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Reverse Doming of the Anterior Mitral Leaflet With Severe Aortic Regurgitation

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The normal anatomic relation of the anterior mitral leaflet to the left ventricular outflow tract suggests that significant aortic regurgitation should have a predictable hemodynamic effect on the motion and configuration of the leaflet, an effect that should be seen by two-dimensional echocardiography. Previous reports have identified an abnormality of mitral opening in the short-axis view that was quite specific but not sensitive. This study was undertaken to evaluate mitral valve motion and configuration in aortic insufficiency using two-dimensional echocardiography. A characteristic pattern of anterior leaflet motion was found in patients with moderately severe and severe aortic regurgitation. This pattern, termed "reverse doming," was seen in the apical and long-axis views in 19 of 22 such patients. The previously described "diastolic indentation" in the short-axis view was found in 16 of these 22 patients. Only 2 of 16 patients with lesser degrees of insufficiency had reverse doming. The sign was not seen in normal subjects nor in 16 patients with cardiomyopathy. For each of the few false positive and false negative findings, there is a seemingly logical hemodynamic explanation.

It is concluded that reverse doming of the anterior mitral leaflet appears to be a sensitive and specific sign for moderately severe and severe aortic regurgitation.

The diagnosis of aortic regurgitation by echocardiography has rested primarily in the domain of the M-mode echocardiogram. The characteristic fluttering of the anterior mitral leaflet, fluttering of the interventricular septum and left ventricular volume overload pattern have constituted the major echocardiographic signs. Recently, abnormalities of mitral valve opening in aortic regurgitation have been described by two-dimensional echocardiography in the short-axis view (1–4). Although this finding was thought to be relatively specific, it was quite insensitive (4). However, the normal motion of the mitral valve and its anatomic relation to the left ventricular outflow tract suggest that significant aortic regurgitation should have a predictable hemodynamic effect on the anterior mitral leaflet, an effect more reproducible than has been previously recognized. This study was undertaken to evaluate mitral valve motion and configuration in aortic regurgitation and to determine whether correlates of severity could be identified.

Methods

Study patients (Table 1). Two-dimensional echocardiograms were reviewed in three groups of patients. Group I consisted of 20 healthy volunteers with normal two-dimensional echocardiograms. Group II comprised 36 patients with aortic regurgitation at cardiac catheterization. The degree of regurgitation was graded angiographically according to established criteria (5). The patients in Group II were then subgrouped according to the severity of the regurgitant lesion: IIA = mild (1+), IIB = moderate (2+), IIC = moderately severe and severe (3+, 4+). Patients with mitral stenosis were excluded from the study. The patients in Group II had a variety of valvular and congenital lesions in association with aortic regurgitation: isolated aortic regurgitation (19 patients); associated aortic stenosis (9 patients); aortic stenosis and mitral regurgitation (3 patients); repaired tetralogy of Fallot (3 patients); discrete subvalvular

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Table 1. Patient Groups

	No. Patients	
Group I: Healthy volunteers		20
Normal two-dimensional echocardiograms	20	
Group II: Aortic regurgitation (AR)		38
A. Mild AR (1+)	8	
B. Moderate AR (2+)	8	
C. Moderate to severe (3+) or severe (4+) AR	22	
Group III: Cardiomyopathy		16
Congestive cardiomyopathy	14	
Restrictive cardiomyopathy	1	
Constrictive pericarditis	1	

aortic stenosis (1 patient); and patent ductus arteriosus (1 patient). Group III consisted of 16 patients with cardiomyopathy; all had cardiac catheterization. Fourteen patients had congestive cardiomyopathy, one had a restrictive cardiomyopathy and one had constrictive pericarditis.

Four patients from Group IIC had echocardiograms performed after aortic valve replacement. The pre- and postoperative studies were compared.

