Hydrogen-detected Ventricular Septal Defects

WALTER H. HERBERT

From The Cardiopulmonary Laboratory, Grasslands Hospital, Valhalla, New York, U.S.A.

The simplicity in the use and the extreme sensitivity of the platinum electrode (Frommer, Pfaff, and Braunwald, 1961; Hugenholtz et al., 1963) have made possible the detection of very small shunts at the ventricular level. These shunts, in the absence of oxygen saturation step-up, were previously unrecognized (Vogel, Grover, and Blount, 1962; Walker et al., 1965).

The general assumption has been that the demonstration of a ventricular septal defect by hydrogen alone was simply a reflection of the very small size of the defect. If the sole difference between the hydrogen-detected defects and those with a measurable oxygen step-up is size, then one would expect the timing of left-to-right flow to be the same in each. However, the study of patients with hydrogen-detected defects revealed that left-to-right flow through the defect was evident in diastole only. This observation was at variance with the systolic and diastolic shunting reported by Levin et al. (1967) in their analysis of oxygen detectable ventricular septal defects.

The observed difference in the character of the left-to-right flow is discussed. It appears that previous implications as to the anatomical size of the hydrogen-detected defects may be invalid.

Subjects and Methods

Only patients with isolated ventricular septal defects and normal intracardiac pressures were considered in this study. Patients with right ventricular or pulmonary hypertension as well as those with associated cardiac lesions were excluded. Twenty-one patients met the criteria. Six of these patients (29%) had hydrogen-detected defects and form the basis for this report. All 6 patients were male and ranged from 2 to 19 years of age (Table).

All patients underwent simultaneous right and left heart catheterization with cine-angiography. Oxygen saturations were determined on an A-O oximeter (accuracy of ±1%). Left ventriculography was performed in the left anterior oblique projection with 75% per cent Hypaque.

Phonocardiograms were monitored with a Cambridge Five Channel Recorder.

A standard 12-lead electrocardiogram is routinely recorded on all patients undergoing cardiac catheterization.

Results

The Table displays the pertinent data recorded from the 6 patients with hydrogen-detected defects. None of the patients had either pulmonary or right ventricular hypertension. There was a minimal right ventricular outflow obstruction (5 mm. Hg gradient) in one patient (Case 2).

There was no oxygen step-up in the pulmonary artery in 4 patients. Two patients had equivocal results with a 3 per cent and a 2 per cent step-up, respectively.

Hydrogen arrival times recorded in the pulmonary artery following a one breath inhalation of hydrogen gas were two seconds or less in all patients.

A review of the standard 12-lead electrocardiogram recorded from each patient showed 4 to be entirely within normal limits, one patient (Case 4) with a suggestion of right ventricular hypertrophy, and the last patient (Case 6) with a minimal right-sided conduction disturbance.

Phonocardiography revealed 5 patients to have holosystolic murmurs with obliteration of the aortic second sound in 3 (Fig. 1). One patient had a short early systolic murmur.

Cine-angiography failed to show the shunt in only one patient (Case 3). In the remaining 5 patients, there was clear visualization of the shunt in diastole (Fig. 2a) with no further dye crossing the septum during systole (Fig. 2b).

Discussion

Levin and his group (1967) defined the characteristics of ventricular septal defect flow in patients.
with quantitatively determinable shunts. In their analysis of patients with normal or near normal right heart pressures, they described both diastolic and systolic shunting with an augmented flow in systole. This systole accentuation was directly related to the pressure gradient across the defect. From Levin et al.'s (1967) observations, in the above reported patients with normal right and left ventricular pressures and no outflow obstruction, one would anticipate a substantial increment in shunt flow during systole. However, no flow at all was seen during this portion of the cardiac cycle.

The demonstration of shunting only in diastole appears to explain the inability to record an oxygen step-up. If, as shown by Levin et al. (1967), the major shunting takes place in systole, elimination of this phase of left-to-right flow would presumably reduce the total shunt volume substantially. In the absence of a systolic flow, the diastolic contribution may well be inadequate to cause a recordable oxygen step-up. It is not necessary, therefore, to infer that the small shunt is secondary to a small defect (Selzer, 1954; Dack, 1960). Certainly, the defect appears large angiographically in diastole.

Defects discernibly patent only in diastole suggest the muscular type. Such defects are presumably reduced or obliterated by systolic contraction (Dammann et al., 1960; Edwards, 1960; Imperial et al., 1960; Saab et al., 1966; Schrire et al., 1965; Vogelpoel et al., 1961). Our angiographic studies suggest that the defects are near the outflow tract, and the observations are consistent with a postero-inferior muscular defect. Saab et al. (1966) showed that 11 out of 23 muscular defects were located in this area. In our cases there was no evidence of multiple defects or for an apical location (Dammann et al., 1960; Edwards, 1960).

