Real-time 3D, 2D trans esophageal echocardiography for the evaluation of rheumatic mitral stenosis initial single center experience

Ecocardiografía transesofágica 2D y 3D en tiempo real para la evaluación de la estenosis mitral reumática Experiencia inicial en un solo centro

Hadeel Rashid ADUL Hameed[1], Shokry Faaz Alsaad[2], Ali Hussein Ahmed Almusaw[3]
[1]Basra health director, ministry of Health sjjamp@gmail.com
[2]Assist. Prof. College of medicine, university of Babylon Shokry.faaz@yahoo.com
[3]Al najaf health director, alihussein.aa@gmail.com
Received/Recibido: 12/28/2020 Accepted/Aceptado: 01/15/2021 Published/Publicado: 03/10/2021 DOI: http://doi.org/10.5281/zenodo.4716296

Abstract

Mitral stenosis (MS) is one form of heart disease of a valvular nature. Narrowing of the mitral valve orifice occurs in the Mitral stenosis. The most common cause of MS is rheumatism fever. Other uncommon causes of MS are calcification of the mitral valve leaflets, congenital heart disease, infective endocarditis, mitral annular calcification, endomyocardial fibroelastosis. The study aims to determine the consistency and viability of using 3dimensional transthoracic echocardiography 3DTEE planimetry (MVA 3D) for mitral valve area (MVA) dimensions in patients that have rheumatic mitral stenosis (RhMS).**:** A cross-sectional study with analytic elements. The data collection was carried out in the Shahid Al- Mihrab outpatient department. Forty-one patient patients underwent Transesophageal echo (TEE) to eliminate atrial thrombi in the left side, referring to our outpatient department for echocardiographic examination and evaluation of RhMS and suitability for percutaneous mitral valvoplasty (PTMV). The investigator and administrator arranged a self-restricted survey form to collect data from the members by straight meeting with participants. Forty-one patients had MS due to rheumatic heart disease (RhHD), where all (100%) assess MVA measurement by 3DTEE. It was significantly low if compare with mitral valve area by transthorasic echo planimetry (MVA TTE planimetry), mitral valve area by transthorasic echo (MVATTEPHT). However, mitral valve area by continuity equation by transthoracic echo (MVAconTTE) measurement was feasible in 5 patients only (12%), were no significant correlation between them. Mitral valve area by transesophageal echo,3dimension (MVA3DTEE) the best agreement with MVA2DTTE PLANEIMETRY was demonstrated (95 percent agreement limits and then with MVAPHTTTE (95 percent agreement limits. The mean ± SD of MVA3D TEE was 1.06 ± 0.79 cm2 in patients with minimal fusion, the mean ± SD of MVA3DTEE was 0.79±0.21 cm2, in patients with partial fusion, and the mean ± SD of MVA3D TEE was 0.69 ± 0.15 cm2 with complete fusion. There was a significant difference in the mean MVA3D TEE among the different degrees of fusions by 3D TEE (p=0.02). Three-dimensional (3D) TEE echocardiography has demonstrated accuracy for measuring MV area for both calcific also improved the “description” of valve anatomy, and provided an advantage for less experienced operators as a method for MV area measurements.

Keywords: 3D, 2D Transesophageal Echocardiography, Rheumatic Mitral Stenosis, Initial Single-Center Experience.

Resumen

La estenosis mitral (EM) es una forma de enfermedad cardíaca de naturaleza valvular. El estrechamiento del orificio de la válvula mitral ocurre en la estenosis mitral. La causa más común de EM es la fiebre del reumatismo. Otras causas poco frecuentes de EM son la calcificación de las valvas de la válvula mitral, cardiopatía congénita, endocarditis infecciosa, calcificación del anillo mitral, fibroelastosis endomiocárdica. El estudio tiene como objetivo determinar la consistencia y viabilidad del uso de planimetría 3DTEE de ecocardiografía transtorácica tridimensional (MVA 3D) para las dimensiones del área valvular mitral (MVA) en pacientes con estenosis mitral reumática (EMRR): estudio transversal con elementos analíticos. La recopilación de datos se llevó a cabo en el departamento de consultas externas de Shahid Al-Mihrab. Cuarenta y un pacientes pacientes fueron sometidos a eco transesofágico (ETE) para eliminar trombos auriculares en el lado izquierdo, remitiendo a nuestro servicio de consulta externa para examen ecocardiográfico y evaluación de EMRR e idoneidad para valvoplastia mitral percutánea (PTMV). El investigador y el administrador organizaron un formulario de encuesta autolimitado para recopilar datos de los miembros mediante una reunión directa con los participantes. Cuarenta y un pacientes tenían EM debido a enfermedad cardíaca reumática (RhHD), donde todos (100%) evalúan la medición de MVA por 3DTEE. Fue significativamente bajo si se compara con el área de la válvula mitral por eco planimetría

