Contribution of His bundle recordings to analysis of abnormal beats with right bundle-branch block—superior axis pattern

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His bundle electrograms were recorded in four patients with ectopic rhythms showing a right bundle-branch block – superior axis pattern. In one case what appeared to be a slow idioventricular rhythm was identified as a His bundle rhythm with transient right bundle-branch block and left anterior hemiblock. The second patient had an idioventricular tachycardia. H deflections were not seen in front of the corresponding QRS complexes. Impulse formation probably occurred in the posteroinferior wall of the left ventricle. To test this assumption regarding the pacemaker site, the latter area was stimulated through a catheter introduced into the middle cardiac vein. Extrasystoles, thus induced, showed a superior axis deviation with predominant R waves in the right chest leads and a VH interval of 50 msec. The ectopic beats observed in the third patient arose in the posteroinferior division of the left branch. The diagnosis was based on the left anterior hemiblock – incomplete right bundle-branch block morphology, and short (15 msec) VH interval. In the last patient (who had established right bundle-branch block and left anterior hemiblock) the extrasystoles arising from a focus below the His bundle could have originated either in the right branch or anterosuperior division of the left branch proximally to the area of block; or anywhere within the posteroinferior division.

His bundle recordings should be analysed not only in the light of the coexisting AV and VA conduction patterns but also considering the morphological QRS changes as well.

The majority of conducting system studies performed in patients with coexisting right bundle-branch block and left anterior hemiblock have dealt with the relation between the conduction defects and AV block. Therefore, it appeared of interest to present the importance of His bundle recordings in the analysis of ectopic rhythms showing predominant R waves in V₁ and a superior axis shift, in which AV block was not the prominent feature.

Material and methods

The technique of His bundle recordings used in our department has been presented in previous communications (Castillo and Castellanos, 1970). However, it should be emphasized that intracardiac electrograms were obtained with bipolar electrodes 1 mm apart,¹ located high in the right atrium (BAE) and His bundle area. Four patients with spontaneous arrhythmias showing

a right bundle-branch block – superior axis pattern were studied. In a fifth patient mechanical stimulation was performed through a catheter located in the middle cardiac vein while atrial pacing was performed from the high right atrium.

Case reports

Case 1 A 52-year-old man had renal insufficiency complicated by mild congestive heart failure. The admission electrocardiogram showed sinus rhythm with slightly notched P waves and an old antero-septal myocardial infarction. Three days later he developed hyperkalaemia. The electrocardiogram (Fig. 1) showed widened, unevenly spaced, ventricular complexes (rate 44 a minute) with an abnormal superior electrical axis and a right bundle-branch block 'pattern'. Small notches within the ST segments were thought to be retrograde P waves. The rhythm was interpreted as 'probably idioventricular'. A transvenous QRS-inhibited pacemaker was inserted, at which time His bundle studies were performed. The first and third QRS complexes in Fig. 2

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(preceded by His bundle deflections) measured 180 msec. The corresponding HV intervals were prolonged (70 msec). P waves, inscribed during the T waves, were positive in lead I and negative in leads II and III. Their onset occurred 90 msec before that of the high right atrial electrogram (BAE lead). This indicated reversed, infero-superior, propagation throughout the atria. The RP intervals measured around 280 msec.

According to recently postulated concepts the pacemaker was probably located in the His bundle itself (Damato and Lau, 1969). Therefore, the abnormal QRS morphology was attributed to complete right bundle-branch block and left anterior hemiblock (Rosenbaum, Elizari, and Lazzari, 1970a). The prolonged HV interval suggested an associated conduction delay in the left bundle-branch or in its posterior divisions (Castellanos and Lemberg, 1971). In addition, as shown in the diagram, the retrograde impulse from the first and third His bundle beats reversed their direction in the upper portions of the AH regions. They then propagated forwardly (from the deflection site), traversed the His bundle, finally reactivating the ventricles. Hence, the second and fourth QRS complexes were reciprocal beats with more prolonged HV intervals and QRS complexes. The latter was ascribed to a further degree of impairment of conduction in the bundle-branches and their divisions.

In summary, His bundle recordings showed that what appeared to have been an idioventricular rhythm was a His bundle rhythm with reciprocal beats showing block in the right branch, anterior division of the left branch, and other parts of the left bundle system.

Case 2 A 55-year-old man was referred for evaluation of chest pain and paroxysmal arrhythmias. The surface electrocardiogram showed sinus rhythm, interrupted by runs of ectopic (wide and bizarre) beats. Normal intraventricular conduction was present during sinus rhythm (Fig. 3, left). The corresponding H deflections were 'sandwiched' between the atrial and ventricular electrograms. The PR interval measured 200 msec. In contrast, the second QRS complex was wide (130 msec) and bizarre. Its electrical axis

FIG. 1 (Case 1) Control tracing showing a slow ectopic ventricular rhythm with right bundle-branch block, superior axis pattern. In Fig. 1 and 2, paper speed and time markers were 50 mm/sec and 1 sec respectively.

