DIAGNOSTIC ELECTROCARDIOGRAPHY

MICHAEL C. RITOTA

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Preface to the Second Edition

My purpose in writing a basic text on diagnostic electrocardiography is to offer the clinically oriented reader – whether primary physician, nurse, or intern – a sound base on which he can build in terms of both physiological concepts and practical applications.

In this new edition I have continued, in the spirit of the first edition, to explain in the simplest terms and, at the same time, clearly and accurately, all the basic elements of electrocardiography, together with those concepts of electrophysiology that will illuminate the interpretation of ECGs without burdening the reader with a great deal of theory and discussion of electrophysiology that might only serve to discourage him.

The outline form used in this book was developed and tested in my years of teaching electrocardiography to general practitioners, interns and nurses as well as paramedical personnel. I begin at the very beginning, because it is important to the reader that no special knowledge of the field be taken for granted. For this reason, I have expanded the section on the reasons for taking the ECG and have completely rewritten, with emphasis on concrete details, the procedure to be followed. The various eardiopathies, and the relevant drawings and ECGs, are presented in ascending order of complexity, at each step utilizing the information presented in the preceding sections.

All of the text and illustrations have been carefully reviewed and revised when indicated. For example, the discussion of the abnormal P waves has been rewritten and expanded.

Among topics newly introduced, with appropriate illustrations, are: atrial T-waves (Ta waves): left atrial hypertrophy; trifascicular block, and hemiblock. Also, an entirely new chapter has been added, dealing with the monitoring leads used in the ICU, with descriptions of the ECG features, the patterns, and indications and limitations of their use.

Most important, in every case the ECG Criteria are given in detail in the context of each topic discussed and illustrated in the book.

It is my hope that the second edition of *Diagnostic Electrocardiography* not only will serve as a source of useful information and instruction but will encourage its readers to explore further the diagnostic potentials of the ECG.

Preface to the First Edition

Cardiovascular diseases cause more than half of all deaths in the United States—indeed, acute coronary thrombosis or acute myocardial infarction has been called the "twentieth century epidemic." In addition, of patients seen by the general practitioner, as many as 50 per cent are found to have cardiac symptoms or actually to be suffering from heart disease.

Heart disease can be aggravated or caused by other diseases. Conversely, heart disease may precipitate diseases of organs such as the brain, as well as the kidney, liver and other visceral organs that depend on cardiac output for proper function.

It is therefore important that physicians in general practice and in specialties other than cardiology be able to interpret cardiac symptoms correctly, since this ability will be useful both in differential diagnosis and in revealing relationships between these symptoms and disorders in other organs and systems.

Electrocardiography is today increasingly important as a tool in the diagnosis of heart disease. It is important to every general physician and specialist, and to interns and nurses connected with cardiovascular services. Knowledge of electrocardiography aids both physicians and students in the evaluation of the treatment and management—and, therefore, of the prognosis—of heart disease.

The purpose of this book is to present simply and accurately the basic knowledge essential to the interpretation of commonly seen electrocardiograms. To accomplish this with the greatest brevity and clarity, the text is organized in outline form, and, since a picture is worth ten thousand words, diagrams and actual ECGs are used to illustrate each point discussed and every feature of the ECG of diagnostic value. Each type of ECG is first presented diagrammatically and much enlarged, for ease of visualization of the features characteristic of that type. The text calls attention to features of diagnostic significance and also to associated conditions. The normal cycle and its components (P-Q-R-S-T-U waves) are stressed in the earlier chapters; the abnormal patterns are shown in the later chapters.

It is hoped that this book will be valuable not only to interns, residents and nurses in Intensive Coronary Care Units but also to all practitioners interested in electrocardiography.

Acknowledgments

Acknowledgement is due primarily to the general practitioner, whose service is unceasing and of inestimable value in the endless war against heart disease.

I wish, next, to express my great admiration of the teachers responsible in large measure for my education in cardiology and electrocardiography: Dr. Sidney P. Schwartz, Dr. Scott Butterworth, and Dr. Leonard Dreifus.

I sincerely appreciate the opportunity given me by Columbus Hospital to teach electrocardiography to physicians in New Jersey, whose inspiration and encouragement moved the author to the writing of this book.

I am ever so grateful for the fine artistry of Mr. Sal Ceraulo and Theodore P. Ritota, M.D. I owe many thanks to Barbara Olsen, R.N., for her secretarial assistance. I thank Edwin Rothfeld, M.D., and Frank Galioto, Jr., M.D., Assistant Professor of Pediatrics, University of Connecticut, for the contribution of some very fine and unusual tracings.

I am especially grateful to Mrs. Dorothy V. Ritota, R.N., B.A., for her kind and patient assistance in reviewing the manuscript.

Finally, I wish to thank Mr. J. Stuart Freeman, Senior Editor, of the J. B. Lippincott Company, for his cooperation in preparation of this book, and Fred Zeller, Senior Vice President, who contributed a great deal of his time and efforts to this new edition.

Contents

1

Technical and Mechanical Considerations

STANDARDIZATION OF THE ELECTROCARDIOGRAM

For the electrocardiogram to be technically accurate certain conditions must be met. The essential prerequisites for good tracings with a minimum of technical errors are:

1. Proper standardization
2. Proper positioning of extremity and chest leads
3. Proper coding

There Must Be Proper Standardization of One Millivolt (Fig. 1-1).

