Surgical Bifascicular Block

By Devkishin B. Pahlajani, M.D., Maria Serratto, M.D., Ashwin Mehta, M.D., Robert A. Miller, M.D., Alois Hastreiter, M.D., and Kenneth M. Rosen, M.D.

SUMMARY
Electrophysiological studies were performed in 18 patients who developed bifascicular block after repair of ventricular septal defect (VSD) or tetralogy of Fallot (TF). Two had transient complete heart block (CHB) in the immediate postoperative period.

The P-A intervals were normal in all. A-H and H-V intervals were prolonged in three and four cases, respectively. Atrial pacing at progressively increasing heart rates was performed in 15 patients; two developed type II block distal to the His bundle (H). The effective and functional refractory periods (ERP and FRP) of the atrium (11 cases) were normal in all. The ERP of the A-V node (seven cases) was prolonged in four and the FRP was increased in three. The ERP of the ventricular specialized conduction system was measured in two cases and was prolonged in one. In all, seven cases had abnormalities indicating disease of the A-V node and/or His-Purkinje system. Recording of intervals, atrial pacing, and determination of refractory periods (RPs) was necessary to reveal all conduction abnormalities. One patient died of unrelated causes. The others are alive and in sinus rhythm with intact conduction 3 to 16.5 years following surgery (mean follow-up of 8.3 ± 0.95 years). The clinical course in patients with normal and abnormal findings was equally benign. Prophylactic insertion of demand pacemakers does not appear indicated in these patients.

Additional Indexing Words:
His bundle electrogram Ventricular septal defect Functional refractory period Complete heart block

Demand pacemaker Effective refractory period Right bundle branch block

Atrial pacing Tetralogy of Fallot Left axis deviation

Recent reports have indicated that patients with an electrocardiographic pattern of right bundle branch block (RBBB) with left axis deviation (LAD) which has developed after repair of ventricular septal defect or tetralogy of Fallot are at risk for late heart block, Stokes-Adams attacks, and sudden death.1-3 In the present study, we have performed electrophysiological studies, including measurement of conduction intervals and refractory periods, in a group of patients with postoperative RBBB and LAD. In addition, follow-up data is presented concerning these patients.

Material and Methods
Records of 87 patients with ventricular septal defects and 75 with tetralogy of Fallot who had total repair were analyzed. Thirty-one patients (19.1%) developed an electrocardiographic pattern of RBBB with LAD; His bundle electrograms (HBE) were performed in 18. Our present study deals with these 18 cases. Cases that had LAD before surgery were excluded from the study. RBBB was diagnosed when 1) QRS duration was ≥ 0.12 sec; 2) there was slurred S in leads I and/or V6; 3) wide R' appeared in aVr and V5. A diagnosis of LAD was made when the QRS axis in the frontal plane was superior to ± 60° (table 1).

All recordings were performed in the postabsorptive basal state under demerol, phenergan, and sparteine sedation. None of the patients were on digitalis or antiarrhythmic drugs at the time of study. His bundle electrograms were recorded with catheter electrodes placed close to the tricuspid valve.4-6 P-A, A-H, and H-V intervals were measured as described by Dhingra et al.7 The variability in the measurements was within ± 2.5 msec. Atrial pacing and recording was performed by placing a bipolar or quadripolar catheter in the high right atrium. Effective and functional refractory periods of the atrium, A-V node, and His-Purkinje system were measured utilizing atrial extrastimulus technique.8,9 All stimuli were delivered using a programmable digital stimulator (manufactured by M Bloom, Philadelphia, Pa.) or a Grass stimulator (Model D588). Refractory periods were measured during sinus rhythm or at the slowest paced rate producing stable atrial capture. The extrastimulus (St) was introduced at decreasing coupling intervals with 10-20 msec decrements in successive test cycles. A, H and V following St were called A1, H1, and V1, respectively, whereas A, H, and V following S2 were called A2, H2, and V2. All recordings were obtained on an Electronics for Medicine multichannel recorder at speeds of 100 and 200 mm/sec. Standard limb leads and lead V1 were recorded simultaneously.

The effective refractory period (ERP) of the atrium was defined as the longest A2 (or S2 interval) which failed to capture the atrium. The atrial functional refractory period (FRP) was defined as the shortest attainable A1A2 interval.
The ERP of the A-V node was defined as the longest A1A2 interval which failed to propagate to the His bundle. The A-V nodal FRP was the shortest propagated H1H2 interval. The ERP of the His-Purkinje system was the longest H1H2 interval which failed to propagate to the ventricles.

