Response of the Interatrial Septum to Transatrial Pressure Gradients and Its Potential for Predicting Pulmonary Capillary Wedge Pressure: An Intraoperative Study Using Transesophageal Echocardiography in Patients During Mechanical Ventilation

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Objectives. **We hypothesized that the directional movement of the interatrial septum and its curvature may reflect the pressure relations between the left and right atria.**

Background. **Interventricular septal shape is primarily dependent on the pressure gradient between the left and the right ventricle. No analogous study has carefully evaluated the determinants of interatrial septum shape and motion.**

Methods. **Patients (n = 52) undergoing cardiac or vascular surgery were studied intraoperatively at multiple intervals with transesophageal echocardiography and simultaneous measurement of central venous pressure, pulmonary capillary wedge pressure and airway pressure.**

Results. **Overall interatrial septum shape, which usually curved toward the right atrium, changed concordantly with the interatrial pressure gradient (pulmonary capillary wedge pressure–central venous pressure difference). The degree of interatrial septum curvature was also primarily dependent on the interatrial pressure gradient and, to a lesser extent, was affected by changes in left atrial size (F = 130.4 vs. F = 14.1). During passive mechanical expiration, the interatrial pressure gradient, usually positive, often reverses transiently and the interatrial septum momentarily bows toward the left atrium. Midsystolic reversal was seen in 64 of 72 episodes when the pulmonary capillary wedge pressure was ≤15 mm Hg but in only 2 of 40 episodes when it was >15 mm Hg (sensitivity = 0.89, specificity = 0.95, positive predictive value = 0.97).**

Conclusions. **These findings suggest that overall interatrial septum shape depends on the pressure gradient between the left and right atria. Midsystolic reversal of the interatrial septum, which probably reflects the increased venous return in the right relative to the left atrium during mechanical expiration, may be a useful indicator of the pulmonary capillary wedge pressure.**

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The interatrial septum is a region of varying flexibility with a concave anterior margin that follows the posterior aortic root, an inferior edge defined by the mitral anulus and a posterior portion that follows the posterior margins of the right and left atria (1,2). The most mobile section, the fossa ovalis, comprises approximately 28% of the total area in adults; it transilluminates easily and has an average thickness of 0.4 mm (1). The first echocardiographic evaluation of the interatrial septum was performed by Matsumoto (3) in 1973 using B-mode echocardiography. He was able to discern the structural differences between a normal interatrial septum and a secundum atrial septal defect. Dillon et al. (4), using two-dimensional echocardiography from a modified left parasternal view of the base of the heart, described the echocardiogram of a normal interatrial septum as a thin relatively straight line extending from the inferoposterior surface of the aorta to the posterior wall of the atria. Tei and colleagues (5,6) described interatrial septum dynamics in normal patients and in several disease states using a right parasternal approach. They suggested that interatrial septal motion is probably due to the interatrial pressure gradient, although no direct hemodynamic data for any of their patients were reported. In addition, only 20% of normal patients could be imaged adequately.

Because of the relative proximity of the interatrial septum to the transducer, its temporal and spatial dynamics are easily evaluated by two-dimensional and M-mode transesophageal echocardiography. From our observations we hypothesized that the movement of the interatrial septum may

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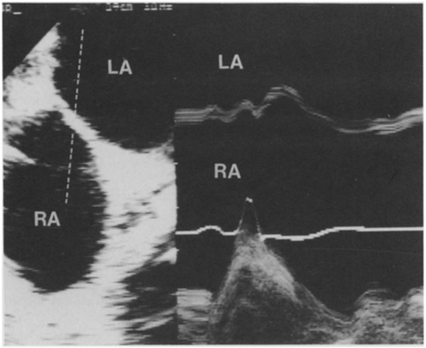


Figure 1. Simultaneous M-mode and two-dimensional images of the interatrial septum. The M-mode cursor (dashed line) was placed through the thinnest portion of the interatrial septum (septum primum). LA = left atrium; RA = right atrium.

reflect the pressure difference between the left and right atria and might be used to predict the interatrial pressure gradient or left atrial pressure. To test this theory and to help identify the factors contributing to motion of the interatrial septum, we performed transesophageal echocardiography in patients undergoing cardiovascular surgery.

