Surgically Induced Right Bundle-Branch Block with Left Anterior Hemiblock
An Ominous Sign in Postoperative Tetralogy of Fallot

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SUMMARY
A review of the electrocardiograms of 291 patients who survived more than 1 month after complete repair of tetralogy of Fallot disclosed that 24 (8.2%) developed a pattern of right bundle-branch block and left anterior hemiblock (RBBB-LAH) following surgery. When the course of these 24 patients was compared with a control group of 100 additional patients who did not develop this pattern following surgery, a significant increase in morbidity and mortality was noted.

Complete heart block developed at some time in the follow-up period in 41.7% of the RBBB-LAH group and in 4% of the control group. The incidence of serious ventricular arrhythmias was 16.7% for the RBBB-LAH group and 1% for the control group. Sudden death occurred in 12.5% of the patients with RBBB-LAH and in 2% of the controls. At the time of this review (1–12 years following surgery) overall late mortality was 25% for the RBBB-LAH group and 2% for the control group.

The study indicates that serious complications are much more frequent in tetralogy of Fallot patients who acquire the RBBB-LAH pattern during surgical repair. Prophylactic or therapeutic pacing may be indicated in many of these patients.

Additional Indexing Words:
Electrocardiogram Congenital heart disease Open-heart surgery Complete heart block Ventricular tachycardia Sudden death

The majority of patients who undergo surgical correction of tetralogy of Fallot develop the electrocardiographic pattern of right bundle-branch block. In addition to the right bundle-branch block (RBBB) pattern, a small number of patients also develop left-axis deviation, or left anterior hemiblock (LAH). Because the combination of RBBB and LAH occurring spontaneously in coronary artery disease, myocardiopathies, and other disorders is a known precursor of complete heart block, the present study was undertaken to determine if the same, or other complications, would arise in patients in whom a similar electrocardiographic pattern is surgically induced.

Methods
The electrocardiograms of 291 patients who underwent surgical correction of tetralogy of Fallot were reviewed. This number represents all patients surviving surgery at The Children's Hospital Medical Center in Boston, Massachusetts, and the Albany Medical Center in Albany, New York, between 1958 and 1971, in whom
adequate pre- and postoperative electrocardiograms were available. Excluded from the study were (1) patients who died within 1 month following surgery; (2) patients who demonstrated complete heart block immediately after operation that has persisted without interruption, so that normally conducted beats in the postoperative period are not available for analysis; and (3) patients with right bundle-branch block or left anterior hemiblock present in the preoperative electrocardiogram.

Right bundle-branch block was diagnosed from a terminal conduction delay producing a QRS duration exceeding 120 msec. The RBBB-LAH pattern was diagnosed when, in addition to the presence of RBBB, the mean frontal QRS axis was found to be superiorly oriented, between −60° and −120°, with a Q_1S_3 pattern (fig. 1). The case records of all patients with postoperative RBBB-LAH were reviewed in detail. The records of an additional 100 postoperative tetralogy patients, who did not demonstrate this pattern, were randomly selected and reviewed as controls.

Specific attention was directed toward mortality and evidence of heart block or arrhythmias developing during the follow-up period.

**Results**

Among the postoperative electrocardiograms from 291 patients, 24 were found to have the RBBB-LAH pattern. This represents an incidence of 8.2%, a figure which is similar to that reported by others following surgical correction of tetralogy of Fallot. Of the randomly selected control patients, 90% demonstrated RBBB and the remaining 10% exhibited only minor or no conduction abnormalities. The frontal QRS axis for this control group varied between 0 and 180° in 77 patients, and was indeterminate in 23.

