Studia Universitatis “Vasile Goldiş”, Seria Ştiinţele Vieţii
Vol. 22, issue 1, 2012, pp. 39-45

PRE-OPERATIVE TRANSTHORACIC LIVE THREE-DIMENSIONAL ECHOCARDIOGRAPHY IN THE ASSESSMENT OF MITRAL STENOSIS: CLINICAL EXPERIENCE

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ABSTRACT
We investigated three-dimensional (3D) live transthoracic echocardiography (TTE) in the assessment of mitral stenosis. Bidimensional (2D) TTE and 3D TEE was performed in 42 patients with mitral stenosis concomitent with cardiac catheterisation, prior to valve surgery. Using a surgical scoring protocol for recognition of the valvular segments, 2D and 3D methods were compared. Adequate echocardiographic visualization of the mitral segments was more frequently obtained by 3D TTE than by 2D TTE. Total 3D TTE score were significantly better than 2D TTE score. Using surgical classification as gold standard, the sensibility and specificity were 93% and 87 % for 3D TEE, and 86% and 79% for 2D TTE. The opening area determined by 3D TEE showed better linear association with the area determined intraoperative or invasively by Gorlin formula compared with 2D TTE. In conclusions, 3D TTE was superior to 2D TTE for the analysis of mitral stenosis and could be used for the accurate identification of the severity.
KEYWORDS
mitral valve stenosis, mitral valve area, three-dimensional live transthoracic echocardiography, bidimensional transthoracic echocardiography, Gorlin formula.

INTRODUCTION

Rheumatic mitral valve stenosis still remains an important public health concern, and the assessment of the severity of mitral valve stenosis requires accurate measurements of the mitral valve orifice area. Direct measurement of the MVA can be performed by planimetry using two-dimensional (2D) echocardiography (Nichol PM et al., 1977). However, planimetry by 2-D echo requires significant experience and operator skill to define the correct image plane that displays the true mitral valve orifice (Binder et al., 2000). As repair techniques have advanced, so has the need to obtain accurate information prior to surgery. Some studies suggest that adding three-dimensional (3D) imaging to standard 2D echocardiography could be helpful in the quantification of valvular diseases (García-Fernández et al., 2010; Wei et al., 2010; Hoole et al., 2008).

Three-dimensional echocardiography is a new emerging technique that allows recording of volumetric echographic data (Pandian et al., 1994). This technique can provide views of the entire valve, allowing a complete assessment of the valve leaflets and commissures (Solis et al., 2009; Uno et al., 2009). 3D echocardiography has a good accuracy (Tamborini et al., 2010), so that several authors recommended already to integrate this new technique in the standard preoperative examination and become an important tool in the decision to process valvular repair/replacement.

The aim of this prospective study was to evaluate two aspects of 3D live transthoracic echocardiography (3D TTE): the accuracy of the method (vs. surgical inspection) in patients undergoing surgery for mitral stenosis; (ii) to compare the accuracy of 3D TEE with 2D TTE; (iii) to compare the valvular area measured 3D TTE and 2D TTE with the area determined by Gorlin method and intraoperative area in patients with mitral stenosis.

MATERIAL AND METHOD

Forty-two consecutive patients with mitral stenosis referred to surgery were evaluated by 2D TTE and 3D TTE. Exclusion criteria were represented by inadequate echocardiografic images, movement artifacts caused by coughing or hiccough, difficulty with ECG registering, and equipment failure.

A complet TTE study was obtained prior to or following the invasive study, in a time gap <48 h; surgery was done in the next 7 days. Three-dimensional and 2D data were compared with invasive and, than with surgical data. The local ethics committee approved the study. Informed consent was obtained from all patients.

The TTE study was performed in all patients using Vivid 9 GE echocardiographic system. Two-dimensional TTE views of the mitral valve was obtained from the parasternal window; the planimetry was also performed. Three cardiac cycles for patients in sinus rhythm and five for patients in atrial fibrillation were recorded, and their results averaged for every patient. The 3D examination was done after a routine diagnostic.

