# Abstracts of Original Contributions: Computer Application Program

**This represents the third publication of computer abstracts by the American College of Cardiology. A total of 56 abstracts were accepted for presentation. Ten will be presented at a special abstracts session on Sunday afternoon, April 12. Twenty-eight of these will be presented as demonstrations at the Computer Applications Committee Booth in the Exhibit Hall. The remaining 18 will be poster presentations during the regularly scheduled poster sessions.**

**Computer abstracts are submitted through a separate call for abstracts and abstract submission form. Each was graded by the 10 members of the Computer Applications Committee. Acceptance was based on relative grade ranking. Many excellent program descriptions were received. We appreciate the interest and the effort of all those who submitted abstracts.**

**Andrew J. Burger, MD, FACC**
*Chairman*
*Computer Applications Committee*

## 839 Part I: 3-Dimensional Analysis Systems

Sunday, April 12, 1992
2:00 PM–5:00 PM
Dallas Convention Center
Room W107

### 839-1 2:00

**Method of Three-Dimensional Reconstruction of the Left Ventricle from Transesophageal Echocardiograms**

Roy W. Martin, Ph.D. and Gerry Bashein, Ph.D., M.D.
University of Washington, Seattle Washington

Three-dimensional (3D) echocardiography generally involves acquiring images from spatially irregular oblique angles. With our 3D transesophageal echocardiographic method we usually acquire about 15 images over 60° scan range in this manner. Reconstruction methods must therefore deal with the obliqueness and uneven spacing.

We have developed a method based on converting Cartesian coordinate information into spherical coordinates. This conversion essentially "unwraps" the endocardial surface making it available for use with existing software packages for interpolating and smoothing irregular spaced data with two independent variables. While in this coordinate system global and regional volumes and ejection fractions are simply calculated. After interpolation the data is assembled into a sequence of three adjacent points which are each considered to be a tile for reconstruction purposes. The regional ejection fraction is calculated for each tile and a color is assigned to it representing the calculated value. The assembled points are then reconverted to Cartesian coordinates and are in a form readily usable by any 3D reconstruction program. During reconstruction we color each tile according to its ejection fraction value producing 3D endocardial surfaces with colored patterns showing the ejection fraction of each region. Further, anatomical landmarks such as the septal wall junctions and the papillary muscle locations are also combined with the reconstructions to aid in LV orientation. We use commercial interpolation and 3D modeling programs which run on Intel microprocessor 286 and 386 based machines. This methodology is being used in reconstructing 3D transesophageal images acquired during cardiac surgery.

### 839-2 2:15

**Three-dimensional Echocardiography: A Method of Visual Guidance for Positioning Two-Dimensional Images with Regard to Their Orthogonal, Non-visualized Dimension.**

Donald L. King, Donald L. King, Jr., Aasha S. Gopal, Mary Y.C. Shao, Columbia University, New York, NY

Two-dimensional (2D) echocardiography does not provide a visual indication of the position and orientation of its image with respect to internal anatomic landmarks in the third "non-visualized" dimension. To overcome this problem we have developed a unique software algorithm used in conjunction with a real-time scanner, a three-dimensional acoustic spatial locater and a personal computer. The system digitizes and saves 2D images and their spatial coordinates, computes the spatial relationship of these images to previous (reference) images taken orthogonal to the real-time image, and displays in real-time this relationship in three views. The computation uses standard line and plane equations and viewport transformations. The line of intersection (LOI) of the real-time and reference images is shown in each image. The third view is an overhead view orthogonal to the line of intersection of the two image planes showing the angular relationship between the two image planes. By alternately or simultaneously observing these three views the operator is able to control the translation, tilt and rotation of the real-time 2D image with respect to anatomic landmarks in the "non-visualized" dimension shown in the reference image. For example, the following relationships can be visualized by the LOI display on appropriate reference images: underangulation of a short axis image; lateral displacement of the long axis image; over or under-rotation of the apical two and four chamber views. The reference long axis LOI display also permits precise positioning of short axis end-planes at the ventricular apex, mitral annulus, and aortic valve when computing ventricular volume and surface area by polyhedral surface reconstruction. Current studies have shown a three-fold improvement of reproducibility using this method to measure left atrial and left ventricular dimensions.

Conclusion : Visual guidance of 2D images by three-dimensional echocardiography using a reference image and the line of intersection display improves the accuracy and reproducibility of 2D image plane positioning and therefore the accuracy and reproducibility of intra-cardiac dimensions, volume and surface area.

839-3 2:30

**Frame-By-Frame Threedimensional Echocardiographic Reconstruction of the Left Ventricle**

Wolfgang Fehske, Juergen Maehle, Bjørn Olstad, Rami Rabahieh, A. v. Smekal, K. Seelos, Ulrich Köhler, Berndt Lüderitz FACC, Dept. of Cardiology, University of Bonn, Germany

Threedimensional(3D) visualization of left ventricular wall motions has not been available as a routine diagnostic procedure. A new computer program for 3D reconstruction of left ventricular cavity is presented that is based on digitally transferred echocardiographic "raw data".
Methods: Continuous 3D-reconstructions are derived from two-dimensional registrations in at least three different apical planes. The rotation angles between the planes are measured by external calipers. Frame-by-frame delineation of the endocardium is achieved by a combination of automatical edge detection and an algorithm that interpolates single manually traced contours. The resulting edges are superimposed on the original registrations and can be corrected by the user. Real-time moving endocardial casts are reconstructed under different views for optimal qualitative recognition of wall motion anomalies (WMA). Quantitative aspects are derived from the computed regional 3D-contraction amplitudes and by phase analyses. The clinical use of the system was examined in 10 normal volunteers and in 85 P with various forms of myocardial infarctions. In 15 P the results were compared to similar reconstructions based on magnetic resonance (MR) cine films.
Results: In all patients 3D-reconstructions were feasible. Continously moving casts revealed significant better informations on wall motion patterns than the comparisons of systolic and diastolic casts alone. WMA could directly be visualized in P with myocardial infarctions but automatical recognition of infarction areas was incomplete. Volume determinations revealed good correlations with MR-values ($r = 0.92$).
Conclusions: Real-time 3D-reconstructions of the LV are possible in routine echocardiography. Further programms and parameters must be tried out for quantitation and automatical recognition of WMA.

839-4 2:45

**3 Dimensional Display of First Harmonic SPECT Functional Maps**

John W. O'Connell, Elias H. Botvinick, Stephen L. Glickman, Michael W. Dae, Todd J. Cohen, Rajagopal Krishnan. University of California, San Francisco, CA

First harmonic analysis of gated planar blood pool studies is of proven utility for the location of pre-excitation foci in Wolffe-Parkinson-White Syndrome. However, accurate localization of the ventricular insertion of the accessory pathway can only be established by triangulation of the pre-excited focus in several planar projections. Computer analysis of gated blood pool SPECT offers a direct approach to defining the pattern of contraction, and indirectly, the pattern of conduction and the location of a bypass pathway in 3 dimensions.

We have developed a novel and perceptually natural approach to the display and analysis of the 3 dimensional timing information. First Fourier harmonic amplitude and phase are computed for each transverse slice. At each of the 34 solid angles spaced about a sphere enclosing the heart, the first harmonic image is rendered by selecting the "hottest" amplitude voxel along each projection ray. Each voxel is displayed by rendering its amplitude value as intensity, and its phase value as hue. The result is a volumetric rendering of amplitude, painted with the corresponding phase map. Intensity weighting suppresses the low amplitude extra-cardiac voxels. Using a dynamic computer display, the investigator can rotate the heart in three dimensions and view from any angle a dynamic display of contraction sequence.

In 10 patients, 3 with pre-excitation during imaging, SPECT slices and volumetric rendering well-paralleled the 12 lead EKG and identified the expected site of the bypass pathways, where the pre-excitation focus was directly visualized without need for triangulation. The method promises improved scintigraphic assessment of intraventricular contraction and, indirectly, conduction. In addition, optimal chamber localization may aid calculation of ventricular volumes, atrial size and function and regurgitant index. A variation of this display may also be useful when applied to gated technetium based perfusion SPECT images.

839-5 3:00

GEOMETRICAL 3D RECONSTRUCTION OF CORONARY STENOSIS: SOFTWARE FOR OBJECTIVE ASSESSMENT OF STENOSIS HEMODYNAMIC SIGNIFICANCE.

Rafael Beyar, Menachem Halmann, Shoshan Nevo, Ehud Grenedier, Walter Markiewicz and Samuel Sideman.
The cardiac system Research, Technion and Department of Cardiology Rambam, Haifa.

It is well recognized that single view of a coronary stenosis can be inaccurate for the assessment of the severity of a lesion. Therefore, three dimensional (3D) reconstruction of a coronary lesion may offer a significant advantage over the standard planar image. We have therefore developed a PC based computer program that uses 2 orthogonal views of a coronary segment, obtained by routine coronary angiography, and reconstructs the vessel in 3D, assuming ellipsoidal cross sectional geometry along the vessel length. The program allows for visualization and rotation of the 3D reconstructed segment as required. The 3D data are then used to yield indices representing stenosis severity and the response to an interventional procedure. The indices that are calculated from the 3D stenosis are the following: a) minimum cross sectional area based stenosis) b): minimum diameter of the stenosis c:) Relatively coronary flow reserve (RCFR) which is calculated from the entire stenosis geometry assuming viscous and turbulent pressure loss terms, and assuming normally reacting microcirculatory bed supplied by that coronary segment. In addition to that the program can give relative and absolute changes following an interventional procedure. The program was tested in 18 patient undergoing angioplasty and the results are detailed in the table below:

| | Area based Stenosis | RCFR | Area Gain Maximum | Area Gain Average |
|---|---|---|---|---|
| Before: | 90±8% | 0.33±0.19 | - | - |
| After: | 55±16% | 0.83±0.09 | 11.0±6.8 | 2.4±1.3 |

Therefore, 3D based analysis of coronary lesions is feasible for objective, physiology oriented, evaluation of coronary stenosis and interventional procedural results.

839-6 3:45

**HYBRID SYSTEMS IN CARDIOLOGY: PREDICTIVE INSTRUMENTS WITH VERY HIGH ACCURACY**

Sanjay Patil, M.D., Sinai Hospital, Detroit, Michigan
Bohdan Pichurko, M.D., Jay Kozlowski, M.D., Mary Lazar, M.D., Muzaffar Piracha, M.D., Shahid Khan, M.D., Melvyn Rubenfire, M.D., FACC

Algorithm-based computing devices have limited usefulness in most clinical settings. The fundamental difference between most computers and physicians lies in the ability of the physician to draw upon a rich repertoire of experiences and reasoning ability. Physicians are also able to adapt their decision-making based on new or novel data. Artificial neural systems overcome many of these differences. We have utilized a combination of neural network and expert system to develop programs for many applications, including hemodynamic interpretation, ventilator management, and chest pain diagnosis. The expert system consists of a defined set of rules, whereas the neural network is the mathematical equivalent of a trainable biological brain. The ability to learn from experience and to extrapolate from that experience is unique to neural systems. In retrospective studies with incomplete data, we find that neural network/expert system hybrids have superior diagnostic accuracy in comparison to clinicians, recursive partitioning methods, logistic regression and rule-based expert systems. In addition, a neural network trained on a data set which consists of a given clinician's opinions is able to reproduce that clinician's opinions on previously unseen data with extremely high concordance rates ($p < 0.001$). Neural networks can classify patterns varying from categorical data to continuous waveforms. We believe that hybrid systems with a large training set could serve as on-line training consultants in many clinical settings.

