Abstracts of Original Contributions: Computer Applications Program

The Computer Applications Committee began as a task force in 1982 and became a full-standing committee of the College in 1983. This year marks the tenth anniversary of this committee and the ninth year in which we are sponsoring educational activities at the ACC Annual Scientific Session.

The abstract process began in 1989. For 1993, a total of 52 abstracts were accepted for presentation. Ten will be presented at a special abstract session on Sunday afternoon, March 14. Twenty-eight will be demonstrated at the Computer Applications Booth in the Exhibit Hall from March 15 to March 18. Fourteen will be presented along with the regularly scheduled poster sessions.

Computer abstracts are graded by the members of the Computer Applications Committee. Many innovative programs using computers are being developed for the cardiovascular community, and we appreciate the interest and effort of all those who submitted abstracts.

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

439 Part I: Neural Networks and ECG Applications

Sunday, March 14, 1993
2:00 PM–5:00 PM
Anaheim Convention Center
Room C-2

439-1 2:00

The Influence of Multiple Output Neurons on the Interpretation of the Electrocardiogram using an Artificial Neural Network.

Willem RM Dassen, Jeffrey C Osborne, Karel den Dulk and Rob GA Mulleneers. Dept of Cardiology, University of Limburg, Maastricht, The Netherlands.

Artificial neural networks (NN) have recently been applied in making single diagnoses based on the ECG. It is unclear however what happens if one NN is trained to make multiple evaluations, like in the complete interpretation of the ECG. To evaluate whether training the network for a second item will influence the training for the first item, the following experiment was performed. Based on a set of 97 ECGs, for which the presence or absence of the diagnosis acute inferior myocardial infarction (IMI) was proven by other techniques, a NN was trained, using 57 cases, each containing 80 ECG measurement parameters, during 250 runs with a training error of 0.05. The remaining 40 cases were used for evaluation of the trained network. By varying the certainty by which the diagnosis acute IMI should be confirmed or excluded, the ROC curves could be calculated. Requiring a certainty of 90 % the correct diagnosis was made in 37/40 cases. Thereafter an artificial second output variable was defined, and calculated as the sum of the peak-to-peak QRS amplitude in lead III and aVF, for both the training and the test set. In the test set the correct classification of the infarct was not influenced by the concurrent determination of the additional output value. Subsequently, in a stepwise increasing number of ECGs in the training set, this second parameter was no longer calculated but randomly selected and therefore did not contain any information, making it deliberately more difficult to learn the relation between these two variables and the artificially created output variable. After each step the network was trained again as described above and evaluated using the same test set. This impairment to learn to predict this second variable did not influence the diagnosis acute IMI in a negative way.
CONCLUSION: This study showed no disadvantage in training a NN to make multiple interpretations simultaneously. The application of a single NN for each diagnosis however makes it more easy to maintain a well-defined training set as gold standard.

439-2 2:15

Combination of Deterministic Logic and Artificial Neural Networks in the Diagnosis of Atrial Fibrillation

Ten-Fang Yang , Brian Devine , Peter W Macfarlane
Royal Infirmary, Glasgow, Scotland, U.K.

It is often difficult for computer software based on deterministic logic to differentiate between atrial fibrillation (AF) and sinus rhythm (SR) with atrial premature beats (APBs) and/or ventricular premature beats (VPBs). For this reason, it was felt worthwhile to investigate the application of software based neural networks (NN) for the detection of AF. In particular, it was desired to know if the combination of NN with the interpretation produced by the Glasgow Program would bring enhanced benefit.

The Glasgow Program for ECG diagnosis uses 3 leads for interpretation of cardiac rhythm. From these 3 selected leads, measurements on PR interval variability, RR interval regularity, presence or absence of discrete P waves, presence or absence of multiple P waves as in AF, are determined.

716 ECGs were selected for a training set. 523 had AF and 193 had SR + (APBs and/or VPBs). These ECGs, with appropriate classification, were fed to a variety of NN containing a different number of input variables and various numbers of neurons in the hidden layers but all with a single output neuron. The training process was performed through the back-propagation mechanism. A test set containing 717 cases with 523 AF and 194 SR + (APBs and/or VPBs) was then studied. The NN with the best performance was found to have 9 input variables and 2 hidden layers each with 50 neurons. For the Glasgow Program, the sensitivity and specificity of the test set were 86.2% and 93.8%, and for NN, 89.9% and 92.8% respectively.

To combine NN and the Glasgow Program, the NN result was accepted if it were AF. The result of Glasgow Program was then accepted for those cases not reported as AF by the NN. In this case, the sensitivity was 92.3% and specificity was 90.7%. Using the reverse procedure, whereby the result of Glasgow Program was accepted if it were SR + (APBs and/or VPBs), and the NN result was thereafter accepted for the remainder, the sensitivity was 83.7% and specificity was 95.9%. Other methods of combination did not enhance the results. It should be noted that specificity refers to SR + (APBs and/or VPBs) and not to regular SR.

In conclusion, the combination of NN and deterministic logic does not lead to any appreciable gains in the diagnosis of AF compared to either alone.

439-3 **2:30**

Use of pacemaker memory capacities in the study of arrhythmias

S. Kutalek, R. Nitzsché, J.L Bonnet, G. Lascault, M. Limousin
Philadelphia, Montrouge, Ivry/Seine.

Current cardiac pacemakers have large memory capacities which allow them to store various significant data. In addition to standard "internal statistics" which provide more information on the pacemaker behavior (percentage of atrial and ventricular paced and sensed events) than on the patient's rhythm, some current pacemakers can also store detailed information on arrhythmias. Such a function is called an "implantable" Holter system. It provides trends or histograms of variations in atrial and ventricular intervals, coupling times of premature beats, etc. and can be accessed via the programmer.

However, interpreting such data may prove complex because they are translated, following pacemaker logic, into a language which is difficult to understand. For instance, the definition of premature beats provided by the pacemaker differs from that of the physician. This is the reason why a program designed to facilate the interpretation of stored data and draw clear and thorough conclusions has been developed for Chorus pacemakers.

Moreover, current standard pacemaker "Holter" functions do not always meet the physicians' needs. To make up for this, a program to analyze the heart rhythm, which can be loaded into Chorus pacemakers after implant, once the physician has a better knowledge of his patient's pathology, has also been developed. This program analyzes bradycardia, sinus pauses and paroxysmal atrioventricular block and stores marker pulses and statistics, when any of these events is sensed by the pacemaker. The criteria for identification of these events can be programmed.

In the long run, the pacemaker is to become an implanted laboratory for rhythm analysis using programs which only store relevant data. Specific software will provide an aid to interpret them.

439-4 **2:45**

Software Based Use of Minnesota Code Criteria for Serial ECG Classification in Large Scale Clinical Trials

Beaver Tamesis, Art Terry, Kim Russell, Karen Stocke, Debbie Kargl, Robert D. Wiens, Pentti Rautaharju, Bernard R. Chaitman, Saint Louis University, St. Louis, Missouri

Bias free serial ECG comparison is an important component of large scale cardiovascular clinical trials comparing different treatment strategies and their impact on frequency of myocardial ischemic and infarct events. Saint Louis University serves as a core facility for several National Institute of Health sponsored clinical trials which apply serial ECG comparison using standard Minnesota code. Hard copy or electronic ECG acquisition from clinical units are sent to the core facility, and measurement of QRS, ST and T wave items are performed by nonphysician coders. The digitized measurements are entered with patient information, ECG date and time, and quality control parameters into an Ingres data base matrice using "C" programming with embedded Structural Query Language (SQL) on a DEC 5100 system using Ultrix 4.1. Minnesota codes are generated for the anterior (V1-5), inferior (II, III, aVF), and lateral (I, aVL, V6) lead groups and are over-read by nonphysician coders. The serial comparison program identifies the most recent ECG and compares it with the tracing immediately preceding in the patient's file, and serial comparison of Minnesota codes are performed. The hierarchal classification of Q, ST, and T wave items are based on the NOVACODE program developed by Rautaharju and colleagues. Progression, regression, and no change, of Q, ST, and T wave items are generated and a printout of sequential ECG comparisons for individual patients are obtained. Minor and major changes are over-read by physicians using a set of coding rules adjusting for minimal interval change that cross Minnesota code threshold resulting in progression codes. The software program permits modification to the serial Minnesota code comparison while maintaining the original measurement matrix. The rest ECG serial comparison program has been used to analyze more than 34,000 ECGs with rapid identification, review, and analysis of serial ECG changes.

439-5 **3:00**

Recurrence Analysis of Heart Rate Variability

Joseph P. Zbilut, Charles L. Webber, Jr., Paul A. Sobotka, Henry Loeb. VA Edward Hines, Jr. Hospital, Hines, IL.

The field of nonlinear dynamics ("chaos" theory) has produced much interest in the application of its methods to cardiac variables such as heart rate variability (HRV). Unfortunately, the standard invariants used to quantify dynamical systems, namely fractal dimension and entropy, have very strict assumptions regarding stationarity, data length, and noise level, which militate against their clinical usefulness. An alternative nonlinear method which is primarily diagnostic is that of recurrence analysis (RA), whereby a suitably embedded variable is empirically quantified for complex periodicities. Data points which "recur" in a small neighborhood of other points in a multidimensional system are calculated, and can exhibit significant state changes in HRV. A program in C for MS-DOS computers was developed which calculates, counting statistics (mean, standard deviation, coefficient of variation), power law and recurrences (and related values). The program is interactive, allowing for choice of data points, embeddings, delays and recurrence neighborhood. Color-coded plots of recurrences are also available.

Preliminary tests have demonstrated larger effect size as compared to more traditional methods of quantifying HRV, such as counting statistics; and moreover, avoids the usual confounding problems encountered by linear techniques, such as power spectrum. RA may be useful as a routine diagnostic monitoring tool for evaluation HRV.

439-6 **3:45**

Three-dimensional Echocardiography: The Ratio of Infarct Surface Area to Subtended Ventricular Volume - A New Method for Assessing Infarct Dilation and Aneurysm Size by Polyhedral Surface Reconstruction

Donald L. King, Aasha S. Gopal, Klaus Schröder, Rolf Schröder, Peter M. Sapin, Columbia University, New York, NY

Echocardiographic measurement of infarct/aneurysm size would aid patient selection for aneurysmectomy by providing a means to quantitatively assess the non-functional portion of ventricular volume. Additionally, a non-invasive method for studying ventricular re-modeling is important for guiding patient management in the thrombolytic era. Current two-dimensional echocardiographic methods of estimating infarct surface area require the use of geometric and image plane positioning assumptions. To eliminate these assumptions, we have developed a three-dimensional echocardiographic method which uses an acoustic spatial locator to register the position of images in a three-dimensional coordinate system. A series of non-parallel, unequally spaced, non-intersecting short axis images are digitized and saved in computer memory together with their spatial coordinates for boundary tracing. Endocardial boundaries are traced and infarct margins are marked. The ventricular surface is then reconstructed by polyhedral approximation using a series of triangles. By summing the areas of the triangles, total endocardial and infarct surface areas are obtained. The volume subtended by the infarct may be arbitrarily defined and computed in two ways: 1) Chord method - By joining the margins of the infarct in each slice; 2) Sector method - By joining the margins of the infarct in each slice with the centroid of that slice. The infarct/aneurysm volume by each method is then computed using our previously described tetrahedron algorithm. The ratio of infarct volume to infarct surface area will increase as the infarct becomes aneurysmal. In vitro studies of our method have demonstrated an accuracy for computing infarct surface area in the range of 1-3%. The tetrahedron volume computation algorithm has previously been validated in vitro and in vivo with a similar accuracy range.