Methods

Study patients. We prospectively performed transesophageal two-dimensional and M-mode echocardiography in 64 consecutive patients referred for elective cardiovascular procedures (44 men and 20 women, 42 to 78 years old [mean 62]). Eight patients were excluded from the study because of inability to obtain an adequate pulmonary capillary wedge pressure. In addition, adequate four-chamber views of the heart could not be obtained by transesophageal echocardiography in four patients. The remaining 52 patients (18 requiring abdominal aortic aneurysm repair, 4 other vascular repair, 3 mitral valve replacement, 3 aortic valve replacement and 24 coronary artery bypass grafting) formed the basis of this study. The protocol was approved by the Committee on Human Research at the University of California, San Francisco.

Experimental protocol. Anesthesia was induced with sufentanil (10 to 15 μg/kg body weight) or fentanyl (75 to 100 μg/kg) and maintained with isoflurane, oxygen and nitrous oxide. Fluids and other medications were given to the patient as warranted by the clinical situation.

We performed transesophageal echocardiography using one of four commercially available probes (Hewlett-Packard, Advanced Technology Laboratories, Aloka Corometrics, Interspec-Vingmed) and sequentially acquired 1) two-dimensional and M-mode views of the interatrial septum at the level of the aortic valve after adjusting the scope to image the thinnest part of the interatrial septum (septum primum) (Fig. 1), and 2) a standard four-chamber view of the heart while mechanical ventilation was stopped. Ventilation was then restarted while the probe was adjusted to reacquire the interatrial septum, and images were obtained for three consecutive ventilatory cycles.

Simultaneous pulmonary capillary wedge pressure and central venous pressure, obtained with a 7.5F pulmonary artery catheter (American Edwards Laboratories), were acquired throughout the study period. Great care was taken to minimize catheter artifact and accurately zero the pressure tracings. Tidal volume and airway pressure, measured directly from the respiratory circuit, were also obtained throughout the study period. Positive end-expiratory pressure was not used in any of the patients during the study period. All patients were studied just after induction of anesthesia; the 30 patients undergoing thoracotomy were also studied with the chest open and in the period after bypass surgery for a total of 112 study periods. Adequate pulmonary artery catheter position was confirmed postoperatively by examining a chest radiograph.

Two independent observers were used—one recorded hemodynamic and ventilatory variables, and the other, without knowledge of the hemodynamic data, recorded two-dimensional and M-mode echocardiographic images.

Measurements. *Hemodynamic variables.* Pulmonary capillary wedge pressure, central venous pressure, electrocardiogram (ECG) and airway pressure were recorded simultaneously on a four-channel Statham Gould recorder or directly from the monitor (Squibb Vitatek). Tidal volume was obtained directly from the ventilator. To determine the pulmonary capillary wedge pressure and central venous pressure for a given period, measurements were taken with ventilation held by averaging at least three cardiac cycles. The instantaneous interatrial pressure gradient was obtained by digitizing the pressure tracings onto a computer (Apple Macintosh) and calculating their difference. We averaged three consecutive mechanical respirations to obtain peak inspiratory pressure and tidal volume.

Echocardiographic variables. Transesophageal two-dimensional and M-mode variables were measured from recordings that were digitized off line with the use of a phantom calibrated computerized video analysis system (Cine view, Freeland Medical Division) or traced directly from the video image. Measurements were made in a random sequence that differed from the order of acquisition by an observer who had no knowledge of the hemodynamic data.