839-7 4:00

## SOFTWARE BASED NEURAL NETWORKS FOR CLASSIFICATION OF ELECTROCARDIOGRAPHIC ST-T SEGMENTS.

Peter W. Macfarlane, Ph.D., F.E.S.C., University of Glasgow, Scotland; Lars Edenbrandt, M.D., Brian Devine, M.Sc.

The art of ECG interpretation is basically one of pattern recognition, and it is generally accepted that the human expert is superior to currently used computer programs for differentiating among various types of ST-T abnormalities. The recent availability of software based neural nets which are reputed to be of value for pattern recognition has made it feasible to compare human versus computer based pattern recognition of ST-T waveforms.

ST-T segments from 1,000 complexes were measured by an established computer program and in addition were classified by two electrocardiographers into one of 8 separate ST-T morphologies. The 1,000 ST-T segments were divided in two with 500 being used together with the classifications to train a software based neural network. Thereafter the network correctly classified 79.8% of the remaining 500 ST-T segments used as a test set.

In a truly blinded fashion, one of the electrocardiographers made a second classification of the 500 ST-T segments in the test set. 85.6% agreed with the initial classification. 43/72 segments incorrectly classified by the electrocardiographer were correctly classified by the network. The opposite was true in 72/101 cases.

The neural network, electrocardiographer and conventional criteria were compared with respect to separating one abnormal ST-T morphology from the other 7. There were similar sensitivities of 87% but specificities were 97%, 98%, and 68% respectively. Thus, with a similar sensitivity, the specificity for the neural network was significantly higher than that for conventional criteria.

Conclusion: Judicious use of software based neural nets may well have a role to play in advancing computer based ECG interpretation.

839-8 4:15

## COMPUTERIZED INTERPRETATION OF THE ECG USING EXPERT SYSTEM AND NEURAL NETWORK TECHNIQUES.

Willem RM Dassen, Petrus HL Schamp, Rob GA Mulleneers and Karel den Dulk.
Dept. of Cardiology, University of Limburg, Maastricht, The Netherlands.

Computerized interpretation of the electrocardiogram has a low false negative, but a high false positive rate. This makes it useful for recognition of normal ECGs but the evaluation of true and false positive ones remains cumbersome. This forms a serious limitation, for, being a closed system, it is impossible to apply different criteria, or to compare alternative interpretation algorithms. To overcome a number of these limitations, an new hybrid ECG interpretation system was developed. The core of this system was formed by a central expert system, coupled to a number of satelite systems, each representing electrocardiographic knowledge in a small domain, in either a rule based or a neural network format. The basic expert system, responsible for the selection of true negative ECGs, presently counts over 900 rules, using 120 concepts and was written in muLisp. The open character of the system allows the implementation of user defined criteria and the comparison of different interpretation programs. Furthermore knowledge not represented in rules, but in the form of a neural network can be applied. In this interactive data-driven configuration the system determines itself which knowledge modules are currently relevant and generates an interpretation, including a list of criteria used, together with their references in the accepted electrocardiographic literature.

839-9 4:30

## THE DYNAMIC SYSTEMS MODEL FOR PREVENTIVE CARDIOLOGY: AN INTERACTIVE TOOL FOR RISK FACTOR PREVENTION

Lewis Mehl, Simon Mittal, Francisco Fuentes

Dynamic systems computer simulation is a tool developed from non-linear mathematics and chaos theory for predicting outcomes in complex systems. We have applied this tool to predicting the approximate time of myocardial infarction using the Stella II computer simulation package on a MacIntosh fx computer. The model, which will run on an SE/30 or any higher level MacIntosh, was developed using data from 43 consecutive patients with acute myocardial infarction admitted to Hermann Hospital/University of Texas. We collected data on coronary artery risk factors, creatine kinase, coronary angiography, and infarct location, morbidity and mortality. Twenty-two patients were used as the learning sample and 21 as the test sample. Patients were dichotomized into early and late onset of myocardial infarctions. The model was 86% accurate in correctly classifying patients into the early or late onset group in the test sample. The cardiologist-patient interactive capabilities of the model present enormous possibilities for reduction of cardiovascular risk factors, and also for patient and health professional education. The program has the capability to track and predict outcome and treatment effectiveness in multi-ethnic populations.

839-10 4:45

## ARTIFICIAL NEURAL NET BASED PCG ANALYSIS OF CONGENITAL AND ACQUIRED HEART DISEASES

Barschdorff, D., Prof. Dr.-Ing.; Ester, S., Dipl.-Ing.; University of Paderborn, Dept. of Electr. Engineering, Paderborn, Germany

The auscultation of the human heart can be regarded as one of the most commonly used first examination methods. This investigation discusses a new computer based adaptive real time system for accurate measurements and automatic diagnosis of the PCG signal.

For signal acquisition, a Littmann-Stethoscope is equipped with two microphones. The first one registrates the heart sound, usually disturbed by environmental background noise like speech, walking and door closing within the auscultation room. These disturbances are seperate measured by the second microphone, acoustically isolated from the first one. An adaptive filter approach is used to remove environment noise from the PCG signal.

In addition to this preprocessing, the peripheral blood-pressure-time function is synchronously registrated at the earlope with a standard infrared earclip. By means of additional patient parameters and this pressure-time function heartcycle periods are extracted from the continuous PCG signal.

For an automatic diagnosis using the PCG signal, short time Fourier spectra in overlapping time intervals are calculated. Real time computing is achived via a Digital Signal Processor (DSP) TMS 320C25. The resulting feature vector describes the time dependency of the spectral distribution in every heart sound period.

For classification of heart diseases, an artificial neural network algorithm, using the backpropagation procedure, is implemented. Training sets for knowledge acquisition contain feature vectors derived from examples of more than 100 heart beat periods of congenital and acquired heart diseases. They originate from data, which were additionally counterchecked by invasive heart catheterization at the cardiology department of the St. Vincenz Hospital in Paderborn.

The diagnostic results, which are presented on the computer display as well as the online PCG registration of each heart cycle, demonstrate the advantages of this neural net approach. The program, written in the "C" language and equipped with a DSP- and ADC-Card, runs on a Toshiba laptop T3200 in real time.

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## 862 Database-Related Applications

Monday, April 13, 1992
9:00 AM–12:30 PM
Dallas Convention Center
Booth 1340

### 862-1

A NETWORK CLINICAL INFORMATION SYSTEM BASED ON THE CLIENT/SERVER COMPUTING MODEL

Paul A. Seelaus, Patricia A. Noonan, Peter B. Kurnik, Harvey L. Waxman
Robert Wood Johnson Medical School/UMDNJ, Camden, New Jersey

A cardiology patient data management system has been developed using the client/server model and a transaction-based Structured Query Language (SQL) server. Client workstations include PC's and Sun workstations. The underlying database server is Sybase's relational database management system on a Sun 3/280. Ethernet TCP/IP supports communications between clients and the server.

Currently supported areas of cardiology include Demographics, Catheterization, Echo, Holter, Stress, Nuclear Imaging, Admission/Discharge/Transfer and Discharge Summary. EPS and PTCA are under development. Patient information is available through a single user friendly interface, each screen or window designed for readability. Separate read, add, edit, delete permissions are enforced by user-id and workstation for each form. All areas are supported by the report generation system and can be queried using a variety of client based SQL tools.

The use of SQL as a standard method of communicating with the data server has simplified the integration of other related operations with the clinical information database. A separate scheduling system with electronic mail was developed for initial capture of patient-events. A Quality Assurance (QA) system checks the schedules and the clinical information to check that forms are completed, corrected, printed and signed in a timely fashion. Cath lab logs, delinquency lists and notes regarding scheduling inconsistencies are generated by the QA system. A patient census is printed each morning and "on demand". The scheduling system, report generator, QA system and census generation are all independent of the database server and can be moved to other workstations to balance network computing load.

The reporting system checks all cath reports for completeness and internal consistency. Any report not satisfying these requirements is printed in preliminary form with an error list. Overriding the report checker is done by the Director of the Cath Lab.

All software was developed with the awareness that information technologies will change. Object oriented data structures and the use of remote procedure calls allow evolution of information handling techniques. This system is not tied to any particular type of network, client workstation, server architecture or database engine.

### 862-2

A DISTRIBUTED USER-FRIENDLY CORONARY ARTERY TREE DIAGRAMMING AND REPORTING SYSTEM

Laurence A. Spero, Donald F. Fortin, Jack T. Cusma, and Thomas M. Bashore, Duke University Medical Center, Durham, North Carolina

Presentation of the anatomic details of cardiac catheterization to clinicians is best accomplished in a pictorial format. To meet this need in a geographically dispersed clinical environment, we have developed a device-independent, graphical user interface (GUI) based coronary artery tree diagramming system which can be used to rapidly create detailed coronary tree diagrams and reports.

Clinicians can enter and review data anywhere on a campus-based local area network on diverse architectures ranging from personal computers (PC) to UNIX based workstations. The display medium is the X-windows release 11.4 based Motif environment. Remote users can use their desktop PC's running Microsoft Window 3.0 along with a standard modem to access the tree diagram as well as maintain a local database. All the data are stored in a commercially available relational database providing extensive querying capabilities. Data from previous studies can be carried forward to the current study providing data consistency as well as a mechanism to track patients over time.

Several templates based on coronary artery dominance and common anatomic variants provide the basis for data entry. A toolbox containing representative icons provides features that result in a customized individual representation of a coronary tree. These include the ability to dynamically resize, move or remove vessel segments, to indicate collateral flow and vessel visualization, and to add lesions of varying severity and morphology. Additional drawing pages are used for depicting the results of interventional procedures and status of bypass grafts.

This system accomplishes the goal of quickly and easily providing detailed graphical cardiac catheterization reports to clinicians at both local and remote sites.

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### 862-4

DEVELOPMENT OF A CLIENT-SERVER, RELATIONAL PATIENT AND CARDIAC CATHETERIZATION DATABASE MANAGEMENT SYSTEM

James E. Tcheng, Donald F. Fortin, J. Douglass Hanemann, Patricia B. Blunden, Laurence A. Spero, Thomas M. Bashore, Richard S. Stack, Daniel B. Mark, David B. Pryor, Robert M. Califf. Duke Medical Center, Durham, NC.

To accommodate expanding data storage and retrieval demands and improve reporting and analysis capabilities, a new database system for the management of cardiology patient data is being implemented at Duke Medical Center. The architecture of this system is based upon client-server computing, permitting multiple users with various types of computer hardware access to centralized database servers via campus-wide Ethernet™ networks.

The project has encompassed two primary programming efforts. The first, development of front-end "client" user interfaces for data entry and recall, has been facilitated by the use of object-oriented software permitting rapid development of data entry screens replicating our current paper data forms. Simultaneously, development of back-end "server" databases has included incorporation of extensive data edit checking and referential integrity. Query is performed using standard Structured Query Language (SQL) commands. An example of a client interface running in Microsoft Windows™ coupled to a Microsoft SQL Server™ database server for the generation of diagnostic and interventional cardiac catheterization procedure reports will be demonstrated.