The horizontal lines on the electrocardiograph paper are spaced 1 millimeter apart and are used to measure voltage. The 1-cm. standardization is the normal standardization. It is used universally so that comparative studies of tracings can be made readily. Standardization of 0.5 cm. is used when there is high voltage or the amplitude of the complexes exceeds the size of the paper. When the stylus inscribes above and beyond the limits of the paper, the complexes can be seen better by reducing the voltage to $\frac{1}{2}$ cm. Double the amplitudes obtained at 0.5 cm. will give you the values for 1-cm. standardization. A 2-cm. standardization is used to increase the amplitude of fibrillatory ("f") waves, flutter ("F") waves, low P waves, and other such waves that may be difficult to discern at 1 cm. because of their miniature amplitudes.

There Must Be a Constant Standard Positioning of the Precordial Electrodes and the Standard Leads (Fig. 1-2).

The lead tips of the lead cable are designated as follows:

RA (right arm)
LA (left arm)
LL (left leg)
RL (right leg)

RL is the grounding wire; the other leads form the Einthoven triangle (Fig. 1-3). The leads must be placed correctly; abnormal patterns result from wrong positioning.

The precordial leads are positioned from V_1 to V_6 (Fig. 1-4) by the use of a small suction cup on lead P (precordial—or C, chest). Lack of precision in location of these leads will result in variation in the patterns. This becomes especially important if serial electrocardiograms are taken or electrocardiograms are taken by different technicians at different times or places. Therefore all rules must be standardized.

There Must Be Careful Code Marking of Each Individual Lead, as Described Below.

Code marking should be done as the electrocardiogram is being taken, in order to avoid errors later, in the mounting of the tracing and lead identification. Coding is best represented by dots (or very short dashes which simulate dots) and long dashes. The code given here is in general use. However, any method is acceptable so long as it is simple and clear. If any code other than the one shown is used, the explanation should be noted on the ECG as soon as the lead is transcribed.

MARKING CODE

STANDARD LEADS	CODE
Lead I (left arm–right arm)	•
Lead II (left leg–right arm)	••
Lead III (left leg–left arm)	•••

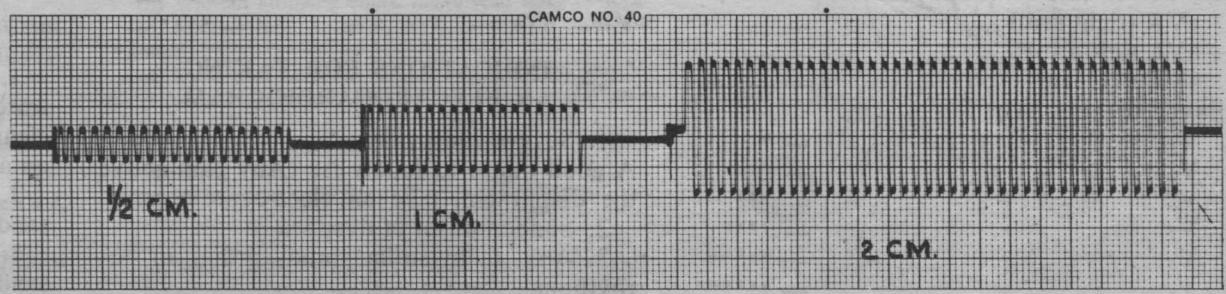


FIG. 1-1. Standardization of 1 millivolt. (*Left*) At 0.5 cm. (5 mm.) $\frac{1}{2}$ mv. (*Center*) At 1 cm. (10 mm.) 1 mv. (*Right*) At 2 cm. (20 mm.) 2 mv.

