Real-Time Wide-Angle Sector Echocardiography: Atrioventricular Canal Defects

DONALD J. HAGLER, M.D., ABDUL J. TAJIK, M.D., JAMES B. SEWARD, M.D., DOUGLAS D. MAIR, M.D., AND DONALD G. RITTER, M.D.

SUMMARY  Real-time 80° phased-array two-dimensional sector echocardiography was used in 44 patients with atrioventricular (AV) canal defect. Anatomic details were surgically confirmed in 33. The apex view allowed visualization of atrial and ventricular portions of complete AV canal defects, with the common AV valve structures between the defects. The apex view also allowed us to differentiate divided and undivided, attached and free-floating common anterior valve leaflets to distinguish types A, B, and C complete AV canal defects. With the apex view, the ostium primum atrial septal defect and the attachment of the AV valve to the crest of the ventricular septum were observed in partial AV canal defect. Short-axis views revealed the cleft in the anterior leaflet of the mitral valve. The rapid and precise definition of anatomic details by this method has eliminated many of the difficulties in diagnosing this defect by M-mode echocardiography.

M-MODE ECHOCARDIOGRAPHIC STUDIES have defined several features for the noninvasive diagnosis of atrioventricular (AV) canal defects. The most characteristic abnormality in these reports has been the apparent movement of the mitral valve anterior leaflet across the plane of the ventricular septum. Although this observation has been noted in both partial and complete AV canal defect, other M-mode echocardiographic features have been useful in differentiating complete from partial AV canal.

M-mode echocardiography, however, did not allow differentiation of complete AV canal with a small ventricular septal defect from partial AV canal defects with scooped-out ventricular septum without ventricular septal defect. Also, M-mode echocardiography did not allow satisfactory distinction among types A, B and C (Rastelli classification) of complete AV canal. Preliminary multicrystal echocardiographic studies described similar features, including multiple mitral valve echoes and apparent movement of the mitral valve through the ventricular septum. These studies, however, did not clarify the precise anatomic definition, primarily because of the inability to provide an apex, or four-chamber, view. Several previous B-mode echocardiographic studies also described recognition of the ostium primum atrial septal defect. More recently, reports of mechanical and phased-array sector echocardiographic imaging have emphasized, on short-axis views, observation of the more inferior position of the ostium primum atrial septal defect (partial AV canal). In two instances of partial AV canal, a mitral valve cleft was also described on short-axis views. Our initial experience with real-time wide-angle sector echocardiography demonstrated similar findings, but also indicated that many of the problems mentioned previously could be substantially resolved.

In this study we assessed the capability of real-time 80° phased-array sector echocardiography in the clinical assessment of AV canal defects. We were primarily interested in a precise description of the echocardiographic-anatomic features, with emphasis on the differential features of AV valve attachments and relationships. We only grossly assessed individual and relative cardiac chamber sizes and functional abnormalities, since these echocardiographic parameters in AV canal have been adequately defined using standard M-mode techniques.

Methods

Forty-four patients with various types and forms of AV canal defect were studied with a commercially available real-time 80° phased-array sector echocardiographic instrument (Varian V-3000). Clinical data and essential features of classification (Rastelli) are presented in table 1. Sixteen of the patients, 3 months–59 years of age (average 10.8 years), had partial AV canal defect. Twenty-six patients had complete AV canal defect, and two had an AV canal type ventricular septal defect and a mitral valve cleft; their ages ranged from 6 months–14 years (average 5.3 years). Fourteen patients with partial AV canal defects, 17 with complete AV canal defects, and the two with an AV canal type ventricular septal defect subsequently had corrective operations, and the anatomic details were confirmed. Ten patients had type A complete AV canal defect, two had type B, and five had type C. After operation, sector echocardiography was done in three patients with complete defect and six patients with partial defect.

