Journal of Medical Sciences

ISSN 1682-4474

science alert

ANSInet
an open access publisher
http://ansinet.com

Research Paper

J. Med. Sci., 8 (3): 209-215
1st April, 2008

Comparative Study Between Echocardiographic and Catheterization Findings in Patients with Rheumatic Mitral Stenosis

[1]Mehrnoush Toufan and [2]Laleh Shahsar

We conducted this study to compare the difference and relations of echocardiography and conventional cardiac catheterization results in hemodynamic assessment of patients with MS. A retrospective, cross-sectional and comparative study was conducted on 166 patients with severe rheumatic MS admitted in Tabriz Shahid Madani Heart Center from 2003 to 2005 for percutaneous transvenous mitral commissurotomy (PTMC). All patients underwent simultaneous trans-thorasic echocardiography (TTE), trans-esophageal echocardiography (TEE) and catheterization and PTMC on the same day. There are significant correlations between TEE, TTE and catheterization findings in patients with rheumatic mitral stenosis. We found both echocardiographic and catheterization data suitable for clinical decision making for management of patients with rheumatic mitral stenosis.

Key words: Echocardiography, cardiac catheterization, aortic stenosis, mitral stenosis, commissurotomy

JMS (ISSN 1682-4474) is an International, peer-reviewed scientific journal that publishes original article in experimental & clinical medicine and related disciplines such as molecular biology, biochemistry, genetics, biophysics, bio-and medical technology. JMS is issued eight times per year on paper and in electronic format.

For further information about this article or if you need reprints, please contact:

Mehrnoush Toufan
Department of Echocardiography,
Shahid Madani Heart Center,
Tabriz University of Medical Sciences,
Tabriz, Iran

Tel: 0098 914 311 1284
Fax: 0411 6563895

ANSInet
Asian Network for Scientific Information

[1]Department of Echocardiography, Shahid Madani Heart Center, Tabriz University of Medical Sciences, Tabriz, Iran
[2]Tabriz University of Medical Sciences, Tabriz, Iran

INTRODUCTION

Rheumatic mitral stenosis (MS) is a frequent cause of valve disease in developing countries. In Western countries, it remains a significant problem, despite the striking decrease in the prevalence of rheumatic fever and still accounts for 12% of native valvular heart disease (Messika-Zeitoun *et al*., 2007; Iung *et al*., 2003).

Percutaneous transvenous mitral commissurotomy (PTMC) has been established as a reasonable treatment of choice since its first introduction as a clinical application (Fawzy *et al*., 2005a; Mangione *et al*., 2007; Saeki *et al*., 1999). The scope of PTMC is expanding and it is increasingly used for patients previously considered to have unfavorable mitral morphology (Das and Prendergast, 2003).

Detailed assessment of mitral valve morphology is required to select patients for successful PTMC. Previously, the only way of knowing stenotic mitral valve condition preoperatively was through elaborate cardiac catheterization (Singh and Goyal, 2007). Over the past decade, utilization of cardiac catheterization for preoperative hemodynamic assessment of patients with mitral and aortic stenosis has steadily decreased. The reason for this trend is the use of echocardiography, which is emerging as a gold standard for clinical characterization of valvular lesions. Since cardiac catheterization is an invasive procedure that is associated with a significant percentage of complications, echocardiographic evaluation of patients with valvular stenosis is safer and more cost-effective (Singh and Goyal, 2007; Popovic and Stewart, 2001). In the next millennium, echocardiography will probably completely replace the use of catheterization for hemodynamic assessment of the severity of mitral and aortic stenosis (Popovic and Stewart, 2001).

Echocardiography is one of the most important examinations for the diagnosis and assessment of severity of valvular heart diseases (Kume, 2007). It is also, the cornerstone for the assessment of mitral anatomy before PTMC (Messika-Zeitoun *et al*., 2007; Das and Prendergast, 2003; Vilacosta *et al*., 1992; Bezdah *et al*., 2007). Echocardiography provides information that makes interventional catheterization procedure safer and easier to perform (Vilacosta *et al*., 1992). Wilkins' score permits evaluation of each variable which, on the basis of its severity, is scored according to a point system ranging from 1 to 4. In patients with severe mitral stenosis, a low total score (< 8) and elastic symmetric commissures suggest valvuloplasty. A total score > 10 and the presence of more than mild mitral regurgitation or of calcification of both commissures suggest valvular replacement. The left atrial and ventricular chamber sizes and other associated valvular diseases can also be assessed at echocardiography. The severity of obstruction can be assessed by echocardiography (Caso *et al*., 2002).