transtorásica (planimetría MVA TTE), el área de la válvula mitral por eco transtorásico (MVATTEPHT). Sin embargo, la medición del área de la válvula mitral por ecuación de continuidad por eco transtorácico (MVAconTTE) fue factible en solo 5 pacientes (12%), no hubo correlación significativa entre ellos. Área de la válvula mitral por eco transesofágico, 3dimension (MVA3DTEE) se demostró la mejor concordancia con la PLANEIMETRÍA MVA2DTTE (límites de concordancia del 95% y luego con MVAPHTTTE (límites de concordancia del 95%. La media ± DE de la ETE MVA3D fue de 1.06 ± 0.79 cm2 en pacientes con fusión, la media ± DE de MVA3DTEE fue de 0,79 ± 0,21 cm2, en pacientes con fusión parcial, y la media ± DE de MVA3D TEE fue de 0,69 ± 0,15 cm2 con fusión completa. Hubo una diferencia significativa en la media de MVA3D TEE entre los diferentes grados de fusiones por TEE 3D (p = 0.02). La ecocardiografía TEE tridimensional (3D) ha demostrado precisión para medir el área de VM para ambos calcificados, también mejoró la "descripción" de la anatomía de la válvula y brindó una ventaja para los operadores menos experimentados como método para las mediciones del área de MT.

Palabras clave: Ecocardiografía transesofágica 3D, 2D, estenosis mitral reumática, experiencia inicial en un solo centro.

Introduction

MS remains a relatively rare disease that in a recent large study analysis of public health records in Sweden found the prevalence of MS in only 1917 (0.02%) individual's one type of valvular heart disease is mitral stenosis (MS)[1]. Narrowing of the mitral valve orifice occurs in Mitral stenosis. MS is most commonly caused by rheumatic fever[2]. A recent UK cohorts study for MS found the prevalence of MS in 0.1% in healthy screened subjects over 65 years[3]. Mitral stenosis shows up (20 to 40) years after a rheumatic fever episode. The most common signs are orthopnea and nocturnal dyspnea, which is paroxysmal. Patients with MS may experience palpitation symptoms, hemoptysis, chest pain, and thromboembolism. As the amount of LA volume is raised, it develops ascites, edema, and hepatomegaly (if right-side heart failure occurs). MS is usually evaluated using noninvasive, invasive measures. The electrocardiogram (ECG), chest x-ray, echocardiogram, and echocardiogram exercise are noninvasive procedures. Invasive MS procedures include a heart catheterization process[4,5]. MS treatment involves a great deal of strategy: medical therapy, percutaneous mitral valvuloplasty or surgical therapy. Medical treatment is intended to avoid endocarditis, minimize the occurrence of rheumatic fever, enhance symptoms and reduce the risk of thromboembolic disease. Valvuloplasty percutaneous mitral balloon is an invasive technique used to treat MS[6]. Echocardiography is the main noninvasive diagnostic method for assessment, rheumatic mitral valve stenosis control, and checks for other lesions. Among the most relevant echocardiography purposes is to determine the extent of MS by calculating the area of the mitral valve (MVA) and choosing appropriate patients for percutaneous mitral valvuloplasty[7]. It has recently been noticed that (3D) echocardiography can actually leave the procedural boundaries that 2-dimensional (2D) echocardiography can current[8,9]. 3DTTE is more reproducible and exact for MVA amount in Rh MS[10,11]. Transthoracic image value in the clinical examination can cooperate correct assessment of the rheumatic mitral valve using 3dimensional images[12]. The study aims to determine the consistency and viability of using 3dimensional transthoracic echocardiography 3DTEE planimetry (MVA3D) for MVA dimensions in patients with RMS.

