Right and Left Ventricular Dimensions as Determinants of Ventricular Septal Motion*

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Echocardiographic studies were performed in 86 patients with right ventricular volume overload. In 45 of these 86 patients, 58 echocardiograms were performed at different intervals in the postoperative period. For control purposes, 60 normal subjects and 18 patients with right ventricular pressure overload were also examined. The right ventricular end-diastolic dimension (RVED) and the left ventricular end-diastolic dimension (LVED) were measured on the echocardiograms. The RVED/LVED ratio was significantly elevated in patients with right ventricular volume overload. In all groups, a RVED/LVED ratio above 0.65 was usually associated with an abnormal motion of the septum; and on this basis the subjects with abnormal septal motion could clearly be separated from those with normal motion. After surgery, significant reductions of the RVED/LVED ratio were observed in patients whose septal motion reverted to normal. The RVED/LVED ratio remained significantly higher, usually above 0.65, in patients with persistent abnormal septal motion. These findings suggest that the relative sizes of the right and left ventricular cavities are probably major determinants of ventricular septal motion. Abnormal motion may result from a change in the end-diastolic shape of the septum.

Several authors have described the echocardiographic features of right ventricular diastolic volume overload. Anterior septal motion and increased right ventricular diameter index have been reported in atrial septal defects, anomalous pulmonary venous returns, tricuspid insufficiency, as well as in other conditions. Many mechanisms have been proposed to explain the abnormal septal motion associated with such conditions. There were recent suggestions that this abnormality results from changes in the geometry of cardiac structures; however, a comprehensive explanation, including reasons for which paradoxical septal motion may persist after surgical correction of the underlying defects, has yet to be found.

The purpose of this study was (1) to review our preoperative and postoperative echocardiographic data in patients with right ventricular volume overload, (2) to examine in these patients the relationships of the right and the left ventricular cavities as compared to normal subjects and patients with right ventricular pressure overload, and (3) to suggest a comprehensive explanation for abnormal septal motion.

METHODS

Two hundred and twenty-two echocardiograms from four groups of subjects were reviewed for this study. The first group was composed of 60 normal subjects who served as controls. These volunteers were mainly medical students, housestaff, or paramedical personnel with no clinical evidence of cardiac disease. The age range for this group was 16 to 39 years (mean, 25 years). Group 2 consisted of 18 patients with right ventricular systolic pressure overload. Their age range was 3 to 50 years (mean, 25 years). The following defects had been found at cardiac catheterization: tetralogy of Fallot, three patients; ventricular septal defect and pulmonary stenosis, three patients; isolated pulmonary stenosis, six patients; mitral stenosis and severe pulmonary hypertension, six patients. Their peak systolic right ventricular pressures ranged from 80 to 130 mm Hg. The third group consisted of 86 patients aged ten days to 63 years (mean, 21 years) with atrial septal defect or anomalous pulmonary venous return, or both. All subjects had a left-to-right shunt at the atrial level proven by cardiac catheterization. Their pulmonary-to-systemic flow ratio as determined by oximetric analysis ranged from 1.1 to 3.1. In most patients, including all those with pulmonary-to-systemic flow ratios less than 1.5, the shunts were further confirmed by the use of one or more of the following techniques: dye-dilution curves, hydrogen curves, or angiographic studies. Systolic pulmonary arterial pressures averaged 32 mm Hg (range, 20 to 75 mm Hg), and seven patients had pulmonary arterial pressures above 50 mm Hg. Included in the fourth group are 45 of these 86 patients who underwent surgical correction of their defects and in whom 58 echocardiographic examinations were performed at different intervals in the postoperative period.

Echocardiograms were recorded with a commercially
examined in the supine position with the transducer in the third or fourth intercostal space near the left sternal border. The ultrasonic beam was moved by tilting the transducer in arc sector between the root of the aorta and the left ventricular apex. Measurements were made where both the interventricular septum and posterior left ventricular wall were best seen, along with some parts of both mitral leaflets or chordae. Figures 1 and 2 illustrate how the measurements were performed. The end of diastole was identified at the peak of the R wave on the simultaneously recorded electrocardiogram. The right ventricular end-diastolic dimension (RVED) was calculated as the distance between the anterior right ventricular wall, which was assumed to be 0.5 cm from the chest-wall echo, and the right side of the interventricular septum. The left ventricular end-diastolic dimension (LVED) was measured between the left side of the interventricular septum and the endocardial border of the left ventricular posterior free wall. For each subject, the RVED/LVED ratio was calculated. Using the left side of the septum as a reference point, septal motion was classified as being either normal, type A, or type B, as previously described.1

