Midterm follow-up dynamic echocardiography evaluation after aortic valve repair for aortic valve insufficiency

Giuseppe D’Ancona*, Andrea Amaducci, John Prodromo, Francesco Pirone, Marco Follis, Calogero Falletta and Michele Pilato

Mediterranean Institute for Transplantation and Advanced Specialized Therapies (ISMETT), Palermo, Italy

* Corresponding author. Department of Cardiothoracic Surgery, ISMETT—Mediterranean Institute for Transplantation and Advanced Specialized Therapies and University of Pittsburgh Medical Center, Via Tricomi 1, 90127 Palermo, Italy. Tel: +39-091-2192111; fax: +39-091-2192354; e-mail: gdancona@ismett.edu (G. D’Ancona).

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Abstract

We prospectively evaluated 46 patients who underwent aortic valve repair (AVR) for AV regurgitation. Rest/stress echocardiography follow-up was performed. Follow-up duration was 30.7 months, age 56 ± 14 years, ejection fraction% 57.5 ± 10.5%. Preoperative bicuspid AV was present in 14 (30.4%), leaflets calcifications in 8 (17.4%), thickening in 17 (37.0%) and prolapse in 22 (47.8%). Surgical technique included commissuroplasty (22, 47.8%), leaflet remodelling (17, 37.0%), decalcification (7, 15.2%) and raphe removal (14, 30.4%). At follow-up, rest/stress echocardiography median AV regurgitation (rest 1.0 vs. stress 1.0) and mean indexed AV area (IAV A) (rest 2.6 ± 0.74 cm2/m2 vs. stress 2.8 ± 0.4 cm2/m2) were unchanged (P = ns). Mean (rest 4.7 ± 3.9 mmHg vs. stress 9.7 ± 5.8 mmHg) and peak (rest 9.5 ± 7.2 mmHg vs. stress 19.0 ± 10.5 mmHg) transvalvular gradients were significantly increased (P ≤ 0.0001). At linear regression, there was an independent inverse correlation between commissuroplasty and AV gradients during stress (B = -9.9, P = 0.01, confidence interval= -17.7 to -2.1). Although follow-up haemodynamics of repaired AVs are satisfactory, there was a fixed IAVA and significant increase in AV gradients. We were not able to identify any pre-existing anatomical condition independently related to this non-physiological behaviour under stress. Moreover, commissuroplasty seems to prevent abnormal increase of the AV gradients.

Keywords: Aortic valve repair echocardiography stress

INTRODUCTION

Aortic valve (AV) repair presents an opportunity to treat aortic insufficiency (AI) while avoiding some of the negative aspects of mechanical or bioprosthetic replacement. Surgical intervention should aim at restoring the normal architecture of the aortic root structure and the competence of the AV. Surgical repair options are dependent on the anatomical morphology of the individual patient.

Although surgical results show favourable outcomes for AV repair patients, these findings have been proposed by high volume centres and are not necessarily reproducible by less-experienced surgeons and for more complex repairs.

Moreover, further research needs to evaluate postoperative stress haemodynamics of patients who have undergone valve repair to determine the functional performance of the repaired valves. In fact, many of those who undergo valve repair instead of replacement are young patients who wish to maintain an active lifestyle after surgery.

The aim of the present study was to evaluate, with echocardiography follow-up, the haemodynamic performance of the native AV in patients previously submitted to AV repair surgery for AI.

MATERIALS AND METHODS

Patients previously submitted to AV repair at the Mediterranean Institute for Transplantation and Advanced Specialized Therapies (ISMETT) were contacted and invited to undergo a clinical and echocardiography follow-up.

Rest/stress echocardiography was performed using a tilting table in the semi-supine position. Patients were asked to cycle with an initial workload of 25 watts. The work load was increased by 25 watt increments every 2 min according to Bruce’s protocol, with the targets of 75% of predicted maximal heart rate or appearance of symptoms [1].

Measurements of left ventricular (LV) dimensions were made from two-dimensional echocardiography images in the parasternal long axis view. LV volumes and ejection fraction (EF%) were calculated by modification of Simpson’s method with two apical views. AV regurgitation was graded on the basis of the regurgitant jet height/LV outflow tract (LVOT) height ratio [mild (1+):<25%, moderate (2+): 25–46%, moderately severe (3+): 47–64%, severe (4+): ≥65%].