The use of client-server technology has numerous potential benefits. User-friendly client interfaces can be developed that improve efficiency, reduce training requirements, and minimize data-entry errors. As demands increase, system-wide performance improvements can be achieved by migration of database servers to more powerful computer platforms. Other database servers such as Oracle™ that support SQL can be easily accessed without upgrading client hardware. Finally, development of this system as a relational database permits integration throughout the Medical Center via common patient indexing and data cross-referencing.

## 863 Database-Related Applications

Monday, April 13, 1992
1:30 PM–5:00 PM
Dallas Convention Center
Booth 1340

### 863-1

**SOFTWARE TO RETRIEVE, REVIEW, AND CONVERT THE AHA ARRHYTHMIA ECG DATABASE**

Seth Suppappola and Ying Sun, Ph.D., Dept. of Electrical Engineering University of Rhode Island, Kingston, RI 02881-0805

A user-friendly software is developed on an IBM PC compatible for manipulation of the American Heart Association (AHA) ventricular arrhythmia database. The purpose is two-fold: 1) to allow quick and easy access to the digital AHA ECG database which contains segments of 2-channel ECG recordings for a total period of >40 hours, and 2) to generate analog ECG waveforms for testing and evaluation of various medical instruments.

The AHA ECG data are distributed in a compressed form using a difference encoding method. The software first retrieves and decompresses the data. Then a variety of functions can be performed: The graphical review functions include selection of tape and channel, scaling of time and amplitude axes, explanation of AHA annotation codes, and custom tape editor. The custom tape editor permits the user to splice together in a single file sections of one or multiple AHA tapes thereby creating data segments tailored to his/her needs. The user may also send selected segments of ECG to a digital to analog converter (Data Translation DT2801A). The system outputs a single channel of ECG along with pulses which correspond to the R waves marked by the database annotation. Waveform generation is done with the help of a direct memory access (DMA) controller to maintain the sample conversion rate precisely at 250 Hz. Moreover, since the DMA controller operates independently, waveform generation can be done concurrently with other tasks, such as reviewing other ECG data or running another program in a DOS shell.

Applications of the software include: 1) performance evaluation of any medical instrument requiring the detection of R waves, 2) front-end processing or evaluation for any software that involves the use of the ECG database, and 3) computer aided instruction of ECG analysis by providing easy access to a large quantity and assortment of ECG data.

### 863-2

**A NUCLEAR CARDIOLOGY INFORMATION, IMAGING AND AUTOMATIC REPORTING SYSTEM**

Bruce B. Dworkin, Ph.D., St. Luke's/ Roosevelt Hospital, New York, NY., Kenneth Nichols, Ph.D. and Alan Rozanski, M.D.

We have developed a relational data base management system programmed in the XBASE and C computer languages for entering, sorting, retrieving, and reporting information derived from nuclear cardiology studies. The system runs on an IBM compatible computer under the MSDOS operating system, or under Novell Netware on a local area network. Screens are included for patient demographics, cardiac history, resting and stress electrocardiograms, wall motion and perfusion studies.

Myocardial perfusion tomograms are acquired from a General Electric nuclear camera and reconstructed into oblique, sagittal, and coronal projections. A Pascal program is run to rearrange the order of the tomograms to pair them so that rest and stress images can be viewed side-by-side on a slice by slice basis. These images are saved along with polar plots of perfusion and transmitted to a PC. The image file is converted into a 512x512 color-mapped "GIF" file on the PC, and imported into the database management software. The images can then be redisplayed and saved on a PC along with quantitative data.

The software also produces an automatic cover letter addressed to the referring physician and a full narrative report, suitable for inclusion in the patient's medical record.

### 863-3

**COMPREHENSIVE DATA BASE FOR CARDIOLOGY PROCEDURES AND TESTS WITH NARRATIVE REPORT GENERATOR ON A LOCAL AREA NETWORK.**

Craig E. Monsen, M.D., F.A.C.C., Rebecca Greenberg, M.S., Bruce B. Dworkin, Ph.D., Kenneth S. Lerrick, M.D., F.A.C.C., Michael V. Herman, M.D., F.A.C.C., Melvin B. Weiss, M.D., F.A.C.C. Westchester County Medical Center, Valhalla, N.Y.

This application provides a comprehensive database and automatic report generator for an active in-hospital division of Cardiology. This system encompasses invasive and noninvasive procedures including patient demographics, cardiac catheterization, nuclear, echo, and stress tests. It was developed using FOXPRO and runs on a twelve station PC based local area network with a NOVELL/ IBM Token Ring environment. Remote access via high speed modem allows data entry and retrieval for satellite facilities and use by physicians at home.

The system consists of a menu-driven interface with context sensitive help screens. To speed data entry, variables and results are entered into the system by use of a coded short hand notation. Free text is also supported. Data is error checked upon entry. A narrative report is then generated from the database for documentation and charting.

Data storage allows immediate access to archived patient studies. Currently, over three years of patient studies consisting of over 15,000 reports are accessible.

This PC based system provides a low-cost, user-friendly, easily adaptable system that meets all database and reporting needs for cardiology.

### 863-4

IMAGE CAPTURE AND DISPLAY WITHIN A CARDIOLOGY DATABASE INTEGRATED WITH THE VA DECENTRALIZED HOSPITAL COMPUTER PROGRAM

Ross D. Fletcher, Ruth Dayhoff, James Kenny, Kevin Crawford, Ronald Jones, Veterans Affairs and Georgetown University Medical Centers, Washington, D.C.

The Veterans Affairs Decentralized Hospital Computer Program is installed in each of its 164 hospitals. The completely searchable database contains all medical admissions, laboratory and pharmacy data. A medicine module for cardiology procedures includes cardiac catheterizations, echocardiograms, exercise tolerance test, Holters, ECG, electrophysiological testing, nuclear cardiology, pacemaker implantations and follow-up. Other medical procedures include GI and pulmonary endoscopy, pulmonary function and bone marrow. The cardiology database automatically enters ECG and Holter data from commercial computerized systems. The pacemaker module automatically transmits a newly registered patient to a centralized registry where cumulative survival curves compute follow up frequency for individual patients. An estimated surgical risk is calculated from historical and catheterization data. LV mass is calculated by ASE and Penn criteria corrected for sex. A summary option lists all procedures for a patient from which the complete reports are selected.

Image capture automatically links to specific patients and specific procedures. A 12 image composite picture menu is displayed on a single screen. Images appear automatically during each report. They include echocardiograms, coronary arteriograms, ventriculograms, Muga and thallium studies.

The system works as a PC workstation in a VAX environment but gains efficiency when downloaded to a complete PC environment either standalone or on an Ethernet Novell network.

## 983 ECG Simulation/Expert System

Monday, April 13, 1992
2:00 PM–5:00 PM
Dallas Convention Center
Lower Level Exhibit Hall
Presentation Hour: 4:00 PM–5:00 PM

### 983-118

**PERSONAL COMPUTER BASED DUAL CHAMBER CARDIAC STIMULATOR**

*Christer Ekwall, Marek Malik, Siemens Elema, Stockholm, St. George's Hospital Medical School, London*

For testing of pacemaker algorithms, a personal computer-based software driven stimulator has been developed. It consists of a hardware unit generating the pacing stimuli and sensing natural cardiac activity, and a software package. The software package has been implemented on a standard IBM PC compatible computer and includes a library of dual chamber pacing algorithms. The computer communicates with the hardware unit via its parallel port. The hardware of the stimulator consists of three main parts. The core of the hardware is a universal state machine. Programmable registers of the state machine define association of individual states with characteristics of pacing pulses which are produced by a pulse generating hardware (second hardware part). The programming of the state machine enables different pacing pulses to be generated. The third hardware part contains sensing circuits with programmable gains which register cardiac activity.

The software part of the stimulator is composed of several program segments which create an open package. One part of the package is devoted to the communication with the hardware unit. The computer communicates with the unit by means of special commands which are decoded by input circuits of the hardware unit, the communication from the unit to the computer uses printer interrupts. The other part of the software package implements pacing algorithms which can be operated in an interactive way. These pacing modes contain implementation of absolute and relative refractory periods, AV and VA delays, and of other pacing intervals but do not include the timing of pacing pulse generation which is performed at the hardware level (but can be modified by the software). The pacemaker is being used in clinical studies investigating complex antitachycardia pacing modes.

### 983-119

COMPUTER SIMULATION OF VENTRICULAR ARRHYTHMIAS IN THE ACUTE PHASE OF MYOCARDIAL ISCHEMIA AND INFARCTION

Paul Fleischmann, Institute of Biomedical Engineering, Graz University of Technology, Austria; Paul Wach; Reinmar Killmann; Gerhard Stark

A computer model using a digitized 1.25mm grid (including more then 100.000 points) of the entire human heart has been developed for simulating the excitation and repolarization process. The purpose of this study was to simulate the electrophysiological mechanisms of ventricular arrhythmias resulting from myocardial ischemia and infarction. In the acute phase and according to the location of coronary artery occlusion two zones of injured myocardium a so called central ischemic zone and a ischemic border zone (1 cm around the center) were defined. In the early phase of ischemia a anteroseptal region was selected where conduction velocity was reduced by 20% in the ischemic border and by up to 40% in the central zone. A dispersion of refractory periods was taken into account mainly prolonging refractory periods in the center up to 35% (simulating post repolarization refractoriness) whereas in the border zone a reduction of about 25% was choosen. In this phase ventricular tachycardia induced by extrasystoles as well as spontaneous tachycardia by various heart rates could be simulated. Therefore for the development of new antiarrhythmic drugs this model seems to be helpful because of the possibility to test electrophysiological effects known out of in vitro or in vivo studies on various arrhythmias.

### 983-120

PREDICTION OF BYPASS TRACT LOCATION IN WOLFF-PARKINSON-WHITE SYNDROME FROM SURFACE DELTA WAVE POLARITY: A COMPUTERIZED ALGORITHM

John M. Miller, M.D., F.A.C.C., University of Pennsylvania, Philadelphia, PA

Catheter and surgical ablative therapy for Wolff-Parkinson-White syndrome (WPW) has recently become an increasingly common practice. Consequently, the focus of the electrophysiologic study in these patients has shifted from elucidating mechanisms of arrhythmias to determining the location of all bypass tracts (BTs) for the purpose of effecting curative nonpharmacologic therapy. The process of localization can be tedious; several algorithms have been proposed to assist the physician in predicting the location of anterogradely-conducting BTs based on the surface delta polarity in sinus rhythm. These algorithms are often difficult to apply due to their complexity, however. Accordingly, a graphics-based computer program was written incorporating features of several common algorithms in which the user selects the delta wave polarity in several ECG leads and the program displays the likely BT location; if the entered delta wave polarity doesn't fit the algorithm, the program warns that a) there may have been a misreading of the ECG or b) multiple anterogradely-conducting BTs may be present to alter the "pure" delta wave pattern.

The program also features a display showing which regions of the atrioventricular groove may contain a BT which yields positive, negative, or isoelectric delta waves in selected ECG leads (i.e., where a BT may exist which has a positive delta wave in lead 1). The program is simple, user-friendly and well-suited to facilitating localization of BTs from the surface ECG prior to invasive procedures. Of course, such an algorithm cannot be applied when there is no preexcitation (concealed BTs).

System requirements: Macintosh II/color monitor; 2 megabytes RAM.

