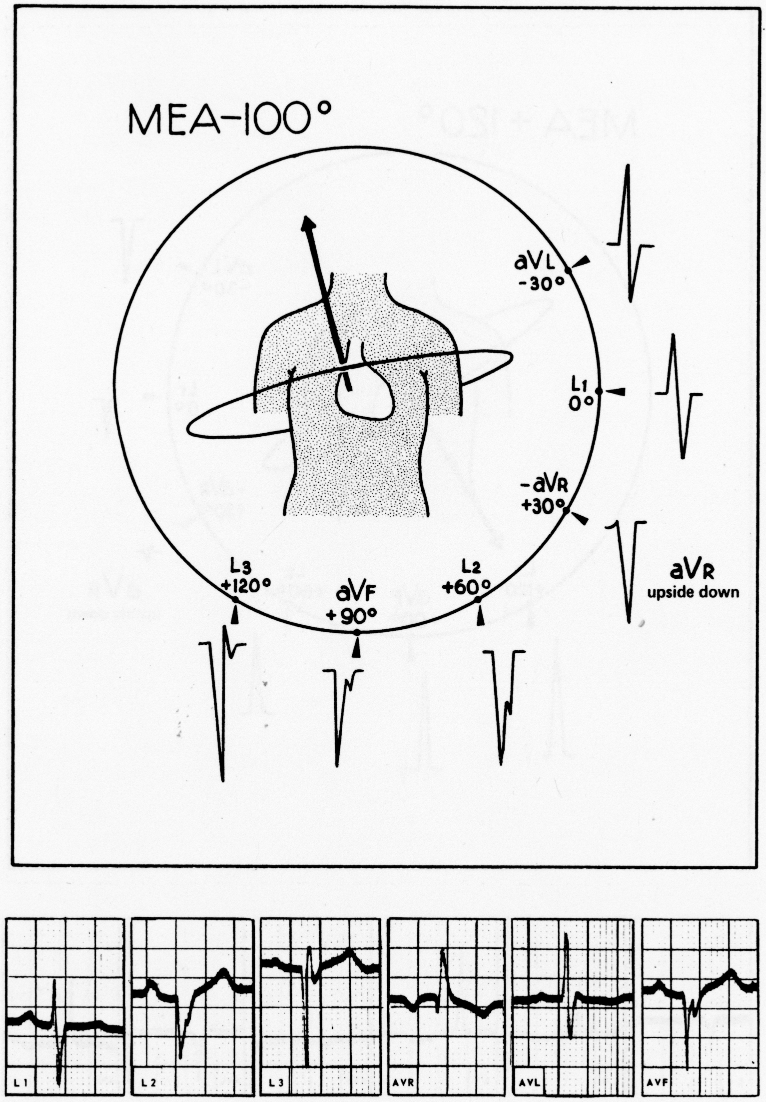

Fig. 1-24. The transitional zone lies between L1 and AVL is resultantly positive, and L1 is resultantly negative, as are L2, L3, AVF, and −AVR. The MEA perpendicular to this transitional zone therefore, lies between −90 degrees and −120 degrees at about −110 degrees. The region beyond −90 degrees is usually considered to be right axis deviation and the axis may also be called +250 degrees.

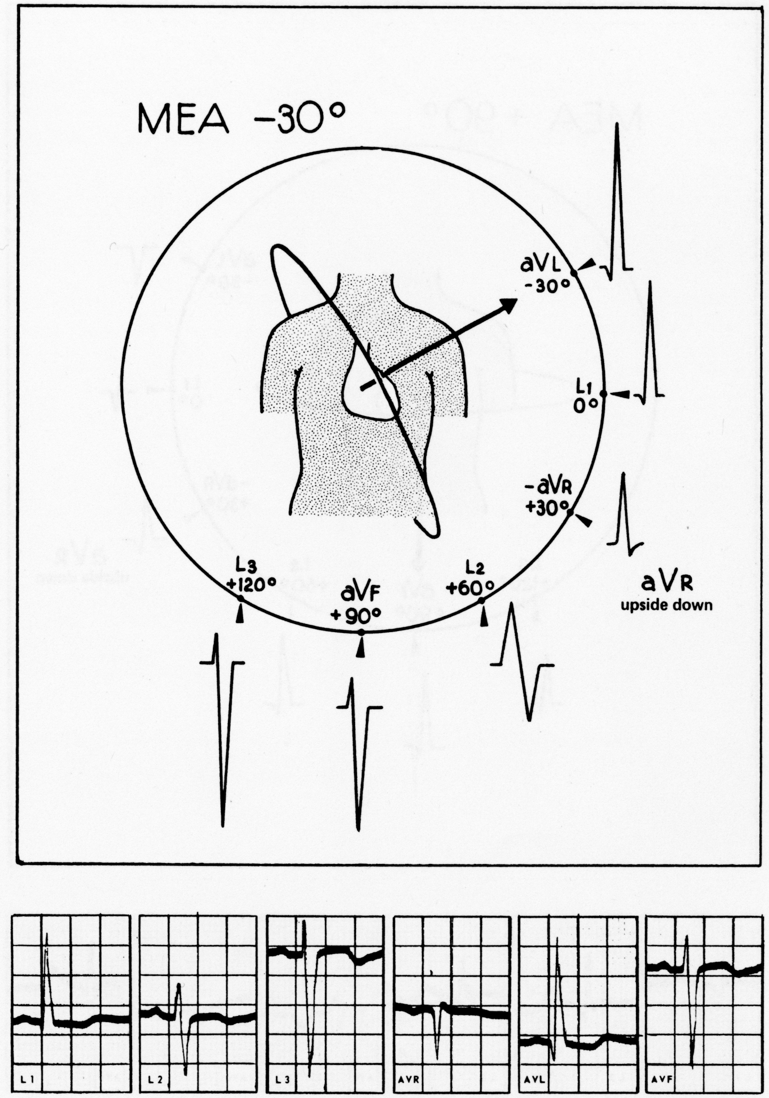

Fig. 1-25. The transitional zone is slightly to the left of L2 at approximately 60 degrees. The tallest R wave is in AVL. The MEA is, therefore, to the left of the transitional zone at −30 degrees or slightly beyond.

