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**Electrocardiographic Manifestations of Concealed Junctional Ectopic Impulses**

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**SUMMARY**

Thirteen episodes of concealed junctional ectopic impulses (JEI) in ten patients are described. In nine patients the JEI manifested as isolated automatic impulses and in one as a parasympathetic junctional tachycardia. In the previously described unexpected prolongation of the P-R interval; 2) striking changes in the duration of the P-R with an occasional sequence of R-P and P-R intervals simulating “supernormal” A-V conduction; 3) unexpected variation of the junctional escape interval explained by junctional parasystole with entrance block; 4) postponed compensatory pause; 5) concealed junctional discharge with reciprocation.

ATRIOVENTRICULAR (A-V) BLOCK due to concealed junctional ectopic impulses (JEI) was first described in 1947. Not until 1962 was the next case of A-V block due to JEI reported. To the best of our knowledge a total of 11 instances of spontaneous JEI concealed within the junctional tissue because of an antegrade and retrograde block have been reported. In each instance the presence of JEI was suspected by its effect on the behavior of the subsequent impulse. The assumption that the unexpected “unphysiological” behavior of A-V conduction was due to concealed JEI proposed by Langendorf and Mehelman in was confirmed in man by direct recording from the His bundle by Rosen, Rahimtoola and Gunnar, in the dog by Damato, Lau and Bobb and in the isolated rabbit A-V conduction system by Moore, Knoebel and Spear.

The purpose of this communication is to present 13 episodes of concealed JEI recorded in ten patients. Manifestations, phenomena, not previously described include: 1) initiation of a marked, greater than 400 msec, and persistent prolongation of the P-R interval, 2) striking changes in the duration of the P-R with an occasional sequence of R-P and P-R intervals simulating “supernormal” A-V conduction, 3) unexpected variation of the junctional escape interval explained by junctional parasystole with entrance block, 4) postponed compensatory pause, 5) concealed junctional discharge with reciprocation.

It is also the purpose of this communication to illustrate and emphasize that much information can be learned from a careful deductive analysis of the surface electrocardiogram and that, indeed, so many of our current electrophysiological concepts were arrived at by just such a process. This approach is especially important in clinical electrocardiography where the observations are truly “experiments” of nature, frequently not reproducible, and where invasive procedures for their documentation or analysis are not always justifiable, nor, as illustrated in this paper, necessary. In this regard, His bundle electrocardiography using standard techniques was performed in cases 4 and 8. In case 4, the invasive study confirmed that early premature JEI conducted aberrantly (fig. 4A). During His bundle electrocardiography in case 8, only intermittent JEI which conducted normally or blocked totally (concealed) were recorded. Thus, the diagnosis of a concealed junctional parasympathetic tachycardia still had to be

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made using deductive analysis of the surface electrocardiogram (figs. 6-8).

**Description of the Electrocardiogram**

In order to facilitate description of the ECG, the JEI recognized by their effect on subsequent A-V conduction were arbitrarily divided into three groups. These include: 1) interpolated JEI with slight or moderate prolongation of the P-R intervals defined as a P-R of 400 msec or less, 2) interpolated JEI, but with a marked prolongation of the P-R interval, greater than 400 msec, and 3) JEI completely blocking transmission of the P wave. They were identified as (1),

**Figure 1** Sections taken from patient 7 and shown for the purpose of defining the varying ECG manifestations of the JEI. (1) Conducted, interpolated junctional impulse with mild to moderate prolongation of the P-R (V1, L2). (2) Conducted, interpolated junctional impulse with marked (greater than 400 msec) prolongation of the P-R interval (V1, L2). (3) Conducted junctional impulse with complete block of P wave (V1, L2). (C1) Concealed, interpolated junctional impulse with mild to moderate prolongation of the P-R (V1, right lower strip). (C2) Concealed, interpolated junctional impulse with marked (greater than 400 msec) prolongation of the P-R (V1, L2). (C3) Concealed junctional impulse with complete block of P wave (V1, right lower strip). In V1 the upper strip illustrates an interpolated, conducted JEI with marked and persistent prolongation of the P-R interval with postponement of the compensatory pause. V1 demonstrates marked prolongation of the P-R but this time is due to concealed JEI. Lead 2 demonstrates two consecutive conducted JEI, the first interpolated and the second blocking the P wave. V1 (right lower strip) illustrates the same sequence of events as recorded in L2 but due to concealed JEI resulting in Type I A-V block.