**RESULTS**

Echocardiographic data from the four groups of subjects are shown in Figure 3. Considering the magnitude of the RVED/LVED ratio in all groups, there is a clear separation between subjects with normal septal motion and those with abnormal motion. Very little overlap of the distribution of values is present, abnormal septal motion being observed in all patients with a RVED/LVED ratio above 0.65. On the same basis, but with less specificity, patients with type A septal motion can be discriminated from those with type B motion.
Normal subjects all had normal septal motion, and there were no echocardiographic findings suggestive of underlying cardiac disease. The mean (±SD) of the RVED/LVED ratio for this group was 0.33 ± 0.06 (range, 0.18 to 0.47). The 18 patients with right ventricular systolic pressure overload all had peak systolic right ventricular pressures above 80 mm Hg but had none of the conditions usually associated with right ventricular volume overload. Normal septal motion was observed in all cases, and the average RVED/LVED ratio for this group was 0.44 ± 0.16 (range, 0.28 to 0.63). The values are significantly higher (P<0.001) than in the normal group but significantly less than those observed in the group with right ventricular volume overload.

Patients with right ventricular volume overload had a mean RVED/LVED ratio of 0.93 ± 0.23 (range, 0.33 to 1.53). Type A septal motion was observed in 60 patients and type B motion in 22 patients; four patients had normal septal motion. The RVED/LVED ratios of patients with type A motion were significantly higher than those with type B motion (mean, 0.97 ± 0.16 vs. 0.73 ± 0.06; P < 0.001). The four patients with normal septal motion all had RVED/LVED ratios below 0.65. Cardiac catheterization data in these cases had
shown small left-to-right shunts (pulmonary-to-systemic flow ratios of 1.1, 1.1, 1.3, and 1.5). As illustrated in Figure 4, there was a gross correlation between the size of the left-to-right shunt at cardiac catheterization and the magnitude of the RVED/LVED ratio on the echocardiogram; however, septal motion was much more clearly related to the magnitude of the RVED/LVED ratio than to shunt size.

Forty-five patients were studied again after surgical correction of their cardiac defects. Figure 5 illustrates the time and sequence of these examinations. Twenty-six patients exhibited normal septal motion on the first echocardiogram performed after surgery. The RVED/LVED ratios were below 0.65 in all cases and were significantly reduced when compared to preoperative values. The RVED/LVED ratio remained significantly higher in the 19 patients with persistent abnormal septal motion (four with type A and 15 with type B).

Multiple postoperative examinations were performed in 13 patients. In three of the 13 patients, septal motion was normal on the first postoperative study and remained normal on following examinations, moderate decreases of the RVED/LVED ratio being observed. In six patients, septal motion was abnormal on the first examination but later reverted to normal. This finding could be related to significant reductions of the RVED/LVED ratio, usually below 0.65. In the remaining four patients, abnormal septal motion persisted for more than one year after surgery, and significantly higher RVED/LVED ratios were observed.

Eight of the 45 patients studied after surgery had persistent abnormal septal motion and an increased RVED/LVED ratio more than six months after the surgery. Four of the eight patients were known to have residual shunts because of incomplete surgical repair of an associated anomalous pulmonary venous return. The four remaining patients had no distinctive features to account for the persistence of abnormal motion.

**DISCUSSION**

The characteristic echocardiographic features of right ventricular volume overload were confirmed in this study. As previously noted, septal motion may be either normal or abnormal after surgical correction of the underlying defects, and reversion to normal is usually related to a significant decrease of the right ventricular end-diastolic dimension; however, the pathophysiologic mechanisms determining septal motion in such conditions are not readily apparent and have stimulated considerable interest and discussion.

Diamond et al. have suggested that the abnormal septal motion accompanying right ventricular volume overload is a manifestation of unequal stroke volumes, the right ventricular stroke volume exceeding the left ventricular stroke volume. Meyer et al. proposed a slightly different mechanism; they believed that the motion of the septum was anterior because the anterior movement of the heart as a whole exceeded the normal posterior motion of the septum. Both a posterior displacement of the septum by a dilated right ventricle and an increased right...
ventricular stroke volume were thought to be responsible for the excessive anterior movement of the heart. These same authors also suggested that after surgery the magnitude of changes in the right ventricular diameter index could discriminate between patients whose septal motion became normal and those with persistent abnormal motion; however, only the relative changes occurring in a given patient and not the absolute value of the right ventricular dimension could be used in this discrimination. Kerber et al. were unable to confirm this finding. In their study, the measurements of right ventricular dimension were not useful in distinguishing between patients with various types of septal motion.