To evaluate our two-dimensional and M-mode echocardiographic recordings of the interatrial septum, we focused on the dynamic shape and motion of the mobile septum primum; both qualitative and quantitative evaluation were performed. The overall shape of the interatrial septum was assessed at end-diastole, midsystole and end-systole and was classified as either convex toward the left or right atrium or at midposition. Interatrial septum length was determined by measuring the septum primum from the two-dimensional images at end-systole. Interatrial septum thickness was measured at the midpoint of the septum primum at end-systole. For quantitative analysis of interatrial septum shape and position changes, we initially considered measuring relative left and right atrial area changes from the four-chamber view. However, the mobile septum primum is often poorly seen in this imaging plane. Even when the transesophageal probe is adjusted to maximize the motion of the interatrial septum, the absolute area changes are small. In addition, atrial size is also dependent on lateral wall motion. For these reasons, we elected to concentrate on the curvature of the interatrial septum itself.

Estimates of curvature of the interatrial septum were obtained by modifying a method that has been used to quantify interventricular septal shape (7). Two chords, the first originating from the posterior edge of the septum primum and the second from the anterior edge, were drawn to span approximately 60% to 70% of the arc formed by the septum primum. Both chords were then bisected by perpendicular lines (Fig. 2). The distance from the intersection of these constructed lines to the interatrial septum is the radius of curvature. Radius of curvature was defined as positive if the interatrial septum bowed toward the right atrium and negative if it bowed toward the left. Curvature can be calculated as the reciprocal of the radius of curvature. Curvature was measured at end-diastole and end-systole. Because interatrial septum size varies in normal persons, radius of curvature was divided by the length of the interatrial septum. From the M-mode recordings, interatrial septum excursion was defined as the difference between interatrial septum position at end-diastole and at end-systole; excursion was also normalized by dividing by interatrial septum length. Qualitative observation of interatrial septal shape was done for three cardiac cycles each at end-inspiration, end-expiration and with ventilation held. All quantitative measurements were analyzed for three cardiac cycles while ventilation was held.

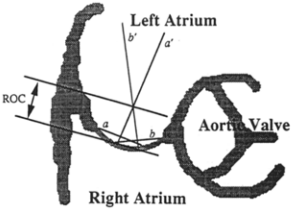


Figure 2. Schematic representation of Figure 4A demonstrates how the radius of curvature of the interatrial septum was measured. The interatrial septum, the left and right atria and the aortic valve are drawn, as seen by transesophageal echocardiography. Two chords (*a* and *b*) were drawn along the interatrial septum. These chords were then bisected by perpendicular lines (*a'* and *b'*). The distance from the intersection of these constructed lines to the interatrial septum is the radius of curvature (ROC). This value was defined as positive if the interatrial septum bowed to the right (as shown) or negative if it bowed toward the left atrium. Curvature is the reciprocal of the radius of curvature.

Left atrial expansion and mitral anulus descent were measured from the four-chamber view of the heart. Left atrial expansion index (LAEI) was calculated as the difference between end-systolic (LA_{sys}) and end-diastolic (LA_{dia}) left atrial widths divided by the end-systolic width:

$$LAEI = [(LA_{sys} - LA_{dia})/LA_{sys}] \times 100$$

The motion of the mitral anulus toward the narrowest distal portion of the imaged left ventricle during systole was calculated by slightly modifying the method of Simonson and Schiller (8). The distance from the posterior wall of the left atrium to the plane formed by the mitral anulus was measured at end-systole and end-diastole. The difference between these measurements was defined as mitral anulus descent. Both of these measures were obtained by averaging three cardiac cycles while ventilation was held.

Data analysis. To determine whether interatrial shape is related to atrial expansion, descent of the base, interatrial septal thickness or the interatrial pressure gradient, we performed a multiple stepwise regression analysis that also allowed the detection of possible effects of age, heart rate and systolic or diastolic blood pressure. Variables with an F ratio ≥4.0 were considered significant and entered into the regression equation. When comparing interatrial septal motion characteristics in patients with elevated or normal pulmonary capillary wedge pressure, contingency table analysis was used. Probability values ≤ 0.05 were considered significant. All values are listed as the mean value ± SD.

