnormalities of coronary micro blood vessels were studied using light and electron microscopes.

**Results:** 1) In <sup>201</sup>Tl-load myocardial scan study, hypoperfusion was observed in 8 out of 17 patients (47%) and redistribution was seen in all 8 patients. 2) In <sup>18</sup>FDG-PET study at rest and fasting, areas with <sup>18</sup>FDG uptake and glucose metabolism (ischemic myocardium) which suggested ischemia were observed in all 17 patients (100%). 3) In histopathological studies, both light and electron microscopes revealed areas with mild fibrosis degeneration around blood vessels and marked narrowing of vascular lumen due to swollen endothelium and thickening of arteriolar media as well as capillary walls.

**Conclusion:** Fibrous degeneration around microvascular vessels and narrowing of vascular lumen due to swollen endothelium, thickening of arteriolar media and capillary walls were thought to cause myocardial ischemia in syndrome X.

### 1191-32 Mitral Annular Calcification is Highly Correlated With Abnormal Myocardial Perfusion SPECT in Patients With Angina Pectoris Under 65 Years Old

Shaul Atar, Tali Sharir, Josephine Chiu, Tomoo Nagai, Huai Luo, Dana Agaitzei, Daniel S. Berman, Robert J. Siegel. *Cedars-Sinai Medical Center, Los Angeles, CA, USA*

An association between mitral annular calcification (MAC) and coronary artery disease (CAD) has been recently suggested. We tested the hypothesis that patients (pts) with MAC and chest pain under the age of 65 have a higher prevalence and severity of perfusion defects on rest TI-201/stress Tc-99m sestamibi single photon emission computerized tomography (SPECT).

**Methods:** We identified 191 consecutive pts with MAC and 172 without MAC ≤ 65 years, who underwent both transthoracic echocardiography and SPECT for evaluation of chest pain. SPECT images were visually scored using a 20-segments model and a 5 point (0-4) scale. The summed stress score (SSS, sum of 20 segments at stress), the summed rest score (SRS) (sum of 20 segments at rest), and the prescan likelihood of CAD were calculated.

#### Results:

	MAC (n = 191)	No MAC (n = 172)	p value
Age range	31-65	23-65	
Female gender	88 (46%)	66 (38%)	NS
Myocardial infarction (MI)	73 (38%)	40 (23%)	0.002
Hypertension	117 (61%)	88 (51%)	0.05
Diabetes mellitus	64 (34%)	37 (22%)	0.01
Prescan likelihood	0.4 ± 0.27	0.35 ± 0.3	0.001
No. of pts with SSS > 3	111 (58%)	68 (40%)	<0.001
Mean SSS	9 ± 10	6.8 ± 10.5	0.017
Mean SRS	4 ± 7	2.6 ± 6.7	0.03

**Conclusions:** In patients with chest pain ≤ 65 years the presence of mitral annular calcification on transthoracic echocardiography significantly correlates with 1) higher prevalence of MI, hypertension and diabetes, and higher prescan likelihood of CAD, and 2) higher frequency and severity of perfusion defects on myocardial perfusion SPECT.

## ORAL

**892 Stress Echo: Assessment of Myocardial Viability**

Tuesday, March 14, 2000, 4:00 p.m.–5:00 p.m.  
Hilton Anaheim, Pacific D

4:00 p.m.

**892-1 Comparison Between Low-Dose Dobutamine Echocardiography and Echocardiography During Glucose-Insulin-Potassium Infusion for the Detection of Myocardial Viability Post Infarction**

C. Linda M.C. van Campen, Lucas J. Klein, Gertjan Tj. Sieswerda, Otto Kamp, Cees A. Visser, Frans C. Visser. *Academic Hospital Vrije Universiteit, Amsterdam, The Netherlands*

**Background:** Previous studies showed that glucose-insulin-K<sup>+</sup> (GIK) infusion results in improvement of LV dysfunction. These positive effects of GIK are not well understood. Therefore, we hypothesized that GIK exerts its beneficial effect only in viable tissue and not in scar tissue.

**Methods:** Twenty-five patients with a recent infarction (MI) underwent both low-dose dobutamine echocardiography (LDDE) and echo during GIK, 6 ± 4 days after MI. The GIK protocol consisted of a fixed dose of insulin (100 mU/kg/hr iv) and a variable glucose/K<sup>+</sup> infusion rate. GIK echos were made at baseline, and after 60 min of GIK. GIK and LDDE echos (13 segment model) were scored on a 4 point scale: 0 = normo–3 = dyskinesia. Dyssynergic segments were viable if wall motion improved at least one point.

**Results:** During LDDE the wall motion score (WMS) decreased from 7.4 ± 3.5 at baseline to 4.6 ± 2.6 at peak dobutamine. During GIK the WMS decreased from 7.3 ± 3.6 at baseline to 4.9 ± 3.2 at 60 min (LDDE vs GIK: ns).

No of segments:	LDDE		
	normal	viable	non-viable
Normal	182	6	2
GIK viable	3	56	10
Non-viable	1	7	58
Agreement:	91%		

**Conclusion:** Echocardiography in patients after MI shows that GIK augments cardiac contractility in viable segments but not in nonviable segments. The high agreement between LDDE and GIK echocardiography suggests that GIK can be used as an alternative to assess myocardial viability.

4:15 p.m.

**892-2 Prognosis of Viable Myocardium Early After Acute Myocardial Infarction: Relation to Indicators of Left Ventricular Systolic Dysfunction**

Otto Kamp, Francisca Nijland, Patrick M.J. Verhorst, Willem G. de Voogt, Cees A. Visser. *Free University Hospital, Amsterdam, the Netherlands*

**Background:** The prognostic value of myocardial viability after acute myocardial infarction (AMI) is still controversial, depending on the patient under study and the outcome endpoint considered.

**Methods and Results:** One hundred thirty-eight consecutive patients (pts) were studied with low-dose dobutamine echocardiography 3 ± 1 days after AMI. Pts were divided in two groups based on presence (n = 55) or absence (n = 83) of viability and followed for in-hospital and late cardiac events. During hospitalization, cardiac events occurred in 37 pts (27%): 2 died; 2 had sustained ventricular tachycardia; 17 had recurrent ischemic events; and 16 had heart failure. Event rate of recurrent ischemia was significantly greater in pts with than without viable myocardium (20% vs 7%; p < 0.05). At Cox regression analysis, viability was the only independent predictor for recurrent ischemic events (chi-square 5.0; p = 0.025). Endsystolic volume index and ejection fraction were both independent predictors for heart failure, whereas gender and endsystolic volume index emerged as independent predictors of hard cardiac events. After hospital discharge, pts were followed for 19 ± 7 months. During this period, cardiac events occurred in 30 pts (22%): 6 pts died of cardiac causes, 1 had sustained ventricular tachycardia, 2 had reinfarction, 15 were hospitalized for unstable angina and 6 for heart failure. Again, viability emerged as the only independent predictor of unstable angina (chi-square 7.7; p = 0.005). Age, hypertension and ejection fraction were the most important independent predictors for hospitalization for heart failure, whereas ejection fraction was the only independent predictor for hard cardiac events.

**Conclusions:** Presence of viability early after AMI is the single best predictor of in-hospital recurrent ischemic events and unstable angina after

discharge. With respect to hard cardiac events and occurrence of heart failure, indicators of left ventricular systolic dysfunction have a higher prognostic value than presence of viability.

4:30 p.m.

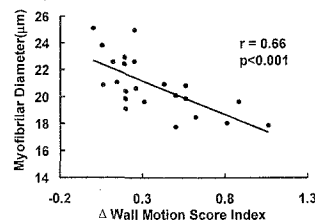
**892-3 Correlation of Histomorphometric Features and Contractile Reserve Assessed by Dobutamine Stress Echocardiography in Patients With Idiopathic Dilated Cardiomyopathy**

Petar Otašević, Zoran Popović, Jovan D. Vasiljević, Srdjan D. Bošković, Dragana Bojić, Milutin Mirić, Milovan Bojić, Radoslav Vidaković, Lorenza Pratali<sup>1</sup>, Aleksandar N. Nešković. *Cardiovascular Research Center, Dedinje Cardiovascular Institute, Belgrade, Yugoslavia; <sup>1</sup>CNR, Pisa, Italy*

**Background:** Assessment of LV contractile reserve during dobutamine stress testing improves the prognostic evaluation of patients with heart failure. To assess the relationship between histomorphometric features (interstitial fibrosis (IF) and myocyte diameter (MD)) and contractile reserve assessed by dobutamine stress echocardiography, we have analyzed 24 consecutive pts with endomyocardial biopsy proven idiopathic dilated cardiomyopathy.

**Methods:** Dobutamine stress echocardiography was performed using 5, 10, 20, 30 and 40 mcg/kg/min infusions, in progressive stages lasting 5 minutes each. Wall motion score index (WMSI), EF, cardiac power output (CPO) and end-systolic pressure/volume ratio (ESPVR) were considered as indices of LV contractility. Contractile reserve was defined as the difference between the values of these indices obtained at peak dobutamine dose and the baseline values. LV biopsy specimens (3–5 per pt) were routinely processed and stained with Masson-trichrome. Both IF and MD were calculated quantitatively using commercially available software for a representative field in each specimen and averaged.

**Results:** Out of 24 pts (21 men, age 43.4 ± 8.7, EF 19.2 ± 8.9%), 17 were NYHA class I/II, while 7 pts were class III/IV. MD and IF showed strongest correlation with change in WMSI (r = -0.66, p < 0.001, Figure, and r = -0.57, p = 0.004, respectively), followed by change in EF (r = -0.60, p = 0.002, and r = -0.47, p = 0.021, respectively). IF showed no correlation with change of ESPVR and CPO, whereas MD was strongly associated with change of both indices (r = -0.56, p = 0.004, and r = -0.46, p = 0.025).



**Conclusion:** Our data indicate that contractile reserve identified by change in WMSI has stronger histomorphometric correlates than dobutamine induced changes in other contractility indices. Additionally, MD demonstrated more powerful association with contractile reserve than IF.

4:45 p.m.

**892-4 Quantitative Assessment of Left Ventricular Myocardial Viability Using Systolic Mitral Annular Descent Velocity: A Study With Dobutamine Stress Pulsed Tissue Doppler Imaging**

Masako Matsuoka, Takashi Oki, Yuichiro Mishiro, Hirotsugu Yamada, Yukiko Onose, Tetsuzo Wakatsuki, Tomotugu Tabata. *The University of Tokushima, Tokushima, Japan*

**Background:** Systolic mitral annular motion velocity (SMAV) recorded by pulsed tissue Doppler imaging (PTDI) usually reflects left ventricular (LV) asynergy corresponding to the infarct regions in patients with myocardial infarction (MI). However, the relationship between SMAV and myocardial viability has not been clarified. We evaluated whether the dobutamine stress PTDI can detect the myocardial viability in patients with MI.

**Methods:** The study population consisted of 26 patients with previous MI who had one major coronary lesion by coronary angiography and 12 normal subjects (mean age: 66 ± 13 and 6 ± 15 years, respectively). We performed Tc-methoxy isobutyl isonitrile scintigraphy in all 26 patients, and divided them into two groups (A group; 14 patients with myocardial viability, B group; 12 patients without viability). Dobutamine was administered intravenously (2, 5, 10 µg/kg/min, 5 minute intervals), and peak first and second systolic motion velocities (Sw1 and Sw2, respectively) were measured at the 6 mitral annular sites (anteroseptal, posterior, inferior, anterior, posteroseptal and lateral sites). LV wall motion score index (WMSI) was also

determined according to the classification of American Society of Echocardiography.

**Results:** At baseline, WMSI was significantly greater, and mean SMAV was significantly lower in both the A and B groups than in the control group, but there were no significant differences between the A and B groups. After dobutamine infusion, WMSI improved in only the A group. Sw1s and Sw2s at the mitral annular sites corresponding to the infarct regions increased significantly with 2  $\mu\text{g}/\text{kg}/\text{min}$  and 5  $\mu\text{g}/\text{kg}/\text{min}$ , respectively, compared to the baseline in the A group. However, there were no significant increases in both the systolic velocities even with 10  $\mu\text{g}/\text{kg}/\text{min}$  in the B group.

**Conclusions:** SMAV, particularly Sw1, obtained by dobutamine stress PTDI is a useful and feasible parameter for detecting the regional LV myocardial viability in patients with MI.

## ORAL

### 904 Computed Tomography/Magnetic Resonance Imaging: Myocardial Perfusion

Wednesday, March 15, 2000, 8:30 a.m.–10:00 a.m.  
Hilton Anaheim, California B

8:30 a.m.

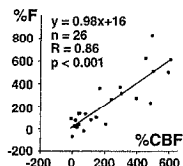
### 904-1 Non-Invasive Quantification of Myocardial Perfusion Reserve With Electron Beam Computed Tomography in Comparison to Intracoronary Blood Flow Reserve by Doppler Ultrasound

Stefan Möhlenkamp<sup>1</sup>, Amir Lerman<sup>2</sup>, Lilach O. Lerman<sup>2</sup>, Patrick F. Sheedy<sup>3</sup>, Thomas R. Behrenbeck<sup>2</sup>, Erik L. Ritman<sup>1</sup>. <sup>1</sup>Depts of Physiology, <sup>2</sup>Internal Medicine; <sup>3</sup>Radiology, Mayo Clinic, Rochester, MN, USA

**Background:** Unlike coronary blood flow (CBF) measurements with intracoronary Doppler ultrasound, which quantitates single vessel CEF and involves selective arterial catheterization, Electron Beam Computed Tomography (EBCT) provides non-invasive estimates for the transmural spatial distribution of perfusion (F) throughout the myocardium with an intravenous injection of contrast agent. This study evaluates the concordance of changes in CBF (%CBF) and F (%F).

**Methods:** We assessed F in the anterior cardiac wall by contrast-enhanced EBCT (i.v. Iopamidol, 0.33 ml/kg over 2 sec) in 13 anesthetized male pigs (54  $\pm$  5 kg) at baseline (infusion of N-saline) and, at 20 min intervals, again after 5 min of continuous intracoronary (LAD) infusion of adenosine (Aden, 100  $\mu\text{g}/\text{kg}/\text{min}$ ) and then nitroglycerine (NTG, 40  $\mu\text{g}/\text{min}$ ). In each animal we evaluated one EBCT cross section at a mid-ventricular level. Doppler studies were alternately performed before or after a complete EBCT study.