The clinical course of the 24 patients who developed RBBB-LAH is graphically shown in figure 2. Patients who showed transient complete heart block in the immediate postoperative period (patients 1–9) are shown as group A, and those without transient heart block immediately after surgery (patients 10–24) are shown as group B. Table 1 shows the incidence of the most common complications which developed following surgery in the RBBB-LAH group and compares the incidences with those from the control group. Transient complete heart block was present in the immediate postoperative period in nine of 24 patients in the RBBB-LAH group; in one additional patient a very high degree of persistent heart block developed for the first time 4 years after surgery (fig. 3). Thus, the incidence of complete heart block developing at any time following surgery in the patients with RBBB-LAH was 41.7% (table 1). In four of the nine patients who had transient heart block following surgery complete heart block recurred in a persistent or repetitive fashion from 5 days to 6 years after surgery. In addition, as mentioned above, another patient with RBBB-LAH, who did not have transient heart block immediately after surgery, developed complete heart block 4 years following surgery. Thus, a total of five of 24 patients with RBBB-LAH, or 20.8%, have developed persistent complete heart block.

There were four patients among the 100 controls (4%) with transient complete heart block in the immediate postoperative period, but in none has the heart block reappeared within a follow-up period of 4–9 years.

Episodes of ventricular tachycardia or persistent bigeminal rhythm with coupled premature ventricular contractions have been noted in four patients (16.7%) in the RBBB-LAH group (table 1). Patient 8 (fig. 2), who had transient complete heart block immediately after surgery, began to have frequent episodes of ventricular tachycardia in the first week after surgery, and these persisted until he died 2½ years later of the arrhythmia. The other three patients in the RBBB-LAH group who developed problems with arrhythmia had no transient heart block immediately after surgery.
Figure 2
A chart illustrating the course of the 24 patients who developed RBBB-LAH following surgical repair of tetralogy of Fallot. Patients 1–9, who had transient complete heart block immediately after surgery, are shown as a group A. Heart block recurred in four of these patients. Group B is made up of patients 10–24, who showed no evidence of heart block in the immediate postoperative period. One of these patients (no. 14) developed heart block 4 years after surgery. Episodes of ventricular tachycardia and sudden death were seen in both groups.

Table 1
Incidence of Complete Heart Block, Ventricular Arrhythmias, and Death Related to Presence or Absence of RBBB-LAH

<table>
<thead>
<tr>
<th>Condition</th>
<th>RBBB-LAH</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>N (no)</td>
</tr>
<tr>
<td>Complete heart block</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Persistent block developing late</td>
<td>20.8</td>
<td>5*</td>
</tr>
<tr>
<td>Transient block immediately postop without recurrence</td>
<td>20.8</td>
<td>5</td>
</tr>
<tr>
<td>Total incidence of complete heart block at any time</td>
<td>41.7</td>
<td>10</td>
</tr>
<tr>
<td>Ventricular tachycardia or persistent ventricular bigeminy</td>
<td>16.7</td>
<td>4</td>
</tr>
<tr>
<td>Overall late mortality</td>
<td>25</td>
<td>6</td>
</tr>
<tr>
<td>Sudden unexpected death</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Death associated with complete heart block</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Death associated with ventricular tachycardia</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviation: N = number.
*Transient complete heart block immediately after surgery had previously been present in four of these five.

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surgery. Patient 16 was well until 9 months postoperatively when he was admitted in ventricular tachycardia which required countershock. Approximately 1 year later, despite treatment with quinidine, he developed a second episode of ventricular tachycardia requiring countershock. In the 4 years since then, while receiving diphenylhydantoin and later propranolol, the patient has not had any documented episodes of ventricular tachycardia, although brief episodes of palpitation have been noted. Patient 20 was first noted to have bigeminal rhythm with coupled premature ventricular contractions approximately 6 weeks following surgery, and these have persisted for over 2 years. Patient 17 was admitted 7 months following surgery in ventricular tachycardia which reverted spontaneously. Since then, during a 4½-year follow-up, he has experienced four additional episodes of ventricular tachycardia while on varying combinations of antiarrhythmic drugs; one of these episodes required countershock and one led to cardiac arrest from which he was successfully resuscitated with external massage. Because of the possibility that transient episodes of heart block may be the initiating factor in these attacks, a demand pacemaker was recently inserted in this patient.