All patients were examined with an 80° phased-array sector echocardiograph using video recordings on 1-inch videotape. A standard 2.25 MHz transducer was used. The patients were examined in the supine or left lateral decubitus position using long-axis, short-axis, subxiphoid or apex sector views. Transducer orientation and tomographic sections have been described elsewhere. The long axis view, which demonstrates an apex-to-base scan of the left ventricle, was obtained with the transducer placed at

From the Mayo Clinic and Mayo Foundation, Rochester, Minnesota.
Address for reprints: Donald J. Hagler, M.D., Mayo Clinic, Rochester, Minnesota 55901.
Received February 8, 1978; revision accepted August 22, 1978.

140
In 26 patients, sector echocardiography was done at the time of cardiac catheterization, and selective echocardiographic contrast studies were performed with injection of indocyanine green dye and saline for better assessment of flow patterns and further definition of anatomic structures. The techniques of contrast echocardiography and its application to real-time sector echocardiography have been reported previously. For these studies, clear and accurate localization of structures and chambers is important. Gain overload and reverberation have been infrequent, and can be avoided with appropriate gain adjustments.

For anatomic correlation of the distinctive sector echocardiographic features in partial and complete forms of AV canal noted with the apex view, we have also obtained appropriate cross sections of pathologic specimens of partial and complete forms of AV canal corresponding to the sector echocardiographic apex view.

Still-frame pictures (35 mm) of the videotaped images were obtained for presentation. These still-frame reproductions are limited in their ability to demonstrate the anatomic and functional features observed with real-time imaging. Because of the lack of motion, observer orientation to the still frames may be difficult. Also, since each sector image is recorded over two videotape fields, each still-frame video image contains only one-half the information contained in the total sector image. Dark and bright areas in the still-frame images may also be noticeable relative to the sequence of the sector scan.

### Results

Preoperative sector echocardiography accurately distinguished partial AV canal from complete AV canal in 32 of 33 surgically confirmed cases. Complete AV canal was recognized by the presence of a ventricular septal defect inferior to the AV valves when the apex (four-chamber) view was used. In partial AV canal, the AV valves appeared directly attached to the crest of the ventricular septum (fig. 1). A defect inferior to the AV valves was not clearly visualized in a 1-year-old infant and was first interpreted as a partial AV canal defect. However, selective left ventricular sector echocardiographic contrast (indocyanine green dye) injections demonstrated a flow pattern consistent with a ventricular communication. At operation, tiny probe-patent communications were found beneath the anterior common leaflet.

### Partial AV Canal

Partial AV canal defect was best demonstrated with the apex view. This view clearly showed the attachment of separate tricuspid and mitral valve leaflet components to the crest of the ventricular septum. The ostium primum atrial septal defect was observed immediately superior to the AV valves (fig. 1). The remnant of the atrial septum was observed apparently suspended from the roof of the atrial cavity. The in-

### Table 1. Clinical Data in 44 Patients With Atrioventricular (AV) Canal Defect

<table>
<thead>
<tr>
<th></th>
<th>AV canal defect</th>
<th>AV canal type VSD with mitral cleft</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. patients</td>
<td>16</td>
<td>26*</td>
</tr>
<tr>
<td>Male/female</td>
<td>8/8</td>
<td></td>
</tr>
<tr>
<td>Corrective operation</td>
<td>14</td>
<td>17</td>
</tr>
<tr>
<td>Type of complete</td>
<td>A</td>
<td>10</td>
</tr>
<tr>
<td>AV canal defect</td>
<td>B</td>
<td>2</td>
</tr>
<tr>
<td>at operation†</td>
<td>C</td>
<td>5</td>
</tr>
</tbody>
</table>

*Includes six patients with Down's syndrome.
†Includes one patient with Down's syndrome.
‡Rastelli classification:
Type A—Multiple chordae attaching a divided primitive anterior AV valve leaflet to the crest of the ventricular septum.
Type B—Chordae attaching a divided primitive anterior AV valve leaflet to an anomalous papillary muscle on the right side of the ventricular septum.
Type C—Undivided, septally unattached (free-floating) common anterior AV valve leaflet.

