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***PROGRESS***  
**IN**  
**CARDIOLOGY**

**3 / 1**

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# **PROGRESS IN CARDIOLOGY**

**New Series**

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edited by

**DOUGLAS P. ZIPES, M.D.**

Professor of Medicine  
Indiana University School of Medicine  
Senior Research Associate  
Krannert Institute of Cardiology  
Indianapolis, Indiana

**DEREK J. ROWLANDS, M.D.**

Consultant Cardiologist  
Manchester Royal Infirmary  
Lecturer in Cardiology  
University of Manchester  
Manchester, England

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## PREFACE

It is obvious that a significant portion of the evaluation of the cardiac patient has shifted from the catheterization laboratory, for years the citadel of the final cardiac diagnosis in the living patient, to other areas and disciplines in the hospital. The contemporary cath lab has become as much a treatment center as a laboratory for cardiac assessment. Virtually all of these other diagnostic techniques employ cardiac imaging of one kind or another. Therefore, we thought it appropriate to focus volume 3/1 and a part of 3/2 on an update about cardiac imaging.

Once again, we have been privileged to have as contributors the major "players" in the field. We have divided the discussion in volume 3/1, somewhat arbitrarily since unavoidable overlap exists, into sections on magnetic resonance imaging, echocardiography and Doppler, positron emission tomography, digital subtraction angiography, and a relatively new area of interest, cardiac sympathetic imaging. In volume 3/2, we will conclude the subject of imaging with an article on the hibernating myocardium and one on myocardial metabolism.

To diversify volume 3/1 a bit, in response to requests by many readers, we have included two articles on cardiac infections and a thorough summary on coronary thrombolysis. The latter will be supplemented by articles in volume 3/2 on new thrombolytic agents and an overview of the many clinical trials and their results.

Also in 3/2 will be chapters on lipids and contemporary coronary care. The latter will encompass the latest techniques dealing with angioplasty, atherectomy, and stents, as well as other contemporary issues about implantable defibrillators, geriatric cardiology, balloon valvuloplasty, and heart transplantation.

We are putting together the pieces for volume 4, to be published in 1991. It will feature new concepts about congestive heart failure, plus a variety of interesting articles related to coronary artery disease. Keep tuned in!

*Indianapolis, Indiana* Douglas P. Zipes  
*Manchester, England* Derek J. Rowlands



## CONTRIBUTORS

### **LEE P. ADLER, M.D.**

Assistant Professor, Department of Radiology  
Case Western Reserve University and University  
Hospitals of Cleveland  
PET Facility  
University Hospitals of Cleveland  
Cleveland, Ohio

### **WILLIAM F. ARMSTRONG, M.D.**

Associate Professor of Medicine  
Indiana University School of Medicine  
Research Associate, Krannert Institute of Cardiology  
Indianapolis, Indiana

### **BENICO BARZILAI, M.D.**

Assistant Professor of Medicine  
Washington University School of Medicine  
St. Louis, Missouri

### **FRANCOIS P. CHAPPUIS, M.D.**

Chief of Clinical Science  
Cardiology Center  
University Hospital  
Geneva, Switzerland

### **JOHN W. COOPER, M.D.**

Assistant Technical Director  
Echocardiography-Graphics Laboratories  
University of Alabama Hospital  
Birmingham, Alabama

### **MICHAEL J. CUNNINGHAM, M.D.**

Assistant Professor of Medicine  
University of Rochester School of Medicine  
Cardiology Unit, Strong Memorial Hospital  
Rochester, New York

### **HANS-JOSEF DEUTSCH, M.D.**

Internal Medicine Clinic III  
University of Köln  
Köln, West Germany

### **PO-HOEY FAN, M.D.**

Research Fellow and Echocardiographic Associate  
University of Alabama at Birmingham  
Birmingham, Alabama

### **EDWARD T.A. FRY, M.D.**

Fellow, Cardiovascular Division  
Washington University School of Medicine  
St. Louis, Missouri

