Lesions of the Atrioventricular Conduction System after Repair of Ventricular Septal Defect

Relation to Heart Block

By Jack L. Titus, M.D., Guy W. Daugherty, M.D., John W. Kirklin, M.D., and Jesse E. Edwards, M.D.

During the repair of congenital defects of the ventricular septum, various disturbances of cardiac function may occur.\(^1\)\(^-\)\(^5\) Permanent complete heart block has been the most serious of these disturbances. Right bundle-branch block seems benign. Increased knowledge of the anatomic features of the atrioventricular (AV) conduction system has resulted in surgical techniques that have nearly eliminated complete heart block.\(^5\) These techniques are based on the assumption that trauma to the AV conduction system occurring during surgical repair of a ventricular septal defect is the cause of postoperative functional disturbances. However, studies documenting an anatomic cause for heart block are few; Reemtsma and associates\(^6\) investigated the lesions responsible for fatal postoperative complete heart block in three cases—one of isolated ventricular septal defect, one of tetralogy of Fallot, and one of common AV canal.

There is general agreement that permanent complete heart block is almost always associated with a lesion in the proximal portion of the AV conduction system.\(^7\)\(^-\)\(^8\) There is not such general agreement concerning the morphology of the conduction system of hearts with right bundle-branch block.\(^7\)

The present study of cases operated upon during a period when heart block was not rare (1955 to 1960) was undertaken to determine whether postoperative interference with AV conduction can be correlated with lesions in the conduction system.

Materials and Methods

In 13 of the 21 human hearts with congenital ventricular septal defects, in which we previously described\(^9\) the location and course of the AV conduction system, surgical closure of ventricular septal defects had been performed. We reviewed these 13 cases in order (1) to establish the presence or absence of injury to the AV conduction system as a result of surgical repair of ventricular septal defects and (2) to correlate morphologic findings with the postoperative functional status of the conduction system.

Since the location and course of the conduction system of the 13 cases under consideration have been previously reported,\(^9\) we have retained in this report the case numbers assigned to the specimens previously. The 13 cases were grouped, according to the situation of the ventricular septal defect, into the following divisions:

1. High ventricular septal defect (immediately beneath aortic cusps) (cases 7 to 13).

2. Multiple defects (cases 18 and 19).

3. Tetralogy of Fallot (cases 20 and 21).

Serial histologic sections of the appropriate areas had already been prepared.\(^9\) These were reviewed, seeking lesions within the conduction system presumed to have resulted from surgical repair of the defect. Since all the patients had died in the immediate postoperative period, the lesions encountered were acute. They included (1) hemorrhage, (2) infarction, and (3) traumatic disruption. Edema was not considered a specific lesion in this study, because its morphologic appearance could not be satisfactorily defined. Lesions were graded 1 to 4, grade 1 representing minimal definite involvement and grade 4 representing involvement of all fibers in any cross section.

The functional status of cardiac conduction after operation was determined from the postoperative electrocardiograms, if available. In some
cases an electrocardiogram had not been made in the immediate antemortem period. In such situations the most recent observation of the physician who cared for the patient was used as the basis for categorizing the type of cardiac rhythm present. The postoperative functional status of the conduction system was considered in one of the following four categories: (1) sinus rhythm, (2) right bundle-branch block, (3) complete heart block, and (4) postoperative functional status of conduction system not established.

In the 13 cases discussed herein the anomalies were surgically repaired during the years 1955 through 1959.

Results

Type of Lesion

1. High Ventricular Septal Defect (Cases 7 through 15). In these nine specimens, it had been previously found that the AV node was normally located and that the common bundle (bundle of His), or either of its main branches, passed posterior and inferior to the defect. Lesions within some part of the major divisions were found in all specimens except that from case 8. The lesions are listed in table 1 and representative examples are illustrated in figures 1 and 2.

2. Multiple Defects (Cases 18 and 19). The common bundle was related to the anterior rim of a large posterior-basal ventricular septal defect in case 18, but not to a smaller midseptal defect. The bundle and both its branches were hemorrhagic where they lay near the repaired basal defect (fig. 3).