## 984 LV Simulation/Image Analysis

Tuesday, April 14, 1992
9:00 AM–Noon
Dallas Convention Center
Lower Level Exhibit Hall
Presentation Hour: 11:00 AM–Noon

### 984-118

INTERDEPENDENCE OF INFARCT MECHANICS ON RESIDUAL MYOCARDIAL FUNCTION: AN INTERACTIVE COMPUTER SIMULATION

Thomas Behrenbeck, Judd E. Reed, Patrick F. Sheedy, John A. Rumberger, Mayo Clinic, Rochester, MN

Quantitation of LV function, especially in the presence of infarction, seeks to obviate subjectivity. However, the necessity of defining a coordinate system to reference regional measurements may bias the results. Many algorithms subdivide the LV into equally spaced sectors about a pre-defined centroid (or center of mass). These efforts have frequently been criticized since the choice of algorithm may affect the parameter sought for quantitation. To better understand the interdependence of infarct size and mechanical characteristics on quantitation of function in the residual myocardium, an interactive computer model of LV cross-sections was developed. The basic tenet of the model is that total myocardial mass must remain constant during contraction but regional motion acts as a syncytium with all sections of the LV. Thus tethering is necessary during systole. The user can vary infarct size (circumferential extent) and mechanical stiffness. Additionally, LV end-diastolic volume, muscle mass, and global EF can be altered independently. Once parameters and infarct characteristics are selected, the resultant regional EF systolic wall thickening and changes in regional muscle mass distribution are displayed graphically for four centroid algorithms: endocardial, epicardial, myocardial (center of muscle mass), and midline (centerline of myocardium).

The results provide insight into the effects of reference coordinate systems on quantitation of noninfarcted myocardial function, the differences between assessment of systolic cavity motion versus myocardial thickening and, especially, the impact of physiologic infarct characteristics on analytic measurements of cardiac function.

## 984-119

**COMPUTER SIMULATION OF COLOR DOPPLER JET BOUNDARIES**

Edward G. Cape, Robert A. Levine, Ajit P. Yoganathan. Children's Hospital - University of Pittsburgh, PA.

Extensive clinical trials have been published which use measurements of color Doppler jet area (CJA) to assess the severity of valvular regurgitation. Such measurements remain semi-quantitative however due to the dependence of CJA on many factors other than regurgitant flow rate through the lesion. While some in vitro studies have addressed these issues, it is impossible to fully explore the effect of all variables in a rigorous manner. A PC based computer model was therefore developed which simulates color Doppler jets for user inputs of lesion velocity, orifice area, chamber depth, transducer depth, and instrument settings.

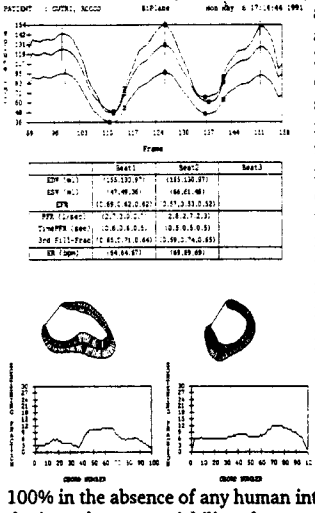
An application of turbulent jet principles and momentum analysis yields a matrix of velocities in the distal flow field for specified orifice conditions. Unconstrained jets, however, expand to nonphysiologic dimensions and an impingement function was applied to modify velocities based on the presence of the distal (atrial) wall. Velocities are then transposed into the "Doppler domain" which requires an iteration algorithm to adjust off-centerline velocities. Iterations are carried out at each step (0.1 mm) along the jet axis to solve for the jet radius at that point. The color jet radius is defined by a threshold velocity which represents a combination of wall filter and gain settings. Jet areas are calculated by numerical integration. The software is easily used for a full range of physiologic conditions for all four cardiac valves. Animation of the output on a Silicon Graphics workstation enhances the user's ability to visualize changes in color Doppler images for different physiologic inputs. Experimental results using this model in our laboratory have shown immediate clinical relevance.

## 984-120

**Fully Automated Analysis of Left Ventricular Systolic and Diastolic Function From Ventriculography.**

Bart G. Denys, Ning Ping Fan, Chi Chao Huang, P. S. Reddy
University of Pittsburgh, Pittsburgh, PA

Analysis of left ventricular angiograms is tedious and is therefore usually limited to an end systolic and end diastolic frame. We developed a fast, fully automated edge detection algorithm for off line analysis of biplane digital angiograms (512 x 512 pixels, 30 frames/sec) running on a low cost workstation. An intelligent spider is launched at the first frame to locate the position of the heart and to determine the region of interest. The edge detection algorithm then traces the ventricular outline frame to frame. Volumes are calculated using biplane area length, integration and densitometric methods. Output (Figure) includes the volume curve, beat by beat parameters of systolic (EF), and diastolic function (Peak filling rate (PFR), time to PFR and 1/3 filling fraction) and regional wall motion (centerline method). Reproducibility is 100% in the absence of any human intervention and accuracy is within the interobserver variability of a manual method. Analysis time is less than 15 minutes for a typical angiogram. This system requires no user intervention and allows for easy and accurate serial measurements.



# 864 Computer-Assisted Instruction

Tuesday, April 14, 1992
9:00 AM–12:30 PM
Dallas Convention Center
Booth 1340

## 864-1

**COMPUTER ASSISTED INSTRUCTION OF CORONARY ANGIOGRAPHY**

Michael S. Remetz, M.D., F.A.C.C.; Michael Cleman, M.D., F.A.C.C.; Henry S. Cabin M.D., F.A.C.C.; Yale University, New Haven, CT

The comprehension of coronary angiography is initially a complex task for the novice. Instruction in the acquisition, view selection, and in-lab critique of acquired data has heretofore been performed in the catheterization laboratory while performing the study. In order to provide a less stressful but comprehensive instructional environment, a MacIntosh-based hypermedia program is provided for teaching fellows training in the performance and interpretation of coronary angiography. The MacIntosh graphic user interface control is simply achieved through point and click with an award-winning attractive software interface design. Digitized coronary angiography images are connected as hypertext and hypermedia. This interactive program is a powerful tool for instruction in gantry angle and resultant coronary artery angiographic view, coronary artery location, and ideal choice of view to best demonstrate the anatomy of a particular lesion location. Demonstration of various degrees of stenosis severity and morphology can also be easily presented. Pitfalls of improper angiographic technique can also be highlighted.

Using this software, the clinician can achieve a high level of familiarity with coronary views and pathology with minimal initial instruction and supervision in a relaxed environment.

## 864-2

**CARDIOVASCULAR DISEASE PREVENTION: A NEW EDUCATIONAL COMPUTERIZED PARADIGM**

Francisco Fuentes, Albert R. Davis, Regina K. Cavanaugh, Albert Granger, Ruby B. Garner, Luis F. Gomez, Philip Orlander, Mark E. Clasen, Joy Schmitz, Robert Yetman, L. Maximilian Buja, James T. Willerson, University of Texas Medical School, Houston, Texas

This innovative preventive cardiology computerized teaching program was created using a problem base format and a self directed methodology. Each one of the 15 integrated modules is intended to optimize the student reasoning process using specific clinical problems and self learning from basic mechanisms to clinical applications. Hypertest computer software facilitated the integration of the multiple modules from evaluating unique aspects of pediatric patients, coronary artery disease prevention and regression, and women and coronary artery disease to community intervention strategies and multiethnic population studies in preventive cardiology. The programming takes place on an IBM-PC compatible (ISA) 80386 equipped computer with VGA graphics capabilities and an internal hard disk and will operate on any MS-DOS/PC-DOS based computer equipped with an 80286 or later Intel CPU, a hard disk and VGA display capabilities. This educational program was evaluated by students and faculty and rated excellent.

## 864-3

### ECHOCARDIOGRAPHY EJECTION FRACTION VISUAL TRAINING

Howard L. Haronian, MD, Yale School of Medicine, New Haven, CT; Patrick J. Lynch, MS, Carl Jaffe, MD.

Visual assessment of left ventricular function and ejection fraction (LVEF) by echocardiography has always been difficult to master since it requires awareness of segmental wall motion as it relates to global contractility. The ability to accurately translate wall motion to a reproducible estimate of LVEF is a valuable skill usually acquired over time guided by clinical experience.

A MacIntosh controlled hypermedia project was devised which allows the user to point & click icons on the computer screen to reveal synchronized examples of myocardial function on an adjacent videodisc player. The user has instant access to more than 200 examples of 2-D echocardiograms with known LVEF, displayed in cine loop format. The examples are taken from actual clinical studies in order to recreate "real life" conditions.

After training the "mind's eye" to estimate LVEF, the user may then try a self administered quiz, scored by the computer. The echocardiograms are presented randomly and the user provides an estimate of LVEF.

The intuitively run program provides the student of echocardiography the accumulated experience of hundreds of cases in less than one hour. A majority of cardiology fellows surveyed at our institution report increased confidence deriving LVEF from echocardiography after use of the program. The project is a valuable aid in learning what is essentially a visual skill - the evaluation of left ventricular function by 2-D echocardiography.

## 864-4

### COMPUTER-BASED LEARNING OF CARDIOVASCULAR PATHOPHYSIOLOGY

Mary E. Fontana, M.D., F.A.C.C., Ohio State University, Columbus, OH; J.S. Pierce, M.S.; A.J. Frisby, Ph.D.; J.L. Burson, Ph.D.; R.C. Comer, Ph.D.

The Independent Study Program of the Ohio State University College of Medicine is a nationally known curriculum for the first two years of medical school which has used computer assisted instruction since its inception in 1970. A Cardiovascular Pathophysiology Study Unit was developed utilizing high quality heart sound and pressure pulse recordings, chest x-rays, ECG's, cineangiograms, schematic diagrams, and real time 2-D echocardiograms (some with sound) to supplement a standard textbook of medicine.

The program is divided into submodules on General Evaluation of the Cardiac Patient, Heart Failure, Electrophysiology and Arrhythmias, Congenital Heart Disease, Valvular Heart Disease, Coronary Heart Disease, Myocardial and Pericardial Disease. Therefore, it can be utilized on a submodular basis as well as in its entirety, which provides time flexibility.

The program is IBM PC/AT compatible and utilizes a Sony or Pioneer videodisc player. Graphics overlays are used to illustrate pathophysiologic principles and point out specific diagnostic information. The two monitor screen design allows amplification of learning objectives and fascilitates instantaneous comparisons among the various presentation modalities of a given diagnosis with other diagnoses, and with the normal heart.

Over 120 students have been through this program since its inception in 1989 (and revision in 1991). They have consistently rated this program as an excellent learning resource. This program has wide application for learning and review of pathophysiology by all medical students, housestaff, fellows, and practicing physicians.

# 865 Computer-Assisted Instruction

Tuesday, April 14, 1992
1:30 PM–5:00 PM
Dallas Convention Center
Booth 1340

## 865-1

### MULTIMEDIA COMPUTER ASSISTED INSTRUCTION

Michael S. Gordon, M.D, Ph.D., F.A.C.C., University of Miami, Miami, FL; Gordon Ewy, M.D., F.A.C.C.; Joel Felner, M.D., F.A.C.C.; Ira Gessner, M.D., F.A.C.C.; David Lawson; Joan Mayer, M.D.; Abdul Sajid, Ed.D.; Clarence Shub, M.D., F.A.C.C.; Robert Waugh, M.D., F.A.C.C.