FIG. 2 (Case 1) Intracardiac recordings showing His bundle rhythm with true block in the right branch and in the anterior division of the left branch (first and third QRS complexes). The second and fourth beats were reciprocal in origin. In the diagram A, H, and V indicate atria, His bundle, and ventricles, respectively. AH and HV represent the AV node and the ventricular specialized conducting system below the His bundle. BAE = bipolar atrial electrogram from the high right atrium. HBE = His bundle electrogram.

pointed superiorly and slightly to the left. A predominant positive deflection was recorded in lead VI. This beat must have originated in the 'ventricles' since it was not preceded by an H deflection. Finally, the right-sided panel in Fig. 3 shows a run of the same ectopic beats occurring at a rate of 75 a minute.

This arrhythmia has been classified as an 'idioventricular tachycardia' by Schamroth (1969).

In summary, His bundle recordings corroborated the ventricular origin of the arrhythmia under consideration. The QRS morphology suggested that impulse formation occurred in the posteroinferior wall of the left ventricle (Meyer and Millar, 1969).

Case 3 A 62-year-old man was referred for intracardiac study because of a history of paroxysmal arrhythmias and syncopal attacks. The control tracing showed a PR interval at the upper limits of normal with a vertical electrical axis. In the absence of lung disease, right ventricular hypertrophy, or a slender body build, the tentative diagnosis of left posterior hemiblock was made (Rosenbaum *et al.*, 1970a).

The first beat in Fig. 4 was induced by atrial pacing from the coronary sinus. The ventricular complexes were identical to those produced by sinus P waves. The second beat was ectopic. It appeared prematurely and was not preceded by atrial deflections. The QRS complexes (measuring 110 msec) showed a superiorly oriented axis with an incomplete right bundle-branch block pattern in lead VI. The corresponding H deflection appeared 15 msec after the onset of depolarization in the surface leads. It should be emphasized that the beginning of the electrogram in the HBE leads does not invariably record the earliest moment of ventricular activity.

This beat was not a His bundle extrasystole because the latter was activated after parts of the ventricles had already been depolarized. On the other hand, the relatively short VH interval suggested that impulse formation did not occur in the peripheral Purkinje networks. If this were the case a longer VH interval and a wider (greater than 120 msec) and more distorted QRS complex would have been recorded (see Fig. 8). Applying the criteria of Rosenbaum *et al.* (1970a) this beat was considered to have arisen within the posterior division of the left branch closer to the ordinary ventricular muscle than to the His bundle. The superior axis reflected the inferosuperior spread of activation through the left ventricle whereas the incomplete right bundle-branch block morphology indicated that the right ventricle was depolarized with 'some' delay.

In summary, His bundle electrograms proved helpful in the diagnosis of left posterior divisional rhythms.

Case 4 A 66-year-old man was admitted with a long history of paroxysmal arrhythmias. A myocardial infarction had occurred several years before. The control electrocardiogram (Fig. 5) showed sinus rhythm with right bundle-branch block, left anterior hemiblock, and an old antero-septal myocardial infarction. This patient also had frequent extrasystoles (X in Fig. 6) having a QRS morphology similar to that of induced by the sinus impulse. The PR, PH, and HV intervals measured 150, 100, and 50 msec, respectively (first two beats in Fig. 7). The VV intervals had a duration of 685 msec. In contrast, the third QRS complex occurred prematurely (VV interval of 575 msec). It was associated with an H deflection which also appeared prematurely (HH interval of 640 msec) and was inscribed 5 to 10 msec after the onset of depolarization. This H deflection more or less coincided with the (positive) sinus P wave indicating that they were unrelated. The morphology of the QRS complex, as well as the short VH interval, suggested (as in Fig. 4) that impulse formation occurred in the posterior division of the left branch. A His bundle rhythm would have had a normal or prolonged HV interval (as in Fig. 2). But since this patient also had apparent 'complete' right bundle-branch block and left anterior hemiblock, the pacemaker might have been located in the right branch or anterior division, proximally to the blocked sites.

FIG. 3 (Case 2) *Idioventricular tachycardia with a right bundle-branch block – superior axis pattern. In this, paper speed and time markers were 100 mm/sec and 1 sec, respectively.*

In summary, though His bundle recordings excluded the possibility of a His bundle rhythm, they did not allow the determination of the exact site of impulse formation within the bundle-branches or their divisions.