The Carpentier nomenclature was applied to the mitral leaflets (Carpentier, 1983). All valvular segments were classified as normal, prolapsing, flail, tenting, perforation, erosion, fibrosis or calcification. The fusion

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of the commissures and vegetations were also noted. Gross etiology was classified as degenerative, congenital, rheumatic disease, infective, or functional. Three-dimensional acquisition and reconstruction times were measured in each patient. A single echocardiographer acquired and measured the 2D and 3D echo studies.

Invasive hemodynamic evaluation was performed within 48 h of the echocardiographic recordings. Using the catheter-based data and the Gorlin's equation, the mitral valve area was obtained (Carabello, 1987).

The surgeon described the anatomy of the mitral valve and measured the opening area. He was aware of the 2D findings, but not of the 3D analysis. All valvular segments were classified as normal, prolapsing, flail, tenting, perforation, erosion, fibrosis or calcification. For the mitral valve the Carpentier classification was used. The fusion of the commissures and vegetations were noted.

The 2D and 3D images (figure 1a and 1b) were analysed off-line separately and blinded to the surgical findings. Segments considered inadequate were not included for the analysis. Valvular morphology data described by the operating surgeon was used as gold standard. He described the anatomy of the valve using the same proforma like for echocardiographic analysis. The surgeon was aware of the 2D findings but not the 3D analysis. Segments were counted as accurately imaged if they matched surgical findings precisely in terms of pathology description and correct location (score = 1). The segments that were not adequately recognised (score = 0) were coded as inaccurate.

Statistical analysis

The sensitivity and specificity of the echocardiographic evaluation were calculated with surgical data as a reference. Variables are expressed as proportions, mean, and standard deviation. The chi-squared test and the student t-test with subsequent two-tailed t-tests were used to compare differences between groups. Correlation between planimetry measured by 2D and 3D TTE and invasive or intraoperative area were evaluated by Pearson's correlation coefficient. Differences were considered statistically significant at the two-sided $P < 0.05$ level. All computations were carried out with the software SPSS 17.0 for Windows (SPSS Inc. Chicago, IL, USA).

RESULTS

From 52 patients with mitral stenosis screened between January 2010 and June 2011, 42 (29 women) were enrolled in the study. Mean age was 44 ± 16 years. Characteristics of the patients study group are presented in Table 1. For each patient, 1-3 acquisitions were realized and the best one chosen for imaging and quantification. Acquisition time ranged between 32 s and 1 min 52 s, depending on the basal heart rate and rhythm disturbances. Mean processing time was 2 min 18 s. Adequate echocardiographic visualization of the valve segments was more frequently obtained by 3D TTE than by 2D TTE imaging (316/336 by 3D TTE and 284/336 by 2D TTE, $p<0.05$). The valve leaflets segments were more clearly identified by 3D TTE than by 2D TTE (237/252 by 3D TTE and 210/252 by 2D TTE, $p<0.05$). For adjacent commissures the results were similar by the two methods (79/84 by 3D TTE and 74/84 by 2D TTE, $p>0.05$).

Total 3D TTE score for the mitral valve was significantly better than 2D TTE score (mean score 7.41 ± 0.58 by 3D TTE vs 6.18 ± 0.75 by 2D TTE, $p<0.05$). This superiority of 3D TTE was irrespective of rhythm ($p<0.05$ for both, sinus rhythm and atrial fibrillation). Using surgical classification as gold standard, the sensibility and specificity were 93% and 87 % for 3D TTE and 86% and 79% for 2D TTE, respectively. The main cause of mitral stenosis was represented by rheumatic fever in all patients (100%).