Conclusion : Three-dimensional echocardiography provides a means to measure infarct surface area and the volume subtended by the infarct. The relationship of the subtended volume to infarct surface area and to total surface area and volume may provide a more precise, quantitative index of the degree of aneursym formation.

439-7 **4:00**

Preprocessing of radio-frequency echo-cardiographic data.

Bart Bijnens, M.C. Herregods, Paul Suetens*, Frans Van de Werf.
Department of Cardiology, University Hospital Gasthuisberg, Leuven, Belgium.
*Department of Electrical Engineering, ESAT, Katholieke Universiteit Leuven.

In this paper we describe a software package that we developed to support myocardial tissue characterization using the radio-frequency (RF) data produced by echocardiography.
If information of a cross-section during a complete heart-cycle is needed, the first problem to overcome is acquisition. Due to the high frequency used in echography (typically 5 MHz), and the large amount of data (B-mode echography is working with ~ 30 images per second), special hardware is needed.
We use a dedicated image processing system with a large image memory to sample the RF-data resulting in 16 Mb of data (one heart-cycle).

In order to process this large data-set, we have written a software package in C, on an IBM RS6000 workstation based on X-windows. This software makes use of the image processing library LUCI, written at ESAT.
Our program uses the sampled RF-data as input. In a first stage the raw data are converted into the "normal" sector image so that the cardiologist can recognise the anatomical structures. This conversion consists of the following steps: compensation for attenuation (= depth-gain compensation), demodulation if required (using FFT) and transformation from rectangular into triangular shape. Next, a contour is drawn around a region of interest (ROI) (for example on the septum). This ROI can be of arbitrary shape so that it becomes possible to indicate only the inner part of the muscle, avoiding the large reflection peak at the interface blood-pool and tissue. Finally, after indication of the ROI in all slices of the heart-cycle, a file containing only the raw data of that ROI, is produced.
Special attention was given to the user interface, which consists of a MOTIF based control-panel. At every stage of the process it is possible to look at other time-slices or display the slices in a cine-loop to see the motion of the heart.

Using the above approach it is possible to implement all available image-processing algorithms for presenting and processing the data. For example, (before indicating the ROI) colourmap manipulation, contour delineation,···, or, (after determining the data of interest) statistic analysis using the commercially available package MATLAB (able to process and plot matrices), even as convolutions, correlations, FFT,···.

439-8 **4:15**

Neural Network Program to Distinguish the Echocardiographic Pixel Pattern in Children with AIDS.

Cheryl Main, Daniel M. Shindler, George R. Kuntz, Larry Frenkel, Norman Sissman, John B. Kostis. Robert Wood Johnson Medical School, New Brunswick N.J.

Neural networks simulate the cognitive process. They can be trained to recognize complex patterns. We used pixel luminance patterns of M-Mode echocardiograms in children with AIDS to train and test our network program. Twenty AIDS patients and ten normal controls were used to train the network to assign -0.4 to AIDS and +0.4 to normals. The network was then tested on 132 AIDS patterns and 46 normal patterns from different patients and controls. The means and standard deviations of the test population as interpreted by the network are presented below. The patterns of the anterior ventricular septum and the posterior left ventricular wall were tested separately.

LV WALL	AIDS (-0.4)	NORMAL(+0.4)
ANTERIOR	-0.31 +/-0.26	+0.14+/-0.42
POSTERIOR	-0.29 +/-0.30	+0.06+/-0.4

Our program is available as freeware with source code. It is written in C language. It consists of: 1) TIFF image file reader that selects and extracts patterns from a QRS gated M-Mode region of interest 2) backpropagation neural network that can be trained and tested on the extracted pixel luminance values.

439-9 **4:30**

Enhanced Coronary Arterial Calcification Quantification by FastCT

Judd E. Reed, Barbara L. Kruger, Patrick Davitt, John A. Rumberger, Patrick F. Sheedy II, Mayo Clinic, Rochester,MN

Interest in quantification of coronary calcification via Fast-CT and its correlation to severity of coronary atherosclerosis is increasing. Repeatability trial results for this procedure have been published. Data are inconclusive, but it appears that while the presence of coronary artery calcification detected by Fast-CT is indicative of coronary atherosclerosis, quantitative grading of calcification extent may lack reproducibility due, in part, to the arbitrary nature of the current "scoring" technique. An alternate technique was developed where the operator identifies the coronary arteries with a three dimensional graphics editor. Attenuation coefficients of all samples (voxels) within a specified radius of the vessel midlines and their location relative to both the vessel and the scanner are stored in a relational database. Scoring by a variety of algorithms is performed as queries of this database without resorting to tedious delineation of each lesion as required by the original technique. Since the operator identifies gross coronary anatomy, this system is easier to use and more reliable. Simple "scoring" criteria identical to those used by the vendored system were employed to validate the new system. Six scans were evaluated with both techniques. Correlation is excellent (slope=0.973, R.Sq.=0.996). Other scoring algorithms were also tested. Preliminary results indicate that the reliability of "calcium scores" can be improved by eliminating arbitrary density and area thresholds, and by correcting for inter-scan patient motion. CONCLUSION: This alternate quantification technique, along with improvements in the scanner performance and refinement of the scanning technique should lead to significantly improved reliability of coronary calcification assessment via Fast-CT.

439-10 **4:45**

Importance of the Conductive Anisotropy of Myocardial Tissue for Computer Modelling of Defibrillation Shocks

Marek Malik, Karel Smits.
St. George's Hospital Medical School, London, England, and Bakken Research Center, Maastricht, The Netherlands

In order to optimise the electrode positions, repeated attempts have been made to simulate the distribution of potentials and currents within the myocardial and other thorax tissues during the defibrillation shocks. All models reported so far have been based on various simplifications. Specifically, they considered the thorax tissues as electrically isotropic.

To investigate whether such an assumption is permissible, a simplified 2D model of thorax cross-section has been developed which compared isotropic and anisotropic myocardial images. The model is composed of 33885 elements in a circular plane with a central ring representing the left ventricle. The tissue is imaged by a discrete network of connectors and described by equations corresponding to Kirchhoff laws. In all experiments, a heterogeneous structure was used with different conductivities for myocardium, lungs, and blood. Each experiment was computed twice: with isotropic myocardium, and with anisotropic myocardial image in which the conductivity along the fibres was 2.25 higher than across.

A total of 500 experiments has been conducted simulating a scale of combinations of surface, epicardial, and transvenous electrodes. For each experiment, the mean and standard deviation of the anisotropic/isotropic proportion of myocardial currents was computed. The mean of such ratia ranged from 0.93 to 1.28; the maximum standard deviation of these ratia was 0.37.

The model showed that the electrical anisotropy of myocardial tissue significantly determines the distribution of defibrillation currents and cannot be ignored in studies simulating the defibrillation shocks.

462 Computer Assisted Instruction I

Monday, March 15, 1993
9:00 AM–12:30 PM
Anaheim Convention Center
Booth 2365

462-1

DIAGNOSIS OF CORONARY ARTERY DISEASE USING NEURAL NETWORKS

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

A connectionist expert system derived from a neural network model has been used to classify patients as to degree of coronary artery disease. The heart of the neural network approach is a learning algorithm which determines weighting factors for potential contributing parameters through analysis of data of known classification. The learning algorithm used here was developed by the authors and utilizes a non-statistical approach to supervised learning. The algorithm generates a non-linear decision surface which divides cases into two or more categories. In this application, four categories are considered: no disease, one, two, or three vessel CAD. The neural network determines the relative importance of each parameter by attaching weights to each. While the general neural network must be trained on a computer, the resulting decision surface can be entered in a programmable calculator to facilitate classification of new cases. Models have been established using standard exercise testing data (ETT) as well as thallium scans, resulting in correct classifications ranging from 85 to 90%. Variables recorded included: age, resting heart rate, resting blood pressure, resting ECG results (coded), exercise parameters including time of angina, heart rate and blood pressure at onset of angina, time of 1 mm ST↓, total duration of exercise, heart rate and blood pressure at end of exercise, total duration of chest pain, total duration of ST↓, reason for stopping exercise. The most important parameters were found to be: percentage change in heart rate from beginning to end of test, maximum ST↓, percentage change in blood pressure from beginning to end of test, peak double product. The program is written in C and runs on a variety of computers, including the IBM-compatible microcomputers. It has the potential of accurately identifying extent of CAD based on clinical and exercise test parameters.

462-2

Electronic Textbook in Human Physiology: The Cardiac Cycle

Naomi C. Broering, Lawrence S. Lilienfield
Georgetown University Medical Center, Washington, DC

The Georgetown University Medical Center Library was awarded a U.S. Department of Education grant in collaboration with the Physiology Department of the Medical School to create an "electronic textbook." The purpose of the project is to enhance learning and visualization by developing a prototype knowledge base of core instructional materials stored in digitized format on Macintosh computers. To launch the project it was decided to focus on the cardiovascular system by building an initial model to be used as the foundation for other physiology components. The first section of the Electronic Textbook combines into one source the major instructional materials needed by students, i.e., faculty lecture notes, text, illustrations, animation, simulation, glossaries, slides, and sound. This self instructional program is based on the principle that certain physiological concepts need to be translated by the human brain into dynamic images from the static pictures and words with which they are presented. Computer graphics and the animation designed on the Macintosh allow detailed demonstration of physiologic concepts in color. Associated with the animations are heart sounds and full text. The student is able to study, in detail, the moving heart and can step through the animations so as to focus attention on necessary detail. The program includes examples of 5 part multiple-choice questions with immediate feedback response to selected answers. Today, the project includes chapters on cardiovascular, renal and endocrine systems. The electronic textbook has been used for two years by the medical students. Response has been unanimously positive.

462-3

Multimedia Computer Textbooks in Cardiology

Michael S. Gordon, University of Miami, Miami, FL; Gordon Ewy, Joel Felner, Ira Gessner, David Lawson; Joan Mayer, Abdul Sajid, Clarence Shub, Robert Waugh.