Discussion

Usefulness of His bundle recordings in differentiating between idioventricular beats and His bundle rhythms with right bundle-branch block and left anterior hemiblock His bundle studies performed in patients with a right bundle-branch block – superior axis morphology have stressed the

FIG. 4 (Case 3) *Ectopic beat showing an 'incomplete' right bundle-branch block – superior axis morphology by probably originating in the posterior division of the left branch. Paper speed and time markers were 100 mm/sec and 1 sec, respectively.*

FIG. 5 (Case 3) Sinus rhythm with old anteroseptal myocardial infarction, right bundle-branch block, and left anterior hemiblock. Electrocardiogram obtained at conventional (25 mm/sec) speed.

relation between intraventricular and atrio-ventricular block. On the other hand, Fig. 1-8 show the importance of catheter recordings in understanding the significance of this pattern when it occurred in ectopic beats. For example, in Case 1, wide and ectopic beats occurring at slow rates were interpreted as 'idioventricular' from the surface electrocardiogram. However, the presence of an H-deflection appearing in front of the QRS complexes with a normal (or in this case prolonged) HV interval indicated that impulse formation occurred within the His bundle. Therefore, the superior and leftward axis was attributed to the inferosuperior spread of activation characteristic of left anterior hemiblock. The predominant positivity in V1 was ascribed to the delayed right ventricular depolarization secondary to the block in the right bundle-branch.

FIG. 6 (Case 3) Ectopic beats (X) with right bundle-branch block - superior axis pattern. Paper speed and time markers were 25 mm/sec and 1 sec, respectively.

A	685	685	685	68
A-H	90	90	90	90
H	685	640	730	
H-V	60	60	60	60
V	685	575	795	

FIG. 7 (Case 3) His bundle electrograms recorded during sinus rhythm and ectopic beating. Paper speed and time markers were 100 mm/sec and 1 sec, respectively.

Usefulness of intracardiac studies in diagnosis of idioventricular tachycardia

In Case 2 the intracardiac recordings showed that the abnormal beats were not preceded by His bundle deflections. The ectopic rate was that of an idioventricular tachycardia (Schamroth, 1969). Previous studies have shown that stimulation of the posteroinferior wall of the heart through catheter electrodes located deep into the middle cardiac vein produces beats with a superior axis (because of the inferosuperior spread of activation) and predominantly positive deflection in the right chest leads (due to delayed activation of the right ventricular free wall) (Meyer and Millar, 1969; Castellanos *et al.*, 1970). The resulting QRS complexes have a duration greater than 120 msec and VH intervals longer than 40 msec (Fig. 8). This area was the probable site of impulse formation in this patient (Fig. 3).

Usefulness of His bundle recordings in the diagnosis of impulse formation in the divisions of the left branch

In Case 3 His bundle electrograms were of value in differentiating between sinus and conducted posterior divisional rhythms. These beats had VH intervals shorter than what would be expected if they had arisen in the peripheral Purkinje system (Fig. 8). The superior orientation of the electrical axis was due to the fact that the impulse emerged from the corresponding division close to the posteroinferior left ventricular wall, thereafter propagating in an inferosuperior direction. A large R wave was

FIG. 8 (Case 4) Ectopic (second QRS complex) produced by mechanical stimulation of the posteroinferior ventricular wall through the middle cardiac vein.

not seen in lead V₁. This indicated that depolarization of the right ventricle was not significantly delayed since part of it was activated by the impulse descending through the right branch. Rosenbaum *et al.* (1970b) believe that while an asynchrony of about 40 to 60 msec is required to produce a pattern of 'complete' right bundle-branch block, 20 msec are sufficient to elicit a hemiblock morphology. This explains why the left posterior divisional beats in Fig. 5 showed a greater degree of left axis shift and a comparatively lesser degree of right bundle-branch block.

On the contrary, when organic right bundle-branch block and left anterior hemiblock were present His bundle electrograms could not differentiate between impulse formation in the posterior divisions or in the bundle-branches or anterosuperior division proximal to the blocked sites.

It is important to emphasize that in this beat the VH intervals did not represent the conduction time from the ectopic site to the His bundle. Rather, they reflected differences between arrival time at the ventricles and His bundle. In fact, the position of the H deflection in relation to the onset of the QRS complex is not only determined by the more proximal or more distal location of the pacemaker within the intraventricular conducting

system but by the spread of activation into the His bundle and ventricles respectively. Similar doubts regarding the classification of 'AV rhythms' by the position of the surface P waves were expressed by Scherf and Schookhoff in 1926.

Importance of surface leads for interpretation of His bundle recordings Fig. 1 to 8 show that His bundle electrograms have to be analysed not only in the light of the underlying AV or VA conduction patterns but also with a thorough understanding of the simultaneously present morphological QRS changes. For this purpose, simultaneous recording of several surface leads with two intracardiac leads is required.

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