Results

The study group consisted of 18 patients (table 1), nine patients with VSD repair and nine with surgical correction of TF. All VSDs were repaired via ventriculotomy and in two cases (DA and WD), surgery had to be repeated, due to residual defect. Ages at the time of study ranged from seven to 26 years with a mean age of 16.7 ± 1.5 years. There were 16 males and two females. The pattern of RBBB and LAD developed immediately after surgery in 15 cases, all of whom had intact A-V conduction. One case had RBBB postoperatively with LAD developing after one year. Two patients had transient CHB in the immediate postoperative period. One of them (SD) required a pacemaker, but returned to sinus rhythm with intact A-V conduction and RBBB and LAD after one month, allowing removal of the pacemaker. This patient has remained in sinus rhythm for a period of 3.2 years following surgery. The other patient (EL) had transient CHB for 48 hours and regained intact conduction with RBBB. The pattern of LAD developed gradually over a period of five years. Three patients of the original 18 have residual first degree A-V block (PR > 0.20 sec) which was not present prior to surgery.

The P-A, A-H, and H-V intervals were compared to age related normal values.7 10 11 The P-A interval was normal in all cases with a mean of 25.6 msec ± 1.99. A-H interval ranged from 53 to 290 msec (mean 106.39 ± 12.75) and was prolonged in three. All three had first degree A-V block (fig. 1A). The H-V interval ranged from 28 to 70 msec (mean ± SEM, 45.78 ± 2.66) and was increased in four cases (fig. 1B). Two of these were in the group with first degree A-V block. One patient with prolonged P-R interval had a normal H-V (fig. 1A). Two cases with prolonged H-V had normal P-R.

The conduction system was stressed with atrial pacing in 15 cases. Three maintained intact A-V conduction up to maximum paced rates of 170, 180, and 200 beats/min, respectively. Ten developed type I block proximal to H at paced rates of 95 to 200 beats/min (mean 165 ± 10). One developed type I block proximal to H at a rate of 140 beats/min and type II block distal to H at a rate of 150 beats/min (fig. 2). This patient had a normal H-V interval, but prolonged A-H and P-R intervals. One patient developed type II block at a rate of 130 beats/min.

Atrial FRPs, measured in 11 cases, ranged from 170 to 300 msec (mean 236.82 ± 11.33) and were normal in all. Atrial FRPs, measured in 11 cases, ranged from

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**Table 1.** Summary of Clinical Data in 18 Cases with Bifascicular Block