The University of Miami Medical Training and Simulation Laboratory has developed computer assisted instruction (CAI) textbooks in cardiology over the last decade with "The Harvey Group", a consortium of cardiologists from Arizona, Duke, Emory, Florida, Illinois and Mayo. Multimedia features include computer and video graphics, laserdisc video and digitized audio. Patient-centered lessons present the history, bedside findings (appearance, arterial and venous pulses, precordial impulses and auscultation), laboratory data (ECG's, X rays, echoes, scintigraphy, angiograms), therapy (including videos of surgery) and pathology.

Teaching features include versions that stand alone or are linked to "Harvey", the Cardiology Patient Simulator, and each may be used in small groups or by an instructor in a lecture hall. The latter presents over twenty menu choices from the patient evaluation, from auscultation to real-time echoes. Students and instructors are provided with grades, an assessment of wrong answers, the number of discussions chosen, the time to complete a lesson, and a performance analysis compared to a national multicenter study.

Pilot studies of over 250 students, residents, fellows and physicians at Miami and Emory carried out from 1988 to 1991 defined problems ranging from excessive program length to equipment malalignment of ECG's and X rays. These were addressed, and a formal multicenter study of 182 senior medical students was carried out during the 1991-92 academic year at Arizona, Duke, Emory and Miami. There were 477 responses to a questionnaire for the first five lessons (normal and 4 valve lesions), 72% for the stand-alone version and 28% for that linked to "Harvey". An average lesson was 60 minutes, the average grade was 70% and 60% elected discussions. Over 90% felt the programs improved their bedside skills, feedback to incorrect responses and discussions were very helpful and rated CAI superior to other teaching systems.

Based on the data described, we shall continue to develop a full curriculum of CAI programs in cardiology.

462-4

EKGenius

Stephen Dubin, Aggie Butler, Douglas Hanes
Drexel University, Philadelphia, Pennsylvania

EKGenius was developed at the Biomedical Engineering and Science Institute at Drexel University with support from Cardiovascular Credentialing International (CCI) to provide a computer-interactive learning environment in electrocardiography for the cardiovascular specialist. EKGenius is a self-paced interactive program which provides a comprehensive review and assessment in electrocardiographic principles, 12-lead EKG interpretation, and arrhythmia detection.

An authoring system was designed to facilitate interactive lesson design, question development, and graphical presentations. Electrocardiograms were scanned from actual clinical tracings and are depicted in high resolution graphic mode in order to display specific features associated with different abnormalities. Specific graphical formats for rhythm strips and 12-lead electrocardiograms are displayed in a realistic manner.

The program is menu driven and combines a simulated examination, tutorial lessons, and practice quizzes. In the exam mode, 50 questions are randomly selected from a bank of 250 questions. The program provides the user with the results at the end of the exam, and the user has the option to review incorrect responses with the associated lesson plans. In the quiz mode, 10 questions are selected from the bank in the category determined by the user. Immediate feedback is provided with each response, and the user has the option of receiving a hint or reviewing an associated lesson. A mode is also available to view the tutorial.

463 Image Analysis I—Coronary Angiography

Monday, March 15, 1993
1:30 PM–5:00 PM
Anaheim Convention Center
Booth 2365

463-1

Quantitative Coronary Angiography: An Inexpensive and User Friendly System.

J. Larry Klein, Sara Gatlin, Steven V. Manoukian and Spencer B. King III. Emory University School of Medicine, Atlanta, Georgia.

Despite the universally accepted fact that there is tremendous inter and intra observer variation in the visual interpretation of coronary angiograms, quantitative coronary angiograpy (QCA) is not widely utilized. A major factor for this lack of use relates to the high cost and the extreme user unfriendliness of most systems. We have developed a system which is quick, easy to use and relatively inexpensive. The system can run on any Macintosh™ II computer with 8 bit graphics. Cine film is digitized using a video digitizing board. The images can be enhanced and analyzed using the public domain NIH image software developed by Wayne Rasband. We have modified the software to facilitate the measurements routinely made. The data can be copied and pasted into a spreadsheet program and formatted for printing of reports. In addition, we have developed the ability to incorporate the data into an extensive data base program so that large loads of clinical data can be easily recalled, reported and analyzed. This system is currently being employed in the Lovastatin Restenosis Trial and the core laboratory for the Medtronic Wiktor™ Stent. For these two trials all images are stored on low cost optical drives, allowing us to recall any pre- or post-intervention image to insure that similar views and normal segments are analyzed. The system costs less than $10,000 including computer, digitizing board, laser printer, monitor and software. The system has all the benefits of the easy to use Macintosh™ and we have trained our fellows and technicians, who have become proficient with its use after just a few hours of practice.

463-2

Computerized Texture Analysis of Coronary Angiograms

Sean T. Gloth, Mary J. Flynn, Gary Gerstenblith. The Johns Hopkins Medical Institutions, Baltimore MD.

Angiographic morphology of coronary artery stenosis has been described using both quantitative and qualitative descriptors and correlated with the likelihood of interventional success as well as anginal pattern. Current techniques use the edges of the coronary lumen to describe the stenosis morphology. We developed a computer program to investigate a group of image processing algorithms, texture operators, not previously tested. These operators use information not only from the lumen edge but the pixel density in the lumen as well.

Digitized images of coronary angiograms are read and displayed in 256 gray scale, 200 X 320 mode using standard monitor and VGA card on MS-DOS computer. In a menu driven system the user selects a region of interest and applies the chosen texture operator using a pointing device. Output is sent both to the screen for immediate feedback and to an ASCII file suitable for statistical analysis as well as surface mapping.

The program demonstrates the ability of the MS-DOS VGA graphics to display and manipulate cardiac images. This system provides an interactive environment to apply the descriptive capability and test the predictive value of texture operators to coronary artery morphology.

463-3

Computer Program for Automatic Quantification and Display of Arterial Geometry and Morphology in Intravascular Ultrasound Imaging

Nenad S. Amodaj, Rade M. Babic*, Miodrag C. Ostojic*, Miodrag V. Popovic**. Faculty of Technology, *Institute for Cardiovascular Diseases, **Electrical Enginering Faculty, Belgrade, Yugoslavia

Intravascular ultrasound provides two-dimensional images that accurately demonstrate both geometry and morphology of the arterial lumen. Our program uses a combination of region and boundary extraction image analysis algorithms to automatically segment image into different tissue regions and extract endocardial boundaries in normal and diseased arteries. Tissue region discrimination is provided by color encoding. The medio-adventitial boundary was most consistently detected in the studied cases. Luminal diameters, luminal area and eccentricity index is calculated automatically. In addition, if the user selects the reference diameter, percentage stenosis data are calculated as well.

By the automatic arterial change measurement during the entire cardiac cycle, and by combining these data with the corresponding measured intraarterial pressures it is possible to get a graphical representation of vessel elastic properties.

The program is PC based and operates in Microsoft Windows environment. It is highly interactive and easy to use. Program accepts images stored to disk by commercial frame grabbers connected to VCR or directly to imaging system. Measurement data can be directly transferred to Windows based spreadsheet or database programs using Clipboard feature.

463-4

Determination of Long-Term Outcome in Patients with Coronary Artery Disease Using an Artificial Neural Network

Ananda R. Jayaweera, Keith C. Drake, Robert Abbott, Sanjiv Kaul. University of Virginia, Charlottesville, Virginia

The determination of outcome is an integral part of evaluating patients with known or suspected coronary artery disease (CAD). Clinical ± stress test (with or without cardiac imaging) ± coronary angiographic data are usually evaluated for this purpose and outcome is determined by the degree of abnormality found in one or more variable. Since a conglomeration of abnormalities determines outcome, we postulated that an artificial neural network (ANN) could be 'trained' to determine outcome. Accordingly, 13 clinical, exercise EKG, Thallium-201 imaging, and coronary angiographic variables were collected from 440 patients undergoing medical management who were followed up for a mean of 4.2 ± 2.2 years. Nonfatal MI and death were considered adverse events. Patients were divided randomly into two groups of 220 each. The ANN (AbTech Corp.) was alternatively trained on one group and evaluated on the other and the results were pooled. The parameters of the network were adjusted to provide the closest agreement between observed and predicted occurrence of events and no events. The 'trained' network was found to have a sensitivity of 85%, specificity of 97%, and a predictive accuracy of 92% for the occurrence of events.

We conclude that ANN can be 'trained' to determine outcome in patients with known or suspected CAD. The added advantages of such an approach are: a) the results are predictable and do not differ based on the physician evaluating the patient; and b) as more data are collected, the ANN continues to get 'trained' and thus provides even better results.

966 Computer Applications Committee Original Contributions I

Monday, March 15, 1993
3:00 PM–5:00 PM
Anaheim Convention Center
Hall D
Presentation Hour: 4:00 PM–5:00 PM

966-19

A Semi-Automated Method for the Identification of Atrial Arrhythmia on 24-Hour Electrocardiograms

Baiyan Xie, Francis D Murgatroyd, Marek Malik. St George's Hospital Medical School, London, England.

Current algorithms for the automated recognition of arrhythmia on 24-hour electrocardiogram recordings are based on abnormal QRS complex morphology and proportionate change in successive coupling intervals. These methods have limited sensitivity and specificity for the detection of atrial fibrillation (AF). Consequently, automated recognition does not allow the separate analysis of, for example, pause length, heart rate trends, and heart rate variability (HRV) during sinus rhythm and AF. Even short episodes of AF introduce considerable artefact into calculations of HRV, so recordings containing AF must frequently excluded from HRV studies.

A package has been developed, in Turbo Pascal language, which exploits the ease with which the trained operator can identify AF visually even from a small-scale printout. A complete printout of a selected channel of a 24-hour electrocardiogram the recording is made, at a resolution of one hour per page: this is then visually inspected for arrhythmia. Confirmation of arrhythmia classification, by referring to a higher resolution display of the recording, is possible but rarely necessary. Using a bitpad, the onset of periods of: (i) sinus rhythm, (ii) frequent atrial ectopy, (iii) atrial fibrillation, and (iv) noise or indeterminate rhythm are entered into a PC-compatible computer. The hour to which the page corresponds is typed in, and the corners marked on the bitpad: the precise timing of each episode is then geometrically calculated and stored in a text file. A list of QRS intervals for the entire recording, downloaded after conventional analysis (on a Marquette Series 8000 system) is then analysed in combination with this file, to produce separate calculations of heart rate, RR interval statistics, and HRV during sinus rhythm and AF.

To verify the precision with which beats could be identified and the two data files combined, 200 ECG complexes, scattered through 10 24-hour electrocardiograms, were each marked by two independent operators. Reference to the original recording revealed that the beat identification was correct in >95% of cases, and correct to within one beat in 100% of cases. In the analysis of 80 24-hour recordings from patients with paroxysmal AF, labelling by this technique added, on average, 20 minutes of analysis time.