In case 19 (fig. 4) the common bundle passed through the valvular ring in the region of intact ventricular septal myocardium separating the two defects and then lay in the remnant of membranous septum forming the posterior limit of the anterior defect. Hemorrhages were found in the bundle and the bundle branches, and a suture had been placed adjacent to the right branch.

3. Tetralogy of Fallot (Cases 20 and 21). In each specimen, a flame-shaped hemorrhage in the floor of the right atrium emanated from

<table>
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<th>Case</th>
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<td>(2) Infarction</td>
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Table 1

Histopathologic Findings in High Ventricular Septal Defect

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Lesions in conduction system following surgical repair of high ventricular septal defect (case 9). a. Right ventricle and pulmonary valve. Defect posterior and inferior to crista supraventricularis has been repaired with Ivalon patch. b. Right atrium and right ventricle. AV conduction system has been dissected. Suture lies across junction of the AV node (N) and main (common) bundle. c. Suture crossing conduction tissue (b) removed to better show AV node and main bundle (M.B.), both of which appear hemorrhagic. d. Histologic section through remnant of membranous septum forming posterior edge of ventricular septal defect (V.S.D.). Common bundle (M.B.) is hemorrhagic (dark areas) and interrupted in its lower part by defect made with suture. The right bundle branch (R.B.) is hemorrhagic [Mallory-Heidenhain (M-H); × 15]. e. Branching of common bundle (B) in remnant of membranous septum forming posterior edge of V.S.D. Bundle nearly transected by a suture (defect) and both left bundle branch (L.B.) and right bundle branch (R.B.) are hemorrhagic (Mallory-Heidenhain; × 15). f. Common bundle and left bundle branch at posterior-inferior angle of V.S.D. are hemorrhagic (Mallory-Heidenhain; × 15). a sutured area in the region of the AV node (fig. 5), and histologically, hemorrhages were seen in the AV node of each heart (fig. 6a). In each specimen, the common bundle lay close to the posterior rim of the septal defect, where, in each instance, trauma to the bundle had occurred (fig. 6b,c,d).

Correlation of Morphologic Findings with Antemortem Functional Status of AV Conduction System (Fig. 7)

1. Sinus Rhythm. A sinus rhythm was present at the end of the operation in case 8, and no lesions were found in the conduction system.

2. Right Bundle-Branch Block. Three patients manifested right bundle-branch block. Postoperative electrocardiograms in case 11 demonstrated right bundle-branch block; also, varying degrees of AV block occurred at times, suggesting disturbances (electrocardiographically) in both nodal and bundle areas. A large part of the bundle was not conclusively demonstrated in the specimen, presumably because it lay in an area of infarction.
in the ventricular septum. The only demonstrably abnormal part of the conduction system was the right bundle branch, which was infarcted and hemorrhagic.

The postoperative electrocardiograms of cases 12 and 18 showed right bundle-branch block. In each specimen, large areas of hemorrhage and infarction were present in the right bundle branch, and lesser degrees of hemorrhage and infarction were found in the common bundle and in the left bundle branch.

3. Complete Heart Block. Complete heart block was proved in six cases (cases 13 to 15 and 19 to 21) and was probable in two others (cases 9 and 10).

In case 9, although a sinus rhythm had been observed at the end of the surgical procedure, a sudden arrhythmia or acute heart

![Figure 2](http://circ.ahajournals.org/lookup/suppl/doi:10.1161/01.CIR.28.1.84/-/DC1)