Echocardiography. Two-dimensional echocardiograms were performed with one of four instruments: the ATL Mark III, the ATL 300, the ATL Duplex or the Smith-Kline 10. The ATL 300 and ATL Duplex studies were performed with a 3 MHz in-line transducer. The ATL Mark III studies were performed with a 3 MHz L-shaped transducer. The Smith-Kline studies used a 2.25 MHz transducer. The standard views were obtained: parasternal long-axis, parasternal short-axis, apical two chamber and apical four chamber. All studies were reviewed by two trained observers with one observer blinded. Specific attention was given to the motion and configuration of the anterior mitral leaflet in diastole. Studies were considered positive for the characteristic sign (discussed later) when both observers concurred.

Cardiac catheterization. The angiographic assessment of aortic regurgitation was made by the cardiologist who performed the catheterizations. He was unaware of the results of the echocardiographic data.

Results

Normal mitral valve motion (Group I). The normal anterior leaflet of the mitral valve opened such that its medial margin lay flush against the septum. At maximal opening, it spanned the left ventricular outflow tract, effectively occluding it during that portion of diastole. Figure 1 illustrates the normal opening of the anterior leaflet in three echocardiographic views. The short-axis and the four chamber views show the leaflet tightly applied against the interventricular septum. The long-axis view shows the leaflet stretched across the outflow tract. The basic three-dimensional relation, at this point in diastole, is that of a membrane stretched across the orifice of a tubular structure, and was seen in all patients in Group I.

Mitral valve motion with aortic regurgitation (Group II). With moderately severe and severe aortic regurgitation, the normal motion of the anterior leaflet was disturbed and a characteristic motion and configuration of the leaflet could be identified. In the long-axis, four chamber and two chamber views, the leaflet could be seen to bow away from the septum or to bow in a direction opposite to that seen with valvular stenosis; hence, the term "reverse doming." The bulk of the regurgitant jet appeared to impinge on the belly

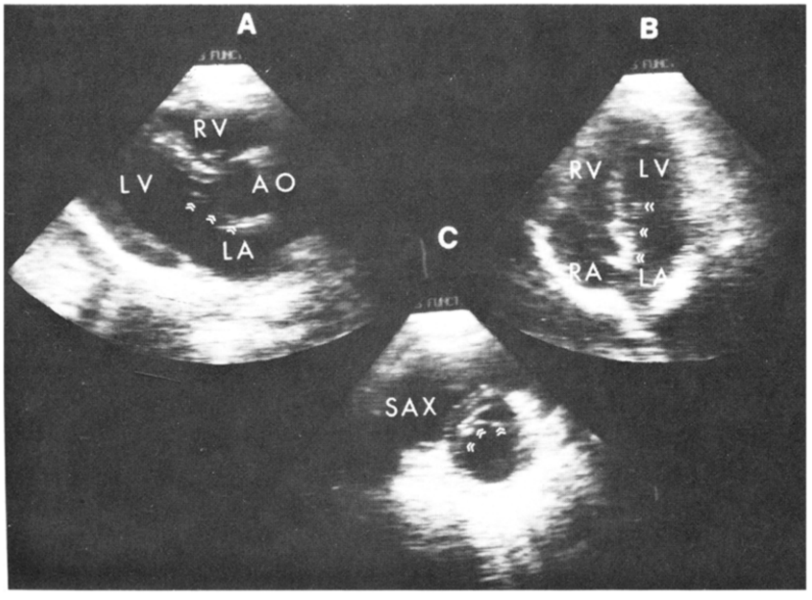

Figure 1. Normal maximal opening of the anterior mitral valve leaflet in early diastole. **A,** In the long-axis view, the opened leaflet is seen stretched across the aortic (AO) outflow tract (**arrowheads**). **B,** In the apical four chamber view, the leaflet lies flat against the septum (**arrowheads**). **C,** In the short-axis view (SAX), the anterior leaflet is flush against the septum for almost half of its visible circumference (**arrowheads**). LA = left atrium; LV = left ventricle; RV = right ventricle.

