because of central, but mostly because of peripheral causes, despite recovery of a normal left ventricular function. As substantial improvements have only been reported by long term retraining, we investigated the effects of a short term, square wave, modified interval training (SWEET) on muscular energetics and ultrastructural composition in 13 HTR (42 ± 9 yrs, 74 ± 12 kg, 10 ± 3 months after the operation) during a 3 sessions/week — 6 weeks program. After defining the maximal tolerated power (MTP) and the ventilatory threshold (VT) during an incremental test (IT), the 45 minutes SWEET sessions consisted in 9 crenels, each of 4 minutes at the power corresponding to the VT (approximately 50–60% of the MTP) followed by 1 minute at 90–100% of the MTP. O_2 uptake (VO_2), CO_2 output (VCO_2), ventilation (VE), heart rate (HR) were compared between the pre and post training IT and SWEET, blood lactates (LA), norepinephrine (NE) during the pre and post training SWEET. The ultrastructural capillary density (CD) and mitochondrial density (MD) on vastus lateralis biopsies were compared before and after training. *Effects of training:* (1) On maximal exercise: there were significant changes in MTP (+16%*), peak VO_2 (+9%*), and VT (occuring at 66 ± 7* vs 59 ± 6% of the peak VO_2). (2) On submaximal exercise: at the same power (approximately 50% of the initial MTP) there were significant decreases of VO_2 (−12%*), VCO_2 (−12%*), VE (−11%*), HR (−7%*), LA (−27%*), NE (−35%*). (3) On ultrastructural aspects: although CD did not change, the MD tended to increase (+17%), mostly because of a significant subsarcolemmal MD increase (+60%*), without a central MD change. The intracellular lipid droplets volumetric density tended to increase (+43%). * $p < 0.05$. *Conclusion:* a short term (6 weeks) endurance retraining program in HTR leads to an enhancement of the muscular oxidative capacity, that resembles the one seen in normal subjects, emphasizing the necessity of an endurance retraining in these patients.

3:00

758-5 Influence of Exercise Training on Skeletal Muscle Vasodilatory Capacity in Chronic Heart Failure

G. Dziekan, W. Hafeli, R. Ratti, J. Myers, W. Reinhardt, U. Goebbels, P. Dubach. *Kantonsspitaler Chur, Basel, Zurich, Switzerland; Palo Alto, DVAMC, Palo Alto, CA; Stanford University, Stanford, CA*

Background. Patients with chronic heart failure (CHF) are known to exhibit abnormalities in redistribution of blood flow and vasodilatory capacity during exercise. Exercise training has recently been recognized as an important therapeutic modality for patients with CHF. Training has been shown to improve vasodilatory capacity among normals in training-specific muscle.

Methods. Seventeen patients with first-diagnosis of CHF due to coronary artery disease (56 ± 5 years, mean EF = 32 ± 6%) were randomized to an exercise training group (N = 8), or a control group (N = 9). At randomization, patients in both groups initiated ace-inhibition therapy. Patients in the training group performed one hour of daily walking along with four sessions per week of high intensity monitored stationary cycling (40 minutes at 70 to 80% peak capacity) at a residential rehabilitation center for a period of two months. Control patients received usual community care. Calf baseline and post-ischemic flow rates were measured by strain gauge plethysmography before and after the study period.

Results. Training resulted in a 25% increase in maximal oxygen uptake (19.6 ± 3 vs. 24.9 ± 3 ml/kg/min, $p < 0.01$), whereas control patients did not change significantly (19.6 ± 4 vs. 19.3 ± 5 ml/kg/min). Leg baseline flow was similar in both groups initially and did not change with training (1.3 ± 0.6 vs. 1.6 ± 0.6 ml/100 ml in trained patients and 1.8 ± 0.6 vs. 1.9 ± 0.6 ml/100 ml in controls). Post-ischemic leg flow however, was significantly higher in both groups (14.4 ± 8.0 vs 19.9 ± 8.1 ml/100 ml in trained patients and 15.0 ± 8.1 vs. 20.3 ± 8.1 in controls, $p < 0.05$ for both groups).