Lesions in conduction system associated with postoperative complete heart block (case 15). a. Main bundle (dark oval area within rectangle) penetrating fibrous valvular ring is hemorrhagic, as are portions of septal leaflet of tricuspid valve (T.V.) and ventricular septum (V.S.). Portion of atrium (Atr.) is also shown (Mallory-Heidenhain; × 7). b. Higher magnification of area enclosed by rectangle in a shows hemorrhage in main bundle (outlined) (Mallory-Heidenhain; × 40). c. Main bundle (within rectangle M.B.) in remnant of membranous septum (M.S.) forming the posterior edge of V.S.D. is hemorrhagic (Mallory-Heidenhain; × 7). d. Higher magnification of area enclosed by rectangle in c shows hemorrhage in main bundle (Mallory-Heidenhain; × 40). e. Main bundle (outlined) has been transected by a suture. This section is near the posterior-inferior angle of V.S.D. (Mallory-Heidenhain; × 12). f. Main bundle branching into left and right branches at the posterior-inferior angle of the surgically closed V.S.D. (D). Dark areas within conduction tissues are hemorrhages (Mallory-Heidenhain; × 12).
Figure 3
Postoperative right bundle-branch block in case of repaired, large posterior-basal V.S.D. (case 18). a. Normal AV node is in plane of defect in ventricular septum (Mallory-Heidenhain; × 4). b. Normal main bundle passes through fibrous AV ring in plane of defect. "M.V." indicates portion of mitral valve (Mallory-Heidenhain; × 4). c. Main bundle (B) branches in lower portion of intact membranous septum just anterior to large, posteriorly situated V.S.D. Dark area along the left endocardial surface is hemorrhage (Mallory-Heidenhain; × 7). d. Right and left bundle branches are hemorrhagic just distal to origin from common bundle. Section represents area approximately 3 mm. anterior to section shown in c. (Mallory-Heidenhain; × 7).

Figure 4
Postoperative complete heart block in case of repaired V.S.D. (case 19). Two defects were present: unrepaired posterior defect just below tricuspid ring and sutured defect posterior and inferior to the crista supraventricularis. a. Normal AV node is in same plane as anterior extremity of more posterior V.S.D. "M.V." and "T.V." indicate mitral and tricuspid valves, respectively (Mallory-Heidenhain; × 8). b. Common bundle near posterior rim of more anterior V.S.D. is hemorrhagic (Mallory-Heidenhain; × 8). c. Hemorrhagic disrupted common bundle immediately subjacent to posterior-inferior extremity of V.S.D. (Mallory-Heidenhain; × 8).

block was thought to have occurred terminally. Hemorrhages and a suture involved the common bundle and both bundle branches.

Another patient (case 10) had temporary complete heart block during part of the operation. Asystole, refractory to an electric pacemaker, occurred 12 hours after the operation. The bundle of His was hemorrhagic (grade 2).

In cases 13, 14, 15, and 19 complete heart block was present at the end of the operative procedure. Hemorrhages or areas of infarction or both were found in the common bundle in each specimen. In cases 13, 15, and 19 the bundle branches were similarly involved.

During operative correction of the tetralogy of Fallot (cases 20 and 21), complete heart block developed and persisted. In each instance, hemorrhage (grade 1 or 2) involved the AV node, and marked traumatic disruption of the bundle and both bundle branches was present.

4. Functional Status of the Conduction System Not Determined. In case 7, postoperative electrocardiograms were not available; therefore, this case was not classifiable ac-}

Figure 5
Floor of right atrium in repaired tetralogy of Fallot (case 21). A flame-shaped hemorrhage (dark area) in region of AV node emanates from a suture. Complete heart block occurred postoperatively.

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cording to the antemortem functional status. Histologically, hemorrhages were found in the common bundle, the right branch and, to a lesser degree, in the left branch.

Summary and Conclusions
Lesions of the atrioventricular (AV) conduction system related to the surgical repair of ventricular septal defects were sought in 13 human hearts from patients who were operated on from 1955 through 1959 and who died in the postoperative period. Lesions were found in 12 of the 13 cases (fig. 8).
hearts showed major lesions in the AV node or the main bundle of His, or both. In two of the nine, available evidence suggested that complete heart block had been present. In the other case, records were insufficient to permit evaluation of the functional status of the conduction tissue.

Three patients had right bundle-branch block. In each of their hearts, lesions were observed in the right branch; in two, lesions also were observed in the common bundle.

We conclude that, in patients operated on for closure of ventricular septal defects, postoperative interference with AV conduction may be correlated with lesions in the conduction system.

References

**Figure 7**
Correlation of postoperative functional status and location of lesions within AV conduction system is schematically represented. "L.B.B." represents left bundle branch; and "R.B.B.,” right bundle branch. Numbers beside each column refer to case numbers (see text).

**Figure 8**
Types of lesions with locations in conduction system are indicated. No such lesions were found in case 8.
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