Research Article

Validation of proximal isovelocity surface area in Mitral valve stenosis

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Abstract

Background: Mitral stenosis (MS) is a disabling and eventually lethal disease unless treated with valvotomy or valve replacement .It has been proposed recently that measuring the flow convergence region proximal to an orifice by Doppler flow mapping can provide a means of calculating regurgitant flow rate. However, this method also can be used to derive cardiac output or flow rate proximal to stenotic orifices and therefore to calculate their areas by the continuityEquation (area=flow rate/velocity) .Applying this method in mitral stenosis would provide a important way to elicited the underlying concept because the predicted areas could be compared with those measured directly by planimetry.

Objectives: To validate the proximal isovelocity surface area (PISA) method in measuring mitral valve area (MVA) in patients with mitral valve stenosis by transthoracic echocardiography.

Methods: This is a cross sectional study conducted in Ibn-Al Bitar center for cardiac surgery for a duration from March 2010 to March 2011 We studied patients with mitral stenosis using 2D imaging and Doppler echocardiography. Doppler color flow recordings of mitral inflow were obtained from the apex, and the radius of the proximal flow convergence region was measured at its peak diastolic value from the orifice to the first color alias along the axis of flow. Flow rate was calculated assuming uniform radial flow convergence toward the orifice, modified by a factor that accounted for the inflow funnel angle formed by the mitral leaflets. Mitral valve area was then calculated as peak flow rate divided by peak velocity by continuous-wave Doppler. A=(6.28r2 X aliasing velocity /peak MS velocity)Xα 1/180°

Results: In the 60 patients studied, mitral valve area by planimetry ranged from 0.5 to 2.2 cm2 with a mean of (1.15±43) . Mitral valve area by the proximal isovelocity surface area (PISA) method agreed well with direct planimetry with no significant p value (p 0.30) with no significant effect of mitral regurgitation (P 0.6) or atrial fibrillation (P 0.12) on the relation between calculated and plan metered Area -Proximal isovelocity surface area (PISA) method also agreed well with mitral valve area calculated from the Doppler-derived pressure half-time in sinus rhythm (p 0.7) and in aterial fibrillation (p 0.9),but not correlate well in presence of mitral valve regurgitation with significant p value (p 0.05).

CONCLUSION: that PISA is a useful method in the measurement of MVA and can be used as third echocardiographic method in patients with unreliable results with classical echocardiographic methods.

Key words: :Transthoracic echocardiography, Proximal isovilocity surface area, Mitral valve stenosis

INTRODUCTION

Mitral stenosis (MS) is a disabling and eventually lethal disease unless treated with valvotomy or valve replacement. Almost all cases are due to rheumatic heart disease with symptoms usually appearing 16 to 40 years after the episode of acute rheumatic fever..[1] Mitral stenosis is, in most patients, a progressive disease. Progression is slow in asymptomatic patients, but becomes more rapid after the onset of symptoms.[2].

The normal mitral valve orifice has a cross sectional area of 4 to 6 cm^2. When the orifice is reduced to 2 cm^2, mitral stenosis is mild and there is a small pressure gradient between the left atrium and ventricle. [3]. The mean rate of progressive valve narrowing is approximately 0.1 cm2/year, [4,5].The mitral valve was the first structure to be identified by echocardiography[6.7,8]. A standard echocardiographic examination of the mitral valve consists of an M-mode tracing, multiple two dimensional views, and Doppler flow evaluation[9] .

M-mode echocardiography — The early diastolic closure slope, the E-F slope, produces an easily recognized pattern ,Although this method is the least reliable means of quantitating the severity of obstruction, a slope of less than 10 mm/sec (normal is >60 mm/sec) from a valve recording made during suspended respiration is evidence for severe mitral stenosis[10]

Two dimensional echocardiography — The elevated gradient initiates the opening motion in an abrupt manner, generating the opening snap and a characteristic "knee bend" appearance on the precordial long axis view.[10,11] ·. The peak gradient can be calculated from the modified Bernoulli equation: $P = 4V2$, where V is the peak velocity as measured by CW Doppler. The mean gradient is calculated from the time velocity integral across the MV as measured by CW Doppler. :*Mean gradient* 0–5 mmHg (mild stenosis) 5–10 mmHg (moderate stenosis) >10 mmHg (severe stenosis) .using pressure gradients alone to estimate the severity of stenosis can be problematic.[12] direct measurement of the orifice area via planimetry is possible .