In the present study, the RVED/LVED ratio was calculated in order to better appreciate the relative dimensions of the right and left ventricular cavities in patients with either normal or abnormal septal motion. In all groups of subjects, this variable could be used with very high specificity to discriminate between patients whose septal motion was normal and those with abnormal septal motion. On the same basis, patients with type A motion could be separated from those with type B motion.

Angiographic studies have shown that in normal subjects the right ventricular end-diastolic volume (RVEDV) is approximately equal to the left ventricular end-diastolic volume (LVEDV); however, in patients with atrial septal defects, the RVEDV/LVEDV ratio is significantly increased (> 1.0) and may remain elevated up to one year after surgical correction. These findings can be related to the findings of the present study. Because the right and left ventricles have different shapes and because of the path of the sonic beam, the echocardiographically recorded right ventricular dimension is normally smaller than the left ventricular dimension. Our group of normal subjects had a mean RVED/LVED ratio of 0.33, which is in close agreement with previous studies. A significant increase of the right ventricular dimension is consistent with right ventricular dilatation, and an elevation of the RVED/LVED ratio probably indicates that the volume of the right ventricle is greater than the volume of the left ventricle.

In interpreting our results, there is, therefore, a strong suggestion that anterior septal motion is related to conditions where the diastolic volume of the right ventricle exceeds that of the left ventricle. The relative stroke volumes do not seem to have much influence, since the same relationship can be observed both in patients undergoing surgery and those without surgery. In the group undergoing surgery, where the stroke volumes are assumed to be equal, six patients initially had abnormal septal mo-

**NORMAL**

Figure 6. Diagrammatic representation of normal septal shape at end of diastole. During systole, septum shortens, and posterior motion is observed on echocardiogram. LV, left ventricle; RV, Right ventricle; S, septum; and LV, left ventricle.

**RVVO**

Figure 7. Diagrammatic representation of septal shape at end of diastole when there is significant dilatation of right ventricle. Anterior septal motion occurs as result of septal shortening during systole. Symbols as in Figure 6. RV, Right ventricle; S, septum; LV, left ventricle; and RVVO, right ventricular volume overload.
pressures of the left ventricle and because of the different anatomic shapes of the two ventricles, the septum bulges convexly in a right anterior direction. As the septum shortens during systole, posterior motion is, therefore, observed on the echocardiogram. In patients with right ventricular volume overload, the right ventricle becomes dilated, its volume exceeding that of the left ventricle. Consequently, there will be changes in the anatomic shapes of the two ventricles; and, according to Laplace's law, wall tension on the right side of the ventricular septum should be increased. The septum will probably be displaced posteriorly and bulge convexly in a posterior direction (Fig 7). If such was the shape of the septum at the end of diastole, the motion of the septum during systole would, therefore, be anterior and towards the right ventricular cavity.

Because the right ventricle is normally elongated and flattened over the convexity of the left ventricle, true inversion of the end-diastolic curvature of the septum probably occurs only when there is significant dilatation of the right ventricle. Flattened septal motion could, therefore, be consistent with a more intermediary position of the septum at the end of diastole. It is likely that after surgery, reductions in right ventricular size are gradual so that the anterior septal motion may persist for a certain time. Our observations, as well as previous findings by others, can be explained on the basis of this mechanism. More direct studies of the end-diastolic shape of the septum in different conditions will probably be necessary to confirm this hypothesis.

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REFERENCES
3 McCann WD, Harbold NB, Giuliani ER: The echocardiogram in right ventricular volume overload. JAMA 221:1243-1245, 1972
10 King DL: Diagnostic Ultrasound. St. Louis, CV Mosby Co, 1974, p 163

ANNOUNCEMENT

Current Problems in Intensive Care: Pulmonary Edema

The St. Francis Hotel, San Francisco, will be the location for the program, Current Problems in Intensive Care: Pulmonary Edema, presented by the University of California San Francisco. The course will be held April 1-2. For information, write to Extended Programs in Medical Education, Room C-135G, University of California, San Francisco 94143.