Only one patient (1%) in the control group has had ventricular arrhythmias; this patient has had three episodes of ventricular tachycardia during a 5-year follow-up, all of which

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**Figure 3**

The postoperative electrocardiogram of a patient (no. 14, fig. 2) taken 4 years following repair of tetralogy of Fallot. Complete heart block is present except for one conducted beat demonstrated in each lead. The conducted beats reveal a prolonged P-R interval and show right bundle-branch block with left anterior hemiblock.
required countershock. He is presently being treated with quinidine.

The incidence of sudden unexpected death is 12.5% (3 of 24) in the RBBB-LAH group. Patient 7 (fig. 2) had a brief episode of complete heart block immediately after operation, but showed a normal P-R interval on discharge. When seen for follow-up examination 2 years after surgery, he was asymptomatic. His electrocardiogram at that time showed the RBBB-LAH pattern and frequent premature ventricular contractions; the P-R interval was 0.18 sec. He died suddenly at home 5 months later, 2½ years after surgery. Of the other two patients in this group, no. 23 had no known problems with heart block or arrhythmia but died suddenly at home 5 months postoperatively. The last patient, no. 24, also had no known arrhythmia problems but was found dead in bed at home 5 weeks following surgery.

Sudden death occurred in two patients (2%) in the control group, in both cases approximately 6 months following surgery. In one instance, a syncopal episode preceded death by 1 month; electrocardiograms following this episode revealed only right bundle-branch block with occasional premature ventricular contractions. The postoperative electrocardiograms in the other patient in the control group who died suddenly also revealed right bundle-branch block with occasional premature ventricular contractions. No preceding syncopal episode or other evidence of heart block had been noted in this patient.

There were three other deaths in the follow-up period in the patients with RBBB-LAH. Two of these (6 and 9) died in complete heart block when their electronic pacemakers failed 32 months and 3 months, respectively, after surgery. One other patient (no. 8) died 2½ years postoperatively of recurrent ventricular tachycardia, as mentioned above. Thus, as shown in table 1, the overall late mortality in patients with RBBB-LAH is 25% (6 of 24) as compared with the overall late mortality in the control group of only 2%.

Discussion

Right bundle-branch block and left anterior hemiblock have been reported in association with repair of ventricular septal defect and tetralogy of Fallot1-7 and following tricuspid valve replacement.6 This phenomenon has been related to direct interruption of the right bundle and the anterior division of the left bundle. Rosenbaum and co-workers6,7 indicated that the pseudobifurcation of the right bundle and the anterior division of the left bundle occurs a few millimeters caudal to the septal leaflet of the tricuspid valve, and this vulnerable location may account for its disunion during surgical repair of the defects noted. That this is the etiology of the postsurgical RBBB-LAH pattern is supported by experimental work in canines and primates.8

Recent work by Gelband and co-workers,9 however, has demonstrated that the RBBB that occurs following repair of tetralogy of Fallot is related to the right ventriculotomy incision and not to the closure of the ventricular septal defect. These authors feel that following surgery the main right bundle branch conducts normally, but the delay occurs more peripherally in the portion of the right ventricle lateral to the ventriculotomy. They postulate that the danger of complete heart block being produced should left bundle-branch block develop later is less in these patients since their main right bundle branch is intact.

The exact site of interruption of the conducting tissue in our patients is not known, as histopathologic examination of the conducting system has not been done. However, for these patients who developed left anterior hemiblock at surgery, a proximal interruption must be surmised. Because the anterior division of the left bundle and the right bundle branch are in close proximity along the upper ventricular septum, it seems likely that both the RBBB and LAH were produced concomitantly. It may well be that in these patients there was also a more distal interruption of the right bundle-branch fibers at the
time of ventriculotomy, as suggested by Gelband and co-workers. In fact, for our control patients who developed only RBBB at surgery, this more distal block may well be the etiology of their postoperative electrocardiographic pattern. For these patients, the later development of conduction abnormalities involving the left bundle may not be as likely to lead to heart block. However, it is clear that when both RBBB and LAH are produced at surgery, the danger of heart block and other complications is quite significant.