Interobserver and intraobserver variability of two-dimensional findings and measurements was determined by randomly selecting 10 patients who were analyzed by two independent observers (interobserver variability) and by one observer on two different occasions (intraobserver variability). The mean of the percent differences between the two observers and the two separate occasions was used to calculate interobserver and intraobserver variability, respectively.

Results

Determinants of interatrial septum motion. In all 112 study periods we found that the shape of the interatrial septum changed concordantly with the instantaneous interatrial pressure gradient measured by the difference of pulmonary capillary wedge pressure and central venous pressure. In the five patients with severe mitral regurgitation (flail posterior leaflet in two patients, flail anterior leaflet in one and other conditions in two) and the two patients with severe tricuspid regurgitation (functional in both), overall shape of the interatrial septum was explained entirely by the interatrial pressure gradient.

The temporal relations among shape of the interatrial septum, central venous pressure and pulmonary capillary wedge pressure are shown in Figures 3 and 4 during positive pressure inspiration and expiration, respectively. During atrial contraction, left-sided pressures are greater than right-sided pressures and the atrial septum bows toward the right. In systole the interatrial pressure gradient sometimes transiently reverses, and the interatrial septum momentarily bows toward the left (midsystolic reversal) (Fig. 4). By early diastole the left to right pressure gradient has been restored and the interatrial septum again bows to the right.

Age, arterial blood pressure and heart rate had no discernible effect on curvature or excursion of the interatrial septum. Both end-diastolic and end-systolic curvature were most strongly affected by the interatrial pressure gradient ($r = 0.77$, $F = 130.4$, $SEE = 3.02$ mm Hg and $r = 0.81$, $F = 166.6$, $SEE = 2.69$ mm Hg) (Table 1, Fig. 5 and 6). To a lesser extent, left atrial expansion also appeared to correlate with curvature ($r = 0.37$, $F = 14.1$ and $r = 0.31$, $F = 8.9$). No relation between curvature of the interatrial septum could be found with descent of the mitral anulus or interatrial septal thickness. Interatrial septal excursion did not correlate with any of the measured echocardiographic variables or the absolute interatrial pressure gradient. Excursion did correlate with the change in the interatrial pressure gradient from end-diastole to end-systole ($r = 0.59$, $SEE = 0.81$ mm Hg).

Effect of mechanical ventilation. Although the cardiac cycle is normally the primary factor in determining atrial pressures, positive pressure ventilation can change the relation of flow to the right and left sides of the heart to induce or suppress midsystolic reversal of the interatrial septum. During expiration the pulmonary capillary wedge pressure–central venous pressure difference can reverse transiently because of a relative increase in right-sided preload and is reflected by bowing of the interatrial septum to the left during systole (Fig. 3,4). End-expiratory midsystolic reversal was seen in 64 of 72 episodes where the pulmonary capillary wedge pressure was ≤ 15 but in only 2 of 40 episodes where the pulmonary capillary wedge pressure was >15 ($p \leq 0.001$; for predicting pulmonary capillary wedge pressure ≤ 15 mm Hg: sensitivity: 0.89; specificity: 0.95, positive predictive value: 0.95) (Tables 2,3). There was no significant difference in tidal volume or peak airway pressures among those patients with midsystolic reversal (tidal volume 695 ± 40 ml, peak airway pressures 22 ± 4 mm Hg) and those without (tidal volume 710 ± 45 ml, peak airway pressures 22 ± 5 mm Hg). Among patients with a thoracotomy there was no significant difference in the predictive value of midsystolic reversal among the patients after induction (0.95), with open chest (0.99) and in the episodes after bypass surgery (0.95). Although larger interatrial septa made midsystolic reversal easier to discern, there was no difference in interatrial septal length in patients with or without midsystolic reversal (1.8 ± 0.4 vs. 1.7 ± 0.4 cm). No interatrial communication could be demonstrated in any patient in saline contrast studies. In addition, no difference