The severity of the aortic or mitral stenosis can be defined with Doppler echocardiographic measurements of maximum jet velocity, mean transvalvular pressure gradient, which can be measured from the continuous-wave Doppler signal across the valve with the modified Bernoulli equation and continuity equation valve area. Planimetry of the orifice area may be possible from the short-axis view. The mitral valve area can also be derived from Doppler echocardiography with the diastolic pressure half-time (Kume, 2007) and also Proximal Isovelocity Surface Area (PISA) method as a reliable and reproducible method (Moya *et al*., 2006).

Here we assess the correlation between echocardiographic and catheterism findings in patients with rheumatic mitral stenosis and compare their results.

MATERIALS AND METHODS

We performed a retrospective, cross-sectional and comparative study on patients with severe rheumatic mitral stenosis.

One hundred sixty six consecutive patients admitted in Tabriz Shahid Madani Heart Center from 2003 to 2005 for mitral valvuplasty or percutaneous transvenous mitral commissurotomy (PTMC), were selected. All patients underwent simultaneous trans-thorasic echocardiography (TTE), trans-esophageal echocardiography (TEE) and catheterism and PTMC on the same day. PTMC success was defined as either Mitral Valve Area (MVA) >1.5 cm^2 or a MVA of more than twice the pre-procedural value, together with no worsening of mitral regurgitation >grade 2+.

Echocardiographic measurements: Echocardiography was done by using Vivid 7, GE, Norwey equipment. Measurement was repeated 5 times in different cardiac cycles and the mean value was used for analysis. Echocardiographic severity of mitral valve disease was judged according to the Wilkins score system, which is based on the semiquantitative grading including the sum of leaflet thickening, mobility, calcification and subvalvular involvement on a scale of 1 to 4 (Wilkins *et al*., 1988). MVA was measured by three methods, PHT, planimetry and PISA methods both in TTE and TEE.

- Evaluation of Spontaneous Echo Contrast (SEC) was done during TTE and TEE study as fine and dense SEC
- LAA velocity was measured by pulse Doppler during TEE study
- LV function assessed by EF
- RVSP measured via TR gradient and mean PAP measured by peak gradient of PR flow using CW Doppler

PTMC technique: The transvenous transseptal approach with Inoue balloon was used in all subjects. The initial balloon size was measured just before each commissurotomy procedure; we selected 27.5-28.0 mm for male patients and 27.0-27.5 mm for female patients. The balloon size was increased stepwise by 0.5 mm consecutive dilatations until a MVA of more than 2.0 cm^2 was reached or MR increased significantly. Hemodynamic parameters, such as pulmonary capillary wedge pressure and left atrial pressure, were measured before and after PTMC. The severity of MR was graded using left ventriculography and Sellers classification.

Then the findings of echocardiography and catheterization were compared. The collected data were analyzed with SPSS 13 statistical software and the results were presented as tables and diagrams.

RESULTS AND DISCUSSION

We studied 166 patients of which 36 (21.7%) were male and 130 (78.3%) were female. The patients had the age range of 14 to 74 years with the mean age of 41.25 years (42.8 years for males and 40.25 years for females). The most common clinical symptoms in admission were palpitation in 9 cases (5%), dyspnea on exertion (DOE) in 68 (41%) and palpitation + DOE in 70 cases (42.2%). Electrocardiography (ECG) findings were normal sinus rhythm (NSR) in 100 cases (62.9%) and atrial fibrillation (AF) in 59 cases (37.1%).

Echocardiographic and catheterization findings are showed in Table 1-3 and are compared in Table 4 and 5.

We studied the correlations between echocardiographic and catheterization findings in patients with rheumatic mitral stenosis.

In symptomatic patients with mitral stenosis, there is significant variability between noninvasive and invasive measures of mitral stenosis severity despite careful, reproducible measurements. The difference between noninvasive and invasive measures of mitral valve area (MVA) before transvenous mitral commissurotomy (PTMC) is strongly related to cardiac output (Derumeaux *et al*., 1992).

