DIAGNOSTIC ELECTROCARDIOGRAPHY

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Preface

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.

MICHAEL C. RITOTA

Acknowledgment

Acknowledgment is due primarily to the general practitioner, whose service is unceasing and of inestimable value in the endless war against 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. Emanuel Goldberger, Dr. Abraham Jezer, the late Dr. J. B. Schwedel, Dr. Scott Butterworth, Dr. William B. Hitzig, Dr. Ralph Miller, Dr. Leonard Dreifus, Dr. Joseph Riseman, Dr. Harry Gross and Dr. H. J. Marriott.

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

To Mr. Harold Scholl and my son Theodore Ritota, a medical student at the University of Autonoma Medical School, Guadalajara, Mexico, I am grateful for the diagrams and other illustrations used in this book.

I am deeply indebted to my friend and teacher, Dr. Ralph Miller, who has patiently and meticulously criticized the text.

Finally, I wish to thank Mr. J. Brooks Stewart for his patient assistance and cooperation in the preparation of this book.

History of the Electrocardiogram

The electrocardiograph, recording the minute electrical currents from the heart, is an achievement of the highest order in medical technology. It is a "biophysical machine" furnishing data that are highly reliable and among the most accurate that may be obtained.

Experiments in animal electricity were first performed by Luigi Galvani (1737-1798), the famous professor of anatomy at the University of Bologna, who hypothesized that the twitching of a frog's muscles which were pierced with metal was due to an electrical current. This concept of electrical impulses in muscle opened the way for progressive research in electrical energy and conduction in the tissues of the heart.

The earliest records of electrical activity of the heart were made in 1878, with the recording wires connected directly to the heart.

In 1887, Augustus D. Waller developed a method whereby electrical currents in the living heart could be recorded at the surface of the body and measured indirectly. This was done by running lead wires from a capillary electrometer and recording and measuring the shadow of its oscillation.

William Einthoven, the great Dutch physiologist, in 1901 invented the string galvanometer. The string galvanometer consists of a fine quartz string covered with gold or silver and suspended between the poles of a powerful electromagnet. The small current (measured in millivolts) passing through the string sets up a magnetic field, causing a deflection of the string. The shadow of the string and of this deflection is cast by a strong beam of light directed through apertures in the arms of the magnet and is magnified by lenses similar in arrangement to that of a microscope. The images of these deflections are focused on photographic plate or film moving at the desired speed.

Within the last ten or fifteen years machinery has been developed with amplifying tubes capable of magnifying this "current deflection" 3,000 times. An electrically heated stylus transposes the changes onto waxed paper.

The string galvanometer was comparatively difficult to manage, and the film had to be developed, with consequent delay in the availability of the information, whereas the presently used equipment has a direct writing stylus and can be read from moment to moment. Originally, only three leads were used; at present, twelve leads are used in the conventional electrocardiogram.

More compact machines are being made and new applications are being found. High fidelity electrocardiographs depict minute changes in the electrocardiogram; and radiocardiography is now being used with stress tests, both in terrestrial settings and in investigations relating to man's activities in space.

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Contents

CHAPTER 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 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.