**Figure 2** (Case 1). Interpolated concealed JEI. This is probably the simplest manifestation of concealed JEI discharge. The rhythm is normal sinus with a P-R of .26-28 sec with an interpolated JEI in L2 (1) followed by a P-R of .40 sec. Prolongation of P-R to .40 and .48 sec is also recorded in aVR and AVL, this time without a manifest QRS; thus the prolongation is unexpected and due to a concealed JEI (C1). The presence of conducted JEI (1) and of R-R intervals of approximately the same duration, irrespective of whether encompassing the conducted (1) or concealed (C1) JEI, make concealed JEI an acceptable explanation for the sudden unexpected prolongation of the P-R interval in aVR and aVL.

**Figure 3** (Case 3). Sinus rhythm with a P-R of .20 sec, JEI and premature ventricular complexes. The Lewis diagram suggests that the concealed impulses originate in the ventricles. However, it appears more likely that, with exception of the second ectopic impulse in L3, these are junctional in origin, with intraventricular aberrancy. Some of the conducted ectopic impulses are interpolated as (1) in L1 and V6 while others block P wave conduction as (3) in V6, V5, aVL and L3. Concealed ectopic discharges (C1) are responsible for sudden and unexpected prolongation of the P-R in aVL and for complete block of P wave with Type II A-V block (C3) in V,R and L3.
FIGURE 4  Figure 4 was recorded in case 4. The basic rhythm in figure 4 is sinus with a P-R of .20 sec. Top) Conducted interpolated JEI (1) with prolongation of P-R to .24 sec are present in L2 and L3. In addition, two conducted interpolated JEI (2) followed by P-R of .68 sec are seen in L3. Following the second of the two, the P-R again measures .64 sec. Unexpected prolongation of the P-R to .60 sec but without a conducted interpolated JEI is seen in L1. Similarly, failure of P wave conduction following a JEI (3) is recorded in L3. Following the second of the two, the P-R measures .65 sec. Unexpect prolongation of the P-R in L1 (C2) and block of P wave in L2 (C3), suggesting Type II A-V block, are due to concealed JEI.

Bottom left) This record demonstrates unexpected prolongation of P-R from 225 to 285 msec and the A-H from 130 to 190 msec due to concealed discharge from the bundle of His (H'). HE = bundle of His electrogram, A = atrial depolarization, H = His bundle depolarization, H' = concealed His bundle depolarization. Time lines, 1 second intervals.

Bottom right) In the top panel, concealed His discharge (H') results in a sudden failure of A-V conduction with the block above the His bundle. On the surface ECG the concealed His discharge simulates Type II A-V block. In the lower panel, the P-R lengthens from 225 to 275 msec with failure of the third P wave to conduct. The pattern is that of a Type I A-V block. Analysis of the His electrogram reveals that the A-V block is due to concealed junctional discharge. The first concealed His impulse (H') is followed by an H'-A interval of 530 msec and prolongation of the A-H interval from 130 to 180 msec. The H-V remains constant. The next H'-A is shorter (485 msec) and the atrial impulse is blocked above the bundle of His.
Table 1. Electrocardiographic Manifestations of Concealed Junctional Impulse