Table 1: Echocardiographic findings of studied patients

	Mean±SD	Min.	Max.
MVA	0.92±0.20	0.46	1.70
LAD	4.85±1.04	3.00	10.00
RVDD	3.49±0.81	2.14	9.37
RVSP	49.46±17.68	35.00	110.00
Total score	8.84±1.53	6.00	14.00

Table 2: The relations of LASEC with LAAEV and ECG

		No	Fine	Dense	p-value
LASEC with LAAEV		38.33 ($cm\ sec^{-1}$)	30.9 ($cm\ sec^{-1}$)	23 ($cm\ sec^{-1}$)	0.000
LASEC with ECG	NSR	31	58	11	0.000
	AF	6.8	50.8	42.4	

Table 3: The relations of total score with age, MVA and LAD

Total score	Age (year)	MVA (cm^2)	LAD
6	29.70	0.04	4.67
7	33.00	1.01	4.38
8	40.48	1.01	4.41
9	42.21	0.38	4.81
10	45.51	0.81	5.27
11	50.69	0.84	5.80
12	46.00	1.14	5.07
13	46.00	0.76	5.15
14	51.00	0.58	4.86
p-value	0.881	0.000	0.000

Table 4: The relations between echocardiographic and catheterization findings in patients with severe rheumatic mitral stenosis

Variables (Measuring Method)				P	R
MVA	(Echo)	LAP mean	(Cath)	0.007	-0.258
MVA	(Echo)	PAP	(Cath)	0.000	-0.411
MVA	(Echo)	EF	(Echo)	0.000	0.347
LAD	(Echo)	MVA	(Echo)	0.000	0.300
MVA	(Echo)	LAAEV	(Echo)	0.0001	0.377
MVA	(Echo)	RVSP	(Echo)	0.0001	-0.424
RVSP	(Echo)	PAP	(Cath)	0.0000	0.718
LAPM	(Cath)	PAP	(Cath)	0.000	0.472
MVA	(Echo)	Sex		0.682	
MVA	(Echo)	TR	(Echo)	0.409	
MVA	(Echo)	Rhythm	(ECG)	0.881	
MVA	(Echo)	RVF	(ECG)	0.081	

Cath: Catheterization, EF: Ejection fraction, Echo: Echocardiography, LAD: Left atrial dimension, MVA: Mitral valve area, LASEC: Left atrial spontaneous echo contrast, LAAEV: Left atrial appendage emptying velocity, RVSP: Right ventricular systolic pressure, TR: Tricuspid regurgitation, RVDD: Right ventricular diastolic dimension, LAP: Left atrial pressure, PAP: Pulmonary artery pressure

Table 5: The relation of age with echocardiographic and catheterization findings in patients with severe rheumatic mitral stenosis

Variables (Measuring Method)				P	R
Age	Year	EF	(Echo)	0.003	-0.252
Age	Year	LAD	(Echo)	0.000	0.284
Age	Year	LAP mean	(Cath)	0.738	-0.032
Age	Year	RVF	(Echo)	0.063	0.185
Age	Year	MVA	(Echo)	0.866	-0.013
Age	Year	RVSP	(Echo)	0.807	0.023
Age	Year	Rhythm	(ECG)	0.000	
Age	Year	Sex		0.000	

Cath: Catheterization, EF: Ejection fraction, Echo: Echocardiography, LAD: Left atrial dimension, MVA: Mitral valve area, RVSP: Right ventricular systolic pressure, TR: Tricuspid regurgitation, LAP: Left atrial pressure

Simultaneous measurement of left atrial and left ventricular pressures is the most accurate method for

determination of the mean mitral valve gradient in patients with mitral stenosis (Nishimura *et al*., 1994). There is no absolute gold standard for MVA measurement in MS. MVA assessed using the hydraulic Gorlin equation in the catheterization laboratory may not be valid under varying haemodynamic conditions and the empirical coefficient of discharge may be inaccurate with different orifice shapes. According to the current ACC/AHA current guidelines, catheterization is indicated to assess haemodynamics when there is a discrepancy between echocardiographic measurements and the clinical status of a symptomatic patient (Messika-Zeitoun *et al*., 2007; American College of Cardiology/American Heart Association, 2006).

