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SPECIAL REPORT

# Report from the First International Conjoint Conference on Cardiovascular Magnetic Resonance and Echocardiography*

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## INTRODUCTION

Since the advent of cardiac nuclear imaging and echocardiography more than 50 years ago, noninvasive imaging has become an indispensable adjunct to modern cardiovascular diagnosis and therapy. However, despite the unparalleled diagnostic power, convenience, and efficiency offered by such technologies, the associated incremental costs are subject to continued intense scrutiny by funding agencies interested in reducing the inexorable inflation of health care reimbursements. As a relative newcomer to the arena of noninvasive cardiac imaging, Cardiac Magnetic Resonance (CMR) promises a quantum leap in diagnostic power. Enthusiasm for the technology is manifest in the academic community by the rapid growth in CMR publications, which has created exposure to the clinical power of CMR by potential early adopters in cardiology private practice settings. Yet, the growth of CMR remains restrained by thorny issues of capital costs, cost-effectiveness, reimbursement, and training.

In view of the burgeoning interest in CMR within the general cardiovascular imaging community, *the First International Conjoint Conference on Cardiovascular MR and Echocardiography* was convened on January, 22–24, 2001, in Atlanta, Georgia just prior to the Fourth

*Conducted in Atlanta, Georgia, January 22–24, 2001, under the auspices of the Society for Cardiovascular Magnetic Resonance (SCMR) and American Society for Echocardiography (ASE).

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Annual Scientific Sessions of the Society for Cardiovascular Magnetic Resonance (SCMR). The philosophical underpinnings of the program derived from: (1) the need for independent professional organizations and other parties interested in cardiovascular imaging to meet each other and share views on the future of research and clinical development; (2) the opportunity to influence investments of time and money in basic and translational imaging research by clinicians, scientists, commercial vendors, health care service provider organizations, and governments; and (3) the practical necessity to develop an efficient comprehensive organization of clinical cardiovascular imaging services with respect to the various health care stakeholders, given the ever increasing complexity and power of imaging technologies.

In view of the manifold similarities in clinical utility between echocardiography and cardiac MR, the organizing committee proposed to focus the *First International Conjoint Conference* on echocardiographic and CMR approaches, and focus future meetings around the contributions and roles of nuclear, PET, CT, and invasive cardiac catheterization methods. Accordingly, the academic societies who cosponsored this first meeting included the SCMR, the American Society of Echocardiography, and the European Working Groups on Cardiac MR and on Echocardiography. Industry participants were invited as cosponsors and are listed in the Appendix.

The following *Specific Aims* of the meeting were addressed in a series of moderated panel presentations over $1\frac{1}{2}$ days that featured audience participation:

1. Discuss the similarities, differences, and favorable attributes/applications of CMR and echocardiographic technologies from basic and clinical perspectives.
2. Initiate dialog and debate among the members of professional organizations, as well as physicians and scientists involved with each technology.
3. Discuss global, political, and economic issues related to advancement of these technologies.
4. Promote scientific exchange through brief overview and review lectures.
5. Discuss the current strengths and weaknesses of each discipline with respect to real-world clinical applications and the evolution of cardiac imaging.
6. Review and suggest mutually acceptable policies on topics related to training, performance, interpretation, credentialing, and reimbursement.

## PANEL OPINIONS

The prevalent opinions expressed in each panel discussion were summarized by the moderators and are presented below in order of their appearance in the program.

### Panel I: Current Applications and Technology. Echo Technology

The purpose of this panel was to describe the state of the art for echocardiographic imaging methods from basic and clinical perspectives. Key *clinical issues* pertinent to echo methods included:

- Satisfaction of the need for rapid data acquisition, interpretation, and presentation of results for established indications such as valvular heart disease, congestive heart failure, congenital heart disease, aortic dissection, pericardial tamponade, among others.
- Satisfaction of the need for bedside and/or portable imaging of critically ill patients.
- Marked improvement of nondiagnostic images in certain patients with the use of harmonic imaging and contrast echocardiography.
- Experimental validation of methods for myocardial perfusion that show clinical promise, although standard clinical protocols are still lacking.
- Proof of the clinical utility of stress (exercise/dobutamine) echocardiography for characterization of coronary artery disease, despite the subtleties of visual interpretation, including the diagnosis of viability and its prognostic implications.