the left sternal border, usually in the third intercostal space. The sector beam was positioned through the long axis of the left ventricle so that on the video display, the cardiac apex was to the observer's left and the base to the right. (Subsequent right-to-left orientation will only be made in reference to the observer's relation to the video image.) The short axis of the left ventricle was also obtained with the transducer placed at the left sternal border near the third intercostal space. The sector beam was positioned through the short axis of the left ventricle so that the left ventricle was posterior and on the right of the video image and the right ventricle was anterior and on the left. From this position, with the transducer angulated superiorly, the aorta was observed with the tricuspid valve noted on the observer's left, the left atrium posterior to the aortic root, and the pulmonary valve superior and on the right. The apex view was obtained from a variable position near the palpable cardiac apex. The apex view showed all four cardiac chambers, the interrelationship of the AV valves, and atrial and ventricular septae. The sector beam transected the heart in an inferior-to-superior direction from apex to base. Since the image orientation of the apical view, unlike those of the long- and short-axis views, has not been standardized, a variable right-to-left orientation was followed to allow the best possible imaging, depending on patient differences and operator preferences.

Subxiphoid tomographic views were also used in more recent patients. The sector beam was positioned in an anterior-to-posterior and inferior-to-superior orientation through the heart to allow visualization of the ventricular chambers, the AV valves, and the atrial chambers. This view was helpful in demonstrating the AV valve and chordal attachments to the crest of the ventricular septum.
ferior tip of the atrial septal remnant characteristically had a bulbous, thickened appearance. This gave the atrial septal remnant a matchstick appearance. Dropout and thinning of the more posterior portion of the atrial septal remnant did not allow consistent diagnosis of associated secundum atrial septal defect. In some patients, deficiency of the septal leaflet of the tricuspid valve was also observed. Five older patients with well-developed AV valves had a long segment of membranous septum attaching the valves to the crest of the ventricular septum. This membranous portion of the ventricular septum bulged toward the right ventricle (fig. 1). The remaining patients had more deficiency (scooping out) of the crest of the ventricular septum, and the valves appeared to be attached directly to the remaining muscular portion of the ventricular septum. The subxiphoid view similarly demonstrated both the AV valve attachment to the crest of the ventricular septum and the ostium primum atrial septal defect posterior to the AV valves. These anatomic features and structural relationships in partial AV canal were verified by a cross section of a pathologic specimen simulating the sector echocardiographic apex view (fig. 2).

The long-axis view was used to observe the right and left ventricular cavities. The right ventricular cavity usually appeared nearly equal in size to the left ventricular cavity. Because of right ventricular volume overload, paradoxic or abnormal ventricular septal motion was observed. The mitral valve motion varied from a nearly normal appearance to decreased diastolic excursion of the anterior mitral leaflet. There were multiple mitral valve echoes, and the orientation of the mitral valve to the left ventricular cavity was abnormal, with the valve opening directed to the ventricular septum rather than to the apex of the left ventricle. The abnormal mitral valve orientation resulted in anterior displacement of the mitral valve leaflets during diastole into the left ventricular outflow tract (fig. 3A). The left ventricular outflow tract was also observed for possible subaortic obstruction, which may be an associated anomaly of AV canal defect.16

In this series, we did not observe fixed systolic and diastolic narrowing of left ventricular outflow tract dimension to suggest obstruction. The aortic valve was observed at the base of the heart, with the left atrium posterior to the aortic root. By rotating the transducer 30° counterclockwise (viewed from above) and with medial transducer angulation, we observed apparent movement of the mitral valve through the plane of the ventricular septum near the crest of the ventricular septum. This view also demonstrated the confluence of the mitral and tricuspid valves at their attachment to the crest of the ventricular septum (fig. 3B). The ostium primum atrial septal defect was observed immediately posterior to the AV valves.