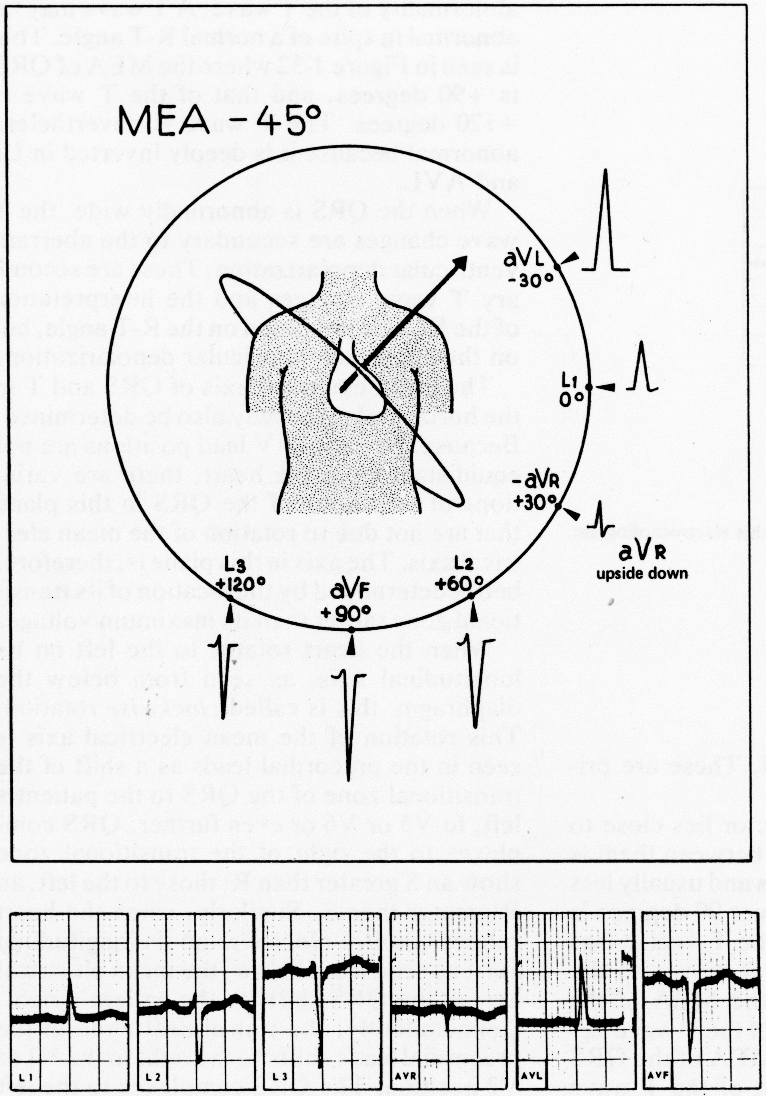

Fig. 1-26. The transitional zone is midway between −AVR and L2. The MEA is perpendicular to this zone toward the positive deflection in AVL. It is approximately −45 degrees.

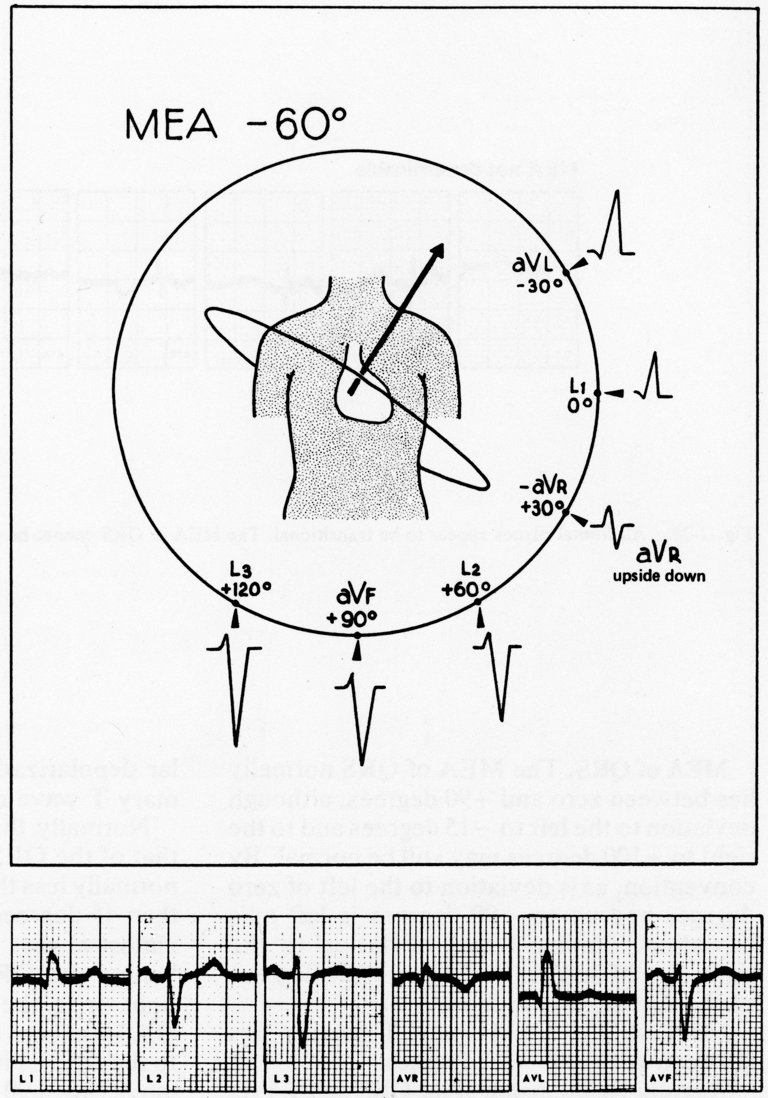

Fig. 1-27. The transitional zone is at −AVR (+30 degrees). The MEA, perpendicular to this zone and to its left in the direction of AVL, is at −60 degrees.

MEA not determinable

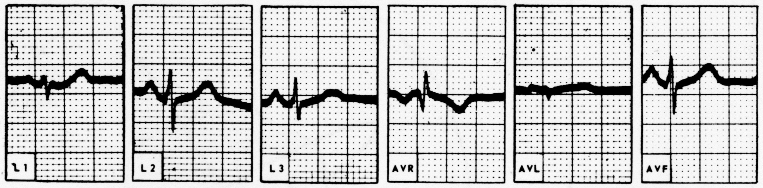

Fig. 1-28. All frontal planes appear to be transitional. The MEA of QRS cannot be determined from this electrocardiogram.

MEA of QRS. The MEA of QRS normally lies between zero and +90 degrees, although deviation to the left to −15 degrees and to the right to +100 degrees may still be normal. By convention, axis deviation to the left of zero degrees and up to −90 degrees is left axis deviation. Similarly axis deviation to the right of +90 degrees and up to +180 degrees or more is right axis deviation.

MEA of T. The MEA of T usually lies between zero and +90 degrees.

Angular Relationship of the QRS and T Vectors. The angle between the mean QRS and the mean T vector represents a sensitive method for differentiating normal from abnormal T waves since it relates the forces of depolarization to those of repolarization and expresses this relationship quantitatively. This relationship is only valid when ventricular depolarization is normal. These are primary T wave changes.