Key *technical features* indicative of continued advancement of the technology included:

- New transducer designs and image processing schemes such as broadband pulses; harmonic/subharmonic and dual frequency transmit/receive electronics; and complete acquisition/analysis "packages" for use with acoustic contrast agents.
- Progress in clinically applicable real-time 3-D imaging.
- Advent of "functional" imaging for tissue characterization (e.g., elasticity, strain modalities).
- Development of methods for phase aberration correction to reduce artifact.

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- Evolution of relatively inexpensive, multimodal hand-held imaging instruments.

**Panel II: Current Applications and Technology. MRI Technology**

The state-of-the-art discussion for CMR methods offered the following points:

- CMR is a "gold standard" method for volumetric assessment of cardiac structure and function, and is an important and robust method for evaluation of ischemic heart disease.
- Established applications include: routine cardiac function and anatomy, disease of the thoracic aorta, constrictive pericarditis, RV dysplasia, complex congenital heart disease, anomalous coronary arteries, and coronary bypass graft patency.
- Emerging applications include: dobutamine stress testing with tissue tagging, myocardial viability assessment, and myocardial perfusion imaging.
- Coronary lumen and wall imaging and invasive/interventional applications of CMR show great promise for long-term development.
- The increasing penetration of real-time imaging is expected to facilitate all CMR applications.

**Panel III: Anatomy and Function**

This panel addressed the first topic of the specific clinical applications by reviewing comparative CMR and echo capabilities and concluded that:

- The combination of TEE and CMR in congenital patients frequently allows a complete clinical assessment without recourse to invasive catheterization.
- CMR is the ideal tool for assessment of diseases of the aorta, although TEE may have practical advantages in the setting of acute dissection.
- For assessment of regional and global function, CMR is the most accurate and reproducible technique currently available. However, in clinical practice, the extensive installed base of echocardiographic imagers and the relatively low cost of echo render it the practical first line technique at this time.
- In large clinical trials, CMR can be employed to reduce patient sample sizes substantially because of its proven high reproducibility for anatomy and function. Accordingly, overall research costs can be reduced.
- In the assessment of regional function, emerging CMR techniques such as tissue tagging (including HARP and DENSE) and echo techniques such as tissue Doppler, have proven utility in research studies. However, neither technique has demonstrated significant impact in clinical practice at this time.

**Panel IV: Perfusion and Viability**

These capabilities represent current challenges and opportunities for both CMR and echocardiography, and salient aspects of clinical implementation were discussed.

- Echocardiography in general is an adequate imaging method for about 90% of patients. If microbubble contrast perfusion methods could be shown to yield robust depiction of myocardial blood flow, the echocardiographic diagnosis of myocardial viability could be enhanced with flow-function mismatch data.
- Detection of myocardial viability with low dose dobutamine is proven, while quantification of the signature of backscattered ultrasound shows potential in clinical research trials.
- The measurement of tissue perfusion and perfusion defects by CMR contrast can be modeled by considering alterations in distribution volumes and other related physiological variables. The phenomenon of "late contrast enhancement" in scar tissue by CMR might be interpreted in this light and permit differentiation of viable (but low flow) myocardium from nonviable scar tissue.
- Quantification of myocardial flow with US or CMR requires an understanding of image artifacts and other complex nonlinear effects on signal propagation that are organ specific.
- 3-D real-time CMR studies, including the use of tagged CMR, show potential as a substitute for stress echocardiography; however, under conditions of high magnetic fields, stress test methodology and EKG monitoring problems require more attention before widespread clinical adoption can occur.

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### Panel V: Moderated Discussion: Industry, Academia and Government Relationships in Technology Development

This panel focused on recent developments in funding initiatives and government programs designed to facilitate advancements in imaging technology.

- Need-based clinical objectives have encouraged new government funding opportunities, which require industrial partnerships for development and evaluation of imaging methods. For example, NIH, NIST, DOD, and DOE all have active medical technology initiatives.
- The scope of grant-in-aid programs at NIH has been expanded to assist technology development. A critical change is the incorporation of technology-driven criteria, as contrasted with conventional hypothesis-based testing, for bioengineering proposals.
- A new NIH institute (Biomedical Engineering and Imaging) has been created by legal mandate from the 106th Congress with a projected funding base of $1.5 billion, which will come from contributions from other institutes. This institute should enable more support for bioengineering and development of medical imaging technology.
- The European situation is complicated by a multiplicity of national regulations and funding sources, although a more cohesive front for advancement of echocardiography and CMR is possible through the efforts of the European Working Groups on CMR and Echocardiography, as well as European Societies of Cardiology and Radiology.