The association of RBBB and LAH is a known precursor of complete heart block. Rosenbaum et al. reported the occurrence in 6% of 148 cases and Watt and Pruitt reported an incidence of 7.7% in 65 cases. However, retrospective reviews of the electrocardiographic patterns preceding complete heart block indicate an incidence as high as 40% to 59%. It is clear that the occurrence of the RBBB-LAH pattern in the nonsurgical patient is a foreboding sign. Consequently, it is not unexpected that this same pattern, surgically induced, is equally ominous.

In the present study, complete heart block developed at some time in over 40% of our patients with RBBB-LAH. In addition, there was a significant incidence of ventricular arrhythmias and sudden death. The poorest prognosis was found in those patients with this pattern who developed transient complete heart block in the immediate postoperative period (group A, fig. 2). Only three of nine patients in this group are alive and well without any significant arrhythmias or heart block. Four patients have died, and two additional patients have had electronic pacemakers inserted.

Nine of 15 patients in group B are alive and well at the time of this follow-up study; six have had complications since surgery. Three of this group have shown significant ventricular arrhythmias and one patient has developed complete heart block. There were two sudden deaths in this group. Thus, while the prognosis is better in patients who do not have transient heart block immediately after operation, significant problems may still develop as late as several years postoperatively.

While the development of complete heart block in these patients can be explained on an anatomic basis, the propensity of these patients to ventricular arrhythmias is less easily understood. It is known that bradycardia predisposes to the development of arrhythmias, and it is a distinct possibility that these patients may develop their arrhythmias following episodes of complete heart block and resultant bradycardia. Linenthal and Zoll, recognizing the danger of ventricular tachycardia or ventricular fibrillation developing with very slow rates in patients with complete heart block, suggested drugs or electronic pacemakers to increase the heart rate to prevent the development of these serious arrhythmias. Han et al. found in dogs that temporal dispersion of recovery of excitability, measured as the range of local refractory period durations at numerous sites on the atrial and ventricular surfaces, was a direct function of the heart rate. In their studies the fibrillation threshold of the ventricle was significantly lower at slower rates than at higher basic rates. The possibility that episodes of complete heart block and bradycardia may be an underlying cause of ventricular arrhythmias and even sudden death in our patients led to the insertion of an electronic pacemaker in one patient who has had numerous episodes of ventricular tachycardia.

Patients who develop RBBB-LAH following surgical repair of tetralogy of Fallot present a difficult management problem. Electrocardiograms in the immediate postoperative period are crucial and the discovery of the RBBB-LAH pattern should forewarn of possible heart block. Careful monitoring of the electrocardiogram may assist in identifying some patients who have only brief episodes of block.

For the patient who is discovered to be in complete heart block following surgery, temporary pacing is indicated; if the block persists or recurs, a permanent pacemaker should be inserted. Smith et al. have reported ventricular tachycardia developing in a patient with
surgically induced complete heart block and a fixed-rate pacemaker when sinus rhythm returned approximately 1 year after surgery. They suspected that competition between the electronic pacemaker and the patient’s own pacemaker may have initiated the arrhythmia. A demand pacemaker may be the most suitable type to use for the treatment of surgically induced block.

Patients with transient complete heart block postoperatively who return to sinus rhythm with a RBBB-LAH pattern fall into a high-risk group; there is a significant chance of having the block recur later. These patients should be evaluated frequently and even a questionable history of a Stokes-Adams attack should probably be taken as an indication for the insertion of a demand pacemaker.

Patients whose postoperative course is marred by ventricular tachycardia represent the most difficult problems regarding management. One may speculate that these episodes of arrhythmia are initiated by brief periods of complete heart block and, thus, insertion of a demand pacemaker may be considered. Also, the patient may be treated with quinidine, procainamide, propranolol, or other antiarrhythmic drugs. It should be realized, however, that these drugs reduce the spontaneous frequency of lower pacemaker sites and could be dangerous if episodes of complete heart block should develop.

Since the high incidence of complications in postoperative patients with RBBB-LAH has only recently been recognized, means for preventing its occurrence at surgery have not yet been established. Kaiser et al.13 have described a method for obtaining epicardial and endocardial electrograms during open-heart procedures; the use of such recordings may be useful in the prevention of this and other conduction abnormalities.

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