The Minnesota Code Manual of Electrocardiographic Findings: Standards and Procedures for Measurement and Classification

The Minnesota Code Manual of Electrocardiographic Findings

including measurement and comparison with the Novacode

Standards and Procedures *for* ECG Measurement *in* Epidemiologic and Clinical Trials

Second Edition
New and Enlarged

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Dedication:

To our mentors and colleagues, Henry Blackburn,

Pentti Rautaharju, and in memory of Geoffrey Rose

Contents

Preface to the Second Edition

The manual is suitable for training electrocardiographers and technicians and can be accompanied by sets of training ECGs already coded by trainers. It is our expectation that the manual will serve as a reference, guide, and training source for those conducting studies that require objective evidence of cardiac disease, both prevalent and incident, by non-invasive, highly standardized, inexpensive recording of the electrocardiogram. In our own ECG Reading Center, this has included epidemiologic studies among healthy populations, diabetics, psychiatric patients, pregnant women, cohorts of patients with clinical heart disease, populations exposed to environmental contaminants such as arsenic, populations exposed to Chagas disease, and in clinical trials of HIV-infected participants, diabetics, hypertensives, children, the aged, dietary intervention studies and phase I and phase II drug studies.

It is 28 years since the publication of the first edition, which is now out of print. We have produced a second edition because, in the interim, we have received continuous requests over the years for copies of the book that no longer existed and also because there have been refinements and extensions to the Minnesota Code that allow a greater range of abnormalities to be coded; there are even clearer means of demonstrating correct and standardized methods of measurements that are incorporated into this second edition; some minor coding rules have been changed; and now the use of the code has been greatly expanded and is used in countless epidemiologic studies and clinical trials worldwide. Even as far back as 1981 the initial publication describing the Minnesota Code was chosen as a citation classic (*CC/NUMBER 51 of SCI December 21, 1981:This Week's Citation Classic :Blackburn H, Keys A, Simonson E, Rautaharju P & Punsar S. The electrocardiogram in population studies: a classification system. Circulation. 21:1160-75; 1960*). It had been cited more than 405 times in published articles. Since then the bibliography has grown many times larger–at the time of writing, over 700 citations were listed in Pub Med. The introduction of digital ECG recordings and analysis has only expanded the role of the Minnesota Code now encompassed in computer programs to analyze digital signals transferred over phone lines or directly on solid digital recording platforms such as CDs. The latter notwithstanding, archival paper tracings are continually mined for data that were collected without digital recording and that are accompanied by other uniquely rich data. Despite my expectations during the 1960s that such archives would cease to be used after the introduction of digital recording, the tide of such treasures has hardly ebbed.

The changes included in this edition arise from more than a quarter of a century of directing central ECG reading and research centers and collectively 60+ large and small epidemiologic studies and multicenter national and international clinical trials. The changes include the description of a new measuring loupe in Chap. 3, developed over the past decade, to better serve a more efficient and a more extensive span for measurement of relevant durations, voltages, and deviations from the isoelectric line. In Chap. 4, the old code 1-2-6 has been removed because of lack of prognostic value, and for a similar reason, code 1-2-8 has been down-coded to 1-3-8 to better represent its place in the hierarchy of Q-wave abnormalities. In addition, a new code 1-3-7 has been added to extend coding of inferior myocardial infarction. In Chap. 7, newer more precise methods of measuring ST-segment and T-wave voltages are presented. Additions to conduction defects in Chap. 9 include measurements for and classification of the Brugada syndrome ECG pattern (code 7-9) and fragmented QRS (code 7-10) – both of the latter codes have been associated with sudden death. The chapter on arrhythmias has minor modifications from the first edition, but, notably, premature beats need no longer be "frequent" by the old definition to be coded in a standard 12 lead ECG, where the presence of any premature beats is significant for prediction of future cardiovascular disease. In Chap. 11, additional codes have been added for lead reversal (with many examples), technical quality, left atrial enlargement (code 9-6), and early repolarization (code 9-7). More detailed criteria are presented in Chap. 12 for the measurement of QT interval, so important in testing all new drugs. New coding forms are presented in Chap. 13, and Chap. 14 on ECG data acquisition has been re-written and expanded to include training of ECG recording technicians and maintenance of recording quality. Chap. 15 on the criteria for significant serial change has been developed in a much more comprehensive manner and has added descriptive tables and new codes for documenting serial change myocardial infarction. Chap. 16 is a new addition on continuous measurements, which can be derived from a standard 12-lead ECG that have independent prognostic value

and includes description of ultrashort heart rate variability. Chap. 17 on quality control is now greatly expanded and includes quality control directions and documentation for both paper (visual) and electronic ECGs. Appendix A has all of the new Minnesota Codes incorporated. Appendix B is new and details the criteria and classification of the Novacode, including significant serial change, MI diagnosis, and comparisons with the Minnesota Code. Finally, Appendix C lists a summary of minor and major code abnormalities that can be used in comparisons of subgroups in experimental studies and analyses.

NC, USA

Ronald J. Prineas

May 2009

Preface to the First Edition

The electrocardiogram (ECG) is mainly used in clinical and hospital practice for diagnosis and for prognosis. But it is also used for systematic population studies and clinical trials in and outside hospital, where a repeatable, valid, and quantitative method is required for classification of ECG findings related to disease. Useful classification depends, in turn, on standardized methods of acquiring the data, on mounting (sampling), and on reading and measurement of the ECG.

In systematic studies the ECG is read centrally, unbiased by clinical information. This blinded classification provides objective criteria for individual events, group differences, and for sequential changes in individuals and groups. Measurement classification criteria and procedural rules for standardized ECG coding were devised and published from this laboratory and became known as the Minnesota Code (Blackburn H, Keys A, Simonson E, Rautaharju P, Punsar S. *Circulation.* 1960;21:1160). Current updated criteria and coding rules are found in the Appendix to this manual.

Since 1960, these criteria and coding rules have been tested and occasionally slightly modified to improve validity and repeatability. The rules are nevertheless continually subject to variation in application because of different quality of recording, baseline trace width, characteristics of the tracing, and the number of beats to be measured. A set of definitions and procedural rules has evolved in this and other laboratories to define more precisely wave onset and offset and wave segments.

Other factors affecting standardized ECG coding include ECG coder training, data acquisition, patient preparation, technician training, and quality control. These are presented in this manual along with unambiguous definitions and measurement procedures.

The current Minnesota Code criteria are found in the Appendix, in sequence from 1–9-codes. In the body of the manual, separate chapters are provided on the exact measurement of continuous ECG variables such as frontal plane axis and heart rate, on standard ECG acquisition and mounting, and on quality control of coding, as well as detailed presentation of the wave classification system.

The codes in the Appendix do not need to be learned by rote for this manual to be used as a training and testing tool. Early in training as ECG findings are recognized, the detailed code may be referred to. It is, however, necessary to develop an efficient personal system for scanning each ECG for all codable findings, and to learn thoroughly *how* to measure the findings detected. While the contents of the coding chapters of this manual need not be mastered in one course, the manual should be used as reference when there is doubt how to measure a particular wave form.

The ECG measurements described here are easily applied by intelligent, trained, and dedicated medical, technical, or lay persons. The manual can be used by electrocardiographers or experienced investigators to teach measurement and coding of the ECG. This laboratory has for two decades trained "ordinary" university students in coding skills as part-time workers for periods of 1–3 years. Nurses, physicians, and technicians have also been successfully trained. Adherence to specific rules and ongoing quality control allow comparisons of results from different observers and centers at different times.

Training requires intensive instruction for a full 10 day course, followed by continual experience. An introductory lecture on electrocardiographic history and physiology imparts understanding of the reasons for the measurements and codes, and is tailored to the sophistication of the students. It explains the current setting of ECG coding for population comparisons and clinical trials and their different requirements from clinical diagnosis. Within 3 months of initial training, further testing for accuracy and speed is carried out.

The introductory lectures also explain the recording of 12 lead ECGs and the expected patterns for each lead, and identify P-, Q-, R-, S- and T-waves. Coders are taken sequentially through the coding material in each of Chapters 3 through 12. At the conclusion of each chapter, sample electrocardiograms are coded for the findings and measurements described in that chapter. The student codings are checked by the instructor before proceeding to the next chapter and remedial work is assigned where needed. Specific codes are sought in each lead separately to recognize the range of normal patterns in each lead.

At the conclusion of instruction with the text material and practice ECGs, a separate test packet of approximately 20 ECGs, as described in Chap. 13, and enriched with examples of major codable findings, is coded for the complete ECG. Results are checked by the instructor. Duplicate coding of actual "unknown" ECGs then starts, initially, with a new coder against a senior experienced coder for

the first three to six months of the program. In this period, misunderstanding of the coding rules is discovered and corrected.

After approximately three months of on-the-job coding, new test packets with approximately 50 ECGs per packet are coded and tabulated according to standard tables of repeatability (Rose G, Blackburn H, Gillum RF, Prineas RJ. *Cardiovascular Survey Methods.* Geneva: WHO; 1982). Coding rates (speed) and test results (accuracy) are compared among coders so that the suitability of coders, or the need for retraining, is determined. Test packets are available from the Director, ECG Coding Laboratory, Laboratory of Physiological Hygiene, School of Public Health, Stadium Gate 27, 611 Beacon Street SE, University of Minnesota, MN 55455, USA.

Was written in Minnesota

Ronald J. Prineas MB, BS, PhD

January 1982

Acknowledgements

We thank many programmers, coders, and electrocardiographers, who over the past decades, have contributed much to the process of ECG coding and refinement of rules of application, and in particular, we acknowledge the contributions of Dr. Yabing Li and Charles Campbell for unflagging dedication to their demand for precise definition of code items for both visual and electronic ECG records. We also thank Dr. Elsayed Soliman for his specific refinements in early repolarization definitions.

1

What Is the Electrocardiogram or ECG[1]?

Electrocardio*gram* is a written record of a heart beat, while electrocardio*graph* is an instrument with which it is recorded. The same is true for tele*gram*, written record, and tele*graph*, the instrument.

The abbreviation *EKG* is obsolete in this country. It comes from the German word, Das *Elektrokardiogramm* as many early works are done in Germanic countries. The spelling and abbreviation has been anglicized to ECG.

An Italian, Galvani, introduced in 1791 the concept that all living tissue can produce an electric current when adequately stimulated. He also showed that injured muscle generates current. If a living nerve attached to a healthy frog leg muscle were allowed to touch the injured area of another frog's muscle, the healthy nerve–muscle frog preparation would twitch!

The Germans, Kolliker and Muller, showed, over a hundred years ago, with the same type of nerve–muscle preparation, that an electrical current was produced rhythmically with each contraction of an animal heart.

An Englishman, Waller, in 1887 was the first to demonstrate in his pet bulldog *Jimmie* that the electrical action of the heart could be registered from the surface of the body. He is also credited with making the first human ECG, which he called a cardiogram. This was registered by light reflected from a capillary tube of mercury, which oscillated with each heart beat from the electrical potential differences the heartbeat causes between the right and left hand.

Einthoven, a Dutchman, worked for some years at Leiden with ECG recording instruments and finally in 1901 devised his own instrument a string galvanometer, so sensitive to changes in intensity of electric currents and so rugged and stable in operation that a new branch of medicine, electrocardiography, was made possible. His instrument consisted of a stretched string of quartz filament coated with silver and suspended in a strong magnetic field. The secret of his success was this high-resistance tiny quartz string, which he first made by attaching fused quartz to the tail of an arrow, heating the quartz to a critical point and firing the arrow, thus producing a very fine, uniform string.