Method

A cross-sectional study with analytic elements. The data collection was carried out in Shahid Al- Mihrab outpatient department in Marjan medical city at Al-Babylon city, Iraq. Forty-one patients Referred to our Outpatient Department for RhMS echocardiographic review and assessment and PTMV suitability. The data were obtained between 1 November 2019 and 1 June 2020. In addition to TTE, all patients were exposed to TEE specifically to exclude left atrial thrombi. The investigator and administrator arranged a self-restricted survey form to collect data from the members by straight meeting with participants. The survey-included_info concerning designated variables like gender, age of patients, a heart rate that measures by the researcher manually. Then the participants underwent echocardiographic examination. Transthoracic two-dimension (2DTTE) echocardiography, a consumer ultrasonic device, was used (Philips Medical Systems, Affiniti 70, S3-1 probe) with the aid of 2D TTE planimetry (MVA_{2D}) to measure MVA. Systematic scanning was conducted from the top to the base of the ventricle on the left side to guarantee the cross-sectional area of MV was got at the leaflets' tips. The image was taken throughout the initial diastole, mostly leaflet of MV detached. Velocity-time integrity (VTI) and transmitral grades mean are got through Doppler of continuous-wave tracings over the mitral valve from the apical 4-chamber view. We measured the MVA using half-time pressure (MVAPHT) and using the 220 / pressure half-time formulation in the lack of no additional than modest mitral or aortic regurgitation[13].

Afterward providing, explain the agreement, patients examine by TEE beneath sedation on a similar day of 2DTTE examination. Conquest was performed using an echo-cardio graphic unit and commercially available matrix-array transducer (Philips Medical Systems, Affiniti 70, X7-2 t probe). At (130-150) degrees, any views were used to obtain the mitral valve. Then figure (2-1) was optimized for 3DTEE image acquisition using the same probe (X7-2t). Next, we obtained 3D "en face" views of the MV utilizing the 3D Zoom mode in real-time. The dedicated Philips affinity 70 advanced quantification program is used to evaluate MVA3D offline on the workstation. Sectral settings designed for image and color quality by moving the mitral valve to the middle of the panel Data were analyzed using a statistical package for the social sciences (SPSS version 23) computer software program.

Statistical analysis was done by SPSS 22, frequency and percentage used for categorical data, mean and SD for con-

tinuous data. Pearson correlation coefficients for correlation. ANOVA test was used to find a difference in MVA and degree of fusion. P-value less or equal to 0.05 is considered significant.

Results

Forty-one patients with rheumatic MS were registered in the current study; the mean age was 43.1± 6.9 years, with a variety between 32-60 years. The male-to-female ratio was 1.7:1, where there were 26(63.4%) males and 15(36.6%) females. In 37(90.2%) patients, sinus rhythm was found, and AF was four, which is used for 2D and 3D attainments of similar ultrasound dais. In the commissural vision, the mitral valve 2 D picture, long axes view, and 4 (9.8%) patients. MVA values were obtained using 2D and 3D echocardiography in table 1.

Table 1: Demographic characteristics of studied groups.

Variables		No	Percentage
Age	< 40 years	10	24.7%
	≥40 years	31	75.6%
	Mean (±SD)= 43.1(±6.9) years		
Gender	Male	26	63.4%
	Female	15	36.6%
Rhythm	Sinus	37	90.2%
	AF	4	9.8%

MVA_{3DTEE} measurements and MVA_{2DTTE} planimetry measurement were feasible in all patients. The mean ± SD of MVA_{3D-TOE} was 0.78±0.213 cm^2 and the mean ± SD of MVA_{2DTTE} planimetry was 1.16±0.36 cm^2, and there were a significant poor positive correlation between them (p=0.002), table 2.

Table 2: Correlation of MVA assessed by 2DTTE planimetry echocardiography and MVA assessed by 3D TEE echocardiography

Method	No	Mean ±SD	Correlation coefficient	P value
MVA_{3D}TEE	41	0.78±0.213	0.58	0.002
MVA_{2D}TTE	41	1.16±0.36		

MVA_{PHT} measurement was feasible in 37 patients. The mean ± SD of MVA_{3D} was 0.78±0.213 cm^2 and the mean ± SD of MVA_{PHT} was 1.33±0.33 cm^2 and there was a significant positive fair correlation between them (p=0.000), table 3.

