Auscultatory Findings in Patients with a Small Ventricular Septal Defect

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The auscultatory and phonocardiographic characteristics of ventricular septal defects have been the subject of several studies,\textsuperscript{1-5} none of them dealing specifically with the features of small defects. The present study represents an attempt to define the phonocardiographic pattern of ventricular septal defect with a small left-to-right shunt and normal pulmonary artery pressure. It was hoped that this might provide the clinician with a means of differentiating the murmur of a small ventricular septal defect from the \textquoteleft{innocent\textquoteright} or \textquoteleft{functional\textquoteright} murmur and from the murmur of mild infundibular pulmonary stenosis.

Material and Methods

Twenty-one patients with small ventricular septal defects form the basis of this report. All were proved at cardiac catheterization to have a left-to-right shunt resulting in a pulmonary blood flow less than twice the systemic flow. Pulmonary artery pressures were normal in all. Twelve patients (group 1) had identical right ventricular and pulmonary artery systolic pressures and nine (group 2) had a slight gradient of less than 20 mm. Hg across the infundibulum of the right ventricular outflow tract. Ten patients were male, 11 were female. Their ages varied from 1 to 22 years. They were all completely asymptomatic and had normal electrocardiograms and roentgenograms.

All patients were carefully examined and phonocardiograms were obtained in all. In two instances the Sanborn Twin-Beam apparatus was used; in the rest of the patients the phonocardiograms were obtained by means of a new Sanborn Poly-Beam recorder.\textsuperscript{*} The tracings were recorded in the recumbent position, at a paper speed of 100 mm. per second. As reference tracings the electrocardiogram, the carotid artery pulsation, the jugular venous pressure tracing, and the linear apex cardiogram were used. The chest expansions during respiration were registered simultaneously with phonocardiograms at the second right and second left intercostal space, in order to elucidate the respiratory changes in the splitting of the second sound. The aortic component of the second sound was identified by means of the dicrotic notch on the carotid artery tracing, allowance being made for a lag of .03 to .04 second between the sound and pressure phenomena. All other tracings were obtained while expiration was held. The intensity of the murmurs was judged exclusively on auscultation (grade 1 to 6 according to Levine\textsuperscript{6}), since the phonocardiograms were not thought to be adequate for such comparison.

The diagnosis of ventricular septal defect was based on oxygen saturation data in 15 of 21 instances. In these cases a minimum of 5 per cent increase in oxygen saturation was found at the ventricular level in at least two sets of blood samples. In the remaining six children the oxygen saturation data were not conclusive enough for the diagnosis of ventricular septal defect. The following ancillary methods were used in these cases:

1. Cineangiography (one patient). In a 1-year-old infant, the catheter was advanced from the right atrium through the foramen ovale, to the left atrium, and into the left ventricle. Indocyanine green was injected and blood samples were obtained from the right heart cavities. The early appearance of the dye in the pulmonary artery and right ventricle proved the existence of a ventricular septal defect. In two additional patients dye was injected through a catheter into the peripheral pulmonary artery; this was assumed to be com-

\textsuperscript{*}The Sanborn Crystal microphone (Model 350-1700-C10) and the Sanborn Heart Sound Preamplifier (Model 350-1700B) in connection with a 4-channel Sanborn Poly-Beam recorder (Model 550M) were used.
3. **Intracardiac phonocardiography** (two patients). The diagnostic significance of this technic is based on the fact that a murmur is maximal at its site of origin and is virtually absent proximally. Thus, in the case of a patient with a ventricular septal defect, the murmur is of maximal intensity at the ventricular level, is absent in the right atrium, and is transmitted slightly to the main pulmonary artery. In two patients intracardiac phonocardiography served as the only evidence of the presence of a ventricular septal defect, whereas in three additional children it confirmed diagnoses based on oxygen saturation data.

**Results**

**Group 1**

Among the 12 patients without any gradient across the infundibulum, the murmur was maximal at the fourth left intercostal space parasternally in seven and at the third left intercostal space in five. The intensity of the murmur was grade III or IV in most instances. There was one patient with a grade II and one with a grade V murmur.