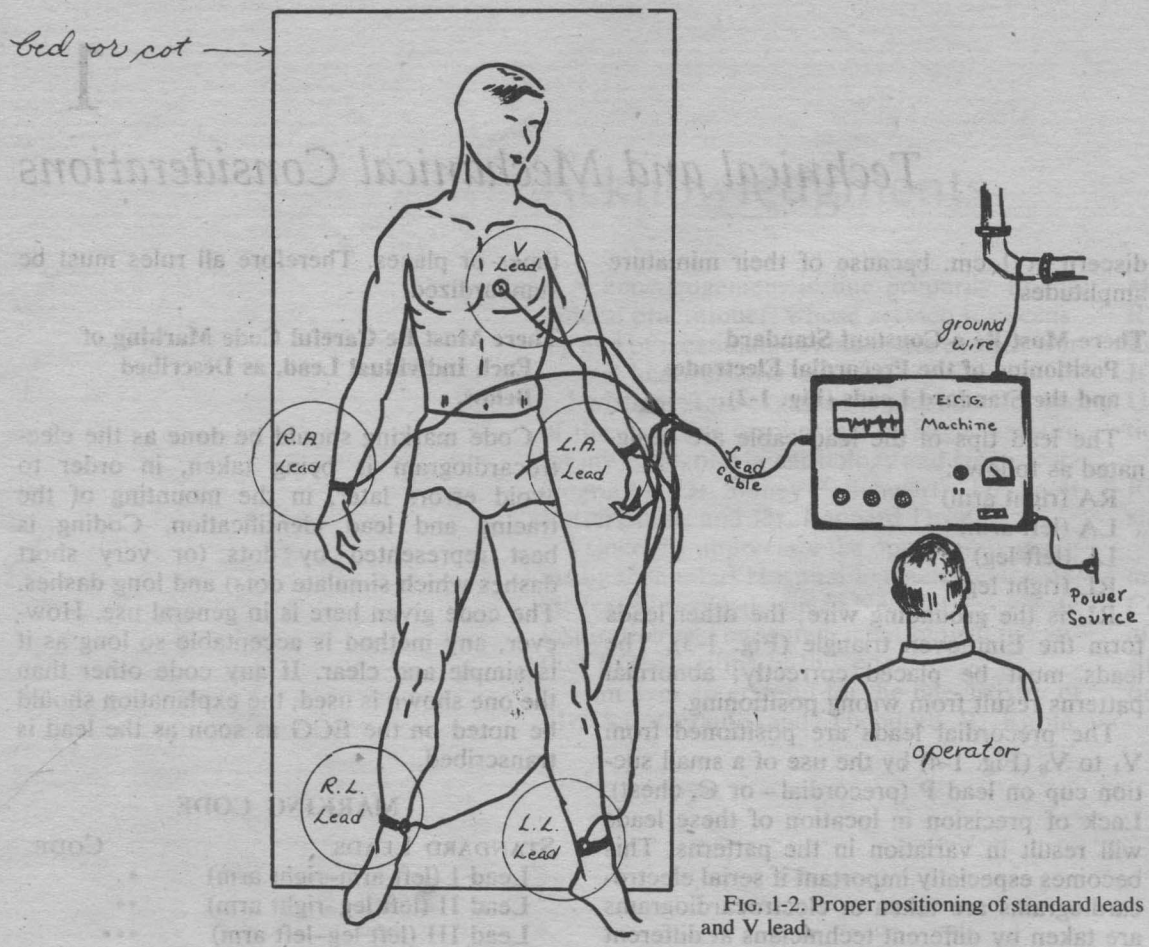


FIG. 1-2. Proper positioning of standard leads and V lead.

UNIPOLAR (AUGMENTED) LEADS	
aVR (right arm)	—
aVL (left arm)	— —
aVF (left leg)	— — —
PRECORDIAL LEADS	
V_1	— •
V_2	— ••
V_3	— •••
V_4	— ••••
V_5	— •••••
V_6	— ••••••
V_3R	— ••• —
V_4R	— •••• —

INDICATIONS FOR TAKING AN ELECTROCARDIOGRAM

1. Severe chest pain

A good motto to follow is: "Any pain above the diaphragm, take an electrocardiogram."

2. Sudden onset of dyspnea
3. Any tachycardia, bradycardia, or arrhythmia

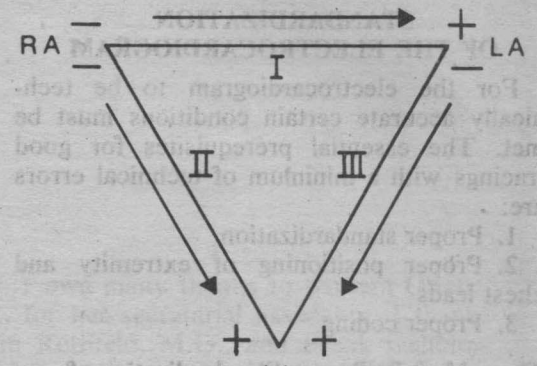


FIG. 1-3. Einthoven triangle.

4. Shock state
5. Syncope
6. Postoperative hypotension
7. Coma
8. All murmurs
9. Cardiomegaly
10. Severe right upper quadrant (gallbladder (?)) *or* epigastric (ulcer (?)) pain
11. Congenital *or* acquired cyanosis
12. Daily cardiac monitoring in coronary intensive care units (this subject is discussed in Chapter 18).
14. Preoperatively, for patients over 50 years of age
15. All cases of hypertension
16. Excessive steroids or diuretics
17. Serial ECGs in the coronary care unit
18. Pacemaker evaluation

TECHNIQUE FOR RECORDING A GOOD ECG

1. Electrode tips must be clean! Use hot water or alcohol. If they are badly corroded, cleanse with fine sandpaper or electrode paste on a piece of gauze.
2. Electrode holes must be clean! Use fine sandpaper wrapped around a toothpick.
3. Lead cable tips must be clean! Use fine sandpaper.

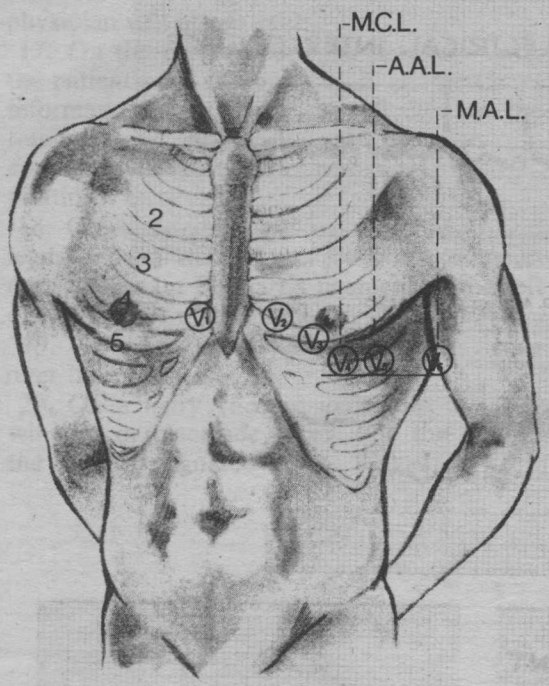


FIG. 1-4. The landmarks for the precordial leads (V leads)

V_1—4th interspace at the right border of the sternum
V_2—4th interspace at the left border of the sternum
V_3—left parasternal line midway between V_2 and V_4
V_4—5th interspace in the left midclavicular line
V_5—in the anterior axillary line at the level of V_4
V_6—in the midaxillary line at the leve of V_4 and V_5
M.C.L., Midclavicular line; A.A.L., anterior axillary line; M.A.L., midaxillary line.

