Echocardiographic estimation of balloon-stretched diameter of secundum atrial septal defect for transcatheter occlusion

Stretched diameter of the atrial septal defect (ASD), determined by balloon sizing at cardiac catheterization, is commonly used to select the sizes of the devices used for transcatheter closure of the secundum ASD. We have previously evaluated the utility of pulmonary/systemic flow ratio and angiographic and echocardiographic (echo) sizes of the ASD in estimating stretched ASD diameter in a group of 16 patients and determined that echo diameter had the best correlation with stretched diameter ($r = 0.82$; $p < 0.001$). The stretched diameter can be estimated: 1.05 × echo diameter in millimeters + 5.49. In this study we have prospectively evaluated this formula in estimating the stretched ASD diameter by two-dimensional echo measurements obtained in two (long and short-axis) subcostal views in another group of 21 patients aged 2.5 to 29 years (median 4.5 years). The echo size of the ASD was 9.7 ± 3.0 mm, whereas the measured stretched diameter was 15.3 ± 4.0 mm. The predicted stretched ASD diameter was calculated according to the above formula and was 15.7 ± 3.1 mm, not significantly different ($p > 0.1$) from the measured stretched diameter. The correlation between predicted and measured stretched ASD sizes was excellent ($r = 0.9$; $p < 0.001$). The mean squared error was 2.4. The differences between measured and predicted values were within 2 mm in all but three patients. It is concluded that stretched ASD diameter can be estimated accurately by two-dimensional subcostal echo measurements, which in turn could be used for selection of device size for occlusion of the ASD. (Am Heart J 1992;124:172.)

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Several workers developed devices for transcatheter closure of secundum atrial septal defects (ASDs).[1-4] Stretched diameter of the ASD by balloon sizing was used as a guide to selection of the size of the device for implantation by all workers.[3-10] Although measurement of stretched diameter of the ASD can be accomplished during cardiac catheterization by passing balloons of varying sizes, as described previously by King et al.,[11] it is a cumbersome procedure and sometimes required the use of very large balloons.[11, 12] Therefore if an alternative, less cumbersome and less invasive method of measuring stretched diameter of the ASD is available, it may be useful in selection of the size of the ASD closure device. In an attempt to devise such a method, we have examined echocardiographic (echo), angiographic, and physiologic measures of ASD size in a group of 16 patients, aged 7 months to 45 years (median 4.5 years), and compared them with the stretched diameter of the ASD.[12] Although the pulmonary/systemic flow ratio and angiographic size have a significant ($p < 0.05$) correlation with stretched diameter ($r = 0.55$ and 0.54, respectively), the echo diameter had the best correlation ($r = 0.82$; $p < 0.001$). Based on the regression equation, the stretched diameter (in millimeters) can be estimated: 1.05 × echo (in millimeters) + 5.49. In this study we wish to report our observations on the prospective evaluation of this formula in estimating the stretched diameter of the ASD.

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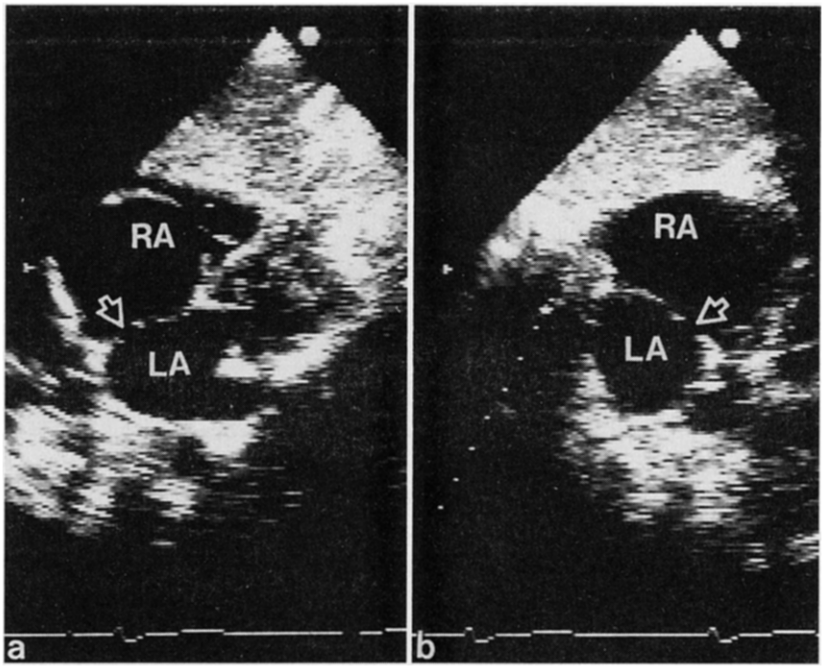

