Noninvasive Approaches to Cardiovascular Diagnosis

edited by

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To Joan and Edith, and to our parents

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Foreword

Heart failure is the most important cause of death in our society today. For decades, cardiovascular disease has been responsible for close to half of all the deaths in the United States.

Sudden death or incapacitation are swords of Damocles that hang over the heads of everyone, but especially males in Western society. Thus the current interest is in diagnostic tests that may make possible early detection of heart disease, particularly coronary heart disease.

This book is primarily about echocardiography and nuclear cardiology. It differs from others in being oriented toward clinical problems. For example, Chapters 3 to 9 describe the use of these and other diagnostic tests in coronary heart disease, valvular heart disease, cardiomyopathies, congenital heart disease, pericardial disease, and venous thrombosis and pulmonary embolism. The first two chapters are concerned with an outline of basic principles, designed primarily for the nonspecialist. Particular emphasis is given to assessment of global and regional ejection fraction of the left ventricle.

As recently as forty years ago assessment of left ventricular function was limited to the appearance of congestion or shock. Subsequent development of methods for cardiac diagnosis have documented clearly that clinical signs are insensitive and that functional changes precede clinical signs. The invention and application of nuclear and echocardiographic methods have made pos-

sible measurement of *regional* as well as global function. In the case of the heart, as with other organs, regional changes are often found before overall function falls outside the wide variability of normal *global* function. This has been called the "homogeneity principle" and provides the basis for early diagnosis. The function of one part of the heart is compared to that of other parts, as in measurement of ventricular wall motion or the distribution of myocardial blood flow.

In addition to their usefulness in the differential diagnosis of chest pain, dyspnea, and fatigue, these methods can also serve well in prognosis and planning treatment. For example, severely impaired left ventricular function can pose a relative contraindication to valvular and coronary artery surgery, while early ventricular failure may indicate the need for cardiac surgery in patients with intracardiac shunts. Drugs, such as propanolol or adriamycin, can be used more effectively if their effect on ventricular function can be measured.

Perhaps the greatest appeal of these methods is their visual display of function. Human beings derive nearly all their sensory input through their eyes. They are better at perception than conception, and therefore like nuclear and echocardiographic images, especially when displayed as motion pictures.

Their greatest limitation is in quantification although we are moving steadily in the direction of improved quantification. For example measurements of ejection fraction, peak ejection and filling velocities of the left ventricular events are becoming commonplace. Methods of monitoring ventricular function are developing rapidly.

Among the most important advances in cardiology today are the application of nuclear and echocardiographic techniques.

This book can serve as a clinical "primer" for cardiologists, internists, nuclear physicians and students who wish to become familiar with this new and exciting field.

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Preface

This monograph is intended for internists and family practitioners, all of whom frequently encounter signs and symptoms suggesting important cardiovascular problems. Since noninvasive approaches are commonly employed as an initial step to investigate potential manifestations of heart disease, guidelines as to the usefulness and limitation of a host of noninvasive procedures are clearly in order. It is our hope that the material presented herein will not only add to the basic fund of information of the practitioner, but will also enable him to formulate an opinion about the attributes and limitations of various noninvasive approaches to problem solving. The mechanisms underlying the efficacy of specific methodologic approaches are spelled out in detail in the first portion of the text. However, it is not our intention to underscore technical execution or the breadth of application of each and every technique we describe, since almost all of this information is available elsewhere (see Introduction).

In the second section, our attention will be directed to the relative potential of several methods for contributing to the solution of important diagnostic cardiovascular problems which are most frequently encountered in hospital and office practice. Discussion is often not restricted to noninvasive test results per se, but also addresses the clinical context in which they are chosen to perform. We unequivocally believe that when noninvasive clinical testing is performed, it is done not in isolation, but as a logical extension of the history and physical examination of the patient

and as an integral part of his or her total evaluation.* Thus in the chapter on coronary artery disease we have emphasized the importance of a history of typical angina pectoris because its pertinence to the diagnosis of coronary artery disease is frequently overlooked in the current wave of enthusiasm for performing noninvasive tests. We feel that similar "apparent digressions" on the natural history and clinical features of specific disease processes in other chapters are necessary to present the applications of noninvasive testing in a more realistic perspective.

While noninvasive diagnostic tests have considerably facilitated approaches to the solution of cardiovascular problems within the past decade, they have by no means provided a definitive and final answer for most problems. Much work still needs to be done on the validation of noninvasive tests, in particular, defining their sensitivity, specificity, and accuracy in specific clinical contexts. Moreover, there are a multiplicity of tests to evaluate a specific function. For example, the left ventricular ejection fraction can be estimated by systolic time intervals, echocardiography and radionuclide scintigraphy. Should all of these tests be used in the same patient, or only one? Similar questions will arise as new tests are introduced. The principles applying to the validation of noninvasive tests are presented in Chapter 11. Ultimately the physician will decide if any or how many noninvasive tests should be used for his patients. It is our hope that the philosophy of integrated approach and the principles outlined in the validation chapter will help the reader to become an informed and judicious ongoing learner, who applies the advances of modern technology with wisdom and foresight.

No work of this nature can be accomplished without the generous cooperation and dedication of a supporting staff. We are indebted to all of our professional colleagues for encouraging our work. We are particularly grateful to our fellows in training and technologists who over the past five years have diligently pursued and performed many of the examinations, which served as a source of materials selected for illustrative purposes in this book. Thanks are also due to Dr. Robert Jones, Department of Surgery, Duke University School of Medicine and Dr. Roberta Williams, of the Department of Pediatrics, Harvard Medical School, for their critical review of Chapter 7 and their contribution of important figures pertinent to noninvasive diagnosis of congenital heart disease. A final special word of thanks must be given to Ms. Carol Krause and Ms. Rosemary Phillips for tolerating the many idiosyncrasies of the authors in production of the manuscript and the illustrations it contains.