### **MICHAEL A. GERBER, M.D.**

Associate Professor of Pediatrics  
University of Connecticut School of Medicine  
Department of Pediatrics  
University of Connecticut Health Center  
Farmington, Connecticut

### **DONALD G. GORDON, M.D.**

Medical Director  
Memorial PET Scan Center  
Jacksonville, Florida

### **K. LANCE GOULD, M.D.**

Professor of Medicine  
University of Texas Medical School  
Houston, Texas

### **MALEAH GROVER-McKAY, M.D.**

Assistant Professor of Medicine and Radiology  
Department of Internal Medicine  
The University of Iowa  
Iowa City, Iowa

### **CHARLES B. HIGGINS, M.D.**

Professor of Radiology  
Chief, Magnetic Resonance Imaging Section  
Department of Radiology  
University of California School of Medicine  
San Francisco, California

### **PAUL R. JULSRUD, M.D.**

Associate Professor of Diagnostic Radiology  
Mayo Medical School  
Mayo Clinic  
Rochester, Minnesota

### **G.B. JOHN MANCINI, M.D.**

Associate Professor  
Director of Digital Cardiac Angiography  
Chief, Veterans Administration Cardiology Section  
Veterans Administration Medical Center  
Ann Arbor, Michigan

### **MILTON MARKOWITZ, M.D.**

Professor of Pediatrics  
University of Connecticut School of Medicine  
Farmington, Connecticut

### **ALAN H. MAURER, M.D.**

Associate Professor of Diagnostic Imaging  
Director of Nuclear Medicine  
Temple University Hospital  
Philadelphia, Pennsylvania

**JAMES G. MILLER, Ph.D.**

Professor of Physics and Research Professor of  
Medicine  
Director, Laboratory for Ultrasonics  
Washington University School of Medicine  
St. Louis, Missouri

**MARK R. MILUNSKI, M.D.**

Fellow in Cardiology  
Washington University School of Medicine  
St. Louis, Missouri

**NAVIN C. NANDA, M.D.**

Professor of Medicine  
Division of Cardiovascular Disease  
University of Alabama at Birmingham  
Birmingham, Alabama

**RICHARD C. PASTERNAK, M.D.**

Assistant Professor of Medicine  
Director, Coronary Care Unit  
Beth Israel Hospital  
Boston, Massachusetts

**JULIO E. PÉREZ, M.D.**

Associate Professor of Medicine  
Washington University School of Medicine  
Medical Director, Cardiac Diagnostic Ultrasound  
Barnes Hospital  
St. Louis, Missouri

**WILHELM J. RUTISHAUSER, M.D.**

Professor, Faculty of Medicine  
Chief of Medicine, Cardiology Center  
University Hospital  
Geneva, Switzerland

**UDO SECHTEM, M.D.**

Internal Medicine Clinic III  
Institute for Clinical and Experimental Nuclear  
Medicine  
University of Köln  
Köln, West Germany

**DAVID J. SKORTON, M.D.**

Professor of Medicine and Electrical Computer  
Engineering  
Associate Chairman for Clinical Programs  
Department of Internal Medicine  
The University of Iowa  
Iowa City, Iowa

**BURTON E. SOBEL, M.D.**

Tobias and Hortense Lewin Professor of  
Cardiovascular Diseases  
Washington University School of Medicine  
Director, Cardiovascular Division  
Cardiologist-in-Chief  
Barnes Hospital  
St. Louis, Missouri

**PETER THEISSEN, M.D.**

Institute for Clinical and Experimental Nuclear  
Medicine  
University of Köln  
Köln, West Germany

**HENRY N. WELLMAN, M.D.**

Professor of Radiology and Medicine  
Director, Division of Nuclear Medicine  
Indiana University Medical Center  
Indianapolis, Indiana

**SAMUEL A. WICKLINE, M.D.**

Assistant Professor of Medicine  
Cardiovascular Division  
Washington University School of Medicine  
St. Louis, Missouri