The history of electrocardiography thereafter is too detailed to recount, but Einthoven's instrument brought it all about. It was early imported in Britain and the United States and widely used here until after the Second World War. The tiny heart currents are now picked up and amplified with transistorized amplifiers, and instead of photographs of a vibrating string we have an "instant ECG," from a direct writing stylus on a moving paper strip. In addition, we now transmit the ECG by FM radio, or by telephone. We can also record and store the ECG on digital recording media, and can now make ECG measurements and even Minnesota Code classifications with computers by converting the analog wave form to digital, or numerical form. (see www.ecglibrary.com/ecghist.html.)

[1] The development of the ECG wave generation and propagation is not meant to be comprehensive but as a guide to expected wave patterns for coding. More comprehensive descriptions can be found in text books of clinical ECG interpretation.

The Electricity Part of the ECG

Heart is made up of many interwoven and interconnected bundles of muscle. Each individual muscle cell has an electrical charge as we learned from Galvani and others. With each heart beat, a wave of electrical excitement moves rapidly through the thousands of linked heart muscle cells. There is at that moment an imbalance of the electrical charge at the outer membrane of these cells caused by a rapid flux of charged ions through the cell membrane. As the wave of excitation passes through the heart muscle, millions of individual cell charge set up an electrical current in the chest. This current flows to the surface, and at the skin produces differences in electrical voltage, which can be measured between pairs of electrodes placed at any two points on the body.

At the beginning of each heart beat, excitation starts from the firing of the pacemaker sinus node in the right atrium and passes in as wave through both atria, the upper thin-walled chambers of the heart. The tiny differences in voltage between distant points on the skin allow us to register a small deflection on a meter, a galvanometer, named after Galvani. Because the paper is moving at the time the meter needle deflects, a little rounded wave is produced. Einthoven named it the P-wave. This is followed by a delay as the impulse is received at the upper part of the ventricular septum, in the A-V node, and this lag is recorded on paper as a straight line.

The exciting electrical wave then spreads rapidly through the large muscle walls of the ventricles over the special (His) bundle of conducting fibers. The ventricular excitation causes sharp and large deflections (still only 1-4 mv), and these deflections as registered on the moving paper are called the QRS waves in the ECG.

Summary

Fig. 1-1

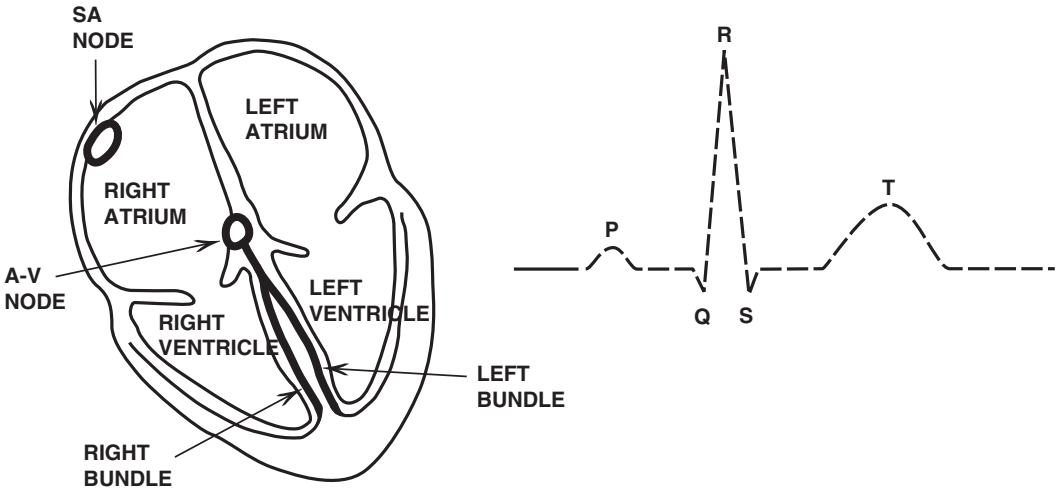


Figure 1.1. Normal heart beat is initiated by spontaneous firing of the sinus (SA) node in the right upper chamber of the heart (right atrium)

As the excitation wave goes through the ventricles, the activated cardiac muscle contracts (excitation–contraction coupling) and ejects the blood into the systemic and pulmonary circulation. Then the electrical charges at the muscle cell return in a slowly receding wave to the original resting, electrical state. This slower wave of electrical recovery of the ventricular muscles is inscribed on the moving paper as another rounded wave called the T-wave.

The shape and direction of the QRS and T-waves depend on the sequence of depolarization and repolarization, the balance and direction of the individual electrical forces of the wave of excitement through the heart, and the location of the electrodes on the skin. For illustration, consider two poles in water with a pressure gauge on each. One hooks up the

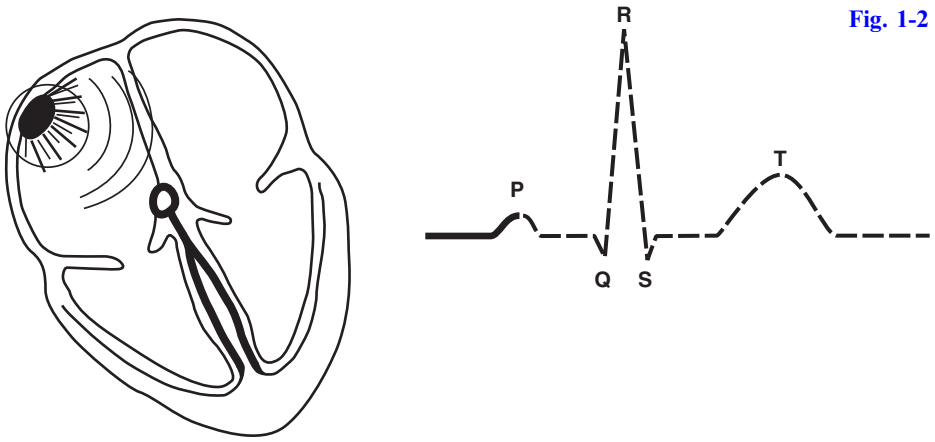


Fig. 1-2

FIGURE 1.2. The excitation wave passes through the muscles of both atria, activating them to contract. This activation produces electrical currents in the chest, which are measured as differences of potential between the electrodes on the body surface. A moving paper strip records these as the small rounded P-wave of the normal sinus beat

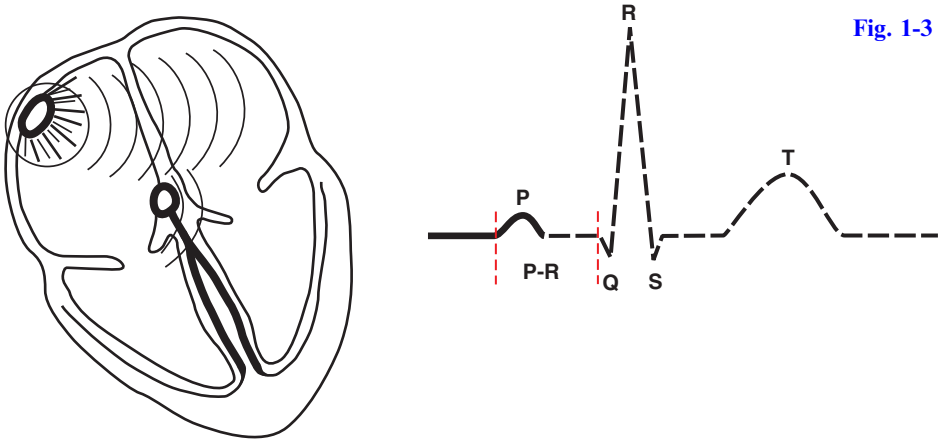


Fig. 1-3

FIGURE 1.3. The electrical wave of activation reaches the atrioventricular (A-V) node between the atria and ventricles and there is a brief delay. The P-R interval includes the P-wave and the period of delay in the A-V node

two pressure gauges so that the meter reads positive if the right–hand pole registers a higher pressure than does the left. Scooping up a wave in the middle and shoving it toward this right-hand pole makes the pressure higher there and the meter registers an upward deflection. A wave toward the left pole makes the pressure lower at the right–hand pole and the meter, and therefore, registers a downward deflection. If a wave starts in the middle and its force travels equally toward and reaches each pole at the same time, we get no difference in pressure, and hence no deflection at all.

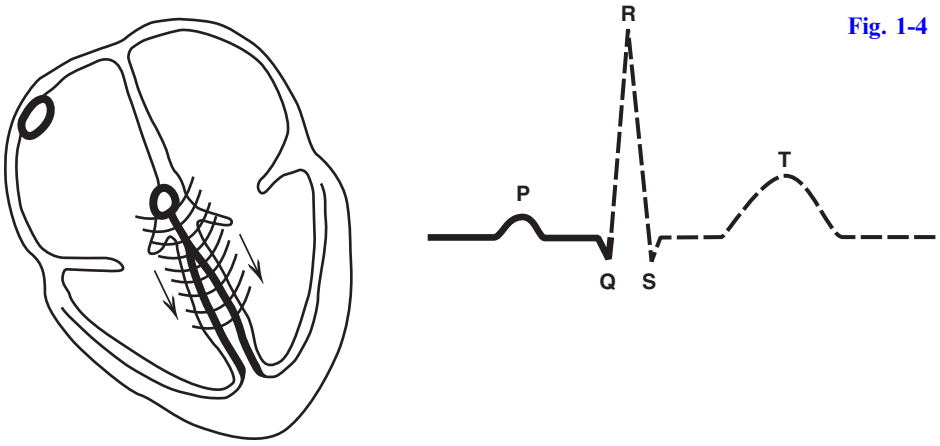


Fig. 1-4

Figure 1.4. The activation rapidly descends the bundle of His in the muscular septum between the two ventricles, and activates those muscles from left to right. This septal activation produces the first ventricular deflection of the ECG, the Q-wave

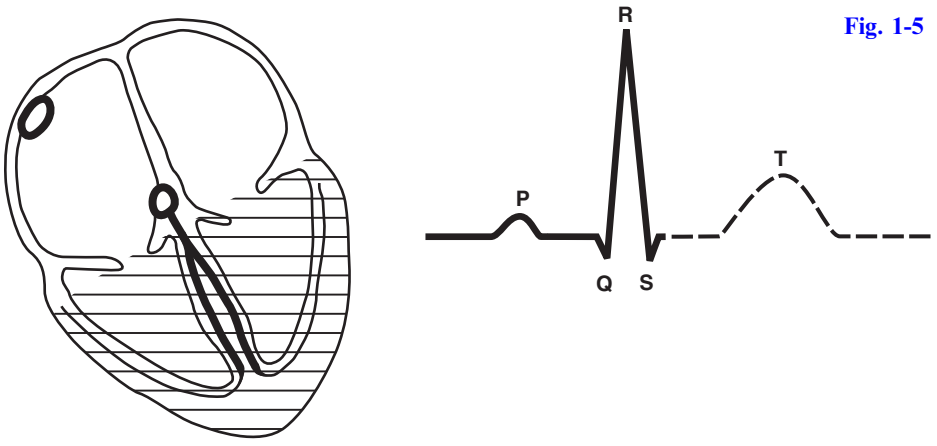


Fig. 1-5

Figure 1.5. The activation then spreads rapidly through the special conducting tissues of the ventricles and the wave progresses, in a generally right to left direction, producing the major ventricular deflection, the R-wave. All regions of the ventricles are eventually activated, the entire QRS complex is recorded, and the ventricles contract and pump blood