**Results:** CBF and F increased after Aden by 376  $\pm$  44% and 386  $\pm$  61% respectively (both  $p < 0.001$ ). CBF and F increased after NTG by 38  $\pm$  9% and 52  $\pm$  17% respectively (both  $p < 0.03$ ). The mean %CBF and %F after Aden and NTG were very similar. %CBF and %F correlated as shown in the Fig. Variation of data around the regression line is in part attributed to EBCT cross sectional sampling area versus upstream assessment of blood flow through the entire perfusion bed with Doppler.



**Conclusion:** This study indicates that changes in myocardial perfusion can be quantified correctly over a wide range of changes in CBF with iv. contrast injections and supports a diagnostic role for non-invasive quantification of myocardial perfusion using fast-CT technology.

8:45 a.m.

### 904-2 High Diagnostic Accuracy of Parametric MR Perfusion Maps for the Detection of Coronary Artery Disease in Comparison With Positron Emission Tomography and X-Ray Coronary Angiography

Juerg Schwitter, Katrin Bertschinger, Stefan Kneifel, Daniel Nanz, Thomas F. Luescher, Borut Marincek, Gustav K. von Schulthess. University Hospital Zurich, Zurich, Switzerland

**Background:** To evaluate the performance of a hybrid echoplanar MR perfusion sequence in comparison with positron emission tomography (PET)

and conventional x-ray coronary angiography (CA) in patients with coronary artery disease (CAD).

**Methods:** In 8 healthy volunteers and 18 patients with suspected CAD, an MR perfusion study (4–6 slices/2RR-intervals, delay time TI 120 ms: sequence A), a PET study, and CA were performed. In the controls and the first 12 patients, a second MR perfusion study was additionally performed with improved myocardial coverage (6–8 slices/2 RR-intervals, TI: 10 ms: sequence B). For the extravascular contrast medium (CM) GdDTPA, phantoms revealed a linear CM concentration-signal intensity (SI) relationship up to 0.5 and 0.2 mmol/l of CM with sequence A and B, respectively. In all subjects GdDTPA (0.1 mmol/kg IV) was administered during hyperemia (dipyridamole 0.56 mg/kg IV) and parametric maps of CM wash-in were generated (pixelwise linear fits) and corrected for baseline SI and input (parametric map divided by slope of SI increase in the left ventricular cavity). On these parametric maps 8 sectors/slice were analyzed and assigned to corresponding coronary arteries. On corresponding sectors of reformatted dynamic <sup>13</sup>N-ammonia PET scans, resting and hyperemic myocardial blood flow and coronary flow reserve (CFR) were calculated. CAD was defined by MR (slope < mean-2SD of controls), by PET (CFR < mean-2SD of controls) and by quantitative CA (QCA:  $\leq 50\%$  diameter stenosis).

**Results:** In controls signal-to-noise ratio during myocardial CM transit increased by 198  $\pm$  39% (77  $\pm$  23% with sequence B,  $p < 0.005$  vs sequence A, paired t test). For sequence A the sensitivity/specificity for the identification of individually diseased coronary arteries was 81%/71% vs PET and 78%/71% vs QCA; for sequence B: 73%/53% and 68%/48%, respectively. For sequence A (18 patients and 8 controls), sensitivity/specificity for detection of CAD was 89%/80% vs QCA, and 94%/86% vs PET, respectively.

**Conclusions:** MR-derived parametric perfusion maps avoid subjective assessment of perfusion defects and are highly reliable in detection of CAD.

9:00 a.m.

### 904-3 Determination of Regional Myocardial Blood Flow by Magnetic Resonance Imaging (MRI) in Comparison to Positron Emission Tomography (PET)

Tareq Ibrahim<sup>1</sup>, Stephan Nekolla<sup>1</sup>, Karin Schreiber<sup>1</sup>, Kenichi Odaka<sup>1</sup>, Stefan Volz<sup>2</sup>, Martin Güthlin<sup>2</sup>, Wolfram Delius<sup>2</sup>, Markus Schwaiger<sup>1</sup>. <sup>1</sup>Nuklearmedizinische Klinik der TU München; <sup>2</sup>Krankenhaus München Bogenhausen, Germany

**Background:** Noninvasive estimation of myocardial blood flow (MF) is a major concern in the evaluation of coronary artery disease (CAD). The purpose of this study was to determine regional MBF by MRI in patients (Pts) with CAD in comparison to healthy volunteers (VOL) and quantitative PET analysis.

**Methods:** A dynamic ECG-gated fast gradient echo sequence (3 short axis slices/heart beat; 5 elements phased array cardiac coil) with a Gd-DTPA bolus injection (0.05 mmol/kg) was performed at rest and under adenosine stress (140  $\mu\text{g}/\text{kg}/\text{min}$ ) of 6 min. duration in 25 Pts (19 M; 63  $\pm$  7 years) with angiographically proven coronary artery disease (Philips 1.5T). All Pts also underwent dynamic PET N-13 ammonia studies at rest and under adenosine stress. MRI time intensity-curves were fitted to measure maximal upslope. Stress/rest-upslope ratio (USR) was calculated as an index of coronary flow reserve (CFR). Polar maps were generated and regional USR was compared in 3 vessel regions to a normal database constructed of 20 VOL, angiographic findings and CFR of dynamic PET analysis.

**Results:** Regional USR averaged 1.45  $\pm$  0.33 in Pts and 2.01  $\pm$  0.46 in VOL. MRI-USR was significantly lower than PET-CFR (2.21  $\pm$  0.84). Both parameters correlated with the severity of stenoses (table). Using a cutoff of 1.20, coronary artery stenoses  $\geq 75\%$  were detected with sensitivity and specificity of 78% and 89%, respectively.

Table 1: MRI-USR and PET-CFR in comparison to angiography

Stenosis	0%	$\leq 50\%$	50–74%	$\geq 75\%$
MRI USR	1.59 $\pm$ 0.27	1.50 $\pm$ 0.26	1.35 $\pm$ 0.38	1.13 $\pm$ 0.17
PET CFR	2.26 $\pm$ 0.76	1.93 $\pm$ 0.42	1.87 $\pm$ 0.43	1.64 $\pm$ 0.45

**Conclusion:** MRI flow measurements represent a promising technique for detection as well as severity assessment of regional CAD, which requires further clinical evaluation.

9:15 a.m.

### 904-4 Prediction of Abnormal Coronary Flow Reserve With Electron Beam Computed Tomography for Coronary Calcification

Elizabeth C. Storen, Thomas Behrenbeck, David O. Hodge, Patrick F. Sheedy, Timothy F. Christian. Mayo Clinic, Rochester, Minnesota, USA

**Background:** Electron beam computed tomography (EBCT) can be used



to screen for atherosclerosis by detecting coronary calcification (CC). The need and sequence of subsequent testing (if any) following EBCT results is undefined. The purpose of this study was to determine whether the EBCT derived calcium score for coronary calcification is associated with coronary flow reserve (CFR) abnormalities by myocardial perfusion imaging (MPI).

**Methods:** The study group consisted of 121 patients who underwent both EBCT and MPI. EBCT image acquisition consisted of 40, 3 mm thick, transaxial slices from which calcium area and Agatston score were calculated. Stress (exercise = 98, vasodilator infusion = 23) perfusion imaging was performed with either thallium-201 (n = 92) or Tc99m sestamibi (n = 29). The MPI were acquired tomographically and considered abnormal if there was evidence of defect reversibility or significant fixed defects. Both area and score varied by CFR.

**Results** (see table):

EBCT	Overall	Normal CFR (n = 28)	Abnormal CFR (n = 93)	p
Score	552 ± 754	217 ± 243	653 ± 826	0.02
Area	166 ± 209	75 ± 194	194 ± 228	0.02

There were significant but weak associations between CC measures and the extent of redistribution by scintigraphy:  $r = 0.38$ ,  $p < 0.001$  for both score and area. Abnormal CFR was found in 6 (5%) patients with no detectable CC, however all 22 patients (18%) with a score > 900 or area > 300 had abnormal CFR. Using ROC curve analysis, the optimal cut-points for CC score (168) and area (67) produced a sensitivity of 60–64% and specificity of 72–74% for predicting abnormal CFR.

**Conclusion:** CC by EBCT is significantly associated with abnormal CFR but is only moderately predictive for CFR at low and intermediate scores. A small cohort of patients with extensive CC can be identified by EBCT who may bypass MPI and be referred directly to angiography. Functional testing by MPI should be considered for others with lesser CC scores.

9:30 a.m.

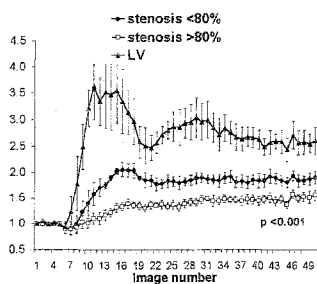
**904-5 Regional Myocardial Perfusion With Entire Heart Coverage During Stress Contrast Enhanced MRI Detects High Grade Coronary Stenosis in Patients**

Carlos E. Rochitte, Heron R. Rached, José R. Parga, Luiz F. Ávila, Cláudio C. Castro, Rosa M. Piva, Roberto Kalil Filho, José C. Nicolau, José A.F. Ramires, Anthony Faranesh. *Heart Institute (InCor), São Paulo University Medical School, São Paulo, Brazil; Johns Hopkins University, Baltimore, Maryland, USA*

**Background:** Detection of myocardial perfusion is crucial to assess functional significance of coronary artery obstructions.

**Methods:** We investigate whether a novel fast gradient-echo EPI MR sequence (FGRET, TR5.9/TE1.8/FA15), able to acquire six short-axis heart-slices in 2 heart beats, can access regional myocardial perfusion during peak stress with dipyridamole in nine patients with known CAD. We obtained myocardial signal intensity normalized to baseline (NSI), from the left ventricle (LV) in all coronary artery territories. Gd-DTPA (0.1 mmol/kg IV bolus) was injected twice: 2 minutes after dipyridamole 0.5 mg/kg/4 min (peak stress) and 20 minutes later (rest).

**Results:** NSI curves of myocardial territories supplied by coronary arteries with and without stenosis > 80% differ significantly at peak stress (see graph). NSI within myocardial territories dependent on coronary arteries with stenosis >80% increased less than in those with <80% stenosis ( $41 \pm 2\%$  vs.  $86 \pm 1\%$ ,  $p < 0.001$ ). Stress/rest NSI ratio was lower in myocardial territories with coronary stenosis >0.80% ( $1.06 \pm 0.01$  vs  $1.23 \pm 0.02$ ,  $p < 0.001$ ). NSI mean increase rate was 4% per image for >80% stenosis myocardial territories and 11% for <80% stenosis territories during the up-slope of the NSI curves.



**Conclusion:** Ultra fast contrast-enhanced MRI allows coverage of the entire heart during stress myocardial perfusion studies. MRI first-pass perfusion studies during stress can detect physiologically significant coronary artery

stenosis as low signal intensity myocardial regions immediately after bolus of Gd-DTPA. MR perfusion studies can detect stress-induced myocardial ischemia in patients with CAD.

9:45 a.m.

**904-6 Transmyocardial Laser Revascularization (TMLR) Improves Regional Wall Motion in Remote and Chronic Ischemic Myocardium**

Olaf M. Muehling, Norbert M. Wilke, Yimei Huang, Sam Wann, Ying Wang, Michael Jerosch-Herold, Mary M. Cayton, Mahmood M. Mirhoseini. *Center of Magnetic Resonance Research, Department of Radiology, University of Minnesota; Heart and Lung Institute Wisconsin and St. Luke's Hospital, Milwaukee, WI, USA*

**Background:** Using cine magnetic resonance imaging (CMR) as a non-invasive, quantitative, diagnostic tool we hypothesized that there is improvement of remote and ischemic myocardial function after TMLR and preservation of left ventricular (LV) function.

**Methods:** In 14 pigs (20–25 kg) ischemia was induced by catheter-guided hollow bead embolization of the LCx. One week after induction of ischemia the animals were randomized either to a treatment (T) or control group (controls). TMLR was performed in 7 of 14 animals. With a high powered (850 W) CO<sub>2</sub>-laser 30 ± 5 channels were created over the postero-lateral aspect of the heart. Follow-up CMR was performed before (n = 14), and 8 weeks (n = 13) after TMLR. Global LV-function was assessed by the cardiac output index (CO-Index, ml/min/kg). Regional wall thickening (RWT) (mm) was quantified with the modified centerline method in the target (postero-lateral) and remote (antero-septal) zone. Microsphere studies were obtained to document changes in regional myocardial blood flow (MBF, ml/min/g). TTC-tissue stains were made to determine infarct size.

**Results:** RWT in the target region was significantly impaired vs. the remote region at 1 week ( $0.8 \pm 0.9$  vs.  $4.8 \pm 1.3$   $p < 0.01$ ). After 8 weeks RWT in the ischemic area improved in T ( $0.4 \pm 0.4$  vs.  $2.8 \pm 1.5$ ,  $p < 0.02$ ) and resulted in a significantly greater wall thickening of T vs. controls ( $2.8 \pm 1.5$  vs.  $1.2 \pm 0.7$ ,  $p < 0.04$ ). RWT in the remote area was increased in T vs. controls ( $5.4 \pm 1.2$  vs.  $3.9 \pm 0.8$ ,  $p < 0.04$ ). CO-Index was decreased vs. baseline in controls ( $172 \pm 34$  vs.  $79 \pm 18$ ,  $p < 0.01$ ) and significantly decreased vs. T after 8 weeks ( $79 \pm 18$  vs.  $117 \pm 10$ ,  $p < 0.01$ ). MBF was improved in the target and remote zone of controls vs. T ( $0.2 \pm 0.04$  vs.  $0.6 \pm 0.2$ ,  $p < 0.04$ ;  $0.8 \pm 0.12$  vs.  $1.2 \pm 0.03$ ,  $p < 0.02$ ) and TTC-stains revealed significant decrease in infarct size ( $6.6\% \pm 1.6$  controls vs.  $3.6\% \pm 1.5$  T,  $p < 0.01$ ).

**Conclusion:** TMLR improves regional myocardial function not only in the ischemic region but also in the remote myocardium. As demonstrated for the first time with CMR there is preservation of global left ventricular function, due to improved myocardial blood flow in the target and remote zone and a reduced infarct size after TMLR.

POSTER

**1212 Stress Echo/Doppler: Miscellaneous Applications**

Wednesday, March 15, 2000, 9:00 a.m.–11:00 a.m.  
Anaheim Convention Center, Hall A  
Presentation Hour: 9:00 a.m.–10:00 a.m.

