Diagnostic Methods in Clinical Cardiology

Edited by Peter F. Cohn, M.D. and Joshua Wynne, M.D.

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For Joan
and
For Charlotte and Canio

Preface

The purpose of this book is to provide the clinician with a survey of diagnostic methods (exclusive of history-taking and physical examination) that are available for the evaluation of cardiac disorders. Emphasis has been placed not on the technical aspects of most of these procedures but rather on their indications, interpretation (from the clinical point of view), and complications. The introductory first chapter is devoted to an overview, including test sequencing in various disease states. The next five parts deal with specific noninvasive and invasive procedures in considerable detail, but always with the clinician — rather than the specialist — in mind.

Our aim is to provide an integrated approach to the evaluation of cardiovascular disease and to bring some logic to the selection of appropriate tests from an increasingly complex and sophisticated array of possible diagnostic procedures. With the proliferation of noninvasive tests (including electrocardiographic, echocardiographic, and radioisotopic procedures), the clinician is often in a quandary as to which test to order, whether the information it provides is sufficiently reliable and diagnostic, and when to proceed to an invasive procedure such as cardiac catheterization. We have attempted to address these issues and provide guidelines for clinical decision-making without being dogmatic or ignoring controversy. While we have co-authored two-thirds of the chapters, we have tried to avoid a monolithic approach and have encouraged each of our contributors to emphasize areas of uncertainty or disagreement. It is our hope that this text will be a useful guide to the clinician in day-to-day patient care decisions.

It is a pleasure to acknowledge the inspiration, enthusiasm, support, and counsel of our colleagues and cardiology fellows. Special thanks are due to Adele Slatko for her superb administrative and secretarial support, and Lin Richter and Katherine Arnoldi at Little, Brown and Company for their editorial skills.

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Notice

The indications and dosages of all drugs in this book have been recommended in the medical literature and conform to the practices of the general medical community. The medications described do not necessarily have specific approval by the Food and Drug Administration for use in the diseases and dosages for which they are recommended. The package insert for each drug should be consulted for use and dosage as approved by the FDA. Because standards for usage change, it is advisable to keep abreast of revised recommendations, particularly those concerning new drugs.

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Chapter 1

Value and Limitations of Cardiac Diagnostic Procedures

AN OVERVIEW

Peter F. Cohn and Joshua Wynne

Traditionally, physicians have relied on history taking and physical examination for evaluation of patients. Until the latter half of the twentieth century, only a limited number of laboratory tests were available to assist in this clinical assessment. In the last several decades, however, a burgeoning medical technology has altered this general approach and inundated the clinician with new diagnostic procedures. In no field of medicine has this phenomenon been felt more strongly than in cardiology. The array of currently available noninvasive diagnostic procedures is indeed awesome, ranging from simple blood tests to complex systems for imaging the heart. In addition to these noninvasive procedures, the development and refinement of cardiac catheterization and related procedures has provided an invasive "gold standard" with which to measure the noninvasive procedures. How is a clinician to approach these tests? In what order should they be performed? What do their results mean? Are there any dangers in performing them? In succeeding chapters, these issues will be addressed for the specific procedures that are discussed in detail. To provide each patient with effective care, however, the physician must maintain an overview into which these specific considerations fit.

Noninvasive cardiac diagnostic tests are composed of those procedures that rely on the electrocardiogram (such as the resting ECG, the 24-hour ambulatory monitor, and the exercise tolerance test); those procedures involving recording of the pulse tracings, usually along with a phonocardiographic recording; ultrasound, radioisotopic studies, nonangiographic x-ray studies, and serum blood tests. Invasive procedures include hemodynamic evaluations and left ventriculography, pulmonary angiography, and coronary angiography.

We believe that the resting electrocardiogram and chest x-ray belong in the first line of diagnostic tests. What to order next (in addition to the history and physical examination) will depend on what disease is suspected. If, for example, a patient with chest pain has findings suggesting coronary artery disease, an exercise tolerance test is the logical next procedure of choice. When this test cannot

be interpreted properly, or when it is not unequivocally positive or negative, some type of radioisotopic study is indicated. Either a myocardial perfusion study or a radioisotopic ventriculogram could be performed, preferably during exercise. Cardiac catheterization is carried out only when these other tests have yielded whatever information they can. When coronary artery disease is acute, as in a suspected myocardial infarction, appropriate serum enzymes must be drawn, "hot spot" radioisotopic perfusion studies performed when indicated, and hemodynamic evaluations obtained in those patients in whom compromise of the left or right ventricle is likely. In this situation, cardiac catheterization is reserved for only those patients who are in shock or impending shock. Other tests that are of value in patients with suspected coronary artery disease are, of course, determination of risk factors, such as glucose intolerance and hyperlipidemia. When valvular heart disease is suspected, the first line of approach after the resting ECG and chest x-ray should include echocardiography, supplemented in some cases by external pulse tracings with phonocardiography. Cardiac catheterization is often performed but not as an initial procedure. If cardiomyopathy is strongly suspected, either echocardiography or a radionuclide ventriculogram should be ordered after the initial work-up. Diseases in which arrhythmias predominate must be evaluated with Holter monitoring or exercise testing.

