Postoperative Left Anterior Hemiblock and Right Bundle Branch Block Following Repair of Tetralogy of Fallot

Clinical and Etiologic Considerations

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SUMMARY

Previous reports have indicated an incidence of right bundle branch block (RBBB) and left anterior hemiblock (LAH) pattern varying from 8–22% following corrective surgery in patients with tetralogy of Fallot. Among 207 patients with tetralogy of Fallot operated on at our institution, 8.7% developed an ECG pattern of RBBB and LAH. These patients were followed for 1–13 years (mean 6.2 years) for a total of 111 patient years. All patients are alive and none have had documented late atrioventricular dissociation, syncope, or other symptoms. Transient heart block was present in one patient in the immediate postoperative period but has not recurred. This group of patients differs significantly from other series in which such an ECG pattern was associated with a marked increase in morbidity and mortality. These data and the experimental evidence suggest that two distinct groups of patients exist: 1) a group in which this ECG pattern is secondary to lesions within the bundle of His and 2) a group in which the pattern is caused by lesions in the peripheral conduction system. It is postulated that these two groups which demonstrate the same ECG pattern may carry significantly different prognoses. Analysis of H-V intervals postoperatively may help identify patients at risk.

Additional Indexing Words:
Electrophysiology
Bifascicular block

The development of the electrocardiographic pattern of right bundle branch block (RBBB) and a superiorly oriented frontal plane QRS axis or left anterior hemiblock (LAH) following the total surgical correction of tetralogy of Fallot has been a subject of recent interest and controversy.1-10 Several recent reports have shown that RBBB-LAH occurs in 8 to 22% of operated patients.4-6 However, the reported clinical significance and prognostic value of this conduction abnormality have varied. Wolff and her associates4 reported RBBB-LAH to occur in 8% of postoperative patients with tetralogy of Fallot, and this pattern was associated with a significantly increased incidence of late complete heart block and sudden death. Other reports, however, accord RBBB-LAH a benign prognosis.6, 8, 9

The marked differences in the clinical course of patients with postoperative RBBB-LAH might suggest that clinically different patient populations exist which are not currently differentiated by the scalar electrocardiogram. Furthermore, the variance in the incidence of late complete heart block might imply that various electrophysiologic abnormalities might result in identical scalar electrocardiograms but may be associated with different long-term prognoses.

The purpose of this study is to review the long-term postoperative course and prognosis of patients with tetralogy of Fallot operated upon at the Columbia-Presbyterian Medical Center who have acquired an RBBB-LAH. The possible electrophysiological mechanisms which may explain this conduction abnormality are discussed.

Method and Materials

The electrocardiograms of 207 patients who underwent surgery for total correction of tetralogy of Fallot between 1960 and 1973 were reviewed. Preoperative electrocar-
diagrams were obtained in each patient 1–2 days prior to surgery. Initial postoperative tracings were obtained immediately after surgery, and repeat tracings were obtained intermittently over the follow-up period which varied from one to 13 years.

All electrocardiograms were analyzed and evaluated for conduction defects and frontal plane QRS axis change. RBBB pattern was diagnosed when the QRS interval exceeded 100 msec and slurred R waves were present in the right precordial leads.11 Left anterior hemiblock was considered to be present when the frontal plane axis, as determined by the standard electrocardiogram, lay between −30° and −120°, and the initial 0.02 second vector was displaced inferiorly and to the right.12 Patients who had RBBB-LAH prior to surgery were excluded.

Follow-up of all patients who developed postoperative RBBB-LAH were carried out either by direct examination or via telephone contact with the patient or his private physician. Recent electrocardiograms were obtained whenever possible. The most recent electrocardiograms were then compared to those obtained immediately after surgery and with all other electrocardiograms available over the long-term postoperative periods. The patients were followed for as long as 13 years (mean, 6.2 years) for a total of 111 patient-years.