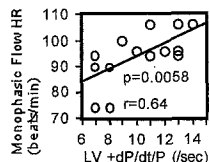
**1212-1 Monophasic Transmitral Flow Velocity Pattern With Less Increase in Heart Rate Indicates Left Ventricular Dysfunction**

Keiko Matsukida, Yutaka Otsuji, Shuichi Hamasaki, Shiro Yoshifuku, Toshiro Kumanohoso, Akira Kisanuki, Chuwa Tei. *Kagoshima University School of Medicine, Kagoshima, Japan*

**Background:** With the increase in heart rate (HR), transmitral flow pattern becomes monophasic. The HR to cause monophasic flow potentially depends on isovolumetric contraction and relaxation time directly related to LV function. We therefore tested the hypothesis that patients with monophasic mitral flow with less increase in HR have LV dysfunction.

**Methods:** We performed simultaneous recordings of high fidelity LV pressure and Doppler mitral flow during right atrial pacing in 17 patients (8 with coronary artery disease, 4 with cardiomyopathy, 2 with aortic regurgitation, 1 with hypertensive heart disease, 1 with mitral valve prolapse, and 1 with paroxysmal atrial fibrillation). HR was increased in every 2 beats/min until the development of monophasic mitral flow. The HR to cause monophasic flow, LV dP/dt, and PQ interval were obtained.

**Results:** 1) The HR to cause monophasic flow varied from 74 to 106 beats/min. 2) By regression analysis, peak positive and negative LV dP/dt/P ( $r = 0.64$ ,  $r = 0.59$ ) and PQ interval ( $r = 0.77$ ) were identified as significant factors to determine HR to cause monophasic mitral flow.



**Conclusion:** Monophasic mitral flow velocity pattern with less increase in HR indicates LV dysfunction with impaired positive and negative dP/dt/P and prolonged PQ interval.

### 1212-2 Coronary Vasodilation or Myocardial Ischemia Produces Diastolic Dysfunction During Combined Dipyridamole-Atropine Stress Echocardiography Test?

Sinisa Stojkovic, Miodrag Ostojic, Branko Beleslin, Rade Babic, Milan Nedeljkovic, Goran Stankovic, Jovica Saponjski, Ana Dikic-Djordjevic, Ivana Nedeljkovic, Jelena Stepanovic. *University Institute for cardiovascular Diseases, Belgrade, Yugoslavia*

**Objective:** The aim of the study was to test whether diastolic dysfunction during dipyridamole-atropine stress echocardiography test is produced by coronary vasodilation or myocardial ischemia.

**Method:** We performed combined dipyridamole-atropine (DipAtr) test in 30 pts (20 with multi vessel CAD and 10 with normal coronary arteries – criterion for CAD > 50% diameter stenosis by coronary angiography) during cardiac catheterisation in oath lab with continuous monitoring of left ventricular end-diastolic pressure (LVEDP), systolic and diastolic blood pressure, echocardiographic LV wall motion (ECHO), 12 lead ECG and symptoms. Well-established DipAtr protocol was used.

**Results:** Time sequence of ischemic events in ECHO positive pts were: LVEDP time  $5.74 \pm 2.79$  min; ECHO time =  $6.89 \pm 2.42$  min; ECG time =  $7.13 \pm 2.63$  min; angina time =  $7.56 \pm 2.56$  min. In group of pts with CAD peak LVEDP ( $22.4 \pm 9.1$  mm Hg) was significantly higher than baseline LVEDP ( $13 \pm 5.8$  mm Hg) ( $p < 0.01$ ). In group of pts with normal coronary arteries LVEDP have not change during DipAtr infusion ( $10 \pm 3.3$  vs.  $10.5 \pm 3.2$ ,  $p = ns$ ). Sensitivity was 95% (19/20), specificity was 100% (10/10), and diagnostic accuracy was 96.7% (29/30) by LVEDP increase (>5 mm Hg) and by ECHO (appearance of new or worsening of preexisting wall motion abnormality). Systolic wall motion index increased from baseline value  $1.18 \pm 0.24$  to peak  $1.37 \pm 0.33$  ( $p < 0.05$ ).

**Conclusion:** LVEDP increase (as the first sign of diastolic dysfunction) was documented only in CAD group of pts (result of myocardial ischemia), followed by ECHO dyssynergy and than by ECG changes and angina.

### 1212-3 The Effect of Hypertensive Blood Pressure Response During Stress Echocardiography on the Predictive Value of Decreased Stress Ejection Fraction for Severe CAD

S. Solis, A.F. Osman, L. Orejarena, C.J. Lavie, A. Grant, Y.E. Gilliland, M.M. Cassidy, J.A. Bernal, R.V. Milani. *Ochsner Medical Foundation, New Orleans, Louisiana, USA*

**Introduction:** A significant fall in global systolic function or ejection fraction (EF) during stress echo is generally considered highly predictive for severe coronary artery disease (CAD), either left main (LM) or severe 3-vessel CAD. Severe hypertension, however, is known to affect the diagnostic accuracy of stress testing. This study served to determine the impact of a hypertensive blood pressure (BP) response during stress echo on the predictive value of decreased stress EF for severe CAD.

**Methods:** Between January 1998 and August 1999, 7,300 stress echoes were performed at Ochsner Medical Institutions. We studied 108 consecutive patients who had significant decreases in EF ( $\geq 5\%$ ) during stress echo who consequently had coronary angiography. We excluded 29 patients with previous bypass surgery. Therefore, our study cohort consisted of 79 patients, including 13 with a hypertensive BP response to stress (peak systolic BP  $\geq 210$  mmHg).

**Results:** The distribution of CAD of all patients with decreased EF during stress echo is shown in Table 1. Table 2 shows distribution in a subset with hypertensive BP response during stress.

Whereas severe CAD is identified in 45% of all patients with decreased EF during stress echo, severe CAD is seen in only 15% in those with a

Table 1: Decreased EF stress

	n = 79	Percentage
LM or equivalent	20	25%
3v	16	20%
2v	8	10%
1v LAD	20	25%
LCX	2	3%
RCA	1	1%
Normal	12	15%
Total	79	100%

Table 2: Hypertensive Blood Pressure Response

	n = 13	Percentage
LM or Equivalent	2	15%
3v	0	0%
2v	2	15%
1v LAD	2	15%
LCX	0	0%
RCA	0	0%
Normal	7	55%
Total	13	100%

hypertensive BP response. The positive predictive value for any significant CAD decreased from 85% in all patients with a fall in EF during stress (including 92% in those without a hypertensive BP response) to only 46% in those with hypertensive BP response.

**Conclusion:** The presence of hypertensive BP response markedly reduces the positive predictive value of decreased EF during stress echo for severe and significant CAD.

### 1212-4 Safety and Prognostic Value of Early Dobutamine-Atropine Stress Echocardiography in Patients With Spontaneous Chest Pain and a Nondiagnostic Electrocardiogram

Marcel L. Geleijnse, Abdou Elhendy, Jarek Kasprzak, Maarten L. Simoons. *Jos RTC Roelandt, Thoraxcenter, Rotterdam, The Netherlands*

**Aim of the Study:** To risk stratify and shorten hospital stay in patients with spontaneous (resting) chest pain and a nondiagnostic ECG.

**Methods:** The study comprised 102 patients (mean age  $58 \pm 12$  years, 67 men) with spontaneous chest pain and a nondiagnostic ECG. All patients underwent serial creatine kinase (CK) enzyme measurement, continuous ECG monitoring for at least 12 h and early dobutamine-atropine stress echocardiography (DASE) in case of negative CK enzymes and normal findings at ECG monitoring. DASE was considered positive in case of new or worsening wall thickening abnormalities. Patients with negative DASE were discharged after DASE. In-hospital and 6 months follow-up events noted were cardiac death, nonfatal myocardial infarction (MI), unstable angina (UA), and coronary artery bypass surgery or angioplasty.

**Results:** Thirteen patients had evidence of evolving MI by elevated CK enzymes or UA by ECG monitoring. In the remaining 89 patients DASE was performed after a median observation period of 31 h (range 12–68 h). During DASE no serious complications (death, nonfatal MI, ventricular fibrillation or sustained ventricular tachycardia) occurred. DASE results were of low quality in 3, nondiagnostic in 6, negative in 44 and positive in 36 patients. In the 80 patients with diagnostic DASE, variables associated with in-hospital events ( $n = 7$ ) were exertional angina ( $p < 0.005$ ), stress-induced angina ( $p < 0.001$ ) and positive DASE ( $p < 0.005$ ). Variables associated with follow-up events ( $n = 11$ ) were history of exertional angina ( $p < 0.05$ ), stress-induced angina ( $p < 0.01$ ) and positive DASE ( $p < 0.01$ ). At multivariate analysis the only significant predictor of events was positive DASE ( $p < 0.01$ ).

**Conclusions:** Early DASE may safely discriminate patients with spontaneous chest pain and a nondiagnostic ECG into low- and high-risk subsets for subsequent cardiac events.

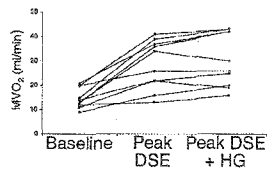
### 1212-5 Adjunctive Handgrip During Dobutamine Stress Echocardiography: Invasive Assessment of Myocardial Oxygen Consumption in Humans

F. Javier Otero, Jose Font-Cordoba, Marti McCulloch, Richard Sheahan, Rohit Parmar, Tonya Cochran, Christopher deFilippi. *University of Texas Medical Branch, Galveston, Texas, USA*

**Background:** Adjunctive handgrip (HG) during dobutamine (Dob) stress echocardiography (DSE) has been shown to increase the sensitivity for detection of coronary artery disease (CAD). This is thought to occur primarily by an increase in wall stress. This study was designed to invasively quantify the impact of adjunctive HG in humans on hemodynamics and myocardial oxygen consumption ( $MVO_2$ ) during DSE.

**Methods:** We performed an invasive hemodynamic evaluation during DSE and adjunctive HG on 11 patients (age 50 ± 8 yrs, 8 males, none with CAD) off beta-blockers for >24 hrs. Coronary sinus blood flow (CSF), right-sided and systemic pressures, oxygen saturations and transthoracic 2D echocardiography, were obtained at each 3-min stage. HG began after 3 min of peak Dob at 1/3 of max HG and was sustained for 2 min. MVO<sub>2</sub> was calculated by Fick.

**Results:** At peak Dob, HR, CSF and MVO<sub>2</sub> (available in 9 subjects) increased whereas PCW and end-systolic circumferential wall stress (ESCWS) decreased from baseline (table). The addition of HG resulted in a modest but significant increase of MVO<sub>2</sub> (graph) and ESCWS.



	HR	SBP	PCW	CSF	MVO <sub>2</sub>	EF	ESCWS
Baseline	79 ± 13	144 ± 18	11 ± 5	126 ± 49	15 ± 6	69 ± 10	117 ± 18
Peak Dob	148 ± 10*	144 ± 26	7.0 ± 3*	270 ± 116*	28 ± 12*	77 ± 11*	109 ± 24*
Handgrip	152 ± 10	150 ± 23	8.4 ± 3†	312 ± 134†	31 ± 13†	74 ± 31	120 ± 23†

\*p < 0.05 between baseline and peak dob †p < 0.05 for comparison between peak dob and handgrip. SBP = systolic blood pressure (mm Hg), PCW = pulmonary capillary wedge (mm Hg), EF = ejection fraction (%), ESCWS = end-systolic circumferential stress (× 10<sup>3</sup> dynes/cm<sup>2</sup>).

**Conclusion:** Adjunctive HG to DSE in humans without CAD results in a significant increase in MVO<sub>2</sub> in the majority of subjects that correlates with changes in ESCWS.

**1212-6 Myocardial Jeopardy Score and Coronary Artery Score in the Estimation of Functional Significance of Coronary Stenosis: Correlation With Physical and Third Generation Stress Echocardiography**

Ivana Nedeljkovic, Miodrag Ostojic, Branko Beleslin, Milan Nedeljkovic, Jovica Saponjski, Goran Stankovic, Ana Djordjevic-Dikic, Jelena Stepanovic, Sinisa Stojkovic, Vladimir Kanjuh. *Institute for Cardiovascular Diseases, Belgrade, Yugoslavia*

**Background:** Coronary artery disease severity described by the number of diseased vessels may underestimate the potential importance of coronary anatomy at one side, and amount of myocardium at risk which may vary in different pts, on the other.

**Objectives:** To determine, in the same group of pts, the relationship between myocardial jeopardy score (JS) and coronary score (CS) and results of dobutamine-atropine (DobAtro), dipyridamole-atropine (DipAtro) and exercise (Ex) stress echocardiography.

**Methods:** We evaluated 166 pts (133 male; 51 ± 10 years; 81 with previous myocardial infarction, 85 with angina pectoris; CAD present in 114 pts: 91 one-, 23 multi-vessel CAD) who all underwent DobAtro (up to 40 mcg/kg/min i.v. Dob with addition of 1 mg of atropine), DipAtro (up to 0.84 mg/kg Dip with addition atropine in Dip echo negatives), Ex (Bruce) and coronary, arteriography (analysed by quantitative arteriography). We calculated JS (a score of 0 for akinetic, 0.5 for hypokinetic and 1 for each normokinetic area subserved by the vessel with ≥50% DS by QCA) and CS (sum of all lesions scored from 0 to 5 in dependence of DS times weighting factor for particular localisation).

**Results:** Univariate logistic regression analysis showed significant correlation between JS, CS and number of diseased vessels and results of DobAtro, DipAtro and Ex (p > 0.0001 for all). However, in multivariable analysis significant predictor of stress echo results was only JS (p < 0.0001) for all tests. The cut-off values for CS with the best predictive value for stress echo positivity were 8.2, 8.2 and 8.3 for DobAtro, DipAtro and Ex (p = ns), and cutoff values for JS were 1.6, 1.6 and 1.7 for DobAtro, DipAtro and Ex (p = ns).

**Conclusion:** CS and JS are practical and useful parameters for determining both anatomic and functional significance of coronary stenosis. JS as the best multivariate predictor confirms that stress test echo results are not only influenced by stenosis severity but also by the amount of myocardium at risk.

**1212-7 Combined Low Dose Dobutamine – Nitrate Echocardiography in Comparison of Dobutamine Alone for Identifying Viable Myocardium**

Yuejin Yang, Fenghuan Hu, Shijie You, Yanwu Wang, Runlin Gao, Yulan Wu, Jilin Chen, Yishu Xu, Zaijia Chen. *Fu Wai Heart Hospital, Beijing, China*

**Background:** Animal studies have shown that nitrate can enhance the ability of dobutamine (Dob) to increase the contractility of viable myocardium. This study was sought to verify that combined low dose Dob-nitrate echocardiography was superior to Dob alone in identifying viable myocardium in patients with acute myocardial infarction (AMI).