Doppler echocardiography — The most frequently used measurement for the determination of the transmitral gradient during diastole is the pressure half-time[10] . The P1/2 is the time it takes for the pressure gradient across the MV to decrease by half . The valve area is calculated using the equation, MVA = 220/P1/2 ,where MVA = Mitral valve area and P1/2 = pressure half-time. It has been proposed recently that measuring the flow convergence region proximal to an orifice, as imaged by Doppler color flow mapping, can provide a means of calculating regurgitant flow rate. [13.14.15].

The proximal isovelocity surface area (PISA) method for estimating valve area is a new technique based on the continuity principle that may circumvent the limitations of the traditional methods[16,17] The MV orifice area can be determined by the continuity principle . MVA = Area LVOT x VTI LVOT/VTI MV This method correlates well with the invasive assessment of MVA

An extension of the continuity principle is to use the proximal isovelocity surface area to calculate the MVA Here, the point of "comparison" is changed from the aortic or pulmonic outflow tracts.[12].

Aim of the study

To validate the proximal isovilocity surface area (PISA) method in measuring mitral valve area (MVA) in patients with mitral valve stenosis by echocardiography

PATIENTS AND METHODS

This is a comparative cross-sectional study conducted in Ibn-Al Bitar center for cardiac surgery for a duration from March 2010 to March 2011including 60 patients randomly selected from patients who attended the center, all the patients with typical rheumatic mitral stenosis selected for image quality suitable for quantification. All patients were sent for ECG to document atrial fibrillation. Echocardiography was done by at least two well-trained operators. Echocardiography:Two-dimensional echocardiography, Doppler ultrasound, and color flow mapping were performed using a (En Visor C) ultrasound imager equipped with a (S 4-2) transducer and a standard velocity map. Color flow mapping of the mitral inflow was obtained from the apical window, with color gain adjusted to eliminate random color in areas without flow. From this window, the four-chamber view provided the most consistent image of the largest proximal convergence radius and allowed the proximal flow to be viewed most nearly parallel to the ultrasound beam. This view was scanned to image the largest proximal flow convergence region, and the aliasing velocity was reduced by shifting the color baseline to maximize this area on the image. Mitral inflow velocities were measured from the apex by continuous-wave Doppler, and the mitral valve was scanned in the parasternal short axis view to image the smallest orifice area for planimetry. The collected data had been tabulated in term of frequency distribution tables that showed the frequency, the mean and standard deviation of different parameters of mitral valve measurements.

Statistical analysis had been done using student's t-test and P value of less than 0.05 had been selected as the level of statistical significance

RESULT

This study had enrolled 60 patients with mitral valve stenosis ,There were 18(30%) men and 42(70%) women(Fig1) ; mean age was (40.5±11.3)Years as shown in table 2. 25(42%) patients were in sinus rhythm and 35(58%) were in atrial fibrillation(Fig2). 17(28.3%) patients had associated mitral regurgitation (3 mild, 7 moderate, and 7 severe by Doppler color flow assessment of jet extent into the left atrium)(Fig3). Eleven patients had aortic insufficiency, which was generally mild.

In the 60 patients studied, mitral valve area by planimetry ranged from 0.5 to 2.2 cm2 with a mean of (1.15+0.43)The radius of the proximal convergence region ranged from 0.6 to 1.9 cm (mean, 1.2±0.29 cm), with most of the aliasing velocities in the range of 19 to 43 cm/s. The angle formed by the mitral leaflets ranged from 80° to 158° (mean, 119±140), and peak velocity by continuous wave range from 1.30 to 3.00 m/s with mean.(2.03±0.49) Mitral valve area by the proximal isovelocity surface area method agreed well with direct planimetry (Table 6) with no significant p value (p0.30) with no significant effect of mitral regurgitation (P 0.6) or atrial fibrillation (P 0.12) on the relation between calculated and planimetered areas. Mitral valve area by proximal isovelocity surface area also agreed well with mitral valve area calculated from the Doppler-derived pressure half-time in sinus rhythm (p 0.7)(Table8) and in atrial fibrillation (p 0.9)(Table7),but not correlate well in presence of mitral valve regurgitation with significant p value (p 0.05)(Table 9).