Normally the T wave vector lies close to that of the QRS. The angle between them is normally less than 60 degrees and usually less than 45 degrees; an angle over 90 degrees is almost always abnormal. The T vector lags behind the QRS vector as it moves to the right or to the left. When the MEA of the QRS is at zero degrees that of the T wave lies to the right of it. When the MEA of the QRS moves to +90 degrees, that of the T wave tends to be to the left of this point. The R-T angle tends to remain within the normal range even when the QRS is left to −15 degrees or right to +100 degrees.

Part of the determination of whether a T wave is normal or abnormal must include the calculation of the angle between QRS and T (Figs. 1-29, 1-30, and 1-31).

The R-T angle is not the sole criterion for abnormality of the T wave. A T wave may be abnormal in spite of a normal R-T angle. This is seen in Figure 1-32 where the MEA of QRS is +90 degrees, and that of the T wave is +120 degrees. The T wave is nevertheless abnormal because it is deeply inverted in L1 and AVL.

When the QRS is abnormally wide, the T wave changes are secondary to the aberrant ventricular depolarization. These are secondary T wave changes and the interpretation of the ECG is not based on the R-T angle, but on the abnormal ventricular depolarization.

The mean electrical axis of QRS and T in the horizontal plane may also be determined. Because the various V lead positions are not equidistant from the heart, there are variations of amplitude of the QRS in this plane that are not due to rotation of the mean electrical axis. The axis in this plane is, therefore, better determined by the location of its transitional zone rather than its maximum voltage.

When the heart rotates to the left on its longitudinal axis, as seen from below the diaphragm, this is called *clockwise* rotation. This rotation of the mean electrical axis is seen in the precordial leads as a shift of the transitional zone of the QRS to the patient's left, to V5 or V6 or even further. QRS complexes to the right of the transitional zone show an S greater than R; those to the left, an R greater than S. Similarly, when the heart rotates *counter-clockwise* on its longitudinal axis, as seen from below, the mean electrical axis of the QRS shifts to the patient's right. Concomitantly, the transitional zone in the precordial leads shifts to the right to the V1 or V2 position. The QRS complexes to the left of this point are upright, with R greater than S, and those to the right of this point are negative, with S greater than R. (See illustration, p. 125.)

The projection of the electromotive forces on the sagittal plane is not routinely determined.

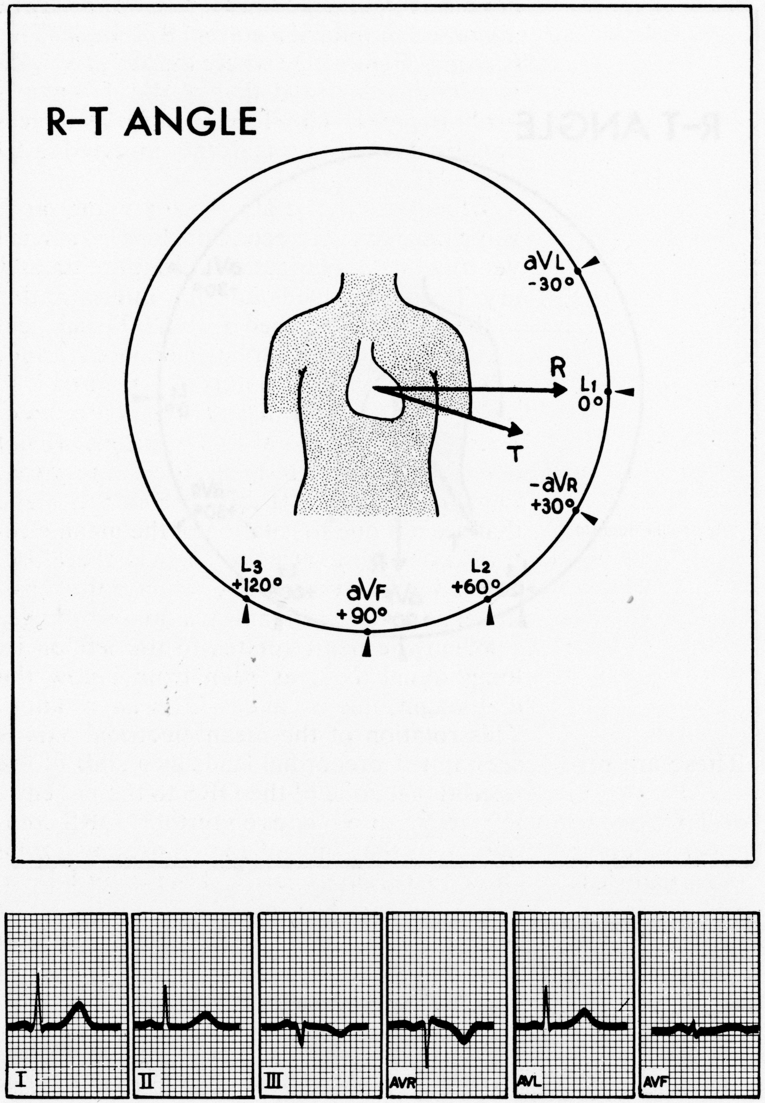

Fig. 1-29. The transitional zone of the QRS is at AVF (+90 degrees) and the MEA is therefore zero degrees. The transitional zone of the T wave lies between L3 and AVF and the MEA of the T wave is +15 degrees. The angular relationship of QRS and T is normal; T is approximately 15 degrees to the right of R.