The valvular opening area determined by 3D TTE (figure 2a) showed better linear association with the area determined invasively by Gorlin formula ($r = 0.97$, $p < 0.001$) compared with 2D TTE ($r = 0.88$, $p < 0.001$) (figure 2b), respectively. If we consider the area determined by the surgeon, the correlation with the valvular opening area determined by 3D TTE (figure 3a) was better ($r = 0.95$, $p < 0.001$) compared with the area determined by 2D TTE ($r = 0.88$, $p < 0.001$) (figure 3b), respectively. Areas determined by 3D echo were on average slightly smaller (1.16 ± 0.23) than those by 2D TTE (1.24 ± 0.19, $p < 0.05$) if we consider as standard the area determined by Gorlin formula 1.15 ± 0.22).

DISCUSSION

The results of this study fully validate 3D TTE as an accurate tool for mitral stenosis evaluation and clinical decision-making. We studied an unselected cohort of patients with mitral stenosis undergoing surgery, irrespective of heart rhythm, with a representative array of etiologies typically encountered at a surgical centre and we observed a valuable incremental role of 3D TTE over 2D TTE in the complete and accurate evaluation of mitral valve morphology prior to valve surgery. This study demonstrates also that 3D TTE is an accurate tool for area calculation and clinical decision-making in patients with mitral stenosis.

Conventional 2D TTE can diagnose valvular diseases, but can not show *en face* views of the leaflets, which can lead to difficulty defining the exact location of defect, and may result in difficulties communicating with surgeons. The detection of valvular lesion location in 2D examination may be influenced by the change of blood pressure (Pepi et al., 2006). As shown in our study, 2D TTE is limited in its ability to completely visualize the mitral valve, in particular the leaflets.

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New generation 3D technology reduces the acquisition and reconstruction time to few minutes and facilitates the visualization of the aortic and mitral valves (Kondur et al., 2008). In the majority of cases in our study, imaging quality was good or optimal and permitted 3D reconstruction. Using surgical classification as gold standard, we found a sensibility of 93% and a specificity of 87% for the identification of valvular pathology using 3D TTE, a percentage comparable to previous studies (Binder et al., 2000; Wei et al., 2010; Hoole et al., 2008). Interestingly, in our patients with adequate echografic window, 3D TTE was not different to 2D TTE in the identification of commissural pathologies, but was significantly superior in the evaluation of leaflet segments. There are several studies that showed similar results (Khaw et al., 2009; Tamborini et al., 2010; Uno et al., 2009); in contrast, Hoole (Hoole et al., 2008) and Muller l (Muller et al., 2006) found that 3D method was excellent in identifying the commissures morphology of mitral valve, in particular if the transesophageal echocardiography was used.

Our study has also demonstrated additional value for determination of maximal opening area of mitral valve. Planimetry of the valve orifice is the only direct measurement in 2D echocardiography. The success rate of mitral valve planimetry in 2D echocardiography has been reported to be as low as 75% depending on the study population (Binder et al., 2000; Garcia-Orta et al., 2007). A major limitation of this method is the difficulty of defining the correct image plane that displays the true valve orifice. Thus, small changes of the transducer position on the chest wall and of its tilting and rotation result in significant changes of calculated orifice area. This is also the main reason that considerable experience and operator skill are necessary for the correct application of this method and why significant interobserver variability has been noted for these measurements (Binder et al., 2000). One of the most important advances in echocardiography during the last decade has been the development of 3D techniques. This method allows instant acquisition of a complete 3D data set without complex post-processing. 3D TTE reduces the potential sources of error (direct anatomic area calculation) and relies only on the quality of the apical acoustic window.

Pearson's correlation coefficient demonstrated in our study a good agreement between area determined by 3D TTE and the area of stenosis determined invasive by Gorlin formula or intraoperative by the surgeon, superior to the 2D TTE method. Also, areas determined by 3D echo were on average slightly smaller than those by 2D TTE; possibly, this fact simply reflects the greater potential of 3D echo to detect the true anatomic orifice area and the tendency of 2D echo to overestimate this area because of difficulties in defining the optimal imaging plane. In contrast to 2D echo, in 3D method the interobserver variability for measurements appears to be significantly less than with 2D echo (Binder et al., 2000; Chu et al., 2008, Zamorano et al., 2004).