966-20

Antiarrhythmic Actions of Verapamil on Circus Movement Tachycardia Using an Atrioventricular Accessory Pathway : A Computer Model Study

Paul H. Fleischmann, Gerhard Stark, Martin Renhardt, Bernhard Tilg, Paul Wach.
Graz, University of Technology, Austria

The antiarrhythmic effect of verapamil in patients with overt Wolff-Parkinson-White-syndrome (WPW) is investigated using a three dimensional celluar automata model of the entire human heart. A 2.5mm grid is used resulting in more then 12,000 elements for modeling the complete heart geometry. The algorithm for calculating the excitation process is based on Huygen´s principle. By including a pathological substrate (e.g. Kent bundle) an orthodromic atrioventricular reentrant Tachycardia (AVNT) is induced by a premature atrial stimulus. In the presence of verapamil conduction velocity in the atrioventricular node (AV) lengthens in a frequency dependent manner. Refractory periods (AV) are prologend including gradual lengthening at short cycle lengths. Without verapamil echo zones lay between the limits of atrial and bypass refractoriness. Following the simulation of verapamil aministration the echo zone changed due to the prolongation of AV-refractoriness. Depending whether the stimulation site was near the Kent bundle or not the inner limit of the echo zone was increased or exceeded the outer limit influencing the induction of Tachycardia.

966-21

Sensitivity of Time- and Spectral-Domain Measures of Heart Rate Variability to Recognition Artefact in the Computerized Analysis of 24-Hour Electrocardiograms

Ruiping Xia, Olusola Odemuyiwa, Francis D Murgatroyd, A John Camm, Marek Malik. St. George's Hospital Medical School, London, England

Measures of heart-rate variability (HRV) in both time and spectral domains have been derived from Holter recordings. This generally involves the computerized recognition of QRS complexes: errors introduced by this automated analysis can be corrected manually , but this is a time-consuming process. This study evaluated the influence of computerized recognition artefact on HRV assessment by five time-domain methods: (1) Standard Deviation of Normal-to-Normal Intervals (NN), (2) Standard Deviation of all Intervals, (3) Percentage of NN Interval Prolongation > 50ms, (4) HRV Index, (5) Triangular Interpolation of the NN Interval Histogram; and by two spectral-domain methods: (6) Fast-Fourier Transformation and (7) Peak to Trough Analysis.

Holter recordings from 557 survivors of acute myocardial infarction were each analysed in three ways: automatically on a Reynolds Pathfinder III system, and both automatically and with detailed manual editing on a Marquette 8000 system. Time-domain calculations of HRV were derived from the results of all three analyses. Spectral-domain calculations of HRV were used to assess low (LF), medium (MF), and high frequency (HF) HRV components from edited and unedited Marquette analyses. Correlation coefficients comparing results derived from the manually-edited analysis to those from the two automated, unedited analyses are shown:-

HRV Parameter	1	2	3	4	5	6	7
Reynolds (uned.)	0.95	0.91	0.94	0.96	0.97		
Marquette (uned.)	0.89	0.91	0.94	0.95	0.96	LF: 0.33	0.38
						MF: 0.40	0.43
						HF: 0.55	0.58

We conclude that time-domain indices of HRV are relatively robust to errors in automated ECG analysis, and of these (4) and (5) are superior to (1), (2), and (3). However, accurate spectral measures of HRV can only be derived from 24-hour ECGs after careful manual verification and editing.

967 Computer Applications Committee Original Contributions II

Tuesday, March 16, 1993
9:00 AM–11:00 AM
Anaheim Convention Center
Hall D
Presentation Hour: 9:00 AM–10:00 AM

967-19

Current Density Reconstruction in the Human Heart from Magnetocardiographic Data.

Bernhard Tilg, Paul Wach, Martin Renhardt, Paul Fleischmann
Institute of Biomedical Engineering, Graz University of Technology, Austria

Since many years the localization of focal electrical events in the human heart from magnetocardiographic data was based on single and multiple current dipole fitting. The multiple dipole solution is only unique by use of m*n-obersavtion points (m ... number of dipoles, n ... degree of freedom of a dipole). Recently the reconstruction of pseudo-current-densities, i.e. the reconstruction of distributed current dipoles in a source plane is employed to localize focal and distributed electrical activities. The algorithm used in our simulations is based on the lead-field-theory and achieves a unique minimum-norm-least-square-solution of the distributed pseudo-current-densities. For the calculation of the magnetocardiogram a computer model of the entire human heart is used. This magnetocardiogram (the normal component of the simulated noise-free magnetic field) in a frontal and a lateral observation plane above the human torso enables us to calculate the distributed current dipoles in parallel source planes. Pseudo-three-dimensional current dipole distributions could be calculated, e.g. to localize an accessory pathway (bundle of KENT) and an ischemic or infarcted tissue in a three-dimensional coordinate system.

This algorithm may be useful as a fully non-invasive diagnostic tool by use of measured magnetocardiographic data for pathological cases like WPW-syndrome, ischemia and infarction.

967-20

DECOMPOSITION OF ARC-LIKE CONVOLUTION OPERATORS INTO 3x3 OPERATORS

Jun-Hua Li, David C. Wilson, and Edward A. Geiser
University Florida, Gainesville, Florida 32610

Matched filters of circular, parabolic, and elliptical shapes were found useful in the search of endocardial and epicardial boundaries for echocardiographic images. Depending on their use, these filters can be shift invariant or shift variant. While the Fast Fourier Transform (FFT) is frequently used to implement shift invariant filters, it is unsuitable for shift variant filters. Further, direct implementations of these filters are not efficient because of their large sizes and because most of the weights of the filters are zero except on the curves.

A systematic analysis is given for the decomposition and optimal approximation of the these filters by a collection of 3x3 invariant filters. Two steps are involved in the process. The first is to optimally approximate the curves as the sum of straight line operators with varying slopes. The second is to decompose each straight line operator into sums and products of 3x3 operators. While the 3x3 computing environment is investigated because of its efficiency and existing hardware support, theoretical analysis indicates that the methods are general and therefore invariant operators of sizes such as 5x5 or 7x7, etc. can also be used.

The decomposition and approximation methods were implemented for a previously developed filter and were tested on a set of images. The results were remarkably similar to the ones obtained using the original filter. Estimates made on better quality images were quite good, although the results on the poorer quality images were not as reliable.

967-21

A Low-Cost System for On- and Off-line Digital Ultrasound Data Transfer Into a Personal Computer

Karl Isaaz, Daniel Winninger, Jean F Bruntz, Etienne Aliot, Hôpital Central, CHRU de Nancy, University of Nancy I, France.

Computer analysis of digitally transferred ultrasound data has become a powerful technique for noninvasive diagnosis of heart disease. Analysis of acoustic properties of the myocardium, detection of endocardial contours, quantitation of pulsed/continuous wave Doppler and colour flow velocity field analysis represent direct applications of this technique. Almost all transducers, display devices and recorders integrated in current ultrasound machines communicate in analog signals and cannot communicate directly with a digital computer. Therefore, an additional device is required (analog-digital converter) which converts the analog signal to discrete numerical values that can be handled by a computer. We propose a simple system which avoids to buy an additional analog-digital converter. The concept is based on the use of the internal analog-digital converter set up on any commercialized video printer which is regularly linked to the echo equipment. In our laboratory, we used the black and white video graphic printer Sony UP-850 which converts the composite video signal input into 6-bit digital data sent to the frame memory of the printer. A simple home-made interface (total cost: US $ 80) permits to transfer the converted digital data (Doppler, Echo imaging) stored in the video printer memory to a personal microcomputer. The advantages of this system are represented by its low cost, the high spatial resolution of the digitization by the video graphic printer (560 x 700 pixels), the possibility of on-and off-line transfer at high rate. Use of a color video printer (like the Sony UP-5000) available on almost all Doppler color flow equipements may allow high resolution (744 x 582 PELS, 8 bits) digital transfer of color flow velocities with no need for acquisition of an additional external analog-digital converter.

464 Computer Assisted Instruction II

Tuesday, March 16, 1993
9:00 AM–12:30 PM
Anaheim Convention Center
Booth 2365

464-1

Contemporary software tools for the evaluation of student performance in clinical simulations of basic cardiovascular disease concepts.

Alina C. Lopo and Ronald H. Stevens.
Department of Microbiology and Immunology, UCLA School of Medicine, Los Angeles, CA 90024.

The strong impact of cardiovascular pathophysiology on other disciplines makes it a focus of integrative problem-solving efforts in medical education. While computer simulations have become a major vehicle for presenting integrated information, there is also the need for sophisticated evaluational tools to determine how knowledge is accessed and utilized during the problem-solving process.

We have constructed multidisciplinary clinical simulations in which students select the information needed to derive a diagnosis. In these simulations, a history and pertinent physical examination findings are provided to the student. This is followed by access to uncued selection of diagnostic procedures and laboratory tests ranging from blood cultures to echocardiography. The student is allowed a predetermined number of attempts at choosing the correct diagnosis from a differential list. Whether or not the correct diagnosis is selected, the problem ends with a summary, in which the pertinent findings are discussed.

Following the students' completion of the problems the user can employ a graphics-based analytical software tool to evaluate the students' problem-solving performance. This software is unique in that it tracks the individual medical student's progress as they progress through the problem. Additionally, performance for the entire class, or user-selected subsets of the class (e.g., students who were not able to reach the correct diagnosis), may also be tracked. Thus, indication of the most common misconceptions and impasses encountered can be readily identified. The presentation will include data on how the simulations were used by 160 second-year medical students and what major conceptual hurdles were encountered in problem-solving. Additionally, we will present how this information can be used to train artificial neural networks which may serve as an electronic critic, guiding students in their problem solving.

464-2

Delivering CVD Knowledge to Health Educators: The Stanford Computer-Based Educator Training Intervention (SCETI)

Beverly A. Simmonds, Joel D. Killen
Stanford University School of Medicine, Stanford, California

The Stanford Computer-Based Educator Training Intervention (SCETI) was designed to educate high school teachers in basic cardiovascular disease risk factor processes prior to delivering a 16-session CVD prevention program to their 9th grade classes. The underlying principles guiding the development of the SCETI program were derived from research examining the use of programmed instruction (PI) in the development and delivery of instructional materials. SCETI was designed to apply the important features of PI: (a) presentation of instructional material in a pre-planned, pre-sequenced order, (b) frequent, active responding by the learner, and (c) prompt feedback of the correct response. SCETI was also designed to incorporate several features afforded by computer-assisted instruction (CAI) in an effort to maximize the effectiveness of the PI-based approach: (a) presentation of information across multiple modalities, (b) motivation for program completion, and (c) immediate access to cross-references.

Seven teachers received SCETI and nine teachers received a traditional half-day training workshop covering the same material. Teachers who received the SCETI program demonstrated significant knowledge gains ($p < .0001$), learned significantly more than did those in the comparison group ($p<.004$), and reported that SCETI was influential in the modification of their own health behaviors. Similarly, students of SCETI-trained teachers appeared to learn more ($p<.05$), exercise more ($p<.001$), and were more likely to select healthier foods ($p<.0001$) when compared to students of workshop-trained teachers.