With a short-axis view transducer orientation, an apex-to-base scan of the left ventricle can be made. Near the apex, papillary muscles were observed within the left ventricular cavity. The right ventricular cavity was noted anteriorly. With transducer angulation toward the base, the mitral valve leaflets were observed. The mitral valve cleft, a pathognomonic abnormality of the mitral valve in AV canal defects, is noted with inspection of the anterior mitral valve leaflet. Instead of the normal “fishmouthed” diastolic appearance of the mitral valve, we observed an opened triangular configuration of the mitral valve leaflets, with separation of the two portions of the anterior leaflet (fig. 4A). As demonstrated, the cleft was typically eccentrically located toward the anteromedial portion of the anterior leaflet. With further angulation to the aortic root, we observed the ostium primum atrial septal defect at a point immediately below the aortic root (fig. 4B). With further superior angulation, the short-axis view at the base demonstrated the aortic and tricuspid valves, and in this position, the upper atrial septum separated the right and left atria. The right ventricular cavity and the pulmonary artery were noted anterior to the aortic root. The pulmonary valve was located anteriorly and to the right of the aortic root.

With the short-axis view at the aortic root level or, more frequently, the apex view through both ventricles
SECTOR ECHO IN AV CANAL/Hagler et al.

and atria, selective left ventricular sector echocardiographic studies with injection of contrast medium (indocyanine green) and saline demonstrated the systolic regurgitant flow of dye from the left ventricle exclusively into the right atrium and left atrium and only subsequent opacification of the right ventricle during the following diastole (fig. 5). Failure to demonstrate systolic flow directly into the right ventricle was consistent with partial AV canal.

Complete AV Canal

The apex, or four-chamber, view best allowed detection of a ventricular septal defect and determination of its relative size. Both the atrial and the ventricular septal defects were observed with the common AV valve structures between the defects. Also, the apex view allowed differentiation of the Rastelli type of AV canal defect based on the AV valve morphology and attachments. The Rastelli type of AV canal was accurately distinguished as A, B or C in 15 of 17 surgically confirmed cases. Types A and B were somewhat similar in their sector echocardiographic appearances. In type A, the anterior common leaflet appeared divided, having separate mitral and tricuspid components with multiple chordal attachments directly to the crest of the ventricular septum (fig. 6A). Type B also appeared to have a divided anterior com-

**Figure 2.** A) Cross section of pathologic specimen with partial atrioventricular (AV) canal defect viewed as sector echocardiographic apex view: apex on top and base at bottom; right ventricle on left and left ventricle on right. Note AV valve attachment to membranous portion of ventricular septum and ostium primum atrial septal defect superior to AV valves. B) Drawing of this section with structures identified.
mon leaflet with separate mitral and tricuspid components; however, the chordal attachments of the mitral and tricuspid portions of the anterior leaflet appeared to join and attach on the right ventricular side of the ventricular septum (fig. 6B). Type C was easily distinguished as a single, undivided, free-floating common anterior leaflet that moved as a straight bar across the crest of the ventricular septal defect (fig. 6C). No chordal attachments to the ventricular septum could be observed. The subxiphoid view permitted visualization of the multiple chordal attachments to the crest of the ventricular septum in type A complete AV canal. These anatomic features and structural relationships in complete AV canal were verified by obtaining a cross section of a pathologic specimen to simulate the sector echocardiographic apex view (fig. 7).

The long-axis view demonstrated abnormalities of the mitral valve. There were multiple mitral valve echoes and abnormal orientation of the mitral valve to the left ventricular cavity. The mitral valve opening was directed more to the ventricular septum than to the apex of the left ventricle, resulting in anterior displacement of the anterior mitral valve leaflet into the left ventricular outflow tract during diastole. With a counterclockwise transducer rotation of about 30°, a scan across the crest of the ventricular septum along the common anterior leaflet allowed the appearance of mitral valve motion through the plane of the ventricular septum. The ventricular septal defect could be observed beneath the common anterior leaflet and the ostium primum atrial septal defect superiorly. In type A complete AV canal, common anterior leaflet chordal attachments could be observed inserting into the crest of the ventricular septum.