4. Explain the procedure to the patient briefly and simply, and make him as comfortable as possible.

5. Apply limb electrodes: on arms, just above flexion of wrist on the dorsal surface; on legs, on anterior bony portion of the tibia. There are fewer muscles and, therefore, fewer tremors at these locations.

6. The electrode screws on the arms should face the legs; screws on the legs should face the heart.

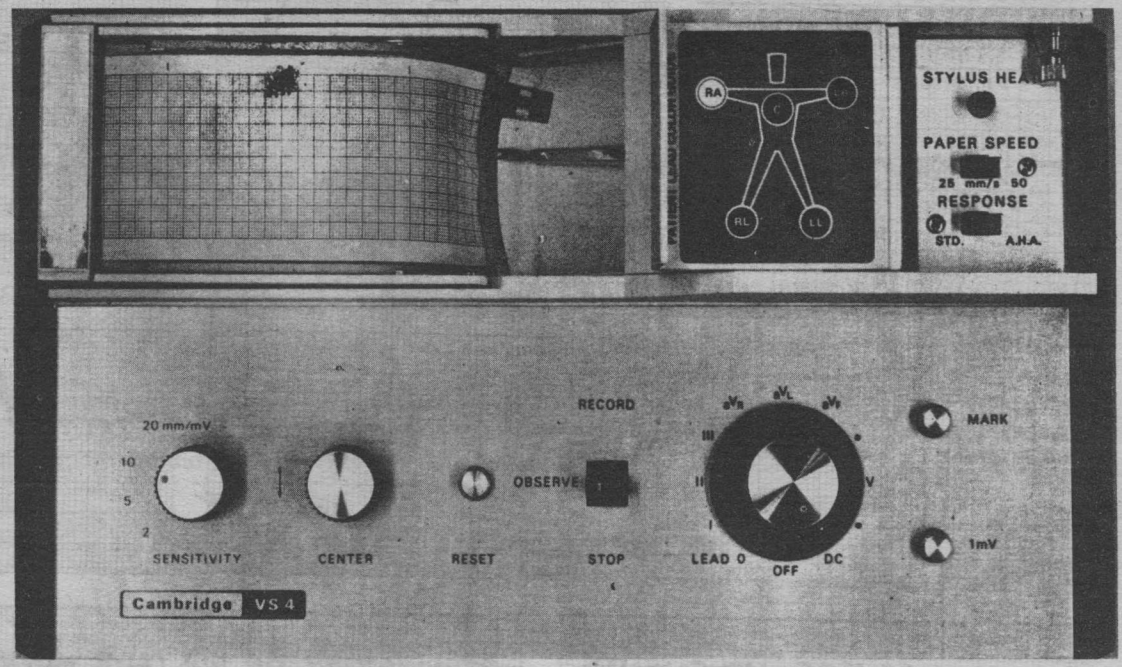
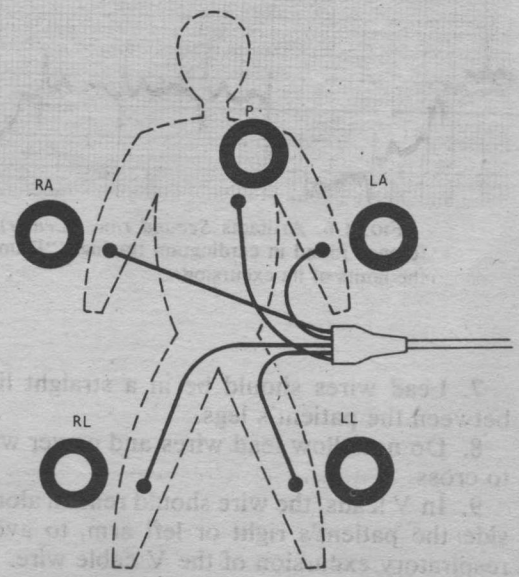


FIG. 1-5. (*Top*) Cambridge electrocardiograph machine, Model VS4. (*Right*) Procedure for taking the electrocardiogram.

1. Connect power cord.
2. Set lead selector to 0.
3. Apply jelly and electrodes to patient.
4. Turn power switch on, set polarity.
5. Attach patient cable.
6. Position stylus to center of chart.
7. Push *Standardize* button to check sensitivity.
8. Record ECG:
   (a) Set lead selector to 1 and turn on record switch.
   (b) Without stopping chart, move lead selector to 2.
   (c) Record lead 3, aVR, aVL, and aVF in same manner.
   (d) Turn lead selector to dot between aVF and V. Stop recording. Prepare electrode positions on patient's chest.
   (e) Attach vactrode, move lead selector to V. Turn on recorder.
   (f) Proceed as in Step (c) for the other V positions. Always set lead selector to dot before or after V when removing vactrode.
   (g) Move lead selector to CF and turn on recorder.
   (h) Stop recording and move lead selector to 0.
9. Turn off power switch.