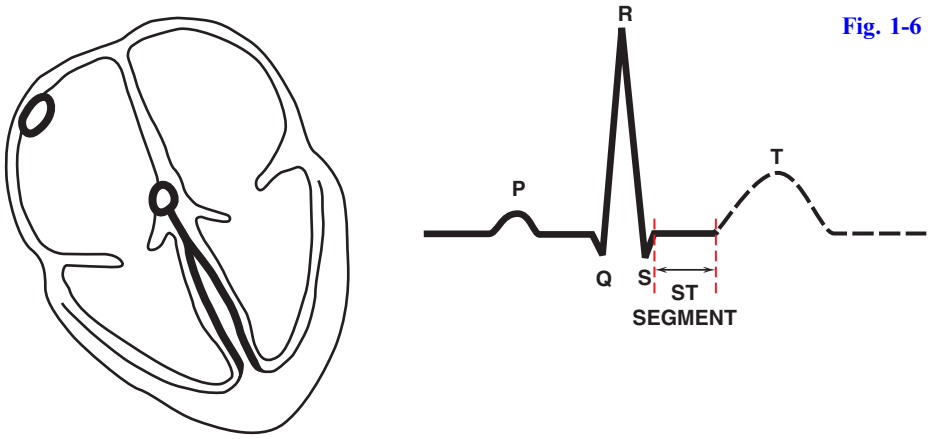


Fig. 1-6

FIGURE 1.6. There follows a short period of relative inactivity recorded as the ST segment

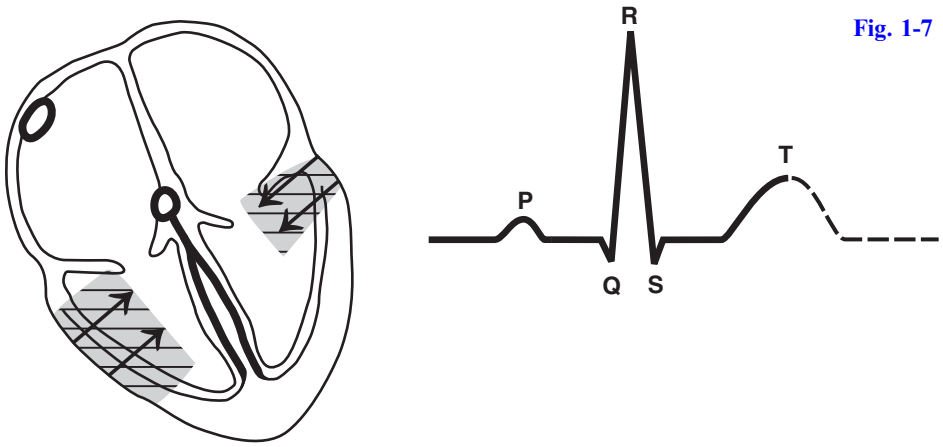


Fig. 1-7

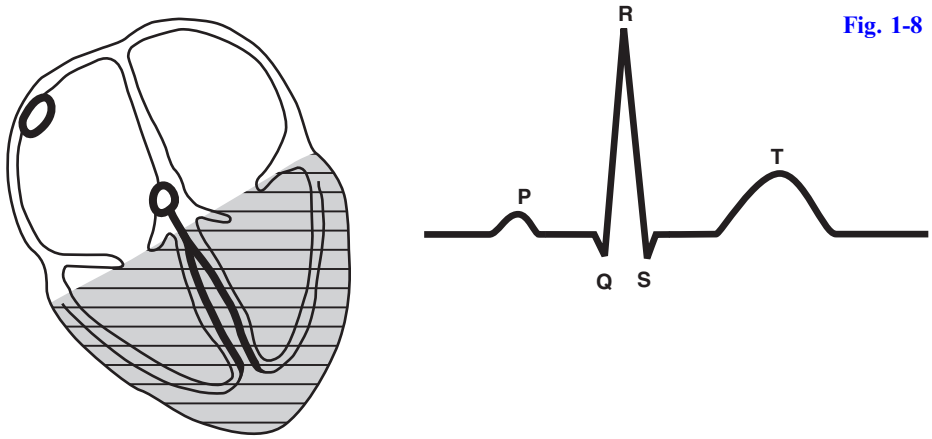


Fig. 1-8

FIGURES 1.7 and 1.8. Then the recovery wave spreads in reverse of depolarization (from the epicardium through the ventricular wall) over the same pathway "repolarizing" the heart, producing a broad blunt wave, the T-wave that is in the same direction as the R wave

2

ECG Leads

The body acts as a large conductor of electrical currents generated by heart. To record, these currents require that only any two points on the body be connected to the electrocardiograph. This establishes the necessary completion of an electrical circuit and is done by means of electrodes attached to the limbs or the chest, each pair of attachments being one "lead." The ECG leads generally used are I, II, III, aVR, aVL, aVF, V_1, V_2, V_3, V_4, V_5, and V_6.

Bipolar Limb Leads (I, II, III)

The major direction of the electrical force wave through the heart ventricles goes from the right to left in a downward direction. Consequently, if we attach the ECG electrodes on the arms with the positive pole of the galvanometer as the left arm, then as the excitation wave approaches it, there is a positive or upright reflection. Actually, the forces from instant to instant form a loop in space, initially and briefly toward the right arm, giving the small Q, then sweeping in a broad orbit toward the left arm, giving the R, and back to the center giving the small S.

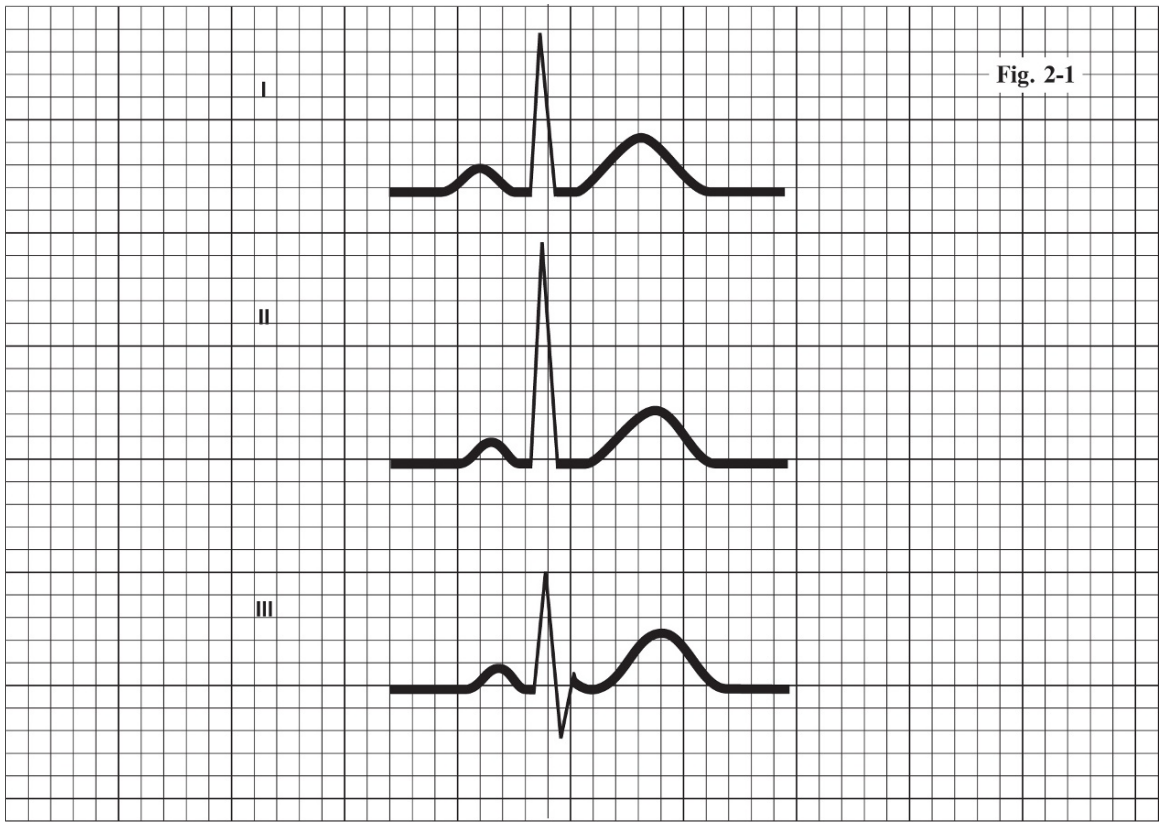


Figure 2.1.

The right arm/left arm lead is lead I and is usually registered as a predominantly upward wave because the *average* and major direction of the wave force is toward the positive left arm (see Fig. 2.1).

The voltage difference between the right arm and the left leg electrodes is measured by lead II. The major direction of the electrical force wave goes parallel, or almost so, to this lead, from above downward, and so the ECG again registers upright, as a mainly positive wave.

In lead III, potential differences are reflected between the left hand and left leg. Here the average major force of the wave rolls over the line of the lead at right angles, and we get a low, absent, or approximately equal positive–negative wave (see Fig. 2.1).

Einthoven devised this triangle (Fig. 2.2) (right arm, left arm, left leg) and calculated that if we record these three leads at exactly the same time, the height of waves in I and III always adds up to those in lead II. He taught us how to calculate the direction of the major wave force from the voltage values in any two... of these... leads. This is called measuring the electrical *axis,* which we take up in Chap. 5. The predominant deflection of the QRS waves *usually* points upward, is positive in I and II, and may be up, down, or in-between in III.

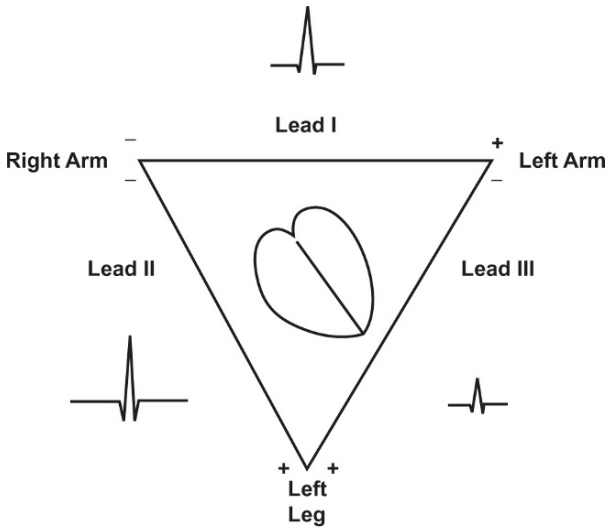


Fig. 2-2

Fig. 2-2

FIGURE 2.2.

Unipolar Limb Leads (aVR, aVL, aVF)

The potential differences in the right arm, left arm and left leg are also recorded between an electrode from each of these sites and a neutral or zero potential by connections from all limb electrodes within the electrocardiograph.

The unipolar leads then reflect potential values from the right arm (aVR), left arm (aVL), and left leg (aVF) and are useful in determining the electrical position of the heart.

The ECG waves in aVR are generally negative or downward deflections; those in aVL and aVF may be upright or of intermediate position depending on the anatomic and electrical position of the heart (see Fig. 2.3).