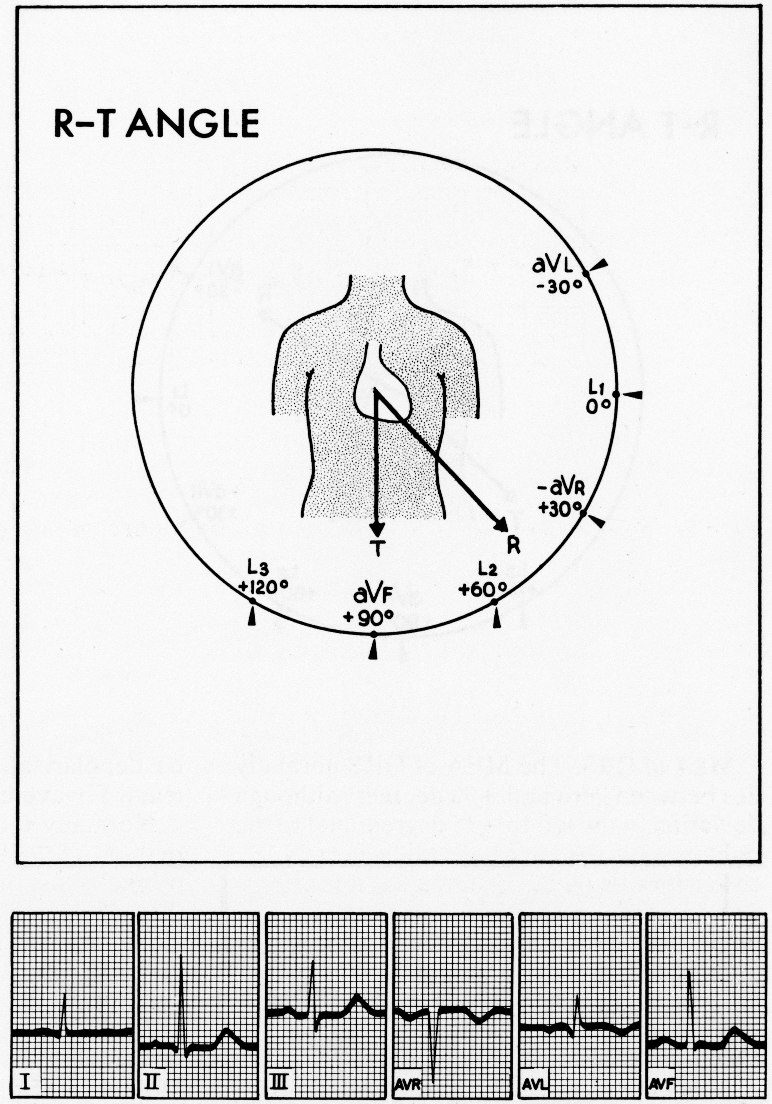

Fig. 1-30. The transitional zone of the QRS is slightly to the left of AVL at about −45 degrees. The transition zone of the T wave is seen in L1 (a flat, isoelectric T), its MEA is perpendicular to L1 and at AVF (+90 degrees). The R-T angle is 45 degrees. The MEA of T is to the *right* of the QRS. Although the angle of R-T is less than the 60 degrees usually given as within the limits of normal, it is abnormal in this tracing because the T is leading rather than following the R wave.

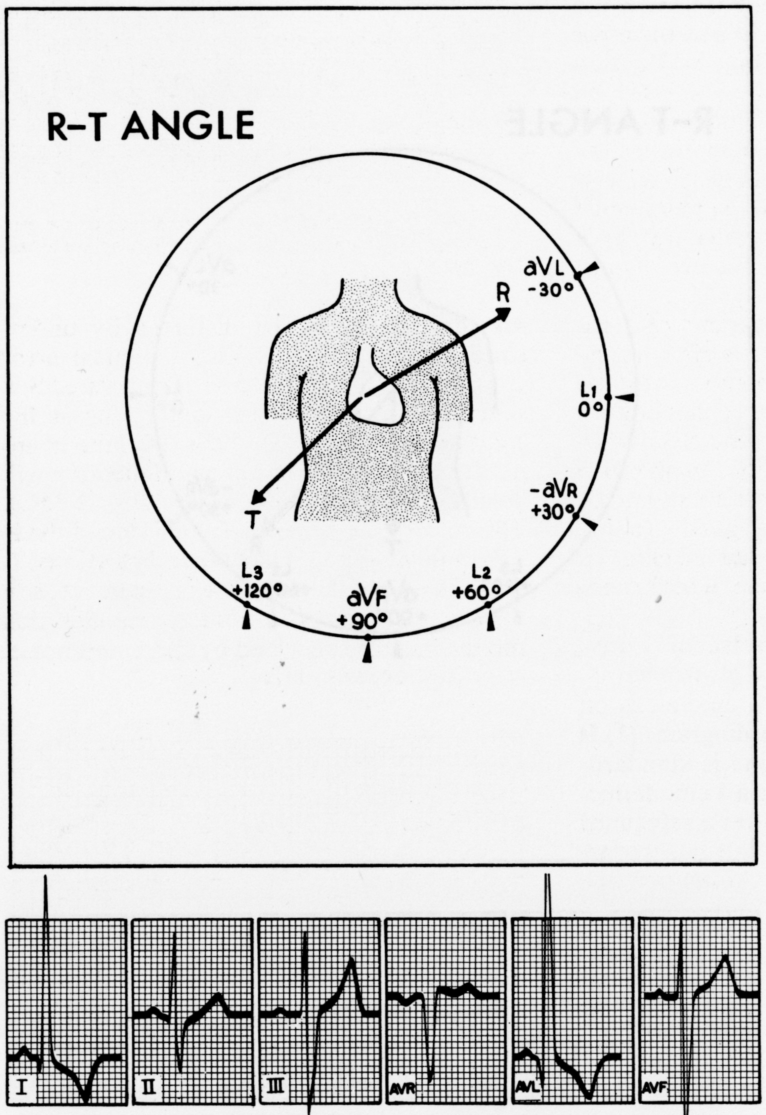

Fig. 1-31. The transitional zone of the QRS is seen in L2 (+60 degrees). Although R of L2 is taller than the S in this lead, the S wave is wider than the R and therefore the area enclosed by the S wave is approximately equivalent to that enclosed by R. The MEA of the QRS is at a right angle to L2 at −30 degrees. The T wave transitions between −AVR and L2, its MEA is at approximately +135 degrees. The R-T angle is widely divergent and is abnormal with an angle of 165 degrees.

