The Conducting Tissues in Primitive Ventricular Hearts without an Outlet Chamber


SUMMARY We have studied the disposition of the cardiac conducting tissues in four hearts from situs solitus individuals possessing primitive ventricles without outlet chambers. These hearts correspond to the type of univentricular heart defined as common ventricle by Lev. All the hearts studied possessed normally positioned great arteries. Two groups, each consisting of two hearts, could be distinguished.

The first type possessed a small posterior ridge which divided the posterior portion of the primitive ventricle into right and left ventricular sinususes. The papillary muscles to the atrioventricular valves were separate structures and arose on each side of this posterior ridge. The conducting tissues in these hearts arose from an atrioventricular node situated in the atrial septum but deviated posteriorly. The atrioventricular bundle pierced the fibrous annulus posteriorly and descended on the posterior ridge, lying to its left side. A bifurcation was not identified, and bundle branches were not present.

The other two hearts had no posterior ridge. A common posterior papillary muscle supported both atrioventricular valves, and in one a marked anterior muscle bar produced obstruction of the pulmonary outflow tract. The connecting atrioventricular node was situated laterally in the right atrioventricular valve orifice, and the atrioventricular bundle descended into the right parietal wall of the primitive ventricle. A bifurcation and bundle branches were not observed.

The disposition of conducting tissue in these hearts differs from that found in "primitive ventricle with outlet chamber" in that the connecting atrioventricular node and bundle are situated anteriorly and are intimately related to the transposed pulmonary artery outflow tract in the latter anomaly. The surgical significance of these findings is emphasized.

DESPITE THE CONSIDERABLE INTEREST engendered by hearts which possess an apparently single ventricular chamber, relatively few investigations into the disposition of the conducting tissues in these anomalies have been published. Monckeberg1 demonstrated that in such hearts the atrioventricular bundle might be related either to a posterior ridge or from an unusually situated atrioventricular node from which it descended anteriorly. Visioli2 confirmed the first arrangement of conducting tissue in a case of what he termed "cor biloculare." We3 showed that the anterior distribution of conducting tissue was to be expected in primitive ventricular hearts with outlet chambers and transposed arteries, and our findings have subsequently been confirmed by Bharoti and Lev.4 Most univentricular hearts possess an outlet chamber.5 In those patients with univentricular hearts in which the outlet chamber is absent, the ventricle is unseptated, presenting as a huge ventricular septal defect. In this arrangement, the conducting tissue might be expected posteriorly, as found in the cases described by Monckeberg1 and Visioli.2

Traumatic heart block is a well-recognized complication when patients with hearts of this type are submitted to corrective surgery.6,7 and this is borne out by experience in our own center. Of six cases submitted to surgery in Liverpool, two developed complete heart block; of these one survived with a permanent pacemaker. Three further patients developed variable rhythms with atrioventricular dissociation but without complete heart block, and two of these died. In view of this high incidence of rhythm disturbance in primitive ventricular hearts without outlet chambers, we have investigated the disposition of conducting tissues in the hearts of the three patients who died, and in a similar heart from our cardiopathological collection.

Definitions and Terms

Considerable controversy surrounds the nomenclature of univentricular hearts. Lev and his colleagues8, 9 divided the

1. Monckeberg H: Cor biloculare. J Path Bact 32: 369, 1929
anomalous hearts into those with a “common ventricle,” which did not possess an outlet chamber, and those with “single (primitive) ventricle,” which did possess an outlet chamber. Van Praagh and his colleagues criticized this terminology on semantic grounds, and in its place suggested that the terms “single” and “common” be used interchangeably, but that the whole group be divided into four categories, types A through D. This classification seems somewhat unwieldy to us, and we have grave doubts concerning the validity of the embryological and morphological premises of such a subdivision. Although our previous study showed that differences in disposition of conducting tissues made it essential to distinguish hearts with an outlet chamber from those without, our studies of single ventricle with outlet chamber and the present study lead us to believe that there is no essential difference between the morphology of the main chamber in the two anomalies, other than a variable degree of hypoplasia of the posterior ridge. We therefore have extended Lev’s use of the term “primitive” ventricle to include hearts lacking an outlet chamber and we refer to the two categories of univentricular hearts in terms of “primitive ventricles” with or without an outlet chamber.