<table>
<thead>
<tr>
<th>Pt.</th>
<th>Age</th>
<th>EFS</th>
<th>Sex</th>
<th>Diag.</th>
<th>Postop QRS Axis (°)</th>
<th>Follow-up (yr)</th>
<th>Present Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>RA</td>
<td>22</td>
<td>23</td>
<td>M</td>
<td>TF</td>
<td>-110</td>
<td>4.7</td>
<td>SR</td>
</tr>
<tr>
<td>DA</td>
<td>12</td>
<td>26</td>
<td>M</td>
<td>VSD</td>
<td>-100</td>
<td>14.3</td>
<td>SR</td>
</tr>
<tr>
<td>JG*</td>
<td>10</td>
<td>22</td>
<td>M</td>
<td>TF</td>
<td>-150</td>
<td>12.0</td>
<td>Exp. May '72</td>
</tr>
<tr>
<td>EL</td>
<td>9</td>
<td>17</td>
<td>M</td>
<td>TF</td>
<td>-180</td>
<td>9.3</td>
<td>SR</td>
</tr>
<tr>
<td>MC</td>
<td>17</td>
<td>24</td>
<td>M</td>
<td>TF</td>
<td>-10</td>
<td>8.5</td>
<td>SR</td>
</tr>
<tr>
<td>AM</td>
<td>11</td>
<td>19</td>
<td>M</td>
<td>TF</td>
<td>-110</td>
<td>7.6</td>
<td>SR</td>
</tr>
<tr>
<td>HB</td>
<td>2</td>
<td>12</td>
<td>M</td>
<td>VSD</td>
<td>-110</td>
<td>9.6</td>
<td>SR</td>
</tr>
<tr>
<td>LR</td>
<td>25</td>
<td>27</td>
<td>M</td>
<td>TF</td>
<td>-80</td>
<td>5.7</td>
<td>SR</td>
</tr>
<tr>
<td>WD</td>
<td>25</td>
<td>20</td>
<td>M</td>
<td>VSD</td>
<td>-10</td>
<td>16.5</td>
<td>SR</td>
</tr>
<tr>
<td>WG</td>
<td>5</td>
<td>16</td>
<td>M</td>
<td>VSD</td>
<td>-60</td>
<td>12.8</td>
<td>SR</td>
</tr>
<tr>
<td>LC</td>
<td>7</td>
<td>12</td>
<td>F</td>
<td>TF</td>
<td>-30</td>
<td>6.1</td>
<td>SR</td>
</tr>
<tr>
<td>MT</td>
<td>4</td>
<td>10</td>
<td>M</td>
<td>VSD</td>
<td>-80</td>
<td>8.2</td>
<td>SR</td>
</tr>
<tr>
<td>BD</td>
<td>3</td>
<td>14</td>
<td>M</td>
<td>TF</td>
<td>-40</td>
<td>12.0</td>
<td>SR</td>
</tr>
<tr>
<td>SR</td>
<td>4</td>
<td>7</td>
<td>M</td>
<td>VSD</td>
<td>-60</td>
<td>3.7</td>
<td>SR</td>
</tr>
<tr>
<td>JT</td>
<td>10</td>
<td>15</td>
<td>M</td>
<td>VSD</td>
<td>-50</td>
<td>6.5</td>
<td>SR</td>
</tr>
<tr>
<td>GD</td>
<td>8</td>
<td>11</td>
<td>M</td>
<td>VSD*</td>
<td>-90</td>
<td>3.0</td>
<td>SR</td>
</tr>
<tr>
<td>SD*</td>
<td>5</td>
<td>7</td>
<td>F</td>
<td>VSD</td>
<td>-90</td>
<td>3.2</td>
<td>SR</td>
</tr>
<tr>
<td>BW</td>
<td>6</td>
<td>15</td>
<td>M</td>
<td>TF</td>
<td>-110</td>
<td>9.6</td>
<td>SR</td>
</tr>
</tbody>
</table>

Mean 9.4 16.7  
sd 6.5 6.3  
SEM 1.5 1.5

*Transient postoperative complete heart block.

Abbreviations: Pt = patient; TF = Tetralogy of Fallot; VSD = ventricular septal defect; SR = sinus rhythm with intact A-V conduction; sd = standard deviation; SEM = standard error of the mean; EPS = electrophysiological study.

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180 to 310 msec (mean 250.46 ± 11.49) and were also normal in all. In three cases, the refractory periods of the atrium were less than 350, 380, and 265, respectively. Atrioventricular nodal ERPs could be measured in seven cases and ranged from 285 to 450 msec (mean 369.29 ± 24.41) and were prolonged in four (fig. 3, left). The A-V nodal FRPs ranged from 360 to 630 msec (mean 487.1 ± 31.96) and were prolonged in three of seven cases. In seven cases, because atrial conduction became the limiting factor, A-V nodal refractory periods could not be measured. The ERP of the His-Purkinje system could be measured in two patients and was respectively 525 (prolonged) and 400 msec (normal) (fig. 3, right).

Means, standard deviations (sd), and standard error of the means (SEM) for the above parameters are given in table 2.

Table 2

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range (msec)</th>
<th>Mean</th>
<th>SD</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>P-A</td>
<td>10–40</td>
<td>25.60</td>
<td>8.49</td>
<td>1.99</td>
</tr>
<tr>
<td>A-H</td>
<td>53–290</td>
<td>106.39</td>
<td>54.08</td>
<td>12.75</td>
</tr>
<tr>
<td>H-V</td>
<td>28–70</td>
<td>45.78</td>
<td>11.29</td>
<td>2.66</td>
</tr>
<tr>
<td>ERP atrium</td>
<td>170–300</td>
<td>230.82</td>
<td>37.57</td>
<td>11.33</td>
</tr>
<tr>
<td>ERP atrioventricular</td>
<td>180–310</td>
<td>250.46</td>
<td>38.11</td>
<td>11.49</td>
</tr>
<tr>
<td>ERP A-V node</td>
<td>285–450</td>
<td>360.29</td>
<td>64.58</td>
<td>24.41</td>
</tr>
<tr>
<td>ERP A-V node</td>
<td>360–630</td>
<td>487.14</td>
<td>84.55</td>
<td>31.96</td>
</tr>
</tbody>
</table>