**Methods:** Combined low dose Dob (3 and 5 μg/kg/min) with isosorbide dinitrate (the mean of 286.5 ± 25.5 μg/min) infusion and low dose (3, 5 and 10 μg/kg/min) Dob alone two-dimensional echocardiography (2DE) tests were performed at 10 ± 3 days after AMI in 31 patients scheduled for coronary revascularization (CRV). CRV was successful in all patients and follow-up 2DE was also conducted 3 months after CRV. Using 16-segment model and 5-grading method, the left ventricular regional wall motion and thickening was graded and scored. The detected viable myocardium, defined as 1 or 2 scores decreasing in at least two adjacent abnormal segments after the two tests, were compared with the post-CRV actual contractile improvement of corresponding segments to calculate the sensitivity, specificity, positive and negative value (PPV, NPV) and accuracy of the tests for identifying viable myocardium and the safety of the tests were evaluated. Comparison was also made between the two tests.

**Results:** Of 221 abnormal segments, 111 and 123 on the two doses Dob-nitrate test, 90, 111 and 115 on the 3 doses Dob alone test and 125 on post-CRV 2DE showed ≥1 grade improvement in contractile function. The sensitivities, specificities, PPVs, NPVs and accuracies of low dose Dob-nitrate 2DE for detecting viable myocardium were 77.6%–87.2%, 85.4%, 87.4%–88.6%, 74.5%–80.4% and 81.0%–86.4%, respectively, in which the sensitivity and accuracy on the 3 μg dose Dob-nitrate 2DE were both significantly higher than the same dose Dob alone (77.6% vs 61.8%; 81.0% vs 72.4%; both P < 0.05) and the sensitivity and accuracy on the 5 μg dose Dob-nitrate 2DE were both equivalent to those of Dob-10 μg alone (87.2% vs 89.4%; 86.4% vs 87.9%; both P > 0.05) without inducing ischemia as at Dob-10 μg alone.

**Conclusion:** Combined low dose (3–5 μg/kg/min) Dob-nitrate 2DE test was more sensitive and accurate, and safer than Dob alone in identifying viable myocardium in patients with AMI.

**1212-8 Utility of Stress Doppler Echocardiography in Patients With Mitral Stenosis Undergoing Percutaneous Mitral Balloon Valvotomy**

Ronnie J. Aviles, Rick Nishimura, Kim M. Andreen, Patricia P. Pellikka, David R. Holmes Jr.. *Mayo Clinic, Rochester, Minnesota, USA*

**Background:** A subset of patients with mitral stenosis (MS) present with symptoms out of proportion to their resting hemodynamics. Exercise hemodynamics may provoke severe obstruction in these patients, indicating that they would benefit from undergoing percutaneous mitral balloon valvotomy (PMBV).

**Methods:** A series of 192 consecutive patients with mitral stenosis who underwent PMBV was identified retrospectively from May 1984 to August 1998. We analyzed ten patients in whom the peak exercise mean mitral gradient doubled from baseline or was greater than 15 mmHg.

**Results:** Five patients were in NYHA Class III and five patients were in NYHA Class II. The mean transmitral valve gradient and pulmonary artery systolic pressure increased from 7 ± 2 mmHg and 39 ± 6 mmHg at rest to 17 ± 6 mmHg (p < 0.001) and 61 ± 9 mmHg (p < 0.0001) with exercise, respectively. The catheter-derived mitral valve area increased from 1.4 ± 0.3 cm<sup>2</sup> to 2.2 ± 0.4 cm<sup>2</sup> (p < 0.0001) after PMBV. Patients were followed for a mean of 84 ± 54 months. All patients reported improvement in symptoms of at least one functional class. The perceived functional capacity increased from 40% at baseline to 77% at last follow-up. All patients were alive at last follow-up and none required repeat PMBV or mitral valve replacement.

**Conclusion:** Exercise Doppler echocardiography is a useful tool in patients with mitral stenosis who present with symptoms out of proportion to resting hemodynamics. If there is a significant increase in transmitral valve gradient during exercise, these patients will experience symptomatic relief from successful percutaneous mitral balloon valvotomy.

## POSTER

**1213** **Ultrasound and Microbubbles**

Wednesday, March 15, 2000, 9:00 a.m.–11:00 a.m.  
 Anaheim Convention Center, Hall A  
 Presentation Hour: 9:00 a.m.–10:00 a.m.

**1213-25** **Quantitative Assessment of Infarct Size *In Vivo* by Myocardial Contrast Echocardiography in Acute Myocardial Infarction Model of the Rat**

Sung Yun Lee, Seung Woo Park, Hyeon-Cheol Gwon, June Soo Kim, Duk-Kyung Kim, Sang Hoon Lee, Kyung Pyo Hong, Jeong Euy Park, Jung Don Seo, Won Ro Lee. *School of Medicine, Sungkyunkwan University, Samsung Medical Center, Seoul, Korea*

**Background:** *In vivo* measurement of the infarct size (IS) in a small animal model is a valuable tool in cardiovascular research. The purpose of this study was to evaluate the feasibility of quantitative assessment of IS by myocardial contrast echocardiography (MCE) in a rat acute myocardial infarction (AMI) model.

**Methods:** We made AMI in 33 Sprague-Dawley rats by ligation of left coronary artery. Five hours later, transthoracic MCE was performed with 13 MHz linear transducer during intravenous infusion of 0.2 mL of ultrasonic contrast agent, made of sonicated dextrose-albumin solution exposed to the perfluoropropane (C3F8) gas. The result was recorded on videotape and analyzed off-line by two independent observers. IS measured by MCE (MCE method) was compared with that of postmortem heart stained with 1% triphenyl tetrazolium chloride solution (TTC method). IS was measured at the level of papillary muscle.

**Results:** 1) For MCE test, interobserver variability was  $r = 0.99$ , and intraobserver variability was  $r = 0.99$ .

2) The variables measured by TTC method were larger than those that measured by MCE method.

	TTC method	MCE method	p value
TMA	66.04 ± 1.66 mm <sup>2</sup>	41.7 ± 1.7 mm <sup>2</sup>	<0.001
IA	27.69 ± 1.05 mm <sup>2</sup>	16.81 ± 0.74 mm <sup>2</sup>	<0.001
IA/TMA	0.42 ± 0.01	0.39 ± 0.02	<0.005

TMA: total myocardial area, IA: infarct area

3) The IA/TMA showed significant correlation between TTC method and MCE method ( $r = 0.86$ ,  $p < 0.001$ ).

**Conclusion:** The IA/TMA measured by MCE method may be useful for *in vivo* estimation of the infarct size in a rat AMI model although the variables by MCE method could be measured smaller than those by TTC method.

**1213-26** **Imaging Myocardial Perfusion in Real-time: A Feasibility Study Using Rapid Mechanical Index Switching During Power Pulse Inversion Imaging**

Danny Skyba, Michalakis Averkiou, Christopher Loflin, Jeff Miller<sup>1</sup>, Elizabeth Le<sup>2</sup>, Howard Leong-Poi<sup>1</sup>, Matthew Coggins<sup>1</sup>, Jeffrey Powers. *ATL Ultrasound, Bothell, WA; <sup>1</sup>MBI, San Diego, CA; <sup>2</sup>University of Virginia, Charlottesville, VA, USA*

**Background:** It has been shown in dogs that the rate of myocardial reperfusion can be interrogated by using high mechanical index (MI) intermittent imaging (II) during contrast echocardiography. Although the method has shown similar results clinically, II is cumbersome due to the difficulty in maintaining a fixed echo window. A new imaging technology named Power Pulse Inversion (PPI) has been developed which can image contrast in real-time (RT) with minimal bubble destruction. It was therefore hypothesized that reperfusion of contrast could be visualized in RT with PPI following a rapid series of high MI destructive frames.

**Methods:** Four dogs were studied in the A4C or SAX view in this feasibility study. An ultrasound system interface was designed which could rapidly switch between a high and low mechanical index. A 0.5 ml bolus of contrast agent followed by a slow (1 ml/sec) 10 ml saline flush (Optison™) was administered. Filling of the left ventricular cavity and perfusion of the myocardium was observed in RT at a low MI (0.1). At the moment of peak contrast, 10 high MI (1.0) RT frames were delivered after which RT low MI (0.1) imaging resumed. Digital cine-loops were analyzed using HDILab software. Regions-of-interest were placed in the mid-septum and anterior beds in the A4C and SAX images, respectively.

**Results:** Low MI PPI successfully imaged myocardial perfusion in real-time. Destruction of the contrast agent in the scanplane was always observed after high MI imaging. The mean signal immediately before and after the high MI frames was  $7.2 \pm 0.98$  dB and  $0.8 \pm 0.60$  dB, respectively ( $n = 12$ ).

This represents a 98.4% percent decrease in linear signal due to the high MI destructive frames. Observable contrast reperfusion in the form of a 1-exponential function (as previously found with II) occurred during low MI real-time imaging. Eight seconds after high MI destruction, the signal intensity returned to within 13.6% of the initial signal intensity measured prior to high MI destruction. This near-complete reperfusion occurred in spite of the decreasing bubble concentration at the tail of the bolus.

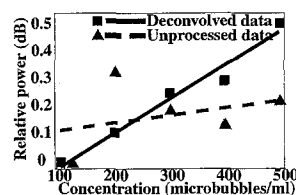
**Conclusion:** PPI combined with rapid MI switching proves to be a feasible method for visualizing myocardial reperfusion in RT. In addition the technique promises a faster alternative for the determination of reperfusion rate and myocardial blood volume. Further clinical studies are necessary to validate this technique versus II.

**1213-27** **Deconvolution Improves the Correlation Between Signal Intensity and Concentration of Contrast Agent NC100100: Implications for Quantification of Myocardial Perfusion**

N.S. Shashidhar, Imran Afridi, Diana Driscoll<sup>1</sup>, William Tobocman<sup>1</sup>, James D. Thomas. *The Cleveland Clinic Foundation, Cleveland, Ohio; <sup>1</sup>Department of Physics, Case Western Reserve University, Cleveland, Ohio, USA*

**Background:** Although quantitative contrast echocardiography implicitly assumes a monotonic, ideally linear, relationship between contrast concentration and image intensity, ultrasound interference from multiple scatterers critically impacts this simple relationship. Fourier deconvolution is a signal processing technique that potentially can undo the effect of such interference, which we tested in an *in vitro* model.

**Methods:** A 12 liter suspension of NC100100 (Nycomed Imaging A/S, Oslo) at physiologically realistic concentrations of 100 to 500 microbubbles/ml was imaged using a 3.5 MHz transducer (B&K Medical A/S, Copenhagen). At each setting of concentration, the RF echo signal was sampled at 40 MHz and 12 bit precision. Fourier deconvolution was performed by dividing the Fourier transform of this signal by the transform of the impulse response obtained from the echo return from a metal target. This was compared to conventional power calculations from the raw signal, analogous to image intensity.



**Results:** Power calculations from the unprocessed signal correlated poorly with concentration ( $R = 0.36$ ,  $p = \text{NS}$ ) while the power in the deconvolved signal showed a significantly better correlation with concentration ( $R = 0.96$ ,  $p = 0.007$ ).

**Conclusions:** 1) Multiscatter interference critically impacts the quantification of contrast concentration by echo videointensity, which may limit assessment of myocardial perfusion; 2) Fourier deconvolution provides a linear relation between bubble concentration and signal power and restores monotonicity, with important implications for perfusion quantification; 3) Further studies are needed to evaluate the effects of attenuation, dispersion and the presence of noncontrast scatterers.

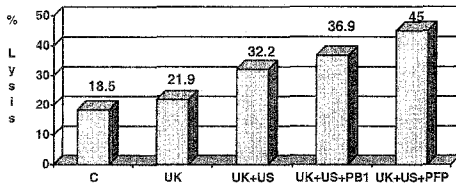
**1213-28** **Enhanced Clot Microfragmentation and Lysis Using Ultrasound and Perfluorocarbon-filled Polymer Microbubbles**

Milind R. Dhond, Chris Dolan, Thanh T. Nguyen, Greg Pulido, William Bommer. *University of California, Davis, CA, USA*

**Background:** Inadequate clot lysis during thrombolytic therapy remains a significant problem. We compared the effects of air-filled versus perfluorocarbon-filled bispheres (Point Biomedical Corp) in enhancing clot microfragmentation and lysis during exposure to urokinase and ultrasound (US) at 20 kHz.

**Method:** Human blood was incubated for two hours to produce fresh clots. These were then dried and weighed. They were then exposed to saline control (C), urokinase alone (UK), UK + US, UK + US + air-filled polymer bispheres (PB1), C + UK + US + perfluorocarbon-filled PB1 (PPF) for six minutes. Clots were then dried and re-weighed to determine % thrombolysis.

**Results:** The % clot lysis for each group were: Saline  $18.5 \pm 4\%$ , UK alone  $21.9 \pm 4\%$  ( $p = \text{NS}$ ), US + UK  $32.2 \pm 8\%$  ( $p < 0.05$ ), US + UK + PB1  $36.9 \pm 8\%$  ( $p < 0.05$ ), and US + UK + PPF  $45.0 \pm 11\%$  ( $p < 0.05$  compared to C,  $p < 0.05$  compared to PB1). (See graph).



**Conclusions:** Ultrasound thrombolysis at 20 kHz is significantly increased with the addition of polymer bispheres (PB1 or PPF). Compared to US + UK, perfluorocarbon-filled bispheres significantly enhanced US thrombolysis compared to air-filled bispheres. Perfluorocarbon-based contrast agents are significantly better at enhancing US thrombolysis than air-filled agents. This has implications in the future treatment of myocardial infarctions and thrombotic disorders.

**1213-29 Targeted Acquisition of Contrast-Enhanced Echocardiographic Images Improves the Assessment of Myocardial Perfusion**

Victor Mor-Avi, James Bednarz, Kirk Spencer, Lynn Weinert, Paul Widner<sup>1</sup>, Roberto M. Lang. *The University of Chicago, Chicago IL; <sup>1</sup>DuPont Pharmaceutical, North Billerica MA, USA*

**Background:** Contrast enhanced Power Doppler imaging used to assess myocardial perfusion, is limited by a high incidence of false positive perfusion defects, mainly in the apex and basal segments of the anterior and lateral walls. The aims of this study were: (1) to determine whether targeted imaging of individual LV walls using a narrow sector improves myocardial contrast enhancement, and (2) to compare the effects of targeted imaging on contrast-enhanced Power Doppler (PD) and gray scale (GS) images.