**Primitive Ventricle with Outlet Chamber** therefore refers to the anomaly which Lev named “single” (primitive) ventricle, which Van Praagh et al. termed single ventricle type A and which others have termed “double inlet left ventricle.”10 (fig. 1A, B).

**Primitive Ventricle without Outlet Chamber** refers to the malformation which Lev previously termed “common” ventricle. It corresponds to the single ventricle type C described by Van Praagh et al. (fig. 1C, D).

**Primitive Ventricle** will be used to describe the main chamber of univentricular hearts (fig. 1).

**Outlet Chamber** will describe the small anterior chamber giving rise to one of the great arteries in the anomaly of primitive ventricle with outlet chamber (fig. 1). The chamber represents the embryonic bulbus.

**Bulboventricular Septum** will describe the septum which divides the outlet chamber from the primitive ventricle (fig. 1).

**Outlet Foramen** will describe the foramen connecting the primitive ventricle with the outlet chamber (fig. 1).

### Materials and Methods

Three of the hearts studied came from patients who died following operation. The fourth heart was taken from the cardiopathological collection of the Royal Liverpool Children’s Hospital. Each of the hearts was studied to ascertain the morphological arrangement of the ventricular chambers, and the situation of any septal structures within the ventricle. In the hearts on which surgical palliation had been attempted, particular care was taken to establish the relationship of the inserted patch to ventricular landmarks. Pertinent features were photographed, in the operated cases both before and after removal of the patch.

Following gross study, the hearts were prepared for histological examination. In all instances the entirety of the tricuspid orifice was sectioned, cutting sections in a frontal plane relative to the interatrial septum. In two hearts this could be accomplished by preparing the tricuspid orifice as a single “block.” In the other hearts it was necessary to divide the orifice into three blocks. These consisted of a) the posterior interatrial septum, including the coronary sinus, b) the anterior interatrial septum including the roots of both great arteries, and c) the lateral part of the orifice. All of the blocks taken were prepared for sectioning by routine embedding in paraffin wax. Sections were cut at 10 microns thickness.

In case 4 a further block, from the right parietal wall of the ventricle, was subsequently sectioned.

All sections cut were retained. Initially, one section in each fifty was mounted and stained using Masson’s trichrome technique. Following examination of these sections, additional sections were mounted and stained from areas of particular interest, mounting all 50 sections if deemed necessary. Some of these additional sections were stained using the Van Gieson technique.

In two of the hearts, the block containing the connecting atrioventricular node was reconstructed. This was performed by drawing each fiftieth section from these blocks on to a plastazote sheet of 5 mm thickness with a magnification factor of ten. The outlines of the tissue were then cut
Table 1. Clinical Data

<table>
<thead>
<tr>
<th>Case</th>
<th>Age at death</th>
<th>Mode of presentation</th>
<th>Clinical course</th>
<th>Catheter diagnosis</th>
<th>Operative procedure</th>
<th>Post-op course</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2 m</td>
<td>Dyspnea during feeding at 2 w</td>
<td>Chest infections Cardiac failure</td>
<td>Large shunt ASD + VSD ? cushion defect</td>
<td>Insertion of patch to septate primitive ventricle</td>
<td>Heart block required pacing Died 24 hrs post-op</td>
</tr>
<tr>
<td>2</td>
<td>3 d</td>
<td>Cyanosis following feeding on first day of life</td>
<td>Rapid deterioration with cyanosis and cardiac failure</td>
<td>ND</td>
<td>ND</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>21 m</td>
<td>Failure to thrive Cyanosis</td>
<td>Persistent mild cyanosis and heart failure</td>
<td>VSD with bi-directional shunt &amp; PHT (? multiple VSDs)</td>
<td>Insertion of patch to septate primitive ventricle</td>
<td>Variable rhythm with AV dis. gastro-intestinal bleeding, died 2 w post-op</td>
</tr>
<tr>
<td>4</td>
<td>4 y</td>
<td>Murmur noted at 2 m on routine examination</td>
<td>Cardiac failure Catheter at 2½/12 PDA ligated and PA banding at 3 m</td>
<td>VSD Banded PA Bidirectional shunting</td>
<td>Insertion of two patches to septate primitive ventricle Debanding of pulmonary artery</td>
<td>AV dis. Required pacing intermittently Re-op for hemorrhage Died 4 d post-op</td>
</tr>
</tbody>
</table>