The LVOT area was calculated from the diameter of the outflow tract (area = diameter^2 x 0.78), assuming circumferential geometry. The velocity of the LVOT was obtained by pulsed-wave Doppler from the apical long axis view, and the maximal instantaneous (AV) gradient was calculated from the peak aortic Doppler velocity by the modified Bernoulli equation (pressure gradient = 4 x velocity^2). With online software, mean AV pressure gradient and time velocity integral (TVI) of the AV and LVOT flow velocities were measured. Three to five cardiac cycles were measured and the values were averaged. AV area (AVA) was...
calculated with the continuity equation: \( \text{AVA} = \frac{\text{LVOT area} \times \text{LVOT TVI}}{\text{AV TVI}} \).

All patients had signed a written consent to the collection and eventual analysis of their personal medical data and the study was approved by the local ethical committee.

Preoperative and intraoperative data had been previously collected in our electronic database. Follow-up data were prospectively collected, focusing on the clinical status and the echocardiography findings.

Data were expressed as mean ± standard deviation. Normality of continuous variables was tested by means of Wilk-Shapiro test. Comparison between rest/stress echocardiography data concerning the AV function was performed using the paired Student’s t or Mann-Whitney test, whenever appropriate.

Multiple linear regression was performed to identify the correlation between rest/stress AV function parameters and group characteristics (including AV preoperative anatomy and AV repair technique adopted). SPSS 14.0 was used to perform the statistical analysis.

## RESULTS

A total of 90 patients were submitted to AV repair for AI from July 2004 to May 2010. Specific AV repair techniques were used according to the presenting valvular anatomy and mechanisms of valve malfunction, as previously described [2]. The following repair techniques were used: shaving/decalcification of the cusps in 18 patients (20%), raphe removal in 22 (24.4%), cusp reinforcement (triangular resection/free margin resuspension/patch repair) in 29 (32.2%), commissuroplasty with pledgets in 41 (45.5%) and ascending aorta replacement in 46 (51.1%).

Operative mortality was 1.1% (1/90). Median AI at discharge was 1 (0–3).

All 89 surviving patients underwent a follow-up telephone interview. Two patients (3.3%) required late AV replacement for recurrent symptomatic severe AI. No patient was deceased at follow-up, and all patients were in NYHA classes I–II. A total of 46 patients gave written consent to a rest/stress echocardiography and were included in the present analysis. The remaining patients refused to undergo a control echocardiography.

Mean follow-up was 30.7 months. Mean age at time of follow-up was 56 ± 14 years and female/male ratio was 13/33. At follow-up, all 46 patients were in NYHA and CCS classes I–II.

Data concerning the preoperative AV anatomy (as shown in preoperative echocardiography and confirmed by intraoperative inspection) and the surgical technique adopted in these 46 patients are summarized in Tables 1 and 2. Every patient had at least one procedure performed on the AV. Furthermore, the ascending aorta was also replaced in 27 patients (58.7%) with concomitant ascending aorta dilatation.

Mean left ventricular ejection fraction was 57.5 ± 10.5%, LV end-diastolic volume 118.4 ± 37.1 ml and LV end-systolic volume 50.2 ± 21.1 ml.

AI grade 3 was present at rest in 4 patients (8.6%), grade 2 in 10 (21.7%), grade 1 in 26 (56.5%) and grade 0 in 6 (13.0%).

Rest and stress echocardiography findings concerning the AV performance are summarized in Table 3. The degree of AI remained unchanged during physical stress (rest mean/median AI 1.3/1.0 vs. stress mean/median AI 1.2/1.0; \( P = 0.4 \)). Notice that at rest echocardiography, mean indexed AV area (IAVA) was 2.6 ± 0.7 cm²/m², mean and peak trans-AV gradients were 4.7 and 9.5 mmHg. During maximal physical stress, IAVA remained unchanged (\( P = 0.08 \)). As a result, under physical stress, there was a significant increase in mean and peak trans-AV gradients (\( P < 0.0001 \)) (Table 3). Three patients interrupted the test for physical exhaustion before reaching maximal effort. All stress echocardiography measurements were taken only at peak of stress.

A multivariate analysis model was built to identify any possible correlation between AV anatomic features, adopted technique for AV repair and trans-AV gradient during stress (dependent variable). At linear regression, a strong independent inverse correlation was noticed between AV commissuroplasty and both mean and peak trans-AV gradient at rest/comparing to controls (Tables 4 and 5). No other factor seemed to have an independent impact on trans-AV gradient.

## DISCUSSION

AV repair for AI should aim at restoring the normal architecture of the aortic root structure and the physiology of the AV at rest and during physical stress.
In a contemporary review including published data on 761 patients, the recurrence rate of AI requiring reoperation after AV repair was ~10% at a mean follow-up of 4 years. Freedom from reoperation ranged from 74 to 100% (mean 89%) at 5 years, and from 51 to 100% (mean 64%) at 10 years [3]. In a large single centre series including over 600 patients, Aicher et al. [4] have shown that freedom from grade >2 AI at a 5-year follow-up was 90% and it was equivalent in both tricuspid and bicuspid AVs.