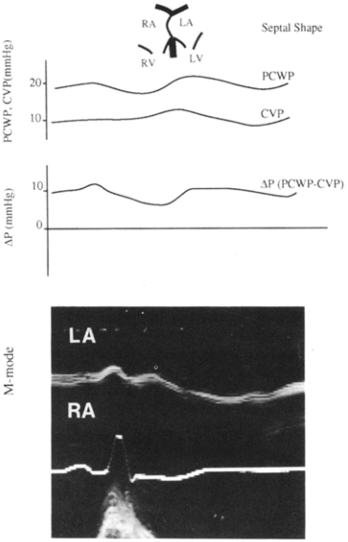
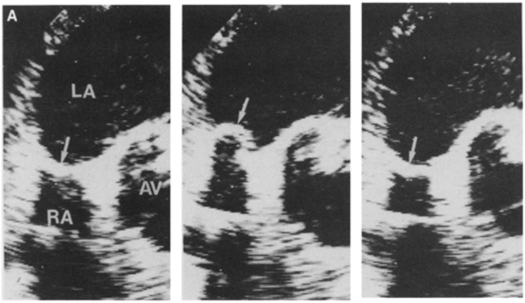


Figure 3. Hemodynamics at inspiration: simultaneous M-mode study of the interatrial septum, pulmonary capillary wedge pressure (PCWP), central venous pressure (CVP) and the interatrial pressure gradient (ΔP, PCWP–CVP) during positive pressure inspiration. With positive pressure ventilation there is increased pulmonary venous return and decreased systemic venous return. Throughout the cardiac cycle pulmonary capillary wedge pressure remains higher than central venous pressure with no reversal of the interatrial septal gradient and the interatrial septum persistently bows to the right. LA, LV = left atrium and left ventricle; RA, RV = right atrium and right ventricle, respectively.



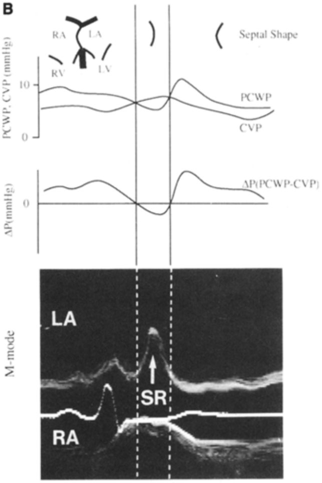


Figure 4. A, From left to right, sequential two-dimensional images of the interatrial septum during positive pressure expiration at end-diastole, midsystole and end-systole, respectively. The **arrow** points toward the interatrial septum; the middle frame shows reversal of the interatrial septum. AV = aortic valve; LA = left atrium; RA = right atrium. **B**, Same patient. Simultaneous M-mode study of the interatrial septum, pulmonary capillary wedge pressure (PCWP), central venous pressure (CVP) and the interatrial pressure gradient (ΔP, PCWP–CVP) at expiration. During midsystole there is a momentary reversal of the interatrial pressure gradient and the interatrial septum moves posteriorly, bowing toward the left atrium (**arrow**, SR [systolic reversal]). RV = right ventricle.

in interatrial thickness was present between patients with or without midsystolic reversal (1.8 ± 0.6 vs. 1.7 ± 0.6 mm).

The patients with midsystolic reversal present during both mechanical inspiration and expiration had a significantly lower pulmonary capillary wedge pressure than that of patients with only expiratory midsystolic reversal or no midsystolic reversal (6 ± 4.4 mm Hg vs. 11 ± 3.3 mm Hg and 20 ± 5.2 mm Hg; positive predictive value for pulmonary capillary wedge pressure ≤ 10: 0.85, $p \leq 0.01$).