**Methods:** 10 patients with normal resting radionuclide images were studied. GS and PD images were obtained (HP 5500) in both the traditional apical two- and four-chamber (A2C and A4C) views and using the targeted narrow sector approach. Contrast enhancement was achieved using iv infusion of Definity (DuPont). Dual triggering was used to acquire pairs of consecutive frames every fourth beat which were analyzed using custom software. Following realignment, a digital subtraction image was created for each GS and PD image pair, and the mean difference in pixel values ( $\Delta$ ) was measured in 6 regions of interest in each view. This index was used to indirectly assess the extent of microbubble destruction, which is presumably related to myocardial perfusion. Targeted acquisition was considered to improve myocardial contrast enhancement in regions where  $\Delta > 30\%$  was noted compared to a non-targeted image.

**Results:** 117 myocardial segments were compared between targeted and non-targeted imaging. The impact of targeted acquisition was observed across all segments measured. Percent of segments that improved with targeted imaging is shown in table. The improvement was most pronounced in the mid- and basal lateral segments in the A4C and in the basal inferior and all anterior segments in the A2C view.

	GS	PD	GS	PD	
A4C	48%	57%	A2C	40%	42%
b-septal	20%	40%	b-inferior	67%	56%
m-septal	40%	50%	m-inferior	22%	11%
a-septal	50%	50%	a-inferior	22%	44%
a-lateral	70%	50%	a-anterior	33%	50%
m-lateral	70%	80%	m-anterior	50%	50%
b-lateral	40%	70%	b-anterior	50%	50%

**Conclusions:** Targeted acquisition improves the assessment of myocardial perfusion based on dual triggering imaging of bubble destruction, and in many segments eliminates false positive perfusion defects due to acoustic shadowing.

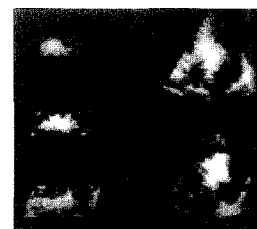
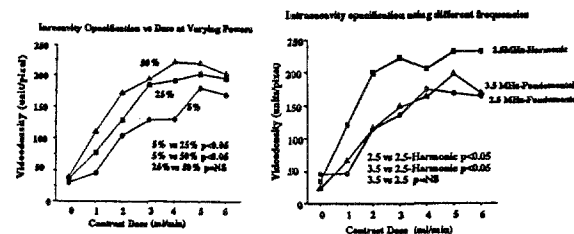
**1213-30 Effect of Harmonics and Varying Power on Cavity Opacification During Contrast Infusion Using Real Time 3D Echocardiography: An In Vivo Study in Closed Chest Dogs**

Rosemary A. Rusk, Yoshiki Mori, Petra S. Mehwald, Suthep Wanitkun, David J. Sahn. *Oregon Health Sciences University, Portland, OR, USA*

**Background:** Availability of intravenous (IV) contrast agents and contrast harmonic imaging has had an important impact in improving LV endocardial definition. When harmonics and contrast agents are combined with real time 3D echocardiography, the result has the potential to facilitate analysis of LV volume and function even in difficult patients. We compared fundamental to harmonic imaging and studied the effect of transmit power on the adequacy of LV cavity opacification using an IV contrast infusion and real time 3D echo.

**Methods:** Three dogs (mean weight 28 kg) received an infusion of Definity® (DuPont Pharmaceuticals) at 6 incremental doses ranging from 0.9–5.4  $\mu\text{l/kg/min}$  (16 ml/min). Scanning of the left ventricle, with a contrast harmonic upgraded model of the real time 3D Volumetrics® scanner, was performed at baseline and at each dose using 2.5 MHz fundamental, 3.5 MHz fundamental and 2.5 MHz with harmonic imaging at each of 3 transmit powers (5%, 25% and 50%). Intracavity opacification was measured by videodensitometry and destruction of the contrast agent (signal void especially near the apex) was also assessed.

**Results:** Peak LV opacification was reached for the 2.5 and 3.5 MHz fundamental imaging at a dose of approximately 3.6  $\mu\text{l/kg/min}$  (4 ml/min), after which there was no further increase in intensity with increasing dose. Using harmonic imaging maximum intensity was achieved at a lower dose (1.8–2.7  $\mu\text{l/kg/min}$ , 2–3 ml/min). At all transmit powers there was significantly increased opacification using harmonic compared with fundamental 2.5 or 3.5 MHz imaging ( $p < 0.05$ ). Opacification was significantly less using 5% power ( $p < 0.05$ ); but bubble destruction was apparent using 25% and 50%, particularly with fundamental imaging. With harmonic imaging a lower dose and intermediate transmit power of 25% yielded the most consistent and intense opacification without noticeable destruction.



**Conclusion:** In conjunction with harmonic imaging in our study it was possible to titrate the contrast infusion rate and vary transmit power to optimize echo contrast enhanced LV endocardial definition during real time 3D cardiac imaging.

**1213-31 Detection and Location of Left Anterior Descending Coronary Artery Stenoses by Contrast-Enhanced Transthoracic Harmonic Echo Doppler**

Carlo Caiati, Lijun Chen, Norma Zedda, Cristiana Montaldo, Sabino Iliceto. *Inst. of Card, Univ. of Cagliari and "S. Maugeri" Foundation, Cassano, Italy*

**Background:** We tested the hypothesis that visualization of color flow in the entire left anterior descending coronary artery (LAD) could be accomplished by a new non invasive Doppler method (contrast-enhanced transthoracic second harmonic echo Doppler) so allowing detection and location of significant stenosis (>50% diameter reduction) by recording convective acceleration of flow at the stenosis site.

**Methods:** Seventeen consecutive patients (pts) undergoing coronary angiography (CA) were submitted to transthoracic contrast-enhanced pulsed wave Doppler recording of blood flow velocity (BFV) in the proximal/mid and distal portion of LAD using Harmonic color Doppler as a guide. In each of the two segments of the artery, velocity was first measured in correspondence of color aliasing if present or if not present, after sampling the whole visualized segment, the highest value was recorded (first site). A reference value proximally or distally to the first recording was then attained.

**Results:** LAD visualization improved with contrast since longer portions of the vessel were visualized. Before enhancement, length of color flow in the two LAD segments was  $21 \pm 9$  mm,  $14 \pm 12$  mm, whereas after enhancement

	LAD BFV (peak diastolic)		
	First site (cm/sec)	Reference (cm/sec)	% increase
Diseased segments	$131 \pm 61$	$37 \pm 15$	$309 \pm 224$
Normal segments	$34 \pm 11$	$29 \pm 7$	$21 \pm 30$

\* =  $p < 0.01$

it was  $32 \pm 13$  and  $24 \pm 12$  respectively ( $p < 0.001$ ). A significant stenosis was detected by CA in 12 pts and in 15 of 24 segments (12 proximal/mid and 3 distal) whereas it was not in 5 pts and in 9 segments. Higher velocities were recorded in the diseased segments of LAD than in the normal ones (see table). If a % increase in BFV  $\geq 70\%$  was considered a positive criteria for LAD stenosis then sensitivity and specificity in identifying all diseased segments or at least one diseased segment was 80%, 100% and 100%, 100% respectively.

**Conclusion:** Enhanced transthoracic Doppler evaluation of BFV in the LAD is a reliable and feasible approach for LAD stenosis detection and location.

### 1213-32 Blush Grade is a Stronger Predictor of 4 Week LV-Function Than Intravenous Myocardial Contrast Echocardiography and Coronary Flow Reserve

Wolfgang Lepper, Rainer Hoffmann, Otto Kamp<sup>1</sup>, Andreas Franke, Carel C. de Cock<sup>1</sup>, Harald P. Kuehl, Gert J. Siesverda<sup>1</sup>, Uwe Janssens, Cees A. Visser<sup>1</sup>, Peter Hanrath. *University Hospitals of Aachen, Germany; University of Amsterdam, Amsterdam, The Netherlands*

**Background:** Angiographic myocardial blush grade (MBG), myocardial contrast echo (MCE) and coronary flow reserve (CFR) measurements have been used to predict recovery of LV-function after acute myocardial infarction (AMI).

**Methods:** To determine the strongest predictor of global and regional LV-function 4 weeks after AMI MBG, i.v. MCE (Sonazoid<sup>®</sup>, Nycomed-Amersham) and CFR measurements were performed in 25 patients 24 h after AMI treated by primary PTCA and stent placement. MBG was graded 1, no or minimal; 2, moderate; and 3, normal blush. The total endocardial border length of the contrast defect on MCE 24 h after revascularization was measured in the 2- and 4-chamber view. CFR was measured using a Doppler guidewire and intracoronary adenosine (12–18  $\mu$ g). Regional and global wall motion score indices were calculated according to ASE guidelines for 2-D echocardiograms performed 24 h and 4 weeks post PTCA.

**Results:** Global wall motion index improved from  $1.74 \pm 0.27$  24 h after PTCA to  $1.59 \pm 0.36$  ( $p < 0.01$ ) at 4 weeks and regional wall motion index improved from  $2.71 \pm 0.40$  to  $2.22 \pm 0.55$  ( $p < 0.01$ ). Correlation of global wall motion at 4 weeks was found to be significant with MBG at 24 h ( $r = -0.65$ ,  $p < 0.001$ ), the size of the perfusion defect as assessed with MCE at 24 h ( $r = 0.67$ ,  $p < 0.001$ ), and CFR at 24 h ( $r = -0.46506$ ,  $p < 0.05$ ). Analysis of covariance revealed MBG as the strongest predictor of global ( $p < 0.05$ ) and regional ( $p < 0.05$ ) wall motion at 4 weeks.

**Conclusion:** MBG was found to be the strongest predictor of LV-function at 4 weeks. This finding demonstrates the present limitations of i.v. MCE in comparison to direct intracoronary perfusion assessment.

## POSTER

### 1214 Doppler Tissue Imaging

Wednesday, March 15, 2000, 9:00 a.m.–11:00 a.m.  
Anaheim Convention Center, Hall A  
Presentation Hour: 9:00 a.m.–10:00 a.m.

### 1214-33 Quantitation of Regional Left Ventricular Function During Dobutamine Echo Using Tissue Doppler is Independent of Image Quality

Peter Cain, Jonathan Chan, Leanne Short, Sudhir Wahi, Tom Marwick. *University of Queensland, Brisbane, Australia*

**Background:** Poor 2D echo image quality (IQ) occurs in many pts undergoing dobutamine echo (DbE) and limits reproducibility of wall motion scoring (WMS). Myocardial Doppler velocity (MDV) may be a quantitative alternative to WMS, and tissue Doppler has the advantage of greater signal-noise ratio. We sought the influence of technically difficult studies on MDV.

**Methods:** 150 pts (91 men, age  $57 \pm 16$ ) underwent a standard DbE protocol. Color MDV (GE-Vingmed S5) was acquired simultaneously with harmonic 2D echo images at each stage. An experienced observer interpreted each of 16 segts as normal, ischemia, viable or scar by 2D. Independent scoring of image quality (IQ) in each segt was obtained using a 4 point scale (A: full endocardial resolution, B:  $>50\%$  segt seen but not endocardium, C:  $<50\%$  seen, D: segt not seen). MDV waveforms of basal and mid-segts were measured off-line. Relationship between MDV and WMS at peak stress was assessed in segts of image quality A–D, and accuracy of MDV for diagnosis of CAD was evaluated in 81 pts undergoing angiography.

**Results:** Of 849 evaluable segts with WMS and MDV, 233 were A quality, 296 of B, 251 of C and 69 of D quality. Levels of MDV in normal and abnormal segts were comparable across the range of IQ (Table). In a linear model, WMS (F value 11.4,  $p < 0.0001$ ) but not IQ ( $p = NS$ ) was related to MDV. Accuracy of MDV for CAD in good (A + B) studies was 71%, compared with 66% in poor studies ( $p = NS$ ).

MDV (cm/sec) in normal/abnormal segments according to image quality.

Image quality	A	B	C	D	
Normal segs	$7.19 \pm 0.17$	$7.36 \pm 0.16$	$7.33 \pm 0.24$	$7.02 \pm 0.11$	$p = 0.41$
Abnormal segs	$5.6 \pm 0.23$	$6.6 \pm 0.31$	$6.14 \pm 0.32$	$5.49 \pm 0.42$	$P = 0.19$

**Conclusion:** MDV is a quantitative technique for assessment of regional LV function that is independent of IQ

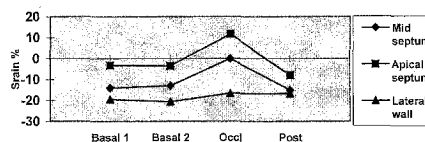
### 1214-34 Myocardial Strain Doppler: A Sensitive New Method for Detection of Ischemia During Off-Pump Coronary By-Pass Surgery

Helge Skulstad, Kai Andersen, Thor Edvardson, Tor Inge Tønnessen, Erik Fosse, Halfdan Ihlen. *National Hospital, Oslo, Norway*

**Background:** Myocardial strain Doppler is a new method in assessment of regional ventricular function, reflecting changes of myocardial segment length. The capability of the method to detect regional left ventricular (LV) ischemia was assessed during off-pump coronary bypass surgery offering an experimental study design in humans.

**Methods:** Myocardial strain Doppler recordings were made by transesophageal echocardiography in seven patients receiving left internal mammary artery graft to left anterior descending coronary artery (LAD) necessitating transient LAD occlusion. Four-chamber views were recorded before and at five minutes of LAD occlusion, and five minutes after completed anastomosis. Invasive hemodynamic measurements were performed simultaneously.

**Results:** Peak systolic strain during LAD occlusion changed  $-14.2 \pm 5.4\%$  (mean  $\pm$  SD) to  $-0.1 \pm 11.8\%$  in the mid intraventricular septum ( $p < 0.05$ ) and from  $-3.3 \pm 13.2\%$  to  $11.6 \pm 7.0\%$  in the apical septum ( $p < 0.05$ ). No significant changes occurred in the LV lateral wall. Septal strain returned to baseline levels after terminated occlusion.



ST segment changes in ECG were observed during occlusion in three patients and left bundle branch block in one. There were no concomitant changes of heart rate, stroke volume, pulmonary wedge pressure or systemic artery pressure.

**Conclusion:** The changes in strain during LAD occlusion reflect systolic lengthening or reduced systolic shortening in segments supplied by LAD, thus detecting myocardial ischemia even without any hemodynamic changes.

### 1214-35 Pulse Inversion Imaging – The Latest Tool to Enhance Endocardial Definition

Jennifer C. Cooke, Jane E. Hancock, Dimitrios J. Patsouras, Dimitra A. Klotsa, Mark J. Monaghan. *King's College Hospital, London, UK*

**Background:** Pulse Inversion imaging (PI) is a new echo technology designed to provide increased sensitivity for detection of ultrasound contrast agents. 2 sequential ultrasound pulses,  $180^\circ$  out of phase with each other, are transmitted down each scan line and the received echoes are added together and should cancel each other out. The non-linear response of contrast microspheres provides incomplete cancellation and the harmonic signal is extracted, without the need for narrow-band filtering. We hypothesised that this form of harmonic imaging should also be sensitive to tissue harmonics, be especially sensitive to moving tissue targets and offer improved resolution over conventional 2<sup>nd</sup> harmonic imaging (2HI) because it does not utilise narrow-band filtering.

