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Precordial lead electrocardiogram and its clinical value

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THE PRECORDIAL LEAD ELECTROCARDIOGRAM
AND ITS CLINICAL VALUE

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CLINICAL SIGNIFICANCE OF THE PRECORDIAL LEADS OF ELECTROCARDIOGRAM

The electrocardiograph is a record of a galvanometer which registers difference in potential between any two points. Standard recording is done between the extremeties; lead I is between the right arm and left arm, lead II is between the right arm and left leg, and lead III is between the left leg and left arm. These three readings form a triangle around the heart known as Einthoven's triangle and forms the basis of electrocardiology. Lead IV is recorded by placing the exploring electrode over the apex beat of the heart and using the left leg as the indifferent electrode. In the CF leads the indifferent electrode is placed as follows; 1, is in the fourth interspace to the right of the sternum, 2, is in the fourth interspace to the left of the sternum, 3 is between 2 and 4 which is in the midclavicular line and in the fifth interspace, 5 is at the same level and at the anterior axillary line, and 6 is at the same level and at the midaxillary line. The left leg is used as the indifferent electrode. If the right arm is used as the indifferent electrode, it is called a CR lead; and for the same reason if the left arm is used as the indifferent electrode, it is called a CL lead. (1) Some men recomend and use an elastic belt of 6 electrodes to be placed over the chest when taking the precordial leads. It has the advantage of being able to duplicate the records and have the electrodes placed equidistantly over the precordium. However, it is not practical in all cases since one belt will not fit patients of all sizes.(2) Wilson has developed a centeral terminal which combines the right arm, left arm, and left leg each with 5,000 ohms resistance to give a universal ground which in the opinion of some authors tends to decrease and artifacts and hence gives a true reading of conditions directly under the exploring electrode--such leads are called the V leads.(3)

The form of any cardiogram depends primarily upon the fact that, although the muscle fibres in the heart follow an oblique or circuitous course, the frequent branching and inter-communication between them enables the wave of excitation to pass fairly directly from the endocardial to the pericardial surface. Having traversed the Purkinje system, the excitatory process appears to spread almost centrifugally outwards from the ventricular cavities. During the QRS interval a wave of positive potential is followed closely by a wave of negative potential spreading outwards from each ventricular cavity. These positive and negative charges are held apart by an electromotive force similar to that between the poles of a battery. The contracting muscle over which the wave has passed and the quiescent muscle ahead of the wave act as normal electrical conductors. Thus the negative potential generated at the proximal side of the wave is conducted backwards to the ventricular cavities and the positive potential generated at the distal side of the wave is conducted outwards to the pericardial surface of the ventricles, but they are not able to neutralize each other by passing in the reverse direction across the wave of excitation. The difference of potential appears to increase as the wave travels so that, within limits, the thicker the ventricular wall, the greater will be the potential difference between its endocardial and pericardial surfaces. Also, where the heart is nearest to the chest wall, its potential will reach an overlying precordial electrode with the smallest amount of loss in transmission.

From the foregoing principles it follows that the ventricular cavity remains negative so long as the wave of excitation is spreading through any part of the heart muscle, i.e. throughout the QRS interval, after which it returns quickly to zero potential. It is also clear that the pericardial surface is positive for nearly always the first part of the QRS interval. At any point on the pericardial surface, however, the potential switches suddenly to that of the ventricular cavity as soon as that point is reached by the wave of excitation, at which time the underlying muscle behaves as a normal electrical conductor. The negative potential of the ventricular cavities is conducted backwards, upwards, and to the right through the auricles and great vessels and is transmitted chiefly to the right upper quadrant of the body which consequently remains negative throughout the QRS interval. Some of the negative charge is, however, conducted forwards from the right auricle and tends to neutralize the positive potential of the adjacent right ventricular pericardium. The positive potential of the pericardial surface of the ventricular muscle on the other hand is chiefly conducted forwards and downwards and to the left, and so dominates the electrical field in the front, left lower, and usually the left upper quadrants of the body.

The initial ventricular deflections of the normal precordial cardiogram consist of an upstroke (ascending limb of R) followed by a deep rapid downstroke (intrinsic deflection of Lewis, descending limb of R and S) and then a return to the iso-electric line. The upstroke is made by the rise of positive potential at the precardial surface underlying the electrode, as the wave of excitation approaches. The intrinsic deflection is made by the rapid switching of the potential at the pericardial surface to that of the ventricular cavity and signals the arrival of the wave of excitation at the point of the pericardial surface underlying the electrode, and the return to the iso-electric line is made by the disappearance of the negative potential of the ventricular cavities which may be rapid or relatively gradual according to whether the excitatory process is still spreading through the other parts of the heart. Generally speaking, as the examining electrode is moved from right to left across the pre-cordium it draws closer to the heart muscle which at the same time becomes thicker. When it has passed the septum it begins to move further away from the bifurcation of the bundle and when it has passed the apex it begins to move further away from the surface of the heart. Hence, with a certain reservation that will be mentioned later, the R wave in the cardiogram becomes progressively higher as the electrode moves from the right border to the apex, after which it becomes lower, and it occurs progressively later as the electrode moves from the septum to the axilla.

