
Systolic Time Intervals in Isolated Ventricular Septal Defect in the Adult

OLA ALFRED NESJE, M.D.

SUMMARY Little information is available on the length of the systolic time intervals in adult patients with isolated ventricular septal defects (VSD). In the present study the external carotid pulse and the phono- and electrocardiogram were recorded in 17 patients, mean age 29 years, with angiographically proved VSD. They had unidirectional left-to-right shunts with ratios of pulmonary-to-systemic blood flow (Qp/Qs) of 1–5.22. Their right ventricular pressures were normal or only moderately elevated.

Left ventricular ejection time was consistently abbreviated, the degree of abbreviation relating significantly with Qp/Qs (r = -0.70, p < 0.01). The prejection period was prolonged but the relationship between its degree of prolongation and Qp/Qs did not reach statistical significance (r = 0.41, p > 0.05). The relationship between the prejection period/left ventricular ejection time ratio (PEP/LVET) and Qp/Qs was statistically significant (r = 0.51, p < 0.05).

We conclude that in adult VSD patients with normal right ventricular pressures, a hemodynamically important shunting, i.e., Qp/Qs above 1.4 or left-to-right shunt exceeding 30% of pulmonary blood flow, may be excluded in the presence of a normal left ventricular ejection time or a normal PEP/LVET ratio.

SEVERAL REPORTS have been published on the phonocardiographic findings in children and adolescents with isolated ventricular septal defect (VSD). Little information is available, however, about the length of the systolic time intervals (STIs) and the contour of the externally recorded carotid pulse in these young patients; and no reports, to our knowledge, have been published on such noninvasive investigations in adult patients with VSD.

The present study was therefore undertaken to determine the length of the STI in adult patients who have an isolated VSD with unidirectional left-to-right shunting and to determine any relationship between deviations of the STI and the magnitude of the shunt.

Materials and Methods

The patients were six women and 11 men with an age range of 15–64 years (mean 29.2 years) (table 1). All patients were in sinus rhythm. Right- and left-heart catheterizations were performed in all patients. The oxygen saturation of mixed venous blood was estimated according to the formula $3SV{C} + IV{C}/4$, where SVC is the superior and IVC the inferior vena cava. Hydrogen inhalation tests were performed in patients in whom there was no difference or only a minimal difference in the oxygen saturation of mixed venous and pulmonary arterial blood. The tests were positive in the pulmonary artery and the right ventricle and negative in the right atrium in all patients. Cardiac output was measured by the Fick method.

From Medical Department B, Laboratory of Cardiology, University Hospital, Rikshospitalet, Oslo, Norway.
Address for correspondence: Ola Alfred Nesje, M.D., Medical Department B, Laboratory of Cardiology, University Hospital, Rikshospitalet, Oslo, Norway.
Table 1. Study Population

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Abbreviations: Murmur = intensity of murmur 1-6 according to Levine; RV = right ventricle; Pulm art = pulmonary artery; LV = left ventricle; S = systolic; D = diastolic; ED = end-diastolic; Qp = pulmonary blood flow; Qs = systemic blood flow; Shunt = shunt in % of Qp; RBBB = right bundle branch block; LAH = left anterior hemiblock; LVH = left ventricular hypertrophy.

Left ventricular angiography, performed with the patient in the left anterior oblique position, showed a VSD in all patients. The defect was situated high in the septum in 15 patients and in the middle part of the septum in two (patients 7 and 17). Pulmonary arterial pressure was normal in all but patient 17, who had undergone surgery for a VSD and an infundibular pulmonary stenosis 7 months earlier. The VSD had reopened, whereas the pulmonary stenosis had been abolished. No patients had detectable right-to-left shunts, and the oxygen saturation of arterial blood was above 95% in all patients.

The external carotid pulse, the phonocardiogram at the left sternal border, and ECG were recorded simultaneously on a direct-writing ink recorder, the Mingograf 61 (Elema-Schöndander), which has a flat frequency response to 500 Hz. The paper speed was 100 mm/sec and all measurements were made on an average of at least five beats.

Carotid pulse recordings were made with a photo-electrical transducer (Portheine, Siemens), which has a time constant of 2.6 seconds and a flat frequency response to 400 Hz. It was attached to the examination couch by means of a metal bar. The left ventricular ejection time (LVET) was measured from the beginning of the pulse upstroke to the incisura (fig. 1). The T time, which is the time needed for the pulse to attain half its total height, was also measured.