(Courtesy of Cambridge Instrument Co., Ossining, N.Y.)

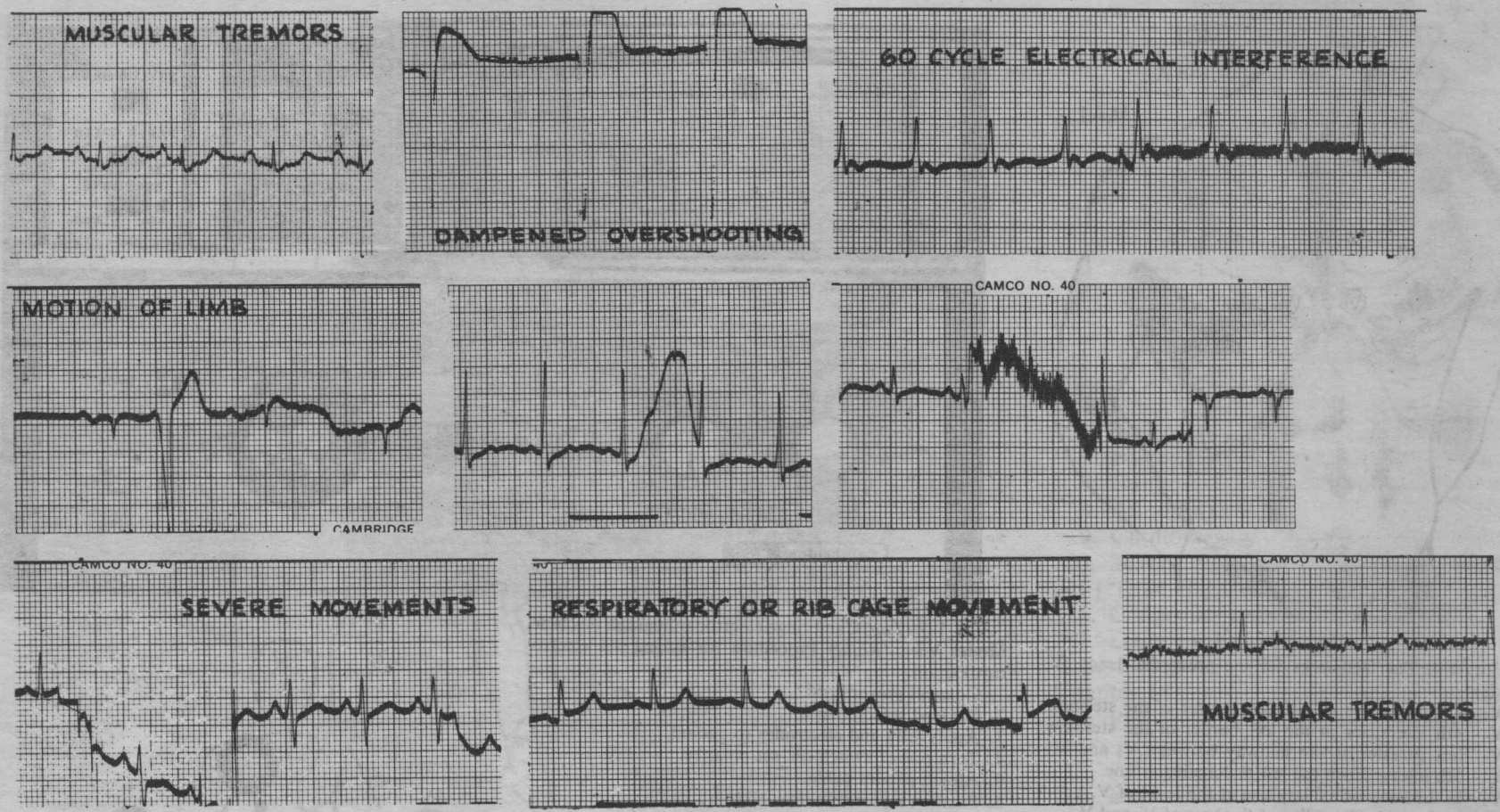


FIG. 1-6. Artifacts *Second row:* (*Center*) Motion of limb. (*Right*) Motion and electrical interference found in cardiogram tracings. "Dampened overshooting" indicates that the stylus is hitting the limits of its excursion.

7. Lead wires should be in a straight line between the patient's legs.

8. Do not allow lead wires and power wire to cross.

9. In V leads, the wire should remain alongside the patient's right or left arm, to avoid respiratory excursion of the V cable wire.

10. Mark the V lead positions on the chest with Magic Marker. This ensures accuracy in serial or repeated tracings.

11. Apply electrode jelly at the points of the previously marked V leads and allow to "pickle" before starting the ECG.

12. Keep the skin between individual V lead positions free of jelly.

13. Turn ECG machine on, turn the lead selector to Lead I and allow machine to warm up.

14. ECG machine must be properly grounded, and if there is 60 cycle interference, which would become evident at this point, it must be shielded.

