Is Right Bundle Branch Block Avoidable in Surgical Correction of Tetralogy of Fallot?

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SUMMARY Right bundle branch block (RBBB) is usually considered almost unavoidable after repair of tetralogy of Fallot (TOF). By modifications of the standard technique, its frequency has been decreased to 32% in a series of 100 consecutive patients. These modifications are: (1) a very short right ventricular incision, avoiding the ventriculotomy-induced RBBB pattern; (2) an infundibular resection limited to the septal attachment of the infundibular septum; and (3) closure of the ventricular septal defect with a patch sutured to the very edge of the muscular septum, avoiding injury to the right bundle branch along the right aspect of the septum. No patient in this series sustained permanent complete atrioventricular heart block. Among patients with RBBB, five had a left anterior hemiblock. Postoperative intraventricular conduction was related to age at operation: The incidence of RBBB was significantly higher in infants. The beneficial effects of a low incidence of postoperative RBBB after repair of TOF are not known.

OPEN HEART CORRECTION of tetralogy of Fallot (TOF) is sometimes defined as total or complete. These terms are frequently misleading because surgery very often induces disorders such as pulmonary insufficiency and right bundle branch block (RBBB). RBBB has been reported to occur after repair of TOF in 60% to almost 100% of cases. In this paper, we describe technical modifications by which this frequency can be decreased.

Material and Methods

From September 1977 to March 1979, 100 patients survived open heart repair of TOF. Seven surgical deaths (all but one in infants younger than 4 months of age) during the same period were excluded from the study because in some cases a good postoperative ECG was not available. There were 63 males and 37 females, ages 1 month to 34 years (mean 4.4 years). Conventional cardiopulmonary bypass with moderate hypothermia was used in patients 1 year of age and older, and deep hypothermia with circulatory arrest was used in patients younger than 1 year old. Cold cardioplegic solution was injected in the aortic root after aortic cross clamping. For outflow tract repair, a prosthetic patch across the pulmonary annulus was inserted in 68 patients, an infundibular patch was used in 27 patients and the remaining five had a direct closure of the right ventriculotomy.

In the whole series, efforts were made to avoid RBBB. Our former technique was modified as follows: (1) The vertical incision of the right ventricle was made very short, not extending downward below the level of the lower edge of the infundibular septum (crista supraventricularis). (2) The resection of infundibular muscle was done very carefully on the septal side. The infundibular septum was freed from its septal attachment, and care was taken not to sever any superficial septal musculature below the inferior border of the ventricular septal defect (VSD). (3) The VSD was closed with a patch sutured to the very edge of the defect by minute single sutures. No attempt was made to avoid the conduction tissue by locating the suture line on the right aspect of the muscular septum.

Damage to atrioventricular (AV) and/or intraventricular conduction was assessed by comparing 12-lead ECGs recorded before and after operation. RBBB was considered present if QRS duration was greater than 0.10 second, with terminal forces directed anteriorly and rightward. RBBB plus left anterior hemiblock (LAH) was diagnosed if RBBB was associated with a leftward QRS axis deviation between -30° and -90°. Postoperatively, many patients had a normal QRS duration together with a notch of the ascending limb in lead V1. This was not considered a pathologic feature if the intrinsicoid deflection was not delayed more than 0.06 second.

Results

At the conclusion of operation, the mean ratio of right and left ventricular pressure was 0.49 ± 0.14. Among the 100 operated patients, the postoperative course was complicated in 17 and uneventful in 83. Patients experiencing minimal right ventricular failure a few days after operation were included in this last group.

AV conduction was unimpaired in 90 cases. Ten patients had transient third-degree AV block. Its duration varied from a few hours to 10 days. There were no late conduction disturbances or sudden death among these patients (follow-up range 4–20 months). No case of permanent third-degree AV block was encountered in this series. Postoperative intraventricular conduction was considered normal in 67 cases. RBBB was noted as an isolated feature in 27 patients, and was associated with LAH in five (5% of the whole series). One patient had isolated left bundle branch block.
The frequency of RBBB was related to age at operation: Patients less than 1 year old had a significantly higher incidence of RBBB than older patients (table 1). It was not related to the type of outflow tract repair or to the pressure ratio between right and left ventricles at the conclusion of the procedure (table 2). In 15 patients with postoperative RBBB with or without LAH, the operative report included mention of resection of a large bundle extending from the lower interventricular septum to the free wall of the right ventricle.