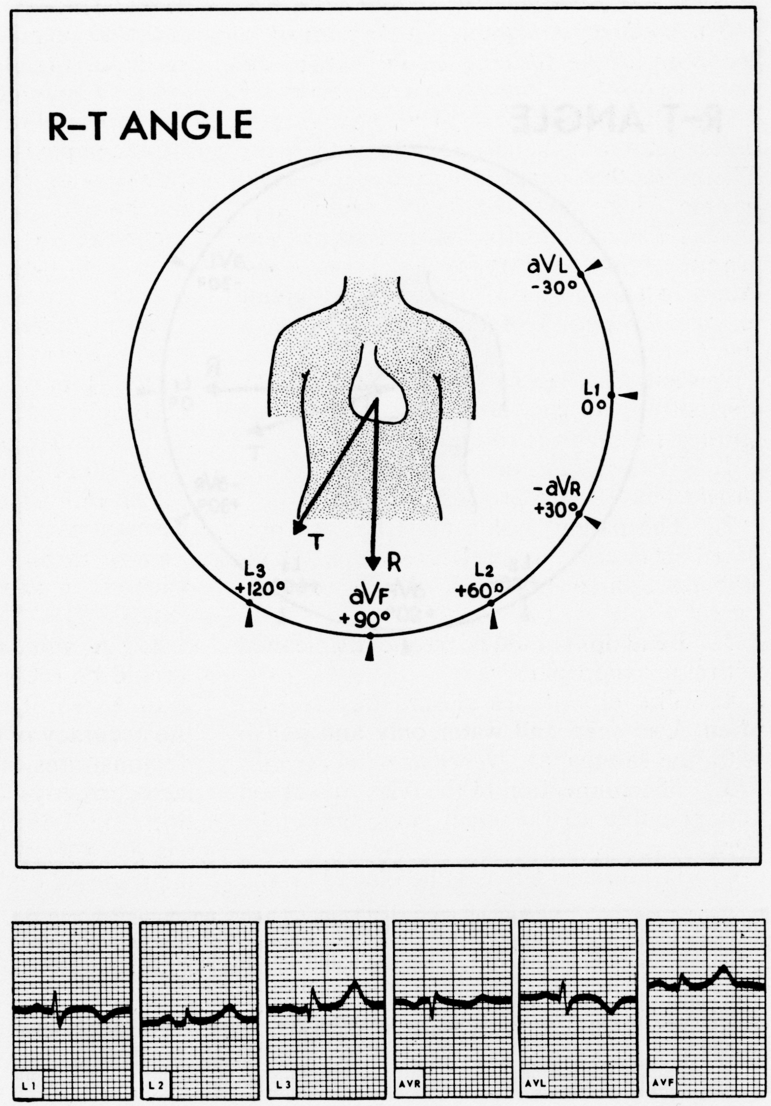

Fig. 1-32. The MEA of R is +90 degrees and that of T is +120 degrees. The R-T angle is only 30 degrees and within normal limits. But an MEA of T at 120 degrees is in itself abnormal. Further, when the MEA of R is +90 degrees, the T axis should be to its left; in this tracing, the T axis is to the right of R. The electrocardiogram is therefore abnormal though the R-T angle is normal.

TECHNIQUE FOR TAKING THE ELECTROCARDIOGRAM

The electrocardiograph is a very sensitive recorder of the differences in voltage between two points. This voltage is inscribed on a strip of paper moving at a constant predetermined rate, usually 25 mm. per second. Therefore, the voltage is plotted as a function of time. There are many electrocardiographs available commercially. Almost all of them are entirely satisfactory for clinical purposes. Almost all are direct writing machines giving an immediate graph of the cardiac electromotive forces.

Precautions Necessary to Avoid Artifacts. Certain precautions should be taken in recording an electrocardiogram:

1. The instructions of the manufacturer should be followed precisely.
2. The patient's skin must be well prepared (salt paste is preferable in most instances, though alcohol is usually satisfactory).
3. Lead tips should be frequently cleaned with fine sandpaper.
4. The electrodes should be cleaned often. Use soap and water only and polish with fine sandpaper. *Never use steel wool.*
5. The connection of the wire tips of the patient cable to the electrodes should be tight.
6. The electrodes must be placed on the correct extremities. This should be double-checked every time an electrocardiogram is taken, since incorrect lead placement is the most frequent single source of serious error in the taking of the record (Fig. 1-33).
7. The electrocardiograph should be properly and well grounded. This can usually be accomplished by proper orientation of the power plug in the wall socket. The new machines have three prong power plugs and if these are inserted in a corresponding three hole wall socket, the machines are always properly grounded.

When taking electrocardiograms of a patient in bed in his own home, it is often necessary to ground the bed. This can usually be accomplished by a direct wire connecting the bed to the grounding post on the electrocardiograph or to a coldwater pipe. In an office set-up with a metal table, the table should be permanently connected to a good ground. Failure to properly ground the machine is a common cause of 60 cycle interference (Fig. 1-34).

8. A standardizing impulse of 1 mv. should be recorded on every electrocardiogram taken. This provides three checks on the accuracy of the electrocardiogram: (1) It demonstrates that the machine is standardized correctly—1 mv. causing a 1 cm. deflection (Fig. 1-35A). (2) It provides a safeguard against a damping defect in the electrocardiograph. If the machine is overdamped, the mv. deflection will be distorted by undershooting (Fig. 1-35B). This technical error can cause artificial depressed or elevated S-T segments as well as other distortions on the electrocardiogram. (3) If the machine is underdamped, the standardizing deflection will be distorted by overshooting (Fig. 1-35C). This may cause excessive amplitude of the R waves (high voltage) and other distortions. If the damping of the machine is incorrect as in Figure 1-35B and C it is recommended that the machine be serviced by the manufacturer or his representative.

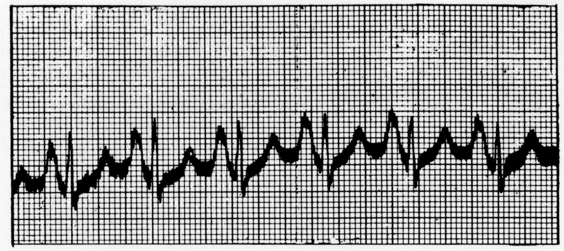

Fig. 1-34. The effect of 60 cycle interference on the electrocardiogram. Characteristically there are 12 spikes to each large box (0.20 sec.).

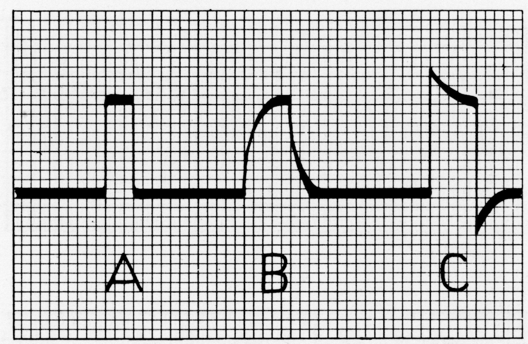

Fig. 1-35. A, A normal standardization impulse. One millivolt causes a 1 cm. displacement of the baseline. B, Effect of overdamping of the electrocardiograph. The standardization impulse is distorted, as seen by the failure of the standardization impulse to be displaced 1 cm. instantaneously. C, When the machine is underdamped the standardization impulse overshoots the 1 cm. mark. Either overdamping or underdamping may result in serious distortion of the electrocardiographic complex.

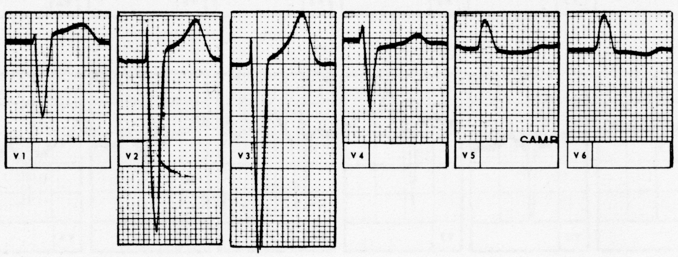

Fig. 1-33. The right and left arm leads are reversed leading to an electrocardiogram that resembles situs inversus with a negative P, negative QRS, and inverted T in L1. But the horizontal leads show normal progression of the R and T waves from V1 through V6 thus ruling out situs inversus and suggesting right arm and left arm lead transposition.