**Methods:** 40 unselected patients (20 females, age range 9–84 yrs, estimated EF ranged from 17–80%) referred for echo evaluation of left ventricular function were studied using an ATL HDI 5000 system in Fundamental (Fun), 2HI and PI modes. All conventional imaging planes were recorded using separate SVHS tapes for each modality. Using the standard 16 segment model, 867 myocardial segments were analysed in each modality by three independent observers. An endocardial definition score of 0 = endocardium not visualized; 1 = endocardium barely visible but sufficient; 2 = good endocardial definition, was ascribed to each segment.

**Results:** Comparing the three modalities, there was better endocardial definition with PI (1.822 per segment) than either Fun (1.623,  $p < 0.00001$ ) or 2HI (1.773,  $p < 0.00001$ ). PI resulted in an increased number of interpretable segments (94.4%) compared with Fun (82.4%,  $p < 0.00001$ ) or 2HI (91.0%,  $p < 0.00001$ ).

**Conclusion:** PI appears to provide superior endocardial definition to either conventional 2HI or Fun imaging modes. The technique may supersede 2HI as the method of choice in patients with suboptimal echo images and during stress echo.

**1214-36 Real-Time Strain Rate Imaging (RT-SRI) Versus Tissue Velocity Image-Derived SRI (TVI-SRI): Compression and Expansion Rate Analysis Using a Tissue Mimicking Phantom**

Marek Belohlavek, Virginia B. Bartleson, Mark E. Zobitz, Randall R. Kinnick, James F. Greenleaf. *Mayo Clinic, Rochester, MN, USA*

**Background:** Strain rate imaging (SRI) is based on the spatial gradient of velocity vector calculation and reflects local compression and expansion rates. The SRI data are either generated in real-time through the analysis of a second harmonic radiofrequency signal or calculated off-line from tissue velocity image (TVI) data. The two different approaches should provide comparable results.

**Methods:** We used a gelatin phantom with stiffness and scattering similar to beef. The phantom was cyclically compressed to generate clinically relevant compression and expansion rates from 1.0 to 3.5  $s^{-1}$  in 8 increments. Both RT-SRI and TVI digital data were collected using GE Vigmed System FiVe, and TVI-SRI values calculated off-line. We compared compression and expansion rates by RT-SRI to those by TVI-SRI using 0 degree and 25 degree insonification beam angles with respect to the vector of tissue motion.

**Results:** Precision of RT-SRI compared to TVI-SRI was high, as expressed by excellent correlation ( $r > 0.97$ ) for all testing combinations, and by a low coefficient of variation for both 0-degree ( $4.6 \pm 1.5\%$ ) and 25-degree ( $9.5 \pm 4.7\%$ ) angle measurements. Accuracy was also high, as documented by the low mean difference (bias  $< 0.57 \pm 0.037 s^{-1}$ ). We observed a trend towards small underestimation by RT-SRI with increasing strain rate values (nonunity slope of a correlation line, increasing bias).

**Conclusions:** The RT-SRI technique has high precision and accuracy, and should be suitable for quantitation of myocardial compression and expansion rates. The small bias can be explained by the differences in transmit and pulse repetition frequencies between RT-SRI and TVI-SRI.

**1214-37 New Echocardiographic Insight From the Doppler Tissue Imaging Modality Applied in Patients With End Stage Heart Failure Treated by Biventricular Pacing Mode**

Stéphane Lafitte, Stéphane Garrigue, Pierre Jais, Jean Marie Perron, Jacques Clementy, Raymond Roudaut. *Cardiologic Hospital, Bordeaux, France*

It has recently been shown that biventricular pacing (BP) can improve symptoms in patients with end stage heart failure (HF). Although BP reduces the QRS width, invasive explorations have not well characterized yet its impact on regional myocardial contractility and left ventricular (LV) wall synchronization. We sought to quantify the BP effects in terms of local electro-mechanical delay (EMD) and LV walls motion, by using the Doppler tissue imaging (DTI) technique. 20 patients ( $65 \pm 7$  years) with drug resistant HF have received a pacemaker for BP therapy (LV pacing via the coronary sinus). Echocardiography was performed one month after the pacemaker implantation with a Sequoia (Acuson, Inc.). The DTI pulsed S wave amplitude and the EMD (delay between the onset of the QRS and that of the S wave) were recorded and analyzed for the 4 basal LV walls and for each patient in 4 pacing modes: sinus rhythm (SR), right ventricular pacing (RP), LV pacing (LP) and BP. BP provided the shortest EMD for the lateral LV wall ( $p < 0.001$ ) with the greatest S wave amplitude increase (Table,  $p = 0.01$ ). However, BP provided similar data compared with those in SR for the other three LV walls ( $p = ns$ ). DTI echocardiography showed a major local EMD shortening associated with a systolic lateral LV wall motion increase. This technique appears to be an helpful non-invasive tool for HF patients treated by BP.

	SR	RP	LP	BP
EMD (msec)	229 ± 41	234 ± 44	244 ± 66	175 ± 37*
S wave (cm/s)	5.7 ± 0.6	6.5 ± 2.0	6.8 ± 1.4	8.4 ± 2.0**

\* $p < 0.001$ , \*\* $p < 0.05$

**1214-38 Diastolic Function From Transmitral Flow: Derivation and Validation of the Myocardial Velocity Gradient to Doppler E-Wave Relation**

Mark W. Sessoms, Jonathan M. Milde, Jennifer B. Lissauskas, Sándor J. Kovács. *Cardiovascular Biophysics Laboratory, Washington University St. Louis, MO, USA*

**Background:** The M-mode echo determined maximal rate of left ventricular wall-thinning, or peak myocardial velocity gradient (peak MVG), has been proposed as a new, independent index of diastolic function. We show that the Doppler E-wave is generated by wall-thinning, and wall-thinning can be derived from conservation of myocardial volume, simplified LV geometry, and the constant-volume pump attribute of the heart.

**Methods:** Doppler E-wave and color M-mode images of the posterior LV wall for 9 normal subjects were analyzed. Two models of LV shape were chosen: cylinder with fixed external (epicardial) dimension and cylinder with semi-ellipsoidal apex. Both generate endocardial movement (wall-thinning) during diastole using the E-wave as input. M-mode images were used for validation.

**Results:** Figure 1 shows model-predicted endocardial movement (white curve) superimposed on color M-mode endocardial movement (black curve). Note close agreement. Figure 2 shows validation of model predicted peak MVG and actual peak MVG for all subjects studied ( $R = 0.81$ ).

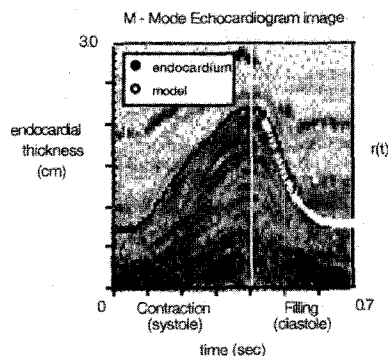


Figure 1

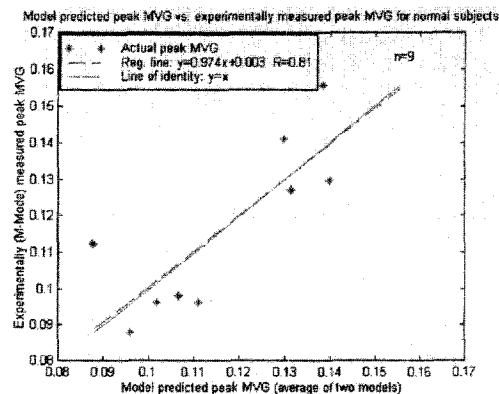


Figure 2

**Conclusion:** Wall-thinning generates the Doppler E-wave. Therefore, wall-thinning throughout early rapid filling (E-wave) and peak wall-thinning rate (peak MVG) are derivable from LV geometry and transmitral flow. Application to selected pathologic clinical subsets is in progress.

**1214-39 Relationship Between Right Ventricular Systolic Pressure and Tricuspid Annulus Motion Interrogated by Doppler Tissue Imaging in Patients With Chronic Pulmonary Hypertension**

Ali Moustapha, Vinod Kaushik, Eddy Barasch. *University of Texas Medical School at Houston and Hermann Hospital, Houston, Texas, USA*

**Background:** Right ventricular systolic pressure (RVSP) cannot be always assessed in the absence of tricuspid regurgitation. Tricuspid annulus (TA) motion can be evaluated by Doppler Tissue imaging (DTI). We hypothesized that TA motion is changed in pulmonary hypertension (PHT) and therefore can help measure RVSP.

NONINVASIVE IMAGING

**Methods:** Thirty (30) patients (pts) with PHT (mean RVSP =  $55.2 \pm 12.1$  mm Hg) and 85 normal controls were recruited. All underwent complete 2-D and Doppler echocardiographic examinations. DTI of early diastolic (e'), late diastolic (a') and systolic (s) velocities (V) and time velocity integrals (TVI) of the lateral (L) and medial (M) TA were averaged from 3 cardiac cycles. Means of samples were compared using ANOVA test. Simple linear regression was used to assess the association between DTI parameters and RVSP.

**Results:** In pts with PHT, lateral e' TVI (Le'TVI), a' TVI (La'TVI) and sTVI (LsTVI) and medial s TVI (MsTVI) were all significantly lower in pts than controls (see table). In addition there was a significant negative correlation between RVSP and Le'TVI ( $r = -0.49$ ,  $p = 0.003$ ) and LsTVI ( $r = -0.55$ ,  $p = 0.006$ ).

	Pts	Controls	p
Le'TVI	$2.1 \pm 0.6$	$2.6 \pm 0.8$	<0.05
La'TVI	$1.4 \pm 0.7$	$1.8 \pm 0.8$	<0.05
LsTVI	$1.3 \pm 0.5$	$1.7 \pm 0.9$	<0.05
MsTVI	$0.9 \pm 0.2$	$1.8 \pm 0.9$	<0.05

**Conclusion:** Early diastolic, late diastolic and systolic TVI of the lateral tricuspid annulus and systolic TVI of the medial annulus are all decreased in pts with PHT. In addition, early diastolic and systolic TVI of the lateral tricuspid annulus negatively correlate with RVSP. Further studies are needed to assess the usefulness of these parameters in measuring the severity of PHT.

#### 1214-40 Age-Associated Changes in Parameters of Mitral Annular Dynamics Assessed by Pulsed Doppler Myocardial Imaging

Sang-Chol Lee<sup>1</sup>, Seung Woo Park, Sun-Young Choe<sup>1</sup>, Hyeon-Cheol Gwon, June Soo Kim, Duk Kyung Kim, Sang Hoon Lee, Kyung Pyo Hong, Jeong-Euy Park, Jung Don Seo, Won Ro Lee.  
<sup>1</sup>Center for Health Promotion; Cardiac and Vascular Center, Samsung Medical Center; Department of Internal Medicine, College of Medicine, Sungkyunkwan University, Seoul, Korea

**Background:** Left ventricular diastolic parameters obtained from pulsed Doppler myocardial imaging (DMI) of the mitral septal annulus have been reported to change with aging. This study sought to find out age-associated changes in diastolic parameters derived from pulsed DMI of various portions of the mitral annuli and a modified Tei index obtained from pulsed DMI of the mitral septal annulus.

**Methods:** One hundred and ninety-four healthy subjects who visited the Center for Health Promotion in Samsung Medical Center, Seoul, Korea for a routine health checkup were examined with pulsed DMI of the mitral annulus. Sample volumes were placed in the septal, lateral, inferior and anterior annuli. Early (E') and late (A') peak diastolic velocities of the annuli motion and their ratio (E'/A') were obtained. The modified Tei index was obtained by dividing the duration of the systolic (S') wave by the time interval between the end of the late diastolic velocity profile and the beginning of the early diastolic velocity profile in wave recordings of pulsed DMI of the mitral septal annulus.

**Results:** The mean age of the subjects was  $53.7 \pm 11.7$  and the gender ratio was 151:43 (M:F). The E'/A' ratio in all measured areas and the modified Tei index showed a constant and significant decline with aging.

Sample volume	Age					r
	30-39	40-49	50-59	60-69	70-	
N	17	68	51	39	19	
Septal	$1.23 \pm 0.41$	$0.88 \pm 0.20$	$0.71 \pm 0.18$	$0.62 \pm 0.24$	$0.55 \pm 0.11$	-0.61
Lateral	$1.59 \pm 0.45$	$1.29 \pm 0.40$	$1.13 \pm 0.44$	$0.96 \pm 0.41$	$0.74 \pm 0.21$	-0.50
Anterior	$1.54 \pm 0.43$	$1.12 \pm 0.46$	$0.89 \pm 0.31$	$0.76 \pm 0.31$	$0.60 \pm 0.16$	-0.54
Inferior	$1.09 \pm 0.42$	$0.89 \pm 0.23$	$0.75 \pm 0.23$	$0.59 \pm 0.21$	$0.56 \pm 0.14$	-0.57
m-Tei	$0.71 \pm 0.05$	$0.66 \pm 0.06$	$0.65 \pm 0.08$	$0.64 \pm 0.05$	$0.61 \pm 0.04$	-0.33

(m-Tei: modified Tei index.  $p < 0.01$  for all r values)

**Conclusion:** Left ventricular diastolic parameters derived from pulsed DMI of the mitral annuli change consistently in all parts of the annuli with aging, showing a significant and constant decline in the E'/A' ratio. A modification of the Tei index, which can be used as an estimate of overall left ventricular function, also shows a small but significant decline with increase in age.

## ORAL

### 911 New Radionuclide Imaging Agents and Stressors

Wednesday, March 15, 2000, 10:30 a.m.–Noon  
Hilton Anaheim, California A

10:30 a.m.

### 911-1 Vasodilator Stress Imaging Using New Adenosine A<sub>2A</sub> Receptor Agonists Administered by Bolus Injection

David K. Glover, Mirta Ruiz, Kazuya Takehana, Frank D. Petruzella, Denny D. Watson, George A. Beller. *University of Virginia, Charlottesville, VA, USA*

**Background:** A new class of stable, highly potent and selective adenosine A<sub>2A</sub> receptor agonists has been synthesized at the University of Virginia. Although i.v. infusions of these compounds have been shown to produce a marked increase in coronary flow (CF), it is unknown whether the duration of CF elevation following a bolus injection would be sufficient to permit stress imaging.