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<tr>
<th>Case</th>
<th>Figure</th>
<th>Manifestations</th>
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<tr>
<td>1</td>
<td>2</td>
<td>Prolongation of P-R</td>
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<td>Prolongation of P-R, Type II A-V block</td>
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<td>Prolongation of P-R, Type II A-V block</td>
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<td>Prolongation of P-R, Type I, Type II A-V block</td>
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<td>6</td>
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<td>Type II A-V block</td>
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<td>7</td>
<td>5</td>
<td>Prolongation of P-R, Type II A-V block</td>
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<tr>
<td>8</td>
<td>6, 7, 8</td>
<td>Prolongation of P-R, Type I, Type II A-V block, attempted Type I A-V block, postponed compensatory pause, &quot;super-normality&quot; of A-V conduction</td>
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<td>9</td>
<td>9</td>
<td>Variable junctional escape interval</td>
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<td>Reciprocation</td>
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<tr>
<td>11</td>
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<td>Reciprocation</td>
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(2), (3) respectively when conducted to the ventricle, and (C1), (C2), (C3) when concealed (fig. 1). The figures are presented in a sequence calculated to simplify as much as possible the description of the electrocardiograms.

The manifestations of JEI were those of Wenckebach A-V block (Type I), attempted Type I block, defined as a gradual prolongation of the P-R interval but without an ultimate block of the P wave, Mobitz II A-V block (Type II), paradoxical R-P, P-R relationship suggesting "super-normality" of A-V conduction and interpolation with a postponed compensatory pause. In addition, there were two cases of reciprocation due to concealed junctional discharge and one instance with an unexpected variation of the junctional escape interval.

The ECG manifestations of concealed JEI observed in each of the tracings are summarized in table 1.

Discussion

The presence of concealed JEI is recognized by its effect on the conduction of the subsequent impulse. The JEI may present as isolated ectopic discharges, junctional parasystole or parasympathetic tachycardia.

An assumption that an unexpectedly altered rhythm is due to concealed JEI can be made only if a similar sequence of events is recorded when the junctional impulses conduct to

FIGURE 5 (Case 7). Sinus rhythm and JEI, with or without intraventricular aberrancy. Interpolated JEI are followed either by mild (1) or marked (2) prolongation of the P-R. Complete block of P waves due to JEI (3) are also recorded. Postponed compensatory pause is seen following the two conducted interpolated JEI in the top strip. Concealed JEI with unexpected prolongation of the P-R (C1) or unexpected block of P wave (C3) are also recorded. The QRS following JEI (2) in the top and bottom strip are assumed to be conducted from the atrium with a long P-R.

FIGURE 6 (Case 8). Figures 6, 7, 8 were obtained from patient 8 on three separate admissions. Analysis of figures 6 and 7 clearly indicates that what appears to be a grossly chaotic A-V conduction in figure 8 is, in reality, an orderly behavior of A-V conduction in response to a concealed junctional parasympathetic tachycardia.

Figure 6 identified conducted interpolated JEI (1), (2), interpolated concealed JEI (C1), (C2) and concealed JEI blocking the P wave (C3). Type I A-V block is registered in L3, due to two consecutive concealed JEI (C1), (C3). Type II A-V block due to concealed JEI (C3) is recorded in aVR. A postponed compensatory pause follows the second conducted interpolated JEI (2) in L3. Persistence of the long P-R for the one cycle following a conducted (2) and again after a concealed JEI (C2) are illustrated in aVR. The sudden failure of P to conduct is not a function of a shorter R-P (e.g., block of P wave after [C3] in L3, but is due to concealed JEI. This is proven by the numerous P waves which follow a much shorter R-P but still conduct to the ventricles.