### Panel VI: Therapeutic and Interventional Capabilities

The discussion focused on the emerging arena of conjunctive applications of noninvasive imaging technologies in therapeutics.

- Echo methods already are employed routinely in interventional situations: e.g., intraoperative TEE and intracardiac echo for mitral valve repair, heart biopsy, valvuloplasty guidance, transatrial septal catheterization, device placement for ASD closure, and electrophysiology studies.
- Advances in ultrasound technology promise to: (1) enhance real-time applications with 3-D approaches such as deployment of occlusive devices in ASD repair, (2) refine criteria for plaque characterization by strain analysis with IVUS utilized as a therapeutic adjunct, and (3) facilitate drug therapies with targeted microbubble destruction and local drug/gene deposition.
- CMR is progressing rapidly in the interventional arena with development of magnet configurations designed to accommodate better patient access for catheterization: e.g., larger and more open bore systems, or combined angiography/CMR suites.
- New CMR "coil-on-catheter" designs promise enhanced resolution and signal for MRI guided intravascular applications such as real time interventional coronary angiography, heart catheterization, and ablation therapy for arrhythmias.
- Development of new approaches for therapeutic angiogenesis in heart and peripheral vasculature will require more accurate assessment of efficacy with methods to quantify perfusion, function, and vascular anatomy as an adjunct to guide further therapy, which are being pursued with both CMR and ultrasound methods.

### Panel VII: Future Organization of Imaging-Related Clinical Services

- The organization of diagnostic echocardiography and CMR services could be coordinated but questions of image modality selection, physician interpretation, and patient referral pool should be solved prospectively with regard to knowledge of the specific patient and the particular disease state in question, and the technology.
- Training in both echocardiography and CMR is best accomplished in the context of certified residency and fellowship training programs, but special programs for postgraduates in practice (and technologists) will be required for widespread clinical adoption of new technologies.
- "Credentialing" of CMR laboratories will require new mechanisms for a growing pool of new users, and "competency" criteria for individual practitioners should follow from specific training requirements and from guidelines provided by academic and professional organizations.
- Setup cost, cost per case, and reimbursement issues are paramount considerations for clinical adoption of CMR that require immediate attention.

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- Cost-effectiveness analysis is recommended for proof of principle for the clinical utility of CMR, in addition to widespread multicenter randomized clinical trials for specific diagnoses compared with gold standards, and meta-analysis of existing trials.

**Panel VIII: Valve Function and Blood Flow Velocity**

- Echocardiographic imaging permits rapid, comprehensive, and accurate real-time characterization of the structure and function of all native or artificial cardiac valves with either transthoracic or trans-esophageal approaches, and serves as the primary clinical diagnostic modality for assessing and following patients with valve diseases.
- CMR offers several potential advantages for characterization of valve diseases: depiction of complex multidimensional spatial and temporal characterization of flow fields; no "window" limitations that affect echo; and no angle dependencies that affect echo Doppler interrogation; and no theoretical Nyquist limitations; and ability to track and adjust for valve through-plane motion.
- Disadvantages of CMR include more cumbersome and time consuming scan planning and data collection and analysis; limited definition of more subtle valvular or subvalvular structural abnormalities; and image artifacts created by mechanical valves; and lack of flexibility for use in situations requiring portability such as operating rooms, at bedside, etc.
- Quantification of flow in coronary arteries with CMR phase contrast methods allows noninvasive estimation of flow reserve in the major epicardial coronary arteries as compared with echo methods, which generally entail assessment of velocities with invasive Doppler flow wire methods.
- For quantification of regurgitation and stenosis, comparisons between echocardiographic and CMR methods for velocity and flow assessment are required to provide confidence regarding equivalency of the two methods prior to widespread clinical adoption.