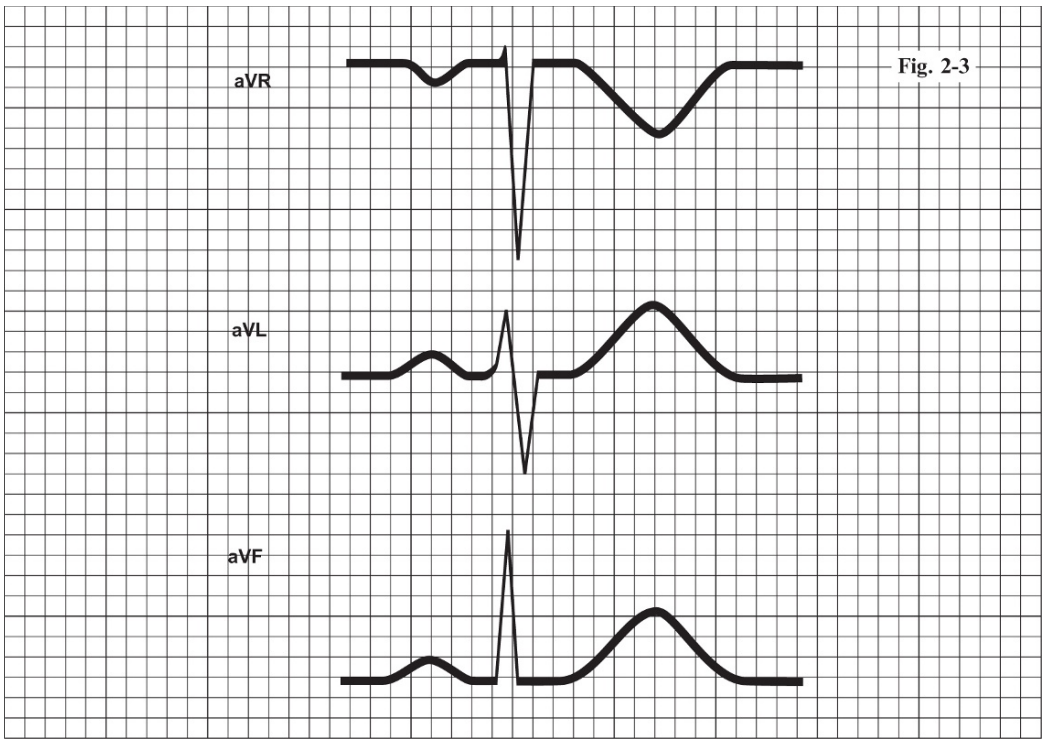


Figure 2.3.

Chest Leads (V_1, V_2, V_3, V_4, V_5, V_6)

We owe to Drs. Wilson and Johnston from the University of Michigan at Ann Arbor the development of chest leads. Much of our information about heart attacks and other heart muscle problems is obtained from these six leads that have been widely used for the last 60+ years. They are often called Wilson leads or V leads or precordial leads, and are named V_1, V_2, V_3, V_4, V_5, V_6. Six is standard but more may be taken. The chest leads are also unipolar leads, reflecting potential differences between six points on the chest and a combined potentials lead inside the electrocardiograph from the three extremity electrodes.

For reference purposes we will define these positions here, but it requires practice to locate the landmarks on a real chest:

> Subscript 1 (V_1) shall be used for a lead from the right sternal margin at the fourth intercostal space; subscript 2 (V_2) for a lead from the left sternal margin at the fourth intercostal space; subscript 3 (V_3) for a lead midway between 2 (V_2) and 4 (V_4); subscript 4 (V_4) for a lead from the fifth intercostal space where it is crossed by the midclavicular line; subscript 5 (V_5) for a lead from the junction of the left anterior axillary, line with the horizontal position of position 4; subscript 6 (V_6) for a lead on the same horizontal level but at the left midaxillary line (see also Chap. 14).

As we look at the body and the heart from the front, or in the frontal plane, we find that the major wave force is directed from body's right to left and down, which accounts for the direction of deflection in frontal plane limb leads I, II, and III. For the chest leads, we look at the heart and body from above, i.e., at the horizontally oriented plane. We find that the major QRS force is directed to the left and somewhat toward the back.

Each of these chest electrodes register positive when the major wave force sweeps toward it. The main wave force is largely away from the positive electrode at V_1 and V_2, and so those leads will register predominantly *downward* deflections. It is *toward* V_5 and V_6 so they will register predominantly upward deflections, while V_3 and V_4 will be somewhere in-between or equiphasic. In detail, the loop starts out toward V_1 and away from V_6, registering a small R in V_1 and Q in V_6. The broad mass of the loop then creates the main force described above, away from V_1 and V_2, toward V_5 and V_6 (see Fig. 2.4).

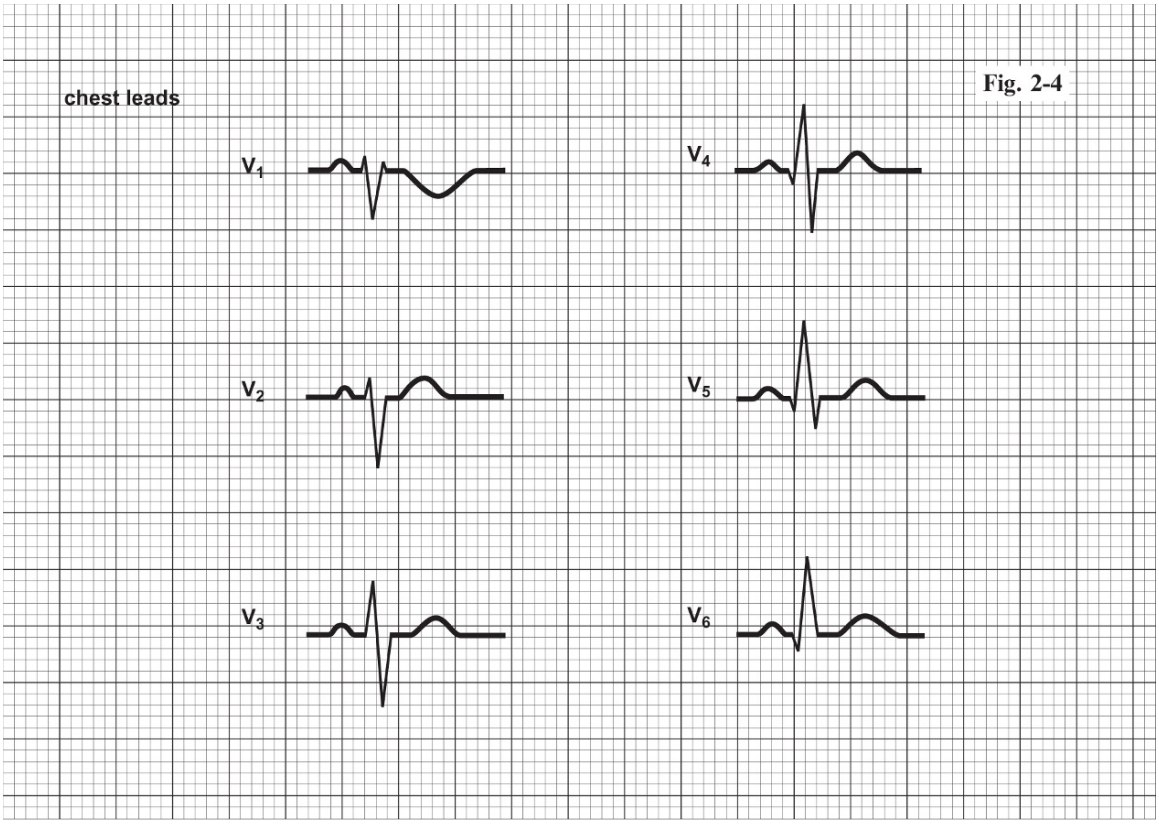


FIGURE 2.4.

This is the pattern that should be remembered now, usually negative QRS waves in V_1 and V_2 and positive waves in V_5 and V_6 with a transitional zone in between. One should be alerted if the wave directions are different from this pattern.

The T-wave recovery force also moves in a slower and smaller loop in space and generally follows the orientation of the QRS forces. With some small exceptions that will be learned, the direction of the T-wave in the limb and chest leads is in the same direction as that of the predominant QRS wave. One should quickly detect whether the T-wave is *opposite* in direction to the main direction of the QRS wave.

3

Measuring Devices

The amplitude (distance of positive peaks and negative nadirs from the baseline) and duration (width from beginning or *onset* to end or *offset*) of ECG waves are measured by visual reference to the grid lines on the ECG recording paper, or by use of devices including a magnified measuring loupe or a clear plastic ruler on calipers. Use of such devices has been demonstrated to improve coding repeatability.

Recording Paper Grid

ECG recording paper is divided into a grid of heavier lines 5 mm apart and lighter lines 1 mm apart. When, as in the majority, ECGs are recorded at a paper speed of 25 mm/second, this means that each millimeter mark on the horizontal axis of the grid represents 1/25 second (0.04 second), 0.25 mm represents 0.04/4 = 0.01 second; 0.5mm = 0.04/2 = 0.02 second; and 0.75 mm = 3× 0.04/4 = 0.03 second (see Fig. 3.1). Amplitude of waves and points of wave onset and offset are measured in millimeter deviations from the baseline (see Fig. 3.2). For durations, (onset to offset 1×mm = 40 ms, and for amplitude 1×mm = 100 μV = 0.1 mV.

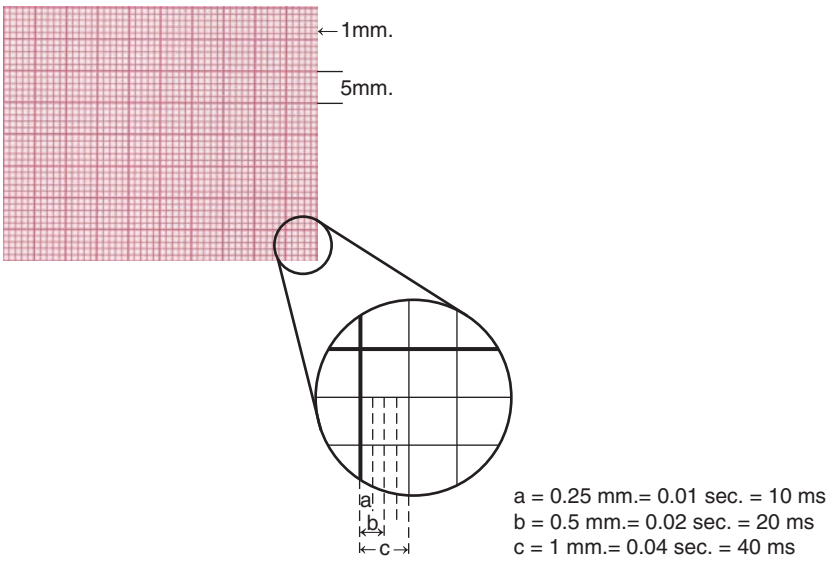


Fig. 3-1

FIGURE 3.1.