In all these tests, the clinician must be aware of the value and limitations of the specific procedures, as discussed in the subsequent chapters. Few of these procedures approach 100 percent sensitivity and specificity; their clinical utility depends on the population in which they are being used. Their major value is in combining with one another rather than standing alone. Therefore, the clinician must learn which of these tests are most appropriate for the disease entity in question. Learning when to order which test is almost as important as learning what the results of these tests indicate.

Part I

Electrocardiography

Chapter 2

The Resting Electrocardiogram

Gilbert H. Mudge, Jr.

The resting electrocardiogram (ECG), one of the most common routine diagnostic tests, has become an integral part of any patient evaluation. An average of 1.4 ECGs are obtained for each hospital admission. Because of this ubiquitous nature, it is often awarded a diagnostic precision that is not entirely justified. An imperfect tool, its results can be interpreted to suggest significant cardiac abnormalities when the patient has a normal heart or may be entirely normal when the patient has advanced cardiac disease. This chapter attempts to place the resting ECG into perspective, emphasizing to the clinician who already has a firm working knowledge of electrocardiography both its capabilities and limitations.

A number of constitutional variables can substantially alter a normal ECG, including sex, age, body height and weight, race, and anatomic position of the heart within the chest as well as the conformation of the chest itself. Women may have smaller precordial lead voltage than do men, which may be attributed to a higher content of body fat and breast tissue insulating the precordial exploring electrode [1, 2]. Females likewise have a higher incidence of vertebral osteoporosis, with partial vertebral collapse, which can enhance R-wave voltage in the precordial leads by moving the heart closer to the exploring electrodes. Age is another significant variable in the normal ECG. The precordial lead voltage in the adolescent is usually significantly greater than later in life [3]. Such QRS changes may also be associated with a shift of the QRS axis in the frontal leads toward the left with progressive age [4]. Such shift in axis will also be seen with differences in body habitus. Obese middle-aged patients have a horizontal axis with diminished R-wave and T-wave amplitude, in contrast to the vertical axis associated with normal body weight. Such variations may be due to positional changes of the heart caused by a protuberant abdomen and elevated diaphragm. An otherwise normal ECG may vary according to race. The black population has been found to have a statistically significant shorter QRS interval, larger QRS amplitude, and a more posteriorly directed T-wave vector in the horizontal plane that leads to T-wave inversion in V1–V3, which may be a totally normal variant [1].

Besides such constitutional considerations, variations in the technique of obtaining electrocardiograms may lead to differences in the ECG changes. Some electro-

cardiographic machines do not respond in the proper frequency to appropriate signals. Significant Q waves seen with one electrocardiographic machine may be incorporated into the R wave by another recording apparatus. The ST segment and height of the T wave can also vary with differences in frequency response and do not reflect changes in the pathologic state. For this reason, subtle changes in the ECG must always be correlated with the clinical condition. Other technical factors, including the use of alcohol solution rather than saline for electrode contact, corroded electrodes, or inadequate contact of the electrodes with the skin may lead to recording falsely low voltage.

Despite meticulous technique, the ECG is also susceptible to day-to-day variations. Such variations in QRS excursion are most often seen in the precordial leads and may vary by as much as 3 to 4 mm [5]. For this reason, some patients may have marginal criteria for left ventricular hypertrophy on one tracing but will not meet those criteria with a subsequent ECG. There is also a natural variation to Q waves, most marked in the inferior leads. Q waves that do not meet criteria for myocardial infarction may be found in the inferior leads on one tracing but absent from the subsequent ECG. Proper evaluation of such small Q waves must include both supine and standing ECGs as well as expiratory and inspiratory tracings.

Variations in the Normal Electrocardiogram

Certain variations in the normal ECG deserve particular emphasis. Incomplete right bundle branch block is found in approximately 2 percent of the normal population and does not represent significant conduction abnormality [6]. The R′ wave is thought to represent late, unopposed activation of the crista supraventricularis of the right ventricular outflow tract. In such cases, the R′ wave is usually smaller than the R wave, with an amplitude usually less than 4 mm. In patients with significant right ventricular hypertrophy and coexistent incomplete right bundle branch block (see under Right Ventricular Hypertrophy), the R′ wave is invariably taller than the R wave.

Another variation in the normal ECG is the S_1, S_2, S_3 pattern. In 20 percent of normal healthy individuals, the bipolar leads may be isoelectric, indicating that the mean vector of depolarization is nearly perpendicular to the frontal plane [6]. Such a finding is also seen in right ventricular hypertrophy, most often due to chronic obstructive pulmonary disease, but in this latter instance, other criteria for right ventricular hypertrophy are usually fulfilled.

Significant variation in T-wave morphology over the right precordial leads with T-wave inversion from V1 to V4 may be seen in normal patients. This is most often seen in healthy young females or the black patient population and can be mistaken for acute anterior myocardial ischemia (Fig. 2-1).