FIGURE 7 (Case 8). This figure is in many respects similar to figure 6 and demonstrates attempted Type I, Type I and Type II A-V block due to a variety of combinations of conducted and concealed JEI. Persistence of prolonged A-V conduction following interpolated conducted JEI (2) is also recorded in the bottom strip. It was important to document this latter phenomenon because similar unexpected and persistent P-R prolongation is seen following a concealed JEI in figure 8.
The concealment of JEI is more common after a longer preceding cycle with the latter cycle frequently caused by the compensatory pause following a conducted JEI. Since refractoriness is directionally related to the preceding cycle length, one might postulate that physiological lengthening of refractoriness following a long cycle, rather than concealed JEI, results in a sudden prolongation or block of A-V conduction. For example, such a relationship exists in figure 3, which illustrates blocked P waves following a long preceding cycle (V4R, L3). However, careful analysis of this example indicates that the unexpected delay or block of A-V conduction cannot be due only to lengthened A-V refractoriness following long cycle because the fifth P in V5 and sixth and thirteenth P waves in V1,R follow equally long or longer R-R intervals and yet their respective P-R intervals are normal. The most likely explanation for this observation is that prolongation of refractoriness following a longer R-R interval increases the likelihood of both antegrade and retrograde block of conduction of JEI, causing concealed JEI discharge after a long pause. The determinants of whether JEI remains concealed or is conducted include coupling interval between JEI and the preceding QRS and the duration of the preceding R-R interval; or, as determined in the His electrogram, coupling interval between the H' of the premature JEI and the preceding H, and the duration of the last regular H-H interval which preceded the H'.

The assumption is made that the markedly prolonged P-R, as seen for example in figure 4A, terminates with a conducted QRS rather than a junctional escape. This
assumption is supported by the fact that the R-R cycles in question are not constant and the fact that much longer R-R intervals without escape complexes are recorded (L₂). One may postulate, however, that the latter results from concealed discharge and displacement of the escape focus by the blocked P wave, allowing an SA impulse to terminate the longest R-R intervals. Thus, simply the presence of longer cycles is not a convincing argument that conduction is SA in origin with a long P-R interval rather than an accelerated junctional escape. There is, however, compelling evidence that the JEl is probably automatic rather than re-entrant, that it originates in the bundle of His, and that the sinus P wave is blocked in the A-V node proper and thus incapable of displacing a His focus even if such existed. Thus, the evidence put forth suggests that the cycles in question are terminated by an SA impulse conducting with a long P-R interval. Furthermore, the patients did not have any of the disorders known to give rise to accelerated junctional discharge.  

The purist may argue that the reciprocating rhythm illustrated in figures 10 and 11 does not represent concealment in the true sense of the word but that it is an example of the limitation of the surface ECG when applied to recognition of site of origin of abnormal P waves. In both cases the junctional impulses conduct to the atrium, thus are not truly concealed. However, such retrograde P waves have been considered as examples of concealed junctional discharge by Langendorf and Mehlman and their junctional origin confirmed by recording directly from the His bundle and by stimulating the bundle of His in the experimental animal.  

In summary, the observations reported in this paper support the conclusion that the manifestations of concealed JEl extend far beyond simple first degree and Type I and Type II second degree A-V block. The manifestations include, or will probably be shown in the future to include, virtually all
of the electrocardiographic phenomena which have been documented to occur following manifest JEI.

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FIGURE 11 (Case 1). Reciprocal due to concealed JEI is similar to the one illustrated in figure 10. The second and third ectopic impulses in aVF suggest a low atrial, coronary sinus or junctional ectopic impulse with antegrade delay. As in figure 10, reciprocation is not evident. However, an analysis of the remaining ectopic impulses permits a diagnosis of reciprocation due to concealed JEI. The first ectopic impulse in aVF is junctional with both antegrade and retrograde conduction. The QRS is aberrant. The ectopic impulses in L5 and V5 are clearly junctional with both antegrade and retrograde conduction and reciprocation. Thus, the documentation of JEI with both antegrade and retrograde conduction in aVF, and of unequivocal reciprocation in L5 and V5, allows a diagnosis of concealed junctional discharge with antegrade block, retrograde conduction and reciprocation in aVF.
Electrocardiographic manifestations of concealed junctional ectopic impulses.
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