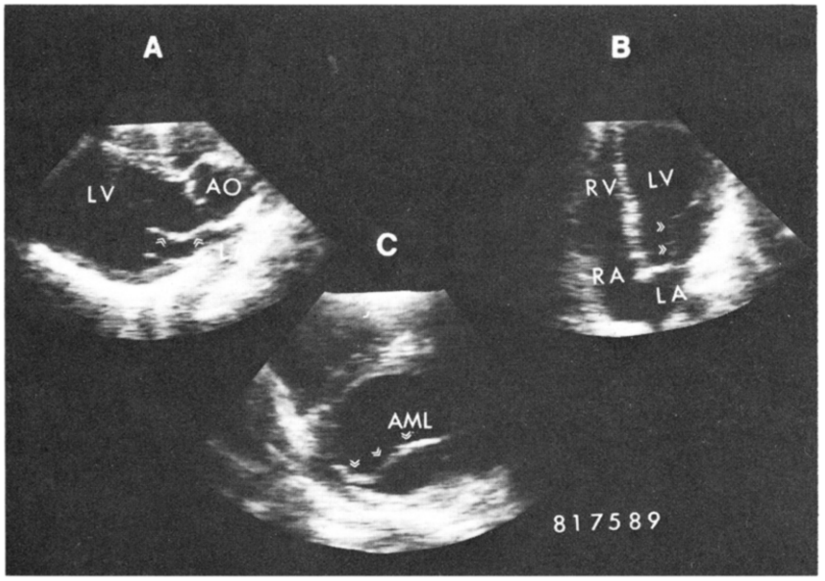

Figure 2. Abnormal opening of the anterior mitral leaflet in severe aortic regurgitation. **A,** The long-axis examination demonstrates a marked decrease in excursion of the leaflet, as well as "reverse doming." **B,** The four chamber view demonstrates a more prominent example of "reverse doming." The tip of the anterior leaflet has moved anteriorly, but the belly of the leaflet is virtually immobilized by the regurgitant jet. **C,** In the short-axis view, the principal indentation of the leaflet is medially (all views at maximal diastolic excursion).

of the leaflet as it opened. The leaflet tips with more inertia and less opposing flow swung in a wider arch. The net effect was to cause the leaflet to bow away from the outflow tract and septum. Figure 2 illustrates this relation. In the short-axis view, leaflet opening appears restricted and diastolic indentation can be observed.

Moderate and severe aortic regurgitation (Group IIC). Of 22 patients in Group IIC with moderately severe and severe aortic regurgitation, 19 demonstrated reverse doming in the long-axis or apical views (Table 2). The four chamber view was the most sensitive view, followed by the parasternal long-axis and the two chamber view, respectively. The characteristic diastolic indentation of the anterior mitral leaflet was seen in the short-axis view in 16 patients.

When diastolic indentation is present, one can identify where the bulk of the regurgitant jet is focused in the short-axis view. The pattern of indentation of the leaflet in this view allows one to predict which of the apical or long-axis views will best demonstrate the reverse doming (Fig. 3). In Figure 3A, the major indentation of the leaflet is medially and inferiorly; reverse doming would therefore be anticipated to be, and was in fact, best seen in the four chamber view and the long-axis view. In Figure 3B, a patient with a prosthetic aortic valve and paravalvular leak from the regurgitant jet is lateral and the four chamber view was normal. The reverse doming was best seen in the two chamber view (Fig. 4).

Table 2. Reverse Doming by Echocardiographic View

Patient Group	Patients (no.)		Two-Dimensional Echo View			
	Total	With Positive Echo	4C	SAX	LAX	2C
I	20	0	0	0	0	0
II						
IIA	8	1	1	1	1	0
IIB	8	1	1	1	1	0
IIC	22	19	18	16	16	10
III	16	0	0	0	0	0

Echo = echocardiogram; 4C = apical four chamber view; LAX = parasternal long-axis view; SAX = parasternal short-axis view; 2C = apical two chamber view.

Mild aortic regurgitation (Group IIA). In patients with less severe aortic regurgitation, the motion and configuration of the anterior leaflet was disturbed to a much lesser extent. In Group IIA (mild aortic regurgitation), one of eight patients demonstrated reverse doming. This was a patient with isolated aortic regurgitation and coronary artery disease who had a very small left ventricular cavity and outflow tract.