Table 3: Correlation of MVA assessed by TTE pressure half time and MVA assessed by 3D TEE echocardiography

Method	No	Mean ±SD	Correlation coefficient	P value
MVA_{3D}TEE	41	0.78±0.213	0.56	0.00
MVA_{2DTTE}	37	1.33±0.33		

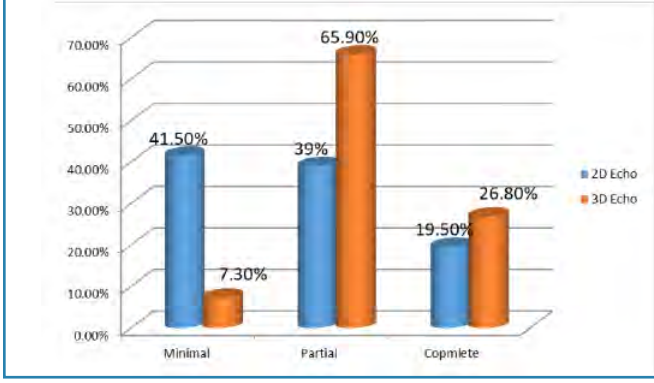
MVA_{con}TTE measurement was feasible in 5 patients. The mean ± SD of MVA_{3DTEE} was 0.78±0.213 cm^2 and the mean ± SD of $MVA_{con\ TTE}$ was 1.1±0.82 cm^2 and there was no significant correlation between them (p=0.19), table 4.

Table 4: Correlation of MVA assessed by CON equation TTE and MVA assessed by 3D TEE echocardiography

Method	No	Mean ±SD	Correlation coefficient	P value
MVA_{3D}TEE	41	0.78±0.213	0.19	0.19
MVA_{CON}TTE	5	1.1±0.82		

Commissural fusion evaluation with 2D TOE showed minimal fusion at 17 (41.5%) patients, partial fusion in 16 (39%) patients, and complete fusion in 8 (19.5%) patients. In contrast, using 3D TEE Echocardiography, minimal fusion was observed in 3 (7.3%) patients, partial fusion in 27(65.9%) patients and complete fusion in 11(26.8%) patients, figure 1.

Figure 1: Associating the Grade of Commissural Fusion Measured by using 3D and 2D TOE.



Only 17.6%(3) of patients shown minimal fusion by 3D echocardiography while 82.4%(14) of them shown partial fusion by 3D echocardiography. For patients with partial fusion by 2D TOE, 68.8%(11) of patients shown partial fusion by 3D echocardiography and the other 31.3%(5) where shown complete fusion by 3D echocardiography and 75%(6) of patients with complete fusion by 2D TOE shown also complete fusion by 3D echocardiography, table 5.

Table 5: Difference in degree of fusion between 2D TOE and 3D TEE echocardiography.

Degree of fusion		3D TEE Echocardiography			TOTAL
		minimal	Partial	Complete	
2D TOE	Minimal	3 (17.6%)	14(82.4%)	0	17(100%)
	Partial	0	11(68.8%)	5(31.3%)	16(100%)
	complete	0	2(25%)	6(75%)	8(100%)
TOTAL		3(7.3%)	27(65.9)	11(26.8%)	41(100%)

The mean±SD of $MVA_{3D\ TEE}$ was 1.06±0.79 cm^2 in patients with minimal fusion, the mean±SD of MVA_{3DTEE} was 0.79±0.21 cm^2 in patients with partial fusion, and the mean±SD of $MVA_{3D\ TEE}$ was 0.69±0.15 cm2 in a patient with complete fusion, and there was a significant difference in the mean of MVA3D TEE among different degrees of fusions by 3D TEE (p=0.02). The least fusion patients had the biggest MVAs, whereas patients with whole fusion had the minimum MVAs, table 6.

Table 6: Difference in the mean MVA with degree of fusion by 3D TEE.

MVA by 3 DTEE		Degree of fusion			P value
		minimal	Partial	Complete	
	Mean	1.06	0.79	0.69	0.02
	SD	0.79	0.21	0.14	

ANOVA Test, p value ≤0.05.

Discussion

The primary purpose of the study was to assess the viability and dependability of 3DTEE expertise for MV purpose and construction valuation, MVA amounts, and commissural fusion calculation for PTMV appropriateness in patients with modest to dangerous RhMS. Therefore, methods which gave us enough information and low variability are desirable. As a comparison criterion, planimeter methods for evaluating MVA are recommended due to they are properly unaffected by hemodynamic variations[14]. In this analysis, 3DTEE measurements of MVA3D were lower than 2D TTE measurements of MVAPHT and MVA2Dplanimetry but with no correlation to MVACON values. Previous studies using 3DTTE[11,15,16] submitted similar observations. Numerous hemodynamic influences can organize MVAPHT. In a recent study, 9.8% of patients with arterial fibrillation with a low consequence on the truth of MVAPHT MVA 3D TEE amounts with look like to results from MVA2DTTE planimetry, due to lesser lateral determination, MVA that seen by used 3DTEE in calcific mitral stenosis show low MVA standards likened to MVA2D TTE or TEE. While other parameters appear when used 3DTTE in MVA.