15. Always wait for the stylus to settle down before recording, especially in the V leads.

16. Take approximately 12 inches of tracing of the standard limb leads, 4 inches of augmented limb leads, and 5 inches of the precordial leads. If there is an arrhythmia, take a

few feet of tracing of Lead II or V_1. The physician will be grateful.

17. On the tracing mark the date, the time, the patient's name, your initials and pertinent information that might be reflected in the tracing (e.g., patient was crying, was uncooperative; had tremors or exaggerated respirations, etc.).

18. On a quadriplegic or amputee, place leads or lead wire tips in jelly on the shoulders and/or on Poupart's ligament in the left or right lower quadrant.

19. On a buxom female, mark the V leads over the breast, not under.

20. On a hairy chested male, dip the lead wire tip or electrode screw into the jelly at the points designated for the V leads.

ARTIFACTS IN THE ELECTROCARDIOGRAM

Artifacts seen in tracings are frequently the result of technical errors and may be due to (a) electrical interference; (b) loose lead wire connections; (c) poor application of jelly or other contact substance. Artifacts may also be caused by (a) motion of the patient, (b) muscle tremor, and (c) severe nervous disorders of the muscular system. (See Fig. 1-6.)

MONITORING LEADS

Monitoring leads are essential in Coronary Care Units, to identify critical arrhythmias that may herald electrical cardiac death. Conventional leads as used at the time Coronary Care units were first set up were not satisfactory. With the better understanding of the electrophysiological nature of cardiac impulse, leads have been developed at new positions on the chest wall, and new uses have been found for the conventional leads, especially lead II and lead V_1.

The cardiac monitor is not an ECG, although it may be run through an ECG machine. Since the image may differ in important respects from that on an ECG of the same condition, the nature and function of the various monitoring leads and the wave forms characteristically associated with them merit special attention and are discussed in detail in Chapter 18.

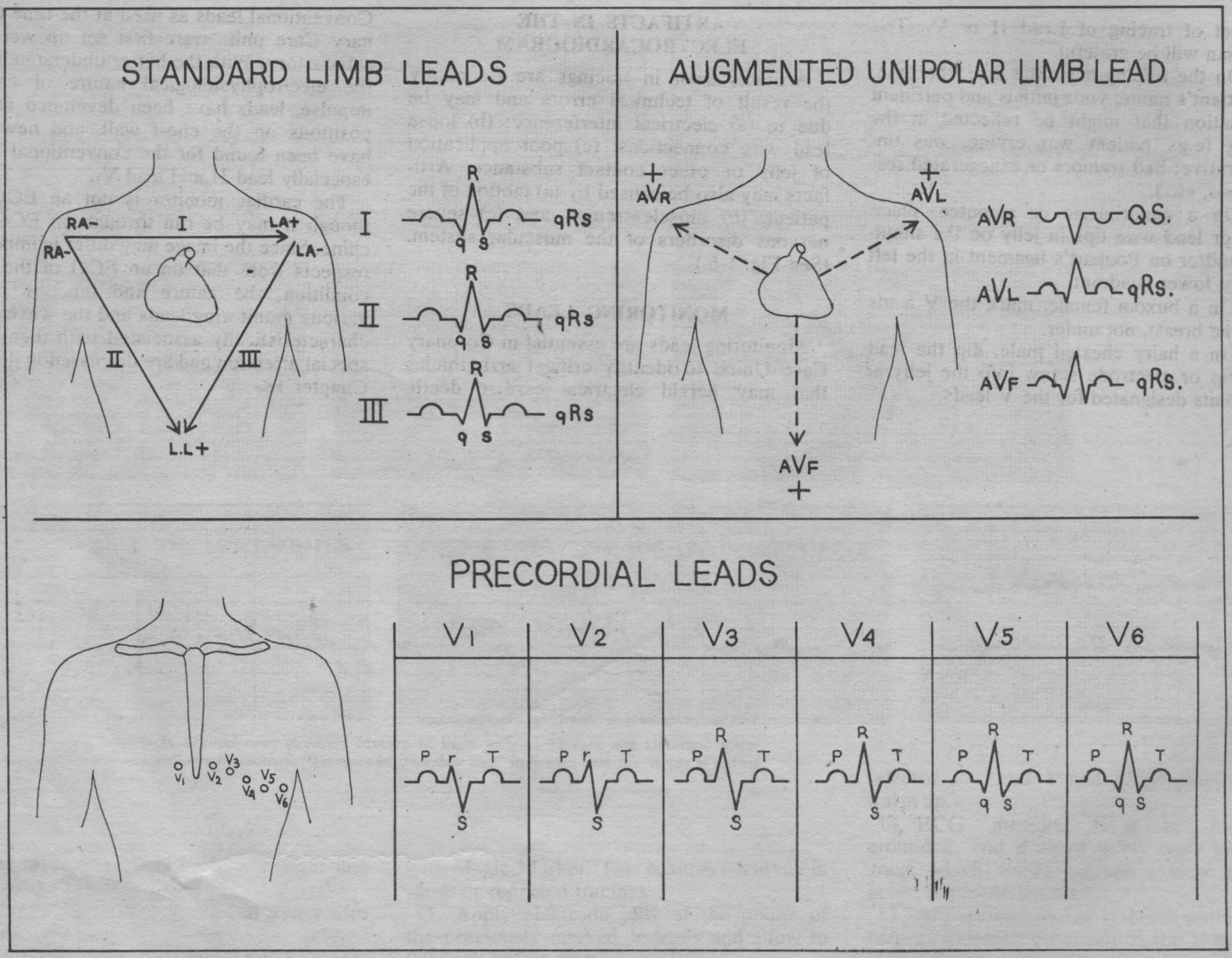
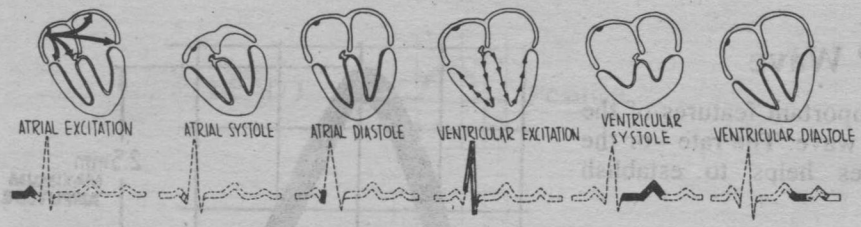