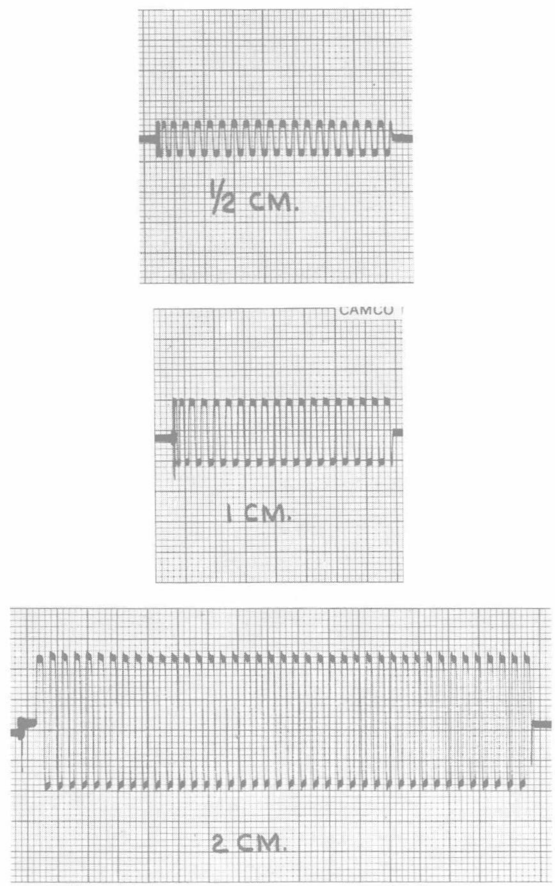


FIG. 1-1. Standardization of 1 millivolt. (*Top*) At 0.5 cm. (5 mm.) $\frac{1}{2}$ mv. (*Center*) At 1 cm. (10 mm.) 1 mv. (*Bottom*) At 2 cm. (20 mm.) 2 mv.