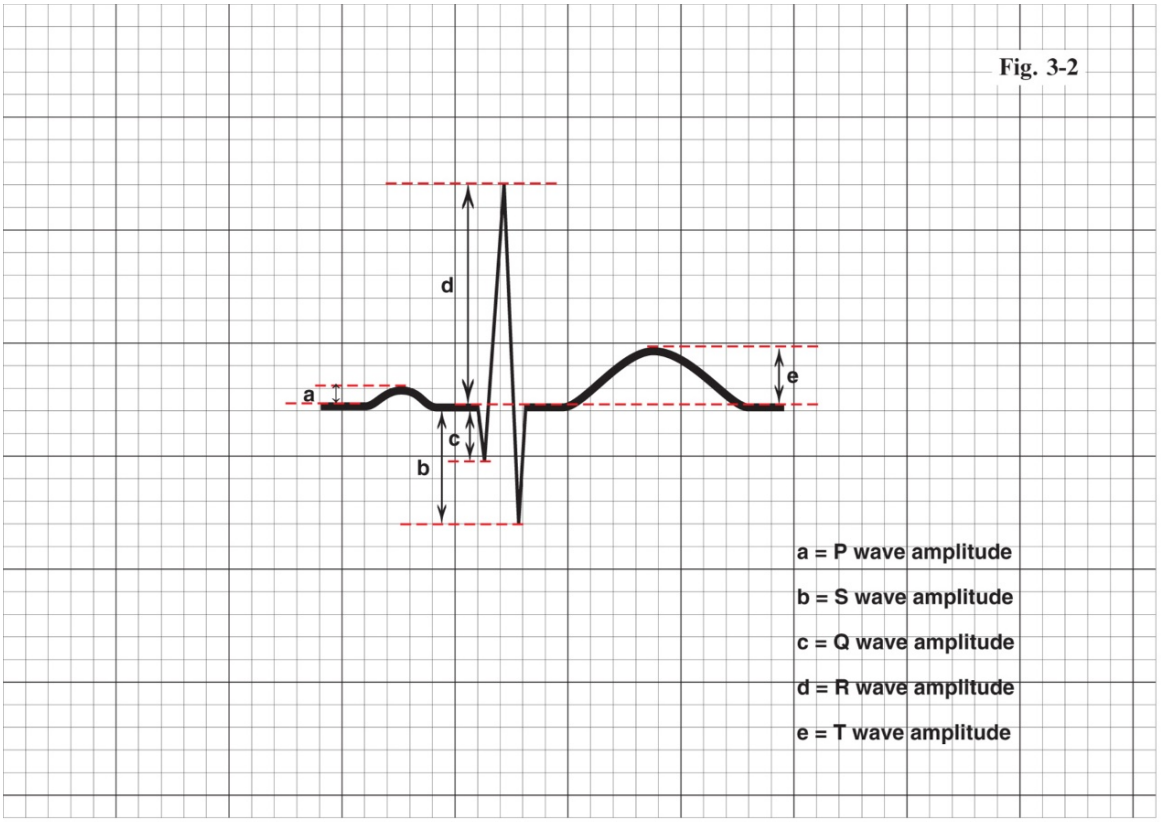


FIGURE 3.2.

The wave limits can usually be determined by reference to the grid lines without the use of measuring devices. However, for those detected close to the boundary of a classification, and for small waves and heart rate estimates, it is more accurate and reliable to use a measurement device.

In the illustrations for the following chapters, two sizes of grid are used as in Fig. 3.3, but without the usually heavier lines at 5 mm intervals. Each division horizontally represents 0.04-second duration and vertically 1 mm amplitude or 0.1 mV.

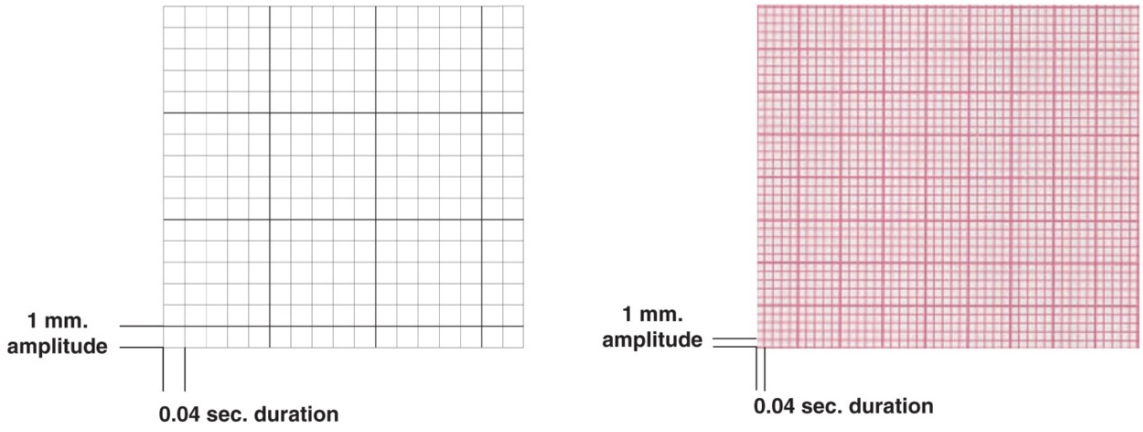


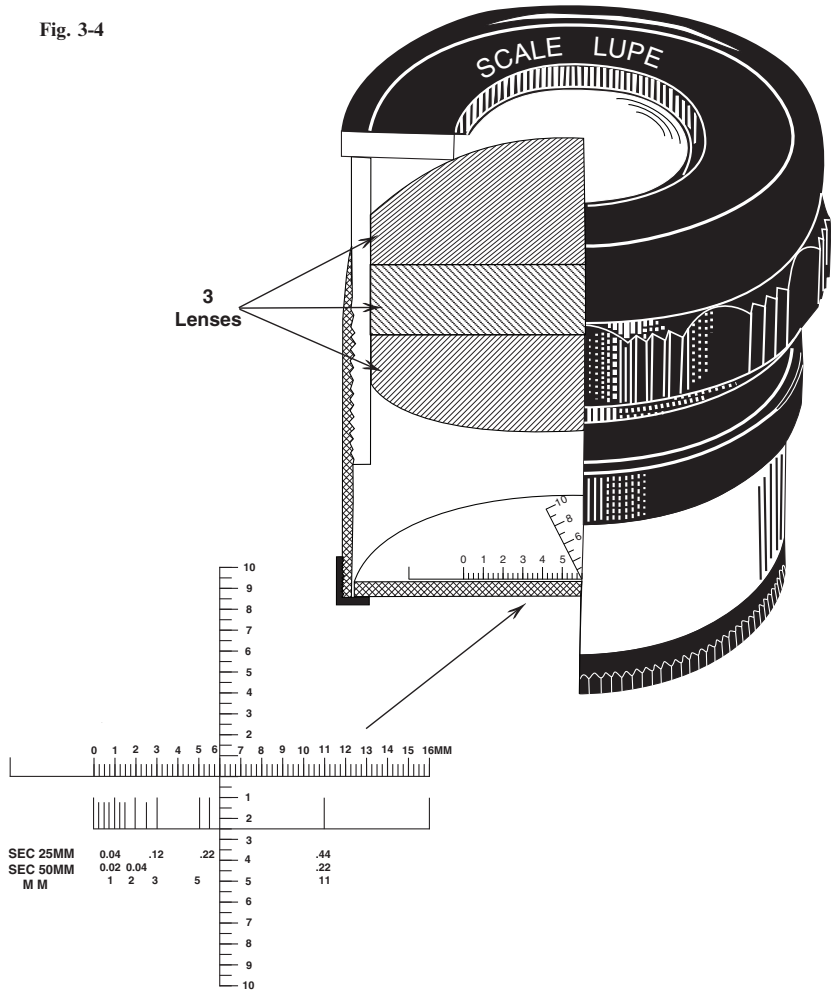
Fig. 3-3

FIGURE 3.3.

Measuring Loupe

For small waves and for wave duration obscured by a grid line, a magnified measuring device must be used. The loupe used in this ECG reading center has improved the repeatability of measurements between different coders and on different occasions. This anastigmatic Loupe 10× has high resolving power and wide visual field, with a grid protected by a coverplate on the bottom (see Fig. 3.4). It has three precision-constructed achromatic lenses (to enable observers to simultaneously inspect the whole picture area, i.e., flat objects less than 32 mm in diameter) and with specially designed scaled reticle for ECG measurement. It is placed flat on the tracing in a good light, positioned in front of the coder. The top lens system may be focused by a screw. With 20 mm effective aperture of the loupe, an observer can inspect the whole image field by merely moving his/her eyeball, without moving his/her face. This is an advantageous feature for a QT interval measurement. The loupe with special reticle may be obtained from our ECG Reading Center, at cost, by writing to the Director, Epidemiological Cardiology Research Center (EPICARE), Department of Epidemiology and Prevention, Division of Public Health Sciences, Wake Forest University School of Medicine, 2000 West First Street Suite 505, Winston-Salem, NC 27104, USA.

FIGURE 3.4.



Plastic Ruler

For measuring longer wave durations and intervals and higher waves, a clear flexible plastic ruler with 1 mm interval is useful. A transparent ruler enables the coder to see the ECG trace beneath so that it can be positioned most accurately. The thinner the ruler, the less will be parallax error.

Calibration Deflection

The first deflection usually seen in the ECG is a square calibration wave (see Fig. 3.5). This should be exactly 10 mm high from the top margin of the baseline to the top of the square wave.

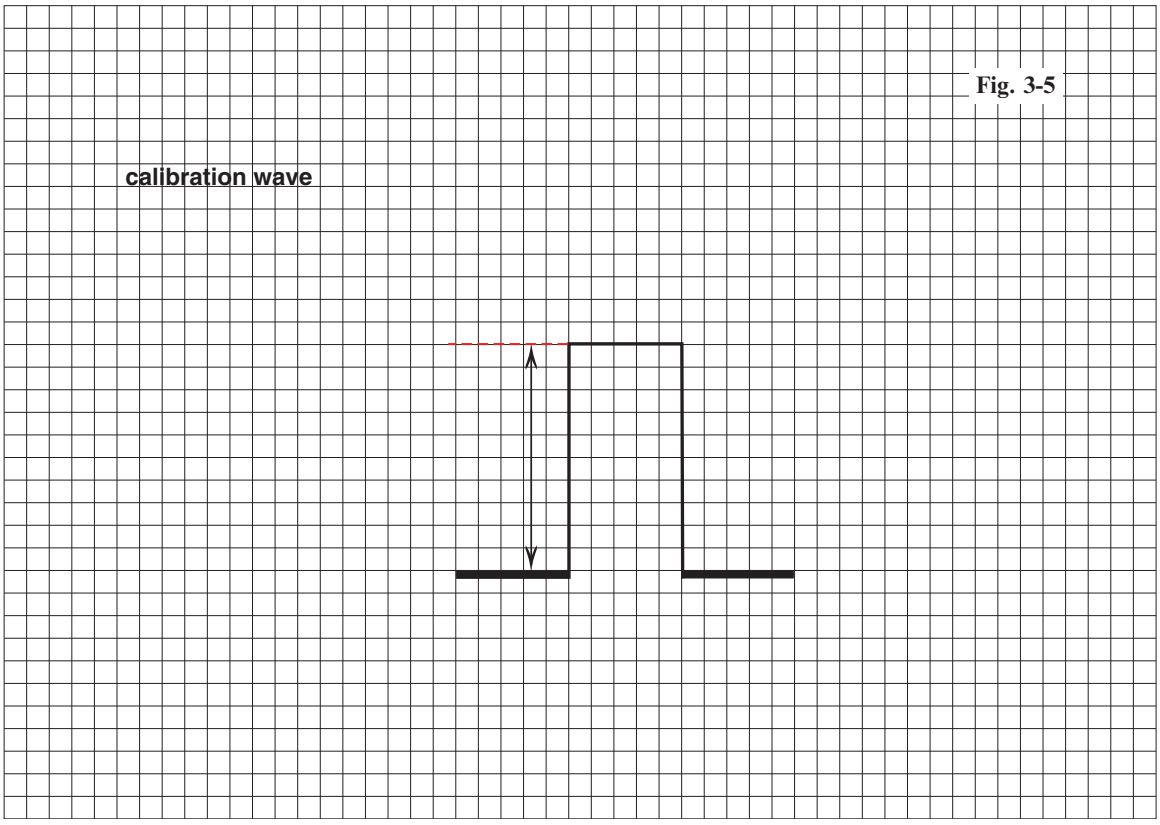


FIGURE 3.5.

