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Three-dimensional Echocardiography: A Novel Technique for Rheumatic Mitral Valve Stenosis Evaluation

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Abstract

Introduction: This study aimed to assess which echocardiographic method has the best agreement with the mitral valve area (MVA) invasively evaluated by the Gorlin's formula and also to evaluate the feasibility and reproducibility of three-dimensional (3D) echocardiography for the estimation of MVA and Wilkins score in patients with rheumatic mitral stenosis (RHMS).

Materials and Methods: This study is a comparative study. This study was conducted to describe the various methods of MV assessment in patients with RHMS. We hypothesized that, since 3D echocardiography allows a different and superior evaluation of MV apparatus, this technique could increase the ability to perform an accurate MVA planimetry immediately after a percutaneous mitral commissurotomy (PTMC). The use of the new transthoracic 3D matrix array probe (Philips, IE33) allows online 3D rendering of cardiac structures, enabling a fast and accurate analysis of cardiac structures.

Results: Fifty consecutive patients with RHMS comprised our study group. There were 32 (64%) women, and the mean age was 32.5±10 years. The mean LA size was 4.83±0.93 cm. Mitral peak gradient was 25.7±6.1 mmHg and mitral mean gradient was 15.5±4.2 mmHg. Mitral stenosis was the predominant valve lesion in all of them, but concomitant mitral regurgitation grade I/II was present in four patients and aortic regurgitation grade II/III was present in two patients. Forty-two patients were in normal sinus rhythm and eight in atrial fibrillation.

Conclusion: Transthoracic 3D echocardiography is a feasible and accurate technique for measuring MVA in patients with RHMS in pre, intra, and post-PTMC states compared to the pressure half-time method, proximal isovelocity surface area and 2D echo planimetry.

Key words: Mitral valve area, Rheumatic mitral stenosis, Three-dimensional echocardiography

INTRODUCTION

Rheumatic mitral stenosis (RHMS) is characterized by restriction of blood flow from the left atrium to left ventricle as a result of a narrowed mitral passage. It is an acquired valve defect. The fundamental treatment for RHMS is to increase the mitral valve area (MVA) by means of percutaneous balloon valvuloplasty or by surgical valve replacement. To establish the time of surgery and an optimal management, it is essential to make appropriate and accurate assessment of its severity. At present, the invasive measurement of the MVA is based on the Gorlin's formula. This method has been used as the invasive reference method to assess the severity of RHMS. However, it is an invasive method that may result in complications and in accuracies. Recently, live three-dimensional (3D) echocardiography has become an available technique in many echocardiography laboratories, providing numerous advantages in the assessment of valvular disease. Our aim was to assess which echocardiographic method has the best agreement with the MVA invasively evaluated by the Gorlin's formula and also to evaluate the feasibility and

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reproducibility of 3D echocardiography for the estimation of MVA and Wilkins score in patients with RHMS.

MATERIALS AND METHODS

Study Design

This study is a comparative study. This study was conducted to describe the various methods of MV assessment in patients with RHMS.

Total Number of Patients

Totally fifty patients were included in this study.

Place of Study

This study was conducted in Government Rajaji Hospital, Madurai. Fifty consecutive patients who were attending cardiology outpatient department fulfilling the inclusion criteria were included in this study.

Inclusion Criteria

Patients with clinical features of RHMS were included in this study.

Exclusion Criteria

All patients with clinical features of rheumatic mitral regurgitation grade II and above were excluded from the study.

MATERIALS AND METHODS

MVA is to be determined by conventional echo-Doppler methods and by 3D with full volume (Philips IE 33 with matrix array transducer). We compare the echocardiographic findings with the invasive MV assessment (Gorlin's formula). Mitral score (Wilkin's score) has to be measured. In the last decade, multiple studies depicted discrepancies between MVA measurements obtained with the pressure half-time (PHT) method and invasive methods during the immediate post-percutaneous mitral commissurotomy (PTMC) period. Our aim was to assess the accuracy of live 3D echo to measure the MVA in the pre- and immediate post-PTMC period. The invasively determined MVA was used as the gold standard. We hypothesized that since 3D echocardiography allows a different and superior evaluation of MV apparatus, this technique could increase the ability to perform an accurate MVA planimetry immediately after a PTMC. The use of the new transthoracic 3D matrix array probe (Philips, IE33) allows online 3D rendering of cardiac structures, enabling a fast and accurate analysis of cardiac structures.