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:

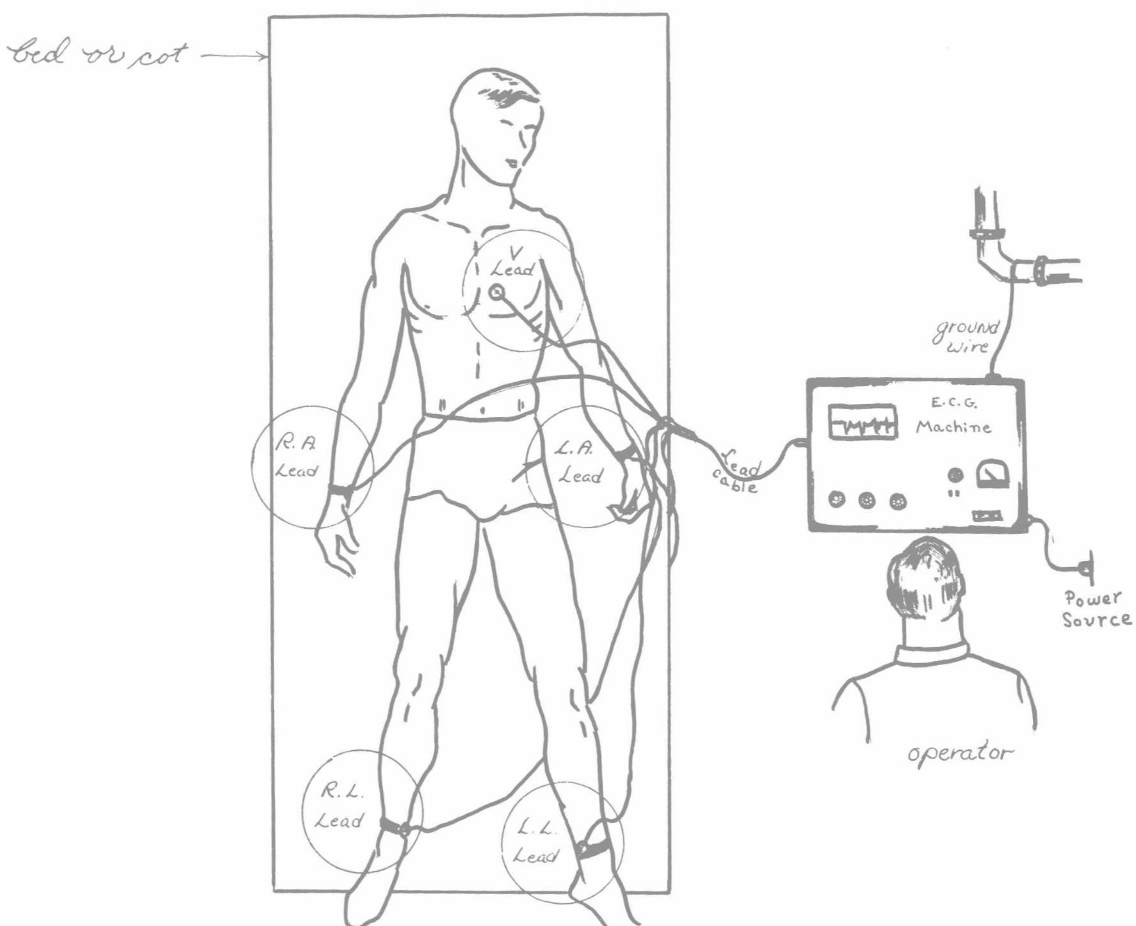
RA (right arm)
LA (left arm)
LL (left leg)
RL (right leg)