Therefore, this study confirms recent data showing that 3D TTE may be integrated in the standard examination facilitating the exact spatial localization of pathological structures and avoiding the need for mental reconstruction of 3D valve anatomy by the examiner.

LIMITATIONS

The number of patients in this study was relatively small; however, we were able to reach several significant observations. Patients were consecutively enrolled, but referral bias is possible and patients may not represent the whole population with significant mitral stenosis. Furthermore, patients with larger valve areas in the moderate range are poorly represented in our sample. Considering invasive assessment of the aortic valve area by Gorlin's equation as the gold standard could be questioned, especially when pullback measurements substitute the ideal simultaneous left ventricular-aorta recordings. Once considered a gold standard, invasive measurement of valvular area with the Gorlin formula has demonstrated flaws (Carabello, 1987) and has been questioned as a clinical standard. Heart catheterization is now recommended only for a small subset of patients with nondiagnostic echocardiography or discrepancies with symptoms (Vahanian et al., 2007; Bonow et al., 2008) a fact being reflected in current clinical practice (Iung et al., 2003).

CONCLUSIONS

Three-dimensional TTE provides accurate analysis of patients with mitral stenosis, and could be used not only for complete recognition of the valvular morphology but also for the accurate identification of the severity. 3D TTE appears to be superior to conventional echocardiographic techniques, particularly to planimetry using 2D TTE. Measurements are simple and can be performed within a few minutes.

REFERENCES

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, 36(4),1355-61, 2000.

Bonow R.O., Carabello B.A., Chatterjee K., de Leon A. Jr, Faxon D.P., Freed M.D., et al, 2008 focused update incorporated into the ACC/AHA 2006 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). Endorsed by the Society of Cardiovascular Anesthesiologists, Society for Cardiovascular Angiography and Interventions, and Society of Thoracic Surgeons, J Am Coll Cardiol 52, e1–142, 2008.

Carabello B.A., Advances in the hemodynamic assessment of stenotic cardiac valves, J Am Coll Cardiol, 10, 912–9, 1987.

Carpentier A., Cardiac valve surgery-the 'French correction'. J Thorac Cardiovasc Surg, 86, 323–37, 1983.

Chu J.W., Levine R.A., Chua S., Poh K.K., Morris E., Hua L., et al., Assessing mitral valve area and orifice geometry in calcific mitral stenosis: a new solution by real-time three-dimensional echocardiography, J Am Soc Echocardiogr, 21(9), 1006-9, 2008.

García-Fernández M.A., Cortés M., García-Robles J.A., Gomez de Diego J.J., Perez-David E., García E., Utility of real-time three-dimensional transesophageal echocardiography in evaluating the success of percutaneous transcatheter closure of mitral paravalvular leaks, J Am Soc Echocardiogr, 23(1),26-32, 2010.

Garcia-Orta R., Moreno E., Vidal M., Ruiz-Lopez F., Oyonarte J., Lara J., et al., Threedimensional versus two-dimensional transesophageal echocardiography in mitral valve repair, J Am Soc Echocardiogr, 20, 4–12, 2007.

Hoole S.P., Liew T.V., Boyd J., Wells F.C., Rusk R.A., Transthoracic real-time three-dimensional echocardiography offers additional value in the assessment of mitral valve morphology and area following mitral valve repair. Eur J Echocardiogr, 9(5), 625-30, 2008.

Iung B., Baron G., Butchart E.G., Delahaye F., Gohlke-Barwolf C., Levang O.W., et al., A prospective survey of patients with valvular heart disease in Europe: The Euro Heart Survey on Valvular Heart Disease, Eur Heart J, 24, 1231–43, 2003.

Khaw A.V., von Bardeleben R.S., Strasser C., Mohr-Kahaly S., Blankenberg S., Espinola-Klein C., et al., Direct measurement of left ventricular outflow tract by transthoracic real-time 3D-echocardiography increases accuracy in assessment of aortic valve stenosis, Int J Cardiol, 136, 64–71, 2009.

