Reversed Sequential Activation of the Atria*

Vectorcardiographic and External Pulse Wave Features

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Limitations of the electrocardiogram for the diagnosis of atrial enlargement and defects in atrial conduction are well recognized. High-magnification vectorcardiography has proven very useful for establishing the diagnosis of atrial enlargement and in defining various types of disturbances in intratrial conduction, either associated with atrial hypertrophy or enlargement or as isolated findings. Study of the high-gain vectorcardiographic P loop can also aid in assessing the site of ectopic supraventricular rhythms with a certain degree of accuracy. We describe herein the utility of combined noninvasive techniques in defining the electromechanical sequence of atrial activity in a patient with a distinctly unusual P wave.

A 73-year-old man with clinical features of the sick sinus syndrome had unusual P waves on the ECG. In leads 2, 3, aVF, and V4 to V6, there were biphasic P waves that were 0.17 to 0.18 second in duration, with an initial bifid negative component comprising 0.12 second of the total atrial deflection (Fig 1). This represented the largest discernible P-wave interval recorded at our institution during a ten-year period encompassing the study of over 200,000 ECGs. In order to elucidate the significance of this P wave, multiple noninvasive techniques were employed.

Figure 2 discloses the vectorcardiograms of the P wave recorded in the patient. The P loops were of unusual configuration and comprised two major components which totaled 170 msec in duration. The initial forces of the P-loop vector were directed superiorly and posteriorly, while the terminal component was oriented inferior, anterior, and to the left of the Z axis. The early component rotated in a clockwise fashion in the horizontal plane and had a “figure-of-eight” inscription in the other two projections. Rotation for the terminal portion of the P loop was clockwise in all three planes.

The echographic left atrial internal dimension measured 4.0 cm, indicating that the bizarre P wave did not arise as a consequence of left atrial enlargement. Simultaneous recording of the apexcardiogram and lead 2 of the ECG demonstrated a delay of 120 msec from the beginning of the P wave to

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the peak of the “a” wave in the apexcardiogram (Fig 3). The external pulse transducer was then directed to the right jugular vein. There was a delay

Figure 3. Simultaneously recorded phonocardiograms of tricuspid area (TA) and aortic area (AA), apexcardiogram (ACG), and lead 2 (LII) of ECG. There is 120-msec interval from beginning of P wave to peak of “a” wave on apexcardiogram. E, Opening point of aortic valve; SB, systolic bulge; 1, first heart sound; 2, second heart sound; and O, opening of mitral valve.

Figure 2. Magnified vectorcardiographic recordings of P loop in frontal plane (FP), left sagittal plane (SP), and horizontal plane (HP). Initial P-loop vector is directed superiorly and posteriorly. Terminal P-loop vector is oriented inferiorly, with major anterior component. There is 70-msec delay between beginning of P wave and its second major upright component on orthogonal lead X.

Figure 4. Simultaneously recorded phonocardiograms of mitral area (MA), tricuspid area (TA), pulmonic area (PA), and aortic area (AA), external jugular venous pulse tracing (VT), and lead 2 (LII) of ECG. Note delay of 250 msec from onset of P wave to peak of simultaneously recorded “a” wave on jugular venous tracing.

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of 250 msec from the onset of the P wave to the peak of the "a" wave of a simultaneously recorded external jugular phlebogram (Fig 4). This interval was corrected to 190 msec by subtracting 60 msec from the observed duration, in order to account for the delay in transmission of the pulse from the right atrium to the positive deflections of the vein in the neck.6

A prolonged P wave on the ECG may represent a manifestation of left atrial enlargement, a delay in intra-atrial conduction, or both in combination. Zoneraich and Zoneraich3 analyzed the various configurations of P waves on the ECG and P loops on the vectorcardiogram resulting from disturbances in intra-atrial conduction. They found that a bifid P wave with initial and terminal components of nearly equal size was frequently found in this setting. Additionally, the initial component was usually positive in leads 2, 3, and aVF of the ECG. Interestingly, the P wave described herein was comprised of major initial negative components in the inferior leads, which were succeeded by positive deflections. The vectorcardiographic findings were consonant with reversal of the usual sequence of atrial depolarization. A major early P-loop vector was directed to the left, superior, and posterior. Such spatial vectors are consistent with a low atrial focus initiating atrial activation. Superiorly directed P-wave vectors are generally considered to represent retrograde depolarization of the atria,8 and this was noted for the initial component of the P loop in the current case. On the other hand, the terminal force of the P vector was oriented inferiorly, with a major portion of the loop displaced anteriorly. This terminal P-loop component taken alone was reminiscent of a high-gain atrial vectorcardiogram from the normal subject.7 It is therefore apparent that the right atrium contributed in major degree to the terminal P-loop forces in this case. Without intra-atrial electrographic mapping, it is impossible to designate a total dissociation of early left and late right atrial depolarization in the same P loop, yet the atrial vectorcardiogram and mechanical recordings suggest that the right atrial events did, in fact, follow those initiated by the left atrium.

There is no temporal delay between the events on the left side of the heart and their external display as recorded by the apexcardiogram.5 Comparing the succession of electromechanical events recorded by the vectorcardiogram and pulse tracings, a 70-msec delay was observed between the P-peak "a" wave of the apexcardiogram (120 msec) and the P-peak "a" wave of the corrected jugular phlebogram (190 msec). This 70-msec discrepancy in peak systolic atrial events corresponds exactly with the elapsed time between the beginning of the P wave and its second component as observed on the X lead of the orthogonal P-wave tracing.

It is concluded that the electromechanical atrial events disclosed by combined noninvasive techniques afforded the diagnosis of reversed sequential activation of the atria in this subject, with a markedly prolonged P wave arising as a consequence of a defect in intra-atrial conduction.

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