These results from a small sample of teachers suggest that PI-based SCETI provides an effective means of improving knowledge, may be related to health behavior changes, and may potentially play an important role in the effective implementation of health education programs.

464-3

The Complete ECG Tutor

P. Pincetl, M.D., L. Pacelli, J. Rios, M.D., F.A.C.C.
George Washington University Medical Center Washington, D.C.

Teaching electrocardiography is very faculty intensive. The increasing complexity of cardiology, the limited curriculum time available and the expanding clinical demands on faculty time inhibits experts from adequately conveying this knowledge. A new methodology is warranted.

We have developed a computer-assisted hypermedia tool called ECG Tutor to meet this need. This application, developed using Asymetrix's ToolBook software and the MacroMind Windows Player, operates on MS-DOS compatible 386sx (or higher) computers with VGA graphics and 2 meg. of memory. Development of this application incorporates object oriented programming using the Asymetrix's OpenScript environment and interfaces a "D-Base3" database of digitized patient ECG's.

The modular design of ECG Tutor allows users to interact with the tool at any level of knowledge or clinical experience. The program provides a comprehensive interactive environment that incrementally addresses electrocardiographic information. The novice starts with the very basic concepts such as the lead systems, wave forms, components of the wave, fundamentals of interval or amplitude measurement as well as axis calculation. Once these fundamentals are mastered, opportunity to practice is offered using a collection of ECG's stored.

Abnormal ECG wave forms are introduced along with detailed explanations on their identification, diagnostic criteria and item accuracy. The user is taught ECG abnormalities using a graphic display of vectorial concepts that facilitate understanding. An inventory of practice ECG's is offered. A test is built at each level of expertise.

At the next level, the learner is presented challenges in arrhythmia interpretation. The final module in the application contains patient cases using animation and a data base of real patient ECG's, and the user is tested over the spectrum of ECG interpretation. A review of current computer-assisted tools for cardiology reveals nothing as comprehensive or interactive as this program.

464-4

Tachpert: An Expert System To Guide diagnosis of Wide complex tachycardia

Andonis G Violaris, Patroklos G Violaris, Dimitris Tsikaderis. Cardiology Department, Northern General Hospital, Sheffield, UK

The differentiation of a wide complex tachycardia is a clinically important but often difficult diagnosis to make. A number of clinical and electrocardiographic criteria have been proposed to assist the diagnostic process but these are often either forgotten or misapplied in the acute situation.

To overcome this we have developed a user friendly expert system (Tachpert-*Tach*ycardia *Expert*) to assist the decision making process. Tachpert was developed using Leonardo 3, a commercially available expert system shell, running on standard IBM PCs. Clinical and electrocardiographic (EKG) facts and rules regarding the differentiation of a wide complex tachycardia are stored within the Leonardo shell. For each patient the user interacts with Tachpert to build up a detailed analysis of clinical and EKG features. Intelligent screen linking is provided, thus depending on the answers given appropriate subsidiary questions would be asked. All information provided is then used in conjuction with the facts and rules programmed into the system to infer the correct diagnosis using backward chaining with 'opportunistic' forward chaining. The facility exists at this stage to interrogate the system and ask why a particular diagnosis was inferred. At the end of the consultation further screens follow requiring the input of any definitive diagnosis made perhaps by electrophysiological studies. The facility thus exists for the expert system to become even more 'expert' with time, as past performance is analyzed and improved upon.

Tachpert thus encourages the critical appraisal of all available clinical and ECG data and aids learning through the ability to interrogate the system at the end of the procedure and ask why a particular diagnosis was inferred. As well as being a diagnostic aid it may thus also be useful for the education of junior staff.

465 Image Analysis II

Tuesday, March 16, 1993
1:30 PM–5:00 PM
Anaheim Convention Center
Booth 2365

465-1

Incorporating Self-Evaluation Techniques into Computer-Aided Instruction of Cardiac Imaging

C Carl Jaffe, Patrick Lynch, Sarah Horton, Harlan Krumholz, Gregory Weltin
Yale University Medical School, New Haven, Connecticut

Computer-aided instruction excels in providing highly enriched presentational environments particularly in subject matter such as cardiac diagnostic imaging where it can incorporate supplementary multimedia informational elements. A less recognized strength, however, is the power of the computer to examine the learning process itself by providing a more thorough understanding of the rate of progress and the degree of subject mastery the student has actually gained from the interaction. Embedded quizes and user-tracking files generated during the student's use of the software offer the basis for examining the extent of the user's knowledge accumulation, as well as providing critical information to the instructional software designer which can be used to improve the didactic encounter. This recursive approach to computer-aided instruction is particularly powerful when applied to learning processes which are primarily visual – such as diagnostic imaging – as opposed to processes which are logical and step-wise algorithmic – such as the diagnostic workup – since visual learning is less well understood. Using examples from specific hypermedia software modules we have developed for teaching myocardial perfusion imaging, echocardiography, and nuclear blood-pool imaging, techniques for incorporating self-assessment into computer learning software will be demonstrated.

465-2

Portable Digital Echocardiographic Image Processing

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

Echocardiographic images can be acquired, stored, manipulated and transmitted digitally using personal computers. A laptop with a framegrabber board, fax modem, cellular interface, and portable ink jet printer is used in our lab to handle echocardiographic reports as well as selected images. Printing of echo images employs dithering and scaling shareware. Low cost commercial software permits remote, completely automated retrieval from any fax machine of images and reports. Images are transmitted by standard or cellular phone.

Stored images are processed for: 1) edge enhancement using digital subtraction techniques such as unsharp masking 2) left sided albumin echo contrast quantitation and pseudocoloring using lookup tables 3) 3D wireframe reconstruction using raster to vector conversion 4) animation with multiframe TIFF and GIF file formats.

We use various file storage and compression options. The presentation includes a description of the recently introduced multimedia file formats which will make the digital manipulation of echo images and Doppler audio even more user friendly on the PC.

This portable setup runs on rechargable batteries, occupies a tabletop area of two briefcases and weighs 31 lbs.

465-3

Enhanced Temporal and Spatial Display of Digitally Transferred Cardiovascular Magnetic Resonance Images with a Personal Computer

G. Wesley Vick, III, Richard E. Wendt, III, Roxann Rokey
Baylor College of Medicine, Houston, Texas

Cardiovascular magnetic resonance (MR) images are routinely printed to film because : 1) there is limited access to display consoles in MR imaging units 2) extant software for these consoles is time inefficient for review of cardiovascular MR studies 3) console software is difficult for nonprogrammers to modify. Use of film for display purposes has the disadvantage of hindering appreciation of cardiovascular motion and of anatomic relationships perpendicular to the plane of examination. Furthermore, use of film for routine review precludes application of many techniques that may contribute to diagnostic efficacy, such as digital image enhancement and use of customized color-coded display look-up tables .

We have developed techniques using public domain and standard system software for digital transfer and display of cardiovascular magnetic resonance images on Macintosh II personal computers. Studies are transferred as binary files via Ethernet connection using standard TCP/IP ftp protocols from scanner Digital VAX minicomputers to a SUN workstation and thence to the Macintosh II. The Macintosh II is equipped with 20 Megabytes (MB) RAM, a two page color display, graphic acceleration, and hardware zoom. Images are archived to 600 MB capacity optical disks. Image sets are organized in two primary display patterns. Multislice spin echo studies are displayed in a "trip through the body" format in which the images are electronically stacked. Anatomic relationships perpendicular to the plane of examination can then readily be detected when the images are animated in an oscillating mode or reformatted in desired slice orientations. Multiphasic cine gradient echo image sets are displayed in a collage format, so that.multiple levels of identical cardiac phase are apparent. Animation of these cine studies is by continuous loop display with an adjustable frame rate control. Images are easily calibrated so that quantitative measurements can be performed on the Macintosh. Non-programmers can modify the user interface to their specifications with simplified macro and scripting methods. Image sets are readily catalogued and displayed by manipulating icons with a mouse or trackball.

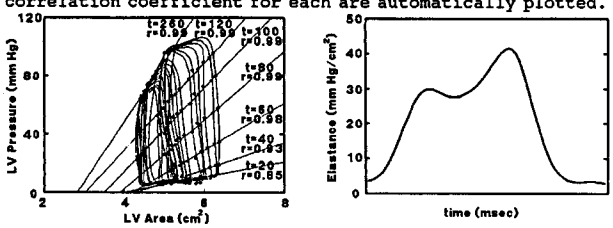
With these methods, cardiovascular MR studies, which typically include much larger numbers of images than other types of MR studies, can be easily organized and rapidly and efficiently accessed and reviewed by clinicians with little computer experience.

465-4

Automated Calculation of Indices of Left Ventricular Function Derived From On-Line Pressure-Area Relations

William A. Mandarino, Lee G. Deneault, Shigeki Morita, Robert L. Kormos, and John Gorcsan III
University of Pittsburgh, Pittsburgh PA

Pressure-volume relations have been used to define LV performance, but are difficult to determine in the clinical setting. Echocardiographic automated border detection (ABD) can measure LV cavity area on-line as an index of LV volume. Pressure-area (P-A) loops can then be constructed on-line by using this area and high fidelity pressure signals interfaced with an Apollo DN3550 workstation. P-A loops recorded during acute alterations in preload induced by inferior vena cava occlusion can be used to derive P-A relations quantitatively similar to pressure-volume relations. Pressure, area and EKG data are transferred to a PC through a customized interface and then read into a program written in ASYST software. Cardiac cycles are separated allowing for interactive elimination of ectopic beats. Indices describing LV contractility and mechanical performance are automatically calculated as follows: end-systolic P-A relationship (end-systole = maximum P/A), preload recruitable stroke force (∫PdA vs. end-diastolic area), and time-varying and maximal elastance (regression of isochronous sets of P-A points throughout systole, see Figures, t in msec). The regression equation and correlation coefficient for each are automatically plotted.



In conclusion, this methodology allows for rapid calculation of multiple indices of LV performance utilizing pressure and ABD area data and has potential applications to many clinical settings.