Conclusion. The trained group improved post-ischemic leg flow, suggesting an improved vasodilatory capacity. However, the control group improved to a similar degree, suggesting that ACE inhibition therapy, not exercise training, causes the improvement. These data underscore the importance of treating these patients with ACE inhibitors.

3:15

758-6 Does Moderate to High Intensity Exercise Affect Left Ventricular Remodeling in Cardiac Rehabilitation Patients After Myocardial Infarction?

Lauralyn B. Cannistra, Ravin Davidoff, Michael H. Picard, Carol J. O'Malley, Anne Dempsey, Gary J. Balady. *Boston University Medical Center and Massachusetts General Hospital, Boston, MA*

LV remodeling (LVR) can occur after MI and may adversely affect prognosis. The effect of regular moderate to high intensity exercise on LVR after MI is debated and needs further study. LVR was evaluated in 44 patients using serial echocardiographic measures including % abnormal wall motion (%AWM) and endocardial surface area/body surface area index (ESAi) taken initially 8 ± 5 wks post MI (echo 1) and 12 weeks later (echo 2). Data were compared between 22 consecutive pts who exercised 3×/wk for 30 minutes at 60–85% HR reserve vs 22 control pts without exercise training, who were matched for age, sex, medications, type and site of MI, revascularization, and %AWM. Exercise patients improved peak MET levels from 5.7 ± 2.3 to 7.7 ± 2.0 ($p < 0.001$). Serial echo data in the two groups follows:

	Exercise (n = 22)	Control (n = 22)
%AWM		
echo1	18.68 ± 13.72	18.26 ± 14.11
echo2	18.00 ± 13.42	17.33 ± 14.77
ESAi (cm^2/m^2)		
echo1	56.89 ± 9.30	64.26 ± 10.33
echo2	54.57 ± 7.40	56.89 ± 9.37

No significant change in %AWM and ESAi occurred in either group from echo 1 to echo 2. Thus, in this group of consecutive patients carefully matched for size and location of infarct, moderate to high intensity exercise does not appear to adversely affect LVR early after MI.

759 Computerization of Cardiology: Expert Systems, Neural Networks, and Decision Analysis

Tuesday, March 21, 1995, 2:00 p.m.–3:30 p.m.
Ernest N. Morial Convention Center, Room 21

2:00

759-1 In Vivo Characterization of Vascular Pathology Using Texture Analysis of Intravascular Ultrasound and a Neural Network Classifier

Evelin Lieback, Isabelle Hardouin, Michael Schartl, Jürgen Boksch, Roland Hetzer. *German Heart Institute, Berlin, Germany*

Intravascular ultrasound has received acceptance for accurate diagnosis of coronary disease. Conventional image formation provides limited information about tissue characteristics.

We have investigated the use of tissue characterization techniques to differentiate different pathologies in plaque tissue and thrombus. Using a PC-based data aquisitation system interfaced to a interventional ultrasound system (IVUS) whose catheter probe operates at 30 MHz, we recorded the intracoronary B-scan images from 10 patients. We analyzed the gray level distribution by means of texture analysis in the plaques or in the thrombus. All in all we calculated 51 texture parameters. The parameters were implemented in a knowledge base. Different classification methods were investigated to determine their ability to differentiate between different plaque types and thrombus. A neural network architecture was developed and implemented for tissue characterization. Learning was achieved through a backpropagation algorithm. Using this neural network it was possible to differentiate between different types of plaques and thrombus. The echocardiographic texture of a thrombus was darker and had a lower heterogeniety than a artherosclerotic plaque. The results indicate that neural network can have an important role in the extraction of maximum information from the ultrasound signal. On the other site the incorporation of tissue characterization into intravascular ultrasound scanners could improve the efficacy of such procedures.

