M-Mode Echocardiographic Techniques and Pattern Recognition

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to

the cardiac patient

FOREWORD

Echocardiography, particularly its techniques and interpretation, is a topic that is commonly given only brief mention or omitted entirely from most medical publications. In this monograph, an invaluable addition to the literature, Sonia Chang describes the specific details of performing the echocardiographic examination, as well as some of the "tricks of the trade" which she has learned during her career in this field.

Although no one can become an expert in echocardiography by merely reading a text, one can become better informed and thus more proficient. The end result, of course, should be an increase in the number of patients who will benefit from this examination. Since the echocardiographer must be able to recognize both normal and abnormal tracings, illustrations of both are provided.

I am proud to have been Sonia Chang's mentor and honored to have been asked to write this foreword. Sonia Chang has made several important contributions to echocardiography. First, she has demonstrated that echocardiographic examinations do not have to be performed by physicians, and perhaps are better performed by people especially trained in these techniques. Because a quality echocardiographic tracing is the primary, and often sole, responsibility of the echocardiographic technologist, this person is certain to aim for the highest possible quality; an excellent tracing is a source of pride and satisfaction.

Another of Sonia Chang's contributions is the introduction of technical standards and innovations to the echocardiographic examination. Her constant emphasis on detail and quality has set standards for the world and has done much to advance the clinical usefulness of this technique. She has helped to develop and perfect a variety of new echocardiographic techniques, such as the M-mode scan, the condensed M-mode scan, and the subxiphoid examination.

Indeed, those who have learned echocardiography under my tutelage at Indiana University School of Medicine owe their high technical standards to Sonia Chang.

HARVEY FEIGENBAUM, M.D.

PREFACE

This procedure manual grew out of the need for an instructional source for the technical aspects of training visiting physicians and fellows rotating through the echocardiographic service at Indiana University, Indianapolis, Indiana, and at Emory University, Atlanta, Georgia.

The manual does not purport to be an atlas representative of all the pattern motions possible with the many cardiac lesions. It *does* attempt to give a ready and comprehensive reference to the physician and technician of the technical aspects of M-mode echocardiographic examination and possible pitfalls in recording and interpreting the more common cardiac abnormalities by this noninvasive procedure.

The illustrations are the results of studies conducted on equipment described in the publications from the Indiana University Echocardiographic Laboratory. However, the techniques used to obtain the illustrations are applicable to almost any type of commercially available equipment designed for echocardiography. Usually only minor modification of equipment is needed to duplicate the tracings described herein.

Most of these tracings were taken from adults with normal anatomical relationship of the intracardiac structures. Complex congenital anomalies are basically worked out using the techniques described in this manual. The interested reader should refer to the literature for more detailed descriptions of the manifestations of complex congenital disease as defined with M-mode echocardiography.

Sonia Chang

ACKNOWLEDGMENTS

I have just come through eight of the most intellectually exciting years of my life. Contributing to the content of those years have been leaders in echocardiography, hospital staff members, visiting physicians, technicians, engineers and patients. From publications and lectures of other investigators, from friendly discussions and from heated arguments have come seeds of ideas leading to the development of an established protocol for routine M-mode echocardiographic examination.

Several people have played major roles in my development as an echocardiographer at Indiana University from 1967 to 1975. To them I express my deepest gratitude and thanks for their instruction, guidance, moral support and daily assistance. To:

Richard Campbell, M.D., who first guided me through the intricacies of intracardiac hemodynamics;

John Chang, my husband, who conceived the idea and encouraged the growth of this procedure manual throughout the years when physicians came to this laboratory for echocardiographic instruction;

James Dillon, M.D., whose sense of humor was always appreciated;

Harvey Feigenbaum, M.D., a highly imaginative and innovative employer, mentor and friend, who encouraged me to leave the cardiac catheterization laboratory and take up echocardiography at a time when this diagnostic procedure was still in its infancy;

Raymond Gramiak, M.D., Michael Johnson, M.D., and Claude Joyner, M.D., from whom I borrowed and modified techniques for examining the aortic valve and great vessels, prosthetic Starr-Edwards valves and the mitral valve, respectively;

Janie Stewart, a superb technician and friend, without whom I would never have had the time to put this manual together in its present format had she not assumed the tedious details that keep a very busy laboratory functioning smoothly;

Arthur (Ned) Weyman, M.D., friend and colleague, contributor par excellence to the field of echocardiography;

Phil Wilson, for his illustrative ability with pen, ink and paint brush; for instruction in how to turn an ordinary tracing into a work of art;

And, finally, to Joe Demma, Carol Eitzen, Donald Izban and Donald Schoch who patiently mounted and printed innumerable illustrations.

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CONTENTS

immediately utilize their background in cardiac anatomy and hemodynamics to record and interpret echocardiographic tracings under proper supervision and long-term instruction by the physician. However, any person with a lively curiosity, bold imagination, willingness to learn and considerable patience has the potential to become an efficient echocardiographer. Manual dexterity has become an important factor. Some artistic inclinations, including an appreciation for the beauty of a well-done echogram, are necessary ingredients for a competent echocardiographer.