**DOUGLAS P. ZIPES, M.D.**

Professor of Medicine  
Indiana University School of Medicine  
Senior Research Associate  
Krannert Institute of Cardiology  
Indianapolis, Indiana

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# UPDATE ON CARDIAC IMAGING

## CONTEMPORARY ASPECTS OF MODERN IMAGING TECHNIQUES

Edited by David J. Sack  
David J. Sack

### HEALTH CARE

### HEALTH CARE

The book is a comprehensive review of the current and emerging aspects of cardiac imaging. It covers the use of various imaging techniques, including echocardiography, nuclear medicine, and magnetic resonance imaging. The book is written for health care professionals and is a valuable resource for those interested in the latest developments in cardiac imaging. The book is divided into two main sections: the first section covers the basic principles of cardiac imaging, and the second section covers the clinical applications of these techniques. The book is written in a clear and concise style, making it easy to read and understand. The book is a must-read for all health care professionals involved in the diagnosis and management of cardiac disease.

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# COMPARATIVE ASPECTS OF MODERN IMAGING TECHNIQUES\*

Maleah Grover-McKay

David J. Skorton

## GENERAL CONSIDERATIONS

### SCOPE OF CARDIAC IMAGING AND ITS ROLE IN CARDIAC DIAGNOSIS

Modern cardiovascular practice requires precise and comprehensive diagnosis. With the exception of electrocardiography and electrophysiologic testing, the predominant laboratory approaches to cardiac diagnosis fall into the category of cardiac imaging methods.<sup>1</sup> Accurate evaluation of cardiac anatomy and physiology allows proper treatment. Important cardiac anatomic characteristics include cardiac chamber and great vessel size, myocardial mass, the presence of intracardiac masses (thrombus, tumor, or vegetation), valve anatomy, pericardial disease, coronary artery and bypass graft anatomy, and myocardial tissue composition. Significant physiologic variables, both at rest and during exercise or during coronary vasodilation, include diastolic filling characteristics, valvular stenosis and insufficiency, intracardiac shunts, regional and global myocardial contractile function, myocardial blood flow and coronary flow reserve, and my-

\*Supported in part by grants HL32295 (Specialized Center of Research in Ischemic Heart Disease) and K04-HL01290 (Research Career Development Award), National Institutes of Health (Dr. Skorton) and a grant from the Education and Research Foundation of the Society of Nuclear Medicine (Dr. Grover-McKay).

ocardial metabolism. Currently available imaging methods permit precise delineation of gross cardiac morphology, coronary and graft anatomy, and chamber and valvular function (Table 1). Conventional imaging methods yield much less information on myocardial perfusion, metabolism, and tissue characteristics than several newer, evolving imaging techniques (Table 2). Therefore, evolving imaging techniques should increase the information available for physiologic investigation and management of patients.

## WELL-ESTABLISHED AND EVOLVING CARDIAC IMAGING METHODS

When attempting to assess the relative merits of these imaging methods for evaluating the heart, knowledge of the "gold standard" for assessment of a given anatomic or physiologic variable is essential. Frequently, the independent stand-

ard against which newer methods are judged may be the established imaging methods, a practice that may not be appropriate. Pathologic examination provides the best standard for cardiac anatomy, but it is not available in most clinical investigations. Measurement of regional myocardial contractile function is most precisely performed with ultrasonic crystals,<sup>2</sup> a technique that is not applicable in patients because it requires surgical implantation of the crystals on and in the myocardium. Similarly, accurate measurements of regional myocardial blood flow, obtained using radiolabeled microspheres,<sup>3</sup> and of regional myocardial metabolism,<sup>4</sup> are not clinical procedures because one must obtain pieces of myocardium on which to perform the measurements. Therefore, because of the inherent limitations of clinical imaging investigations, it is sometimes difficult to assess the absolute or comparative efficacy of the different techniques. Nonetheless, based on currently available information, in this