**Panel IX: New Technology**

The principle suggestions for future technical improvements included:

- *Continued efforts to increase scanning speeds for both ultrasound and CMR*: Improved acquisition speeds in CMR could permit beat to beat myocardial motion analysis. Real time 3-D ultrasound has been shown to have clinical value for assessment of myocardial size, mass, and function and offers the promise of image guided therapeutic interventions. Greater scanning speeds are needed in ultrasound 3-D to increase the overall field of view and to take advantage of the improved resolution of high-frequency transducers.
- *Three-dimensional visualization*: With the advent of real time 3-D scanning either with ultrasound or near real time MR, the dynamics of individual chambers of the heart can now be visualized and assessed. Improved image segmentation methods are required to easily derive quantitative geometric information from these images. Accurate, fast, and reliable quantitative of various cardiac functional parameters should ultimately improve patient outcomes. Also, simple "fly through" image manipulation software is required to permit rapid visualization of regions of interest. "Global positioning" methods may become important to increase and simplify 3-D data acquisition with ultrasound.
- *Improved tissue contrast and identification*: CMR continues to develop new pulse sequences to improve visualization of flow and perfusion. MR spectroscopy may give us the potential of noninvasive metabolic assessments. Pulse sequence methods have also been applied in some experimental ultrasound scanning methods and show promise in improving image quality and in the enhancement of tissue contrast both in the presence and absence of externally introduced contrast agents. These new methods need to be explored further particularly in view of the higher speed imaging now possible through parallel processing. Increased speeds allow repeated ultrasound transmissions in the same direction with different pulse sequences without reducing the frame rate.
- *Contrast agents*: Improved contrast agents are needed for both CMR and ultrasound to improve

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assessment of myocardial perfusion. Current agents, particularly for ultrasound, have varying contrast as a function of location in the image field and often produce shadowing. Repeated noninvasive assessment of the size of myocardial at-risk regions is an important goal of patient management. Assessment of at-risk regions is greatly aided by the continued development of 3-D methods.

- *Improved resolution*: Ultrasound 2-D arrays offer the potential of increasing resolution by a factor of 4 or 5 over conventional systems. High technology 2-D arrays, which incorporate local electronic amplification and/or processing, need to be developed. In conjunction with real time 3-D imaging, noninvasive ultrasound imaging of the coronary artery tree will be possible. With contrast agents, high-resolution imaging should be able to identify sub-millimeter vessels. Higher frequency arrays will improve image quality further, however, this will necessitate high density, high performance electronics in the transducer assembly.

### Panel X: Atherosclerosis and Coronary Artery Disease

Noninvasive imaging of coronary artery anatomy and lesion severity represents a Holy Grail for both echo and CMR methods.

- Echo can rapidly characterize the clinical sequellae of acute and chronic coronary disease, such as complications of acute myocardial infarction.
- Echo permits reliable and rapid assessment of global and regional function of infarcted or ischemic ventricles, although CMR may be more accurate for purposes of quantification.
- CMR may ultimately provide an opportunity for arterial plaque imaging in vivo, and permit quantitative characterization of plaque morphology and composition.
- Both CMR and echo may provide information regarding the extent of disease in proximal coronary arteries, although large scale clinical trials need to be conducted to determine utility of the current research methods employed.
- Emerging technologies such as intravascular CMR or echo imaging may provide additional capabilities for interventional assessments that are potentially useful for patient care.

## SUMMARY

The opinions formulated in this conference represent expressions of promise and enthusiasm about charting the course for the future of cardiovascular imaging and the role that might be played by CMR and echocardiography. All attendees agreed that this conference provided a novel venue for friendly debate and discussion in an open forum that could facilitate research and clinical service planning, and that other similar conferences should be held to focus on additional methodologies and topics. Indeed, planning is already underway for a Second Conference with comparative CMR and nuclear imaging as a focus.

## APPENDIX

### Program Committee

Samuel A. Wickline, M.D., Co-Chair
David J. Sahn, M.D., Co-Chair
Richard Kerber, M.D.
Nathaniel Reichek, M.D.
Dudley J. Pennell, M.D.

### Panel Chairmen

- *Panel I*: Current Applications and Technology. Echo Technology: Richard Kerber and David Sahn
- *Panel II*: Current Applications and Technology. MRI technology: Nat Reichek
- *Panel III*: Anatomy and Function: Dudley Pennell
- *Panel IV*: Perfusion and Viability: Tom Budinger
- *Panel V:* Moderated Discussion: Industry, Academia and Government Relationships in Technology Development: Tom Budinger
- *Panel VI*: Therapeutic and Interventional Capabilities: Sam Wickline
- *Panel VII*: Future Organization of Imaging-Related Clinical Services: Anthony DeMaria
- *Panel VIII*: Valve function and flow: James Thomas
- *Panel IX*: New Technology: Olaf Von Ramm
- *Panel X*: Atherosclerosis and Coronary Artery Disease: Richard Kerber