The echocardiographic examination is unlike any other type of ultrasound procedure. Because the heart is a dynamic organ, reflecting the hemodynamics within its chambers, the art of recording meaningful tracings must be acquired at the bedside. Classroom teaching is useful to educate the examiner about diseases that may be identified by echocardiography. Patterns of motion to be expected from specific cardiac disease can be learned and by comparing tracings from many sources, one can follow the "state of the art." But only by having the transducer in one's hand and examining several hundred patients personally, can one achieve expertise in recording echocardiographic tracings.

Technicians should utilize ancillary activities to aid their "basic education" at the bedside. Attendance at conferences is useful. At such meetings patients are presented who have been studied with electrocardiography, echocardiography, phonocardiography, treadmill exercises and cardiac catheterization. At this time diagnostic studies and further medical management of the patient are discussed; the technician may see the overall picture of the patient's clinical status and treatment. This personalization of every examination keeps echocardiography from becoming just another static diagnostic procedure.

Generalized reading on the most common types of acquired heart disease and of common congenital disease is also helpful. Particular attention to the anatomical structure of the normal and congenitally deformed hearts is essential. Short, in-depth discussions of cardiac abnormalities and hemodynamics with staff members who are willing to teach are invaluable.

There is no shortcut to becoming a proficient echocardiographer. Efforts to help educate the technician have been persistently attempted through organized courses, regional meetings and short-term visits to other laboratories. All these efforts and others are needed, but all experienced echocardiographers agree that the most useful teaching-learning process lies in the harmonious cooperation between the echocardiographic physician and his technician in their own laboratory.

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INSTRUMENTATION

All the techniques in this manual can be adapted to echographic instruments with strip chart recorders. Practically none of the scanning techniques can be recorded on Polaroid camera apparatus, although the techniques are used to visually locate one structure in relation to another. The condensed scan techniques require strip chart recorders with recording capabilities of 10 mm/sec and superb resolution. However, any scan may be recorded at faster speeds, and the dimensions measured as desired.

Good housekeeping of the equipment is essential for optimal operation and trouble-free years of use. Be sure to:

1. Keep air filters clean.
2. Wipe transducers off after each examination to prevent corrosion of the facing material.
3. Check the focusing of the echograph and strip chart recorder periodically, especially if many portable studies are done. The jiggling over elevator door bases and uneven tunnels may disturb the focusing. Also, if many people use the echograph, someone invariably turns the wrong knob.
4. Check electrocardiogram leads periodically for wear or breakage.
5. Damp-mop the coupling gel from the equipment to prevent corrosion and staining of cabinet and metals.
6. Keep a supply of slow-blow fuses on hand.
7. Repair or replace worn-out or defective parts at the first sign of difficulty.

The first place to check when the echograph or strip chart recorder malfunctions is the numerous *fuses* on both instruments. Replacement of burned-out fuses will usually solve the problem, but only temporarily since there is an underlying cause for the trouble. Confer with service representatives. A simple adjustment or component replacement made promptly may save a large repair bill later.

Operating Controls

The description of the controls and their function in the instruction manuals accompanying the different types of echograph instruments is usually adequate. Most echographs have a set of controls that can be made to interact and produce very specific results in the graphic presentation of information from oscilloscope to paper or prints. These controls are commonly known as "reject," "near gain," "coarse gain," "damping" and "depth compensation." Although these controls are in different locations on different instruments, they all work in similar ways. Figure 1 shows the front panel of a commercially available echograph, which will serve as a representative model to facilitate discussion.

Reject

From the technician's point of view, reject is the control that eliminates low amplitude echoes from the system altogether. The

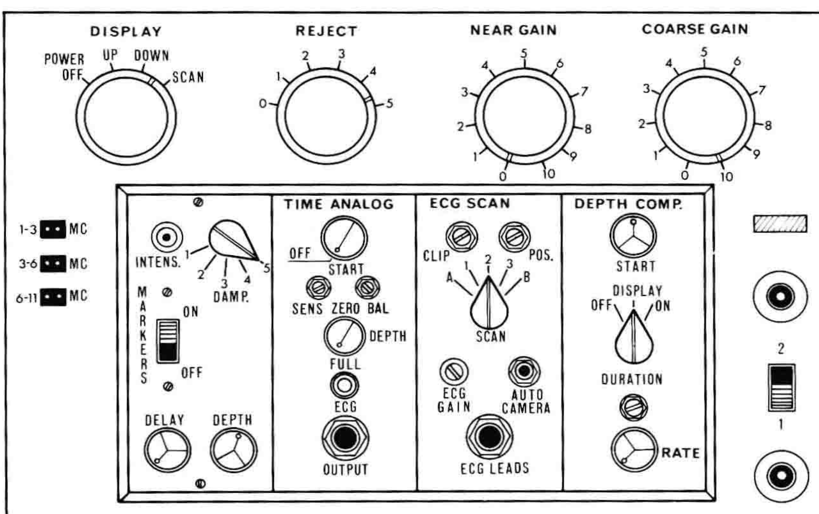

Figure 1. Front panel of commercially available echograph. Most tracings recorded in this manual used following settings: reject, 2 or 3; near gain, not more than 3; coarse gain, variable; damping, 3; depth compensation, maximum slope ending in midseptum.