**Results**

Of the study population of 207 patients, a total of 18 patients (8.7%) developed the electrocardiographic pattern of RBBB-LAH immediately following surgery. In none of the 18 patients did RBBB-LAH disappear during the follow-up period. All of the patients are alive and well. None of the patients have documented later atrioventricular dissociation or syncope, and no individuals have developed symptoms which would suggest the presence of undiagnosed cardiac arrhythmias. Transient heart block was present in one patient in the immediate postoperative period, but this has not recurred. This patient is alive and well nine years following operative repair (table 1). The prognosis of this population of patients, therefore, appears excellent.

**Discussion**

An incidence of RBBB-LAH ranging from 8 to 22% among patients after surgical repair of tetralogy of Fallot has been reported from several centers.4, 6, 8 However, observations regarding the clinical course have varied significantly. Cairns et al.,6 Downing et al.,8 Bocala and associates8 and this report have shown no increased incidence of late complications associated with this electrocardiographic pattern. This contrasts with the clinical follow-up data reported by Godman et al.,7 Wolff and associates4 and the cumulative data reported by Moss10 for patients with a postoperative RBBB-LAH pattern. Among the patients reported by Wolff, 41.7% developed complete heart block and 12.5% died suddenly from six months to two years after surgery.4 These serious complications far exceeded similar occurrences in a control group of postoperative patients. For this reason, post-surgical RBBB-LAH was considered by these authors to be an ominous prognostic sign. Godman et al.7 noted that seven of 11 patients who developed late complete heart block following repair of ventricular septal defect or tetralogy of Fallot had acquired an RBBB-LAH pattern on their postoperative electrocardiograms. Five of ten patients had prolonged H-V

**Table 1**

**Clinical Summary**

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<th>Pt.</th>
<th>Age at surgery (yr)</th>
<th>Yr follow-up</th>
<th>QRS duration Pre-op</th>
<th>QRS duration Postop</th>
<th>Max. QRS frontal plane axis Pre-op</th>
<th>Max. QRS frontal plane axis Postop</th>
<th>P-R interval Pre-op</th>
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*Transient heart block 10th postoperative day.*

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times documented by bundle of His electrograms.

Cairns and his associates\textsuperscript{8} present a more favorable view of the prognostic implications of this conduction abnormality. In their review of 141 patients operated upon for tetralogy of Fallot, 22\% were noted to develop an RBBB-LAH pattern following surgery. No mortalities were attributed to complications arising from the conduction disturbance.

On the basis of this disparity and on experimental evidence,\textsuperscript{13-15} we propose that two separate and distinct groups of patients may exist based on difference in etiology of the conduction abnormality.

The electrocardiographic pattern of RBBB following open heart surgery may occur as a result of injury to any part of the right bundle branch during surgery. Titus and associates\textsuperscript{16} have demonstrated injury to the proximal part of the right bundle branch at operation. However, Gelband et al.\textsuperscript{17} and Krongrad et al.\textsuperscript{18} have shown that a RBBB pattern usually occurs following a right ventriculotomy. It would appear from these observations that peripheral (fig. 1 — site 1) rather than proximal (fig. 1 — site 3) disruption of the right bundle branch is the predominant cause for postoperative RBBB, although in some instances, interruption of the right bundle branch in both areas may occur.

Similarly, a superiorly oriented frontal plane QRS axis may be produced as a result of various electrophysiologic mechanisms not necessarily associated with injury to the anterior fascicle of the left bundle. The superiorly oriented frontal plane QRS axis seen with endocardial cushion defects is thought to result from the asynchronous activation of the left ventricle as a result of the early activation of the posterior left ventricle.\textsuperscript{19-21} An electrocardiogram showing “left anterior hemiblock” in such patients, therefore, does not represent left ventricular conduction delay, but results from the asynchronous activation of the left ventricle secondary to the anatomic abnormality.

