Mitral valve closure index

Echocardiographic index of severity of mitral stenosis

M. F. SHIU

From the Cardiac Department, St. Thomas's Hospital, London

A new echocardiographic index of mitral valve diastolic closure, based on the rate of diastolic apposition of the anterior and posterior mitral leaflet echoes, was measured in 40 patients with mitral stenosis. This mitral valve closure index correlated highly significantly with the mitral valve orifice area (calculated from the Gorlin formula) ($r=0.87$). Correlation between the diastolic closure rate (based on the EF slope) and the calculated valve area was poor ($r=0.37$).

It is proposed that the mitral valve closure index excludes movement extraneous to the mitral apparatus and expresses the actual rate of valve closure, thus avoiding some of the factors known to contribute to the poor specificity of the diastolic closure rate. The better correlation of the mitral valve closure index with the calculated valve orifice area makes it possible to assess the severity of mitral stenosis by echocardiogram with greater accuracy and confidence.

The echocardiogram provides substantive evidence of organic mitral valve disease when its presence is only suspected or clinically undetected. It also provides surgically important information on the thickness and pliability of the valve leaflets and size of the left ventricular outflow tract. In the assessment of the functional severity of mitral stenosis the echocardiogram has so far made no definite contribution. Several investigators (Edler, 1967; Effert, 1967; Gustafson, 1967) proposed that the diastolic closure rate based on the EF slope of the anterior leaflet of the mitral valve reflects the severity of mitral stenosis but, like others (Mary *et al.*, 1973; Cope *et al.*, 1975), we found it to be insensitive and often misleading in individual patients. We report here a new index of mitral valve closure, derived from the rate at which the anterior and posterior leaflet echoes approximate, which correlates with the severity of the mitral stenosis sufficiently well to be of clinical value.

Methods

Forty patients with dominant mitral stenosis were studied by cardiac catheterisation and echocardiography. The mitral valve area was calculated using the Gorlin formula (Gorlin and Gorlin, 1951). Cardiac output was estimated by duplicate indocyanine green dye dilution curves. Direct left atrial

pressure by the transeptal technique was obtained in all cases and the mean mitral gradient over 10 cycles was measured by planimetry of simultaneous left atrial and left ventricular pressure recordings. Left ventriculography excluded significant mitral regurgitation in all cases.

Echocardiograms were obtained with a Smith-Kline Ekoline 20 Ultrasonoscope and a 7.5 cm focused transducer with a frequency rate of 2.25 MHz and recorded on a Cambridge Multichannel photographic strip chart recorder. Particular care was taken to record the mitral echo where the anterior leaflet excursion was maximal and where the posterior leaflet echo was continuously present. The diastolic closure rate (DCR) of the anterior mitral leaflet was measured by the standard method (Feigenbaum, 1972). The EF slope is generally a single measurement when the anterior mitral leaflet is recorded at the level of maximum excursion (Rodger and Sumner, 1975). Where biphasic movement is seen, we have taken the earlier slope as suggested by Ross (1972). The distance between the anterior and posterior mitral leaflet echoes was measured at early (X_1), and at end diastole (X_2) in atrial fibrillation or at the point of minimal separation in mid diastole in the presence of sinus rhythm. A mitral valve closure index (MVCI) was obtained by dividing X_1-X_2 by the time (t) over which closure had occurred and expressing it as a percentage of

Received for publication 3 December 1976

the initial leaflet separation, i.e.

$$\text{MVCI} = \frac{X_2 - X_1}{t \times X_1} \times 100\%$$

(Fig. 1). When the diastolic descent of both anterior and posterior mitral leaflet echoes are strictly linear, the MVCI can be simply expressed as the difference between the two diastolic closure rates divided by the initial mitral leaflet separation i.e.

$$\text{MVCI} = \frac{\text{DCRa} - \text{DCRp}}{X_1} \times 100\%$$

Results

In the 40 patients studied, the age ranged from 28 to 69 years, with 31 women and 9 men. Twelve patients were in sinus rhythm, and the remainder were in atrial fibrillation. All degrees of severity of mitral stenosis were encountered—the calculated mitral valve area ranging from 0.4 cm² to 3.8 cm². The diastolic closure rate (EF slope) correlated poorly with the calculated valve area (MVA) ($r=0.37$) (Fig. 2). In the same patients, the correlation between the mitral valve closure index and the calculated valve area was much better ($r=0.87$) (Fig. 3). The regression equation was $\text{MVCI} = 33 \text{ MVA} - 12$ ($P < 0.001$). The patients were assigned into three groups of severe, moderate, and mild stenosis in the same way as has been done by previous investigators (Cope *et al.*, 1975), with calculated valve areas of < 1.3 cm², 1.3 to 1.8 cm², and > 1.8 cm², respectively (Fig. 4). The mean

