

under the above conditions indicates that the subjacent muscle has been completely activated and is, therefore, no longer producing potential differences. If potential differences directly opposed to those which were produced by the activation of this subjacent muscle, now complete, are still existent they will produce an effective potential difference of such a character as to indicate relative negativity on that side of the body on which the investigated point lies.

Considerations such as these lead us to conclude that *R* of the normal human electrocardiogram is produced by unopposed potential differences resulting from activation of the apical regions of the heart, and that the *S* deflection is produced by unopposed potential differences resulting from activation of the thick ventricular walls at the cardiac base.

They also lead to the conclusion that in bundle branch block the average spread of the excitation wave during the inscription of the chief initial deflections is from the contralateral toward the homolateral side.

We have also applied these considerations to the analysis of the curves which depict ventricular preponderance and to the analysis of the *T*-deflection of the electrocardiogram.

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The Form of the Electrocardiogram. IV. The Mean Electrical Axis and the Center of Stimulation.

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Just as a material body may be considered the sum of an infinite number of material particles differing from each other only with respect to their orientation in space, so the ventricular muscle may be considered the sum of an infinite number of units differing only with respect to the direction in which the excitation process passes over them, and consequently in the direction of the potential differences which they produce during ventricular activation.

The analysis of the electrocardiogram is greatly complicated by the fact that not all of the muscle units are activated at the same time. This difficulty may be eliminated by determining the mean deflection in each of the 3 standard leads over any desired interval. The mean deflection in lead *I* (Me_I) during the QRS interval may be expressed by the following equation:

$$Me_I = \frac{1}{QRS\text{-Int.}} \int_S^Q (QRS) dt.$$

In this equation the value of the integral is the area under the curve, determined by planimeter, between the onset of Q and the end of S .

If the mean deflection for any interval be determined for each of the 3 standard leads in this manner, the mean electrical axis and the mean manifest potential difference may be obtained by means of Einthoven's triangle. In this way the electrocardiogram, so far as the interval in question is concerned, may be reduced to a single vector.

The mean electrical axis during the inscription of P will give the average direction of the excitation process in the auricles. The mean electrical axis during the QRS interval will give the average direction of the excitation process in the ventricular muscle. The mean electrical axis during the inscription of T will give the average direction of the wave of ventricular deactivation. The electrocardiogram will thus be reduced to 3 simple vectors.

In the case of a homogenous mass of excitable tissue immersed in a large body of non-excitable medium having the same electrical conductivity, it may be shown that the total electrical effect, so far as points distant from the mass are concerned, may be represented by a single vector drawn from the point of stimulation to the center of mass, provided only that the mass is of such a form that the excitation process will reach every point within it by radial spread. The vector mentioned will give the direction of the average spread of the excitation process and its length will be a function of the magnitude of the total electrical effect.

Each of the cardiac ventricles is lined by Purkinje tissue, which conducts the impulse with great rapidity as compared with the ordinary ventricular muscle. The spread of the excitation wave through the ventricular walls is, therefore, much the same as if the excitation wave spread radially from a point within the ventricular cavity. This imaginary point may be called the center of stimulation. The mean electrical axis during the inscription of QRS will then point from the center of stimulation toward the center of mass of the ventricular muscle. The total electrical effect, or the value of the integral in equation (I), will be a function of the distance between these 2 points.