**Methods:** In 6 anesthetized, open-chest dogs with critical LAD stenoses, we administered either JMR-193e ( $n = 3$ ) or DWH-146e ( $n = 3$ ) by i.v. bolus injection ( $1-2 \mu\text{g/kg}$ ). Hemodynamics were recorded at 15 sec intervals and regional blood flow was measured with microspheres. <sup>99m</sup>Tc-sestamibi (MIBI) was injected at peak flow and the animals were then killed.

**Results:** CF and arterial pressure (AP) responses to the 2 agonists were similar. Both compounds increased CF in a controlled, repeatable manner. CF in the normal LCx increased 323% from  $35 \pm 6$  to  $112 \pm 15$  ml/min ( $p < 0.001$ ) resulting in a 4:1 regional myocardial flow disparity between the LAD and LCx zones. CF peaked 2.5 min post injection and was  $\geq 95\%$  peak for  $\sim 2$  min. CF returned to baseline after 15 min with a pharmacodynamic  $t_{1/2} = 4.4 \pm 1.2$  min. Although AP decreased 14% from  $117 \pm 3$  to  $101 \pm 5$  mmHg ( $p < 0.001$ ) at peak CF, it remained above 100 mmHg. By comparison, in 2 dogs receiving an adenosine bolus, AP fell initially from  $105 \pm 21$  to  $22 \pm 4$  mmHg. The mean <sup>99m</sup>Tc-sestamibi defect count ratio (LAD/LCx) on ex vivo images of heart slices was  $0.64 \pm 0.03$ , similar to our previous studies using adenosine infusions.

**Conclusions:** Bolus delivery of these new adenosine A<sub>2A</sub> receptor agonists produced maximal CF elevation with sufficient duration to permit injection of a tracer for stress imaging. These vasodilator properties would simplify clinical imaging protocols by obviating the need for an infusion pump.

10:45 a.m.

### 911-2 Detection of Platelet-Rich Coronary Thrombi Using a Novel Radionuclide Imaging Agent (Technetium 99m-DMP-444) in a Canine Model: Interaction With Abciximab

Joseph Mitchel, Tianjie Lai, Michael White, Dadong Li, Tod Alberghini, Ahmad Saloum, David Knibbs, Satyendra Giri, David Waters, Gary V. Heller. *Hartford Hospital, Hartford, CT, USA*

**Background:** Acute thrombus formation can be accurately identified in canine coronary arteries using a new IIb/IIIa platelet inhibitor, DMP-444, labeled with technetium (Tc) 99m (*Circ. 1999; abstract*). We tested the ability of this agent to identify platelet-rich thrombus in a canine model by nuclear imaging following acute injection, delayed injection and its ability to detect thrombus with abciximab administration.

**Methods:** Endothelial injury of the LAD was performed by electrical stimulation to induce a platelet-rich thrombus at a flow limiting stenosis site. Five groups underwent Tc 99m-DMP-444 injection: acutely, at five minutes post stimulation ( $n = 4$ ), delayed injection at one hour ( $n = 4$ ), abciximab administration acutely followed by Tc99m-DMP-444 injection at one hour ( $n = 5$ ), Tc99m-DMP-444 injection acutely and abciximab at two hours ( $n = 5$ ), and a control group: no electrical stimulation ( $n = 4$ ). Planar nuclear imaging was performed for two hours following administration of each agent. Image interpretation was performed by three blinded readers. The presence of platelet-rich thrombus was confirmed by gross appearance and weight, nuclear counts, and electron microscopy (EM).

**Results:** Positive images were identified in all acute and delayed injections of Tc99m-DMP-444 following stimulation, with gross thrombus formation present in each case. Negative images were present in all control animals. Image results in these groups corresponded to platelet presence by EM, thrombus size and nuclear counts. In endothelial stimulated cases receiving abciximab, 50% of the nuclear images were negative with positive interpretations correlating with larger thrombus burdens.

**Conclusion:** Platelet-rich thrombus formation can be accurately identified in canine coronary arteries following acute and delayed adminis-



tration of Tc-99m-DMP-444. Abciximab administration may interfere with Tc-99m-DMP-444 identification of thrombus.

11:00 a.m.

### 911-3 Noninvasive Imaging of Atherosclerotic Plaques With In-111-Labeled Lipid-Seeking Coproporphyrin

Diwaker Jain, Padmakar Kulkarni, Frank D. Kolodgie, Navneet Narula, Ram Rammohan, Brijeshwar S. Maini, Gunnar Snyder, Renu Virmani, Elmo R. Acio, Jagat Narula. *Hahnemann University School of Medicine, University of Pennsylvania Medical School, Philadelphia, PA; Yale University School of Medicine, New Haven, CT; Southwestern University School of Medicine, Dallas; Armed Forces Institute of Pathology, Washington, DC, USA*

**Background:** Unstable atherosclerotic plaques are pathologically characterized by attenuated fibrous cap, large lipid pool, and intense macrophage infiltration. Recently, porphyrins have been shown to bind to atherosclerotic lipids with high affinity. We hypothesized that imaging with radiolabeled porphyrins will allow noninvasive diagnostic modality for unstable plaques. For this purpose In-111 was used to label coproporphyrin.

**Methods:** 12 NZW rabbits were studied. Atherosclerotic lesions were induced in 7 of 12 by infradiaphragmatic balloon deendothelialization followed by 1% cholesterol and 6% peanut oil diet for 12 wks. 1.25 mg coproporphyrin labeled with upto 1.3 mCi of In-111 was injected intravenously.

**Results:** Radiolabeled porphyrin cleared rapidly from circulation as 2-compartment model with  $T_{1/2\alpha}$  15 and  $T_{1/2\beta}$  32 min. Abdominal lesions were imaged best at 2 h after injection; there was no uptake in control rabbits. Intense uptake in lesions was confirmed by ex-vivo imaging and macroautoradiography; there was no radioactivity in the excised control aorta. Porphyrin uptake was also confirmed pathologically by UV autofluorescence in lipid lesions. Quantitative uptake (% injected dose/gram) in lesions ( $0.04 \pm 0.006$ ) was 11-fold higher than control specimens ( $0.003 \pm 0.002$ ). Organs of maximum radiation burden included liver ( $0.73 \pm 0.07$ ), spleen ( $0.38 \pm 0.11$ ), renal cortex ( $0.13 \pm 0.05$ ), and bone marrow ( $0.06 \pm 0.02$ ).

**Conclusions:** Since porphyrins are integral component of human body, have high affinity to atherosclerotic lipid pools and in radiolabeled form rapidly clear from blood, they should constitute attractive imaging agents for the detection of unstable plaques.

11:15 a.m.

### 911-4 In Vivo Noninvasive Serial Monitoring of Atherosclerotic Progression and Regression With FDG-PET in a Rabbit Model

Gérard Helft, Stephen G. Worthley, Zhuang Y. Zhang, Cheuk Tang, Oswaldo Rodriguez, Azfar G. Zaman, John T. Fallon, Josef Machac, Monte Buchsbaum, Valentin Fuster, Juan J. Badimon. *Mount Sinai School of Medicine, New York, New York, USA*

**Background:** Macrophages are central in both and plaque vulnerability. Thus, the ability to document and subsequently monitor the macrophage composition of atherosclerotic lesions could provide important information on plaque vulnerability and potentially direct future therapies. FDG has a high affinity for macrophages within tumors and we have previously reported a high correlation between FDG uptake and macrophage content within atherosclerotic lesions in an experimental rabbit model. We now report the ability of FDG-PET to monitor atherosclerotic progression and regression in this rabbit model.

**Methods:** Aortic atherosclerosis was induced by a combination of cholesterol rich diet for 9 months and double balloon denudation in New Zealand White rabbits ( $n = 8$ ). The rabbits were subsequently randomized into a progression group receiving the same cholesterol diet ( $n = 4$ ) and a regression group ( $n = 4$ ) receiving a normal diet for a further 6 months. *In vivo* imaging was performed with a GE brain PET camera 30 mins post injection of 34–72 mBq for each rabbit at 9 and 15 months. Uptake of FDG was assessed by a ratio of aortic atherosclerotic lesions to cardiac uptake in 32 consecutive sections per aorta. A serial comparison between the same atherosclerotic aortic segments could thus be made in the same animal.

**Results:** At 9 months, atherosclerotic aortas showed an intense focal uptake of FDG (mean  $0.62 \pm 0.11$ ). At 15 months, progression group showed a significant increase ( $p < 0.001$ ) in this uptake in each rabbit (mean ratio increase 0.14). Conversely, regression group showed a significant decrease ( $p < 0.05$ ) in the uptake in 3 of 4 rabbits (mean ratio decrease 0.17), and no significant change in 1 rabbit.

**Conclusion:** FDG-PET permits for the first time the serial monitoring of progression and regression of atherosclerosis in an experimental model. This may allow the stratification of risk in patients with atherosclerosis in the future.

### 911-5 Detection of Residual Coronary Stenoses by Assessing Coronary Flow Reserve Using <sup>99m</sup>Tc-N-NOET Vasodilator Stress Imaging Early After Coronary Reperfusion in a Canine Model of Infarction

Kazuya Takehana, Mirta Ruiz, Frank D. Petruzella, Denny D. Watson, George A. Beller, David K. Glover. *University of Virginia, Charlottesville, VA, USA*

**Background:** Reperfusion (Rep) is often incomplete following thrombolytic therapy in acute myocardial infarction due to the presence of residual coronary stenoses. Detecting mild to moderate stenoses requires assessing coronary flow reserve (CFR) with vasodilator stress. We have previously shown that <sup>99m</sup>Tc-N-NOET (NOET) is a viability independent flow tracer in the acute phase of Rep, and thus may be well-suited for assessing CFR in this setting.

**Methods:** Twelve anesthetized, open-chest dogs underwent 60 min of total LAD occlusion followed by either full Rep (Grp1,  $n = 4$ ) or Rep through a residual stenosis that abolished CFR (Grp2,  $n = 8$ ). Infarct size was similar in both groups (9% vs 8% LV). NOET was given during peak vasodilator stress, 2 hrs after full or partial Rep and initial and redistribution (Rd) images were acquired. Regional blood flow was assessed with microspheres.

**Results:** Injection flow ratios (LAD/LCx), NOET defect count ratios from quantification of *in vivo* and *ex vivo* images, and *in vitro* NOET activity ratios from gamma well counting are shown below:

	Flow Ratio	Initial NOET	Rd NOET	Ex Vivo	In Vitro
Grp 1:	$0.57 \pm 0.09$	$0.73 \pm 0.01^*$	$0.79 \pm 0.01^*$	$0.80 \pm 0.02^*$	$0.84 \pm 0.06^*$
Grp 2:	$0.36 \pm 0.02^\dagger$	$0.61 \pm 0.02^{*\dagger}$	$0.67 \pm 0.02^{*\dagger}$	$0.70 \pm 0.03^{*\dagger}$	$0.67 \pm 0.04^*$

\*  $p < 0.01$  vs Injection Flow;  $^\dagger p < 0.01$  Grp 1 vs Grp 2

Both initial and Rd NOET uptake differentiated between the 2 Grps. CFR was diminished in the Rep zone of Grp 1 (Flow ratio  $< 1$ ), despite the absence of a stenosis, as a result of endothelial and/or microvascular dysfunction. Thus, the difference in NOET uptake between the 2 Grps was less than expected.

**Conclusions:** In this model with some CFR preservation, NOET can detect residual coronary stenoses. However, with more prolonged occlusion resulting in more severe endothelial/microvascular dysfunction, it may be difficult to distinguish varying degrees of vessel patency using CFR techniques.

11:45 a.m.

### 911-6 Prognostic <sup>99m</sup>Tc-Technetium-HL91 Can Identify Hypoxic, Viable Regions in Ischemic-Reperfused Myocardium With Infarct

Zhonglin Liu, Gerald Johnson III, Curtis L. Hart, Michael W. Eaton, Christopher J. Higgins, David R. Okada, Robert D. Okada. *William K. Warren Medical Research Institute of the University of Oklahoma Health Sciences Center, Tulsa, Oklahoma, USA*

**Background:** Prognostic™ TM (HL91 = 4,9-diaza-3,3,10,10-tetramethyldecane-2,11-dione dioxime) is a new technetium-99m labeled imaging agent which has been shown in preliminary studies to demonstrate increased uptake in ischemic tumor cells with minimal hepatic uptake. The purpose of this study was to determine the activities of <sup>99m</sup>Tc-HL91 in normoxic (N), hypoxic-viable (H) and hypoxic-nonviable (NV) myocardium following injury and infarct due to ischemia with limited reperfusion.

**Methods:** A 1.5 h. left circumflex artery occlusion was followed by 4.5 h. reperfusion at 10% baseline flow, injection of <sup>99m</sup>Tc-HL91 (555 MBq; 15 mCi), and 4 h. gamma camera imaging in 5 open chest canine experiments. Microspheres were injected during baseline, occlusion, time of tracer injection, and at the end of the experiment. After sacrifice, heart slices were imaged. Blood flow and tracer activity were determined by well counting. TTC stain was used to mark infarcts which were sized using computerized digital planimetry. Creatine kinase enzyme assays were performed to assess developing injury. Tissue oxygen was measured using phosphorimetry.

**Results:** Mean infarct size was  $16.4 \pm 3.7\%$  (mean  $\pm$  sem) total left ventricle. Five of 5 dogs demonstrated <sup>99m</sup>Tc-HL91 "hot spots" on *in-vivo* and *ex-vivo* gamma camera images. Microsphere-determined, normalized end flow ratios of NV/N =  $0.07 \pm 0.02$  and H/N =  $0.28 \pm 0.04$ ;  $p < 0.05$ . End flows (ml/min/gm) in both H ( $0.26 \pm 0.04$ ) and NV ( $0.05 \pm 0.01$ ) were significantly reduced compared to N ( $0.87 \pm 0.07$ ;  $p < 0.05$ ). Gamma well-counted, normalized tissue activity ratios for NV/N =  $1.08 \pm 0.11$  and H/V =  $2.34 \pm 0.14$ ;  $p < 0.05$ . Tissue activity (cpm/gm) in N ( $1.2 \pm 0.07 \times 10^5$ ) and NV ( $1.13 \pm 0.06 \times 10^5$ ) tissues were not significantly different ( $p = ns$ ).

**Conclusions:** In contrast to high <sup>99m</sup>Tc-HL91 activity in viable, hypoxic tissue, normoxic and nonviable myocardium demonstrate similar low <sup>99m</sup>Tc-HL91

uptake and retention. Thus,  $^{99m}\text{Tc}$ -HL91 can mark hypoxic viable regions by "hot spot" imaging in myocardium with infarct. This agent warrants further clinical studies in situations where there is a need to differentiate ischemic-viable from nonviable myocardium.