968 Computer Applications Committee Original Contributions III

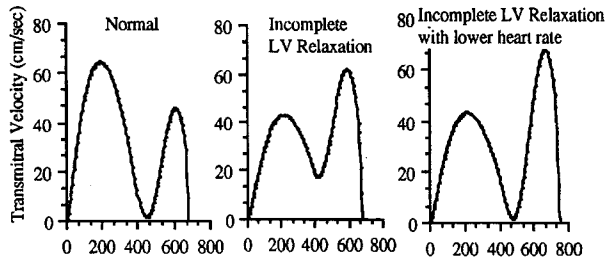
Tuesday, March 16, 1993
3:00 PM–5:00 PM
Anaheim Convention Center
Hall D
Presentation Hour: 3:00 PM–4:00 PM

968-19

Computer Simulation of The Transmitral Velocity Curve Over the Entire Diastolic Left Ventricular Filling Period

Karl Isaaz, Olivier Jeanraux, Antoine Henrot, Gerard Ethevenot, Etienne Aliot.
CHRU de Nancy, University of Nancy, France

The purpose of this work was to study, based on a computer numerical simulation, the physiological determinants of the transmitral velocity curve during the entire left ventricular (LV) diastolic filling period. The mathematical model is based on a coupled system of 4 differential equations: the first equation describes the relation between mitral flow and the left atrium(LA)-LV pressure difference, the second equation shows how LV pressure is affected by both active relaxation and flow, the third equation shows how passive LA pressure is affected by flow and the fourth equation describes how active LA pressure is built up during atrial systole. The 4 equations are implemented by fourth order Runge-Kutta integration using a personal microcomputer (IBM-compatible 386SX-20). The influence of 14 different input variables can be studied: mitral orifice area, end-systolic LA and LV volumes, rate of LV relaxation, constants of LA and LV stiffness, end-systolic pressure, LA and LV pressures at zero volume, maximal LA and LV elastances, unstressed LA volume, heart rate, duration of atrial systole. Input to the program allows automatic calculation of transmitral velocity curve, LA and LV pressure curves for a wide range of input variables. The model allows also to analyze the reflex changes that might occur in response to primary changes in the physiological variables in order to preserve cardiac output. Conclusion: This mathematical modelling allows to explore the physiological determinants of the transmitral flow velocity from early to late diastolic phase. This model might help to analyze Doppler echocardiographic indexes used for the noninvasive assessment of ventricular diastolic function.



968-20

A Procedure for the Quantitation of Myocardial Blood Flow and Viability with Positron Emission Tomography (PET).

Heather Boyd, Adriaan A Lammertsma, Ranil de Silva, Terry Jones and Paolo G Camici. MRC Cyclotron Unit and RPMS, Hammersmith Hospital, London (UK).

A quantitative procedure has been developed to measure regional myocardial blood flow (MBF) and viability simultaneously, by analysis of transmission, and oxygen-15 labelled carbon monoxide ($C^{15}O$) and water ($H_2{}^{15}O$) emission PET scans. This involves image manipulation, region of interest (ROI) selection with the generation of corresponding time activity data and non-linear regression analysis using a previously described mathematical model. This kinetic model has been implemented in the PRO-MATLAB (The MathWorks Inc.) environment running under the SunOS operating system (Sun Microsystems, Inc.). For each selected myocardial ROI (ROI_{myo}) , the program gives values of: **a)** MBF; **b)** the perfusable tissue fraction (PTF); **c)** the spillover fraction from the left ventricular chamber; and **d)** myocardial viability, i.e. the perfusable tissue index (PTI). The bulk of the procedure involves preparing the input for the modelling program. As input, the program requires time activity data generated by projecting ROI_{myo}, and separately, left atrial ROIs (ROI_{la}) to each frame of the $H_2{}^{15}O$ image sequence. The time activity data obtained from the ROI_{la} provides the arterial input function. The ROI_{la} are drawn on the blood volume, a functional image derived from the $C^{15}O$ scan. The ROI_{myo} are drawn on the intersection of the anatomical tissue fraction (ATF) image (a functional image obtained by subtracting the blood volume from the transmission image normalized for tissue density) and the "washout" image (an image obtained by subtracting the blood volume from the addition of the "washout" frames of the $H_2{}^{15}O$ image sequence.). The PTI is defined as that proportion of the myocardium which is perfusable by water within a given ROI_{myo}. It is obtained by taking the ratio PTF/ATF, the latter value being derived from the application of the ROI_{myo} to the ATF image. The above procedure enables the realization of routine quantitative assessment of both MBF and myocardial viability from PET data acquired using ^{15}O labelled tracers alone.

968-28

Combined Clinical and Financial Database for Health Services Research

Debbie Canup, Fara Hicks, Peter Hollings, Phil Kelly, James Hatcher, William Oliver, William S. Weintraub. Division of Cardiology, Emory University School of Medicine, Atlanta, Georgia

Emory University has had a clinical database for cardiovascular procedures since 1973. Included are over 70,000 patients with over 50,000 cardiac catheterizations, 15,000 coronary angioplasties, 20,000 coronary artery bypass operations and over 5,000 other operations. Recent emphasis on cost-effective medical care has made examination of the cost of the procedures a much more important issue. Thus, Emory has begun a program of transferring both hospital and physician charges from financial databases to the clinical database. The hospital charge collected is the UB-82 billing form. Physician billings at Emory also use a standard structure, permitting efficient data transfer. The clinical information in collected by clinical personnel, hospital charges by the hospital finance office, and physician charges by the Emory clinic business office. The financial information is transferred electronically via magnetic tape. To date 1400 hospital bills and 5000 physician charge data forms have been entered into the database. All bills an patients undergoing cardiovascular procedures since 1985 as well as future bills will be included. Financial data is incorporated into the same data structure as the clinical database. The database used an underlying relational database (Informix) with a highly structured hierarchy imposed on the underlying core. This hierarchy is two level: 1) by patient, 2) a lower level hierarchy by episode, which roughly but not exactly corresponds to a hospital admission. The financial information is incorporated into specific hospital and physician billing tables, which fit into both levels of the hierarchy. This detailed structure has proven extremely powerful and flexible for queries that may be either quite simple or extremely complex. The financial portions of the database are already being used in several major prospective clinical trials as well as for descriptive studies. Using these methods, financial and even cost-effectiveness evaluations of medical care may be expected to become a frequent counterpart to clinical studies.

466 Database I

Wednesday, March 17, 1993
9:00 AM–12:30 PM
Anaheim Convention Center
Booth 2365

466-1

Relational Database System for Analyzation of Clinical, Histological- and Immunohistological Dependencies in Arteriosclerotic Plaque Tissue

Michael Fleuchaus, Peter Gonschior, Brigitte Mack, Berthold Höfling
Med. Dept. I, Klinikum Großhadern, University of Munich, FRG

Arteriosclerosis is supposed to be a disease which is caused and influenced by a variety of pathogenetic factors. Due to a wide diversification in histologic and immunohistologic findings in arteriosclerotic plaque tissue, obtained by directional atherectomy, these pathogenetic changes inside the arterial vessel wall which finally lead to the development of an arteriosclerotic lesion cannot be adequately analyzed without digital assistance.

Therefore we designed a database system which files all clinically and histologically essential data acquisited by analyzation of arteriosclerotic tissue specimen obtained by directional atherectomy. Furthermore we performed immunohistochemical analysis with over 25 antibodies and added the results to the database. The database is developed in a 4th Dimension (ACIUS; Paris, France) environment on a Macintosh IIci (Apple Computers, Inc.; Cupertino, USA). It combines an easy to use interface with powerful analyzation features that allow combination of nearly all clinical, histological and immunohistological findings. All stored values though can be used for statistical analysis and several calculations that point out correlated values.

Digitally assisted analyzation and comparison of clinical, molecular biologic and experimental data may provide an insight into the major determinants of arteriosclerotic lesion development since complex pathogenetic changes seem to take place which cannot be adequately analyzed without computerized help.

466-2

A Macintosh Based Database Management System For Cardiovascular Procedures

Mark A. Tannenbaum, Todd Jones, Jon Thelin, Les Roth, Thomas M. Brown, David F. Gordon. Iowa Heart Center, Des Moines, Iowa.

This application represents the development of a relational database utilizing the client server model on a Macintosh platform for the integrated collection and reporting of data from invasive cardiac procedures and cardiac surgery. The program was developed utilizing the software product 4th Dimension with externals written in C and Pascal languages. It runs on an Ethernet network which serves the hospital workstations as well as the remote access of the system from a physician's office or home.

The goal of this project was to establish an application with an intuitive graphical interface which would create a database with multiple user outputs. Entry tasks are compartmentalized to allow efficient and accurate data recording. Workstations are located outside each procedure room. All diagnostic information and recommendations are entered by the physicians. In an attempt to eliminate duplicate effort and, thereby, increase the potential for accurate and detailed data entry by the physicians, the application will produce a note for the chart, a heart diagram, a preliminary as well as a final narrative report, and a letter to the referring physician. Conclusions are automatically generated by the program to insure standardization for data analysis.

The database also provides statistical reports and graphical representations of these analyses. Ad hoc searches can readily be performed by any user based upon predefined security limitations. Procedures are defined by CPT codes allowing for daily physician billing reports. In addition, the application provides for patient scheduling and serves as a logbook as well as an on-line patient archive.

This Macintosh based application provides a comprehensive database management system in an efficient and easy to use format.

466-3

Computer-Linked Organizer Enhances the Management of Cardiac Patients

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

We have used a commercially available electronic palmtop organizer (ORG), equipped with 64Kbyte schedule mode memory to maintain pts clinical data. We have recently acquired the data into prewritten templates to assure standard format and complete data set for each pt. The ORG is backed up by personal computer (PC) via a PC-Link interface with an upgraded software version. The pt record can be edited, printed and placed in the chart as the daily note. It also can be transferred to another ORG or to the office PC, which can be remotely accessed via modem. During the last 30 months we have collected records on 605 hospitalized pts. Following discharge, all pt's records were uploaded to the office PC as one file. The average size of a cumulative pt file is 2.3 Kb. By using text filters and searches, it has been possible to retrieve specific information, and to highlight trends of the selected data.

This improved methodology of data acquisition provided us with: 1) Standardization of data entry by using templates. 2) Placing legible printouts rather than handwritten notes in the chart. 3) Access to pt data independent of the chart. 4) Ability to retrieve selected information through text filters and searches. 5) Rapid, concise and accurate formulation of a discharge summary. 6) Updated office file. 7) Instantaneous recall of information on readmitted pts. 8) Accurate billing information.

This data collection and management system is an important step in eliminating the problems of illegible handwriting and provides new capabilities in the management of hospitalized cardiac pts. It links the bedside environment to the doctor's office software packages. This information system can be made applicable to evolving DOS based palmtop computers and has a potential role as a front end of computer assisted pt management.

466-4

Integrating Knowledge to Databases on Congenital Heart Diseases - a tool to validate and retrieve data

Beatriz de Faria Leão, MD, PhD; Institute of Cardiology of Rio Grande do Sul, Porto Alegre, RS, Brazil; Marinez Barra Rossi, Sandra Viegas, Paulo Zielinsky.