Postoperatively, the presence of RBBB was associated (table 2) with a higher incidence of cardiac complications (28% vs 11%) compared with patients without RBBB (p < 0.05). In the first 3 months after operation, cardiac catheterization was performed in 31 cases. One patient had a significant residual VSD that was subsequently closed.

**Discussion**

There are several possible anatomic substrates for RBBB after open heart repair of TOF. Intraventricular conduction can be impaired at three levels. The most widely accepted mechanism is the interruption of the terminal right ventricular conduction network by the right ventriculotomy. Kronrad et al. suggested that the ventriculotomy-induced RBBB pattern was due to disruption of a distal branch of the right bundle. Whatever the exact mechanism, a very short incision in the right ventricular infundibulum is the best way to avoid ventriculotomy-induced RBBB pattern. This pattern is not by itself a major conduction disturbance, but its differentiation from central injury to the right bundle branch cannot be made by standard ECG criteria. This differentiation is possible only with sophisticated intracardiac recording techniques. Thus, from a pragmatic standpoint, the ventriculotomy-induced RBBB pattern obscures any intraventricular conduction defect produced by operation and is therefore best avoided.

The second site at which right bundle branch conduction can be blocked is within the moderator band. This muscular bundle is often transected with the distal part of the right bundle branch during resection of muscle below the level of the VSD (the trabecula septomarginalis). Resection of the upper part of the trabecula septomarginalis is of little value in repair of TOF, because the muscle bundle is oriented from the base to the right ventricular apex, and does not take part in producing the infundibular stenosis. In most cases, resection of the parietal extension and the body of the infundibular septum (crista) is sufficient to relieve the stenosis, and does not impair intraventricular conduction, because there is no conduction tissue in the parietal portion of the infundibular septum (Anderson R.H.: personal communication).

The third possible site of surgical disruption of the right bundle branch is the inferior border of the VSD during insertion of the patch. This is reflected by the frequency of RBBB after transatrial closure of isolated membranous VSD. The patch is usually inserted on the right aspect of the muscular septum to avoid the conduction tissue, which is presumed to occupy the rim of the defect. This technique endangers the right bundle branch, because even though it penetrates the crest of the septum, it becomes superficial on the right aspect of the muscular septum. When the patch is sutured to the crest of the defect as advocated by Starr and colleagues and our group, the ventricular conduction tissues are avoided because these structures are rarely found directly on the crest. The penetrating AV bundle is not endangered by this technique because its location is much more posterior in the remnant of the membranous septum found between aortic and tricuspid annuli. In this series no patient developed permanent AV block.

The relative frequency of these three sites of injury (right ventriculotomy, VSD closure and infundibular resection) has been studied by Horowitz et al. Using intraoperative mapping in 26 patients, these authors found the RBBB to be proximal in six cases, distal in five and at the level of distal ramification of the bundle in 15. In contrast, Sung et al. showed that in 10 of 11 patients, the disruption of the ramifications of the right bundle branch was responsible for the RBBB pattern.

Despite use of our technique, RBBB developed postoperatively in one-third of the patients in this series. In 15 of these 32 patients, a large muscular bundle extending from the lower part of the septum to the right ventricular free wall had to be resected. This resection was consistently associated with postoperative RBBB. In later cases, we tried to transect such bundles as far as possible from the septum to avoid injury to the conduction tissue. In 17 cases, no explanation was found for the RBBB.

The only significant factor found to correlate with
intraventricular conduction defects was age at operation (table 1). The frequency of RBBB in infants younger than 1 year of age was twice that in the older group (52% vs 24%, \( p < 0.01 \)). The technical modifications discussed above are more difficult to implement in infants, because the size of the right ventriculotomy is proportionally longer in the smaller hearts.

The beneficial effects of reducing the frequency of RBBB after correction of TOF are still to be delineated. The rate of bifascicular block (RBBB and LAH) in this series was 5%, compared with the commonly reported incidence of 15–20%. Though the prognostic significance of bifascicular block is controversial\(^\text{10}\) it is almost certainly best avoided. The deleterious effects of RBBB on right ventricular function have been shown after closure of VSD with pulmonary hypertension\(^\text{11}\) but not after repair of TOF. Such a study has been impossible because in no series has a consistent control group without RBBB been available. The present approach makes feasible a prospective study of the influence of RBBB on late results after repair of TOF.

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**References**

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