The short-axis view of the mitral valve and left and right ventricles allowed demonstration of the ventricular chamber sizes, the presence or absence of two papillary muscles near the cardiac apex, and the mitral valve anterior leaflet cleft. Scanning from apex to base showed the left ventricular outflow tract and the great vessel relationships. Also, the ostium primum atrial septal defect was observed at a point just below the aortic root.

**AV Canal Type Ventricular Septal Defect with Mitral Valve Cleft**

The longitudinal and apex views demonstrated enlargement of the left ventricle and the left atrium.

---

**Figure 3.** A) Longitudinal sector view in 2-year-old patient with partial atrioventricular (AV) canal demonstrates large right ventricular cavity. Mitral valve appears slightly abnormal, with increased echoes and unusual orientation to ventricular septum and left ventricular outflow tract. B) Slight clockwise transducer rotation and medial angulation in same patient with partial AV canal demonstrate confluence of mitral and tricuspid structures at crest of ventricular septum. During diastole, confluence allows appearance of mitral valve movement through ventricular septum. A = anterior; P = posterior; I = inferior; S = superior; LV = left ventricle; RV = right ventricle; vs = ventricular septum; mv = mitral valve; ao = aorta; LA = left atrium; tv = tricuspid valve.
and deformity of the mitral valve, as described with complete AV canal. With the apex view, a ventricular septal defect was apparent between the mitral and tricuspid valves; however, the ostium primum portion of the atrial septum was intact. The apex-to-base scan in the short-axis view demonstrated the most characteristic abnormality, which was the cleft in the mitral valve anterior leaflet (fig. 8). In these patients, the mitral cleft appeared more centrally located, probably because of more nearly normal AV valve attachments.

Common Atrium

One patient with complete AV canal and two with partial AV canal had no evidence of an atrial septal remnant on apex views. These patients at operation were found to have common atrium.

Contrast Sector Echocardiography

Selective left ventricular injection of indocyanine green dye and saline allowed demonstration of the ventricular septal defect. In patients with a very large
ventricular septal defect, the longitudinal view may be sufficient to demonstrate a direct systolic left ventricular-to-right ventricular shunt. However, small ventricular septal defects were best demonstrated using the apex view with selective left ventricular dye injection (fig. 9).

Postoperative Assessment

Sector echocardiography after surgical correction allowed demonstration of the atrial and ventricular portions of the prosthetic patch and the repair of the mitral valve cleft. In partial AV canal, the apex view demonstrated the atrial prosthetic patch, and the AV valves remained attached to the crest of the ventricular septum. In complete AV canal, the prosthetic patch was demonstrated in the longitudinal, short-axis, and apex views. In the longitudinal view, the prosthetic patch reestablished continuity of the ventricular septum and the anterior aortic wall, so that apparent movement of the mitral valve through the plane of the ventricular septum was no longer present.
However, the mitral valve continued to appear to be displaced anteriorly into the left ventricular outflow tract. The apex view demonstrated both the atrial and the ventricular portions of the prosthetic patch and its attachment to the right side of the ventricular septum (fig. 10). The AV valves were attached at the midportion of the prosthetic patch. Short-axis views showed the repair of the mitral valve anterior leaflet cleft and allowed assessment of mitral valve function (fig. 11).

Discussion
In this study, real-time 80° phased-array sector echocardiography allowed rapid and precise definition of the form of AV canal defect and the AV valve abnormality in 96% of the cases. The combination of sector echocardiography and contrast (left ventricular dye) sector echocardiography resulted in a correct diagnosis in all cases.