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 E.C.G. as soon as the lead is transcribed.



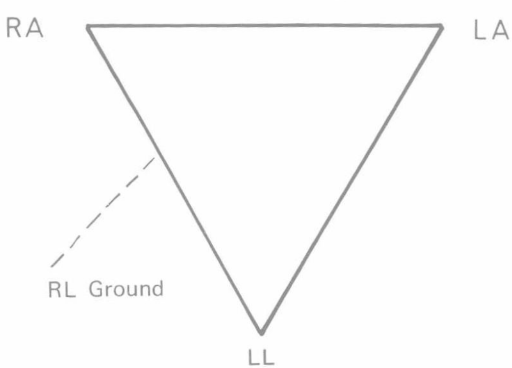


FIG. 1-2. (*Top, left*) Proper positioning of standard leads and V lead.

FIGURE 1-3. (*Bottom, left*) Einthoven triangle.

Marking Code

STANDARD LEADS	CODE
Lead I (left arm–right arm)	•
Lead II (left leg–right arm)	••
Lead III (left arm–left leg)	•••
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
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
13. Trauma to the chest
14. Preoperatively, for patients over 50 years of age
15. All cases of hypertension

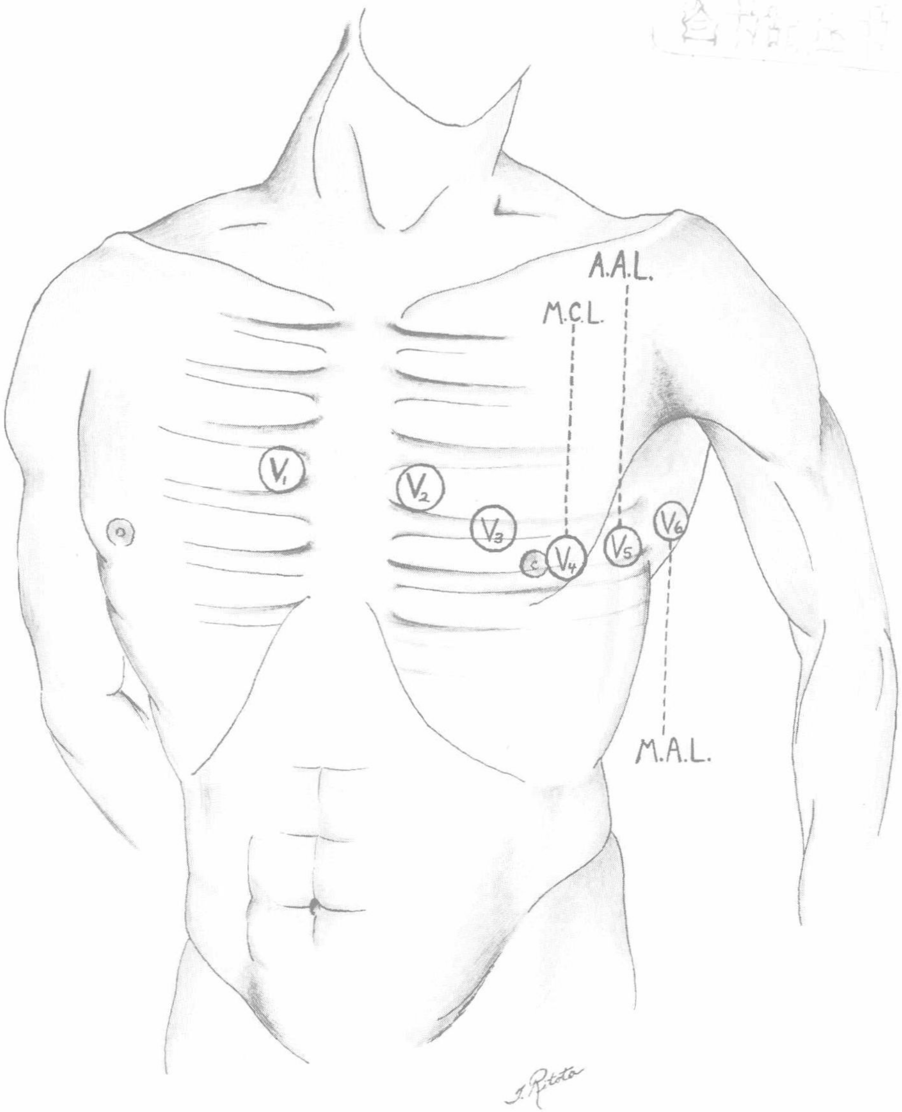


FIG. 1-4. The landmarks for the precordial leads (V leads)
V_1 – 4th interspace at the right border of the sternum
V_2 – 4th interspace at the left border of the sternum
V_3 – left parasternal line midway between V_2 and V_4
V_4 – 5th interspace in the left midclavicular line
V_5 – in the anterior axillary line at the level of V_4
V_6 – in the midaxillary line at the level of V_4 and V_5
MCL – Midclavicular line. AAL – Anterior axillary line. MAL – Midaxillary line.