2:15

759-2 Use of Artificial Neural Networks within Deterministic Logic for Computer ECG Diagnosis of Myocardial Infarction

T.F. Yang, B. Devine, P.W. Macfarlane. *University of Glasgow, Dept. of Medical Cardiology, Royal Infirmary, Glasgow, Scotland*

The study was aimed at assessing the effect of incorporating neural networks (NN) inside an existing deterministic computer ECG analysis program in order to enhance the diagnosis of myocardial infarction. Separate neural networks were trained for inferior and anterior myocardial infarction using 200 normals, 100 IMI, 80 AMI and 42 left ventricular hypertrophy cases, all clinically validated. All the networks had a single output to discriminate between MI and non-MI. A variable number of inputs to the networks was used consisting of QRS ± ST-T measurements. Separate test sets including 200 normals, 42 LVH, 101 AMI and 80 IMI cases were then utilised to find the best performing neural networks for IMI and AMI. The best neural network for each of IMI and AMI was then selected and inserted into the existing Glasgow Program (GP) for ECG analysis together with some modifications (M) to the diagnostic logic. The modified and original GP were then assessed using a completely new test set composed of 74 AMI, 52 IMI, 60 LVH and 230 normals.

Results:

	AMI Se	IMI Se	NSp	LSp	OSp
GP	76%	69%	100%	93%	99%
GP + NN + M	78%	88%	100%	85%	97%

Se = sensitivity, Sp = specificity, N = normal, L = LVH, O = overall

Conclusions: This first report of neural networks for the diagnosis of myocardial infarction embedded within a deterministic logic program has shown that (1) the technique significantly improves the diagnosis of inferior though not anterior MI; (2) the evaluation of specificity using only normals is misleading; (3) the technique can usefully be adopted selectively to enhance diagnostic ECG programs in future.

2:30

759-3 Prediction Models for Outcome of Coronary Surgery and Coronary Angioplasty on a Desktop

William S. Weintraub. *Emory University Sch of Medicine, Atlanta, GA*

There is a need in clinical practice for rapid accessibility of outcome data in rapid fashion for clinical decision making. Data for this purpose come largely from clinical trials and databases. Emory University has a cardiovascular database with 80,000 patients which includes all cardiovascular surgical procedures and interventional procedures in the coronaries since 1972. Querying the database to examine outcome is practical for research, but limited as a clinical tool. Thus, the data in the database are largely accessible through published datasets and prediction models. These prediction models have been reflected in a computer program that may run on a personal computer. In hospital outcomes are predicted by stepwise logistic regression and long term outcome (time-to-event) by Cox model analysis. Mean survival curves for the Cox model are needed as well as the coefficients. The data for survival curves is stored in an Access 2.0 database. The primary application is programmed in Visual Basic 3.0 and will run on any IBM PC or clone running DOS 5.0 or higher and Windows 3.0 or higher. The application uses a full graphical user interface. The in-hospital outcome data are expressed as percentages. Survival (time-to-event) data are expressed as survival curves. The entire application is mouse controlled and there is no typing at any time. The user starts the program from a windows icon and then a main menu offers a selection of models. The user clicks on a model. Then a specific screen for the model appears and the user selects values for the correlates of the endpoint. When done the user clicks for the data to be displayed. Movement within models and between models is straight forward, simple and fast. The current models after coronary surgery: in hospital death, Q wave myocardial infarction, stroke, death after reoperative surgery, long term survival, non-fatal events and survival after reoperative surgery. The current models after angioplasty: in hospital death, Q wave myocardial infarction, emergency surgery, restenosis, long term survival and long term cardiac events. Clinical cardiologists and cardiology fellows can learn to use the program essentially immediately, without training. Clinical understanding and proper use of the tool are the limitation as the computer application has been simplified as much as possible.

2:45

759-4 Information Integration for Cardiology Decision Support

D.L. Hudson, M.E. Cohen, P.C. Deedwania. *University of California, San Francisco; California State University, Fresno; VA Medical Center, Fresno*