Abbreviations: AV dis. = AV dissociation; VSD = ventricular septal defect; ASD = atrial septal defect; PDA = patent ductus arteriosus; PHT = pulmonary hypertension; d = days; m = months; y = years; ND = not done.

round, and the margins occupied by conducting tissue, fibrous tissue, ventricular and atrial myocardium indicated. The sections were then fixed together in correct sequence, and the edge thus created colored to show the disposition of the various tissues.

Results

Clinical Data

The relevant clinical data from the four cases are shown in Table 1.

Table 2. Summary of Pathological Findings

<table>
<thead>
<tr>
<th>Case</th>
<th>Atrial situs</th>
<th>Great arteries</th>
<th>Ventricular morphology</th>
<th>Septal structures present</th>
<th>Other anomalies</th>
<th>Coronary arteries</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>S</td>
<td>NR</td>
<td>Primitive ventricle</td>
<td>Well formed anterior ridge continuous with conus septum</td>
<td>E.F.E. of left atrium</td>
<td>Normal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Posterior ridge present</td>
<td>Posterior ridge present and continuous with oblique muscle mass passing across floor of right ventricle</td>
<td></td>
<td>Well formed anterior descending from left coronary</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Posterior papillary muscles discrete</td>
<td>Hypoplastic aortic arch Pre-ductal coarctation P.D.A</td>
<td></td>
<td>Normal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Aortic-mitral continuity</td>
<td></td>
<td></td>
<td>Well defined anterior descending from left coronary</td>
</tr>
<tr>
<td>2</td>
<td>S</td>
<td>NR</td>
<td>Primitive ventricle</td>
<td>Well marked anterior and apical ridge separating ventricular sinususes and continuous with posterior trabeculum. Posterior ridge separate (Poorly formed)</td>
<td>E.F.E. of left atrium</td>
<td>Several anterior descending vessels from left coronary</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Posterior septum present but hypoplastic</td>
<td></td>
<td></td>
<td>Otherwise normal</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Posterior papillary muscles discrete</td>
<td></td>
<td></td>
<td>Single coronary from left coronary cusp.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Aortic-mitral continuity</td>
<td></td>
<td></td>
<td>No major anterior descending artery</td>
</tr>
<tr>
<td>3</td>
<td>S</td>
<td>NR</td>
<td>Primitive ventricle</td>
<td>Well formed anterior ridge continuous with conus septum</td>
<td>Mitral stenosis E.F.E. of left atrium</td>
<td>Slight E.F.E. of both atria Single coronary artery</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Posterior septum completely absent Aortic-tricuspid-mitral continuity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Common papillary muscle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>S</td>
<td>NR</td>
<td>Primitive ventricle</td>
<td>Anterior ridge and conus septum well developed. Trabecula septomarginalis prominent and obstructing R.V. outflow</td>
<td>Slight E.F.E. of both atria Single coronary artery</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Posterior septum absent Common papillary muscle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Aortic-mitral continuity</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: S = solitus; NR = normally related; E.F.E. = endocardial fibro-elastosis.
In all cases the pulmonary artery had a complete muscular conus, resembling the normal pulmonary infundibulum. In contrast, the aortic valve was in fibrous continuity with the left atrioventricular (A-V) valve in three cases and with both atrioventricular valves in the fourth. The right A-V valve resembled the normal tricuspid valve, possessing three cusps and a pattern of papillary muscles typical of a tricuspid valve. In contrast, the left A-V valve had two cusps and a pattern of papillary muscles resembling that with a mitral valve. In case 3 the left A-V valve was stenosed with fusion of the commissures and thickening of the cusps. Examination of the sinus portion of the chamber revealed evidence of structures which enabled the hearts to be subdivided into two groups.