RESULTS

Fifty consecutive patients with rheumatic mitral stenosis comprised our study group. There were 32 (64%) women, with a mean age of 32.5±10 years (Table 1). The mean left atrial (LA) size was 4.83±0.93 cm. Mitral peak gradient was 25.7±6.1 mmHg and mitral mean gradient was 15.5±4.2 mmHg (Table 2). Mitral stenosis was the predominant valve lesion in all of them, but concomitant - mitral regurgitation grade I/II was present in four patients and aortic regurgitation grade II/III was present in two patients. Forty-two patients were in normal sinus rhythm and eight in atrial fibrillation.

Comparison of Noninvasive Methods with Invasive Methods

MVA determined by different methods was PHT: 0.86±0.23 cm^2; 2D 0.85±0.23 cm^2: Proximal isovelocity surface area (PISA) 0.68±0.13 cm^2: Live 3D: 0.63±0.21 cm^2; and Gorlin's method: 0.69±0.15 cm^2 (Table 3). Kruskal Wallis Chi-square-test was used to test the significance of difference between quantitative variables that showed a better agreement when comparing the invasively determined MVA with live 3D-determined MVA than when comparing the former with the 2D, PHT, and PISA determined MVA. Agreement between live 3D and 2D, PHT, and PISA was also evaluated, showing acceptable results. Agreement between live 3D and 2D PHT and PISA was also evaluated, showing acceptable results.

The time required to obtain and analyze the 3D images, evaluated in 50 consecutive patients, was 27±5 min. The best 3D echocardiography method to obtain adequate images for planimetry was the 3D full volume using zoom method in all patients. The view for 3D planimetry was the apical 3-chamber view.

Valve Score: Evaluation of valve score was different for 2D compared with 3D. The 3D assessment showed the best agreement. The best intraobserver agreement when using

Table 1: Age distribution

Age group (in years)	Cases *n* (%)
Up to 20	10 (20)
21-30	11 (22)
31-40	18 (36)
41-50	9 (18)
Above 50	2 (4)
Total	50 (100)
Range (years)	13-52
Mean±SD (years)	32.5±10

SD: Standard deviation

Table 2: Profile of case study

Variable	Value
Age (years)	32.5±10
Sex	Male−18 (36%)
LA (cm)	4.83±0.93
Mitral PG	25.7±6.1
Mitral MG	15.5±402

LA: Left atrial

Table 3: Pre-PTMC MVA as measured by various methods

Method	Pre-PTMC MVA	Difference from		Correlation with		Regression coefficient	
		3D-ECHO	Gorlins	3D-ECHO	Gorlins	3D-ECHO	Gorlins
PISA	0.68±0.13	0.05±0.17	−0.072±0.13	0.5533	0.4481	0.864	0.676
2DPL	0.85±0.23	−0.22±0.3	0.16±0.21	0.1431	0.161	0.126	0.14
PHT	0.86±0.23	−0.23±0.28	0.17±0.18	0.189	0.4092	0.172	0.338
3DPL	0.63±0.21	-	−0.07±0.13	-	0.737	-	0.956
Gorlin	0.69±0.15	-0.07±0.13	-	0.737	-	0.956	-

PTMC: Percutaneous mitral commissurotomy, MVA: Mitral valve area, PISA: Proximal isovelocity surface area

2D each was noted in the evaluation of MV calcification and for 3D in valve flexibility.

In the pre-PTMC evaluation, the invasively determined MVA showed a better agreement with live 3D results than with PHT or 2D echo results. After the PTMC, the higher accuracy of the live 3D planimetry still remained. Thus, using the invasively determined MVA as the gold standard, live 3D planimetry has a better agreement compared to PISA and 2D echo planimetry in both the pre- and post-PTMC periods. Although PISA also compared favorably with invasive data in the pre-PTMC period, this agreement is lost in the post-PTMC period. The correlation coefficient between 3D planimetry and invasive Gorlin's is significant, i.e., 0.737 which is >0.5 (statistically significant) and the $r = 0.956$ which is very nearer to 1.000 (statistically significant).

DISCUSSION

Due to rapid urbanization and overcrowding, RHMS remains an important public health concern in developing countries. PTMC has become the procedure of choice in symptomatic patients when the stenotic MV is not heavily calcified and mitral regurgitation is not significant because it is cost-effective and safe.[1] This technique may also be used in patients with less favorable anatomic features, particularly in patients who are considered to be at high surgical risk such as pregnant women, very elderly patients, and patients with associated severe ischemic heart disease or associated with other comorbidities, i.e., severe pulmonary, renal, or malignant diseases. The results of PTMC are equivalent to those of surgical, open commissurotomy and both give better results than closed mitral commissurotomy.