Valve repair techniques are determined by the underlying patient anatomy. The classification scheme of El Khoury’s group [2] provides guidance to the surgical technique on the basis of the anatomic deficiency. AV repair cannot be easily performed in all patients and by any surgical team. In particular, the anatomy of the valve appears to play a central role in the outcome of the repair. It is clear that calcified valves presenting with cusp restriction and deficient cusp tissue are not amenable to durable repair. The predictive value of AV anatomy for valve reparability was evaluated in a study of 163 patients undergoing surgery for AI. Types I and II lesions (normal and prolapsing cusp motion, respectively) were considered repairable unless cusp body calcification was present, while type III lesions (restrictive cusp motion) were considered non-repairable. Transoesophageal echocardiography classification of lesion type agreed strongly with surgical inspection (93%) and was strongly predictive of valve reparability and postoperative outcome [5].

Furthermore, repair for bicuspid AVs may give very good perioperative outcomes but does not prevent the progression of disease over time, or evolution towards cusp calcification and degeneration that is typical of bicuspid AVs [6, 7].

Stress haemodynamics of patients who have undergone valve repair are necessary to determine the functional performance of the repaired valves. Graeter et al. were the first to investigate AV gradients during exercise in patients who had undergone AV preserving aortic replacement and compared them with patients submitted to composite replacement of AV and aorta and healthy volunteers. Their findings suggested that preserving the AV restores nearly normal haemodynamic function of the AV [8].

More recently, Schmidtke et al. [9] evaluated the stress haemodynamics of repaired bicuspid AVs in a group of 25 patients. Compared with healthy controls, repaired bicuspid AVs presented significantly higher transvalvular gradients (both at rest and under stress) and significantly smaller AV areas [9].

Our results are in line with the existing literature and confirm that mid-term follow-up rest and dynamic performance of repaired AVs is satisfactory. Tolerance of maximal physical stress is well documented overall. In particular, the continence of the repaired valves remains unchanged during strenuous effort, even in patients that present at rest with grade 3 asymptomatic AI despite previous AV repair. Our analysis of the haemodynamic performance of the repaired valves demonstrates that the IAVA remains almost unchanged even during maximal stress. This condition leads to a significantly increased transvalvular gradient. Although this finding has no major clinical impact presently, this situation is not physiologic. In fact, we have recently documented that increased cardiac output achieved during maximal physical stress in adults is accompanied by a significant increase in the IAVA and a stable trans-AV gradient [10]. Interestingly, similar findings have been observed in patients that have undergone the David procedure in which the anatomically normal native AV is reimplanted in a straight Dacron tube. In these patients, after exercise, the valve behaves much like the valve of normal subjects [10].

When surgical repair is performed directly on the AV, the pre-existing anatomical imperfection of the valve and the surgical technique adopted to correct it may, theoretically, contribute together to the future haemodynamic performance of the repaired AV.

The presence of calcifications, thickenings and clefts make the procedure more cumbersome, although feasible. In this case, the abnormal cusp area either may be removed with a triangular resection or can be shaved to improve leaflet pliability.

In our analysis, we were not able to identify any pre-existing anatomical condition of the AV independently responsible for the alteration in the physiological haemodynamics (particularly the trans-AV gradient). Even the presence of a native bicuspid anatomy did not per se independently alter the performance of the repaired AV and did not impact, a priori, its haemodynamics during physical stress.

Moreover, our results confirm that when the surgical repair techniques are applied following the systematic approach proposed by experienced Boodhwani et al. [2], there is no direct independent negative impact on the stress performance of the repaired AV.

Of note, techniques such as commissuroplasty with pledgeds can be used to realign the commissures and provide a more homogeneous coaptation and distribution of the stress on the AV surface. Our analysis demonstrates that this technique is protective towards abnormal increase of the trans-AV gradient, even during strenuous physical effort.
In conclusion, we have to recognize that, although our analysis was not able to identify any preoperative anatomical condition or intraoperative intervention directly and independently responsible for an alteration in the physiologic performance of the repaired AV under physical stress, we have observed an unchanged IAVA under stress resulting in a significant trans-AV gradient increase. It is reasonable to believe that these findings are a result of combined and multiplicative action of different variables that could not be detected in our regression analysis model.

We have to stress that, although these echocardiography changes have not reached a pathologic level and are not accompanied by limitations in physical stress, their evolution in the years to come cannot be predicted.

Conflict of interest: none declared.

REFERENCES