## ORAL

## 912 New Techniques in Echocardiography

Wednesday, March 15, 2000, 10:30 a.m.–Noon  
Hilton Anaheim, California B

10:30 a.m.

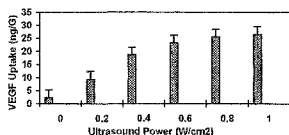
## 912-1 Ultrasound Power Increases Myocardial Vascular Endothelial Growth Factor Uptake in a Dose Dependent Manner

Debabrata Mukherjee, James Wong, Brian P. Griffin, Stephen G. Ellis, Subha Sen, Thomas Porter<sup>1</sup>, James D. Thomas. *Cleveland Clinic Foundation, Cleveland, OH; <sup>1</sup>University of Nebraska, Omaha, NE, USA*

**Background:** A limitation of tissue-targeted drug delivery is the need for direct arterial cannulation. We postulate a mechanism by which agents injected intravenously may be targeted to a tissue using ultrasound (US) and ultrasonic contrast agents.

**Methods:** We used a rat model to test the ability of US and an ultrasonic contrast agent perflurocarbon exposed sonicated dextrose albumin (PESDA) to increase uptake of vascular endothelial growth factor (VEGF) in the myocardium. Continuous wave (CW) Doppler ultrasound (0.2–1.0 watts/sq.cm at 1 MHz for 15 minutes) was applied to the chest wall overlying the myocardium during intravenous injection with VEGF (100  $\mu\text{g}$ /kg) preincubated with PESDA (0.1%). VEGF uptake was measured quantitatively in the heart by ELISA (ng/g tissue) and morphologically by fluorescence microscopy.

**Results:** There was a linear increase in myocardial VEGF uptake upto 0.6 watts/sq.cm with a subsequent plateau. Fluorescence microscopy revealed deposition of VEGF in the endothelium of small intramyocardial arterioles.



**Conclusions:** These results show a dose dependent increase in myocardial VEGF uptake with ultrasound + PESDA. Thus, ultrasound, in conjunction with myocardial contrast agents, may be used to augment myocardial VEGF uptake 10–13 fold.

10:45 a.m.

## 912-2 Strain Rate Imaging Can Accurately Identify Infarct Segments in Patients With Myocardial Infarction: A Clinical Study

Donato Mele, Bjorn Olstad<sup>1</sup>, Mario Donateo, Iginio Pedini, Paolo Alboni, Robert A. Levine<sup>2</sup>. *Division of Cardiology, Ospedale Civile, Cento, Italy; Norwegian Biomedical University, Trondheim, Norway; Noninvasive Cardiac Lab., Mass. Gen. Hospital, Boston, USA*

**Background:** Two-dimensional (2D) color Doppler Tissue Imaging (DTI) provides a spatial map of myocardial velocities but cannot distinguish active from non-ischemic passive wall movements. To overcome this limitation, Strain Rate Imaging (SRI) has recently been developed to measure regional velocity gradients that result from wall thickening and are virtually unaffected by motion of adjacent segments and heart translation. The aim of this study was to evaluate the feasibility of SRI and its ability to recognize abnormal regional systolic function compared to color DTI, 2D B-mode and anatomic M-mode (AMM).

**Methods:** Twenty-four patients (62  $\pm$  9 years, 17 males) with myocardial infarction who underwent a gated stress  $^{99m}\text{Tc}$ -sestamibi scan showing fixed perfusion defects with no signs of ischemia were studied. One high frame-rate cine-loop cardiac cycle for each of the 3 standard apical views was acquired (Vingmed System 5) and analyzed on a PC workstation. LV wall motion over time by SRI and DTI were displayed along a curved M-mode line passing through the LV walls from base to apex in each view. Regional systolic function was evaluated visually by each echo technique using the ASE 16-segment model by independent observers (384 total segments).

**Results:** By nuclear perfusion, there were 304 non-infarct and 80 infarct segments. SRI showed the best accuracy for recognizing the infarct segments:

	SRI	DTI	B-mode	AMM
Sensitivity	91%	63%	78%	87%
Specificity	84%	73%	71%	77%
Accuracy	86%	71%	72%	79%

The interobserver coefficient of agreement (k) for SRI was 0.85.

**Conclusions:** Color SRI is a new technique that improves evaluation of LV segmental wall motion compared with other ultrasound techniques, mainly because it can identify segments that are moving passively but not thickening normally. Therefore, it can assist in evaluation of regional systolic function in patients with myocardial infarction.

11:00 a.m.

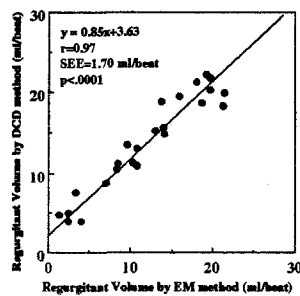
## 912-3 A Two-Dimensional Digital Color Doppler Flow Method (DCD) Implemented Using Two Orthogonal Planes Improves Calculation of Pulmonary Regurgitant Volumes and Regurgitant Fractions in a Chronic Animal Model

Yoshiki Mori, Michael Jones, Rosemary A. Rusk, Timothy Irvine, David J. Sahn. *Oregon Health Sciences University, Portland, OR; LAMS-NHLBI, Bethesda, MD, USA*

**Background:** While a two-dimensional digital color Doppler (DCD) method for calculating cardiac output in the LVOT appears to be accurate, it has not been used clinically for calculating stroke volumes through right ventricular outflow tract (RVOT), possibly because of the asymmetrical geometry of flow profiles in the RVOT. We tested the hypothesis that the DCD method using an average of two orthogonal planes could provide accurate estimation of forward and regurgitant flows.

**Methods:** In six sheep with surgically created chronic pulmonary regurgitation (PR), 22 different hemodynamic states were studied using the DCD method in two orthogonal planes. Reference pulmonary regurgitant volumes (RVs) and regurgitant fractions (RFs) were obtained with pulmonary and aortic electromagnetic flow meters (EMFs). Epicardial echocardiographic studies were performed using Toshiba PowerVision with a 5 MHz transducer. Short and long axis orthogonal views of the RVOT were used to measure the forward and regurgitant flows.

**Results:** Using a single plane, the RVs and RFs by the DCD method correlated with those by EMFs but showed wide variability (Long axis:  $r = 0.89$ ,  $\text{SEE} = 3.69$  ml/beat for RV;  $r = 0.78$ ,  $\text{SEE} = 14\%$  for RF). The RVs and RFs by the DCD method using the average of calculations in two orthogonal planes correlated well with references and were more accurate than the method using either single plane ( $r = 0.97$ , mean difference =  $1.8 \pm 1.8$  ml/beat for RV;  $r = 0.94$ , mean difference =  $3 \pm 7\%$  for RF).



**Conclusion:** Our study demonstrated that the DCD method using the average of two orthogonal planes yielded accurate pulmonary RVs and RFs. This method should have clinical importance for serially quantifying PR in patients followed after surgery for tetralogy of Fallot.

11:15 a.m.

## 912-4 Left Atrial Volume and Function: Relationship to Left Ventricular Function

Fabrice Bauer, Michael Jones<sup>1</sup>, Takahiro Shiota, Jian Xin Qin, Hiroyuki Tsujino, Agnese Travaglini, Arthur D. Zetts, Julio A. Panza<sup>1</sup>, James D. Thomas. *The Cleveland Clinic Foundation, Cleveland, OH; <sup>1</sup>NHLBI, Bethesda, MD, USA*

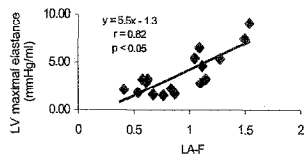
**Background:** Change in left atrial (LA) volume throughout the cardiac cycle include LA filling during left ventricular (LV) systole, LA passive emptying in early LV diastole and LA active emptying late in LV diastole.

**Aim of the Study:** To compare each LA phase to the corresponding LV event.

**Methods:** A LV pressure catheter and a conductance catheter were in-

serted in 10 sheep to measure peak negative dP/dt, the maximal LV elastance  $E_m$  and the LV stiffness K. The largest (L), the smallest (S) and the Pre-A (P) LA volumes were determined by epicardial real-time 3D echocardiography from an apical 4-chamber view. LA filling (LA-F) was expressed as (L-S)/S, LA passive emptying (LA-PE) as (L-P)/L and LA active emptying (LA-AE) as (P-S)/P. The parameters were measured before and after coronary occlusion. The relationship between LA-F, LAPE and LA-AE and  $E_m$ , peak negative dP/dt and K were analysed.

**Results:** LA-F was correlated to  $E_m$  ( $y = 5.5x - 1.27$ ,  $r = 0.82$ ,  $p < 0.05$ , figure). There was a correlation between LA-AE and K ( $y = 0.18x - 0.003$ ,  $r = 0.71$ ,  $p < 0.05$ ). There was a positive weak correlation between LA-PE and the peak negative dP/dt ( $y = 1407x + 855$ ,  $r = 0.51$ ,  $p < 0.05$ ).



**Conclusion:** In this animal study, hemodynamic and real-time 3D echocardiography revealed that LA filling and LA emptying depended on LV performance.

11:30 a.m.

**912-5 Variation of Tissue Doppler Myocardial Velocities Due to Perturbations in Preload: A Preserved Relationship in Normals**

Neil L. Greenberg, Michael S. Firstenberg, Lisa Cardon, Mario J. Garcia, James D. Thomas. *The Department of Cardiology, The Cleveland Clinic Foundation, USA*

Tissue Doppler echocardiography (TDE) is a diagnostic imaging tool that can assess early diastolic tissue velocities ( $E'$ ) which have been proposed as an index of LV relaxation. Recently, animal studies have suggested that  $E'$  is preload dependent – but, this is contradictory to what has been observed clinically in patients with underlying cardiac disease.

**Methods:** To determine the effects of preload alterations on  $E'$  and early diastolic filling velocities (E) we performed tilt table maneuvers ( $+90^\circ$ ,  $+45^\circ$ ,  $-6^\circ$ , and  $-30^\circ$ ) in 8 normal volunteers. Real-time 3D and Doppler echocardiography were performed to determine end-diastolic volume and E. Left ventricular lateral wall ( $E'_{lat}$ ) and septal ( $E'_{sep}$ ) velocities were measured by TDE. For each individual, changes in EDV were compared against  $E'_{lat}$ ,  $E'_{sep}$ , and E velocities by linear regression.

**Results:** Overall, from  $+90^\circ$  to  $-30^\circ$  EDV increased by  $29.1 \pm 12.7$  ml ( $EDV = 0.22x + 113.3$  cc/tilt,  $r = 0.95$ ). Changes in EDV linearly correlated with E (average correlation:  $r = 0.73 \pm 0.18$ ).  $E'_{lat}$  and  $E'_{sep}$  also correlated with EDV (average correlation:  $r = 0.67 \pm 0.25$  and  $r = 0.80 \pm 0.14$  respectively) (see table). Differences in correlations between E/EDV,  $E'_{lat}$ /EDV, and  $E'_{sep}$ /EDV were not significant.

Angle:	-30	-6	45	90	p-value*
EDV	125 ± 15	122 ± 26	102 ± 22	97 ± 23	0.05
E	85 ± 12	76 ± 9	60 ± 10	59 ± 12	0.005
$E'_{lat}$	16.6 ± 2.1	16.4 ± 3.0	10.4 ± 1.5	8.9 ± 2.4	0.001
$E'_{sep}$	13.7 ± 1.6	12.3 ± 2.4	8.6 ± 1.2	8.0 ± 1.5	0.002

\* By repeated measures analysis of variance

**Conclusions:** In normal subjects, early diastolic myocardial tissue and transmitral filling velocities are preload dependent and correlate with changes in end-diastolic volume.

11:45 a.m.

**912-6 Preload and Beta-Receptor Induced Alterations in Ventricular Relaxation as Quantified by Tissue Doppler Echocardiography**

Michael S. Firstenberg, Mario J. Garcia, Neil L. Greenberg, Jeanne Drinko, Jill Odabashian, Leonardo Rodriguez, James D. Thomas. *The Department of Cardiology, The Cleveland Clinic Foundation, USA*

Previous research has suggested a qualitative relationship between early diastolic myocardial velocities ( $E'$ ) as measured by tissue Doppler echocardiography (TDE) and LV relaxation ( $\tau$ ). We sought to determine if preload and pharmacologic alterations in  $\tau$  can be correlated with TDE.

**Methods:** 8 closed-chest dogs each had a high fidelity conductance catheter placed into the LV for continuous determinations of end-diastolic pressures (EDP), volumes (EDV), and  $\tau$ . TDE in the region of the septum was performed at 5 different stages of beta-receptor modulation (baseline, high/low dose infusion of esmolol/dobutamine). In addition, for each stage, preload was altered with inferior vena caval balloon occlusion and continuous hemodynamics and TDE were obtained. Linear regression analysis was performed on the  $E'$  vs  $\tau$  measurements obtained prior to preload reduction. The resulting equation was used to predict  $\tau$  from  $E'$  measurements during caval occlusion. Paired t-testing, linear regression analysis, and analysis of variance were each performed when appropriate.

**Results:** Prior to caval occlusion  $\tau$  ( $n = 35$ , mean:  $56.8 \pm 15.5$  ms, range: 26–94 ms) correlated with  $E'$  ( $\tau = -6.47E' + 82$ ,  $r = 0.74$ ,  $p < 0.01$ ). Caval occlusion resulted in significant changes in preload,  $E'$ , and  $\tau$ . Beta-modulation also changed baseline heart rate and  $\tau$  (both  $p < 0.05$ )

	Baseline	Occlusion	p-value
Tau (msec)	56.8 ± 15.5	62.7 ± 18.2	<0.01
EDV (ml)	54.6 ± 16.3	33.6 ± 12.7	<0.01
$E'$ (m/sec)	3.6 ± 1.9	2.4 ± 1.1	<0.01

Despite significant changes in preload,  $E'$  still correlated similarly with  $\tau$  ( $\tau = -6.12E' + 81.4$ ,  $r = 0.71$ ,  $p < 0.001$ ) for all measurements ( $n = 375$ ). Predicted vs. actual predicted  $\tau$  during caval occlusion were similar ( $y = 0.95x + 3.8$ ,  $r = 0.71$ ,  $p < 0.001$ )

**Conclusions:** Changes in ventricular relaxation, either through preload alterations or beta-receptor modulation, can be quantified non-invasively by early diastolic myocardial tissue echocardiography.

NONINVASIVE IMAGING

**Plan to Attend Next Year!**

American College of Cardiology  
50th Annual Scientific Session

Orlando, Florida  
March 18–21, 2001