A lower lateral resolution relative to 3DTEE demonstrates superior precision compared to conventional 2D and Doppler approaches compared to the Gorlin model derived MVA used as the gold standard. In only 63 percent of patients, MVA2D evaluation was possible; this is low than the value that appears in other previous studies. The causes are 20% of patients aged 75 years old with dangerous MS. MVA2D is technically interesting and needs practical knowledge, especially in old patients with serious MS in whom audio openings are often deprived, and the MV is often misshapen and deeply hardened[14]. 3DTEE provided us with excellent MV image quality and resolution as opposed to 3DTTE[12]. In our studies, we used disconnected recreated 3DTEE equipment recommended that 3DTEE could allow for additional exact and reproducible assessment of the MV leaflet plus MVA in RhMS patients[17,18]. When comparing with other previous studies 3D zoom style to get 3D pictures of the mitral valve in actual period over one cardiac beat plus the time we used three beats afterward assigning the patient to ECG[19]. The 3D zoom style was preferred over the numerous full-size beats varied angle gaining mode due to there are no boundaries associated to arrhythmias plus breathing that hardly controlled in sedated patients[20]. Some time we suffered from different shape characterization and distribution of the mitral valve orifice, especially useful for MVA evaluation of eccentric mitral valve orifices, so 3D TEE used, 3D zoom mode was very fine. 3DTEE in RhMS, as thoroughgoing visualization of the mitral valve, is a big advantage over 2D echocardiographic methods. Precise assessment of commissural fusion and comprehensive morphological evaluation in all patients is given. In 19 percent of patients compared with 3DTEE[10], with 2DTTE, the grade of commissural fusion was underestimated in line with previous studies. Ideally, the MV commissures are easier to be visualized by 3DTEE, as some are separated into separate 2D planes. This can be easily measured by observing at the commissures from the atrial, ventricular, and lateral viewpoint. We used these commissural calcification numbers as a significant analyst of the consequence post PTMV[19].

Because current 3D images reflect a 3D surface rendering of the mitral valve, 3DTEE does not often easily visualize commissural calcification. MV calcification is mostly found to be endothelial zed during surgical procedures rather than on the commissure's surface. 2Dimage, which is cross-sectional, allows better calcification characterization while 3D is good for plugging bulk; this minaret is complementary to 2D and 3D methods. Commissural morphology assessment in patients considered for PTMV[21,22] offered extra prognostic value overhead other mechanisms of MV's anatomy.

Conclusion

Three-dimensional (3D) TEE echocardiography has demonstrated accuracy for measuring MV area by planimetry for all of the patients who had RhMS. And also improved the "description" of valve anatomy and provided an advantage for commissural fusion and calcification assessment in less experienced operators as a method for MV area measurements, suitability for PTMV, assessing MVA and commissural shape in best RhMS patients using 3DTEE. MVA estimate in 3DTEE delivers brilliant reproducibility and likens well with confirmed 2DE approaches.

References

1. Shah, S.N. and Sharma, S., 2019. Mitral Stenosis. In *StatPearls [Internet]*. StatPearls Publishing.

2. Andell, P., Li, X., Martinsson, A., Andersson, C., Stagmo, M., Zöller, B., . . . Smith, J. G. Epidemiology of valvular heart disease in a Swedish nationwide hospital-based register study. *Heart 2017, 103*(21), 1696-1703.

3. d'Arcy, J. L., Coffey, S., Loudon, M. A., Kennedy, A., Pearson-Stuttard, J., Birks, J.Wilson, J. Large-scale community echocardiographic screening reveals a major burden of undiagnosed valvular heart disease in older people: the OxVALVE Population Cohort Study. *European heart journal, 2016, 37*(47), 3515-3522

4. Blanken, C. P., Farag, E. S., Boekholdt, S. M., Leiner, T., Kluin, J., Nederveen, A. J., . . . Planken, R. N. Advanced cardiac MRI techniques for evaluation of left-sided valvular heart disease. *Journal of Magnetic Resonance Imaging, 2018, 48*(2), 318-329.

5. Wunderlich, N. C., Beigel, R., Ho, S. Y., Nietlispach, F., Cheng, R., & Siegel, R. J. Imaging for mitral interventions: methods and efficacy. *JACC: Cardiovascular Imaging, 2018, 11*(6), 872-901.