The Institute of Cardiology of RS keeps a database of about 5000 Congenital Heart Disease (CHD) patients, where data are stored under a relational data model. The utilization of "flat" data structures to describe the patient's medical data, such as diagnosis, surgeries and complications, although efficient from the computer storage point of view, turns queries cumbersome and hard to define. In addition, the lack of standardization in describing the diagnoses, together with the presence of associated lesions, impose and additional burden to data retrieval. So far, queries are hindered and not easily handled without the assistance of the system analyst. Therefore, it was decided to integrate the CHD database with a knowledge base, in order to enhance the semantics of the database "flat" data structures. A frame-based model was used to represent knowledge about CHD diagnoses, surgeries and complications. The connection between the morphological sequential approach to describe CHD diagnoses and the diagnoses' names, commonly employed in the daily medical activity, is explicitly represented in the knowledge base. To provide an even more medically-oriented application, an hypertext user interface is used. The interface "per se" is an electronic book to teach cardiac morphology, in use, since August 92. Drawings and schemes with buttons allow users to define complicated queries in the patients' database. Presently this integrated application is being used to validate our CHD database. A testing database with 1000 cases was used to validate the prototype. The results revealed that the knowledge-base is very useful in pointing to the incompleteness of the stored data, especially in connection with associated lesions. Whenever a diagnosis is incomplete or not well defined in the database, the corresponding record is singled out for correction. Presently, the database is under validation, a time-consuming effort, that demands laborious searches in the conventional medical files. The results of this full evaluation are discussed. The utilization of a knowledge base to validate medical data and elicit information from them is one of the major traits of this contribution. Hopefully, it will allow for the creation of better, more reliable and efficient computer applications for medical care.

969 Computer Applications Committee

Wednesday, March 17, 1993
9:00 AM–11:00 AM
Anaheim Convention Center
Hall D
Presentation Hour: 9:00 AM–10:00 AM

969-19

Learning from Percutaneous Transluminal Coronary Angioplasty Database

Von-Wun Soo, Jan-Sin Wang, and Shih-Pu Wang
National Tsing-Hua University, and Taipei Veterans General Hospital, Taiwan, R.O.C.

The main interest of this research is to discover clinical implications from a large PTCA data base. A concept formation model D–UNIMEM, a modified version of Lebowitz's UNIMEM, is proposed for this purpose. We integrated two kinds of class memberships for clustering: feature–disjunction class membership and the index–conjunction class membership. The former is a polythetic clustering approach which serves at the early stage of concept formation. The latter which allows only relevant instances to be placed in the same cluster serves as the later stage of concept formation. Two kinds of learning experiments were carried out on the PTCA data base: unsupervised and supervised learning. In the former, D–UNIMEM extracted interesting correlations among features from the learned concept hierarchy. One of such statements as "Among the PTCA patients, if a patient can only sustain 265.85± 41.8 seconds while accepting treadmill test then the patient often has LAD stenosis." was induced. In the latter, prediction accuracy of the concept formation model was examined. We used statistical leave–one–out technique to evaluate the learning experiments. One of the evaluation results of the learning experiments was to predict the ECG–MI based on EF, SPECT and TMX records, the accuracy ranged between 63% and 91%. The PTCA database currently contained about 12000 records of 945 patients under PTCA treatment in Taipei Veterans General Hospital. The records include the data of patients' history, symptoms, non–invasive tests (ECG, EF, TMX, TH–201, etc.), CATH results, PTCA results, CABG, Follow–up and Mortality reports. The system is implemented in C and runs under SUN spark station.

969-20

UMCATH — A Data-Driven Catheterization Laboratory Database and Clinical Reporting System with a Network Graphical User Interface

Marge Scerbo, Matthew Larson, William R. Sommers, Samuel Rodriguez, William R. Herzog, Paul A. Gurbel, J. Lawrence Stafford, Andrew A. Ziskind. University of Maryland, Baltimore, Maryland

The University of Maryland Cardiac Catheterization Laboratory has in the past depended upon 'paper data' for all catheterization and interventional records. There was a need for a computerized database at a reasonable cost. The goal of system design was to create a user-friendly database that would generate clinical reports and provide a database for use in research, quality improvement, and administrative reporting. We required 1) ease of data entry 2) report generation on demand, including routine and special requests 3) availability of data for further analysis in a variety of formats for research, and most importantly 4) a data-driven system which would permit easy updating of a large number of modifiable tables without programmer assistance, e.g. to change catheter options, guidewires, etc.

A data-driven collection and reporting system was developed using SAS which includes packages for not only data collection, analysis, and reporting, but a true screen development system, including icon-based menuing design. The modular system was designed to run on a VAX/VMS system utilizing Pathworks' X server to provide a common GUI (Graphical User Interface.) The system is ethernet compatible, the hospital network standard, and permits access by both IBM compatible and Macintosh computers over the network. No matter which workstation is chosen, the interface appears the same. Such ethernet compatibility also allows future connections to pass reports via fiber rather than paper to medical records and billing departments.

In summary, this data-driven VAX-based system, constitutes a low-cost, easy-to-use catheterization laboratory database and clinical reporting system that provides a uniform graphical user interface for networked workstations, IBM-compatible and Macintosh computers.

969-21

A Set of Software Tools for Cardiological Follow-up

Francesco Pinciroli, Dipartimento di Bioingegneria of the Politecnico di Milano and Centro di Teoria dei Sistemi of the C.N.R. - Italy - Carlo Combi, Giuseppe Pozzi, Ruggero Rossi

Software integration can provide additional value that the medical user should appreciate. We built up a set of four mutually-integrating software packages. Any package runs under MS-DOS operating system on IBM-compatibles machines equipped with HD. The first package (DI) is for drug interactions. It adds the backward search from effects to their possible causes. Searches among several drugs are made easy too. Some (634) interactions involving cardiological drugs are presently stored in the thesaurus. The second package (DD) is a drug-dosage electronic handbook. It stores information on some (1724) cardiological drugs. Also it allows the storage of any drug prescription. By this the drug history of any patient becomes easily available. The third (GPC) and the fourth (GPI) are time-oriented packages. They are for the management of the follow-up of data of patients after acute miocardial infarction (some 370 data per visit) and of hypertensive patients (some 440 data per visit). Simple statistics and time-oriented graphics presentations are included. For deeper statistical methods data are ready to be exported to the CSS (Complete Statistical Software) package. Integration comes, for instance, by considering GPC with DI linked to it, in such a way to warn, fully-automatically and even if not asked, any time the new drug may cause negative interactions. Part of the software performances were defined by cooperating with the Working Group on Methodology, Statistics and Informatics of the Italian Association of Hospital Cardiologists. They are involved in defining standards for cardiological databases. Many hundreds copies of each package have been distributed to Italian Institutions and private cardiologists. Because of the level of the requested user-training, the distribution of GPC and GPI was made in the occasion of short courses given by employing a travelling informatized classroom (TIC), consisting of some 15 portable PCs, printers and data-displays.

467 Database II

Wednesday, March 17, 1993
1:30 PM–5:00 PM
Anaheim Convention Center
Booth 2365

467-1

A Cardiology Database Integrated with the VAMC Decentralized Hospital Computer Program with Image Capture and Display

Ross D. Fletcher, Ruth Dayhoff, 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 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. 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. The database contains 2485 catheterizations, 3990 Holters, 11,440 ECGs, 7,983 Echos, 4,119 ETTs, and 454 EPs at the VAMC, Washington, DC.

Image capture automatically links to specific patients and specific procedures. A 12 image composite picture menu is displayed on a single screen. Full screen images appear automatically during each report. They include echocardiograms, coronary arteriograms, ventriculograms, MUGA, thallium studies, x-rays and ECG. The system also captures bone marrow, GI and pulmonary endoscopy, microscopic pathology, gross operative and dermatological images. The system can operate as a PC workstation with a VAX connected through Ethernet but gains efficiency when downloaded to a complete PC environment.

467-2

Macintosh™-based Interventional Cardiology Database: Combines Powerful Relational Database with User-Friendly Apple™ Macintosh™ Computer System

Sabino R. Torre, Samin K. Sharma, Douglas H. Israel, Jonathan D. Marmur, John A. Ambrose. Mount Sinai Medical Center, New York

We have created a database for the interventional cardiology laboratory utilizing FoxBASE™ 2.0 for the Macintosh™ which has the following features: (1) >250 administrative, clinical, and angiographic variables, (2) relational structure linked to both clinical and coronary stenosis variables with a many-to-one compatibility, (3) Macintosh™ user-friendly interface with input screens that are identical to cath lab worksheets, (4) default values for all applicable variables, (5) capable of importing data from other Dbase™-based databases (i.e. stress tests, echocardiography), (6) capable of storing individual cine frames with a frame grabber for archiving purposes, (7) report generation, (8) powerful search capability for clinical and research purposes, and (9) interface to statistical packages (i.e. Statview IV™) for administrative and research purposes.

In conclusion, we have developed a powerful relational database for the interventional cardiology laboratory utilizing FoxBASE™ 2.0 for the Macintosh™. This database management software will enable the interventional cardiologist to combine powerful administrative, clinincal and research capabilities with the user-friendly interface of the Apple™ Macintosh™ computer system.

467-3

Interactive Computer Program for Training in the Use of High Frequency Oscillatory Ventilation

Don McCumin and George Sheplock. Wilford Hall USAF Medical Center, San Antonio, Texas.

The purpose of this computer program is to provide an interactive training module for a new method of ventilation - High Frequency Oscillatory Ventilation. The software uses the Macintosh based commercially available Labview (National Instruments, Austin, Texas). The trainee is presented with a computer screen which represents the faceplate of the HFOV ventilator with the appropriate dials and gauges (Sensormedics 3100 , Yorba Linda, Ca.). By using the mouse the dials can be manipulated to change the mean pressure, pressure amplitude and ventilator frequency in Hertz. When the program is activated the trainee is presented with one of a variety of case scenarios which involve an infant who is failing conventional ventilation. The trainee then "sets up " the HFOV and initiates the therapy. Constantly displayed on the screen are heart rate, blood pressure and saturation which change based on the ventilator settings, i.e. the blood pressure will drop if the mean airway pressure is excessive. The trainee can request an ABG and CXR by activating an on screen radio button. The ABG results "pop-up" and are based on the ventilator settings and are presented in tabular form. The CXR also "pops-up" and represents an actual radiograph which has been digitized. The trainee can also request a cardiac echo by activating another radio button. The echo data "pops-up" with shortening fraction, RV output, LV output, PDA status, and the peak velocity of the tricuspid regurgitation jet for the estimation of the pulmonary artery pressure. Additionally, a digitized video movie of the 2D/Color Doppler echo can be run. This feature takes advantage of the Quicktime system extension of the Macintosh. A HELP button provides interpretation of the echo data. Finally, an intervention button allows the trainee to have other therapeutic options including giving volume or pressors which are influenced by the echo data, CXR, ABG heart rate,blood pressure and saturation. If the trainee makes the proper decisions the infant improves and the trainee must wean the ventilator. The scenarios are based on real cases. The module is helpful to train clinicians in the use of the ventilator and also to develop a better understanding of the use of echo data in the management of critically ill neonates.