The University of Miami Medical Training and Simulation Laboratory has developed a multimedia Computer Assisted Instruction (CAI) system, production facilities and teaching programs with a consortium of cardiologists, educators and engineers from Arizona, Duke, Emory, Florida, Illinois and Mayo. We have met quarterly for the last decade to produce, refine and evaluate our CAI system and lessons.

Once produced, editing/updating is accomplished in a few minutes. The lessons provide laserdisc video, computer and video graphics and digitized audio. Removable discs handle storage needs and student performance data. The program may stand alone, be linked to "Harvey", the Cardiology Patient Simulator, or be used to teach large groups. Each patient-centered lesson presents the history, bedside findings (appearance, arterial and venous pulses, precordial impulses and auscultation, including "dissection" of the acoustic events), laboratory data (ECG's, X rays, echos, scintigraphy, angiograms), therapy (including videos of surgery) and pathology.

The first 5 lessons (normal, aortic regurgitation, aortic stenosis, mitral regurgitation, mitral stenosis) are now undergoing a formal independently evaluated multicenter study involving 6 institutions. Initial data on 295 senior students revealed an average lesson lasted 70 minutes and over 90% rated the programs excellent. All students requested additional programs, rated CAI superior to other systems, including slide programs, and felt the programs improved their bedside skills. Problems have included tight-fitting stethophones, imbalance of laserdisc and voiceover sound levels, thermal drift of arrows on graphics, equipment malalignment of ECG's and X rays, and excessive length of initial programs. These have been corrected. Based on our experience, we believe that the widespread use of CAI and computer testing systems is inevitable.

## 865-2

### MacHeart: COMPUTER ASSISTED INSTRUCTION IN LEFT VENTRICULAR DYNAMICS

Charles Caron,* Ying Sun,† Richard Lucariello,* Salvatore Chiaramida *
*Cardiology, Our Lady of Mercy Medical Center, Bronx, NY 10466
†Electrical Engineering, University of Rhode Island, Kingston, RI 02881

MacHeart is a computer based interactive instructional system developed by the Department of Cardiology designed to teach basic left ventricular hemodynamics as an adjunct to traditional cardiovascular teaching at Our Lady of Mercy Medical Center. The format consists of a series of multiple choice questions with detailed explanation integrated with computer generated left ventricular hemodynamic waveforms.

The software system consists of three functional units: 1) an analogue model for the cardiovascular system, 2) interactive graphics, and 3) a text editor for annotations and questions. A previously developed analogue model serves as the mathematical basis for hemodynamics. Pressure and flow waveforms are generated using the 21-element electrical circuit that represents the dynamics of left ventricle, mitral/aortic valves, aorta, coronary arteries, carotid/subclavian arteries, and peripheral vessels. Via interactive graphics the user can adjust the circulatory parameters on the analogue model, select and organize a set of waveforms for display. A text editor is available for the entry and modification of annotations associated with a particular scenario. Questions can be made up and stored to disk along with the model parameters. These question/waveform files are later retrieved for instructional purposes. A library of cardiovascular disease states has been created and currently includes scenarios such as high peripheral resistance, low vascular capacitance, high viscoelastic loss, intraaortic balloon counterpulsation, valvular stenosis and regurgitation. The software has been implemented for the MacIntosh II computer.

This interactive tool has been useful in increasing the resident staff's knowledge of left ventricular hemodynamics in both normal and pathological situations.

### 865-3

**Computer-Assisted Surgical Technique.**
**Switch Operation for Transposition of the Great Vessels.**

François Lacour-Gayet MD, Claude Planché MD.
Marie Lannelongue Hospital, Paris Sud University, France.

Based on an experience of 450 Switch Operations, this soft-ware was device to provide practical surgical solutions to face most of the surgical problems encountered in the surgical field during anatomical repair.

This soft-ware was developed on Macintosh Computer, using the Hypercard soft-ware.It contains 125 cards of surgical drawings with a minimal quantity of text. This soft-ware has already been used by numerous surgeons of various country, during a yearly surgical course on congenital heart surgery organized in our institution.

Surgical Technique is a field that can be easily projected in this type of Computer Application. The development of Video Disk in the near future will provide direct views of the operative field in addition to the theoretical surgical technique.

### 865-4

**An Electronic Book to Support the Management of Congenital Heart Diseases Databases**

Beatriz de Faria Leão, MD, Phd; Institute of Cardiology of Rio Grande do Sul, Porto Alegre, RS, Brazil. Viviane Bernardo, Raul Ivo Rossi F°, Marinez Barra Rossi, Paulo Zielinsky

In the last decade, due to the advances of cardiac surgery and cardiological interventions, the number of patients with corrected congenital heart diseases (CHD), reaching adult life is increasing. It is, therefore, mandatory to have adequate follow-up files of these patients. Computerized databases seem to be the best solution to store efficiently these data. It is crucial to assure that the patients' diagnoses is correctly stored, specially regarding complex and associate lesions. The morphological sequential analysis(MSA) approach is, so far, the most complete and comprehensive proposal of a controlled vocabulary to describe CHD diagnoses, although not very much employed in the daily clinical activity. In order to support physicians to easily build consistent CHD databases, an expert database system with knowledge about diagnoses, surgeries, interventions and complications in CHD was developed. Like the experts, this system knows the connection between the diagnoses usually employed in the daily clinical activity and the MSA. For each main diagnosis the system assumes parts of the MSA, asking the user to detail others, depending on the medical context. For example, for the Tetralogy of Fallot's diagnosis, the systems assumes that the A-V and V-A connection are concordant and the "situs" is "solitus", forcing the user to detail the morphology of the ventricular septal defect, the right ventricle outflow tract, the straddling and overriding of the AO over the ventricular septum, the coronary arteries, etch... By knowing also about surgeries and interventions, the system only allows consistent data to be entered. The communication with the user is performed trough a graphical user interface(GUI), using hypertext technics that allowed for a construction of an "electronic" book. Drawings, with buttons for selection, representing the different morphologies of CHD, were largely employed throughout the book. This electronic book can be used in both directions, either to enter or to retrieve patients' data. It is possible to easily make complex selections on the CHD database, only by pointing and selecting in the GUI. In addition, the system can be used as a teaching tool for non-experts on CHD. The results of the first evaluation of this system are also presented.

## 985 Coronary Anatomy

Tuesday, April 14, 1992
2:00 PM–5:00 PM
Dallas Convention Center
Lower Level Exhibit Hall
Presentation Hour: 2:00 PM–3:00 PM

### 985-118

SYSTEM FOR 3-D RECONSTRUCTION AND MODELLING OF CORONARY ARTERIES GIVES RISE TO NEW DIAGNOSTIC APPROACHES

H. Oswald, A. Wahle, G.A. Schulze, J. Beier, E. Wellnhofer, E.Fleck - German Heart Institute Berlin, FRG

The combination of different imaging systems, like angiography, intravasal ultrasound and angioscopy, on one hand and the calculation of complex geometric parameters on the other hand motivated us to develop a system for 3-D reconstruction of a given coronary tree based on digital angiograms.
Methods for 3-D reconstruction of skeletons and related cross sections of the coronary arteries from arbitrary, non-orthogonal, biplane views have been implemented. The recontruction starts with interactive definition of corresponding points in biplane images. These points marked in both views are control points for the automatic search of centerlines and the detection of vessel edges. Each step of the process can be verified visually. Rendering the 3-D model can be done by using a wire frame model or very complex techniques, based on solids, like general cylinders and spheres, or triangulated surfaces.
The reconstruction of coronary arteries pre and after intervention (e.g. PTCA or laser-angioplasty) demonstrates a clinical application of the system. The 3-D model in conjunction with the original angiograms and the exact positioning of an intravasal imaging device, including related pictures, will be shown. The calculation of geometric parameters like length of the coronary tree and angles of bifurcations is feasible.

### 985-119

LOW COST HARDWARE-SOFTWARE
APPLICATIONS FOR QUANTITATIVE ANGIOGRAPHY

Kenneth Khaw, M.D., UMDNJ-Robert Wood Johnson Medical School, New Brunswick, NJ; George R. Kuntz, B.S.; Daniel Shindler, M.D.; John B. Kostis, M.D., F.A.C.C.; Abel E. Moreyra, M.D., F.A.C.C.

Various computer-based techniques in digital angiography have been generally used to increase precision and speed in measurements. Commercially available image processing software for image enhancement and measurements were used to test whether accurate measurements were possible from cine images. Cine images of a 1cm X 1cm grid with various size coronary catheters and wires were obtained. The central regions of cine images were then magnified 4 times, captured and averaged by a frame grabber board in a 386 computer. The edge enhancement was accomplished through the Kirsch edge detection operation. Catheter and wire diameters (diam) were obtained (n=10 samples each) using the imaging software by using luminance profiles in the region of interest. Percent difference (% Diff), standard deviation (SD) and covariance (CV) were calculated. Result:

| True Diam(O.D.) | Measured Diam | % Diff | SD | CV |
|---|---|---|---|---|
| 2.229mm | 2.220mm | 3.1% | 0.145 | 6.43 |
| 1.998mm | 1.967mm | 1.6% | 0.008 | 4.04 |
| 0.965mm | 1.063mm | 10.2% | 0.121 | 11.37 |

With this affordable software-hardware system, accurate and reproducible measurements from cine images can be obtained. Its accuracy for objects >1mm is comparable to other dedicated coronary artery analysis systems. Therefore, it can be used in studies quantitating coronary artery diameters and lesions.

### 985-120

**IMPLEMENTATION OF A FINITE STATE AUTOMATON FOR CORONARY ANATOMY DESCRIPTION AS A SUBROUTINE LIBRARY**

James B. Wallis, M.D., F.A.C.C. Long Beach VA Medical Center; Long Beach, CA

Software utilizing a finite state automaton can "understand" complex coronary and bypass graft description. For example, "95ML(A D1;B D2)." is converted into **"Selective coronary angiography revealed a 95% stenosis in the mid portion of the left anterior descending coronary artery, after the origin of the first diagonal branch, before the origin of the second diagonal branch."** This software can perform an automated extraction of meaning from coronary anatomy described this way, so that, for example, it can calculate the number of vessels diseased. We have previously implemented such software on a minicomputer with customized, locally written data base engine, user interface and report formatter to provide a comprehensive cardiac catheterization laboratory information management system. This software has now been written for 80x86-based platforms. Commercially available software provides a Structured Query Language capability as well as visually pleasing reports. Hardware required is much less expensive than for the original version, and considerably less software maintenance is necessary without sacrificing efficiency: In its first two days of operation, one month's backlog of catheterization reports was generated.
**Summary:** Software providing automated handling of complex coronary and bypass graft description can now be inexpensively integrated into widely available cardiology information systems.

## 986 Nuclear Image Analysis and Reperfusion

Wednesday, April 15, 1992
9:00 AM–Noon
Dallas Convention Center
Lower Level Exhibit Hall
Presentation Hour: 11:00 AM–Noon

### 986-118

QUANTIFICATION OF MYOCARDIAL PERFUSION SPECT IMAGING.

Piotr J. Maniawski, M.S., Yale University, New Haven, CT, Diana J. Errico, Albert J. Sinusas, M.D., F.A.C.C., Frans J. Th. Wackers, M.D., F.A.C.C.

We developed a new software package for the quantitation of a defect size from myocardial perfusion SPECT imaging based upon circumferential profile analysis of reconstructed short axis slices.