TABLE 1. USEFULNESS OF CONVENTIONAL IMAGING TECHNIQUES

	CXR	ANGIO	ECHO	Planar IVG	Planar Perfusion Imaging
<i>Cardiac Anatomy</i>					
Chamber size	+	+++	+++	++	0
Myocardial mass	0	+	+++	+	0
Intracardiac masses	0	++	+++	+	0
Valve anatomy	0	++	++++	0	0
Pericardial disease	+	+	++	0	0
Coronary anatomy	0	+++	+	0	0
Graft patency	0	++++	0	0	+
<i>Cardiac Physiology</i>					
Diastolic filling	0	++	+	+++	0
Valvular stenosis/insufficiency	+	++++	+++	+	0
Intracardiac shunt	+	++++	+++	++	0
Myocardial function	0	+++	++	+++	0
Myocardial blood flow	0	0	+	0	++
Tissue characterization	0	0	+	0	0
Myocardial metabolism	0	0	0	0	0

0, No information; + + + +, maximum information; angio, angiography; CXR, chest roentgenogram; echo, echocardiography; IVG, isotope ventriculography.

TABLE 2. USEFULNESS OF EVOLVING IMAGING TECHNIQUES

	Digital Angio	Computer- Assisted/ Transesophageal Echo	SPECT IVG	SPECT Perfusion Imaging	MRI	MRS	UFCT	PET
<b>Cardiac anatomy</b>								
Chamber size	++	++	++	0	++	0	++	++
Myocardial mass	+	+++	++	+	++	0	++	++
Intracardiac masses	++	++	0	0	++	0	++	0
Valve anatomy	++	+++	0	0	++	0	++	0
Pericardial disease	+	+++	0	0	++	0	++	0
Coronary anatomy	+++	++	0	0	++	0	++	0
Graft patency	++	+	0	+	+	0	++	++
<b>Cardiac Physiology</b>								
Diastolic filling	++	+	++	0	+	0	++	0
Valvular stenosis/insuf.	+++	++	++	0	++	0	++	0
Intracardiac shunt	+++	++	++	0	++	0	++	0
Myocardial function	+++	+++	+++	0	++	0	++	++
Myocardial blood flow	++	+++	++	+	++	0	++	++
Tissue characterization	+	++	0	+	+	++	++	++
Myocardial metabolism	0	0	0	0	0	++	0	++

0, No information; +, ++, +, maximum information; angio, angiography; echo, echocardiography; IVG, isotope ventriculography; MRI, magnetic resonance imaging; MRS, magnetic resonance spectroscopy; PET, positron emission tomography; SPECT, single photon emission computed tomography; UFCT, ultrafast computed tomography.

chapter we discuss and compare selected aspects of standard and evolving cardiac imaging methods.

The well-established cardiac imaging methods include chest roentgenography, conventional cardiac angiography, echocardiography (including Doppler studies), first-pass and gated isotope ventriculography, and  $^{201}\text{Tl}$  myocardial perfusion imaging. With the exception of two-dimensional echocardiography, these are all planar techniques. Planar images are acquired by detection of energy on a two-dimensional surface, such as film cassette or gamma camera crystal. The heart is a three-dimensional organ whose structure changes over time. Therefore, two-dimensional imaging techniques provide limited information because cardiac structures are superimposed.

Newer imaging techniques have been developed to overcome some of the limitations of established techniques. Evolving cardiac imaging methods include digital angiography, transesophageal and computer-assisted echocardiography, single-photon-emission computed tomography (SPECT), ultrafast computed tomography (CT), nuclear magnetic resonance imaging (MRI) and spectroscopy (MRS), and positron emission tomography (PET). An important advance has been the development of CT methods, both radioisotope and x-ray based. Three-dimensional information is obtained by the tomographic techniques because images are acquired in multiple planes and the data may be reconstructed either mentally or by computer.<sup>5</sup> Another major advance has been the capability to characterize the physiologic state of tissue by its structure or biochemistry, which was not possible using conventional imaging techniques. Computer-assisted echocardiography, MRI, MRS, and PET provide information about tissue composition, and MRS and PET

provide information about tissue biochemistry.