Kondur A., Pitta S., Afonso L., Incremental utility of real-time three-dimensional echocardiography in the diagnosis and preoperative assessment of cleft mitral valve in adults, Eur J Echocardiogr, 9, 586–8, 2008.

Muller S., Muller L., Laufer G., et al., Comparison of three-dimensional imaging to transesophageal echocardiography for preoperative evaluation in mitral valve prolapse, Am J Cardiol, 98, 243–48, 2006.

Nichol P.M., Gilbert B.W., Kisslo J.A., Two-dimensional echocardiographic assessment of mitral stenosis. Circulation, 55, 120–8, 1977.

Pandian N.G., Roelandt J.R.T.C., Nanda N.C., Sugeng L., Cao Q.L., Azevedo J., et al., Dynamic three-dimensional echocardiography: methods and clinical potential, Echocardiogaphy, 11, 237e59, 1994.

Pepi M., Tamborini G., Maltagliati A., Galli C.A., Sigillo E., Salvi L., et al., Head-to-head comparison of two- and three-dimensional transthoracic and transesophageal echocardiography in the localization of mitral valve prolapse, J Am Coll Cardiol, 48, 2524–30, 2006.

Solis J., Sitges M., Levine R.A., Hung J., Three-dimensional echocardiography. New possibilities in mitral valve assessment. Rev Esp Cardiol, 62(2),188-98, 2009.

Tamborini G., Muratori M., Maltagliati A., Galli C.A., Naliato M., Zanobini M., et al., Pre-operative transthoracic real-time three-dimensional echocardiography in patients undergoing mitral valve repair: accuracy in cases with simple vs. complex prolapse lesions, Eur J Echocardiogr, 11(9),778-85, 2010.

Uno K., Takenaka K., Ebihara A., Nawata K., Hayashi N., Nagasaki M., et al., Value of live 3D transoesophageal echocardiography in the diagnosis of mitral valve lesions, Eur J Echocardiogr, 10, 350–1, 2009.

Zamorano J., Cordeiro P., Sugeng L., Perez de Isla L., Weinert L., Macaya C., et al., Real-time three-dimensional echocardiography for rheumatic mitral valve stenosis evaluation: an accurate and novel approach, J Am Coll Cardiol, 43(11), 2091-6, 2004.

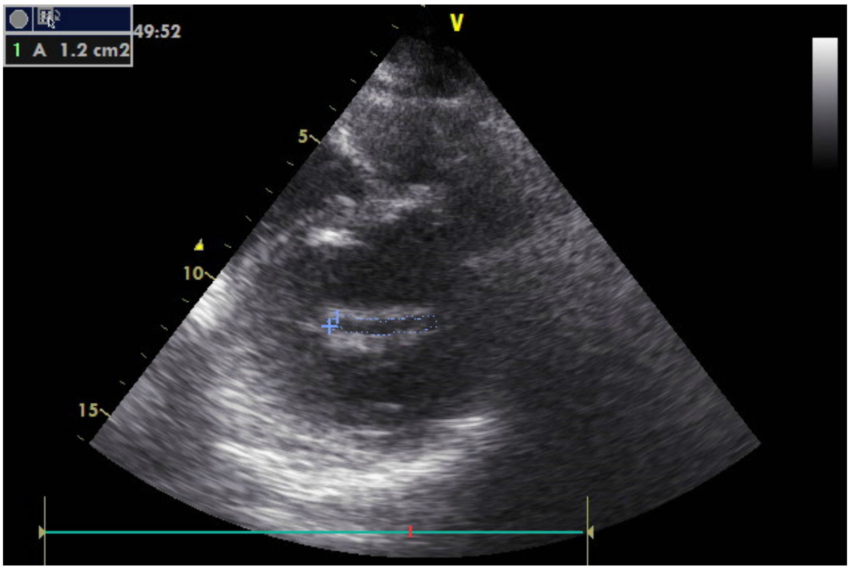
Vahanian A., Baumgartner H., Bax J., Butchart E., Dion R., Filippatos G., et al., Guidelines on the management of valvular heart disease: The Task Force on the Management of Valvular Heart Disease of the European Society of Cardiology, Eur Heart J, 28, 230–68, 2007.