Fig. 1. Selected video frames from two-dimensional, subcostal, four-chamber views of the atrial septum in a long **(a)** and short-axis **(b)** view show ASD *(arrow)*. Echo size of the atrial septal defect is measured from the leading edge to the trailing edge in both views and averaged. *LA*, Left atrium; *RA*, right atrium.

METHODS

We have used "buttoned" double-disk devices[13] to occlude secundum ASDs under a Food and Drug Administration–approved clinical trial with an investigational device exemption at three institutions (University of Arizona, University of Michigan, and University of Wisconsin). Approval by the Human Subjects Committee (Institutional Review Board) from each of the three institutions is also obtained. Informed consent was obtained from parents (for children) or patients (adults), as appropriate. Twenty-one patients with clinical and laboratory studies suggesting the need for surgical correction of the ASD, seen during a 6-month period ending August 1991, were offered transcatheter closure of the ASD as an alternative to surgical closure. Their ages varied from 2.5 to 29 years (median 4.5 years). Subcostal views of the atrial septum (Fig. 1) were used to visualize the ASD. The atrial septum was scanned in the conventional long-axis view of the atrial septum (Fig. 1, *a*), and a video frame showing ASD size was chosen for measurement. The transducer was turned 90 degrees clockwise and a short-axis view of the atrial septum (Fig. 1, *b*) was similarly chosen. Average of these two values was used as the echo measurement of the ASD. The echo studies were obtained within 24 hours before cardiac catheterization.

Stretched diameter of the ASD was determined after cardiac catheterization preparatory to transcatheter closure of the ASD by slowly withdrawing progressively larger balloons in a manner described by King et al.[11] and our group.[12] In young children, 5F Fogarty dilatation atrioseptostomy catheters (American Edwards Laboratories/Baxter, McGraw Park, Ill.) introduced through 6F sheaths placed percutaneously in the femoral vein were used. In older children in whom a 50 cm long atrioseptostomy cath-

Table I. Size of the ASD

Case No.	*Age (yr)*	*Echo diameter (mm)*	*Stretched diameter (mm)*	
			Measured	*Predicted*
1	5.0	7.5	13.0	13.4
2	4.5	10.5	15.5	16.5
3	3.5	10.0	16.0	16.0
4	3.0	7.0	10.0	12.8
5	22.0	18.0	25.0	24.4
6	2.5	8.0	15.0	14.0
7	16.0	15.5	23.5	22.0
8	4.5	11.5	19.0	17.8
9	8.0	10.0	16.0	16.0
10	29.0	10.5	21.0	16.5
11	4.0	9.0	15.0	14.9
12	5.0	7.5	11.0	13.4
13	5.0	10.0	12.0	16.0
14	2.5	10.0	14.0	16.0
15	3.5	7.0	14.0	12.8
16	3.5	12.0	15.0	18.0
17	6.5	11.0	15.0	17.0
18	5.0	6.0	12.0	11.8
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20	6.5	10.0	17.0	16.0
21	4.0	7.0	13.0	12.8