Electronic medical records pose a challenge because of the complex types of data which are included. Decision support systems must be able to deal effectively with these data types. In the expert system demonstrated here, a diversity of data types are included. These data are processed by three different methods. However, the different methods of processing are transparent to the user. An overall rule-based interface integrates the different methods into one comprehensive system. Data types include crisp data, fuzzy data, temporal data, and numerical representation of chaotic analysis. Some data items which appear to be crisp, for example, test results, are more accurately represented as fuzzy numbers which indicate the degree of precision of the test. Four types of temporal data are considered: change in value from previous value, change in value relative to a specified time interval, duration data, and sequence data. A measure developed by the authors which determines the degree of variability in time series data is also included. The knowledge-based portion of the system utilizes approximate reasoning techniques which allows weighting of antecedents and partial presence of symptoms. The rule base is used as the interface which invokes a neural network model or time series analysis if certain rules are substantiated. The neural network model is a three-level feed-forward model based on a non-statistical learning supervised learning algorithm developed by the authors. Input data can be of any ordered form, including binary, categoric, integer, or continuous. The network can categorize data into two or more classes, and also produces a degree of membership for each class. Time series data, such as electrocardiograms, are important measurements for many diagnoses. An ECG may have an overall interpretation which can be used in the rule-based component, or categorized to be used in the neural network component. However, other analyses may also prove useful. In the application shown, a measure of variability for 24-hour Holter tapes is used. The combination of these techniques is illustration in a decision support system for the diagnosis and treatment of heart disease, including the use of a rule base, a supplementary neural network model of exercise testing data (ETT), and a time series analysis for Holter data.

3:00

759-5 Use of an Interactive Electronic Whiteboard to Teach Clinical Cardiology Decision Analysis to Medical Students

John F. Murphy, Nilesh L. Jain, S. Andrew Spooner, Scott W. Hassan, John L. Schnase, Edward S. Metcalfe, Paul A. Schoening, Edward L. Cunnius, Mark E. Frisse. *Washington University School of Medicine, St. Louis, MO*

We used innovative state-of-the-art computer and collaboration technologies to teach first-year medical students an analytic methodology to solve difficult clinical cardiology problems to make informed medical decisions. Clinical examples included the decision to administer thrombolytic therapy considering the risk of hemorrhagic stroke, and activity recommendations for athletes at risk for sudden death. Students received instruction on the decision-analytic approach which integrates pathophysiology, treatment efficacy, diagnostic test interpretation, health outcomes, patient preferences, and cost-effectiveness into a decision-analytic model.

The traditional environment of a small group and blackboard was significantly enhanced by using an electronic whiteboard, the Xerox LiveBoard™. The LiveBoard features an 80486-based personal computer, large (3' × 4') display, and wireless pens for input. It allowed the integration of decision-analytic software, statistical software, digital slides, and additional media. We developed TIDAL (Team Interactive Decision Analysis in the Large-screen environment), a software package to interactively construct decision trees, calculate expected utilities, and perform one- and two-way sensitivity analyses using pen and gesture inputs. The LiveBoard also allowed the novel incorporation of Gambler, a utility assessment program obtained from the New England Medical Center. Gambler was used to obtain utilities for outcomes such as non-disabling hemorrhagic stroke. The interactive nature of the LiveBoard allowed real-time decision model development by the class, followed by instantaneous calculation of expected utilities and sensitivity analyses. The multimedia aspect and interactivity were conducive to extensive class participation.

Ten out of eleven students wanted decision-analytic software available for use during their clinical years and all students would recommend the course to next year's students. We plan to experiment with the electronic collaboration features of this technology and allow groups separated by time or space to collaborate on decisions and explore the models created.

3:15

759-6 Computerization of the ACC/AHA Guidelines for PTCA and CABG — Use of a Relational Database for Comparison with RAND Expert Panel Ratings and University of Maryland Revascularization Appropriateness Scores (RAS)

Michael A. Lauer, Andrew A. Ziskind, Cynthia C. Lemmon, Robert A. Vogel. *University of Maryland, Baltimore, Maryland*

With the increased emphasis on determining the need for coronary revascularization, appropriateness scoring systems have been developed. We developed software to apply clinically the complex ACC/AHA Guidelines for PTCA (1993) and CABG (1991).

Using 4D on an Apple Macintosh, we designed a relational patient database which captures key clinical information: patient demographics, clinical presentation, medications, comorbidity, exercise test results, left ventricular function, angiographic data, and followup events. Compiled code automatically assigns the patient to the proper clinical subsection, interprets relevant coronary anatomy and calculates the appropriateness classification — Class I (general agreement with indication), Class II (divergence of opinion), and Class III (general agreement that procedure is not indicated). In addition to providing objective appropriateness scores using the ACC/AHA PTCA and CABG Guidelines, the system automatically compares those scores with RAND Expert Panel Ratings and the University of Maryland RAS.

Reports can be produced based on specified search criteria for an individual patient or an entire patient group, thus allowing analysis of patterns of