Right Bundle-Branch Block and Left Anterior Fascicular Block (Left Anterior Hemiblock) Following Tricuspid Valve Replacement

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SUMMARY
Right bundle-branch block occurred in 42.8% and left anterior hemiblock in 35% of 14 patients after surgical replacement of the tricuspid valve. The combination of RBBB with left anterior hemiblock is caused by injury to the branching portion of the bundle of His or more likely, by a lesion involving the pseudobifurcation. This study provides further proof that left anterior hemiblock may be produced by a "central" lesion of the conduction system. An attempt was made to re-define the relationships of the bundle of His and bundle branches to the membranous septum and septal leaflet of the tricuspid valve and to correlate the site of surgical injury with the type of conduction disturbances produced.

Additional Indexing Words:
Atroventricular block  Bundle of His  Pseudobifurcation  Surgical heart block

The frequent occurrence of conduction disturbances following intracardiac surgery is well documented.1-4 Appreciation, early in the era of open heart surgery, of the close relationship of the conduction system to the posteroinferior margin of the membranous septum resulted in a rapid diminution of the incidence of postoperative atroventricular (A-V) block following repair of high ventricular septal defects.5 The incidence of right bundle-branch block (RBBB), however, remains high,6 and recently, it has been shown that left anterior hemiblock7-9 may also occur after repair of high ventricular defects.6,10

Tricuspid valves are being replaced with increasing frequency for rheumatic and traumatic disease as well as for Ebstein's anomaly.11-15 However, comprehensive studies of conduction disturbances following tricuspid valve replacement have not been reported. The purposes of this study were threefold: The first was to assess the overall incidence of different conduction disturbances resulting from tricuspid valve replacement; the second was to correlate the type of conduction disturbance with the site of injury, and the third was to clarify why the anterior division of the left bundle branch (LBB), which is a left ventricular structure, may be injured in a surgical procedure done from the right side of the heart.

Methods
The case records and ECGs of 15 patients who survived tricuspid valve replacement at the University of Kentucky Medical Center between the years 1966 and 1968 were analyzed. There were eight females and seven males. Two patients had traumatic tricuspid insufficiency. The remaining 13 had rheumatic heart disease. In the
Table 1

Incidence of Conduction Disturbances

<table>
<thead>
<tr>
<th>Type of conduction disturbance</th>
<th>No. of patients</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete A-V block</td>
<td>1</td>
<td>Patient died 3 days after operation. Presence or absence of I-V conduction disturbances undetermined.</td>
</tr>
<tr>
<td>Temporary complete A-V block and subsequent I-V conduction disturbance</td>
<td>2</td>
<td>I-V conduction disturbances present on ECGs taken after recovery of A-V conduction.</td>
</tr>
<tr>
<td>I-V conduction disturbances only</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>No conduction disturbances</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>15</td>
<td></td>
</tr>
</tbody>
</table>

Table 2

Cases Showing I-V Conduction Disturbances Following Tricuspid Valve Replacement

<table>
<thead>
<tr>
<th>Case</th>
<th>Age (yr)</th>
<th>Sex</th>
<th>Valves replaced</th>
<th>Mean QRS axis</th>
<th>Conduction disturbances</th>
<th>Preoperative</th>
<th>Postoperative</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>44</td>
<td>F</td>
<td>M, T</td>
<td>+90°</td>
<td>IRBBB</td>
<td>LAH and IRBBB</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>44</td>
<td>M</td>
<td>M, T</td>
<td>Indeterminant</td>
<td>IRBB</td>
<td>LAH and RBBB</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>29</td>
<td>F</td>
<td>A, M, T</td>
<td>+105°</td>
<td>None</td>
<td>LAH and RBBB</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>29</td>
<td>F</td>
<td>A, M, T</td>
<td>+60°</td>
<td>RBBB</td>
<td>LAH and RBBB</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>38</td>
<td>M</td>
<td>T</td>
<td>+30°</td>
<td>None</td>
<td>LAH and RBBB</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>50</td>
<td>F</td>
<td>M, T</td>
<td>+105°</td>
<td>None</td>
<td>IRBB</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>35</td>
<td>F</td>
<td>M, T</td>
<td>+100°</td>
<td>None</td>
<td>IRBBB</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>17</td>
<td>M</td>
<td>A, M, T</td>
<td>+30°</td>
<td>IRBBB</td>
<td>RBBB</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: A = aortic valve; M = mitral valve; T = tricuspid valve; RBBB = right bundle-branch block; IRBBB = incomplete right bundle-branch block; LAH = left anterior hemiblock.

two patients with traumatic tricuspid incompetence only the tricuspid valve was replaced. In eight, both mitral and tricuspid, and in five, mitral, tricuspid, and aortic valves were replaced. One patient with complete A-V block died without recovering A-V conduction; therefore, intraventricular (I-V) conduction disturbances (RBBB and left anterior hemiblock) could be evaluated in only 14 patients.