The electromechanical interval (Q-Aₚ) was measured from the Q wave of the ECG using the extremity lead which best defined the onset of ventricular depolarization, to the first high-frequency vibrations of the second heart sound on the phonocardiogram. The aortic and pulmonary component were identified by means of the incisura of the carotid pulse, and in patients where the systolic murmur tended to conceal the beginning of the aortic component (Aₚ), its exact beginning was determined by using a phonocardiogram obtained in the second right intercostal space.

The preejection period (PEP) was obtained by subtracting the LVET from the Q-Aₚ. The expected time intervals according to heart rate and sex were obtained by using Weissler's formulas, with all measurements in milliseconds (msec): Expected Q-Aₚ for women: 549 - 2.0 x heart rate (HR), standard deviation (SD) ± 14; for men: 564 - 2.1 x HR, SD ± 14. Expected LVET for women: 418 - 1.6 x HR, SD ± 10; for men: 413 - 1.7 x HR, SD ± 10. Expected PEP for women: 133 - 0.4 x HR, SD ± 11; for men: 131 - 0.4 x HR, SD ± 13.

The deviations of the measured time intervals (Δ Q-Aₚ, Δ LVET, and Δ PEP) were obtained by subtracting the measured time intervals from the expected time intervals. The PEP/LVET was obtained by using the measured time intervals. This quotient is not influenced by HR or sex. Its normal value is 0.345 ± 0.036.

The recorded time intervals were further compared to the normal values for STIs obtained in our laboratory in 21 women, mean age 31 years, and 34 men, mean age 31 years. The regression equations for
the women were (msec): $Q-A_2 = 542 - 2.02 \times HR, SD \pm 12; \text{LVET} = 408 - 1.53 \times HR, SD \pm 10; \text{PEP} = 134 - 0.49 \times HR, SD \pm 11$. The regression equations for the men were (msec): $Q-A_2 = 538 - 2.16 \times HR, SD \pm 15; \text{LVET} = 414 - 1.83 \times HR, SD \pm 11; \text{PEP} = 124 - 0.33 \times HR, SD \pm 11$. The changes in the measured time intervals ($cQ-A_2, c\text{LVET}$, and $c\text{PEP}$) were calculated by subtracting the measured time intervals from the expected time intervals according to these equations. The $\text{PEP/LVET}$ for women was $0.333 \pm 0.04$; and for men, $0.346 \pm 0.04$.

Results

LVET was shortened in all patients (table 2); $\Delta\text{LVET}$ was shortened by more than 2 sd in seven of the eight patients with a moderate shunt (pulmonary blood flow/systemic blood flow $[Qp/Qs] 1.4-2.0$), and it was shortened by more than 3 sd in the three patients with large shunts ($Qp/Qs > 2.0$). A statistically significant indirect relationship was found between $\Delta\text{LVET}$ and $Qp/Qs (r = -0.70, p < 0.01)$ (fig. 2). The degree of correlation between $c\text{LVET}$, calculated from our own regression equations for normal subjects, and $Qp/Qs$ was slightly less ($r = -0.67, p < 0.01$).

PEP was prolonged in all patients with moderate-to-large shunts, and there was a positive but statistically insignificant relationship between $\Delta\text{PEP}$ and $Qp/Qs (r = 0.41, p > 0.05)$ (fig. 3). The correlation between $c\text{PEP}$ and $Qp/Qs$ was almost identical ($r = 0.40$).

In one patient the abbreviation of LVET tended to be associated with a corresponding prolongation of

![Figure 1](image_url)  
**Figure 1.** Recording from a patient with ventricular septal defect. Top tracing: ECG, standard lead II. Middle tracings: phonocardiograms from the left sternal border, upper 100 Hz, lower 200 Hz. Bottom tracing: carotid pulse. LVET = left ventricular ejection time; $Q-A_2 =$ electromechanical systole.

![Figure 2](image_url)  
**Figure 2.** Relationship between magnitude of shunt ($Qp/Qs$) and deviation of left ventricular ejection time from the expected normal value ($\Delta\text{LVET}$) ($r = -0.70, p < 0.01$).
The murmur was holosystolic in all patients. It started with the first heart sound and continued until or beyond the aortic component of the second heart sound. In five patients the murmur had the same intensity throughout systole, whereas it had a crescendo-decrescendo or spindle form in the rest. There was no relationship between the shape of the murmur and the size of the shunt.

**Discussion**

The present study shows that an isolated, unidirectional VSD in the adult is characterized by an abbreviation of LVET and a prolongation of PEP. The study demonstrates a statistically significant relationship between STI deviations and magnitude of interventricular shunting in VSD patients with normal right ventricular pressures. The results suggest that a hemodynamically important VSD, i.e., with a Qp/Qs above 1.4 (or, expressed alternatively, with a left-to-right shunting exceeding 30% of pulmonary blood flow) can be excluded in the presence of a normal LVET or PEP/LVET. On the other hand, as some of the patients with minimal shunting (Qp/Qs < 1.4) had abbreviated LVET and increased PEP/LVET, the study also shows that such changes do not necessarily signify hemodynamically important shunting in a patient.