Beats to Be Measured

The first beat in a lead is defined as a beat with a complete P-wave, QRS complex, and T-wave. If part of the P-wave is missing, that beat is not included for coding measurements (see Fig. 3.6). The last beat in a lead to be included for coding measurement must include the T-wave, at least to its peak (see Fig. 3.7).

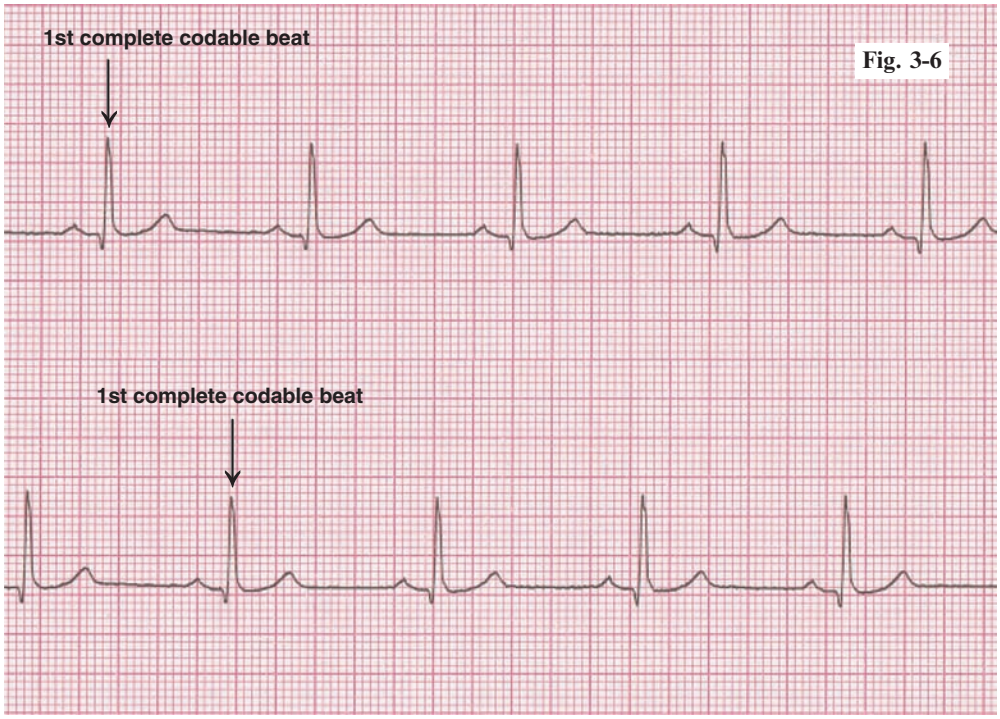


FIGURE 3.6.

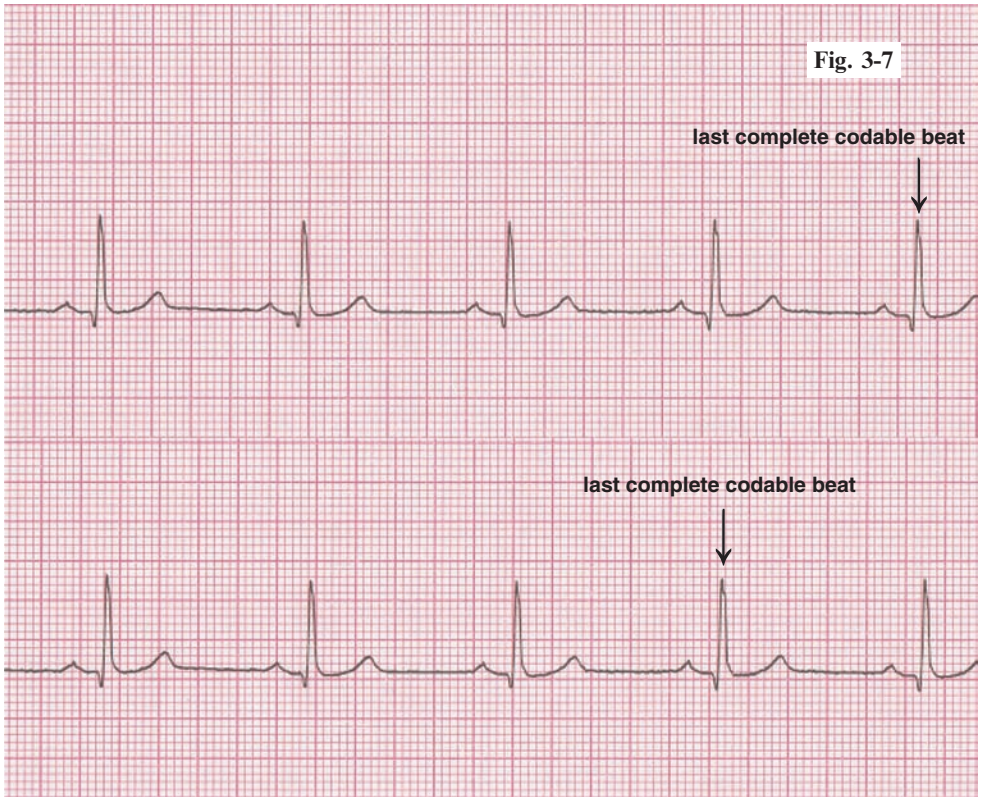


FIGURE 3.7.

Mathematical Symbols

To conserve space and to make precise definitions, mathematical symbols have been used throughout this text for the following:

> = greater than
< = less than
≥ = equal to or greater than
≤ = equal to or less than

So that, 0.06 second < Q duration < 0.07 s, means a Q-wave duration greater than 0.06 second but less than 0.07 second.

Differences in Measurement between Visual and Electronic Measurements

There are times when checks (over-reading) need to be made for visual confirmation of computer coding of digital ECG data. At such times, it is important to recognize that there are differences in measurement precision between the two modes of coding. First, most electronic programs use either an average or *median* beat, whereas visual coding generally requires accepting the findings in the *majority* of beats. Second, the electronic measurement starts from an isolelectric line of virtually no width, whereas the paper record has to contend with an isolelectric line (baseline) of finite width. The electronic signals at the time of publication can measure at a sampling rate of 500 second, so that the electronic measurements applied in computer coding are often a shade longer in duration when measuring specific intervals and a shade greater in measuring voltage deviations from the isoelectric line.[1]

Reference

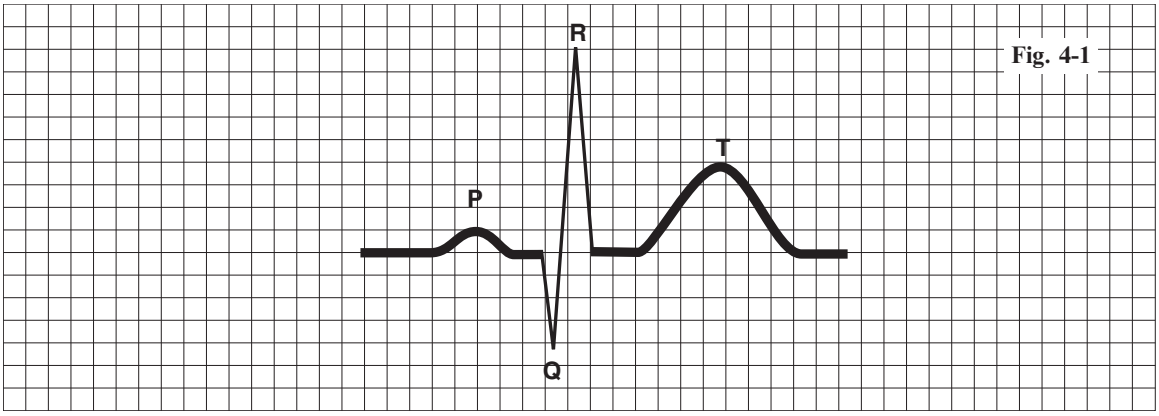
1. Rautaharju PM, Seale D, Prineas RJ, Wolf H, Crow R, Warren J. Changing electrocardiographic recording technology and diagnostic accuracy of myocardial infarction criteria: improved standards for evaluation of ECG measurement precision. *J Electrocardiography.* 1978;11(4):322-330.

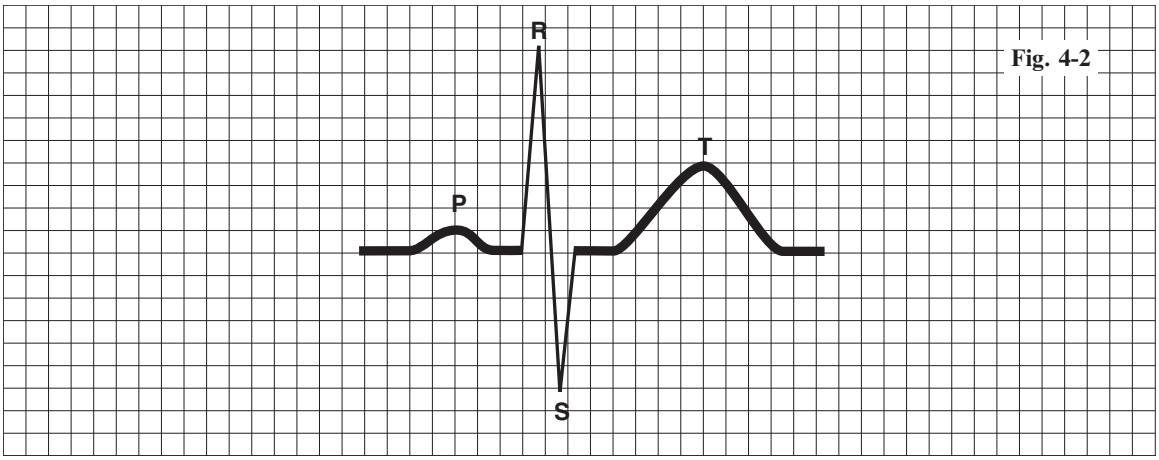
4

Q-QS Waves (1-Codes)

Injured regions of the heart may become electrically inactive. Myocardial infarction is the most frequent cause of this. The normal excitation wave may be altered by this nonfunctioning part of the heart, thus changing the appearance of the QRS complex. In this situation, the early part of the QRS complex appears as a deep, wide negative Q- or QS-wave in certain leads. Smaller areas of injury cause lesser Q-waves.

Ideally, one would measure the amplitude and duration of *all* Q-waves and refer to standard values for classification. Practically, this is too tedious for visual-manual coding. Instead, the code provides classes that generally reflect degrees of Q-QS abnormality according to lead.