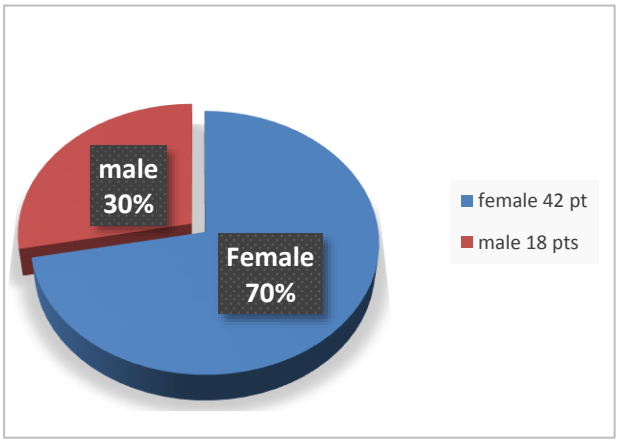

Figure1. Distribution according to gender in patients with mitral stenosis

Table 1. Descriptive Statistics

Variables	No.	Minimum Area	Maximum Area	Mean ±SD
Area by pressure half time cm^2	60	0.50	2.20	1.1592±0.4360
Area by planimetry cm^2	60	0.5	2.2	1.158±0.436
Area by PISA cm^2	60	0.36	2.60	1.1322±0.5106
Peak velocity m/s	60	1.30	3.00	2.0528±0.4975
Angle	60	80^0	158^0	119.95±14.17
Radius cm	60	0.60	1.91	1.2058±0.2941
Aliasing velocity m/s	60	18	79	37.92±13.29

Table 2: distribution of patients according to age

Age years	No.	%
10-20	**2**	**3.4**
21-30	**22**	**36.65**
31-40	**23**	**38.3**
41-50	**10**	**16.65**
51-60	**3**	**5**
Total	**60**	**100**
Mean ±SD	**40.5+11.3**	

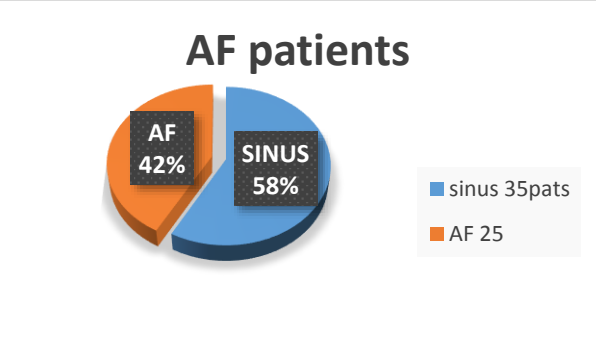

Figure 2. Percent of sinus and AF in mitral stenosis patient

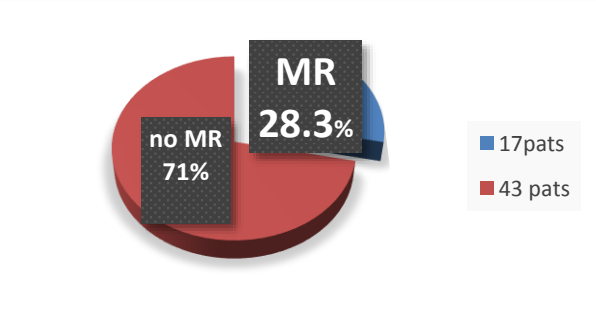

Figure 3. Percent of association of mitral regurgitation in mitral stenosis patient

Table 3. PISA vs planimatry

p=0.30			
Area cm^2	**No**	**Mean±SD**	**Std. Error Mean**
planimetry	60	1.158±0.436	5.635E-02
PISA	60	1.1322±0.5106	6.592E-02