Frequently the onset of the excitatory process in the septum and adjacent parts of the ventricular wall causes the ventricular cavity to become slightly negative before the impulse has finished spreading through the most distant parts of the Purkinje network. In this event, when a tracing is taken from the left side of the precordium the negative potential is conducted electrically from the cavity through the as yet quiescent muscle underlying the electrode and causes a negative deflection (descending limb of the Q wave) in the cardiogram. The R wave then occurs relatively late in the QRS interval and the arrival of the wave of excitation at the pericardial surface underlying the electrode will mark the end of very nearly the end of the excitatory process in the heart. It will therefore mark the end or very nearly the end of the negative potential in the ventricular cavities. Thus the intrinsic deflection in the cardiogram will terminate at, or very near the base line and there will be little or no S wave. The behaviour of the T wave is still in some cases obscure. Although it is well known that during the T wave the myocardium is relaxing, the nature of this process and its variations from normal are not too clearly understood.(4). Recent studies of 161 healthy men and women from the ages of 5 to 46 years old have shown the following: 1) a negative T wave in V-1 is normal and a negative T in V-6 is abnormal; 2) in men over 19 years of age, a negative T wave in V-2,3,4,5,6 is probably abnormal; 3) in women of the same age group a negative T wave in V-3,4,5,6, and in girls of 12 to 18 years of age a negative T wave in V-4,5, and 6 may be considered abnormal; 4) in children of 5 to 11 years of age a negative T wave is abnormal only in V-6 and sometimes in V-5; 5) in adults a deviation of the S-T segment is normal if it is positive and under 1.5mm. in height and in children it is normal if it is under 1mm. in height.(5)

Characteristic variations from the normal QRS complexes are produced by certain forms of ventricular hypertrophy or damage. In the case of left ventricular preponderance the normal differences between the two sides of the precordium are increased. On the right side of the precordium the positive potential is apparently neutralized by the increased negative potential generated in the left ventricle and conducted from the cavity of that ventricle through the auricles and adjacent tissues. Consequently the R wave is very small or absent and the S wave is deeper and somewhat wider than usual. Complexes of this type extend well across the precordium and may be obtained from the apex. Still further to the left the R wave suddenly becomes abnormally high and rather wide and tends to occur rather late, and is therefore frequently preceded by a Q wave. The transition from the small to the high R wave observed in the 3rd, 4th, or 5th chest lead is marked by inversion of the T wave.

In right ventricular preponderance the R wave is highest on the right side of the precordium usually in the 2nd or 3rd chest lead, where T is frequently inverted and Q may be present, S is small or absent. In this condition leads from the left side show a small R similar to that normally found of the right side and S is correspondingly deep; T is upright. From these considerations it is apparent that patterns developed can be correlated with the anatomic and functional experimental evidence in both normal and hypertrophied hearts; and it has been suggested that multiple chest leads give a better index of ventricular hypertrophy than do standard limb leads by the definite patterns obtained from multiple chest leads which lend themselves to analysis on a deductive physiological, instead of on an empirical basis (6).

In bundle branch block the septum of the affected side distal to the block remains quiescent until the excitatory process from the unaffected side has spread through the septum. While the septum is the seat of a spreading excitatory process, positive potential is generated upon its quiescent surface. This is conducted through the cavity and free wall of the ventricle and results in a small R wave of the affected side of the precordium. The completion of the excitatory process in the septum causes the potential of the affected side to switch to that of the opposite ventricular cavity. This negative potential causes an S wave or a notch upon the R wave in tracings from the precordium to the affected side. The subsequent spread of the excitatory process in the free wall of the affected ventricle causes a second rise of positive potential which reaches the chest wall far out on the affected side. There will thus be a secondary R wave which may be followed by a more or less normal intrinsic deflection or the return to the base line may be rather slurred. In the care of left bundle branch block the secondary R wave is frequently obtained only from the axillary leads. Tracings from the normal cardiogram only in that the R wave is small or absent and the return of the S wave to the iso-electric line is delayed. The widening of S is due to the late excitatory process in the opposite ventricle, the negative potential generated therein being conducted across the septum and through the cavity and contracting free wall of the normal ventricle, and so to the precordium.