Follow-up

The 18 patients have been followed for periods ranging from 3 to 16.5 years, with a mean follow-up of 8.5 ± 0.92 years. Only one patient died, and this was due to surgery for a residual uncorrected congenital heart defect. The remaining 17 patients are alive, asymptomatic, and in sinus rhythm, with intact A-V conduction. No patient has developed spontaneous late heart block. Seven of the patients have abnormal electrophysiological findings (table 3, group A). None of these had abnormalities of the A-V node alone. Two had abnormalities of the His-Purkinje system alone, these consisting of only H-V prolongation. Five patients had combined abnormalities involving both the A-V node and His-Purkinje system. The group with A-V nodal abnormalities was composed of one patient with prolonged A-H intervals, two patients with prolonged refractory periods, and two patients with prolonged A-H intervals and prolonged refractory periods. The His-Purkinje system abnormalities in these five patients consisted of isolated H-V prolongation in two patients, type II block distal to the His bundle induced by atrial pacing in two.

Figure 1

Standard ECG leads and HBE. Timelines = one/sec; paper speed = 100 mm/sec. A) Patient DA. First degree A-V block with prolonged A-H interval of 170 msec and normal H-V interval (50 msec). P-A = 26 msec; P-R = 0.25 sec. B) Patient EL. First degree A-V block with prolonged A-H (136 msec) and H-V (70 msec) intervals. A-H = 136 msec; P-A = 30 msec; P-R = 0.23 sec.

Figure 2

Standard ECG leads and HBE. Timelines = one/sec. Patient DA. At the pacing rate of 150 beats/min, type II block distal to H develops. Note the second and fourth H not followed by ventricular activity. Paper speed 200 mm/sec.

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patients, and a prolonged refractory period in one patient.

To evaluate the clinical significance of such abnormal data, we compared the follow-up periods in the two groups. The group with abnormal conduction studies was followed from 4.7 to 14.3 years (mean 9.4 ± 1.25), and the range in the group with normal conduction was 3 to 16.5 years (mean 7.9 ± 1.32) (table 3, group B). Thus, the two groups were followed for approximately the same length of time. There was no difference in the clinical status of the two groups, either before or after surgery. Specifically, no patient had episodes of dizziness or syncope following surgery.

**Discussion**

The conduction system associated with ventricular septal defect and tetralogy of Fallot has been studied

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**Table 3**

Summary of Electrophysiological Data in Two Groups: Group A: Abnormal; Group B: Normal

<table>
<thead>
<tr>
<th>Pt.</th>
<th>P-R</th>
<th>P-A</th>
<th>A-H</th>
<th>H-V</th>
<th>Pacing response</th>
<th>ERP-At</th>
<th>FRP-At</th>
<th>ERP-AVN</th>
<th>FRP-AVN</th>
<th>ERP-VSCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>RA</td>
<td>0.15</td>
<td>18</td>
<td>87</td>
<td>46</td>
<td>Normal</td>
<td>&lt;350</td>
<td>—</td>
<td>430†</td>
<td>535†</td>
<td>525†</td>
</tr>
<tr>
<td>DA</td>
<td>0.25</td>
<td>26</td>
<td>170</td>
<td>50</td>
<td>Type II at 150</td>
<td>240</td>
<td>260</td>
<td>450†</td>
<td>510†</td>
<td>—</td>
</tr>
<tr>
<td>JG</td>
<td>0.39</td>
<td>40</td>
<td>290</td>
<td>58†</td>
<td>Normal</td>
<td>&lt;380</td>
<td>—</td>
<td>390†</td>
<td>630†</td>
<td>—</td>
</tr>
<tr>
<td>EL*</td>
<td>0.23</td>
<td>30</td>
<td>136</td>
<td>70†</td>
<td>Normal</td>
<td>265</td>
<td>285</td>
<td>—</td>
<td>400</td>
<td>—</td>
</tr>
<tr>
<td>MC</td>
<td>0.17</td>
<td>23</td>
<td>105</td>
<td>44</td>
<td>Type II at 130</td>
<td>210</td>
<td>220</td>
<td>410†</td>
<td>480</td>
<td>—</td>
</tr>
<tr>
<td>AM</td>
<td>0.17</td>
<td>36</td>
<td>67</td>
<td>63†</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>HB</td>
<td>0.13</td>
<td>25</td>
<td>53</td>
<td>55†</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

*Transient CHB immediately after surgery.
†Indicates abnormal values as compared to age-related normal data.