Moderate aortic regurgitation (Group IIB). In this group only one of the eight patients manifested reverse doming. In this patient, abnormal mitral motion in both the four chamber and long-axis views, as well as diastolic indentation in the short-axis view was noted. This patient had repair of tetralogy of Fallot with residual aortic insufficiency and a persistent ventricular septal defect and a 2:1 left to right shunt.

Analysis of data. The sensitivity of reverse doming for moderately severe and severe aortic regurgitation in the three groups of patients was 0.86. This was derived by dividing the number of true positive tests (all patients in Group IIC with reverse doming) by the number of patients with the lesion at catheterization (all patients in Group IIC).

Specificity was 0.94 and was determined by dividing the number of true negative tests (all patients with negative echograms in Groups I, IIA, IIB and III) by the total number of patients who did not have moderate to severe or severe

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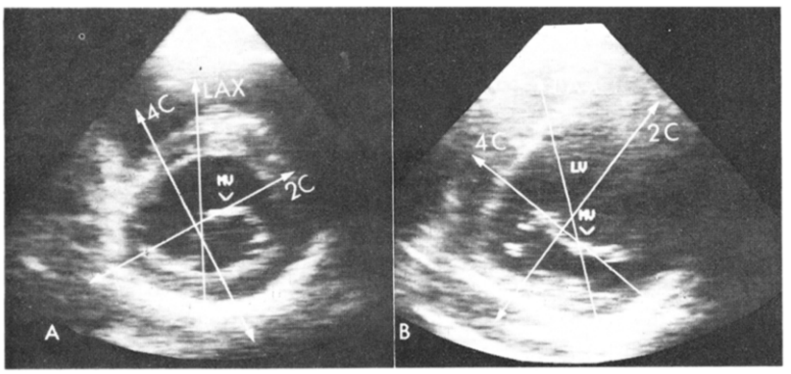

Figure 3. Short-axis view of two patients with severe aortic regurgitation. **Lines** have been superimposed on both images to indicate the respective planes of the apical and long-axis (LAX) views. **A,** The bulk of the regurgitant jet strikes the mitral valve (MV) leaflet medially causing the obvious indentation. This region corresponds to the plane of the four chamber (4C) and possibly the long-axis views. One would then expect to see the reverse doming in those views. Such was the case in this patient. **B,** The jet is lateral in the plane of the two chamber (2C) and long-axis views. The two chamber view demonstrated "reverse doming" (see Fig. 4); the four chamber (4C) view was normal.

aortic regurgitation (all patients in the study with the exception of those in Group IIC).

Mitral valve motion in cardiomyopathy (Group III). In order to exclude the possibility that the abnormal mitral valve configuration was merely due to reduced mitral flow, echocardiograms from 16 patients with cardiomyopathy were analyzed. Figure 5 illustrates the characteristic position of the anterior mitral leaflet at its point of maximal diastolic excursion in a patient with congestive cardiomyopathy. The leaflet has limited anterior motion and it is bowed toward the septum and away from the left atrium. This was a characteristic motion seen in all 14 patients with congestive cardiomyopathy in Group III. The point of similarity with leaflet motion in aortic regurgitation is the decreased amplitude of excursion. The leaflet configuration itself is significantly different. Neither the patient with restrictive myopathy nor the patient with constriction manifested reverse doming or this myopathic configuration.

Mitral valve motion after aortic valve replacement. Four patients in Group IIC, each of whom had reverse doming before surgery, had echocardiograms after aortic valve replacement. Three patients had normalization of mitral motion; the fourth with severe left ventricular dysfunction developed the mitral valve motion noted in the patients with cardiomyopathy. Figure 6 illustrates the pre- and postoperative echocardiogram of a patient whose mitral valve motion returned to normal after aortic valve replacement.