Reproducibility. For the quantitative echocardiographic variables, the interobserver variability was 13 ± 17% for interatrial septal curvature, 9 ± 6% for interatrial septal excursion, 14 ± 8% for left atrial expansion, 8 ± 5% for interatrial septal thickness and 11 ± 17% for descent of the mitral anulus. The corresponding variables for intraobserver variability were 14 ± 18%, 10 ± 8%, 13 ± 5%, 7 ± 5% and 13 ± 10%. There was no disagreement between observers or, on separate occasions, on overall shape or the presence or absence of midsystolic reversal.

Discussion

In this study intraoperative transesophageal two-dimensional echocardiography and hemodynamic data were used to describe the motion of the interatrial septum and to determine the underlying mechanisms for the observed

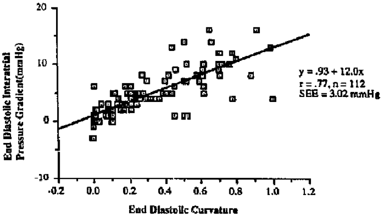
Table 1. Stepwise Regression Analysis of Interatrial Septal Curvature and Excursion With the Interatrial Pressure Gradient, Left Atrial Expansion, Interatrial Septal Thickness and Mitral Anulus Descent

	End-Diastolic IAS Curvature		End-Systolic IAS Curvature		IAS Excursion	
	F	r	F	r	F	r
Interatrial pressure gradient (mm Hg)	130.4	0.77	166.6	0.81	<4.0	—
Left atrial expansion index (%)	14.1	0.37	8.9	0.31	<4.0	—
Interatrial septal thickness (mm)	<4.0	—	<4.0	—	<4.0	—
Descent of the mitral anulus (cm)	<4.0	—	<4.0	—	<4.0	—

A stepwise linear regression analysis was performed to test for possible influences of heart rate, systolic and diastolic blood pressure and age. Variables with an F ratio ≥4.0 entered the regression equation. IAS = interatrial septum.

shape changes. We found that the interatrial septum bows markedly toward the right during atrial contraction at end-diastole, has variable shape during midsystole, but by end-systole is usually again bowed toward the right atrium. Controversy exists over the primary determinants of interatrial septal motion; some investigators have thought that the interatrial pressure differences (6,9,10) are most important, whereas other investigators have speculated that the interatrial septum moves in response to the relative volume changes (11) between the atria. In nine patients undergoing cardiac catheterization, Yonezawa and colleagues (10) found that the M-mode motion of the interatrial septum closely parallels the interatrial pressure gradient throughout the entire cardiac cycle except during atrial contraction. Simultaneous M-mode and two-dimensional images and pressure tracings from our study confirm this finding and revealed that the reason for the apparent discrepancy of interatrial septal motion during atrial contraction is the posterior motion of the entire heart through the transesophageal echocardiographic scanning sector. Although the motion of the interatrial septum on M-mode study was posterior toward the left atrium, the interatrial septum remained appropriately bowed to the right (Fig. 7). The close concordance of interatrial septal shape to the interatrial pressure gradient in our study strongly suggests that the instantaneous relative pressure changes in the atria are primarily responsible for overall interatrial septal shape. The actual curvature of the interatrial septum is mostly determined by the interatrial pressure gradient but also, to a lesser extent, by left atrial volume changes. The influence of volume is probably due to changes in circumferential tension on the mobile interatrial septum. During atrial contraction, while the regions posterior and anterior to the fossa ovalis thicken (12), the relatively inert septum primum can move more freely. Large left atrial volume changes will allow the interatrial septum to bow more prominently. Although no hemodynamic data are available, previous studies have found markedly increased interatrial septal motion in patients with acute mitral regurgitation (5,6,9,11), normal amplitude in patients with chronic mitral regurgitation (5,6) and decreased motion in patients with mitral stenosis (5,6,9,11). Atrial pressure and volume are intimately related; the relative decrease in interatrial septal motion in chronic mitral regurgitation or mitral stenosis is probably due to both chronic elevation in left atrial

Figure 5. Relation between the end-diastolic interatrial pressure gradient and end-diastolic curvature of the interatrial septum.