Phonocardiographically, the murmur was found to be pansystolic and plateau-shaped in seven instances, starting with the first sound and extending up to or just beyond the aortic component of the second sound (fig. 1). In three cases the murmur was restricted to the first half of systole (fig. 2). On auscultation these early systolic decrescendo murmurs had a high-pitched quality and their short duration could readily be appreciated. In the remaining two cases without infundibular gradient, the murmur was clearly diamond-shaped, extending slightly beyond the aortic component of the second sound. One of these murmurs had a mid-systolic, the other a late systolic peak (figs. 3 and 4).

The second sound was best heard at the second left intercostal space and was of normal intensity in all patients. In some of the children with a pansystolic murmur the splitting of the second sound was difficult to appreciate. On the phonocardiograms, by contrast, the splitting was visible in all in-
Diamond-shaped murmur with midsystolic peak in a patient without infundibular or valvular gradient.

In only one patient was a faint apical middiastolic rumble registered. In one child a prominent diastolic "click" was heard and registered at the fourth left intercostal space. Because of its timing (.18 to .19 second after the second sound) and its high-pitched quality, it was thought not to represent a third sound.

Intracardiac phonocardiograms were obtained in three children and showed a pansystolic murmur in the right ventricle. No murmur was demonstrated in the right atrium, but a faint ejection murmur was registered in the main pulmonary artery.

**Figure 4**

Diamond-shaped murmur with late systolic peak in a patient without infundibular or valvular gradient.

**Group 2**

All nine patients in this group showed a systolic pressure gradient at the infundibular level. The gradient varied from 6 to 18 mm Hg and was thought not to be of hemodynamic significance.

At auscultation the murmurs tended to be somewhat louder than in the previous group; they were all at least grade III in intensity and six of them were estimated to be grade V or VI. The point of maximal intensity was at the third or fourth left intercostal space parasternally.

The pattern of the murmur was analyzed on the phonocardiograms; in four cases it was pansystolic and plateau-shaped, and in five diamond-shaped. Among the latter there were three with a midsystolic and one each with an early and late systolic peak (fig. 6).

The second sound was of normal intensity with a rather wide, easily audible split in most patients. The phonocardiograms showed the splitting in held expiration to be normal in two and wide (.04 second or more) in seven cases. In the eight patients with an adequate respiratory tracing the splitting increased on inspiration. In most instances the pulmonary component of the second sound was slightly less intense than the aortic component.

In two children intracardiac phonocardiograms were obtained in three children and showed a pansystolic murmur in the right ventricle. No murmur was demonstrated in the right atrium, but a faint ejection murmur was registered in the main pulmonary artery.
grams were available. In one, a patient with a gradient of 16 mm Hg at the infundibular level, a loud diamond-shaped murmur was recorded in the main pulmonary artery whereas the murmur in the body of the right ventricle was more pansystolic. In the other, a patient who had a 6-mm. gradient, only a faint ejection murmur was registered in the pulmonary artery and a loud pansystolic murmur was present in the outflow tract of the right ventricle.

Discussion

The typical murmur of a ventricular septal defect is considered to be loud, high-pitched, pansystolic, and maximal at the lower left sternal border. Phonocardiograms are reported to show that the murmur starts with the first sound, is plateau-shaped, and extends to the aortic closure or slightly beyond it.1-5 The long duration of the murmur is based on the persistent gradient between the right and left ventricle throughout systole. The second sound is thought to be normally split and to vary with respiration.

It is well documented that in the presence of pulmonary hypertension, secondary to increased pulmonary vascular resistance, the murmur loses its pansystolic character.2 Less well recognized is the fact that the murmur of a small ventricular septal defect may also greatly differ from the typical pattern.

In fact a pansystolic, plateau-shaped murmur was found in only half (11 out of 21) of the patients of the present study. Seven individuals had a distinct diamond-shaped murmur and in the remaining three children a short, early systolic, decrescendo murmur was found.