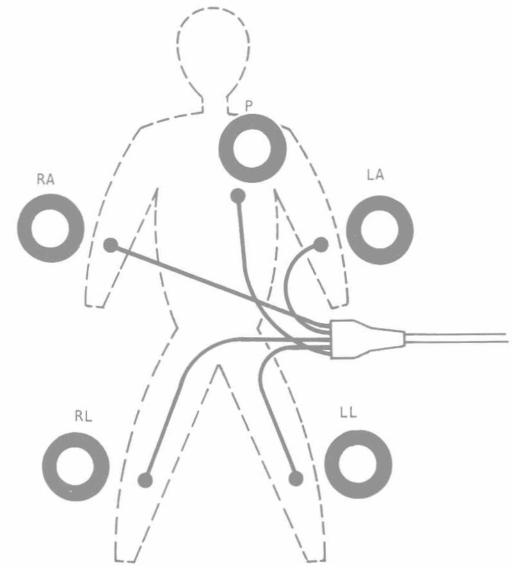
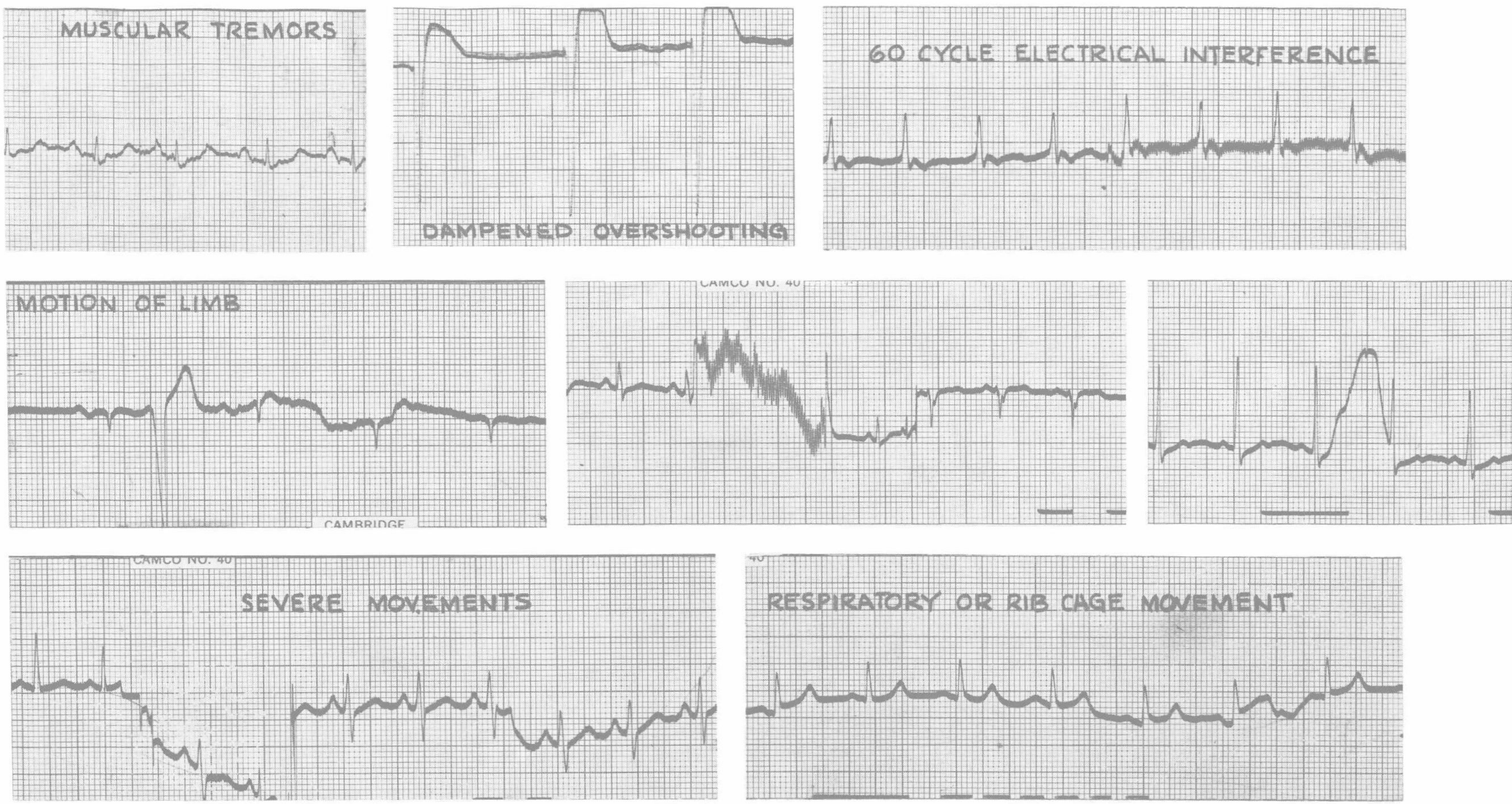


FIG. 1-5. Procedure for taking the electrocardiogram.
1. Connect power cord.
2. Set lead selector to 0.
3. Apply jelly and electrodes to patient.
4. Turn power switch on, set polarity.
5. Attach patient cable.
6. Position stylus to center of chart.
7. Push *Standardize* button to check sensitivity.
8. Record EKG:
   (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.)