Discussion

From the three-dimensional relation of the anterior mitral leaflet to the left ventricular outflow tract, it is not surprising that severe aortic regurgitation is detected by two-dimensional echocardiography. If the normal anatomic relations are maintained, virtually any regurgitant jet from the aorta should impinge somewhere on the anterior mitral leaflet. The observed physical effect on the leaflet will vary depending on the volume of the jet and its location. The short-axis view, which interrogates the leaflet through its full circumference, would be expected to be the most sensitive view; however, it was less sensitive than the four chamber examination primarily for technical reasons. In patients with no apparent mitral disease in the parasternal long-axis view, the short-axis examination tended to concentrate on wall motion abnormalities. As a result, diastolic motion of the anterior mitral leaflet was frequently not well recorded.

Sensitivity and specificity of reverse doming. Although the sensitivity and specificity of anterior mitral

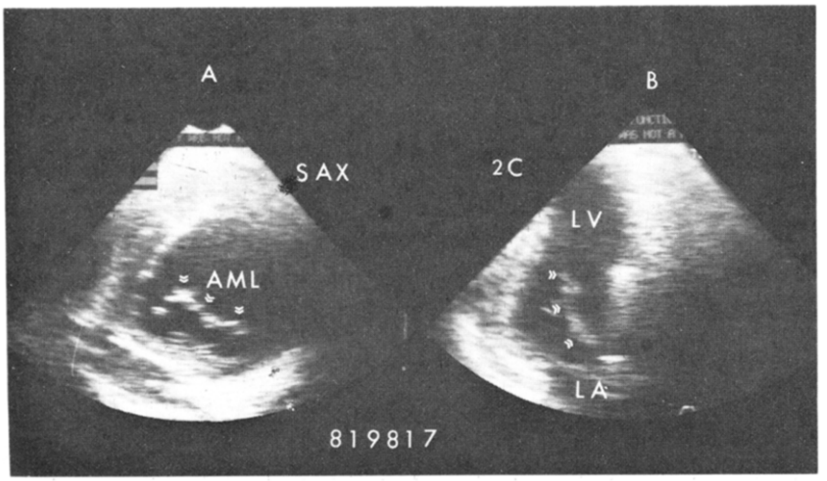

Figure 4. Short-axis (SAX) **(A)** and two chamber (2C) **(B)** views of a patient with an aortic prosthetic valve and a paravalvular leak. The four chamber view was normal. "Reverse doming" can be clearly seen in the two chamber view.

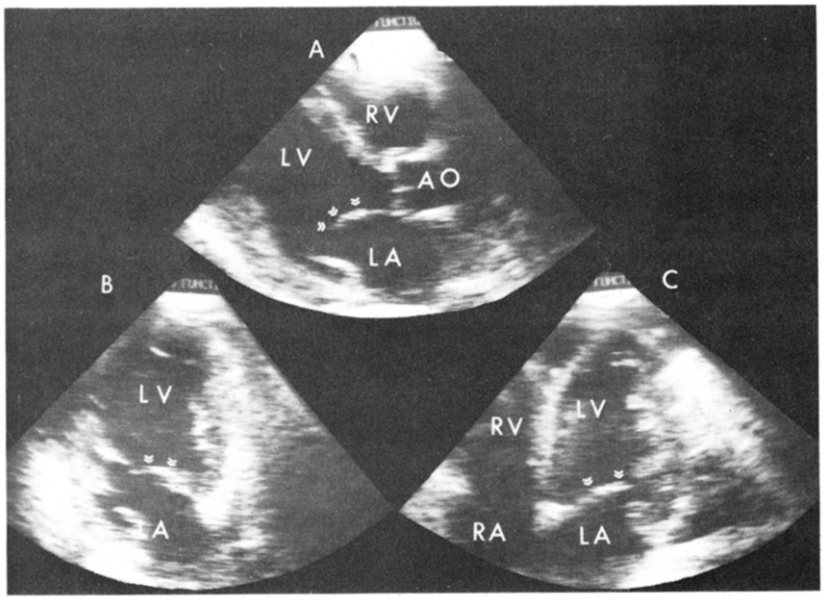

Figure 5. Characteristic mitral valve motion in congestive cardiomyopathy. In the long-axis **(A)**, two chamber **(B)** and four chamber **(C)** views, anterior mitral leaflet excursion is diminished and the leaflet is bowed toward the septum in contrast to "reverse doming."