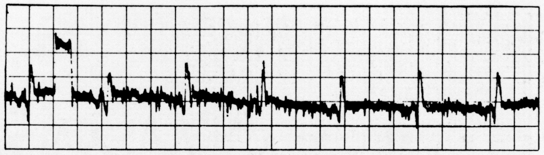

Fig. 1-36. Effect of somatic tremor on the electrocardiogram. Note the coarse, irregular movement of the baseline.

Fig. 1-37. Weaving or shifting baseline leading to distortion of the various components of the electrocardiogram, particularly the P, S-T, and T waves.

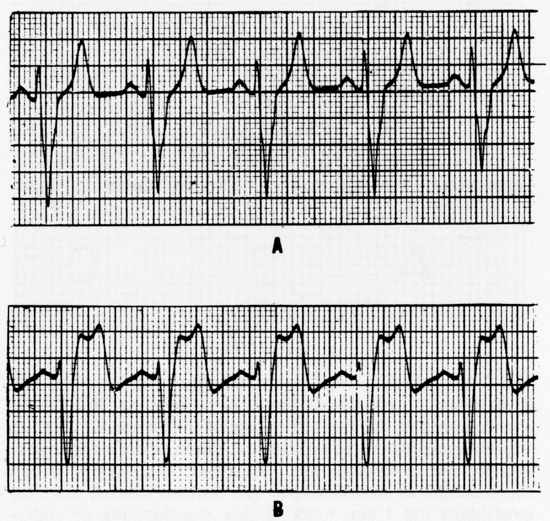

Fig. 1-38. A, B.

9. The patient should be completely relaxed so as to avoid muscle tremors. These are manifested on the electrocardiogram as an irregular, rapid movement of the baseline (Fig. 1-36). By routinely placing the limb electrodes high on the arms and legs, somatic tremor is usually eliminated.

10. A weaving or shifting baseline may be due to a defect in the electrocardiograph itself or to slippage of the electrodes on the patient's skin. The latter can be easily corrected by tightening the electrode strap (Fig. 1-37).

11. In intensive care or coronary care units the patient's cardiogram is usually visualized on the oscilloscope monitor. Several artifacts are introduced by this technique which can make the electrocardiogram valueless for diagnostic interpretation. In order to produce a stable baseline and to eliminate tremor and noise, a series of filters is integrated into the monitor circuitry. These result in distortion of the electrocardiogram tracings. The S-T segment and T waves are usually deformed (Fig. 1-38A). The QRS may be deformed as well (Fig. 1-38B). Provisional diagnoses made from such strips should always be confirmed by an electrocardiogram taken directly from the patient in the conventional manner.

12. Placement of the chest leads. In taking the chest leads it is important that they be correctly placed in conformity with current prescribed practice. Deviation from these prescribed points will result in changes of patterns in serial tracings and make judgments of these serial changes incorrect or difficult, if not impossible.

13. Seriously ill patients frequently have an electrocardiogram taken daily or even more often. In order for these serial tracings to be strictly comparable, it is necessary that the V leads be taken from the same precise locations on the chest each time. Marking the V lead points on the chest with indelible ink will enable the electrocardiograph technician to achieve conformity in the V leads (Fig. 1-39).

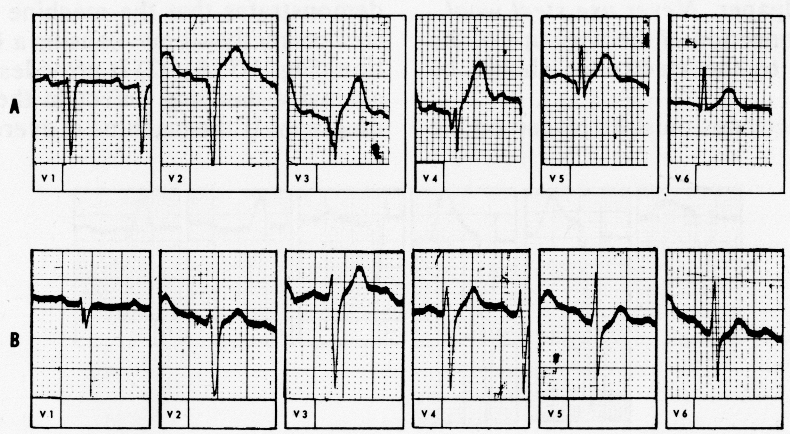

Fig. 1-39. V leads from a patient with an old myocardial infarction show disappearance of Q wave with change in placement of the precordial leads. In strip A, abnormal Q waves are seen in V2, V3, and V4. These are not seen in strip B, with slightly different electrode placement.

14. The location of the lead placement for the oscilloscopic monitor does not conform to the prescribed chest lead placements for electrocardiography. Electrocardiogram strips taken from the monitor therefore cannot be used for comparison with the standard chest leads from the same patient.

15. A frequent source of error in the taking of the V leads is the improper use of the electrode jelly or paste. The electrode jelly or paste must not be allowed to spread or be smeared between two lead positions. The resultant salt bridge between V lead positions leads to gross inaccuracy in the recorded electrocardiogram (Fig. 1-40).

16. The new electrocardiographs can be run at 25 or 50 mm. per second. If the electrocardiogram is inadvertently taken at 50 mm. per second, serious problems in interpretation may arise. The physician should be alerted to this error when it appears that the heart rate is abnormally slow and all components of the electrocardiogram are abnormally wide (Fig. 1-41).

17. A tilted stylus in the electrocardiograph may lead to a nondiagnostic electrocardiogram. The R wave may show notches, slurring, or breaks in the curve which are artifacts (Fig. 1-42).

18. The electrocardiogram should be recorded in the center of the electrocardiogram paper and without any part of the complex getting too close to the top or the bottom of the paper. When this does occur, the electrocardiogram complex may become deformed in one of several ways. The top of an R or T wave or the bottom of an S wave may simply be chopped off leading to a rounded R or S rather than a sharp pointed one. The amplitude of the R or S (or T) may be sharply reduced and lead to failure of diagnosis of high voltage. And, finally, electronic circuitry in the electrocardiograph may reduce the amplitude of or widen an R and S wave as it approaches the limits of the width of the electrocardiogram paper (Fig. 1-43).