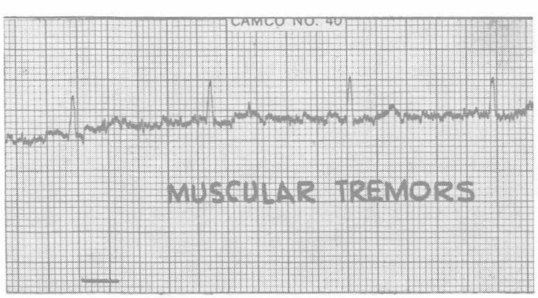


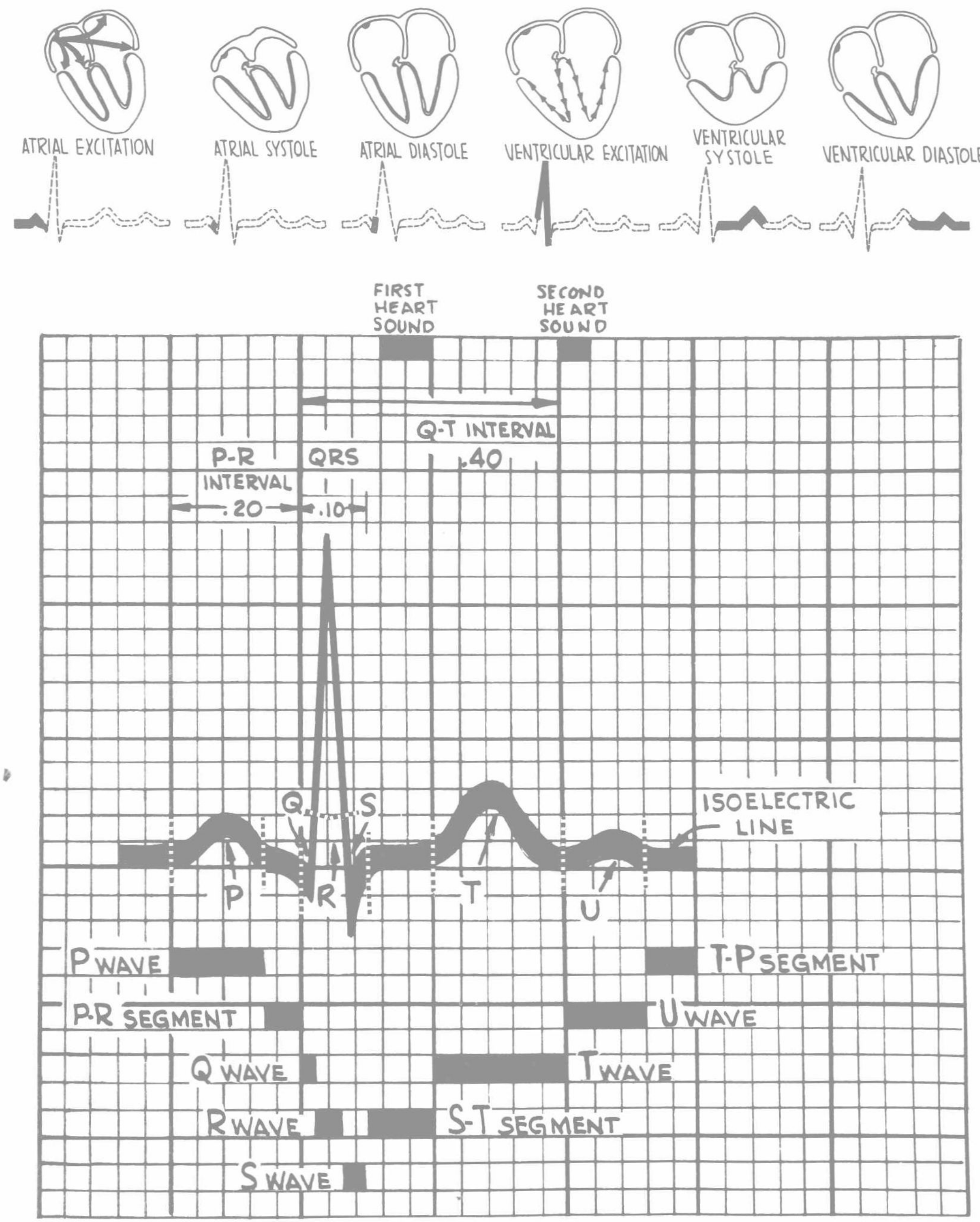
FIG. 1-6. Artifacts found in cardiogram tracings. *Second row,* (*Center*) Motion and electrical interference. (*Right*) Motion of limb. "Dampened overshooting" indicates that the stylus is hitting the limits of its excursion.