Fig. 2 Relation between diastolic closure rate (DCR) and calculated mitral valve area in 40 patients with dominant mitral stenosis. The correlation was poor with $r=0.37$.

values of the mitral valve closure index for the three groups were 13, 49, and 74, respectively, with highly significant differences between the means: $P < 0.001$ both between severe and moderate, and severe and mild, and $P < 0.005$ between moderate and mild stenosis.

None of the patients with a mitral valve closure index above 40 had severe stenosis. All the patients with mild stenosis had a mitral valve closure index over 50, though 6 of them could have been misdiagnosed as severe mitral stenosis with diastolic closure rates below 25 mm/s. This more sensitive

Fig. 1 The mitral valve closure index (MVCI) is calculated as

$$\text{MVCI} = \frac{X_2 - X_1}{t \times X_1} \times 100\%$$

Where X_1 and X_2 represent anterior and posterior mitral leaflet separation in early (X_1) and end (X_2) diastole (or before atrial contraction in cases of sinus rhythm, as here), and t -time, in seconds, between X_1 and X_2 . Alternatively

$$\text{MVCI} = \frac{\text{DCRa} - \text{DCRp}}{X_1} \times 100\%$$

where DCRa and DCRp are the diastolic closure rate of the anterior and posterior leaflet echo, respectively.

Fig. 3 Relation between the mitral valve closure index (MVCI) and mitral valve area in the same 40 patients as in Fig. 2. The correlation is highly significant ($r=0.87$), the regression equation being $MVCI=33 MVA-12$.

discrimination by the mitral valve closure index is also seen in Fig. 5, which shows the echocardiograms of 3 patients with severe, moderate, and mild stenosis (MVA 1.0 cm^2 , 1.5 cm^2 , and 2.0 cm^2 , respectively), all of whom also had a diastolic closure rate below 20 mm/s . Their mitral valve closure index were clearly different, being 10, 43, and 80, respectively, reflecting the different rates of true valve closure.

Discussion

In the normal heart, the anterior and posterior mitral valve leaflets reach maximum separation in

early diastole after which rapid closure occurs so that they are virtually apposed in mid-diastole (Rushmer *et al.*, 1956). This yields a mitral valve closure index value of the order of several hundred (Fig. 6). By contrast, in mitral stenosis, a persistent gradient of pressure across the valve results in delayed closure (Zaky *et al.*, 1968). The reduction in the rate of valve closure would be expected to reflect the severity of the mitral obstruction. In very severe stenosis, the valve would remain fully open throughout diastole, giving a mitral valve closure index of zero.

The diastolic movement of the anterior mitral leaflet echo is thought to reflect both valve movement and movement of the ring, the latter being profoundly influenced by cardiac output, heart size, and left ventricular filling (Zaky *et al.*, 1968). With increasing stenosis, diastolic closure rate reflects leaflet movement less and ring movement more (Chakorn *et al.*, 1972), a fact which certainly contributes to the poor correlation between diastolic closure rate and mitral valve area (Cope *et al.*, 1975). Zaky *et al.* (1968) suggested that a reasonable estimate of valve closure can be made by subtracting the ring excursion from the diastolic closure rate, but this presents practical difficulties because with single beam echocardiograms simultaneous recording of the two structures is not possible. On the other hand, simultaneous anterior and posterior mitral leaflet echoes can be obtained in the majority of patients with mitral stenosis, and measurement of the rate of approximation of the two echoes would be expected to give actual closure movement of the valve. The exclusion of any movement extraneous to the mitral valve apparatus by this method of measurement may well explain the better correlation of the mitral valve closure index with the calculated mitral valve area

Fig. 4 Distribution of the mitral valve closure index (MVCI) in severe, moderate, and mild mitral stenosis. Mean values are shown in figures and bars, together with the standard error. The P values of the differences between the means are shown.