Circumferential count profiles were generated for all slices by identifying the peak counts in 36 radial sectors of the left ventricle and were superimposed on the lower limit of normal curve . Each profile was subdivided in four anatomical regions ( anterior, septal, inferior and lateral ). A variable circular region of interest was superimposed on each of the slices to determine the slice volume. A volume weighted regional defect size was then calculated as the area below the lower limit of normal expressed in proportion to 1) the total area below the normal limit curve and 2) relative volume of the slice. Regional defect sizes for individual slices were averaged to provide values for three sections of the left ventricle : basal, midventricular and apical. A defect size for the apex was calculated separately using a long axis slice. Finally, defects per section and a global defect size were determined. The quantitated defects reflect both the extend and severity of abnormal perfusion.

Initial validation of the program was performed using computer simulation and animal model. Both models showed good correlation between theoretical and measured defect sizes ( r=0.99 and r=0.90 respectively ). Reproducibility of a method was also excellent ( intra- and interobserver variability r=0.99 ).

This new software provides a reliable, easy to interpret quantitative assessment of myocardial perfusion defect sizes with SPECT imaging and presents an alternative to widely used but more abstract bull's eye approach.

### 986-119

IMAGE-ANALYSIS SOFTWARE TO FACILITATE THE PROCESSING OF DYNAMIC POSITRON EMISSION TOMOGRAPHIC STUDIES OF THE HEART

Kondapuram S. Sampathkumaran, M.S., Pilar Herrero, M.S., Sherman E. Owens, Judy J. Hartman, R.N., Steven R. Bergmann, M.D. Ph.D., F.A.C.C., Robert J. Gropler, M.D. Washington University, St. Louis, MO

Positron emission tomography (PET) has the unique capability for quantification of regional myocardial perfusion and metabolism in absolute terms, but requires the analysis of large amounts of data, which is both operator intensive and time consuming. Accordingly, we have developed a software package to facilitate these analyses. The software has been implemented on a DEC 3100 workstation with 12 Mbyte of memory, two 778 Mbyte Fujitsu Winchester disk drives and ULTRIX operating system. The software was developed in C programming language with an X Windows graphics interface. Myocardial images can be analyzed in the transaxial orientation or in true long-axis or short-axis views. The program can generate time-activity curves in either irregular regions of interest or using a semi-automatic routine. The time-activity curves can then be analyzed to quantify regional myocardial perfusion (using O-15 water and a one-compartment model) and oxygen consumption (based on the myocardial turnover of C-11 acetate). A typical analysis (i.e., generation of the time activity curves and calculation of perfusion and oxidative metabolism) takes less than 10 min to complete. Data can be displayed as tables, as circumferential profiles, or as parametric images. Estimates of perfusion and oxidative metabolism using this approach agree closely with estimates derived with previously validated software. In conclusion, the image-analysis software package we have developed is fast and user friendly and provides accurate quantitative measurements of perfusion and oxidative metabolism. It should prove quite useful in both research and clinical studies of the heart by PET.

### 986-120

Non-Invasive Prediction of Reperfusion on Basis of Computer Quantitative Analysis of ECG in AMI.

P.Buszman, A.Szafranek, S.Pasyk
Silesian Center of Cardiology, Zabrze, Poland

200 patients (pts) with Pardee wave in ECG and chest pain of less than 6 hour duration were given thrombolytic treatment.The result of the therapy was assessed with coronarography.Conventional 12 lead ECG was performed before and after thrombolysis(the mean interval was 3.5+1 hour).Pts were divided into 2 groups:I (50 pts) -without recanalisation (TIMI grade 0 or 1) and II (150 pts)-with good result(TIMI grade 2 or 3).Analysis of ECG included quantitative assessment of ventricular de and repolarisation period.There were significant differences between the two groups in relation to fractional change of ST elevation, abs value of increment of T and QRS axes as well as QRS width.Linear discrimination analysis was performed using Rosenblatt Perceptron method and IBM PC/AT.Separate algorithms of reperfusion were calculated for anterior and inferior/lateral infarct.Sensitivity and specificity of this method for prediction of reperfusion were 98 and 97% respectively for inferior / lateral infarct and 100% for anterior infarct.We concluded that these algorithms can be easily implemented into a pocket calculator and could be useful in clinical practice.

## 866 Expert Systems/Decision Analysis/Simulation

Wednesday, April 15, 1992
9:00 AM–12:30 PM
Dallas Convention Center
Booth 1340

### 866-1

**Expert System Diagnosis of Wide Complex Tachycardia**

Steven Georgeson, Howard Warner.
Temple University Hospital, Philadelphia, Pennsylvania

The differentiation between ventricular tachycardia (VT) and supraventricular tachycardia with aberrancy (SVT with aberrancy) in a patient with a wide complex tachycardia is often difficult. Numerous criteria have been developed to aid in the differential diagnosis. Unfortunately, many of these criteria are not used or are misapplied when a patient presents with a wide complex tachycardia.

To help differentiate between VT and SVT with aberrancy, an expert system was developed using a commercially-available expert system shell (*EXSYS*) running under the MS-DOS operating system. The expert system is rule-based and assigns probability values to the goal states through the process of backward chaining. The goal states for this expert system were VT and SVT with aberrancy. The user is queried for the presence of various abnormalities on the presenting twelve lead EKG (eg, QRS axis, duration and morphology), comparison with previous EKG's, the patient's history and the effect of vagal maneuvers on the tachycardia. From published data, each abnormality is assigned a probability based on the positive predictive value of the abnormality for VT and for SVT with aberrancy. By combining the positive predictive values, the expert system assigns a final probability for VT and for SVT with aberrancy. In addition, the expert system provides a compilation of the rules applied, including an explanation of the rule and references to the medical literature.

This expert system may be useful as a diagnostic tool and as a teaching aid in the differentiation between VT and SVT with aberrancy in a patient with a wide complex tachycardia.

### 866-2

CASSPERT- AN EXPERT SYSTEM TO GUIDE EQUIPMENT CHOICE AND STRATEGY IN CORONARY ANGIOPLASTY

Andonis G Violaris, Patroklos G Violaris, Ray Leonard, David C Cumberland.
Department of Cardiology, Northern General Hospital, Sheffield, UK

Success in coronary angioplasty depends on the optimal matching of the differing vessel and lesion characteristics in each individual patient with the three technical components, the guide catheter, guide wire and angioplasty balloon. As indications for coronary angioplasty become more extensive and the choice in equipment wider, success relies increasingly on the correct choice of equipment. CASSPERT is a user friendly Expert System, developed using LEONARDO 3, an expert system shell running on a PC, which has been developed to assist in this decision making process. Technical specifications and operative characteristics of all available guide catheters, guide wires and angioplasty balloons are stored within LEONARDO's own object-oriented database. For each patient the user interacts with CASSPERT to build up a detailed profile of clinical, investigational and angiographic features. This information is then used, together with the technical data, to make an initial choice of equipment to use, which can then be further refined by local considerations such as cost and availability of equipment. Patients suitable for research protocols are recognised automatically, and information concerning the patient, the recommended system, the system actually used, and the outcome of the procedure are stored within CASSPERT's own database, and can be exported in dBase IV or Lotus 123 format. Thus CASSPERT encourages critical appraisal of clinical and angiographic interpretation and aids learning through the on line help and explanation facilities. In addition the integral database encourages audit and expediates research. These factors make it likely that such systems will become widely employed in the future for high technology interventional procedures such as coronary balloon angioplasty.

### 866-3

**Cardiologist On-line: The use of Artificial Neural Systems to Simulate Clinical Decision-making in Cardiology.**

Sanjay Patil, MD, Sinai Hospital, Detroit, Michigan
Jay Kozlowski, MD, Mary Lazar, MD, Muzaffar Piracha, MD,
Shahid Khan, MD, Chandra Narala, MD, Melvyn Rubenfire, MD, FACC

Algorithms are unable to incorporate 'clinical sense' into a diagnostic process. Two artificial intelligence methodologies (artificial neural networks and expert systems), have been shown to have predictive accuracy to within 90% of a human domain expert. By using pattern recognition, neural networks are able to extrapolate incomplete data under conditions of uncertainty. In addition, they are not subject to fatigue or intra-observer variation. Neural systems can be easily trained and improve their performance with large training sets. We developed a neural network to categorize patients with chest pain on the spectrum of ischemic heart disease, pulmonary embolism and aortic dissection. We combined this neural network with an expert system to create a hybrid system for chest pain diagnosis. In retrospective studies, this system reliably reproduced the impressions of cardiologists when presented with previously unseen data. The hybrid system improves upon logistic regression and recursive partitioning techniques, particularly with incomplete data. Data are being prospectively collected on 200 patients admitted with chest pain, including historical features, enzyme and EKG findings. These patients have chest pain which meets criteria for hospital admission. Endpoints being taken are enzyme or EKG proven MI, and angiographically demonstrated presence or absence of coronary artery disease or aortic dissection, and positive perfusion scans. Patients reaching endpoints within 72 hours are eligible. These data will be presented independently to two cardiologists and to the hybrid system, after which diagnostic impressions will be compared and the results published.

### 866-4

AN EXPERT SYSTEM FOR CHEST PAIN ANALYSIS

D.L. Hudson, M.E. Cohen, P.C. Deedwania
University of California, San Francisco, California

An expert system for the analysis of patients reporting to the emergency room with the complaint of chest pain will be demonstrated. This system, EMERGE, has been under development for the last decade. The three principal components of the expert system - the inference engine the knowledge base, and the user interface - have all undergone continuous revision during this time frame. EMERGE is a rule-based system which incorporates techniques for handling uncertain and missing data, including the ability to weight signs, symptoms, and test results according to their relative significance. This is a significant advantage over most expert systems in which all contributing information is considered to be of equal importance. The knowledge base was derived from existing medical outlines known as criteria maps. The system contains facilities for easy updating of the knowledge base to accommodate new medical knowledge. EMERGE contains three user interfaces: a question mode in which the user is prompted to supply either a yes/no response or a degree of presence of a finding; a data-driven mode in which the user may enter significant findings in phrase form, accompanied by a degree of presence, if desired; a menu-driven mode in which the user can select by number any significant findings which are present for the current case. The latest addition to the EMERGE expert system is the use of a neural network model featuring a learning algorithm which can be used to derive information directly from data. This aspect is useful in a number of ways. First, newly accumulated data can be used to update the existing knowledge base directly. Secondly, the neural network model can be used to obtain pertinent weighting factors for contributing information, as discussed above. Finally, the neural network model can be used independently as a second type of decision aid. The EMERGE system runs on IBM PC compatible computers and is written in the C programming language.

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## 867 Expert Systems/Decision Analysis/Simulation

Wednesday, April 15, 1992
1:30 PM–5:00 PM
Dallas Convention Center
Booth 1340

### 867-1

COMPUTER DISPLAY OF SERIAL CHANGES IN EXERCISE BODY SURFACE POTENTIAL MAPS IN NORMALS AND CORONARY ARTERY DISEASE PATIENTS

Marandapalli R. Sridharan, MD, FACC, VA Medical Center and Medical College of GA, Augusta, GA; Leo G. Horan, MD, FACC; Nancy C. Flowers MD, FACC; Patricia C. Orander; Rebecca L. Thornton, MD; Michael L. Rhodes, MD; John Doster, MD

Multi-channel body surface map data were obtained during the standard Bruce protocol for 17 normal subjects and 22 patients with coronary artery disease. Data was acquired, amplified and digitized on a portable Compaq Deskpro 286 computer and analyzed on a Macintosh. Serial dual maps (rest and post-exercise) were displayed in both isometric and isocontour projections. Hypercard was used for displaying these maps in animated fashion and for storage, printing and collation with collateral data (e.g., thallium stress test images). The animated display of body surface potential patterns showed the dynamic nature of changes during stress testing. High gain display (x4 standard gain) of STT showed subtle changes for both normal and patient groups and was further enhanced by programmatic subtraction of exercise pattern from resting pattern.