*Parisi AF: Noninvasive cardiac diagnostic tests—Their attributes and limitations. Chest 72:417-9, 1977 (Editorial)

Introduction

Many excellent textbooks are currently available which deal with the technical execution, breath of application, and nuances of noninvasive cardiac diagnostic methods. Most of these monographs are technique oriented, emphasizing the applicability of a single method to those diagnostic areas wherein it has proven most fruitful. The information compiled in these texts forms an invaluable resource; the list of available suggested reading appended to this section is intended for those who wish to pursue in greater depth use of one or more techniques covered in this book.

The ensuing chapter explains principles underlying different noninvasive methods and is of necessity *technique oriented.* Given this foundation the remainder of our approach is *problem oriented;* emphasizing the relative merits and limitations of different methods in the context of other available information in order to elucidate common cardiovascular diagnoses. The reader is reminded that the area of noninvasive diagnosis is rapidly expanding—new techniques and new claims for old techniques are continually being introduced. It is hoped that our approach considering the relative merits and limitations of several noninvasive testing procedures in the light of a total clinical picture will be adopted as a means of evaluating and utilizing noninvasive diagnostic methods now and in the future.

SUGGESTED READING

GENERAL TEXTS

Chung EK: Non-invasive Cardiac Diagnosis. Philadelphia, Lea & Febiger, 1976

Weissler AM (ed): Non-invasive Cardiology. Philadelphia, Grune & Stratton, 1974

ECHOCARDIOGRAPHY

Feigenbaum H: Echocardiography. 2nd ed. Philadelphia, Lea & Febiger, 1976

Friedewald VE Jr: Textbook of Echocardiography. Philadelphia, Saunders 1977

Goldberg SJ, Allen HD, Sahn DJ: Pediatric and Adolescent Echocardiography. Chicago, Yearbook, 1975

Gramiak R, Wagg RC, (eds): Cardiac Ultrasound. St. Louis, Mosby, 1975

Williams RG, Tucker CR: Echocardiographic Diagnosis of Congenital Heart Disease. Waltham, Little, Brown, 1977

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Strauss HW, Pitt B, James AE: Cardiovascular Nuclear Medicine. St. Louis, Mosby, 1974

Pierson RN, Kriss JP, Jones RH, MacIntyre WJ: Quantitative Nuclear Cardiology. New York, Wiley, 1975

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Taval ME: Clinical Phonocardiography and External Pulse Recording 2nd ed. Chicago, Yearbook, 1976

EXERCISE STRESS TESTING

Naughton J, Hellerstein HK (eds): Exercise Testing and Exercise Training in Coronary Heart Disease. New York, Academic, 1973

Ellestad MH: Stress Testing—Principles and Practice. Philadelphia, Davis, 1975

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Preliminary Considerations

ONE

Methodology

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Several noninvasive diagnostic techniques are commonly used to aid in solving cardiac diagnostic problems. We stress the general approach to the examination and underlying physical and physiologic principles; the reader is referred elsewhere for a more detailed explanation of the technical execution of each specific method discussed.

Noninvasive tests can be divided arbitrarily by the nature of the written test results.[1] *Imaging techniques* demonstrate underlying gross anatomic features and pathologic structural abnormalities in pictorial or nearly pictorial form. Echocardiography and radionuclide scintigraphy have dominated the interests of clinicians in the past decade and hence will be discussed in greater detail herein. Other techniques, such as CAT scanning, have been effectively applied to delineate normal and pathologic anatomy in other areas of the body and undoubtedly will be effectively applied to the cardiovascular system in the relatively near future.

Many techniques produce important physiologic and pathophysiologic information from which meaningful conclusions can be drawn about underlying structural and functional abnormal-

ties. We have placed these together under the heading *Deductive Techniques* and will discuss therein pulse tracings, systolic time intervals, and exercise electrocardiography. Brief mention will also be made of the cardiac Doppler applications as a currently emerging deductive technique.

IMAGING TECHNIQUES

Echocardiography

Echocardiography is a generic term intended to connote the use of pulsed reflected ultrasound as a diagnostic tool for delineating the anatomy of the heart. Sound consists of energy waves which are characterized in part by their frequency. The frequency of sonic waves is measured in cycles per second (Hertz-Hz). Audible sound encompasses frequencies between 20 and 20,000 Hz. Sound beyond 20,000 Hz, i.e., the upper frequency limit of normal human hearing, is termed ultrasound. The ultrasound used in examination of the heart is usually of the order of 1.5 to 5 million cycles per second (MHz), most commonly 2.25 MHz. Ultrasound in the 3 to 5 MHz range allows better definition of anatomic structures but penetrates tissues less well than ultrasound in the 1.5 to 3.0 MHz range. Higher frequency ultrasound is commonly used in pediatric echocardiography; adult echocardiographers tend to use the lower frequency range because greater depth penetration is required to traverse the adult chest and heart.

Ultrasound is emitted in extremely short pulses from a special transducer that also acts as a signal receiver for reflected ultrasound waves. The active element in an echocardiographic transducer is a piezoelectric crystal. The term "piezoelectric" signifies that the crystal can transform electrical energy into mechanical (sound) energy and vice versa. Single crystals that are used in adult clinical echocardiography are commonly pulsed for a duration of 1/1,000,000 of a second (1 μsec); this pulsing is repeated every 1/1,000 of a second (1 msec). Periods of sound transmission are followed alternatively by periods of sound reception, during which echoes reflected from structures within the heart are detected. The duration of the transmission period and the duration of the reception period differ by three orders of magnitude, since the trans-