Wei J., Hsiung M.C., Tsai S.K., Ou C.H., Chang C.Y., Chang Y.C., et al., The routine use of live three-dimensional transesophageal echocardiography in mitral valve surgery: clinical experience, Eur J Echocardiogr, 11, 14–8, 2010.

Table 1. Baseline characteristics of the study group (data are presented as mean ± standard deviation or number (%)).

Characteristics	Date
Number of patients	42
Age, years	44 ± 16
Woman/Male	29 (69%) / 13 (31%)
Body mass index, kg/m^2	25.4 ± 4.2
Heart rate, beats/min	79 ± 12
Atrial Fibrillation	14 (33%)
Mean blood pressure, mmHg	95.2 ± 14.5
New York Heart Association class	2.8 ± 0.8
LV ejection fraction (%)	59 ± 11
PSAP, mmHg	48.2 ± 14.8

LV = left ventricle; PSAP = pulmonary systolic artery pressure.



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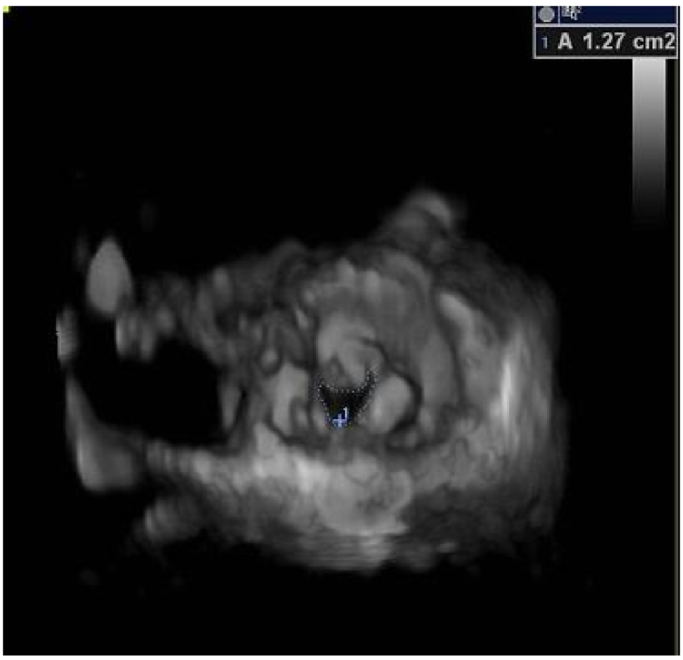

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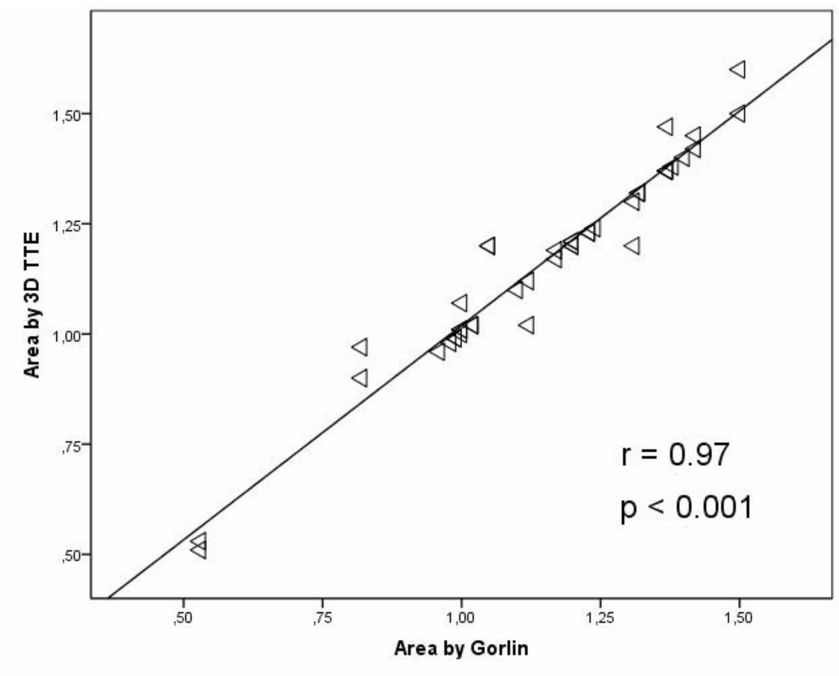
Figure 1. Mitral opening area determined by bidimensional and live three-dimensional transthoracic echocardiographic study in a patient with mitral stenosis.