The normal group showed 2 types of response to exercise: a) early (J-point) reversal pattern of ST response; and b) slightly increased positivity superiorly in both the right and left sides. The majority of the coronary artery disease group responded to exercise with even greater and more protracted positivity superiorly both on the right and left, predominantly posteriorly and well outside the standard ECG survey zone. A few patients displayed a persistent ST reversal pattern. No significant changes were seen in the QRS complex in either group with exercise.

This interactive format permits rapid and immediate assessment of clinical and electrical data and facilitates the acquisition of skill in such interpretation. Serial comparative analysis of the animated display of both normal and abnormal response to exercise is essential to re-evaluation of the separation and overlap between these different populations and to the development of new standards for the expanded methodology of body surface mapping and new definitions of sensitivity, specificity and predictive accuracy.

### 867-2

NEURAL NETWORK PROGRAM THAT ACCEPTS LUMINANCE VALUES FROM DIGITIZED ECHOCARDIOGRAMS FOR TISSUE CHARACTERIZATION

George R. Kuntz, Daniel M. Shindler, Olga I. Shindler, John B. Kostis, Robert Wood Johnson Medical School, New Brunswick, N.J.

Neural networks are used in computing to simulate the thinking process. We wrote a simple program in C language that accepts luminance values from digitized echocardiographic images for the purpose of tissue characterization. The program is intended to accept an initial pattern of pixel intensities that contain evidence of cyclic variation. Based on this teaching pattern it is expected to learn the acoustic "signature" of normal, infarcted and hypertrophic myocardium. It repeatedly processes the input values until a preset error value is reached. We demonstrate how this is being implemented on a personal computer in our echocardiography laboratory. In addition to a PC, a setup is required for digital image aquisition. Once the images are digitized a region of interest is selected and luminance values are calculated. The presentation includes examples of M mode and 2D luminance values with a discussion of advantages and disadvantages of each approach.

### 867-3

PROGRAM FOR EVALUATION OF DIAGNOSTIC VALUE OF NONINVASIVE TESTS FOR CORONARY ARTERY DISEASE DETECTION APPLYING BAYES' THEOREM

Jelena D. Pantelic-Babic, Rade M. Babic, Miodrag C. Ostojic, Tatjana B. Jakovljevic, Slavko D. Simeunovic. Federal Bureau of Measures and Precious Metals, Belgrade, Yugoslavia

Bayes' theorem is applicable in different fields where conditional probabilities are involved. A PC based interactive program applying this theorem is created to facilitate calculation of discriminative parameters in noninvasive diagnostic tests for coronary artery disease (CAD) detection, such as: sensitivity, specificity, diagnostic accuracy (including their 95% Confidence Intervals), prevalence, post-test probability, risk ratio, false positive and false negative response. These parameters are calculated from data on diagnostic test results compared against gold standard (coronary angiography) in testing population subjected to a particular test. The program is developed in LOTUS-123 environment using its advanced programming language facilities.

A comprehensive database (compiled from the literature data) for automatic prevalence estimation of individual patients based on the data such as age, sex and presenting symptoms, is provided as well. In the estimation of post-test disease probability of consecutive patients with unknown CAD prevalence who underwent diagnostic test, the user is enabled either to determine pre-test disease probability (prevalence) on the basis of clinical experience, or to leave decision to the program database contents. All calculated data are graphically presented. In case of two, three or more independent diagnostic tests applied on the same patient, it is possible to take post-test probability of the previous test as input prevalence for the later one, and so on. After checking of an individual patient against gold standard, recalculation of diagnostic parameters of a particular test is provided, as well.

In clinical practice program appeared to be particularly effective when introducing new diagnostic tests for CAD detection by determining their diagnostic value and discriminative power in a series of various available tests, providing the possibility of their direct intercomparison (graphical and statistical). The program proved, as well, to be a practical tool in clinical decision making concerning individual patients subjected to a battery of diagnostic tests, facilitating the recognition of CAD, depending on test results.

### 867-4

MEDPACE ELITE - A COMPREHENSIVE SIMULATION OF A DUAL-CHAMBER ACTIVITY-RESPONSIVE CARDIAC PACEMAKER AND VARIOUS ARRHYTHMIAS AND CONDUCTION DISTURBANCES

Alasdair D. Malcolm, St. George's Hospital, London SW17 0QT, England, Jonathan P. Streete, David G. Dunham.

An application has been developed for the Apple Macintosh computer to provide on-screen simulation of the operation of the Medtronic Elite pacemaker generator and its programmer within the context of various cardiac rhythm and conduction disturbances. The MedPace Elite software makes it possible to learn about the extensively programmable functions of this dual-chamber activity-responsive pacemaker and to observe the interaction of the pacemaker with the simulated electrical activity of the heart displayed as a continuous electrocardiographic trace.

A library of arrhythmias and conduction disturbances is provided, with adjustable antegrade and/or retrograde conduction. When the pacemaker is "installed" the area beneath the electrocardiographic trace displays in diagrammatic form the timing cycles of various circuits in the pacemaker plus sensed and paced cardiac events. Seven levels of activity can be chosen and will influence the pacemaker's activity sensor accordingly. Pacemaker mediated tachycardia is a selectable feature, automatically initiated by setting the pacemaker's Atrial refractory period to its minimum value and introducing an atrial premature beat. Effects of various programming adjustments on the tachycardia rate or in achieving tachycardia termination can then be demonstrated.

As cardiac pacemakers become more complex so there is a need for correspondingly sophisticated training to utilize fully and optimally the available functions for a particular patient's needs. MedPace Elite is a way of providing such training for a specific pacemaker.

## 987 LV Wall Motion and Membrane Simulation

Wednesday, April 15, 1992
2:00 PM–5:00 PM
Dallas Convention Center
Lower Level Exhibit Hall
Presentation Hour: 3:00 PM–4:00 PM

### 987-118

**COMPUTER ASSISTED DETECTION AND QUANTIFICATION OF REGIONAL WALL MOTION, LEFT VENTRICULAR FUNCTION AND REMODELING**

Andrea Giordano, Pantaleo Giannuzzi, Fabio Comazzi, Giuseppe Minuco, Pier Luigi Temporelli, Alessandro Imparato, Amerigo Giordano and the EAMI Study Group. Fondazione Clinica del Lavoro - Veruno Medical Center, Veruno, Italy.

In order to obtain more objective and detailed analysis of wall motion abnormalities (WMA), left ventricular (LV) shape distortion and remodeling, a computer system for digital image acquisition, storage and quantitative analysis has been developed. The system allows on-line acquisition of echocardiographic images and semiautomatic frame by frame endocardial contouring, while a cine-loop is displayed on a secondary monitor. Variability in endocardial contouring was assessed in 56 echo sections relative to 10 normal subjects and 10 infarcted patients. End-diastolic and end-systolic endocardial surface areas were used for the analysis and both inter- and intra-observer variability were better than 4%.
Quantitative analysis is carried out after frames-to-beat normalization and contour segmentation. A data-base of normal ranges of both area and length for each echo section and segment has been obtained by studying thirty normal subjects (54±9 yrs) with this system. Long axis sections, divided into 20 areas by equally spaced lines perpendicular to the LV long axis plus 3 for the apex region, are used, together with normal ranges, in order to automatically detect the extent of WMA and objective indexes of LV enlargement and shape distortion.
This system is used in the EAMI Study (Exercise training in Anterior Myocardial Infarction) which is an on-going multicenter randomized trial designed in order to investigate the effects of physical training on ventricular function and remodeling after anterior myocardial infarction.

### 987-119

**MS WINDOWS PROGRAM FOR QUANTITATION OF LEFT VENTRICULAR SYSTOLIC FUNCTION FROM END-DIASTOLIC AND END-SYSTOLIC ANGIOGRAPHIC IMAGES**

Nenad S. Amodaj, Rade M. Babic, Dragan V. Mitrakovic, Miodrag C. Ostojic. Faculty of Technology and Metallurgy, Belgrade, Yugoslavia

Quantitation of Left Ventricular (LV) global and segmental function is important for assessing functional significance of Coronary Artery Disease and for decision making regarding further interventions and estimation of their results.

A PC based program is developed to enable this quantitation procedure. Program operates in Microsoft Windows environment and is therefore user friendly, interactive and flexible. Program consists of three functional modules: image processing, contour extraction and analysis module.

Image processing module permits image manipulation (retrieving and storing in several standard formats), enhancement (contrast stretching, noise suppression, histogram equalization) and calibration.

Contour extraction module operates in two modes: manual and automatic - operator guided. In manual mode operator traces contour with mouse or other pointing device; in automatic mode operator defines critical points in the area of interest which is followed by automatic contour extraction (directional derivative edge detection and edge linking).

Analysis module calculates LV volumes and Ejection Fraction from end-diastolic and end-systolic contours. These contours can be superimposed interactively by appropriate translation and rotation. Regional systolic LV function is determined by application of Radial Shortening method with variable (user defined) number of Central Chords. Graphical representation of Chordal Percentage Shortening is provided as well.

Our program has an advantage of integration with other Microsoft Windows programs, such as word processors, spreadsheets and drawing programs for documentation and presentation purposes. Utilizing this program, PC equipped with an additional digitizing device (frame grabber or scanner) becomes an inexpensive tool for Catheterization Laboratory practice.

### 987-120

**CLASS-I-ANTIARRHYTHMIC DRUGS: COMPUTER SIMULATION OF SODIUM CHANNEL BLOCK**

Horst P. Herb, Georg Schmidt, MD, Jörg Weirich, MD, Peter Honerjäger, MD, Petra Barthel, Heinz Kreuzberg, Gregor Morfill, PhD.

Center for Nonlinear Dynamics in Cardiology, Max-Planck-Institute and Technical University of Munich, F.R.G.

The blockade of cardiac sodium channels by class-1-antiarrhythmic drugs can be expressed as a periodic ligand binding and unbinding of the drug molecules and the channel binding sites during the different channel states. The apparent binding and unbinding rate coefficients during the channel states describe this process.

Utilizing the hitherto published coefficients of 12 different drugs, we developed a computer program to simulate the extent of sodium channel blockade at any dosage and heart rate.

The degree of channel block can be plotted against time and heart rate. Another mode allows the on-line observation of blockade during real or simulated heart rhythms. Moreover, blockade during ischemia as well as drug combinations can be simulated.

According to their kinetic behavior at different heart rates and dosages, the drugs fall into into three groups:

- Disopyramide, Nicainoprol, Propafenone and Prajmalium cause only a small increase of blocked channels at high heart rates.
- Lidocaine, Lorcainide, Procainamide, Quinidine and Tocainide cause a clear increase in the number of blocked channels at high heart rates reaching significant levels at rates above 250 bpm even with low dosages.
- Encainide, Flecainide and Mexiletine show an intermediate behavior.