Doppler echocardiography provides a noninvasive alternative for measurement of the transmitral gradient. Nishimura *et al.* (1994) conducted a study on 17 patients with mitral stenosis who underwent transseptal cardiac catheterization and simultaneous measurement of (1) transmitral gradient by direct left atrial and left ventricular pressures, (2) transmitral gradient by pulmonary capillary wedge and left ventricular pressures and (3) transmitral gradient by Doppler echocardiography. The best correlation with the smallest variability was comparison of the Doppler-derived mean gradient with the gradient from direct measurement of left atrial and left ventricular pressures. They concluded that compared with the transmitral gradient obtained by direct measurement of left atrial and left ventricular pressures, the Doppler-derived gradient is more accurate than that obtained by conventional cardiac catheterization and should be considered the reference standard. Doppler echocardiographic studies and mitral echo score is used to assess the safety, efficacy and long term results of mitral balloon valvotomy (MBV) (Fawzy *et al*., 2005a, b; Söderqvist *et al*., 2006; Hildick-Smith *et al*., 2000). Ito *et al*. (1997) compared the immediate and long-term outcome of percutaneous transvenous mitral commissurotomy (PTMC). Stepwise multivariate analysis revealed that the echocardiographic score was the only significant predictor of both the immediate and long-term outcome. Doppler echocardiography is quite accurate in estimation of MVA and can reliably discriminate the critical size of the orifice (Moro and Roelandt, 1986).

Fifty nine cases (37.1%) had atrial fibrillation (AF) in this study. Chronic AF is common in patients with MS. Because AF induces electrical and mechanical remodeling of the left atrium, left atrial (LA) compliance is likely to be changed in its presence. The presence of AF has a significant influence on LA compliance in patients with moderate to severe MS (Kim *et al*., 2007). Chronic atrial fibrillation (AF) is associated with an increased frequency of embolic events and negative impact on cardiac function and therefore, an increased morbidity and mortality risk in patients with rheumatic mitral valve stenosis (RMS) (Kabukçu *et al*., 2005).

Kabukçu *et al.* (2005) evaluated the clinical, echocardiographic and left-and right-heart hemodynamic data for 92 patients (68 women) with MS and AF and compared with data from 118 patients (88 women) with MS with sinus rhythm. Mean diastolic mitral valve gradient and pulmonary artery pressure did not differ in patients with and without AF. Right atrial pressures were higher in patients with AF (7.6±3.3 vs. 6.3±1.9 mm Hg, $p<0.02$). The authors suggest that (1) AF occurred in older patients, who had a longer disease process and more serious symptoms; (2) hemodynamic derangements (mitral valve gradient, pulmonary artery pressure) did not differ in patients with and without AF; (3) greater mitral valve score, more tricuspid valve involvement, higher LVEDD, which are suggestive of greater rheumatic activity process were more frequently seen in patients with AF than in those without AF. These findings support the opinion that AF is a marker of widespread rheumatic damage in patients with RMS (Kabukçu *et al*., 2005). In this study, we found significant relation between age and rhythm, so that AF was occurred more in older patients. Doppler pressure half-time (PHT) is widely used for mitral valve area (MVA) assessment. For MVA assessment, the PHT method should be used cautiously even before PMC, especially in older patients or those in AF (Messika-Zeitoun *et al*., 2005). Doppler-derived mitral inflow indices reflect left ventricular (LV) filling pressures but often vary with age. Diastolic filling is impaired in LV pressure overload states (D'Agate *et al*., 2002).

In 72 consecutive patients (mean age 61.3 years, range 38-89 years) referred for balloon mitral valvotomy (BMV), Transoesophageal echocardiography (TEE) was performed immediately before BMV and the mitral commissures were scanned systematically. Anterolateral and posteromedial commissures were scored individually according to whether non-calcified fusion was absent (0), partial (1), or extensive (2). Calcified commissures usually resist splitting and scored 0. Scores for each commissure were combined giving an overall commissure score for each valve of 0-4, higher scores reflecting increased likelihood of commissural splitting. Valve anatomy was also graded by the method of Wilkins *et al.* (1998) which does not include commissural assessment. Commissure score was the strongest independent predictor of outcome. TEE assessment of commissural morphology predicts outcome after BMV, adding significantly to the Wilkins score (Sutaria *et al*., 2006). In this study, echocardiographic severity of mitral valve disease was judged according to the Wilkins score system, which is based on the semiquantitative grading including the sum

of leaflet thickening, mobility, calcification and subvalvular involvement on a scale of 1 to 4.