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.

CHAPTER 2

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



Atrial excitation starts at the sino-auricular 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.

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.

FIG. 2-1. (*Right*) P-Q-R-S-T-U cycle.

The P Wave

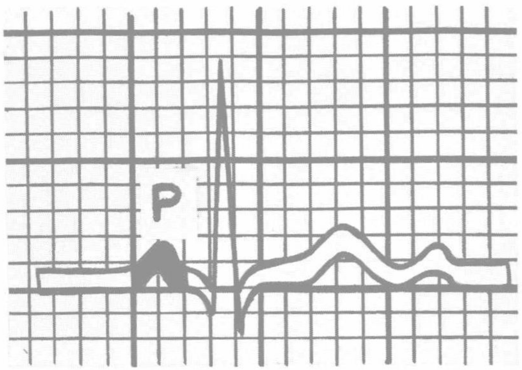


FIGURE 2-2

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 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.

The Normal P Wave (Fig. 2-3)

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 does not exceed 0.10 sec. (see Fig. 2-3).

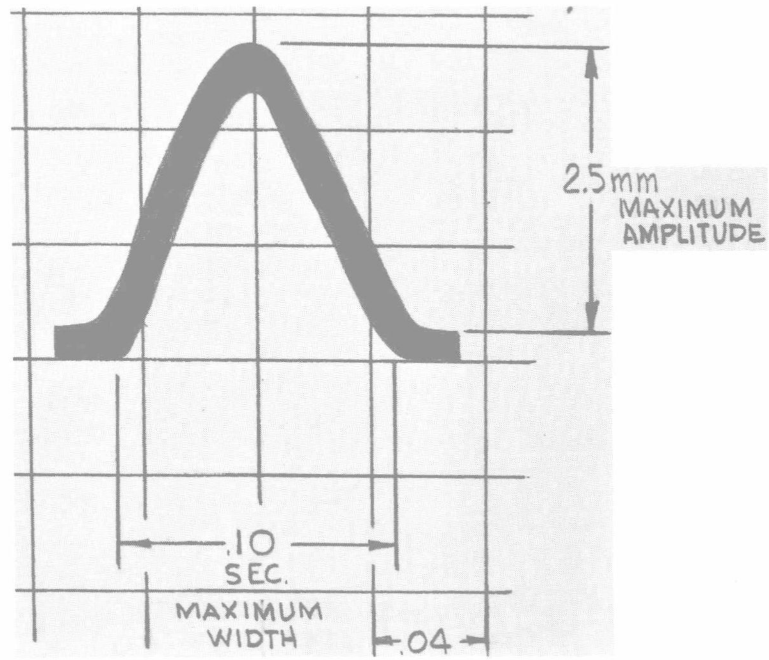
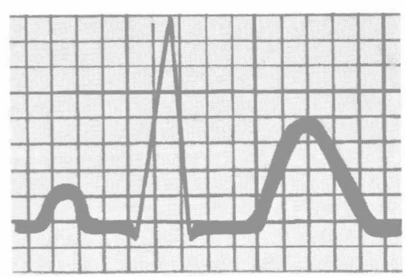


FIG. 2-3. Normal P wave: maximum limits.



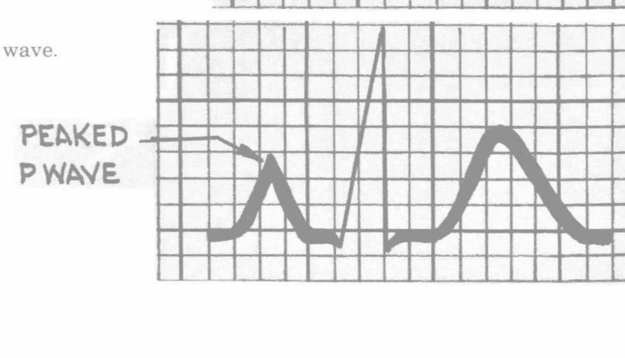


FIG. 2-4. (*Above*) Normal configuration of P wave. (*Right*) P mitrale. (*Bottom, right*) P pulmonale.