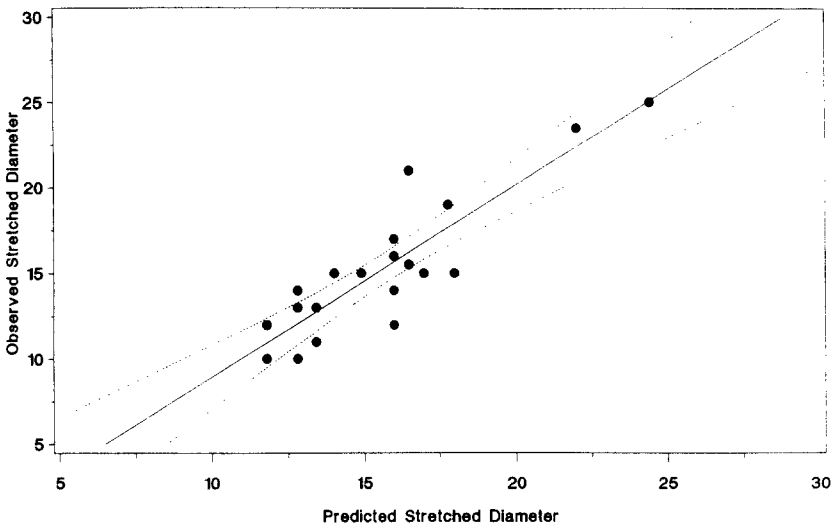

Fig. 2. Relationship of predicted and measured stretched ASD diameters is plotted. A regression line and 95% confidence limits *(interrupted lines)* are also shown. r Value is 0.9, $p < 0.001$, and mean squared error is 2.4.

eter does not reach the atrial septum, a 6F or 7F Fogarty arterial embolectomy catheter (American Edwards Laboratories/Baxter) was used. If the defect was too large so that these catheters were withdrawn across the ASD without any resistance, an 8F occlusion balloon catheter (Meditech, Watertown, Mass.) was used. Balloon sizing was performed percutaneously in all patients. Diluted contrast material, three parts saline solution and one part contrast material, was used to inflate the balloon. The tip of the deflated balloon catheter was positioned in mid-left atrium under biplane fluoroscopic control. Balloon inflation was begun with 0.5 ml diluted contrast material and increased by aliquots of 0.5 ml with each successive inflation. Gentle traction was applied on the catheter during balloon inflation to prevent floating of the balloon and obstruction of mitral flow. The balloon was gently pulled across the ASD; no force was applied so that inadvertent balloon septostomy was not performed. The balloon catheter was repositioned immediately in the mid-right atrium so that the inferior vena caval flow was not obstructed while the balloon was deflated. When the balloon could not be pulled across the ASD, 0.1 to 0.2 ml aliquots of contrast material were used for balloon deflation. The balloon size, which can be snugly withdrawn across the defect, was considered the stretched diameter of the ASD; the diameter of the balloon was measured in vitro with calipers and a series of calibrated circular holes. No balloon rupture or any other complications were encountered during balloon sizing.

The data are expressed as mean ± SD. The Student t test was used for comparison of various measures of ASD size. The measured and calculated (predicted) ASD diameters were compared further by plotting scattergrams and developing regression lines and 95% confidence limits for the lines. Pearson correlation coefficients were also calculated. The level of statistical significance was set at $p < 0.05$.

RESULTS

Echo size of the ASD was 9.7 ± 3.0 mm with a range of 6 to 18 mm. The measured stretched diameter was 15.3 ± 4.0 mm (range 10 to 25 mm), significantly ($p < 0.01$) larger than the echo diameter. The estimated stretch diameter of the ASD based on the calculation with the formula (stretched diameter = 1.05 × echo + 5.49) was 15.7 ± 3.1 mm (range 11.8 to 24.4 mm), not significantly different ($p > 0.1$) from the measured stretched diameter. The echo and measured and predicted stretched diameters of the ASD are listed in Table I.

The relationship of predicted and stretched diameters is shown in Fig. 2; the correlation coefficient was 0.9 ($p < 0.001$). The mean squared error was 2.4, signifying a tight relationship between these values. When individual measurements are scrutinized (Table I), the differences between the measured and predicted values were within 3 mm in all but two patients.

DISCUSSION

In our previous study, we found that stretched diameter of the ASD had better correlation with echo ASD diameter than with angiographic size and pulmonary/systemic flow ratio. The formula developed from that study was used in this study to predict (estimate) the stretched diameter of the ASD based on echo measurements. The correlation between the predicted and measured diameter of the ASD was good, thus validating the formula (stretched diameter = 1.05 × echo + 5.49 mm) in its ability to predict the stretched diameter.

Balloon sizing of the defect, although cumbersome, has not been associated with any complications in this study. There were also no complications in our previous study[12] or in the study by King et al.[11] Estimated diameter may also be used to screen out patients noninvasively whose stretched diameter is too large for transcatheter closure.

In this study we measured the echo ASD size in two different views (Fig. 1) so as to be able to pick up oval defects, which may give different sizes in different views. Averaging the two will avoid both underestimation and overestimation of the size of the defect. It is concluded that estimation of the stretched diameter of the ASD is feasible with echo measures and application of the formula. The estimated stretched diameter in turn can be used for selecting the size of the device used for ASD closure.

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