Peixoto *et al.* (2001) conducted a study to evaluate prior mitral surgical commissurotomy and echocardiographic score influence on the outcomes and complications of percutaneous mitral balloon valvuloplasty. They performed 459 complete mitral valvuloplasty procedures and concluded that the higher echo score group had smaller mitral valve areas postvalvuloplasty.

In a study evaluating the usefulness of TEE during percutaneous mitral balloon valvulotomy (PMBV), TEE was most helpful in guiding transseptal puncture, aiding in proper positioning of the balloon during the dilatation procedure and enabling early detection of complications. The results show that PMBV when aided by TEE has a tendency to decrease the frequency of significant mitral regurgitation without compromising the final mitral valve area. TEE decreased the x-ray exposure time and was well-tolerated. Thus, TEE provides information that makes this interventional catheterization procedure safer and easier to perform (Vilacosta *et al.*, 1992).

During the past few decades, the effect of intraoperative TEE influence on perioperative cardiac surgical decision making has become increasingly more appreciated. Data from several clinical investigations have consistently implicated an important, clinically significant and cost-effective role for TEE as a safe and valuable hemodynamic monitor in identifying high-risk patients, in assisting in the determination of the definitive surgical approach and in providing a timely post-cardiopulmonary bypass evaluation of the procedure, thereby allowing for the opportunity to immediately re-intervene or to at least triage patients appropriately. Intraoperative TEE has perhaps been most useful for the perioperative evaluation of cardiac valvular disease, especially during surgical procedures involving the mitral valve (Shernan, 2007).

Slater *et al.* (1991) compared the clinical decisions utilizing either Doppler echocardiographic or cardiac catheterization data in adult patients with isolated or combined aortic and mitral valve disease. A clinical decision to operate, not operate or remain uncertain was made by experienced cardiologists given either Doppler echocardiographic or cardiac catheterization data. They suggested that for most adult patients with aortic or mitral valve disease, alone or in combination, Doppler echocardiographic data enable the clinician t o make the same decision reached with catheterization data (Slater *et al.*, 1991). Present results are compatible with this finding and we found both echocardiographic and catheterization data suitable for clinical decision making for management of patients with rheumatic mitral stenosis.

Krishnamoorthy *et al.* (1999) aimed a study to estimate mean transmitral gradients by simultaneous Doppler echocardiography and cardiac catheterisation and determining mitral valve area by pressure half time, Gorlin's formula and two-dimensional echocardiography so as to assess the relative accuracy of these methods before and after PTMC in patients with rheumatic mitral stenosis. All the three methods are equally accurate in estimating transmitral gradients and mitral valve area in mitral stenosis before balloon mitral valvuloplasty. Two-dimensional echocardiography is the best to estimate mitral valve area after balloon mitral valvuloplasty. Echocardiography can replace hemodynamic measurement of gradients and mitral valve area before and after balloon mitral valvuloplasty. But pressure half time is not recommended for measuring mitral valve area immediately after balloon mitral valvuloplasty where two-dimensional echocardiography mitral valve area is to be employed. Although both TEE and intracardiac echocardiography were safe and effective for on-line guidance of BMV, TEE provided better imaging capabilities (Chiang *et al.*, 2007).

CONCLUSION

There are significant correlations between TEE, TTE and catheterization findings in patients with rheumatic mitral stenosis.

ACKNOWLEDGMENTS

The authors wish to thank to Tabriz Cardiovascular Research Center, Echocardiography lab and Catheterization lab of Imam Reza Heart Center.

REFERENCES

American College of Cardiology/American Heart Association, 2006. Task Force on Practice Guidelines; Society of Cardiovascular Anesthesiologists; Society for Cardiovascular Angiography and Interventions; Society of Thoracic Surgeons. Bonow, R.O. *et al.*, 2006. ACC/AHA guidelines for the management of patients with valvular heart disease: A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (writing committee to revise the 1998 Guidelines for the Management of Patients With Valvular Heart Disease): Developed in collaboration with the Society of Cardiovascular Anesthesiologists: Endorsed by the Society for Cardiovascular Angiography and Interventions and the Society of Thoracic Surgeons. Circulation, 114 (5): e84-231.