P-Wave Forms (Fig. 2-4).

Contrast the form of the normal P wave with the P mitrale and the P pulmonale.

P mitrale is bifid and usually is more than 0.10 sec. in width. The width of the notch (between its peaks) is at least 0.03 sec. P mitrale commonly is found in rheumatic heart disease with mitral stenosis; atrial septal defect; and tetralogy of Fallot.*

P pulmonale is seen most often in chronic emphysema, cor pulmonale and right ventricular hypertrophy. The P wave is sharply peaked and symmetrical in leads II, III and aVF. It is usually tall and prominent, but its measurements may be within normal limits.

* Thomas, P., and Dejong, D.: Brit. Heart J., 16:241, 1954.

The P-R Interval

The P-R interval measures the period of time from the beginning of the ascending limb of the P wave to the beginning of the Q wave or the R wave if no Q wave is formed. P-Q is equivalent to the P-R interval (Fig. 2-7).

The normal range of the P-R interval is 0.12 sec. to 0.20 or 0.21 sec. Any prolongation of the P-R interval denotes delay in atrioventricular nodal conduction. A prolonged P-R interval is first-degree heart block (Fig. 2-6).

The P-R interval varies with heart rate. The higher the rate the shorter the conduction time through the atria and the atrioventricular node to the bundle of His.

The P-R Interval and the Heart Rate*

Heart Rate (per min.)	P-R Interval (in seconds)
40 to 70	0.20 to 0.21
71 to 90	0.19 to 0.20
91 to 120	0.18 to 0.19
121 to 140	0.17 to 0.18
141 to 160	0.16 to 0.17

* After Ashman and Hull: Essentials of Electrocardiography. New York, Macmillan, 1937.

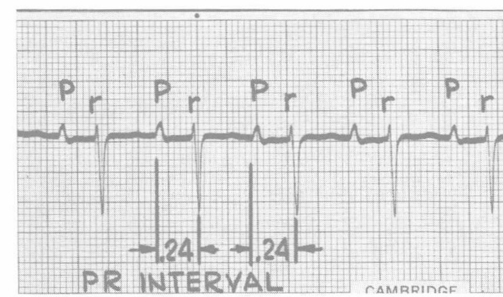


Fig. 2-6. Prolonged P-R interval in first-degree heart block. The P-R intervals marked (arrows) measure 0.24 seconds. The P-R interval here starts from the beginning of the P wave and ends at the onset of the ascending limb of the R wave.

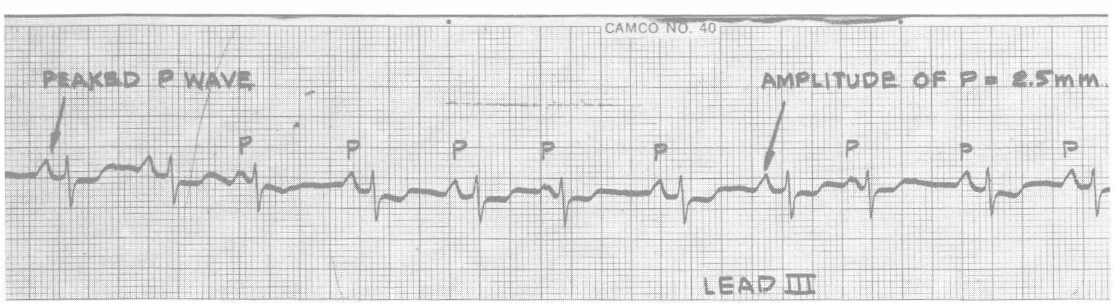


Fig. 2-5. (*Top*) Peaked P waves, cor pulmonale. The patient had chronic asthma and bronchitis. (*Bottom*) P mitrale. Large atrium. P waves are broader than 0.10 sec.