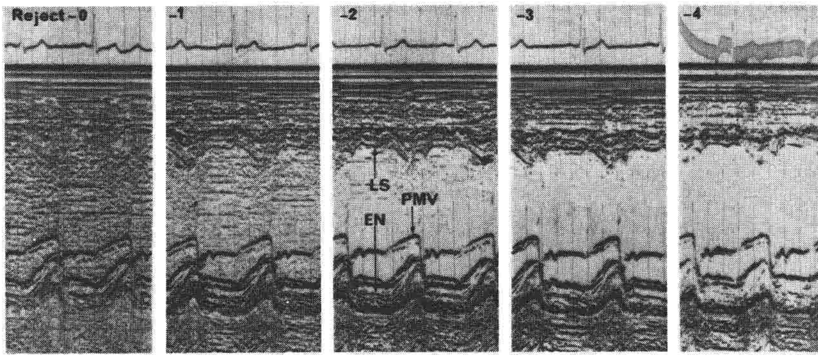

Figure 2. Effects of reject (see text). LS = left side of septum, EN = endocardial surface of posterior left ventricular wall and PMV = posterior mitral valve.

echoes no longer exist and cannot be acted on by gain or damping. If the reject is set on "0" or "1" (Figure 2), many echoes with very low amplitude are seen to fill the ventricular chamber between the left septum and the endocardium of the posterior left ventricular wall. These echoes do not contribute to the value of the study and are best eliminated by raising the reject to a higher level. The tracing in Figure 2 becomes more acceptable with the reject set on "2" or "3." All the structures that can be used for routine left ventricular measurements are clearly defined. By raising the reject to "4," too many echoes have been eliminated from the system and useful information is lost.

Gain

Gain is the control that amplifies echoes received from the transducer. It may be increased or decreased at will to make the recording graphically acceptable for measurements. Signals perpendicular to the structure being examined will be reflected as strong and solid lines on the tracing.

Gain will not improve the tracings if the transducer is incorrectly positioned on the patient's chest. Gain can only amplify those signals that are being received. It does *not* select those echoes which are most useful to make a diagnosis.

Near Gain

Near gain controls the amplitude of those echoes received from the transducer and which are located between the crystal artifact (Figure 3) and the depth compensation ramp (Figure 5).

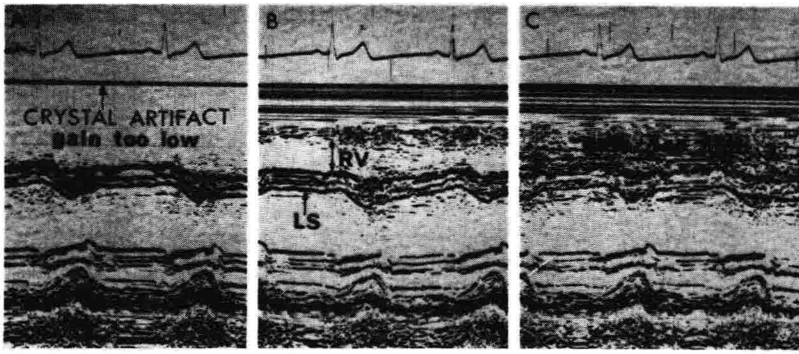

Figure 3. Effects of near gain when depth compensation ramp is ending at right side of septum. Near gain controls amplitude of those echoes received between crystal artifact and end of depth compensation ramp. *A*, Near gain was turned off; *B*, near gain is properly set at low level so that only structures which are useful are observed, in this case chest wall and right ventricular wall; *C*, near gain was turned too high. Useful structures cannot be identified at this level of amplification, and usefulness of "near gain" is defeated. RV = right ventricle and LS = left side of septum.

In Figure 3*A* the near gain has been turned completely off, so that no echoes are being received in the area between the crystal artifact and the right side of the septum. In Figure 3*B* the near gain has been increased to a level just high enough to amplify echoes from the chest wall, the right ventricular wall and anything else which may lie in the pathway of the sound beam between the right ventricular wall and the right side of the septum. Sometimes the tricuspid valve may be seen if the right ventricle is dilated. Figure 3*C* displays the effect of too much amplification of echoes being received between the crystal artifact and the right side of the septum. The right ventricular wall cannot be identified, and an accurate right ventricular dimension could not be taken.

Coarse Gain

Figure 4 demonstrates how coarse gain controls the amplitude of *all* received echoes equally. If the coarse gain is set too high, the dominant echoes such as the right and left sides of the septum will be poorly defined (Figure 4*B*). This is because echoes that are not essential to the quality of the study are being overamplified and thus seen and recorded with desired structures. If the coarse gain setting is too low, the septal and posterior left ventricular wall echoes appear broken and poorly defined (Figure 4*C*). The transducer is perpendicular to the septum and posterior left ventricular wall, but the coarse gain is too low to record the complete motion of these structures.

Figure 4*A* is the most acceptable tracing. The right and left side of