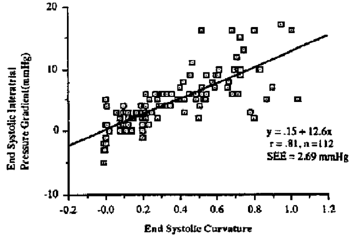


Figure 6. Relation between the end-systolic interatrial pressure gradient and end-systolic curvature of the interatrial septum.

Table 2. Relation Between Ventilatory Systolic Reversal of the Interatrial Septum (IAS) and Pulmonary Capillary Wedge Pressure

	Pulmonary Capillary Wedge Pressure (mm Hg)						
	≤10	11	12	13	14	15	>16
Ventilatory IAS systolic reversal	37	8	11	2	2	4	2*
No IAS reversal	2†	0	1	0	3	2	38

*The two patients who had systolic reversal and high wedge pressures had severe associated tricuspid regurgitation. †Of the two patients with no reversal and low pulmonary capillary wedge pressure, one had severe mitral regurgitation and the other had markedly decreased tidal volumes (380 ml).

Table 3. Ventilatory Systolic Reversal of the Interatrial Septum (IAS) and Differentiation Between Normal and Elevated Pulmonary Capillary Wedge Pressure

	Pulmonary Capillary Wedge Pressure	
	≤15	>16
Ventilatory IAS systolic reversal	64	2
No IAS reversal	8	38

Positive predictive value of systolic reversal for a pulmonary capillary wedge pressure ≤15: 0.97; sensitivity, 0.89; specificity, 0.95.

pressure throughout the cardiac cycle with an accompanying decrease in left atrial volume changes.

Several other factors may contribute to interatrial septal motion. Tei et al. (13) selectively cut the chordae to either the anterior or the posterior leaflet in dogs. Increased "shuddering" of the interatrial septum was seen in those dogs with a posterior flail leaflet, although no difference in the total amplitude of interatrial septal motion could be found between anterior and posterior flail leaflets. In our study, interatrial septal motion of the two patients with severe mitral regurgitation due to a posterior flail leaflet could be explained entirely by pressure effects. Theoretically, the degree of systolic descent of the ventricular base might affect interatrial septal motion by tethering the inferior portion of the fossa ovalis. We could not find a direct relation between interatrial septal motion or shape and mitral anulus descent. Although direct kinetic energy from regurgitant jets and descent of the base may contribute to interatrial septal motion, the overall effect is probably small.

In normal patients at end-diastole and end-systole, left atrial pressures generally exceed right atrial pressures; at midsystole there can be considerable variation in the direction and magnitude of this relation (14). However, at normal preloads the increase in right-sided venous return relative to the left with passive mechanical expiration will cause even those patients with predominantly greater left-sided pressures to have midsystolic reversal. End-expiratory midsystolic reversal appeared to be a powerful predictor of pulmonary capillary wedge pressure <15 (positive predictive value 0.95) under a variety of conditions seen in the operating room. In addition, the presence of midsystolic reversal during both the inspiratory and expiratory phases of mechanical ventilation appears to be associated with a pulmonary capillary wedge pressure <10 mm Hg.