Figure 2. *Scatter plots with linear regression fit for valvular opening area determined by 3D live transthoracic echocardiography and area determined invasively by Gorlin formula (a) and for the area determined by 2D transthoracic echocardiography planimetry and that determined by Gorlin formula (b), in patients with valvular stenosis. The unit for all valvular areas is cm^2.*



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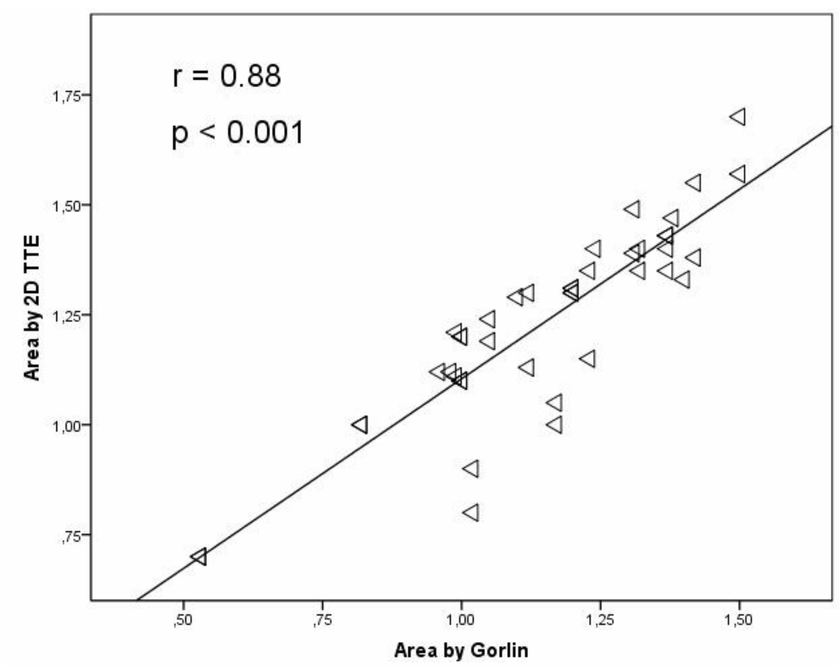