**Group A**

In two hearts (cases 1 and 2, table 2) a posterior ridge was present dividing the posterior part of the ventricle into separate sinuses. The posterior papillary muscles of the atrioventricular valves arose separately on either side of this ridge (fig. 2). In neither case did this ridge continue anteriorly and in both cases it passed obliquely to the right, dividing the ventricle unequally. This was particularly marked in case 1.

In both these specimens a second, posterior, trabeculum was present which lay to the left of the first and which was directed more centrally. In both cases a sinus was present behind this structure, and in case 2 it continued, with a well-

![Figure 2](image-url)

**Figure 2.** A) View of heart from case 1 with RV opened. The specimen is viewed from the right looking posteriorly and to the left. The tricuspid and mitral valves can be seen on either side of the posterior ridge. B) View of specimen from case 2. RV opened and viewed from the right. Tricuspid and mitral valves are seen on either side of the posterior trabeculum. A well developed anterior ridge is present. Abbreviations: PV = pulmonary valve. PT = posterior trabeculum. Post. Ridge = posterior ridge.

![Figure 3](image-url)

**Figure 3.** A) Left ventricular view of specimen from case 4 after removal of patches showing probe through posterior defect. A common papillary muscle supports the septal leaflets of both mitral and tricuspid valves. B) Right ventricular view of same specimen before removal of patches. The common papillary muscle can be seen between the two patches. The large muscle bundle which obstructed the RV outflow tract is seen cut across.
FIGURE 4. Photomicrographs of sections from case 2 showing A) posterior connection; B) conducting tissue on side of posterior ridge; C) poorly formed anterior node; D) anterior bundle ascending to fibrous ring (unconnected to the anterior node). Abbreviations: Post. Trab = posterior trabeculum; Post. Ridge = posterior ridge; Vent. C.T. = ventricular conducting tissue.
formed apical septum which in turn was continuous with an anterior ridge.

**Group B**

The two remaining hearts (cases 3 and 4, table 2) did not have a posterior ridge. In both these hearts the septal cusps of both atrioventricular valves were tethered by a common papillary muscle (fig. 3a). This muscle was separated from the posterior wall of the primitive ventricle by a sinus, and in one of the operated specimens, it had been necessary to insert a patch both in front of and behind this structure to avoid leaving a residual septal defect (fig. 3b). One of these hearts also showed a prominent muscular bar which passed from the underside of the conus septum to the apex of the chamber, and which gave rise to the anterior papillary muscle of the tricuspid valve (fig. 3b). This structure had produced considerable obstruction to the pulmonary outflow tract following insertion of the patch.

**Histological Findings**

Two distinct distributions of conducting tissues were found, depending on the presence or absence of the posterior ridge.

**Group A (cases 1 and 2)**

In both hearts with a posterior ridge, a well-formed node was observed in the interatrial septum (fig. 4a). This structure passed posteriorly to form an atrioventricular bundle which perforated the fibrous annulus. The bundle then descended down the posterior ridge (fig. 4b) and split into subendocardial ramifications. In case 1, this bundle had been severely traumatized by stitches, and the extensive hemorrhage made accurate delineation of the boundaries of the bundle ramifications impossible. In case 2, the bundle ramified to the left side of the posterior ridge, as demonstrated by the reconstruction (fig. 5a). These ramifications did not extend on to the posterior septum which divided the great arteries, or its apical extension. In this case, however, further conducting tissue was identified on this septum, forming subendocardial ramifications on its left side. A well-formed anterior bundle ascended from this tissue toward the aortic root (fig. 4d). Although the bundle reached the annulus, it did not pierce the fibrous tissue. However, a second aggregation of node-like tissue was identified in the atrial myocardium to the left of the aortic root and directly above the bundle (fig. 4c). In the other case, no evidence of extranodal collections of conducting tissue related to the tricuspid annulus was observed.