Previously, it was difficult occasionally to establish echocardiographically the diagnosis of partial AV canal. No significant M-mode echocardiographic findings may occur in instances of partial AV canal in which only a slight AV valve abnormality is present. This problem is easily resolved by 80° sector echocardiography, which allows rapid demonstration of the ostium primum atrial septal defect using the apex view. Extensive deficiency (scooping out) of the crest of the ventricular septum in partial AV canal by M-mode echocardiography may resemble type A complete AV canal with a tiny ventricular septal defect. The apex view in partial AV canal demonstrated the attachment of the AV valves to the crest of the ventricular septum, thereby improving our ability to differen-
FIGURE 8. Short-axis sector view at level of mitral valve in 4-year-old patient with atrioventricular canal type ventricular septal defect, intact atrial septum, and mitral valve cleft. Cleft in anterior leaflet is noted during diastole. A = anterior; P = posterior; R = right; L = left; LV = left ventricle; RV = right ventricle; vs = ventricular septum; aml = anterior mitral leaflet; pml = posterior mitral leaflet.

Patients with tiny ventricular septal defects and chordal attachment to the crest of the ventricular septum may appear to have partial AV canal with scooping out of the ventricular septum. However, contrast sector echocardiography allowed demonstration of these tiny ventricular communications. In this series, one patient was thought to have partial AV canal by sector echocardiography; however, left ventricular contrast sector echocardiography using the apex view revealed a direct left ventricular-to-right ventricular shunt compatible with complete AV canal defect, which was surgically confirmed.

Angiography and M-mode echocardiography do not allow precise definition of AV valve attachments; nor do they adequately differentiate various forms of AV canal.

FIGURE 9. Apex sector view in 1-year-old patient with type A complete atrioventricular canal and tiny ventricular septal defect. Selective left ventricular indocyanine green dye injection opacifies left ventricular cavity; during systole, dye flows directly into right ventricle (large arrow). Small arrow indicates systolic timing on ECG. I = inferior; S = superior; R = right; L = left; LV = left ventricle; RV = right ventricle; vs = ventricular septum; RA = right atrium.

FIGURE 10. Apex sector view in 9-year-old patient after repair of type B complete atrioventricular canal. Atrial (single arrow) and ventricular (double arrows) portions of patch are noted, and, as described surgically, ventricular septal patch is placed on right side of ventricular septum. inf = inferior; sup = superior; R = right; L = left; RV = right ventricle; vs = ventricular septum; LV = left ventricle; tv = tricuspid valve; mv = mitral valve; RA = right atrium; LA = left atrium.
complete AV canal defect (Rastelli classification). In this study, 80° phased-array sector echocardiography accurately differentiated types A, B and C complete AV canal. The preoperative diagnosis was incorrect in two patients: type C was thought to be type B in one and type A in the other. However, with additional experience, the accuracy of diagnosis should improve. Since posterior leaflet attachments may be present in all types, specific scanning techniques (superior transducer angulation) must be followed to allow examination of the anterior common leaflet. The short-axis view of the mitral valve anterior leaflet clearly demonstrates the mitral valve cleft in both complete and partial forms of AV canal. This feature also was demonstrated in two patients with a ventricular septal defect of the AV canal type. This latter observation has not been possible with either angiography or M-mode echocardiography. On the apex view, the recognition of a more posterior defect between the AV valves also supports the diagnosis of AV canal type ventricular septal defect.

The sector echocardiographic observations noted with the longitudinal view have allowed correlation with previous observations on M-mode echocardiography. The apparent movement of the mitral valve anterior leaflet through the plane of the ventricular septum could be demonstrated in partial AV canal and was found to consist of diastolic mitral valve approximation to the ventricular septum and subsequent opening of the tricuspid valve, giving the appearance of a single AV valve motion. We also noted multiple mitral valve echoes and anterior displacement of the mitral valve into the left ventricle outflow tract.

Previous M-mode echocardiographic studies have not allowed detection of common atrium. In this series, three patients with common atrium were correctly diagnosed with no evidence of atrial septum on the apical (four chamber) view.

We conclude that the rapid and precise definition of anatomic details using 80° phased-array sector echocardiography has eliminated many of the difficulties in diagnosing AV canal defect by M-mode echocardiography. Sector echocardiography has allowed better differentiation of partial from complete AV canal defects as well as differentiation of types A, B and C complete AV canal defect. Precise demonstration of the mitral valve anterior leaflet cleft, not previously possible with M-mode echocardiography or angiography, has also been accomplished.