Thus, the program facilitates the understanding of the mode of action of class 1 antiarrhythmic drugs and points out possible mechanisms of proarrhythmia.

## 988 Database Systems

Thursday, April 16, 1992
9:00 AM–Noon
Dallas Convention Center
Lower Level Exhibit Hall
Presentation Hour: 10:00 AM–11:00 AM

### 988-118

**AN ADVANCED IMAGE PROCESSING AND DATABASE MANAGEMENT SYSTEM FOR ANALYSIS OF CARDIAC IMAGES USING CINE CT**

Judd Reed, B.S., Thomas Behrenbeck, M.D., Ph.D., Patrick F. Sheedy, M.D., John A. Rumberger, Ph.D., M.D., FACC, Mayo Clinic, Rochester, Mn.

Numerous studies have shown the applicability of cine CT to quantitatively define cardiac anatomy and function at rest, during pharmacologic manipulation and during dynamic exercise. Despite these advances, image analysis is tedious and time-consuming. Additionally, re-analysis of the data or efforts to review the data from a variety of emerging aspects (e.g. - three and four-dimensional displays, changes in reference coordinate systems, etc.) usually require re-tracing of the data. The current cardiac image analysis software available from the manufacturer is limited in scope and usefulness to the ever expanding applications in cardiovascular disease and is not coupled to any permanent archival and retrieval system. A generic approach to image display, edge detection and analysis of cine CT images has been developed which characterizes the dynamic motion of the cardiac surfaces of the left and right ventricles during the cardiac cycle as a series of 64 sided polygons in three-dimensional space. The loci of these polygons are stored in a rectangular array during analysis on a SUN workstation equipped with an on-line video co-processor. Following image analysis, the loci are transferred to a commercially available data base management system (INGRES, ASK Computer Systems Inc., Alameda, Ca.). Database entry of the radial locations of the cardiac borders, from a common centroid, facilitates retrieval, re-analysis and display of the data as individual tomograms or as three and four-dimensional surfaces. Once the loci are entered into the database, specific algebraic and or direct access queries can be built to retrieve information related to global and regional wall motion and thickening. The results of individual queries can be displayed on the SUN workstation or reported to other systems in ASCII format. Review and focusing of data analyses can be used much like a literature search program which allows for further refinement of the search until the desired data-set is achieved.

This approach represents the first attempt to define an anatomic database for use with any advanced cardiac imaging system directly incorporated from a data display and analysis package.

988-119

## New Application of Computer-Linked Electronic Organizer in the Management of Hospital Cardiac Patients

Yzhar Charuzi and Arie Shefer
Cedars-Sinai Medical Center, Los Angeles, California.

The routine follow up of hospitalized patients (pts) is based on handwritten progress notes. We have used a commercially available pocket size electronic organizer with 128Kb memory to store daily pts notes. The organizer is backed by personal computer (PC) via a PC link interface. This information can be printed and placed in the chart, transferred to another physician's organizer or to a personal computer in the office which can be accessed by a modem. During the period 4/90 to 9/91 we have collected 330 records on hospitalized cardiac pts. The average cumulative file size was 1.3Kb.

The information on individual pt provided us with:
1) A continuous access to pt data, independent of the chart.
2) Rapid and accurate formulation of a discharge summary.
3) Update of the office file with hospital information.
4) Easy recall of information on rehospitalized patients.
5) Improved billing information.

This information system which is easy to use, is the first stage in eliminating the problems of illegible handwriting and provides new dimensions in efficient management of hospitalized cardiac pts. It serves as a bridge between the patient's chart and the medical office software packages, and links the bedside environment to the doctor's office. With further development, this system should become a front end of computer assisted pt management.

988-120

## A POWERFUL MULTI-LAYERED RELATIONAL DATABASE AND REPORT GENERATOR FOR THE ECHOCARDIOGRAPHIC LABORATORY

Jiri Sklenar, Martin T. Phillips, Sanjiv Kaul.
University of Virginia, Charlottesville, Virginia.

We have created a database for the echocardiographic laboratory which has the following features: a) >500 demographic, administrative, and clinical variables structured in a multi-layered format using INGRES; b) relational structure linked both to anatomic and pathologic entities; c) a user-friendly interface with screens that are similar to laboratory worksheets; d) default values for all variables and error checking for numerical variables; e) flexibility to provide data entry relevant only to the particular examination without having to be queried for all variables; f) educational information is also available for each anatomic and pathoplogic entity at the stroke of a key, which contains a brief description and a relevant bibliography - cross-reference and direct access to MEDLINE is also provided; g) automatic billing and report generator, the latter uses WORDPERFECT and has both graphic and text capabilities; h) flexible report format depending on the extent of pathology found, and apart from presenting quantitative data and abnormal findings, the report also specifically answers the clinical question being asked; and, i) interface to statistical packages for purposes of research.

In conclusion, we have developed a powerful, multi-layered, relational database for the echocardiographic laboratory with sophisticated report generation and educational and research capabilities, at the same time providing a very user-friendly interface.

# 868 Physiology/Image Analysis

Thursday, April 16, 1992
9:00 AM–12:30 PM
Dallas Convention Center
Booth 1340

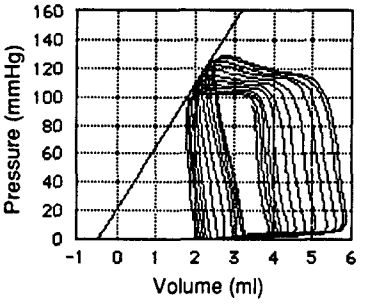
868-1

## ACQUISITION AND ANALYSIS OF THE LEFT VENTRICULAR PRESSURE-VOLUME RELATIONSHIP USING LABVIEW

Steven C. Cassidy, David F. Teitel. The Ohio State University and Children's Hospital, Columbus, OH

Analysis of the left ventricular end-systolic pressure-volume relationship and calculation of indices of function to date have been very labor intensive. To automate acquisition and analysis of pressure-volume data in the laboratory, we used LabVIEW, an icon-based programming language for the Macintosh, to create various applications. The first application is used to acquire data by analog-to-digital conversion of analog pressure and volume signals. Data are then graphically displayed to insure that they are of adequate quality for analysis. Another application is then used to evaluate left ventricular systolic function. This application uses the iterative technique for defining end-systole, calculates end-systolic elastance from end-systolic pressure-volume points, calculates stroke volume, ejection fraction, stroke work, maximum and minimum derivative of ventricular pressure, and heart rate. Pressure-volume loops and the end-systolic elastance regression are then graphically displayed (Figure). This program exports indices of function and pertinent pressure-volume data from each beat to a text file. These applications have helped to automate and speed the process of evaluating ventricular function using pressure-volume relationships.

FIGURE




868-2

## Results of Frame-by-Frame Curvature Difference Ventriculogram Analysis

Edward Marcus , C. Michael Gibson , Judith Gwathmey
Beth Israel Hospital, Boston, Massachusetts

A curvature difference computer model describing frame-by-frame shape change characteristics of the left ventriculogram has been developed. This frame-by-frame model predicts three characteristic shape change regions during systole: apical, apical lateral, and lateral regions where concavity change is positive, positive to negative ,and negative respectively. We have analyzed ventriculograms with the frame-by-frame method for 20 patients listed in the Beth Israel Hospital data base as having normal left ventricular function. Of the twenty assumed normals studied, sixteen were identified by the model as normal and four did not match model assumptions. Review of patient charts on the four computer identified abnormals indicated :

patient #1 - coronary fistula
patient #2 - mitral stenosis
patient #3 - coronary artery disease
patient #4 - no coronary or valvular disease

In all four computer identified abnormal patients, normal ejection fractions (EF=76.5 ± 11) were observed and model detection of abnormalities were flagged by the computer during mid-systolic intervals. These results strongly indicate that frame-by-frame curvature difference modeling detects the subtle influence of coronary and/or valvular pathologies on mid-systolic ventricular shape change of patients with apparently normal completed wall motion.

## 868-3

**SHAPE FEATURES MATCHING AND LV WALL MOTION ASSESSMENT.**

Maurizio Baroni@,Giuseppe Barletta*,Anna Toso*,Flavio Venturi*,Fabio Fantini*. @Department of Electronics Engineering, *Cardiology Unit,University of Florence-Italy

Curvature (C) analysis of LV contours is able to separate normal and abnormal cases at specific cardiac phases. Moreover, since LV shape changes smoothly in both time and space it seems reasonable to assess wall motion by matching C features frame-to-frame. To this aim the LV contours (RAO cineangiography, 25 f/s) were manually digitized in 16 normal subjects and 9 CAD pts who underwent two consecutive ventriculographies. C was estimated by approximating the sequences of rectangular coordinates with an adaptive Fourier series. The points of local maximum and minimum C were detected along each contours, tracked frame-to-frame and extrapolated if necessary throughout systole. Some of these feature trajectories were discarded being in contrast with physiologically based criteria; the others, though in small and variable number, provided reference markers for the 2nd step of the algorithm. This takes into consideration 90 equispaced points on the end-diastolic contour. The points lying between two adjacent markers were mapped onto the next contour proportionally to local displacement and C changes. Starting from these sampled points the local matching was repeated till the end-systolic contour.In this way, segment shortening is assigned in the case of inward displacement and C decrease; segment expansion is assigned in the case of outward displacement and C increase.

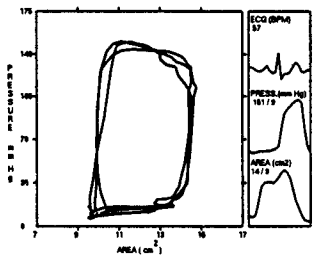
The resulting smooth segmentation is in close agreement with cardiologists' judgement,unlike other wall motion methods (radial shortening, centerline model).

## 868-4

**ON-LINE INTEGRATION AND DISPLAY OF VENTRICULAR PRESSURE-AREA RELATIONSHIPS USING ECHOCARDIOGRAPHIC AUTOMATED BORDER DETECTION**

Lee G. Deneault, Thomas A. Gasior, William A. Mandarino, Wilfred Lee-Foon, David M. Prater, John Gorcsan III.
University of Pittsburgh, Pittsburgh, PA

Left ventricular (LV), pressure-volume relationships have been utilized to accurately define both systolic and diastolic ventricular function. Unfortunately, there are difficulties with acquiring on-line LV volume measurements, and an invasive procedure is required to obtain these data. Echocardiographic automated border detection (ABD), can now provide instantaneous measurement of LV cavity area by automatically outlining endocardial borders. By using ABD echo area as an index of LV volume, the objective was to generate on-line pressure-area loops which should reflect pressure-volume relationships. The process was automated by an Apollo DN 3550 graphics workstation along with SignifiCAT hardware and software. The analog ABD echo area signal from a Hewlett-Packard Sonos 1500 system was concurrently sampled, displayed, and stored through a customized interface. LV pressure signals were integrated using specialized data acquisition software and graphics routines written in 'C' and 'X' windows. ECG, pressure, and echo area signals along with pressure-area loops were displayed in real-time. An example of 3 consecutive beats is shown from a patient with normal LV function. The mid-LV level was used for ABD echo area, and pressure was measured with a micromanometer catheter.




In conclusion, pressure-area loops can be acquired and displayed on-line using echo ABD coupled with the Apollo workstation. Its potential application to the understanding of pressure-volume relationships and LV function is promising.