Abbreviations: Pt = patient; ERP = effective refractory period; FRP = functional refractory period; AVN = atrioventricular node; At = atrium; VSCS = ventricular specialized conduction system.
in detail by Lev. In both anomalies, the common A-V bundle is related to the posterior wall of the defect and bifurcates on the floor of the defect near the distal wall in the infracristal septal defect. The right bundle is closely related to the distal wall of the defect and is likely to be traumatized during placement of sutures around the patch. The common A-V bundle in tetralogy is also related to the floor of the septal defect, though lying more on the left side of the summit of the ventricular septum below it. The left bundle branch has a wide origin and is therefore less commonly involved in the injury. In cases where injury of this bundle occurs, the anterior division is likely to be affected, since the posterior fascicle is given off before the common bundle. In more extensive lesions, all three fascicles, common bundle, A-V node, and approaches to the A-V node may be involved. Such lesions were present in Lev's cases, and the pathologic changes were related to hemorrhage, necrosis, interruption, and inflammation. On the other hand, Gelband et al. and Krongrad et al. have shown that a RBBB pattern usually occurs following tetralogy repair or ventricular septal defect repair, and is often a result of a right ventriculotomy secondary to surgical parietal block in the right ventricle. However, the association of RBBB and LAD suggests damage to the central portion of the conduction system, although it is also consistent with parietal right bundle branch block from the ventriculotomy, with left axis deviation due to damage to the left anterior division of the left bundle.

Trifascicular disease can be diagnosed when the H-V interval is prolonged. Using this criterion, we had four cases with trifascicular disease. Such findings could also occur when the disease is located in the common A-V bundle distal to the recording site, or in more distal Purkinje networks. Two of these cases had normal P-R interval. This can occur if the conduction time through the A-V node is normal. Two patients with prolonged H-V interval also had prolonged A-H interval, suggesting involvement of both the His-Purkinje system and A-V node. All three patients with first degree A-V block had prolonged A-H interval, indicating A-V nodal dysfunction. In the third patient who had a normal H-V interval, disease of the His-Purkinje system became evident when he developed block distal to the His bundle with an abnormal response to atrial pacing. One additional patient with normal P-R and H-V developed block distal to the His bundle with atrial pacing.

The normal P-A and refractory periods of the atrium suggest lack of atrial involvement from surgery. The prolonged A-V nodal refractory periods in four patients suggest A-V nodal dysfunction due to trauma during surgery. Two of these cases had prolonged A-H interval. Response to atrial pacing was normal in all four cases.

In two cases, the refractory periods of the His-Purkinje system were more than the refractory periods of the A-V node, and block occurred distal to H, following Sa at coupling intervals of 460 and 295 msec, respectively. Witt et al. considered this to be a normal response. However, values for His-Purkinje system refractory periods in one of the two patients (patient RA, table 3), were prolonged when compared to normal adult values. The other patient, who at the time of study was 18 years old, had a normal refractory period of the His-Purkinje system. On the other hand, his H-V interval was prolonged. Both may have surgical damage to the His-Purkinje system.

In conclusion, electrophysiological abnormalities were common in patients with postsurgical bifascicular block. It is of note that surface electrocardiographic criteria could not detect those patients with abnormalities, with the exception of P-R prolongation, caused by A-V nodal dysfunction. Surprisingly, none of the abnormal patients had isolated abnormalities of A-V nodal function, all having abnormalities of either the His-Purkinje system alone, or both the A-V node and His-Purkinje system. Despite demonstration of conduction abnormalities in approximately 40% of the patients, no patient progressed to heart block over a mean follow-up period of approximately eight and one-half years following surgery. These results are in agreement with those of Downing and associates who have followed their patients from one to ten years after surgery without observing any serious conduction defects. Also, if we can extrapolate from adult data, the present findings are in agreement with those of Denes et al. who found a low risk of progression of conduction disease in adults with chronic bifascicular block. The present data suggest that prophylactic permanent pacing is not indicated in patients with congenital heart disease and postsurgical bifascicular block, even if electrophysiological abnormalities are demonstrated. However, continued longitudinal study of these patients may allow definition of a high risk group in the future.

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