Addendum

Since submission of this report, we have studied 19 more patients with AV canal defects (complete in eight, partial in 11). All were correctly diagnosed preoperatively by the wide-angle two-dimensional examination. This experience further supports the observations presented in this report.

Acknowledgment

We are indebted to Dr. J. T. Lie and Robert Mieras, Department of Pathology and Anatomy, for their assistance with pathologic material, and to Robert C. Benassi, Medical Graphics, for his artistic assistance.

References


Intraoperative Recording of Specialized Atrioventricular Conduction Tissue Electrograms in 47 Patients

Macdonald Dick, II, M.D., William I. Norwood, M.D., Carl Chipman, B.S., and Aldo R. Castaneda, M.D.

SUMMARY Intraoperative mapping of the specialized atrioventricular conduction system was performed in 47 patients during cardiac surgery. Specialized conduction tissue electrograms were identified in 37, and atrioventricular conduction preserved in 92%. Specialized conduction tissue was identified in 27 patients with atrioventricular canal defect; complete heart block was avoided in 25. Conduction tissue was located in six of 12 patients with complex transpositions; atrioventricular conduction was preserved in all six. Other lesions in which the technique was useful were Ebstein's anomaly and single atrium. Limitations to the technique are 1) deep hypothermia and circulatory arrest; 2) interruption in atrioventricular conduction during mapping; 3) inadequate exposure and access to probable sites of conduction tissue; 4) variation of size and spatial relations of individual malformations; and 5) limited time for identification of unusually located conduction tissue. Indications for use of this technique include patients with both forms of atrioventricular canal, complex transpositions, atrioventricular discordance, single ventricle and single atrium.

ELECTROPHYSIOLOGIC IDENTIFICATION of the specialized cardiac conduction system was introduced in 1970 to prevent major injury to the cardiac conduction tissue during open heart surgery. Several reports have described mapping the conduction system in patients with selected cardiovascular malformations, including incomplete atrioventricular (AV) canal, complete AV canal, transposition of the great arteries, atrial septal defect, ventricular septal defect, tetralogy of Fallot, corrected transposition of the great arteries with either situs solitus or situs inversus, Ebstein's anomaly, and single ventricle. In this report we review our experience with intracardiac mapping and define the limitations and indications of this electrophysiologic technique in patients with congenital heart disease.

Materials and Methods

Between March 1, 1974 and August 31, 1977, intraoperative mapping of the specialized AV conduction tissue was performed at the Children's Hospital Medical Center, Boston, in 47 patients with complex congenital heart disease. In all the patients the course of the specialized conduction system was either unpredictable, unknown or particularly vulnerable and thus at risk at surgery; identification by the electrophysiologic technique was performed in an attempt to preserve AV conduction.

Recording of the intracardiac specialized conduction tissue potentials was performed in the manner previously described. After institution of cardiopulmonary bypass the area suspected of containing

From the Departments of Cardiology and Cardiovascular Surgery, Children's Hospital Medical Center, and the Departments of Pediatrics and Surgery, Harvard Medical School, Boston, Massachusetts.

Supported in part by Grants HL 10436 and HL 05855 from the National Institutes of Health, Bethesda, Maryland.

Address for reprints: Macdonald Dick, II, M.D., Department of Cardiology, Children's Hospital Medical Center, 300 Longwood Avenue, Boston, Massachusetts 02115.

Received March 10, 1978; revision accepted August 22, 1978.

Real-time wide-angle sector echocardiography: atrioventricular canal defects.
D J Hagler, A J Tajik, J B Seward, D D Mair and D G Ritter

Circulation. 1979;59:140-150
doi: 10.1161/01.CIR.59.1.140
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 1979 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/59/1/140.citation

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Circulation can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Circulation is online at:
http://circ.ahajournals.org//subscriptions/