**Group B (cases 3 and 4)**

In both these hearts, a hypoplastic node-like structure was present in the interatrial septum (fig. 6c). This structure did not give rise to an atrioventricular bundle and did not make contact with ventricular myocardium. Instead, the connect-

**Figure 5.** Drawings of reconstructions of blocks from cases 2 and 3. A) Posterior block (viewed from the front) from case 2 showing posterior interatrial septum (AM), posterior trabeculum (PT) with sinus behind it (arrowed) and apical ridge (AR). Note the bundle (in black) passing down a ridge to the right of the posterior trabeculum and apical ridge into the right ventricular sinus (compare with fig. 2 B). B) Lateral block from case 3 (viewed from the left) showing lateral connection with bundle passing down on to muscular trabeculum (compare with fig. 7). Abbreviations: AM = atrial myocardium; N = node (dark hatched); VM = ventricular myocardium. The fibrous ring and tricuspid valve leaflet tissue are indicated by the "coarse dotted" area between AM and VM.
ing atroventricular bundle was located laterally in the tricuspid orifice. It arose from an aggregation of specialized tissue adjacent to the fibrous annulus (fig. 6a, b). Further aggregations of conducting tissue spread both anteriorly and posteriorly in the atrial tissues adjacent to the annulus from this main node-like structure. From the lateral “node” a well-developed bundle pierced the fibrous annulus and descended into the ventricular myocardium in each case (fig. 6a). In case 3, this bundle passed down a well-developed trabecula and divided into subendocardial ramifications resembling the normal left bundle branch (fig. 7). The bundle in case 4 descended out of the block of tissue as a discrete structure, but in a block removed from the distal ventricle, tissue of left bundle branch type was identified on the right parietal wall. This tissue was severely traumatized and could not be followed with accuracy. In neither case was a discrete right bundle branch structure observed, and no further specialized tissue was identified in relation to the tricuspid orifice. A reconstruction of the lateral conducting system from case 3 is illustrated in figure 5b.

Correlation of Electrocardiographic Patterns with Histological Findings

All four patients had left axis deviation, in three cases with widening of the QRS complexes (cases 1, 2 and 3). Q waves present in the left chest leads, which may have suggested septal activation, were observed in cases 1 and 3, and were absent in cases 2 and 4. Although the significance of correlating this small number of cases cannot be statistically validated, we did look for but failed to find any correlation between the conducting pathways observed and either the overall QRS axis, the presence or absence of Q

**Figure 6.** A) Photomicrograph of lateral node and bundle in case 4. B) Similar section (lower power) from lateral connection of case 3. C) Section of posterior interatrial septum from case 3 showing hypoplastic posterior node. Abbreviations: Tric. Lft. = tricuspid leaflet; Mitral Lft. = mitral leaflet.
waves in the lateral chest leads, or the presence of widening of the QRS complexes.

Discussion

Surgical Considerations

The present results indicate that the conducting tissues in primitive ventricles without outlet chambers are distributed in a totally different fashion from that demonstrated in primitive ventricles with outlet chambers. It is of great importance that differences in conduction pathways exist within the group of primitive ventricles without outlet chambers. In two of our specimens the atrioventricular node and bundle were in posterior positions, as has been previously documented. However, in the remaining two cases the atrioventricular node was situated laterally in the right atrioventricular orifice and the bundle descended to the right parietal wall of the ventricular chamber. To the best of our knowledge such an arrangement has not been previously described.

All the hearts presently described were similar in possessing a single ventricular chamber which received both atrioventricular orifices and gave rise to both great arteries, the great arteries being normally related in all. On detailed study the differences in conduction patterns could be related to differences in gross morphology of the heart. The cases with a posterior bundle possessed a hypoplastic posterior ridge and distinct papillary muscles to both A-V valves. In contrast, the hearts with laterally conducting systems did not exhibit a posterior ridge and a common papillary muscle supplied the posterior cusps of the A-V valves.

We would therefore suggest that the presence of a posterior ridge in primitive ventricle without outlet chamber

![Diagram](http://circ.ahajournals.org/)

**Figure 7.** Photograph of heart from case 3 after removal of patch, with line diagram of same. The specimen is viewed from below with the apex removed and all four valves are seen. Sutures in the septal tricuspid leaflet, conus septum, and anterior ridge are seen (dotted in diagram). A probe is present in the aortic root. The stenosed mitral valve is clearly seen. Common chordal attachments to a small posterior papillary muscle are shown. The sites of posterior node (straight arrow) and lateral node and connection (curved arrow) are indicated on the diagram. The conducting tissue passed down a heavy trabeculum on the right lateral wall of the ventricle. Abbreviations: PA = pulmonary artery; Ao = aorta; MV = mitral valve; TV = tricuspid valve.