Bezdah, L., M.A. Drissa, R. Kasri, H. Baccar and A. Belhani, 2007. Echocardiographic factors determining immediate result of percutaneous mitral balloon commissurotomy. Tunis Med., 85 (6): 479-484.

Caso, P., L. De Simone, A.R. Martiniello, I. Caso and S. Severino *et al*., 2002. Mitral stenosis: Echocardiographic evaluation. Ital Heart J. Suppl., 3 (7): 698-706.

Chiang, C.W., H.L. Huang and Y.S. Ko, 2007. Echocardiography-guided balloon mitral valvotomy: Transesophageal echocardiography versus intracardiac echocardiography. J. Heart Valve Dis., 16 (6): 596-601.

D'Agate, D.J., R.H. Smith and J.M. Lazar, 2002. Doppler echocardiographic assessment of left ventricular filling pressures in elderly patients with moderate/severe aortic stenosis. Am. J. Geriatr. Cardiol., 11 (3): 173-176.

Das, P. and B. Prendergast, 2003. Imaging in mitral stenosis: Assessment before, during and after percutaneous balloon mitral valvuloplasty. Expert Rev. Cardiovasc. Ther., 1 (4): 549-557.

Derumeaux, G., T. Bonnemains, F. Remadi, A. Cribier and B. Letac, 1992. Non-invasive assessment of mitral stenosis before and after percutaneous balloon mitral valvotomy by Doppler continuity equation. Eur. Heart J., 13 (8): 1034-1039.

Fawzy, M.E., H. Hegazy, M. Shoukri, F. El Shaer and A. El Dali *et al*., 2005a. Long-term clinical and echocardiographic results after successful mitral balloon valvotomy and predictors of long-term outcome. Eur. Heart J., 26 (16): 1647-1652.

Fawzy, M.E., M.A. Stefadouros, H. Hegazy, F. El Shaer and M.A. Chaudhary *et al*., 2005b. Long term clinical and echocardiographic results of mitral balloon valvotomy in children and adolescents. Heart, 91 (6): 743-748.

Hildick-Smith, D.J., G.J. Taylor and L.M. Shapiro, 2000. Inoue balloon mitral valvuloplasty: Long-term clinical and echocardiographic follow-up of a predominantly unfavourable population. Eur. Heart J., 21 (20): 1690-1697.

Ito, T., M. Suwa, Y. Hirota, Y. Kita and Y. Otake *et al*., 1997. Comparison of immediate and long-term outcome of percutaneous transvenous mitral commissurotomy in patients who have and have not undergone previous surgical commissurotomy. Jap. Circ. J., 61(3): 218-222.

Iung, B., G. Baron, E.G. Butchart, F. Delahaye and C. Gohlke-Barwolf *et al*., 2003. A prospective survey of patients with valvular heart disease in Europe: The euro heart survey on valvular heart disease. Eur. Heart J., 24: 1231-1243.

Kabukçu, M., E. Arslantas, I. Ates, F. Demircioglu and F. Ersel, 2005. Clinical, echocardiographic and hemodynamic characteristics of rheumatic mitral valve stenosis and atrial fibrillation. Angiology, 56 (2): 159-163.

Kim, H.K., Y.J. Kim, J.L. Shin, S.J. Hwang and S.H. Jo *et al*., 2007. Echocardiographic and hemodynamic findings in patients with mitral stenosis undergoing percutaneous mitral commissurotomy comparing those with chronic atrial fibrillation versus those with normal sinus rhythm. Am. J. Cardiol., 100 (7): 1153-1156.

Krishnamoorthy, K.M., S. Radhakrishnan and S. Shrivastava, 1999. Simultaneous echocardiographic and catheterisation gradients and mitral valve area during balloon mitral valvuloplasty. Indian Heart J., 51 (4): 410-413.

Kume, T., 2007. Echocardiography is necessary to confirm the presence and severity of valvular heart disease. Kyobu Geka., 60 (8): 647-652.