A gradient across the right ventricular infundibulum was not the only factor responsible for the production of a diamond-shaped murmur, for two patients without a demonstrable gradient had a diamond-shaped murmur, whereas four with a slight gradient had a plateau-shaped murmur. The latter observation may result because the pansystolic murmur of the ventricular septal defect masks the simultaneous and perhaps softer diamond-shaped murmur of very mild infundibular pulmonic stenosis. The diamond-shaped murmur of pure ventricular septal defect, on the other hand, may occur because turbulence created by a small orifice may be similar to that originating at the site of a stenosed pulmonary valve, and may reach its maximum intensity in midsystole. One of these diamond-shaped murmurs had a late systolic peak (fig. 4), which according to Vogelpoel and Schrire6 is characteristic of severe pulmonic stenosis. The latter diagnosis could easily be disproved, however, even on physical examination, by the normally split second sound. These findings indicate that a sharp separation of “regurgitant” from “ejection” type systolic murmur11 is not always possible. Even the most careful auscultation may fail to differentiate between a small ventricular septal defect, a ventricular septal defect with a slight degree of infundibular stenosis, and the rare case of isolated mild infundibular pulmonic stenosis.

Two of three patients with an early systolic decrescendo murmur had a minimal left-to-right shunt not demonstrable by oxygen saturation data. Although the presence of
such a murmur certainly suggests a minimal defect, the fact that the third patient did show an appreciable increase in oxygen saturation (Qp/Qs = 1.7) indicates that this is not invariably the case. A plausible explanation of the pattern of this murmur may be that it originates from a small defect in the muscular portion of the ventricular septum closing off during systole. The same murmur was described by Evans et al., and a similar explanation was offered. The difficulty of separating this type of short and early systolic murmur from a so-called "innocent" or "functional" murmur is obvious. Even heart catheterization, if unaccompanied by more refined methods of shunt detection, may fail to reveal the true nature of the underlying abnormality. Thus the entire concept of what constitutes a "functional" murmur at the lower left sternal border may be brought under closer scrutiny, in terms of the criteria on which this diagnosis is based. Only one child had a mitral diastolic flow murmur, which contrasts with its common occurrence in larger ventricular septal defects.

In accordance with previous observations, appreciable splitting of the second sound and inspiratory widening were recorded in all patients in whom a satisfactory tracing was obtained. Wide splitting was found in half of our cases, particularly in those with an associated slight infundibular gradient. In the latter group one could assume that the contraction of the infundibular chamber was prolonged as suggested by Johnson. Wide splitting was also noted, however, in four patients without a gradient across the infundibular, suggesting that this may be inherent in the physiology of small ventricular septal defects and may be caused by prolongation of right ventricular systole itself. A hypothesis to explain this phenomenon may be offered. In contrast to the hemodynamics of large ventricular septal defects in which both ventricles act as a common ejective force with the left ventricle directing blood into the pulmonary artery, in cases with a small opening in the ventricular septum, the left ventricle injects blood into the right ventricle, which in its turn forwards it to the pulmonary artery. Another hypothesis proposed for the wide splitting of the second sound in ventricular septal defect is based on the assumption that aortic closure occurs earlier than normal because of a shortened left ventricular systole. Possibly a combination of these two mechanisms may cause the wide splitting of the second sound in these cases.

Summary

The auscultatory and phonocardiographic findings were analyzed in 21 cases of small ventricular septal defect. Eleven patients had identical right ventricular and pulmonary artery systolic pressures, whereas in nine a minimal systolic gradient across the infundibulum of the right ventricle was demonstrated. One half of the patients, with or without an infundibular gradient, had a pansystolic plateau-shaped murmur. Several patients, mostly those with an infundibular gradient, had a distinct diamond-shaped murmur. A few children showed an early systolic decrescendo murmur. Appreciable, even wide splitting of the second sound with inspiratory widening, was demonstrated. It is proposed that a sharp differentiation between "ejection" and "regurgitant" systolic murmurs...
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may be difficult under certain circumstances. Furthermore, it is suggested that the definition of an "innocent" or "functional" murmur may depend on the sensitivity of the diagnostic methods used.

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References


Religio Medici

Nature a Bible Open to All

Thus there are two Books from whence I collect my Divinity; besides that written one of GOD, another of His servant Nature, that universal and publick Manuscript, that lies expans'd unto the Eyes of all: those that never saw Him in the one, have discovered Him in the other.—Sir Thomas Browne. Religio Medici, 1642. Edited by W. A. Greenhill, M.D., Oxon., London, MacMillan and Co., Limited, 1950, p. 27.
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