Figures 4.1 and 4.2. The 1-codes classify Q- and QS-waves, which also depend on the type of R-wave present. The earliest positive deflection in a QRS complex is the R-wave. Any negative deflection that *precedes* the R-wave is a Q-wave (see Fig. 4.1). Any negative deflection that follows the R-wave is an S-wave (see Fig. 4.2)

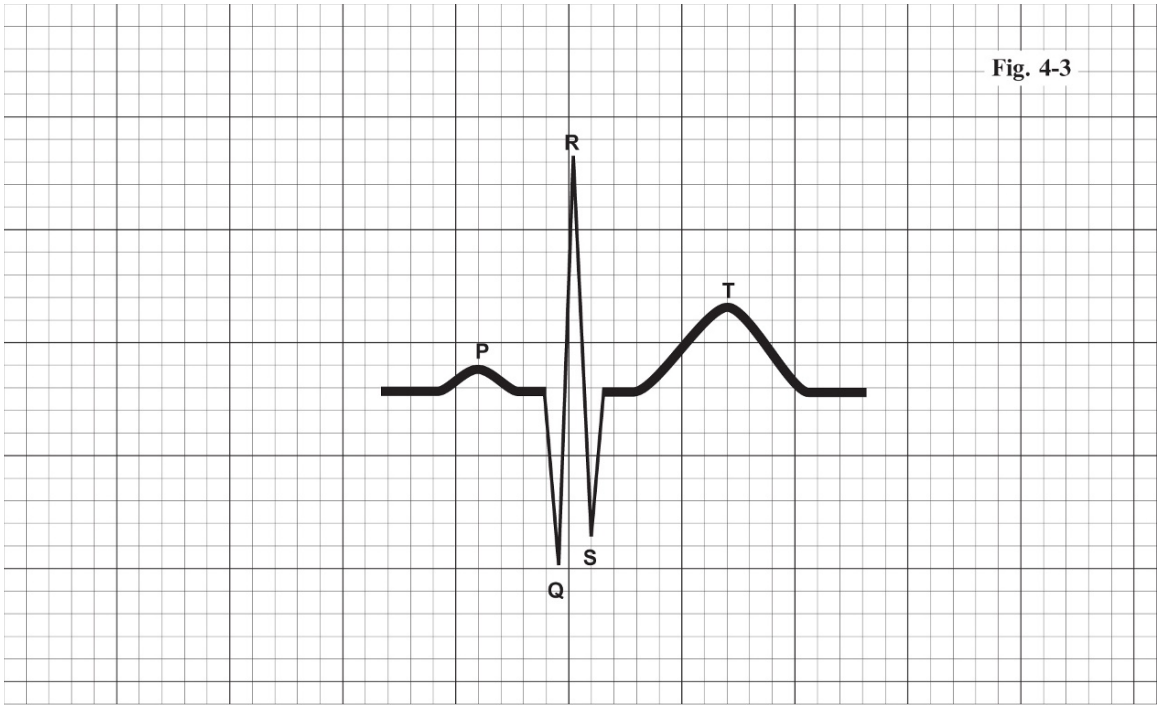


FIGURE 4.3. A Q-wave and an S-wave may be present in the same complex

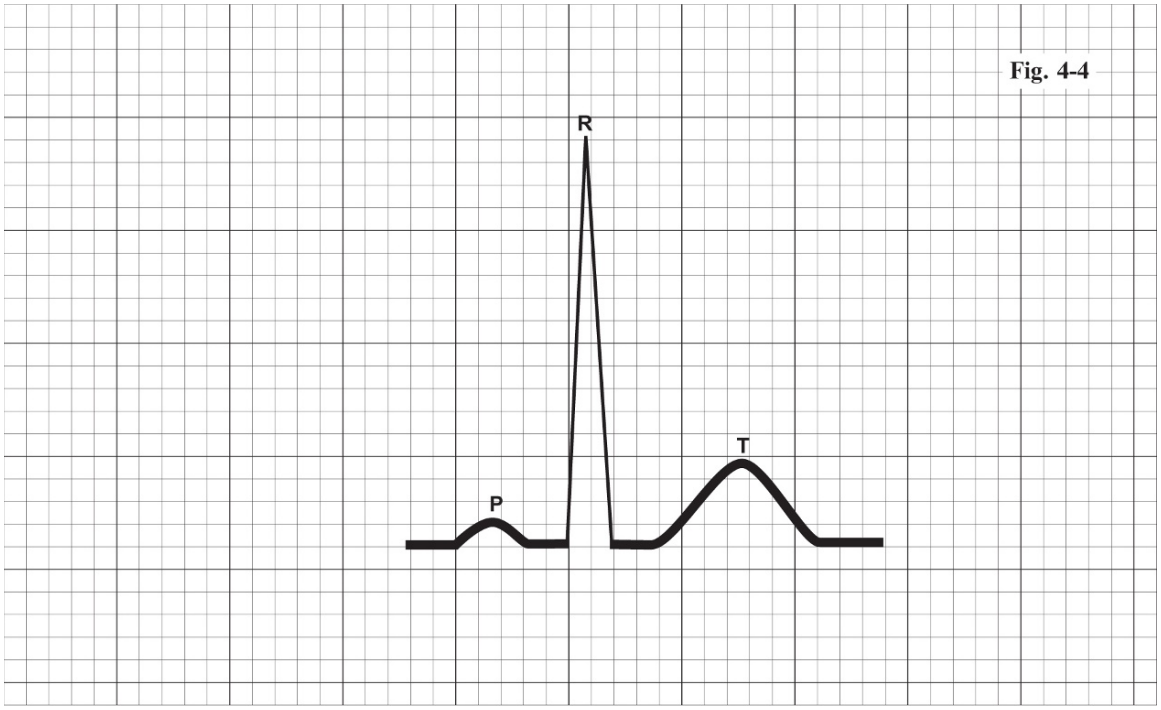


FIGURE 4.4. There may be no Q- or S-wave, in which case the QRS complex would consist only of an R-wave

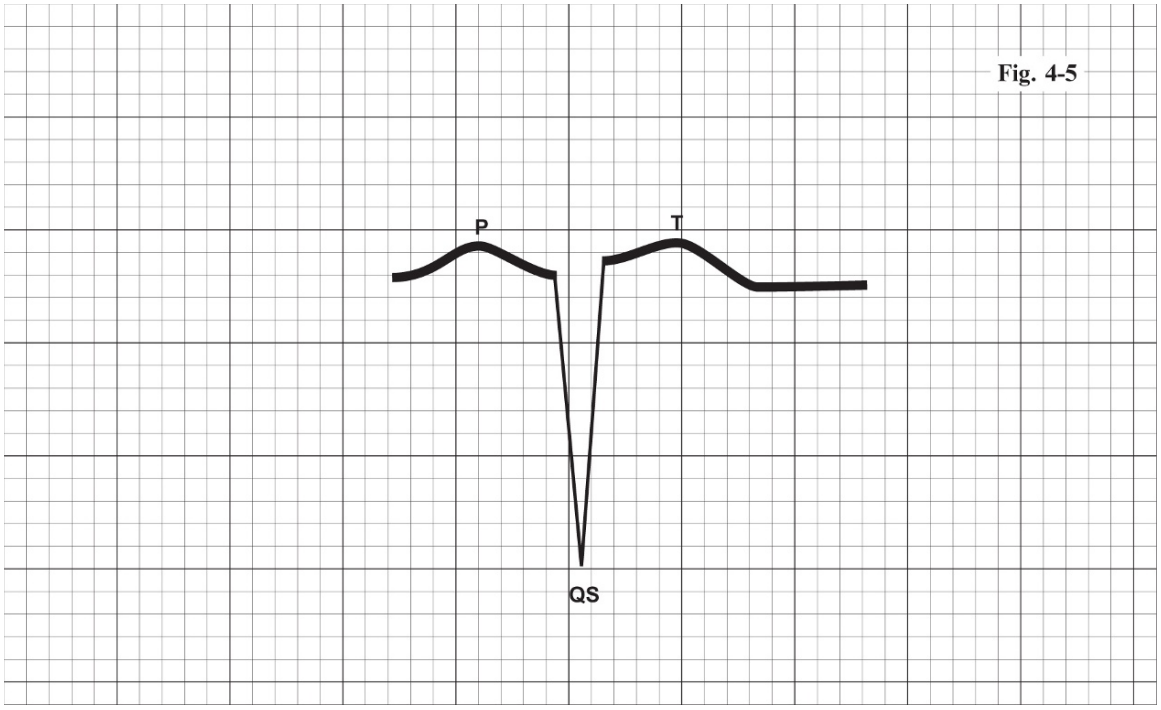


Figure 4.5. If there is no R-wave, then by definition there can be no Q-wave (because a Q is the first negative wave to precede an R-wave and an S the first to follow). The whole QRS complex is negative and is called a QS-wave