Criteria for RBBB were a slow terminal QRS force directed anteriorly and to the right, and a QRS duration of 0.12 sec or more. Block was termed “incomplete” when QRS duration was less than 0.12 sec. Left anterior hemiblock was diagnosed when the AQRS became −45° or more.7-9 Left anterior hemiblock in the presence of RBBB was recognized when the axis of the QRS deflection (AQRS) became oriented superiorly between −60 and −120°, with a q1–S2 pattern and a very small r/S ratio in lead II.7,10,16,17

Results

The incidence of conduction disturbances in the 15 patients are listed in table 1. Three of the 15 patients (20%) developed complete A-V block during operation and were paced. Two of these recovered A-V conduction a few hours later; the third patient died after 3 days without recovering A-V conduction. An immediate postoperative tracing was not available to determine the width of the QRS complex of the idioventricular beats in any of these three cases. Eight patients developed I-V conduction disturbances, and in the remaining six patients neither A-V nor I-V conduction disturbances were observed in the postoperative ECGs.

The I-V conduction disturbances are listed in table 2. Five patients developed left anterior hemiblock and six RBBB (incomplete in three). In all instances of left anterior hemiblock RBBB was also present (fig. 1). However, in two (cases 1 and 4), the degree of RBBB was not appreciably greater than before operation (fig. 2), and in one (case 3), left anterior hemiblock was transient and lasted less than 2 weeks (fig. 3). In case 1,
Figure 1

Case 2. The preoperative tracings show an indeterminate mean QRS axis, severe right ventricular hypertrophy, and a small degree of incomplete RBBB. The postoperative ECG is characteristic of RBBB with left anterior hemiblock. Note the change in the direction of the initial QRS forces, with the appearance of a Q wave in leads I and aV_{1}, and the disappearance of q from leads III and aV_{F}. These ECG changes have persisted.

Figure 2

Case 4. The preoperative tracings show an AQRS at about +60°, left ventricular hypertrophy, and RBBB with a QRS interval of 0.12 sec. The postoperative ECG shows, in addition, a high degree of left anterior hemiblock with deep S waves in leads II and III (as commonly seen in the presence of severe left ventricular hypertrophy). The AQRS has shifted to −60°. The degree of RBBB has not changed appreciably. These ECG changes have persisted.
Case 3. The preoperative tracings show an AQRS at about +105° and biventricular hypertrophy. ECGs taken on the first and second postoperative days were characteristic of RBBB with left anterior hemiblock. The AQRS shifted to −60°. However, left anterior hemiblock was transient, and a third ECG on the 13th postoperative day showed only incomplete RBBB. The AQRS shifted back to about +120°. The patient died the next day.

Discussion

Involvement of the anterior division of the LBB during tricuspid valve replacement may seem enigmatic, but appreciation of the anatomic relationships of the conduction system provides a reasonable explanation. The relationships of the conduction system to the tricuspid valve are illustrated in figures 4 and 5. The bundle of His comprises two segments: “penetrating” and “branching.”4, 7, 17–21 The penetrating portion is protected within the rigid structure of the central fibrous body and is only a few millimeters superior to the insertion of the septal leaflet of the tricuspid valve. The branching portion extends from the point where the most posterior fibers of the LBB originate from the main bundle to the point marking the origin of the RBB and the most anterior fibers of the LBB. This segment of the bundle is precisely at the level of insertion of the septal leaflet of the tricuspid valve. There is no true bifurcation of the bundle of His in the human heart, but rather a branching segment from which the RBB and the two divisions of the LBB arise. The bundle
considered a right ventricular structure and the LBB and its two divisions are considered left ventricular structures, all three are centrally located in the upper part of the muscular septum and within the thin fibrous sheath of the membranous septum and, therefore, can be involved in pathologic processes stemming from either side of the heart.

Depending upon the site and extent of injury (fig. 6) to the conducting system, five types of conduction disturbances may be expected after tricuspid valve replacement: (1) Monofascicular complete A-V block with a narrow QRS complex due to a lesion of the penetrating portion of the bundle of His. (2) Complete A-V block with a wide QRS complex due to an extensive lesion of the branching portion. This has been termed a "proximal" form of bifascicular block.22 Unfortunately, no postoperative tracings of our cases with complete A-V block showing idioventricular beats were available to test these two possibilities. (3) RBBB with left anterior hemiblock due to a lesion limited to the branching portion after the posterior fibers of the LBB have been given off, or more likely, to a lesion of the pseudobifurcation (site 3 and 3' of fig. 6). This occurred in five of our 14 cases. (4) RBBB alone due to a lesion of the initial segment of the RBB and this was seen in three of our cases, and (5) left anterior hemiblock alone due to a lesion of the proximal end of the anterior division of the LBB. An example of left anterior hemiblock alone, however, was not seen in our cases. This type of correlation of the site of injury to the ECG manifestations is an oversimplification because surgical injury is often diffuse and involves more than one area, but nonetheless our data are consistent with such correlations.