Table4. PISA vs pressure half time

P=0.29			
Area cm^2	**No.**	**Mean± SD**	**Std. Error Mean**
Pressure half time	60	1.159±0.4360	5.629E-02
PISA	60	1.132±0.5106	6.592E-02

Tabe 5. MVA by PISA, pressure half time and planimetry in AF patients

Group Statistics					
Area cm^2	**sinus**		**AF**		
	No.	**Mean± SD**	**No.**	**Mean±**	**P**
Pressure1/2time	35	1.086±0.388	25	1.261±0.484	0.12
Planimetry	35	1.085±0.389	25	1.261±0.485	o.12
PISA	35	1.063±0.470	25	1.228±0.557	0.21

P value significant if < 0.05

Tabe 6. MVA by PISA, pressure half time and planimetry in MR patients

Group Statistics						
Area cm^2						
	N0 MR			**MR**		
	No.	**Mean ±**	**SD**	**No.**	**Mean±SD**	**P**
Pressure1/2time	43	1.173±0.427		17	1.33±0.33	**0.05**
planimetry	43	1.173±0.428		17	1.12±0.46	0.69
PISA	43	1.152±0.516		17	1.08±0.50	0.63

Table 7. MVA by PISA vs pressure half time and planimetry in AF patients

AF			
Area cm^2		**No.**	**Mean ±SD**
	Area.plan	25	1.261±0.485
	PISA	25	1.228±0.557
	Pressure1/2time	25	1.261±0.484
	PISA	25	1.228±0.557

Table 8. MVA by PISA vs pressure half time and planimetry in sinus rythem

sinus			
Area		**N0**	**Mean±SD**
	Pressure1/2time	35	1.0863±0.3886
	PISA	35	1.0631±0.4702
	Area.plan	35	1.085±0.389
	PISA	35	1.0631±0.4702

Table 9. MVA by PISA vs pressure half time and planimetry in MR

MR group				
Area cm^2		**No.**	**Mean±Std. Deviation**	**P**
	Pressure1/2time	17	1.33±0.33	**0.05**
	PISA	17	1.08±0.50	
	planimetry	17	1.12±0.46	0.30
	PISA	17	1.08±0.50	

Table 10. MVA by PISA vs pressure half time and planimetry in no MR

No MR		
Area cm^2	**No**	**Mean±SD**
Pressure1/2time	43	1.1737±0.4276
PISA	43	1.1523±0.5160
planimetry	43	1.173±0.428
PISA	43	1.1523±0.5160

DISCUSSION

The advent of Doppler flow mapping has led to attempts to extract quantitative physiological information from the displayed flow fields in accordance with fluid mechanical principles. One such approach is based on the observed flow accelerate on proximal to regurgitant and shunt lesions[20-21].

It has been proposed that these laminar flows could provide a measure of regurgitant flow rate unaffected by the complexities of turbulent flow beyond the orifice. The ability to visualize such flows with existing systems has indeed correlated with moderate to severe regurgitation[13],. On the other hand, flow convergence regions are seen proximal to stenotic lesions as well, where they are especially prominent because they represent the entire forward output across such valves. In particular, observations of such regions in mitral stenosis have suggested the possibility of testing these principles in the context of that disease.

The results of this study validate the flow convergence concept by demonstrating that it can be used to calculate mitral orifice area by continuity in patients with mitral stenosis. The results agree well with two independent measurements of orifice area: direct planimetry and the Doppler pressure half-time method,. The results also point out the need to account for geometry proximal to the orifice in applying the flow convergence method. Without correcting for the angle of the inflow funnel, the area would have been overestimated by up to 100%. The effect of inflow angle is also likely to be important in assessing flows through regurgitant orifices within a nonplanar leaflet geometry surrounding the orifice. And the correcting factor measured by dividing α/180 which is the angle formed by the inflow funnel of both mitral leaflets was one of the most important factors deciding the final results of MVA by PISA method, in addition to the radius which measured from mitral valve leaflets tip to first colour aliasing, unfortunately the correcting factor was one of limiting factors in applying PISA method in MVA measurement because measurement of the α angle not present in echocardiography device software built-in and needs off-line analysis and measurement by protractor .