6. Karády, J., Ntalas, I., Prendergast, B., Blauth, C., Niederer, S., Maurovich-Horvat, P., & Rajani, R. Transcatheter mitral valve replacement in mitral annulus calcification–"The art of computer simulation". *Journal of cardiovascular computed tomography, 2018, 12*(2), 153-157.

7. Schlosshan, D., Aggarwal, G., Mathur, G., Allan, R., & Cranney, G. Real-time 3D transesophageal echocardiography for the evaluation of rheumatic mitral stenosis. *JACC: Cardiovascular Imaging, 2011, 4*(6), 580-588.

8. Pérez de Isla, L., Casanova, C., Almería, C., Rodrigo, J. L., Cordeiro, P., Mataix, L., Zamorano, J. L. Which method should be the reference method to evaluate the severity of rheumatic mitral stenosis? Gorlin's method versus 3D-echo. *European Journal of Echocardiography, 2007, 8*(6), 470-473.

9. Zamorano, J., & de Agustín, J. A. Three-dimensional echocardiography for assessment of mitral valve stenosis. *Current opinion in cardiology, 2009, 24*(5), 415-419.

10. Messika-Zeitoun, D., Brochet, E., Holmin, C., Rosenbaum, D., Cormier, B., Serfaty, J.-M., Vahanian, A. Three-dimensional evaluation of the mitral valve area and commissural opening before and after percutaneous mitral commissurotomy in patients with mitral stenosis. *European heart journal, 2007, 28*(1), 72-79.

11. Sebag, I. A., Morgan, J. G., Handschumacher, M. D., Marshall, J. E., Nesta, F., Hung, J., . . . Levine, R. A. Usefulness of three-dimensionally guided assessment of mitral stenosis using matrix-array ultrasound. *The American journal of cardiology, 2005, 96*(8), 1151-1156.

12. Sugeng, L., Coon, P., Weinert, L., Jolly, N., Lammertin, G., Bednarz, J. E., Lang, R. M. Use of real-time 3-dimensional transthoracic echocardiography in the evaluation of mitral valve disease. *Journal of the American Society of Echocardiography, 2006, 19*(4), 413-421.

13. Hatle, L., Angelsen, B., & Tromsdal, A. Noninvasive assessment of atrioventricular pressure half-time by Doppler ultrasound. *Circulation, 1979, 60*(5), 1096-1104.

14. Baumgartner, H., Hung, J., & Bermejo, J. Echocardiographic assessment of valve stenosis: European Association of Echocardiography (EAE)/American Society of Echocardiography (ASE) recommendations for clinical practice. *Eur J Echocardiogr, 2009, 10*, 1-25.

15. Binder T.M., Rosenhek R., Porenta G., Maurer G., Baumgartner H..Improved assessment of mitral valve stenosis by volumetric real-time three-dimensional echocardiography. J Am Coll Cardiol, 2000, 36:1355–1361.

16. Xie M.X., Wang X.F., Cheng T.O., Wang J., Lu Q. Comparison of accuracy of mitral valve area in mitral stenosis by real-time, three-dimensional echocardiography versus two-dimensional echocardiography versus Doppler pressure half-time. Am J Cardiol, 2005, 95:1496–1499

17. Langerveld J., Valocik G., Plokker H.W., et al. Additional value of three-dimensional transesophageal echocardiography for patients with mitral valve stenosis undergoing balloon valvuloplasty. J Am Soc Echocardiogr, 2003, 16:841–849.

18. Hozumi T., Yoshikawa J..Three-dimensional echocardiography using a muliplane transesophageal probe: the clinical applications. Echocardiography, 2000, 17:757–764.

19. Salcedo E.E., Quaife R.A. A framework for systematic characterization of the mitral valve by real-time three-dimensional transesophageal echocardiography. J Am Soc Echocardiogr. 2009, 22:1087–1099.

20. Perk G., Lang R.M., Garcia-Fernandez M.A., et al. Use of real time three-dimensional transesophageal echocardiography in intracardiac catheter based interventions. J Am Soc Echocardiogr, 2009, 22:865–882.

21. Sutaria N., Northridge D.B., Shaw T.R. Significance of commissural calcification on outcome of mitral balloon valvotomy. 2000, Heart 84:398–402.

22. Cannan C.R., Nishimura R.A., Reeder G.S., et al. Echocardiographic assessment of commissural calcium: a simple predictor of outcome after percutaneous mitral balloon valvotomy. J Am Coll Cardiol, 1997, 29:175–180.