In four of our patients the predicted pulmonary capillary wedge pressure from the presence or absence of midsystolic reversal differed noticeably from the measured pulmonary capillary wedge pressure (Table 2). The two patients with midsystolic reversal and a high pulmonary capillary wedge pressure had associated severe tricuspid regurgitation. Although pulmonary capillary wedge pressure was high, the severe tricuspid regurgitant *V* wave allowed midsystolic right atrial pressure to transiently exceed left atrial pressure during the expiratory phase of positive pressure ventilation. Conversely, of the two of the patients with a very low pulmonary capillary wedge pressure (≤10) and no midsystolic reversal, one had severe mitral regurgitation with a large *V* wave that prevented the rise in central venous pressure caused by mechanical expiration from ever exceeding left atrial pressure, and the other had the lowest tidal volume (380 ml) in the study, which probably prevented any significant respiratory effect on the interatrial pressure gradient. Ventilatory midsystolic reversal or its absence, as an estimate of pulmonary capillary wedge pressure, should be used cautiously in those patients with severe mitral or tricuspid regurgitation or in patients with a low tidal volume.

Our study is limited by several factors: 1) The left atrial pressures were not measured directly. In the group studied, left atrial pressure catheters were not used to monitor postoperative care. The differences between mean pulmo-

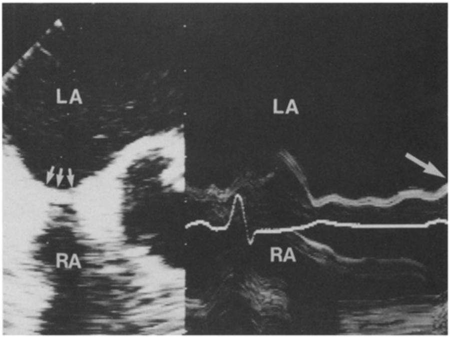


Figure 7. Simultaneous M-mode and two-dimensional images of the interatrial septum. The large arrow shows the posterior motion of the interatrial septum toward the left atrium (LA) during atrial contraction. However, as the small arrows in the two-dimensional image illustrate, the interatrial septum remains appropriately bowed toward the right atrium (RA).

nary capillary wedge pressure and left atrial pressure are usually within 2 mm Hg (15,16). To minimize the discrepancy between left atrial pressure and pulmonary capillary wedge pressure we studied patients without positive end-expiratory pressure and confirmed adequate catheter position by a postoperative chest radiograph (17,18). 2) The quantitative echocardiographic measurements of curvature and excursion of the interatrial septum, descent of the mitral anulus and left atrial expansion were marked by moderate interobserver and intraobserver variability. Interatrial septal curvature isolated from ventilatory data does not predict pulmonary capillary wedge pressure with clinically useful precision. However, changes in the interatrial septum relative to respiratory cycle are easily evaluated and can reproducibly predict pulmonary capillary wedge pressure. It is these qualitative characteristics of interatrial septal motion that are the most useful in the clinical setting. 3) Left atrial volumes were not directly measured. The left atrial expansion index has been found by our laboratory to be the most reproducible measure of changes in atrial size. Although not a direct measure of volume, left atrial expansion index does give some idea of left atrial compliance. 4) Our study group did not contain any patients operated on exclusively for right-sided lesions, and this selection bias may have artificially increased the predictive value of ventilatory midsystolic reversal. 5) Our study was concerned with the mechanisms of interatrial septal motion and was necessarily confined to patients in the operating room; the use of midsystolic reversal to predict left atrial pressure in the outpatient or critical care setting in spontaneously breathing patients should be the subject of further studies.

Conclusions. Our study demonstrates that interatrial septal motion and shape are primarily dictated by the interatrial pressure gradient. In addition, pulmonary capillary wedge pressure can be estimated by determining the relation between interatrial septal motion and positive pressure ventilation. The presence of expiratory midsystolic reversal is associated with pulmonary capillary wedge pressure <15 mm Hg (positive predictive value 0.97) and, if midsystolic reversal is present regardless of the ventilatory phase, pulmonary capillary wedge pressure is probably <10 mm Hg (positive predictive value 0.85). Other studies have shown that systolic predominance or biphasic systolic pulmonary venous flow also predicts normal or decreased left atrial pressures (19,20). These techniques illustrate how transesophageal echocardiography can provide a convenient, relatively noninvasive method for estimating left-sided pressures in anesthetized patients undergoing cardiovascular surgery.

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