Injury to the His bundle can also account for RBBB-LAH. Watt and Pruitt\textsuperscript{13} and Krongrad and associates\textsuperscript{14} have shown that discrete lesions in the distal part of the His bundle produced early activation of the posterior left ventricular wall and an RBBB-LAH electrocardiogram in the canine heart. Krongrad and coworkers\textsuperscript{15} have also shown that injury entirely within the His bundle can produce the electrocardiographic pattern of “trifascicular block,” that is, RBBB-LAH and a prolonged P-R interval.

Finally, peripheral disruption of left bundle branch fibers directed toward the anterior left ventricular wall is another cause of superior shift in the frontal QRS axis, a true left ventricular conduction delay and the typical RBBB-LAH scalar electrocardiogram.\textsuperscript{15,22} Since the right bundle and the fibers to the anterior left ventricular wall are adjacent structures, and are in proximity to the ventricular septal defect, there seems little doubt that a combined lesion of the proximal right bundle and part of the left bundle branch can occur after repair of tetralogy of Fallot (fig. 1). However, an identical electrocardiogram may also be produced by a peripheral disruption of the right bundle branch due to the ventriculotomy and an isolated injury to part of the left bundle branch in cases where the course of the left bundle is somewhat atypical.\textsuperscript{23} Potential combinations of lesions resulting in a postoperative RBBB-LAH pattern are depicted in figure 1.

The different clinical behavior in the two groups of patients and prognostic significance of this electrocardiogram therefore may be explained by the different

\begin{figure}[h]
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\includegraphics[width=\textwidth]{figure1.png}
\caption{Schematic representation of the specialized A-V conduction system showing the various sites of injury that might account for a scalar electrocardiogram showing a right bundle branch block (RBBB) and left anterior hemiblock (LAH). RBBB might be produced by lesions to the peripheral branches of the right bundle during the ventriculotomy (site 1), injury to or excision of the moderator band (site 2), injury to the proximal part of the right bundle branch during the VSD closure (site 3), isolated injury to the fibers of the left bundle supplying the anterior part of the left ventricle (site 4) or injury to the proximal part of the His bundle caused by the shift in the frontal orientation of the QRS complex (LAH). Injury at any of sites 1, 2 or 3 and site 4, will cause the electrocardiographic pattern of RBBB-LAH. Because of the spatial proximity of sites 3 and 4, it is likely that combined lesions will occur. RBBB-LAH may be also caused by lesion to the distal part of the His bundle (site 5). Such patients are likely to have a different clinical course (see discussion). Additional injury to the more proximal parts of the His bundle (site 6) may account for a prolongation of the P-R interval or H-V time in some of these patients (“trifascicular block”). LBB = left bundle branch; RBB = right bundle branch; VSD = ventricular septal defect; Sep. RBB = septal division of right bundle branch.}
\end{figure}
locations where lesions to the specialized A-V conduction system occurred during surgery. It is likely that in patients with a benign long-term follow-up period as described in this report and by others that a peripheral disruption of the conduction system occurred during surgery (Fig. 1). A-V conduction following surgery occurs via undamaged branches of the specialized A-V conduction system. Early postoperative complete heart block is rare. Although no untoward clinical effects have currently been detected in these patients, the possibility still exists that heart block might occur if and when the patients develop arteriosclerotic heart disease affecting the remaining conduction fibers during adulthood.

His bundle lesions, on the other hand, may not only cause transient complete heart block immediately after surgery in patients with RBBB-LAH, but may also progress to permanent complete heart block. In the absence of a stable subsidiary pacemaker, an Adams-Stokes attack or sudden death may result.

Without the presence of postoperative transient complete heart block, or a prolongation of the P-R interval, these two groups of patients — the first with peripheral injury to the specialized A-V conduction system, and the second with a His bundle lesion — cannot currently be differentiated by the scalar electrocardiogram. Detection of H-V time prolongation in these patients, as performed by Godman et al., might suggest His injury and a more guarded prognosis. It seems reasonable, therefore, that His bundle recordings using the catheter technique should be performed in patients with surgically-induced RBBB-LAH.

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