**Figure 8.** Diagrams to illustrate concept of morphogenesis of primitive ventricle with and without outlet chamber in relation to sites of conducting tissue. The diagrams represent transverse sections through the ventricular mass. The central figure shows the primitive loop with all three ridges present. The sites of the conducting tissue are shown as dark hatched. Abbreviations: RBVR = right bulboventricular ridge; LBVR = left bulboventricular ridge; PIVR = posterior interventricular ridge; B = bulbus; V = ventricle.
should make the surgeon highly suspicious of the presence of posterior conducting tissue (fig. 8). However, in both hearts of this type a prominent trabecula was present in the left side of the ventricle to the left of this ridge. The trabecula extended downward to join the apical septum and it was difficult on gross examination to decide which ridge carried the conducting tissues. Clearly, use of a His bundle probe, as described by Kaiser et al.\(^5\) and shown in the experience of Edie et al.,\(^6\) is recommended in the repair of this malformation.

When the posterior ridge is absent in primitive ventricle without outlet chamber, then a lateral conducting system should be suspected (fig. 8). Such a system might be expected to be relatively immune to surgical trauma. However, both our cases with this type of conducting system suffered postoperative rhythm disturbances and in one case the ventricular conduction tissue was shown histologically to be severely traumatized. The cause of this trauma was unclear, but it might have resulted from retraction of the right margin of the ventriculotomy during insertion of the patch.

The presence of a single papillary muscle supplying both valves in these cases adds to the surgical difficulties, and in one of the specimens it proved necessary to insert a patch on both sides of this muscle. Another complication in the latter case was the large muscular band obstructing the outflow to the pulmonary artery. Since this band also gave rise to the anterior papillary muscle of the tricuspid valve, we suspect that its removal would have resulted in severe tricuspid incompetence. In fact, it was deliberately left undivided as it was feared that it might carry conducting tissue. All these observations indicate that special care is needed when dealing surgically with this second type of primitive ventricle without outlet chamber.

Development of Conducting Tissue

In our previous study\(^4\) we interpreted our findings in terms of a ring of conducting tissue related to the tricuspid orifice in the fetal heart.\(^4\) We suggested that the anterior node in primitive ventricle with outlet chamber was a remnant of this ring. We have subsequently studied normal hearts of varying ages and found additional evidence of remnants of this ring related to the tricuspid orifice in a proportion of all hearts studied.\(^\text{16}\) These remnants were found most frequently at the lateral margin of the right atrioventricular orifice, the location in which Kent described accessory atrioventricular conducting pathways.\(^\text{16}\)

We believe that the lateral conducting pathways observed represent atrioventricular connections formed through this ring of specialized tissue owing to the absence of a posterior connection. Absence of the posterior connection is probably related to failure of the posterior ridge to form. Although both connections in our cases were lateral, the finding of remnants of a ring of conducting tissue related to the tricuspid orifice in fetal, infantile, and adult hearts suggests that connections could be formed at any point around the tricuspid orifice.

In one of the present cases (case 4) a collection of atrial specialized tissue was observed in the retroaortic tissues in relation to the anterior part of the mitral orifice and was closely related to, although not in contact with a well formed anterior bundle. Therefore, an atrioventricular connection could be formed between the anterior part of the left atrial ring and the ventricular conducting tissues. Such retro-aortic “nodes” are a normal finding in other mammalian species,\(^\text{17, 18}\) although in these animals they do not form atrioventricular connections.

Addendum

Since submitting this manuscript for publication we have studied the conducting tissue in a fifth heart exhibiting the features of primitive ventricle without outlet chamber and with normally related great arteries. In this case only atrioventricular connection was via a small anterior A-V node and a tenuous bundle descending on to an anterior ridge. This further demonstrates the considerable variability of the conducting tissue in this anomaly.

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