19. On occasion the ECG technician may

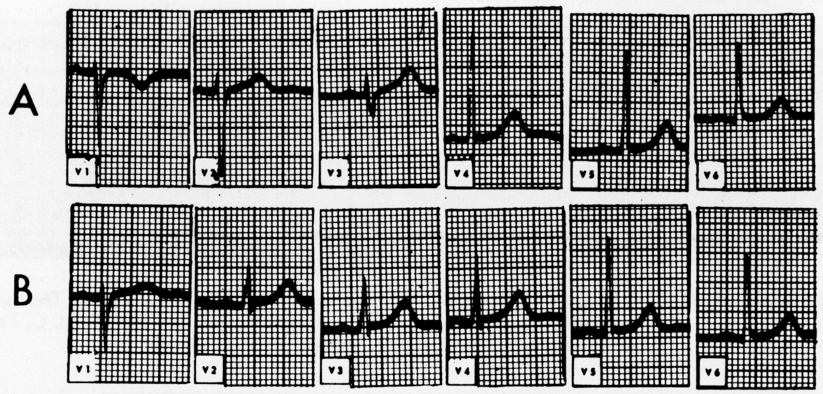

Fig. 1-40. A and B are the V leads taken from the same points on the chest wall from the same patient. In A the salt paste dots were discrete, at B the salt paste of contiguous lead points were permitted to contact each other (a salt paste bridge). Note the loss of diagnostic specificity in B. The inverted T wave in V1 is now upright, an rS complex in V2 is now a totally upright R with a notched and slurred upstroke. Similar changes are seen in V3. If an old anteroseptal infarct were present in V2 and/or V3, the salt bridge could have wiped it out.

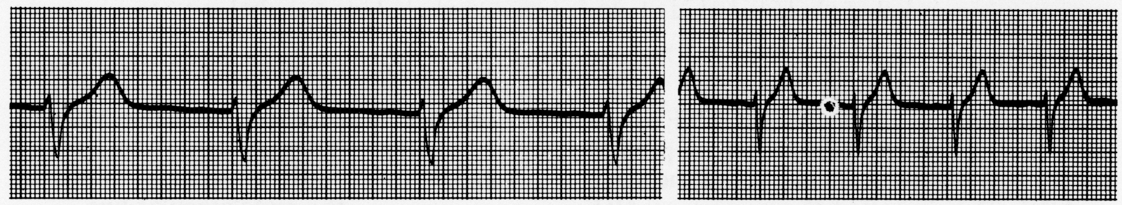

Fig. 1-41. Left, 50 mm. per second. Right, 25 mm. per second.

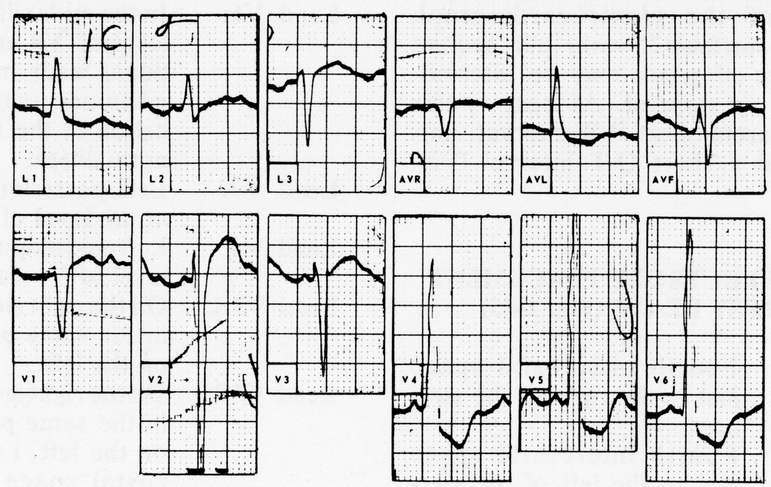

Fig. 1-42.

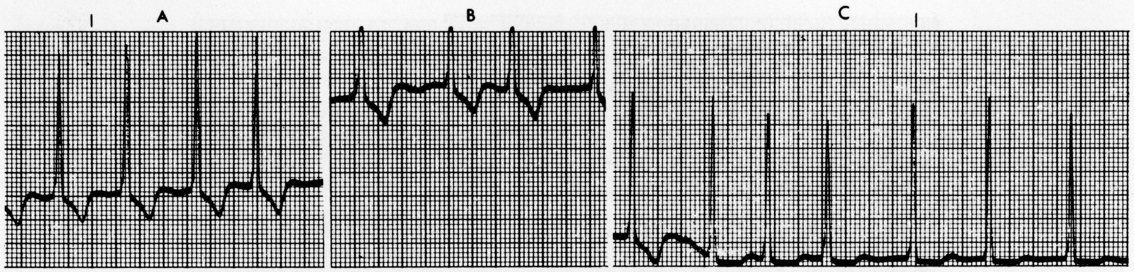

Fig. 1-43. A, The ECG is correctly centered and a tall R, depressed S-T, and inverted T wave are seen. B, The tracing is at the top of the strip, the tall R is amputated and appears to be of normal amplitude. The S-T and T and unchanged. C, The ECG is at the bottom of the strip, the tall R wave is retained, but the S-T and T appear to be near normal.

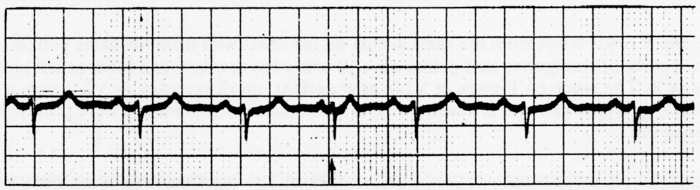

Fig. 1-44. Transient failure of paper movement.

leave the lead selector switch on AVF as she takes the precordial V leads. All six precordial leads will then be identical and the same as AVF. This is called the *persistent AVF syndrome*.

20. Due to defect in the paper advance mechanism of the electrocardiograph machine, the normal 25 mm. per second steady advance of paper may be intermittently slowed or stopped. At beat 4, this causes an apparent short P-R interval, narrow QRS, and a short Q-T interval (Fig. 1-44).

CORRECT ELECTRODE PLACEMENT FOR CHEST LEADS (Fig. 1-45)

Lead V1:	Fourth intercostal space just to the right of the sternum.
Lead V2:	Fourth intercostal space just to the left of the sternum.
Lead V3:	Midway between V2 and V4.
Lead V4:	Fifth intercostal space in the midclavicular line.
Lead V5:	The anterior axillary line at the level of V4.
Lead V6:	In the midaxillary line at the level of V4 and V5. Additional leads may be taken, when necessary, for clarification of the suspected abnormalities.
Lead V7:	Left posterior axillary line at the level of V6.
Lead V8:	Left midscapular line at the level of V6 and V7.
Lead V3R:	On the right side of the chest in the same position as V3 on the left.
Lead V4R:	On the right side of the chest in the same position as V4 on the left, i.e., fifth intercostal space in the midclavicular line on the right.