Although the Gorlin-derived MVA[2,3] has been used before and after PTMC, echocardiography is of paramount importance in assessing the indication before this procedure, as well as the success and possible complications afterward. Until recently, MVA was assessed indirectly by the PHT[4] method, direct planimetry, 2D transthoracic echocardiography,[5] 3D transthoracic echocardiography,[6-9] or by 3D transesophageal echocardiography; all these methods have their advantages and limitations, patients with RHMS who require an intervention can be easily identified using non-invasive techniques and the results can be predicted by a careful pre-PTMC Doppler echocardiographic evaluation. Before the op PTMC, the pressure gradient, MVA, and severity of valve regurgitation can be used to evaluate patients' reliability. Prior to PTMC, Doppler echocardiographic estimation of MVA[5,10] correlates well with invasive estimation. Immediately following PTMC, the PHT method has been shown to have a poor agreement with invasive data.

There are various reasons for this inaccuracy: The development of an atrial septal defect in many patients after PTMC, and the PHT method assumes that the LA and left ventricular compliances remain stable: This assumption is not valid in the immediate period following PTMC because rapid changes in the LA pressure and left ventricular filling occur in this setting, affecting the compliance of both the left atrium and ventricle. Compared to the PHT method, planimetry (2D or 3D) is not as dependent on hemodynamic variables (heart rate, cardiac index, cardiac rhythm, left ventricular systolic and diastolic dysfunction, left ventricular and atrium compliance, left ventricular hypertrophy, and concomitant valvular disease). Accordingly, planimetry[5] of MVA should be more accurate in the setting of PTMC. Planimetry of MV orifice using 2D echo 6 is a valid method but has its own setoff limitations, especially following commissurotomy when the mitral orifice becomes irregular and technically difficult to trace, particularly if calcium is present. Transthoracic 3D echocardiography[6,11] was the most accurate ultrasound technique for measuring MVA, with a better pre- and post-procedural agreement with the invasively Gorlin-derived MVA[2] compared to 2D planimetry[12] and PHT-derived MVA. The success rate for 3D echocardiography[13] in 50 consecutive mitral stenosis patients in this center was 100% for all methods, making transthoracic 3D echocardiography a feasible technique, with an acceptable acquisition and analysis time of approximately 75+5 min. Post-PTMC, the agreement with the Gorlin-derived MVA was much better, in contrast to 2D planimetry and PHT-derived MVA,[14] which may be due to the hemodynamic and compliance changes affecting the latter as per Chen *et al.*[11] In addition, compared to conventional 2D planimetry, live 3D echocardiography[13,15] was superior, especially post-PTMC. In 2D planimetry,[11] malpositioning errors in depth and angle of the ultrasound beam can easily lead to an overestimation of the MVA up to 88%, which is not an acceptable accuracy for patient management.

Furthermore, it was easier and faster to define the image plane with the smallest orifice area, when 3D echocardiographic planimetry was used and reproducibility for the Wilkins score was better than for 2D echocardiography. Similarly, with PISA[16] which has better correlation coefficient as comparable to live 3D echo, the methodology is cumbersome to follow, especially for the beginners, who can do easily the live 3D echo. We also inferred that 3D image data sets, by providing the possibility of "computer slicing" to generate equidistant parallel cross-sections of the MV independently from physically dictated ultrasonic windows allow accurate and reproducible measurement of the MVA.

CONCLUSION

Transthoracic 3D echocardiography offered visualization of the entire MV apparatus, and allowed en face views of the mitral funnel orifice, from which accurate measurements of the MVA can be made pre-PTMC. It was also a very suitable technique for monitoring both the efficacy of the PTMC procedure (commissural splitting, MVA before and after) as well as its complications (leaflet tearing and mitral regurgitation) with a better accuracy compared to 2D planimetry and PHT-derived MVA live 3D 9 echo allowed a different and superior evaluation of the MV apparatus, improving the ability to obtain an accurate measurement of the MVA.

Hence, transthoracic 3D echocardiography is a feasible and accurate technique for measuring MVA in patients with rheumatic mitral stenosis. In pre-, intra-, and post PTMC states compared to the PHT method, PISA and 2D echo planimetry.

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