In myocardial infarction the damaged muscle conducts electricity in a normal manner, but cannot respond to the wave of the ventricular wall, the potential of its pericardial surface must at all times be that of the ventricular cavity. It is therefore negative throughout the QRS interval and there is no R wave in the cardiogram from that region. The T wave is inverted with an associated high takeoff of the T from the QRS complex over the infarct and over a region surrounding the infarct where the myocardial changes are of minor degree. If the infarct involves endocardial surface, but not the whole thickness of the ventricular wall, the negative potential of the ventricular cavity is at first conducted through infarct and normal muscle to the surface of the chest, and the first part of the QRS complex consists of a Q wave. Then, as the wave of excitation, spreading outwards around the periphery of the infarct, reaches and spreads through the normal muscle between the infarct and the percardial surface an upstroke will be registered which may or may not go above the base line. On the arrival of the excitatory process at the pericardial surface overlying the infarct there is a return to zero potential unless the excitatory process is still spreading through other parts of the heart, in which case there will be a secondary negative wave. Precordial leads taken on 65 patients with low voltage (under 5mm) in the extermety leads showed 35 to have myocardial infarction and arteriosclerotic heart disease in 15 of the cases (7).

In an evaluation of the use of multiple versus single precordial leads for practical clinical electrocardiography, the Committee of the American Heart Association has expressed the opinion that a single precordial lead from the region of the cardiac apex, or from any other part of the precordium, is inadequate and has stated that three is the least number of precordial leads that can be regarded as satisfactory for general purposes (8).

Studies have been done to show the advantages of employing multiple rather than single precordial leads, in conjunction with the three limb leads, in routine electrocardiographic diagnosis using lead IV and the CR leads for comparison. Electrocardiograms were taken on 224 patients of which 68 were normal. The CR leads yielded a more complete definitive pattern of normal precordial potentials for each case than did the contours in the single lead IV. For the 156 patients with definite clinical evidence of cardiac disease, the electrocardiographic findings yielded significant data when the ten-lead record of each case was analyzed with regard to the type of electrocardiographic information furnished by the different CR leads in the individual cases with clinical evidences of heart disease. The CR-1 and 2 leads are particularly useful for revealing abnormalities affecting preponderantly the right auricle or right ventricle, the CR-5 and 6 leads are particularly useful for revealing abnormalities affecting preponderantly the anterolateral aspects of the left ventricle, and the CR-3 and 4 leads are necessary to complete the definition of the precordial electrical field. In 2 patients with clinical evidences of long standing mitral stenoses, and in one case of chronic cor pulmonale due to extensive pulmonary fibroses, and in one case of interauricular septal defect, the CR-1 and 2 leads yielded evidence indicating right ventricular hypertrophy, and in two patients with coronary arterioscleroses the presence of right bundle branch block was detected, when in each of these cases the findings noted in leads I, II, III, and IV were not regarded as definitely abnormal. Leads CR-3 and 4 in one instance revealed the presence of an acute anteroseptal myocardial infarction, the electrocardiographic diagnosis of which would have been missed had the tracing included only leads I, II, III, and IV. In eight additional cases, with hypertension or arterioscleratic heart disease, leads CR-r and 6 revealed electrocardiographic evidences of left ventricular hypertrophy, or of non-specific myocardial abnormality which were not detected in leads I, II, III, and IV. Thus, for 10 percent of the 156 patients with heart disease, the combination of leads I, II, III, and IV had to be interpreted in each as being within normal limits, whereas, from one or another of the multiple CR leads, the electrocardiographic findings permitted either a non-specific or a definitive diagnosis of abnormality. Leads CR-5 and 6, being placed in an anatomic position of the chest, tended to show a more accurate orientation and interpretation of an enlarged left ventricle.(9)

A comparative study of the different precordial leads was done by Hoyos and Tomayo in which each kind of precordial lead (from CR-1 to CR-6, from CL-1 to CL-6, from CF-1 to CF-6) in about one hundred patients with heart disease. These were selected to include the following conditions: left or right axis deviation, ventricular hypertrophy, angina pectoris, coronary sclerosis, and myocardial infarction. There was no important variation found in normal or in abnormal conditions in the precordial leads using the CR or the V leads, thus there is no practical advantage in preferring the latter. CR leads are easier to be recorded. Since in some normals a downward P and a downward R was found in Leads CF-1 to CF-3, the CR leads seem to be preferable.(10)

Summary and conclusions:

1. The principles underlying the interpretation of chest leads are discussed along with the technique of recording and the terminology of precordial leads are explained.
2. The deflections of the normal precordial cardiogram is explained on an anatomical and physiological basis.
3. Characteristic variations from the normal complexes are explained in cases of:
    a) right and left ventricular hypertrophy,
    b) bundle branch block, and
    c) myocardial infarction or damage.

    It is felt that from these considerations it is apparent that the QRS complexes and T waves of the precordial cardiograms, unlike those of the standard leads whose interpretation is still largely empirical, lend themselves to rational interpretation and that most of the common findings can be explained in terms of myocardial pathology.
4. The various chest leads are evaluated for practical clinical electrocardiography with the following results:
    a) the standard limb leads are inadequate without at least three precordial leads, and
    b) the CR leads seem to be the leads of choice.

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