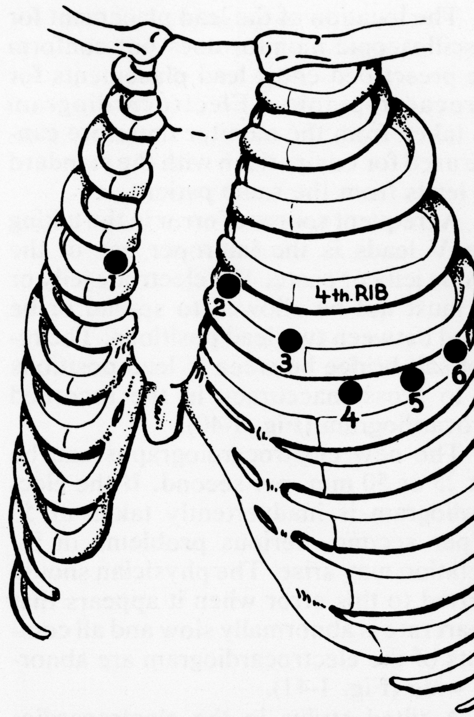

Fig. 1-45. Schematic drawing of chest indicating correct positions of the standard precordial leads.

Leads one intercostal space above and occasionally one intercostal space below the normal positions on the left side of the chest may be taken to localize certain types of myocardial damage more accurately.

Leads may be taken between any two standard chest leads. These are labeled half leads. For example: A lead between V3 and V4 is lead V3½. A lead may be taken over the ensiform cartilage, a VE lead.

THE NORMAL ELECTROCARDIOGRAM

Normal Values for the Individual Components of the Electrocardiographic Complex. The normal values for the various components of the electrocardiographic complex listed below are, at best, approximations since there is a large overlap between the normal and the abnormal for any figures given in electrocardiography. The diagnosis should not be established on the basis of minor deviations in amplitude or duration from any of these figures. The values given in the following section are only to be used as average standard values. When a measured segment of the electrocardiogram is in the borderline-abnormal range, confirmatory evidence for its abnormality must be sought in all other parts of the electrocardiogram. If no other abnormality is found, it should be reported as borderline. Conversely, on occasion, a value that falls within the accepted limits of normal for that wave may, in fact, be abnormal because of other abnormalities found in this or previous electrocardiograms.

The electrocardiogram obtained from a direct-writing electrocardiograph machine is recorded on a preprinted graph paper. The vertical lines are time-interval markers. The distance between the light lines is 0.04 sec. at standard paper speed (25 mm./sec.). Every fifth line is a heavier line. The distance between heavy vertical lines is 0.20 sec. (Fig. 1-46 [upper left corner]).

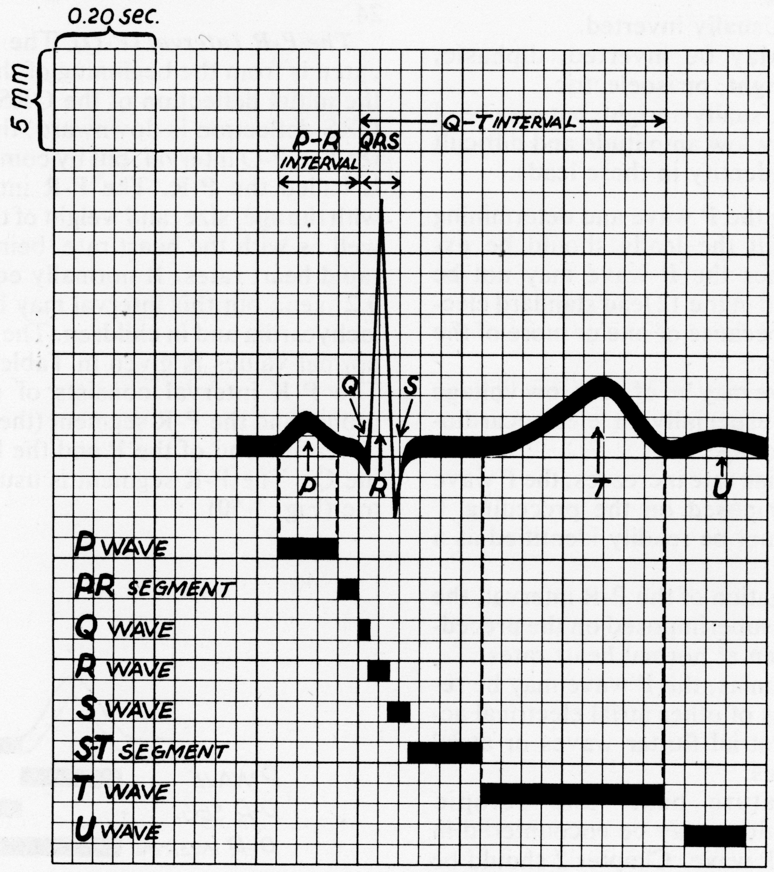

Fig. 1-46. Schematic representation of the component parts of the normal electrocardiogram. Duration of the waves, segments, and intervals is indicated.

The distance between the light horizontal lines is 1 mm. At normal standardization of the electrocardiogram, 1 cm. equals 1 mv. The distance between the light horizontal lines represents 0.1 mv. Every fifth line is a dark line and the distance between dark lines is 5 mm. or 1/2 mv.

The P Wave. The P wave is usually readily identifiable in regular sinus rhythm as a small, slow deflection following the longest isoelectric period and preceding by 0.12 to 0.21 sec. the larger and more rapid main ventricular deflection, the QRS (see Fig. 1-46).

The method for determining the mean electrical axis of P is the same as that for QRS, detailed on pages 6–14.

The normal P wave is less than 0.10 sec. in width and less than 2.5 to 3 mm. in height. The contour of the P wave is usually smooth but occasionally there may be slight peaking. The mean electrical axis of the P wave usually lies between +45 and 50 degrees, but may on occasion shift left to 0 degrees or right as far as 90 degrees (Figs. 1-47–1-49).

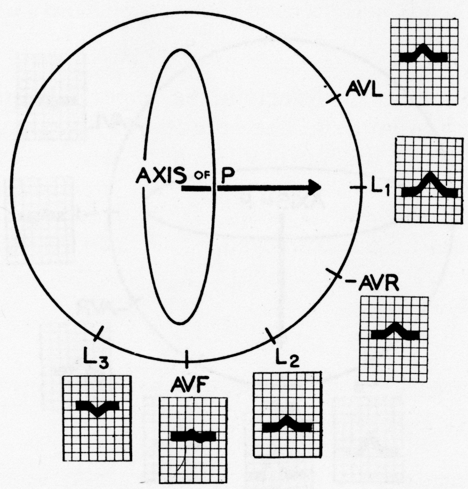

Fig. 1-47. The configuration of the P wave in the various frontal lead positions when the mean electrical axis of P is zero degrees. Note that the largest P wave is in lead 1, that the transitional P complex is present in AVF, and that the P wave is inverted in lead 3.