FIG. 1-7. The Einthoven triangle, the hexaxial system and the normal 12-lead electrocardiogram. Note the ascendancy of R and the descent of S from $V_1 - V_6$.



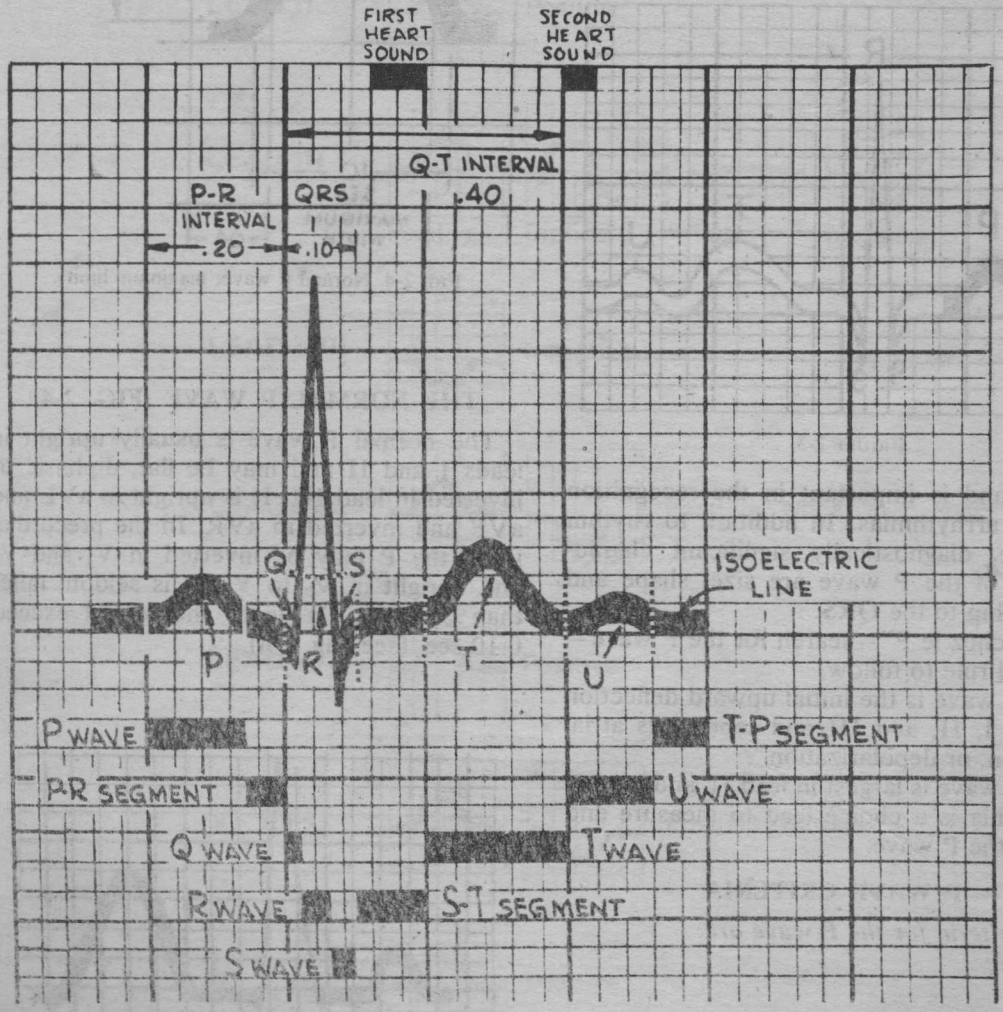


FIG. 2-1. P-Q-R-S-T-U cycle.

2

P-Q-R-S-T-U Cycle

Atrial excitation starts at the sino-atrial node and spreads through both atria. The excitation starts at some point before the P wave and includes the entire P wave. The P wave represents depolarization of the atria.

The P-R segment is the period of atrial repolarization. It is usually isoelectric. It also represents conduction through the A-V node and into the ventricles up to the Purkinje fibers.