Condorelli23 obtained RBBB in canine hearts by partial transection of the bundle of His (probably at the level of the branching portion). Sciaccia and Sangiorgi24 demonstrated conduction disturbances which we would classify as left anterior hemiblock after partial transection of the bundle of His in the area of insertion of the septal leaflet of the

Figure 4

Relationships of tricuspid valve to the conduction system in the human heart. Photograph taken from the right side, under the dissecting microscope (reduced from ×10). The membranous septum (MS) has been separated from the muscular septum and the tricuspid valve has been removed, except for the insertion of the septal leaflet (T). The conduction system has been dissected. The right bundle branch (RBB) appears as a direct continuation of the bundle of His, which is seen to arise from the oval-shaped structure of the A-V node (AVN). HB indicates the penetrating portion of the bundle. The two arrows indicate the limits of the branching portion, from which the left bundle branch (LBB) is given off. The inferior arrow also points to the pseudobifurcation of the bundle of His into a right bundle branch and anterior part of the left bundle branch.

of His gives off the fibers of the LBB almost perpendicularly in an orderly and sequential fashion. After the posterior fibers have been given off, the bundle contains only the fibers of the RBB and the anterior division of the LBB. What appears in some microscopic sections as a bifurcation (fig. 5) is in fact the point at which the RBB separates from the most anterior fibers of the LBB. This "pseudobifurcation"10,17,22 is only a few millimeters below the insertion of the septal leaflet of the tricuspid valve. A small lesion at this site may produce RBBB and left anterior hemiblock simultaneously. It should be stressed that the RBB is a direct continuation of the bundle of His after all the fibers of the LBB have been given off. The initial segment of the RBB is located a few millimeters below the insertion of the septal leaflet of the tricuspid valve. Although the RBB is
Serial sections of the conduction system in a normal human heart. The diagram at bottom right shows the level of sections 1 to 5; the solid black indicates the A-V node, bundle of His, main LBB, and the thin anterior division and thicker posterior division. The parallel interrupted lines correspond to the RBB. (1) The arrow points to the penetrating portion of the bundle within the central fibrous body. (2) Branching portion (upper arrow). The fibers given off toward the left (left arrow) correspond to the posterior part of the LBB. On the right, insertion of the septal leaflet of the tricuspid valve. (3) Pseudobifurcation of the bundle of His into the RBB and most anterior part of the LBB, just atop the summit of the muscular septum. (4) Terminal part of the pseudobifurcation. (5) Distal portion of the RBB.

It has been suggested that fibers destined to form the RBB and LBB are already differentiated in the lower third of the bundle of His. It has been suggested that fibers destined to form the RBB and LBB are already differentiated in the lower third of the bundle of His. This early differentiation and a lesion of the main bundle need not be invoked to explain RBBB and left anterior hemiblock in our cases since both fascicles have a short common pathway where a localized lesion (site 3', fig. 6) would cause RBBB and left anterior hemiblock. Injury to the distal portion of the anterior division of the left bundle is unlikely to have been the cause of left anterior hemiblock in our cases.

Conduction disturbances were a common and significant complication of tricuspid valve replacement even in our retrospective study in which the true increase was probably underestimated because complete ECGs were not always available early in the postoperative period.
It may be argued that injury of the conduction system was associated with aortic or mitral valve replacement and not tricuspid valve replacement. Conduction disturbances as a result of mitral valve replacement alone are virtually unknown. A high incidence of complete A-V block was reported in the early experience of aortic valve replacement.\textsuperscript{26} Subsequently, the incidence diminished because of improved appreciation of the relationships of the bundle of His to the commissure between the right coronary and noncoronary aortic cusps. In two of our five cases in which RBBB and left anterior hemiblock occurred, the aortic valve also had been replaced, and it is possible that left anterior hemiblock resulted from the trauma of this procedure. In the two cases in which both mitral and tricuspid valves were replaced, and in the case in which only the tricuspid valve was replaced, it is hard to conceive that RBBB and left anterior hemiblock resulted from anything other than direct injury of the conduction system during tricuspid valve replacement.

Complete A-V block produced at the time of surgery adversely affects the surgical result. Block of the RBB alone or in combination with block of the anterior division of the LBB causes no immediate concern, but the long-term prognosis has yet to be determined. Left anterior hemiblock and RBBB may lead, in time, to complete A-V block.\textsuperscript{7, 17, 22, 27, 28} This progression has not been documented in surgical RBBB with left anterior hemiblock, but total dependence of A-V conduction upon the posterior division of the LBB may increase the risk of complete heart block in later life. Therefore, surgical attention should be directed not only to the avoidance of damage to the main bundle, but also the right bundle and left anterior division.

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