leaflet reverse doming were good when the normal anatomy of the outflow tract and anterior mitral leaflet were preserved, such is not always the case. It is apparent that the intracardiac anatomy can be distorted, and that anterior mitral leaflet motion may not accurately reflect the presence or severity of aortic regurgitation. Three patients with moderately severe and severe aortic regurgitation did not manifest reverse doming. One patient had a high ventricular septal defect through which a large portion of the regurgitant flow entered directly into the right ventricle, rather than into the left ventricular outflow tract; thus, the amount of blood impinging on the anterior mitral leaflet was reduced.

In the other two false negative cases, the left ventricular cavity was also large and dilated, with distortion of the outflow tract by anterior displacement of the septum. The anterior mitral leaflet, even when fully open, did not reach the septum. A paraseptal channel was thus created through which regurgitant blood could pass without encountering the anterior mitral leaflet.

The opposite situation may help explain the presence of reverse doming in the one patient with mild aortic regurgitation (Group IIA) who had a false positive reverse doming. This patient, with isolated aortic regurgitation and coronary artery disease, had a small left ventricular cavity and outflow tract. The small outflow tract, the septal wall of which may have been rendered significantly less compliant by ischemic heart disease, could have resulted in an exaggeration of the hemodynamic effect of a small regurgitant jet.

One patient with moderate aortic insufficiency (Group

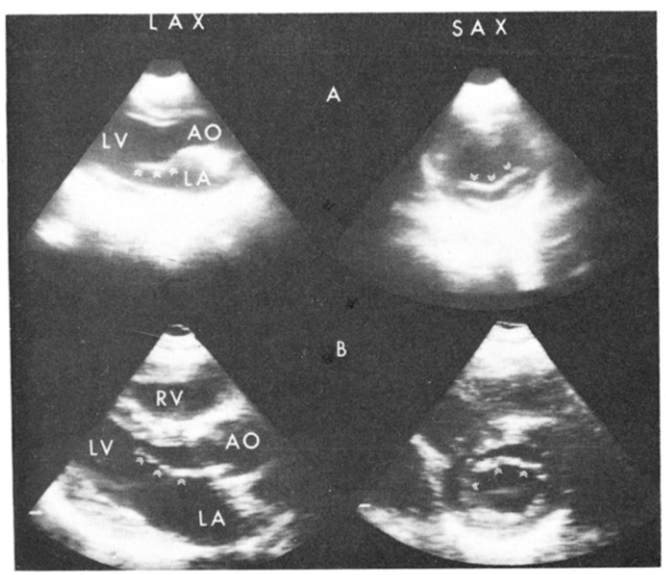

Figure 6. Long-axis (LAX) and short-axis (SAX) views at the point of maximal diastolic opening of the mitral valve in a patient with severe aortic regurgitation before **(A)** and after **(B)** aortic valve replacement. Leaflet opening returns to normal in the absence of the regurgitant jet. In the four chamber view, reverse doming was present before surgery; after surgery, anterior mitral leaflet motion was normal.

IIB) manifested reverse doming. This patient had repaired tetralogy of Fallot with a persistent ventricular septal defect and 2:1 left to right shunt. As in the patient in Group IIA, the septal wall of the outflow tract may have been less compliant secondary to the septal hypertrophy or the surgical patch, or both.

Clinical implications. The anatomic relation of the anterior mitral leaflet and left ventricular outflow tract is such that severe aortic regurgitation probably can be reliably detected by two-dimensional echocardiographic examination of the anterior mitral leaflet. In the short-axis view, the anterior mitral leaflet is seen to have the diastolic indentation previously described (4). In the apical and long-axis views, a characteristic "reverse doming" is produced by the hemodynamic effect of the regurgitant jet on the anterior mitral leaflet. Our preliminary results suggest that these findings are sensitive and specific for moderately severe and severe aortic regurgitation. There may be a logical explanation for the few exceptions. The relatively small numbers in this study require that these findings be confirmed by others, especially with regard to lesser degrees of aortic regurgitation.

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