Mangione, J.A., S.A. Cristovão, G.I. Mayor and H. Abensur, 2007. Percutaneous mitral valvuloplastry in a pregnant woman guided only by the transesophageal echocardiography. Arq. Bras Cardiol., 88 (3): e62-65.

Messika-Zeitoun, D., A. Meizels, A. Cachier, A. Scheuble and O. Fondard *et al*., 2005. Echocardiographic evaluation of the mitral valve area before and after percutaneous mitral commissurotomy: The pressure half-time method revisited. J. Am. Soc. Echocardiogr., 18 (12): 1409-1414.

Messika-Zeitoun, D., E. Brochet, C. Holmin, D. Rosenbaum and B. Cormier *et al*., 2007. Three-dimensional evaluation of the mitral valve area and commissural opening before and after percutaneous mitral commissurotomy in patients with mitral stenosis. Eur. Heart J., 28 (1): 72-79.

Moro, E. and J. Roelandt, 1986. Determination of stenotic mitral valve area using Doppler echocardiography. A comparison with hemodynamic studies. G Ital. Cardiol., 16 (5): 411-416.

Moya, J.L., J. Darriba-Pollán, A. García-Lledó, D. Taboada and P. Catalán-Sanz *et al*., 2006. Evaluation of mitral regurgitation severity using a simplified method based on proximal flow convergence. Rev. Esp. Cardiol., 59 (10): 1019-1025.

Nishimura, R.A., C.S. Rihal, A.J. Tajik and D.R. Jr. Holmes, 1994. Accurate measurement of the transmitral gradient in patients with mitral stenosis: A simultaneous catheterization and Doppler echocardiographic study. J. Am. Coll. Cardiol., 24 (1): 152-158.

Peixoto, E.C., R.T. Peixoto, I.P. Borges, P.S. Oliveira and M. Labrunie *et al*., 2001. Influence of the echocardiographic score and not of the previous surgical mitral commissurotomy on the outcome of percutaneous mitral balloon valvuloplasty. Arq Bras Cardiol., 76 (6): 473-482.

Popovic, A.D. and W.J. Stewart, 2001. Echocardiographic evaluation of valvular stenosis: The gold standard for the next millennium? Echocardiography, 18 (1): 59-63.

Saeki, F., Y. Ishizaka and T. Tamura, 1999. Long-term clinical and echocardiographic outcome in patients with mitral stenosis treated with percutaneous transvenous mitral commissurotomy. Jap. Circ. J., 63 (8): 597-604.

Shernan, S.K., 2007. Perioperative transesophageal echocardiographic evaluation of the native mitral valve. Crit. Care Med., 35 (8): S372-383.

Singh, S. and A. Goyal, 2007. The origin of echocardiography: A tribute to inge edler. Tex Heart Inst. J., 34 (4): 431-438.

Slater, J., A.J. Gindea, R.S. Freedberg, L.A. Chinitz and P.A. Tunick *et al*., 1991. Comparison of cardiac catheterization and Doppler echocardiography in the decision to operate in aortic and mitral valve disease. J. Am. Coll. Cardiol., 17 (5): 1026-1036.

Söderqvist, E., P. Cain, B. Lind, R. Winter and J. Nowak *et al*., 2006. Feasibility of creating estimates of left ventricular flow-volume dynamics using echocardiography. Cardiovasc Ultrasound, 31 (4): 40.

Sutaria, N., T.R. Shaw, B. Prendergast and D. Northridge, 2006. Transoesophageal echocardiographic assessment of mitral valve commissural morphology predicts outcome after balloon mitral valvotomy. Heart, 92 (1): 52-57.

Vilacosta, I., E. Iturralde, J.A. San Román, M. Gómez-Recio and C. Romero *et al*., 1992. Transesophageal echocardiographic monitoring of percutaneous mitral balloon valvulotomy. Am. J. Cardiol., 70 (11): 1040-1044.

Wilkins, G.T., A.E. Weyman, V.M. Abascal, P.C. Block and I.F. Palacios, 1988. Percutaneous balloon dilatation of the mitral valve: An analysis of echocardiographic variables related to outcome and the mechanism of dilatation. Br. Heart J., 60 (4): 299-308.