Before discussing the use of particular imaging methods in specific clinical problems, some general strengths and weaknesses of the several modes of cardiac imaging can be considered. Echocardiography does not use radiation to produce images, but adequate images are not obtained in all patients studied. Conditions that make imaging difficult include obesity, lung disease, abnormal chest-wall configuration, calcification of cartilage, and advanced age. Transesophageal echocardiography yields high-quality images in these patients; however, the test is more invasive. Doppler ultrasound methods offer unique information about cardiovascular blood flow velocity, direction, and pattern. With isotope ventriculography, it is possible to obtain images in most patients. Studies may be limited by the inadequate labeling of the red cells that can occur in patients receiving heparin and in those who have received chemotherapy. Excess tissue such as fat or breast can attenuate counts, thereby decreasing image quality. The coarse spatial resolution of radioisotope methods precludes an assessment of fine structural detail, such as wall thickness or valve motion. Radiation is delivered, but the dose to the patient is low (Table 3). MRI can produce tomographic images in a multitude of imaging planes without using radiation or contrast material; however, image acquisition is slow, and images must be gated to the cardiac cycle to overcome the low signal-to-noise ratio. Therefore, the acquisition of acceptable images may be limited by the inability to acquire an adequate electrocardiographic (ECG) signal to obtain ECG-gated images and by the inability of the patient to lie still for sufficient data collection. Newer, rapid scanning methods may obviate some of these problems.<sup>6</sup> It may not be



**TABLE 3 RADIATION EXPOSURE TO PATIENT FROM CARDIAC IMAGING STUDIES****X-Ray Techniques**

Method	Total Dose (rads)
CXR	0.05-0.1
Ultrafast CT	2-10 rads/slice
Cardiac cath	1-130 (24)

**Radioisotope Techniques**

Method	Isotope	Dose mCi	Dose MBq	Target organ	Target organ dose (rads)	Total body dose (rads)
IVG	<sup>99m</sup> Tc	20	740	marrow	1.0	0.3
Thallium	<sup>201</sup> Tl	3	111	kidney	3.6	0.72
PET	<sup>82</sup> Rb	120	4440	kidney	2.16	0.15
	<sup>15</sup> O	30	1110	lung	0.28	0.05
	<sup>13</sup> N	20	740	lung	1.67	0.02
	<sup>11</sup> C	20	740	liver	1.10	0.24
	<sup>18</sup> F	10	370	heart	1.98	0.06

CT, computed tomography; IVG, isotope ventriculography; MBq, megabequerel; PET, position emission tomography; Rb, rubidium; Tc, technetium; Tl, thallium

advisable to use MRI in patients with implanted metal devices, such as pace-makers. Ultrafast CT uses ionizing radiation and intravenous contrast material during rapid acquisition of tomographic images. Exquisitely detailed cardiac anatomy is visible with ultrafast CT. Obesity, motion of the patient, and arrhythmias degrade image quality. PET provides unique, noninvasive information about myocardial metabolism. Information about myocardial blood flow and gated studies to evaluate regional wall thickening can be obtained and compared with myocardial metabolism at the same anatomic location. The radiation dose to the patient is low; however, anatomic resolution is not as clear as with other techniques. Angiography offers high spatial and temporal resolution, but it involves radiation, contrast material injection, and catheterization.

In addition, information obtained from angiography is predominantly anatomic.

## COST-BENEFIT CONSIDERATIONS

The cost of a given cardiac imaging procedure has at least two components: the cost to the institution and the cost to the patient. Several components of cost to the institution exist, including the purchase price of the equipment, maintenance, personnel, and overhead (including space). The cost to the patient is not only monetary, but also includes the biologic risks. The monetary cost of an imaging procedure to the patient varies among institutions and depends on institutional costs that take into account the number of studies performed. The rel-