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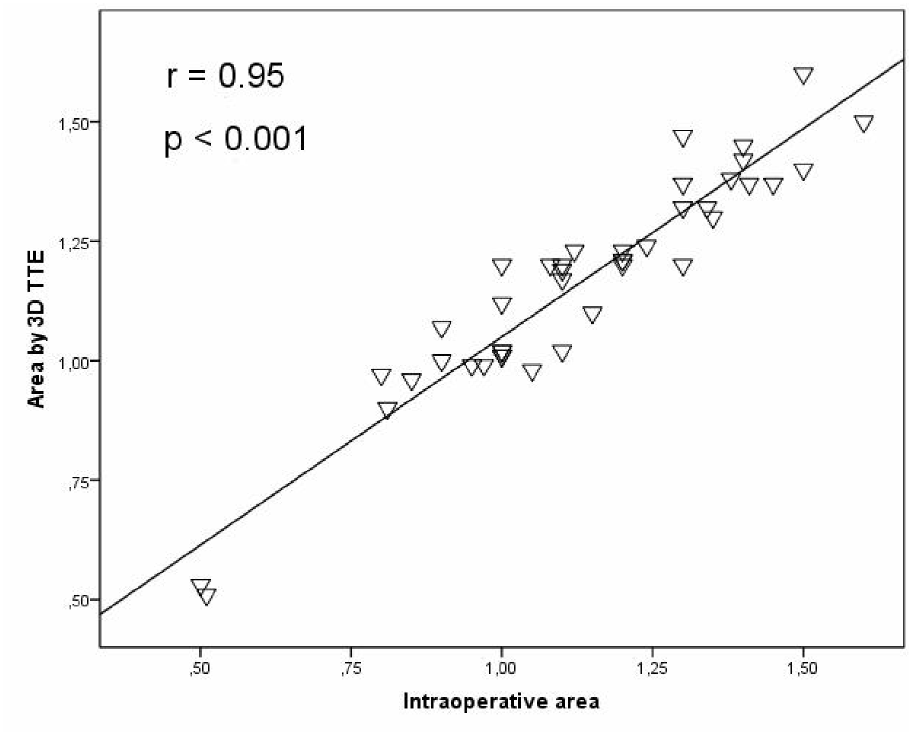
Figure 3. *Scatter plots with linear regression fit for valvular opening area determined by 3D live transthoracic echocardiography and area determined intraoperative (a) and for the area determined by 2D transthoracic echocardiography planimetry and that determined intraoperative (b), in patients with valvular stenosis. The unit for all valvular areas is cm².*



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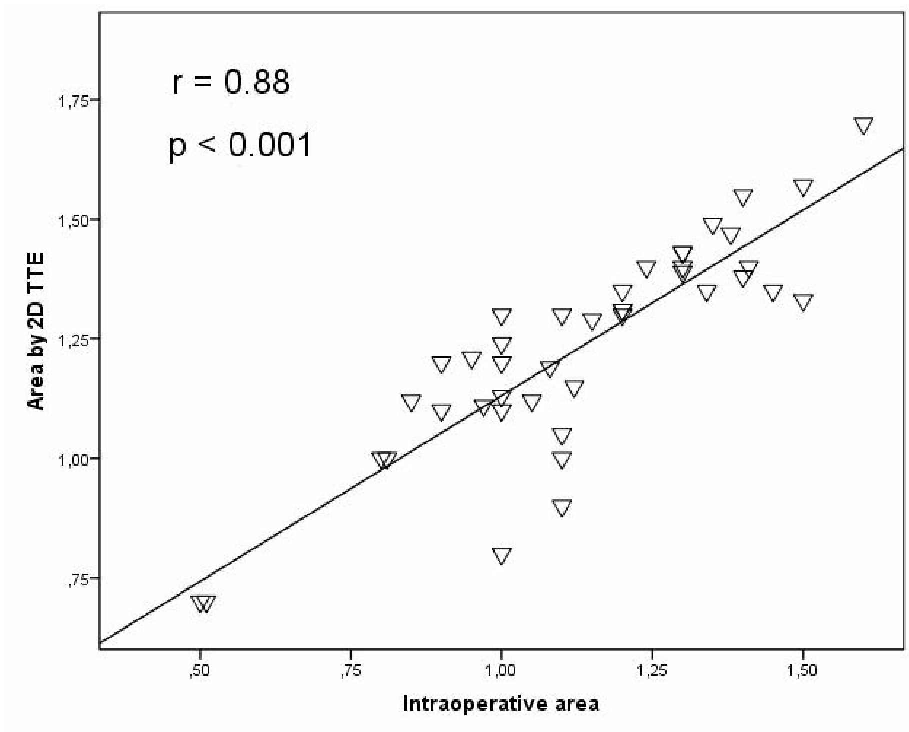

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