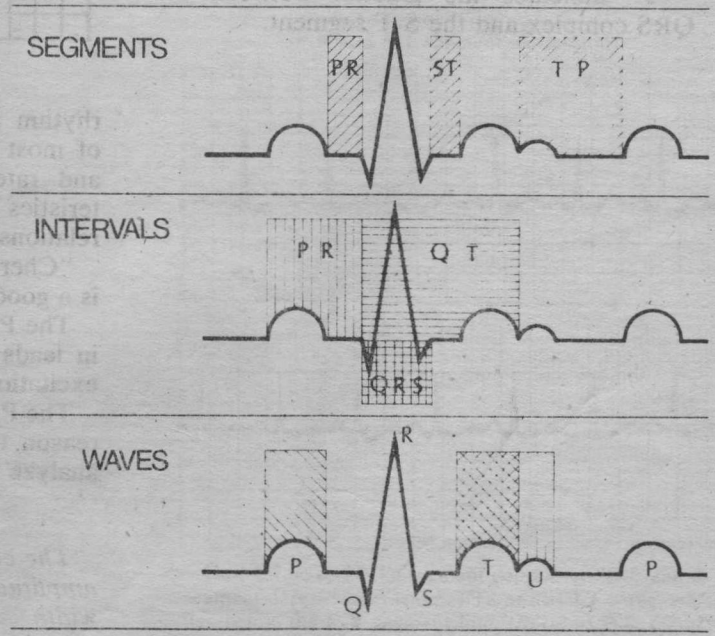


FIGURE 2-2

The Q wave represents the first wave of ventricular excitation or depolarization.

The P-R interval is the summation of the periods of atrial depolarization and atrial repolarization.

The QRS interval represents the complete depolarization of the ventricular musculature.

The S-T segment represents the early phase of repolarization. The S-T segment and the T wave together represent almost all of the complete phase of ventricular repolarization. The Q-T interval represents the time of ventricular activation or depolarization through the period of repolarization.

Ventricular diastole follows the end of the T wave.

The U wave represents the after potential of the T wave. This is in the recovery phase and during ventricular diastole.

"J" indicates the junction between the QRS complex and the S-T segment.

The P Wave

One of the most important features of the ECG record is the P wave. The rate—or the absence—of P waves helps to establish

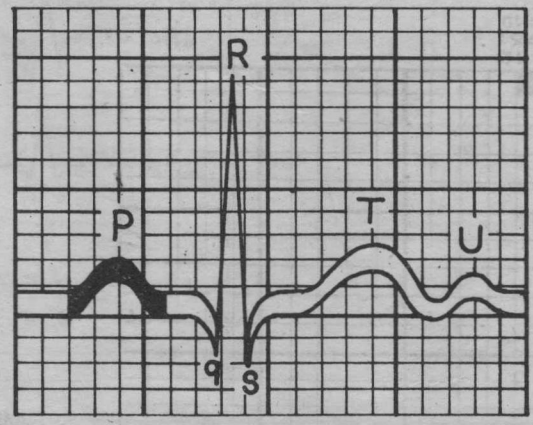


FIGURE 2-3

rhythm and is important in the recognition of most arrhythmias. In addition to rhythm and rate, diagnostically significant characteristics of the P wave are size, shape and relationship to the QRS.

"Cherchez le P"—search for the P wave—is a good rule to follow.

The P wave is the initial upward deflection in leads I, II, and III and represents atrial excitation, or depolarization.

The P wave is largest in lead II, and for this reason this is a choice lead to measure and analyze the P wave.

P WAVE CRITERIA

The criteria for the P wave are:
amplitude
width
shape
polarity.
(See Figs. 2-4, 2-5 and 2-6.)

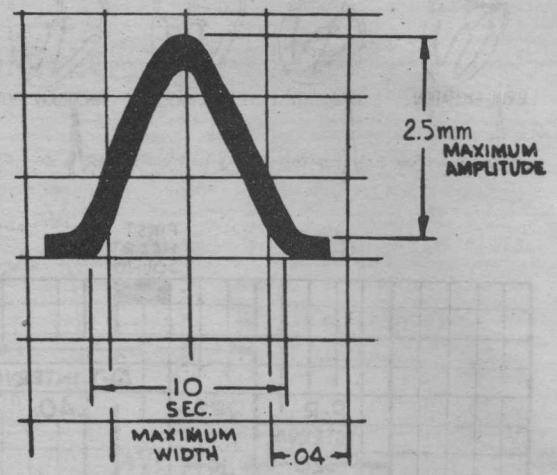


FIG. 2-4. Normal P wave: maximum limits.

THE NORMAL P WAVE (FIG. 2-4)

The normal P wave is usually upright in leads I and II and may be flat, diphasic or inverted in lead III. It is upright in aVL and aVF and inverted in aVR. In the precordial leads the P may be inverted in V_1 and V_2 and upright in V_3 to V_6. It is seldom taller than 2.5 mm. Its width should not exceed 0.10 sec. (see Fig. 2-4).

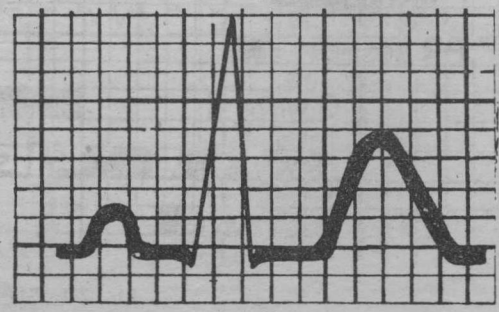


FIG. 2-5. Normal configuration of P wave.