Though it has been suggested that a deep Q wave pattern in left ventricular leads may be more frequently associated with patients with muscular defects (Saab et al., 1966), none of our patients showed such an abnormality.

### TABLE

**CATHETERIZATION DATA OF PATIENTS WITH HYDROGEN-DETECTED VENTRICULAR SEPTAL DEFECTS**

<table>
<thead>
<tr>
<th>Case No., age (yr.), and sex</th>
<th>Right ventricle</th>
<th>Pulmonary artery</th>
<th>Left ventricle</th>
<th>Oxygen step-up (% satn.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Systolic</td>
<td>Diastolic</td>
<td>Systolic</td>
<td>Diastolic</td>
</tr>
<tr>
<td>1 13 M</td>
<td>—</td>
<td>—</td>
<td>19</td>
<td>6</td>
</tr>
<tr>
<td>2 13 M</td>
<td>33</td>
<td>5</td>
<td>28</td>
<td>6</td>
</tr>
<tr>
<td>3 19 M</td>
<td>23</td>
<td>3</td>
<td>22</td>
<td>8</td>
</tr>
<tr>
<td>4 2 M</td>
<td>26</td>
<td>7</td>
<td>25</td>
<td>15</td>
</tr>
<tr>
<td>5 15 M</td>
<td>21</td>
<td>4</td>
<td>20</td>
<td>6</td>
</tr>
<tr>
<td>6 8 M</td>
<td>21</td>
<td>5</td>
<td>21</td>
<td>7</td>
</tr>
</tbody>
</table>

![Fig. 1.—Case 1. The holosystolic murmur as recorded at the lower left sternal border (LLSB) obliterates the second sound. aVR, augmented right limb lead; CP, carotid pulse; Resp., respiration.](http://heart.bmj.com/BrHeartJ first published as 10.1136/hrt.31.6.766 on 1 November 1969. Downloaded from http://heart.bmj.com on September 17, 2023 by guest. Protected by copyright.)
FIG. 2.—Case 5. (A) The top frame shows the diastolic shunt (arrow). Non-opacified dye is seen entering the left ventricle (LV) from the left atrium (LA). Ao, aorta. The lower frame is later in diastole. The shunt is still visualized. Diastolic filling of the left ventricle is complete. (B) Systole. No left-to-right flow is seen.

Only one of our patients had a short early systolic murmur of the type described as characteristic of a muscular defect which is occluded by systole (Van der Hauwaert and Nadas, 1961; Vogelpoel et al., 1961). The other 5 patients had holosystolic murmurs, 3 of which obliterated the aortic component of the second sound. The latter has been reported as indicative of large shunts (Bleifer, Donoso, and Grishman, 1960). The angiographic studies belie the auscultatory findings in that no systolic shunt is visualized despite the murmur generally attributed to left-to-right flow (Bleifer et al., 1960; Dammann et al., 1960; Van der Hauwaert and Nadas, 1961). Our conclusion is that the 6 cases of hydrogen-detected defects are examples of muscular defects in the postero-inferior aspect of the interventricular septum. These defects may be of moderate anatomical size but are reduced considerably by systolic contraction (Dammann et al., 1960; Edwards, 1960; Imperial et al., 1960; Saab et al., 1966; Schrire et al., 1965; Vogelpoel et al., 1961). The net effect is to permit an easily appreciable diastolic flow with an almost absent shunt during systole. The presence of the systolic murmur suggests that the defect remains patent throughout systole (Vogelpoel et al., 1961) but that the systolic shunting is of an insufficient magnitude to be visualized angiographically.

**SUMMARY**

The timing of left-to-right flow through hydrogen-detected ventricular septal defects was com-
pared to that reported in patients with ventricular septal defects showing a measurable oxygen step-up.

In 6 patients with hydrogen-detected defects, left-to-right flow was discernible angiographically only in diastole. This observation was at variance with the studies of Levin et al. (1967) who reported both diastolic flow and an augmentation of shunting in systole in patients with oxygen step-up ventricular septal defects.

The hydrogen-detected defects appeared to be located in the postero-inferior portion of the muscular septum where presumably its margins are nearly approximated by systolic contraction. This narrowing, of what may be anatomically a large defect, precludes a significant systolic shunting. Though there is sufficient flow to produce the characteristic holosystolic murmur, the volume of flow is insufficient to be recorded by oxygen step-up determinations or to be visualized angiographically.

REFERENCES