The present results differ from those reported by Leatham and Segal, who found isovolumic contraction time and LVET to be normal in 17 children with VSD whose ages ranged from 4-18 years (average 11 years). This discrepancy is probably due to the great difference in age between the two groups of patients and to the fact that pulmonary artery pressures tended to be higher in the patients studied by Leatham and Segal than in the present patients.

Several reports have been published on shunt direction and left ventricular volumes in patients with
isolated VSD,11-13 but no studies on left ventricular contractility, rate of ventricular ejection and aortic blood flow in these patients seem to have been reported. In the absence of such information it might seem justified to assume that the left ventricular hemodynamics of VSD patients with normal systolic pressures in the right ventricle to a certain degree might equal those of patients with mitral insufficiency: In both conditions, part of the left ventricular stroke volume is ejected into a chamber with a lower impedance than the left ventricle and in both conditions this ejection starts before the opening of the aortic valves and reaches its maximum during the period of aortic ejection.4, 11, 12, 14, 15 The fact that all the present patients had holosystolic murmurs indicates that left-to-right shunting continued throughout systole in all of them.2, 4

The assumption of a hemodynamic similarity between VSD and mitral insufficiency seems to be supported by the direction of the STI deviations in our patients. The abbreviation of the LVET and prolongation of the PEP correspond to the deviations reported in patients with mitral insufficiency.16-18 The finding that the degree of abbreviation of LVET related significantly with the magnitude of the left-to-right shunting is of particular interest because it corresponds to a finding reported by Kitchiner, Lewis and Gotsman.16 In an angiographic study of patients with mitral insufficiency they found a similar relationship between the degree of abbreviation of LVET and the volume regurgitated into the left atrium.

The abbreviated LVET found in patients with mitral insufficiency has been ascribed to an inability of the left ventricle to sustain aortic blood flow and pressure during the latter part of ventricular ejection.19-21 It is possible, however, that the short LVET may be due partly to the increased rate of ventricular ejection reported to exist in patients with mitral insufficiency.22, 23 Because a greater part of the forward stroke volume is ejected during the first half of aortic ejection,19-21 a normal or near-normal stroke volume may be ejected during a LVET, which is shorter than expected.

Table 2 shows that PEP deviated less from the expected normal than did LVET. PEP was prolonged by 2 sD or more in only four of the 11 patients with Qp/Qs ratios above 1.4. This prolongation corresponds to that reported in patients with mitral insufficiency, but as the cause of the prolongation of PEP in mitral insufficiency is not known,18 the assumed hemodynamic similarity between mitral insufficiency and VSD does not explain the prolonged PEP in our patients.

On the basis of the findings of Leatham and Segal,5 Tavel suggested that the length of the STI might help in separating patients with VSD from patients with mitral insufficiency. The present study shows that this is not possible, as the STIs deviate in the same direction in both conditions.

None of the present patients had a rapidly rising pulse that collapsed in late systole, a so-called waterhammer pulse found in some patients with mitral insufficiency.4 This result does not support Wood's suggestion that patients with VSD might have this

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Abbreviations: Qp = pulmonary blood flow; Qs = systemic blood flow; Q-A2 = electromechanical systole; LVET = left ventricular ejection time; PEP = pre-ejection period. Δ Q-A2, Δ LVET, Δ PEP = deviations from the expected time intervals according to Weisler's regression equations;20 cQ-A2, cLVET, cPEP = changes from the expected normal values according to our own regression equations for normal women and men.
type of pulse. On the contrary, the result suggests that the finding of such a pulse might help in differentiating between VSD and mitral insufficiency.

The STIs in the present patients were compared to two sets of normal values, one obtained by Weissler et al. in 211 normal subjects and the other in 55 normal subjects studied in our laboratory. From a methodologic point it is interesting that there was little difference between the deviations (ΔQ-A2, ΔLVET, ΔPEP) calculated from Weissler’s regression equations and the changes (cQ-A2, cLVET, cPEP) calculated from our own equations, and also that the deviations and the changes showed the same degree of correlation with the magnitude of interventricular shunting. These findings suggest that the slight variation in the length of STIs in different normal populations is without clinical importance.

References

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_Circulation_. 1980;62:609-614
doi: 10.1161/01.CIR.62.3.609

_Circulation_ is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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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:
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