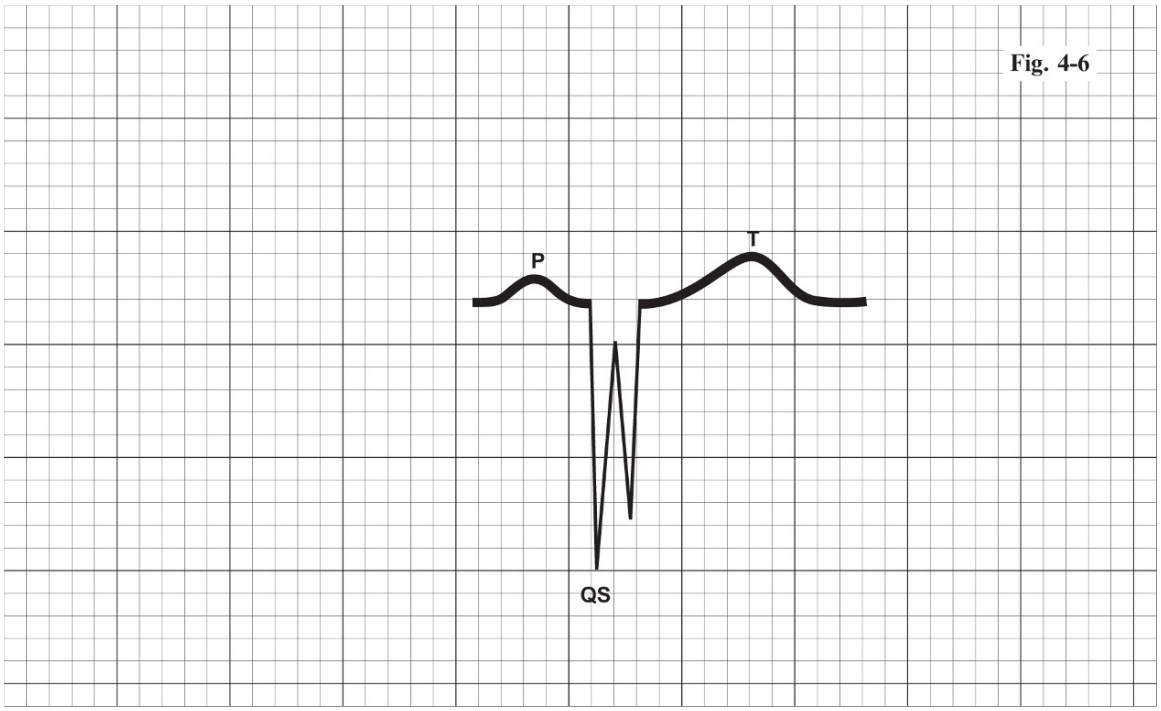
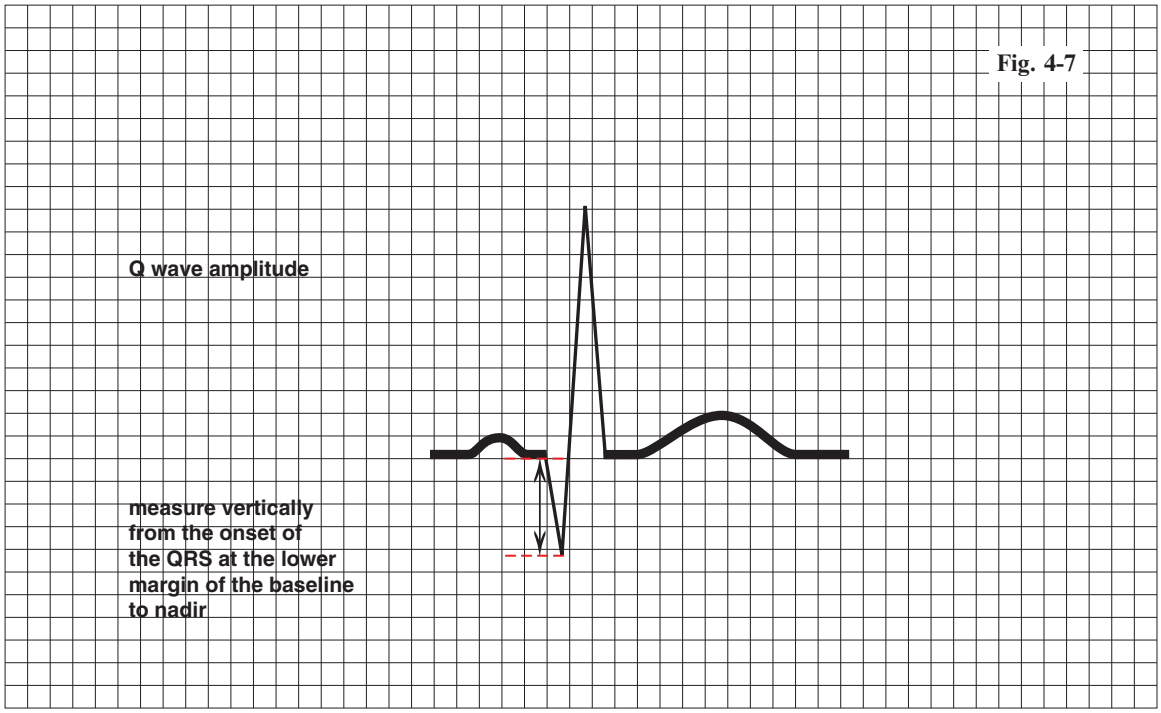
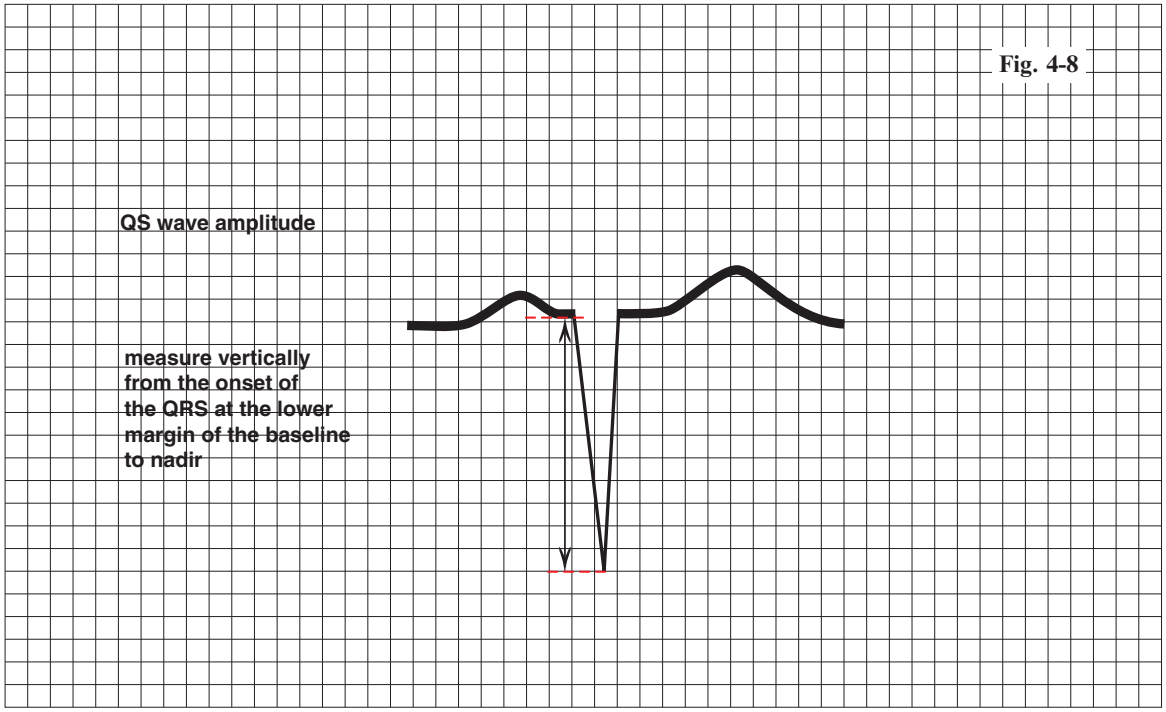


Figure 4.6. A special form of the QS-wave is a W pattern. Here the negative QRS complex is notched with a central deflection. However, the peak fails to reach the reference baseline (the upper margin of the baseline at the onset of QRS) and the W pattern is classified as a QS-wave





FIGURES 4.7 and 4.8. The presence or absence of codable Q- or QS-waves depends on the amplitude of the Q- or QS-wave, which must be ≥1 mm in the majority of beats in any lead (with two exceptions for codes 7-7 and 7-8, see Chap. 9), the duration of the Q-wave, which must be ≥0.02 second in the majority of beats in any lead, the amplitude of the accompanying R-wave, and the lead location of the Q- or QS-wave

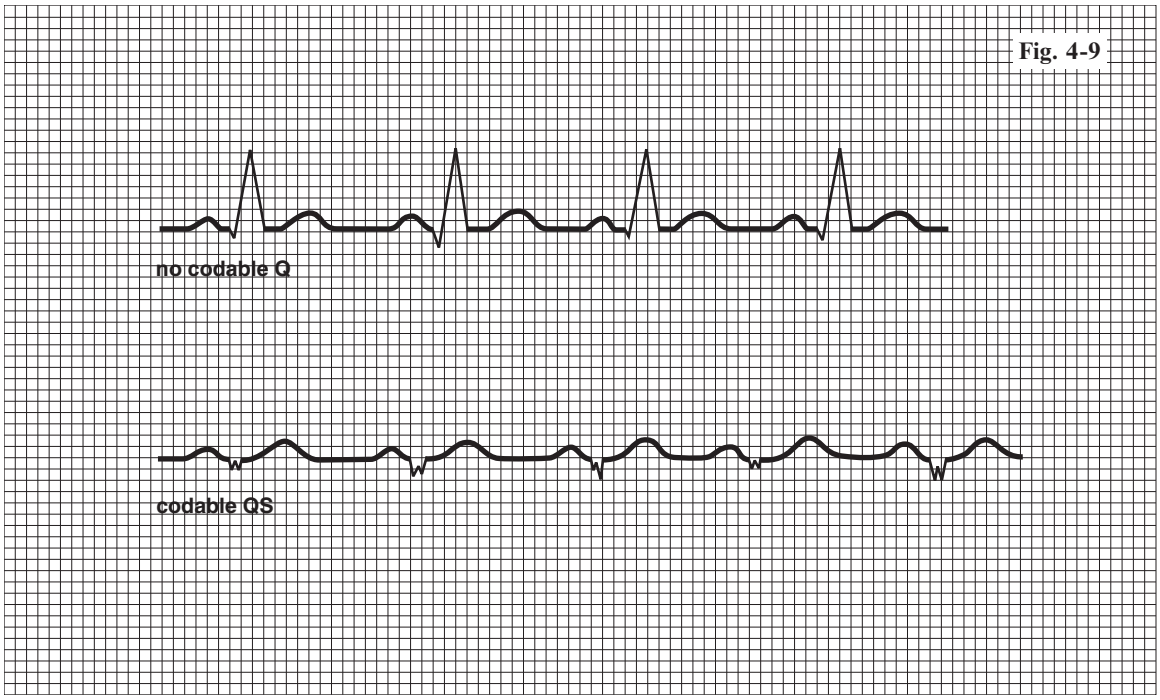


Figure 4.9. If the amplitude of the Q- or QS-wave is <1 mm in 50% or more of beats in a lead, it is not codable

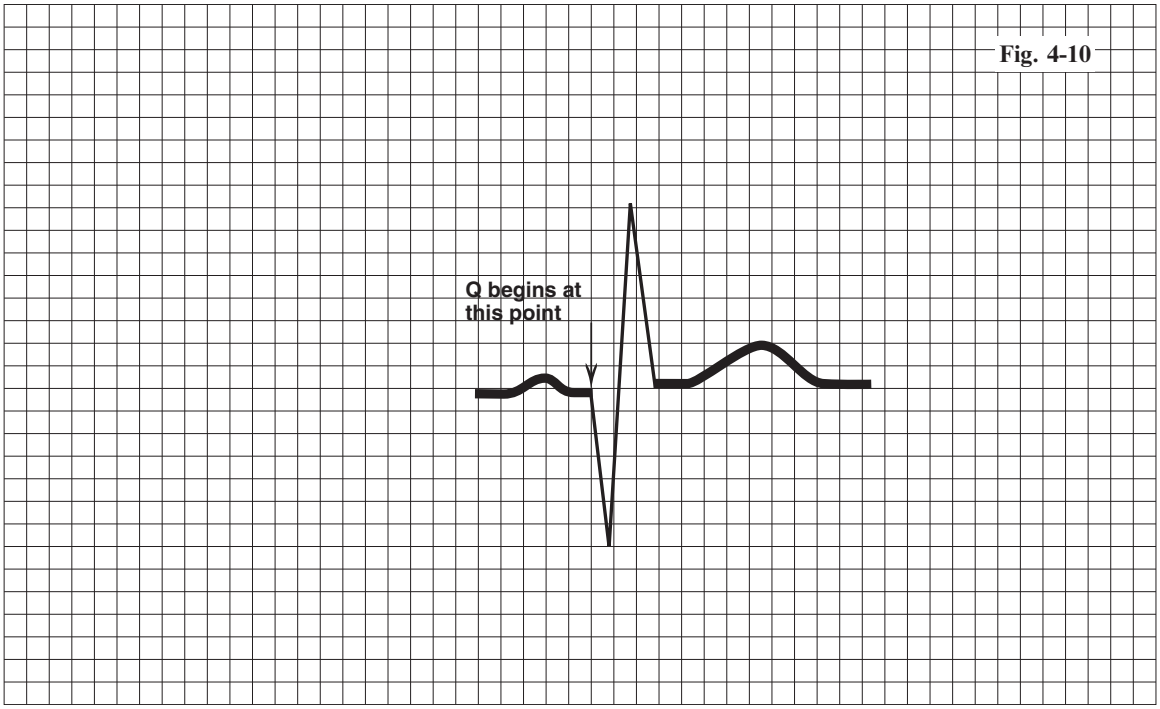


Figure 4.10. The duration of the Q-wave is measured horizontally from the first sharp downward deflection from the baseline to the point that intersects the ascending trace of the R-wave