In addition to validating the flow convergence concept, this technique may provide a simple and useful alternative to calculate orifice area in mitral stenosis when the pressure half-time is affected by altered chamber compliance or aortic insufficiency . and direct planimetry from the parasternal window is technically limited. This calculation may be not dependable if mitral stenosis is associated with mitral regurgitation or atrial fibrillation.

The small size of the proximal convergence region on the video image can limit measurement precision. Such errors can be minimized by lowering the aliasing velocity to increase the measured radius. This also provides

the most hemispheric isovelocity contours for which the proximal convergence calculation is most accurate, because in the immediate vicinity of an orifice, isovelocity contours tend to flatten out, leading to flow underestimation.[13,22] (In the current study, the measured radii, which represented the entire forward flow through a narrowed inlet, were relatively long [1.2+0.3 cm] compared with the visualized orifice dimension, predisposing to accurate flow calculations.) Shifting the baseline to reduce the aliasing velocity has potential limitations; for example, if the aliasing velocity is very low relative to the Nyquist limit[23,24] , selective suppression of low velocities by the color wall filter will cause overestimation of the mean velocity output displayed by color Doppler and therefore overestimation of the proximal flow convergence radius[25].

Despite this potential, moderate degrees of baseline shifting have been used in practice with accurate results. The limited temporal resolution of Doppler color flow mapping can cause variability in measuring peak flow rate [26].

In mitral stenosis, however, flow rate varies relatively slowly after its early diastolic peak, minimizing this variability. Potential variations in leaflet geometry proximal to the orifice may not always be accounted for completely by the simple angle correction used. In this regard, it is worth noting that the continuity equation, in principle, predicts effective orifice area at the vena contracta, where velocity is highest, as opposed to the anatomic orifice area, which is generally somewhat larger [27].

In this study, however, the continuity and planimetered (anatomic) values coincided well. A potential explanation for this is that milder restriction of the converging flow by the leaflets in planes perpendicular to the measured funnel angle was not taken into account, causing a mild overestimation of flow rate and predicted area. In the end, however, the empirical modification used provides good agreement with planimetered values in the clinical application studied.

The current study results are nearly comparable with results of Robert D. et al study in which the accuracy of PISA area estimates in mitralstenosis is at least comparable to those of planimetry and pressure half.time and reasonable accuracy of the PISA method ispossible in irregular rhythms [28] .

Also current study results are comparable with result of Dilek Ural et al study in which MVAs measured by PISA are closely correlated to classical echocardiographic methods, especially to planimetry , However, in cases with inadequate image qualities, planimetry lost its reliability, and measurements of PISA was not affected . its results were closer to Doppler pressure half-time.[29].

Also the current study results were comparable with result of L Rodriguez et al study in which Mitral valve area by the proximal flow convergence method agreed well with direct planimetry and showed no significant effect of mitral regurgitation or atrial fibrillation on the relation between calculated and planimetered areas. Correlation was also good with mitral valve area calculated from the Doppler-derived pressure half-time[30] .But the current study results were not comparable to the study by Messika-Zeitoun et al which was showing that using a fixed angle value of 100^0

provides an accurate estimation of the mitral valve area (MVA) by the proximal isovelocity surface area (PISA) method in patients with mitral stenosis (MS) in attempt to make PISA method more popular in assessing the MVA. The method proposed by Messika- Zeitoun et al. is subject to some difference with our study. In their study the angle range was 90^0- 115^0. This means that there is 11% overestimation and 11.5% underestimation at most with the use of 100^0 as the fixed angle. the angle range is quite narrow In a previous study by Messika-Zeitoun et al.while in our study the range of the angle was very wide with range of (80^0-158^0) which explain clearly the non-similarity between the current study results and the study by Messika- Zeitoun et al[31].

Conclusion :

The proximal isovilocity surface area (PISA) method by echocardiography allows accurate estimation of mitral valve area in mitral stenosis. This application provides a unique opportunity for comparing predictions based on flow convergence with directly measured values-in this case, planimetered orifice areas and area by pressure half time . Therefore, these results validate the proximal isovilocity surface area (PISA) method by echocardiography in measuring mitral valve area MVA in patient with mitral valve stenosis .

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