467-4

Modified Oracle Database System for Quality Ensurance in Heart Catheterization

Ludwig Drude, Clemens Zygan, Bernhard Maisch.
Philipps University of Marburg, Department of Cardiology, Marburg, FRG

To ensure a high quality of invasive cardiac procedures in heart catheterization the indication, the data from heart catheterization itself and therapeutic consequences have to be documented in detail. In recent years in German cardiological departments different and incoherent database systems were installed to realize complete documentation. Our aim was to create a single database system which would meet the requirements of many departments and would enable them to communicate within this system. Of all available database systems the structure of the oracle database (Oracle Corporation USA) seemed best suited to handle the vast amount of data which are accumulated for one single patient. Based on the oracle database we created our which has now worked for more than two years successfully. More than 540 items are documented:

Indication: patients history, physical examination, EKG, ergometry, echocardiography, Holter EKG, and myocardial scintigraphy. Right and left heart catheterization: registration of pressure in all chambers, volumens, wall motion in all segments, coronary status, valve status and all technical data (e.g. type of catheter used, x-ray dose, contrast medium). Diagnosis and therapy: detailed characterization of the underlying heart disease and proposed therapeutic regime. Complication: detailed documentation of all possible complications. Angioplasty: detailed documentation of all steps and results. Heart surgery: indication, documentation of waiting period and complications.

Presently about 30 German centers have started with this database. Our and the experience of most has shown this to be a very successful means of data management. This database works either as a single work station (IBM compatible PC) or in a network (Novell Net). In addition several moduls such as statistical management of all data or automatically printed catheter protocol are available.

970 Computer Applications Committee Original Contributions V

Wednesday, March 17, 1993
3:00 PM–5:00 PM
Anaheim Convention Center
Hall D
Presentation Hour: 3:00 PM–4:00 PM

970-19

Interactive Software for Analysis of Global or Segmental Cardiac Systolic and Diastolic Performance by Pressure-Volume (Dimension) Relations.

Ping Tan, H. Sidney Klopfenstein, Jakob Vinten-Johansen.
Bowman Gray School of Medicine of Wake Forest University, Winston-Salem, NC 27157.

Spectrum is a multicomponent program written in Microsoft C (7.0) for the IBM PC/AT or compatible and available for both WINDOWS and MS-DOS. This program acquires, processes and reports cardiovascular hemodynamic data, and evaluates ventricular performance based on pressure-volume, and pressure-diameter indices using three popular indices. Up to 16 channels of data can be digitized at up to 1000 Hz directly or using the Codas[R] (Dataq, Inc.) acquisition system. User interactive videographics allows immediate display of analog data and subsequent data processing. Data can be variably smoothed and displayed in time-based or X-Y coordinate formats and different channels may be superimposed. Cardiac cycles can be determined, and systole and diastole defined automatically by user selected algorithms. Ventricular systolic performance is assessed by linear and curvilinear regression analysis of end-systolic pressure-volume (or diameter), dP/dt_{max}-end-diastolic volume (or diameter), and stroke work-end-diastolic volume indices. Diastolic characteristics are determined by exponential regression analysis of end-diastolic pressure volume (or diameter) data. Systolic and diastolic characteristics may also be determined for segment length data. Algebraic calculations may be performed from user supplied equations which may utilize most mathematical functions applied to phasic or mean data from any or all channels to create new channels or discrete variables. All analog and pressure-volume (or diameter) data can be plotted on screen, plotter, or laser printer at any point. Images may also be exported in HPGL-format to CorelDraw[R] and other graphics programs. Reported hemodynamic variables, ventricular performance data, and user defined variables are organized in an ASCII or binary format suitable for direct transfer into data base management systems, including Statistical Analysis Systems (SAS[R]), LOTUS[R] and Quattro[R].

970-20

Cardipower: An Improved Method of Haemodynamic Functional Assessment

Charles D.O.Potter, Dereck R.Wheeldon, Gordon Wright*, John Wallwork. Papworth Hospital, Cambridge, England. * W.E.Dunn Unit of Cardiology, University of Keele, Staffordshire, England.

Conventional haemodynamic measurements give a relatively poor assessment of cardiac function. A method of on-line computation of the power output of the heart and impedance spectrum of the systemic system has been developed. The software has been designed to allow calibration, signal monitoring, data capture, data analysis, display of computed parameters and waveforms and data storage.

High fidelity analogue pressure and flow signals from the ascending aorta are fed via an A/D board, signal conditioner and math coprocessor to a microprocessor with a 40 MByte hard disc. The pressure and flow waveforms are visualised near real-time and 2000 point data blocks can be captured and stored for later analysis.

During analysis between 4 and 10 complete waves are selected from those captured. All calculations are based on a single pulse derived as a mean of those selected, with the data being tested for stationarity and coherence. Fast fourier transforms are then performed on the selected waves and the single mean wave is constructed. Data is displayed for the maximum, minimum and mean pressure and flow signals. Total cardiac power is calculated and this is further subdivided into the mean and pulsatile components. The input impedance to the systemic system is calculated and divided into its resistive and compliance elements.

This approach allows comprehensive evaluation of cardiac hydraulic performance separate to the load and also enables the load to be characterised. The technical problems relating to both clinical and experimental applications have now been overcome and the system is in use as an outcome measure for clinical donor heart preservation and reperfusion studies. The system lends itself to considerably wider clinical monitoring applications and to a better understanding of impedance matching in the human cardiovascular system.

468 Computers and Complex Data Display

Thursday, March 18, 1993
9:00 AM–12:30 PM
Anaheim Convention Center
Booth 2365

468-1

Heart Surface to Body Surface: An Animated Correlation During Ventricular Activation and Repolarization

Leo G. Horan, Patricia C. Orander, Marandapalli R. Sridharan, David B. Geselowitz, Nancy C. Flowers, Weiqun Yang, Judith W. Hubbard and Jerry D. Allison
VA Medical Center & Medical College of GA, Augusta, GA

An anatomically accurate model of the inner and outer ventricular myocardial boundaries of the canine heart as well as the surrounding torso boundary has been constructed from serial cross-sectional magnetic resonance images (MRI). When combined with collated time-correlated data from endocardial and epicardial monophasic action potentials and body surface potentials, an animated series of 4 surface maps results. The evolution of these simultaneous electrical displays illustrates the synthesis of body surface maps during QRST from ventricular sources and gives credibility to the lead tensor-cardiac multipole as an improved paradigm for genesis of the ECG.

An interactive display in Supercard format permits the viewer to examine the formation of the heart-in-torso model from MRI slices. This leads, in turn, to the development of a set of 4 simultaneous surface maps in which instantaneous potential values are indicated both by wire-frame elevation and color-coding. The dynamic millisecond-by millisecond events of activation and repolarization may then be followed as they impact on the final display on the body surface. The viewer may electively use the tools of reverse motion and replay to gain insight into the interaction between right and left ventricular contributions, the effect of epicardial breakthrough on saddle formation, and the fine integration of the many phase 3 elements which produce the T wave.

468-2

Graphical Analysis of Heart Rate Variability

Jeffrey N. Rottman, Robert E. Kleiger, Richard Steinman, J. Thomas Bigger Jr., Washington University, St. Louis, MO and Columbia University, New York, NY

Decreased heart rate variability (HRV) is an important prognostic indicator following myocardial infarction. Components of HRV can also provide valuable information about autonomic tone. Standard algorithms for computation of indices of HRV have been described. Unfortunately, most implementations have been limited, proprietary, specific to a particular ambulatory ECG system, and of undefined accuracy.

We have developed a graphical suite of programs for use under MS-Windows providing comprehensive and validated tools for the analysis of HRV. A well-defined *beat file* format and a variety of input conversions allow analysis data from a number of ambulatory ECG systems. The accuracy of the computations has been validated against prior standards. Computations include time-domain indices such as mean and standard deviation of R-R and N-N (normal-to-normal) intervals (SDRR, SDNN), root-mean-squared successive differences (rMSSD), percentage of successive N-N intervals differing by more than 50msec (pNN50), and more complex measures such as SDNNIDX and SDANN. An N-N histogram baseline width measurement that has been proposed as a robust measurement of HRV can be computed. These measurements are available over the entire 24 hour period or defined shorter periods (day, night, and transitions). Frequency-domain (FFT) measures of high and low frequency power are available. A flexible framework makes it straightforward to extend the analyses to include other techniques.

This program provides a standard for reporting HRV analyses from different sources and comparing different methods of analysis. In addition the graphical interface makes it easy to explore the relationships present in the data among circadian rhythms, heart rate, degree of ectopic activity, input noise, and the various measures of heart rate variability. For example, measures of vagal tone such as pNN50 are observed to show sporadic "spiking" in an apparently random fashion, rather than smooth fluctuation. This tool may facilitate studies of the physiological basis of the different measures of HRV.

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468-3

Interactive Computerized Analysis of Monophasic Action Potential Durations, Intracardiac and Surface Electrogram Intervals, and Pressure Waveforms.

Francis D Murgatroyd, Jeremy Broadis, Christopher Oakley, Edward Rowland. St George's Hospital Medical School, London, England.

The varied morphology of monophasic action potentials (MAPs), especially those recorded from the atrium, makes their automated measurement prone to error. However, manual analysis is laborious and subject to observer bias. An interactive package has been developed for the measurement of amplitude and duration of MAPs, intervals and durations of conventional electrocardiograms, and blood pressure waveforms.

Up to 16 channels of data, appropriately filtered and continuously sampled at 1kHz with 12-bit resolution are written to hard disk in real time. The resulting file is analysed using a package developed in Spike2 language (Cambridge Electronic Design Ltd.). An event channel is automatically set up to define each beat: this can be derived from any electrocardiogram channel and edited manually. For each beat, MAP onset is defined as the point of maximum slew rate. Within a predetermined window from this time, the MAP height is determined as a maximum (for MAPs of conventional "hump" morphology), the point of inflexion (for MAPs without a hump), or a fixed interval after the onset (for "triangular" MAPs). MAP durations for each beat are then measured as the times from onset to 50%, 70%, 90%, and X% (selected) repolarization. As the terminal portion of repolarization is subject to beat-to-beat fluctuation, MAP duration to 70%, 90%, and 100% repolarization is also determined from a tangent calculated at the point of maximal rate of repolarization.

Along with these measurements of MAP duration, the MAP height, beat-to-beat interval, blood pressure (peak or mean), and intervals between activation on selected electrocardiogram channels, are also recorded automatically. The waveform and points of measurement for each beat are displayed for a preselected time, allowing visual inspection, interruption, and manual editing of the automated analysis. All measurements are written to an ASCII text file.

468-4

Software that Produces Families of Starling Curves in Assistance to Cardiac Patient Management

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

We demonstrate the use of a computer model to generate the Starling relations for left ventricular contraction under various preload, afterload, inotropic state, and heart rate conditions. The ventricular-vascular coupling is characterized by an analog electrical model. Preload is altered by changing the pulmonary wedge pressure in the model. Afterload is altered by changing the vascular resistance (R) and capacitance (C). An example of the resulting Starling curves for different afterload conditions is shown below. To assist clinical management of cardiac patients, the software is first used to generate a library of different families of Starling curves. Then, based on the measured cardiac output and pulmonary wedge pressure from the patient, the best-fit family of curves is displayed in superposition with the actual data. The software is used as a tool to characterize ventricular performance and to predict and interpret effects of pharmacologic agents.