Fig. 5 Echocardiogram from 3 patients with mitral valve areas of A, 1.0 cm^2 , B, 1.5 cm^2 , and C, 2.0 cm^2 . The diastolic closure rate was below 20 in each instance, but the mitral valve closure indices were A, 10, B, 43, and C, 80, clearly denoting severe, moderate, and mild stenosis respectively.

compared with that of the diastolic closure rate. The effect of extraneous movement on the diastolic closure rate is shown in the echocardiogram of a patient with severe stenosis (Fig. 7) in whom the diastolic closure rate varied 0 to 15 mm/s with successive beats. The mitral valve closure index was zero in every beat because the posterior leaflet echo was parallel to that of the anterior. The poor specificity of the diastolic closure rate is particularly important in patients with mild mitral stenosis. For example, a diastolic closure rate of less than 25 mm/s has been suggested as indicating moderately severe mitral stenosis (Feigenbaum, 1972), yet 6 of our patients with calculated mitral valve area

ranging from 2.0 cm^2 to 3.8 cm^2 had a diastolic closure rate below that value. A correct assessment was possible with the mitral valve closure index since this was above the severe stenosis range in all six.

We have found the mitral valve closure index to be a reliable index of the mitral valve area throughout the whole range of mitral stenosis. A mitral valve closure index of 20 or less was invariably associated with severe mitral stenosis, and mitral valve closure index of over 80 excluded significant stenosis (mitral valve area $>1.8 \text{ cm}^2$).

In conclusion, previous attempts to correlate echocardiographic indices with the severity of

Fig. 6 Normal mitral echogram showing rapid combined diastolic closure movement of the anterior and posterior leaflets, giving a mitral valve closure index of 500.

Fig. 7 Echocardiogram from a patient with severe mitral stenosis ($MVA=0.6 \text{ cm}^2$). The diastolic closure rate varied from 0 to 15 mm/s between successive beats despite no true valve closure movement (i.e. $MVCI=0$) in each beat.

mitral stenosis have been unsuccessful and have not justified the substitution of echocardiography for the cardiac catheterisation in the preoperative assessment of patients. In the study, we have established that an index derived from the rate of apposition of the mitral leaflet echoes expresses the fundamental haemodynamic disturbance in mitral stenosis. The index correlated highly significantly with the calculated mitral valve area suggesting that this non-invasive method of quantifying mitral stenosis is accurate and reliable.

I thank Dr. M. M. Webb-Peploe and Dr. B. S. Jenkins for their encouragement and advice on the preparation of this paper.

References

- Chakorn, S. A., Siggers, D. C., Wharton, C. F. P., and Deuchar, D. C. (1972). Study of normal and abnormal movements of mitral valve ring using reflected ultrasound. *British Heart Journal*, **34**, 480-486.
- Cope, G. D., Kisslo, J. A., Johnson, M. L., and Behar, V. S. (1975). A reassessment of the echocardiogram in mitral stenosis. *Circulation*, **52**, 664-670.
- Edler, I. (1967). Ultrasoundcardiography in mitral valve stenosis. *American Journal of Cardiology*, **19**, 18-31.
- Effert, S. (1967). Pre- and post-operative evaluation of mitral stenosis by ultrasound. *American Journal of Cardiology*, **19**, 59-65.
- Feigenbaum, H. (1972). *Echocardiography*. Lea and Febiger, Philadelphia.
- Gorlin, R., and Gorlin, S. G. (1951). Hydraulic formula for calculation of the area of the stenotic mitral valve, other cardiac valves, and central circulatory shunts. I. *American Heart Journal*, **41**, 1-29.
- Gustafson, A. (1967). Correlation between ultrasoundcardiography haemodynamics and surgical findings in mitral stenosis. *American Journal of Cardiology*, **19**, 32-41.
- Mary, D. A. S., Pakrashi, B. C., Wooler, G. H., and Ionescu, M. I. (1973). Study with reflected ultrasound of patients with mitral valve repair. *British Heart Journal*, **35**, 480-487.
- Rodger, J. C., and Sumner, D. J. (1975). Measurement of diastolic closure rate of normal mitral valve. *British Heart Journal*, **37**, 504-513.
- Ross, F. G. M. (1972). Ultrasonic investigation of the heart. In *Ultrasonics in Clinical Diagnosis*, p. 120. Ed. by P. N. T. Wells. Churchill Livingstone, Edinburgh and London.
- Rushmer, R. F., Finlayson, B. L., and Nash, A. A. (1956). Movements of the mitral valve. *Circulation Research*, **4**, 337-342.
- Zaky, A., Nasser, W. K., and Feigenbaum, H. (1968). Study of mitral valve action recorded by reflected ultrasound and its application in the diagnosis of mitral stenosis. *Circulation*, **37**, 789-799.

Requests for reprints to Dr. M. F. Shiu, Cardiac Department, St. Thomas's Hospital, London SE1 7EH.