Original Research

Mitral Valve Repair: Beyond the French Correction

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Key words: **Edge-to-edge technique, triangular resection, mitral repair, superior transseptal approach, ring annuloplasty, mitral valve.**

Introduction: We analysed retrospectively patients who underwent mitral valve repair using techniques beyond the "French correction", as popularised by Carpentier.

Methods: From June 1997 to June 2006, 153 patients underwent mitral valve repair. Their mean age was 63.1 ± 13.5 years (range 19-87). Mean Euroscore was 4.9 ± 2.1 (2-13). Type II lesions were present in 109 cases. There were 123 degenerative cases. Preoperative mitral regurgitation (MR) was severe in 145 cases. Ninety patients were in NYHA class III/IV. The transseptal approach was employed in 89.5% of the series. Annuloplasty alone was performed in 36 patients, whereas leaflet plication/exclusion was applied in 53 patients. The edge-to-edge technique was used in 79. Mitral valve repair was combined with procedures for ischaemic heart disease in 41 patients.

Results: The mean postoperative stay was 8.1 ± 3.7 days (4-25). There was no mortality in the isolated mitral valve repair group. New onset atrial fibrillation occurred in 17% postoperatively. Mean follow-up was 34.3 ± 25.1 months (0-105). No or mild MR was present in 139 (91%) patients, while 144 (94%) were in NYHA class I. Four patients underwent redo repair. There was a statistically significant difference in relation to the MR between patients who had Alfieri repair with annuloplasty compared to no annuloplasty ($p<0.001$). Furthermore, there was a significant difference between the isolated valve and the combined group in terms of postoperative hospital stay ($p=0.006$) and survival ($p=0.033$).

Conclusions: Our study demonstrates that the techniques beyond the "French correction" simplify the repair, especially when combined with other cardiac procedures. These techniques were applied with no mortality in the isolated mitral valve repair group.

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The superiority of mitral valve repair compared to replacement is well documented, especially when preservation of left ventricular function is taken into consideration.[1] Alain Carpentier published his initial experience of mitral valve repair under the landmark article "the French correction".[2] Since this publication, mitral valve reconstruction has become the gold standard for correcting mitral valve regurgitation (MR) secondary to myxomatous pathology.[3,4] Mitral valve repair is also associated with low thromboembolic, bleeding, and infective complications.[5,6] Otavio Alfieri introduced his technique of edge-to-edge repair (E2E) as an innovative technique to repair myxomatous mitral valve regurgitation, particularly when the pathology is secondary to anterior leaflet prolapse.[7-9]

We analysed retrospectively the short- and mid-term outcomes of our patients who underwent mitral valve repair using techniques beyond the "French correction". We used the E2E and triangular exclusion techniques as the main tools to repair the mitral valve in a single surgeon procedure.

Methods

Patients

During the period from June 1997 to June 2006, 153 patients underwent mitral valve repair using alternative techniques to the "French correction". There were 103 men and 50 women with a mean age of 63.1 ± 13.5 years (range 19-87). Fifteen (9.8%) patients were in New York Heart Association (NYHA) class I, 48 (31.4%) were in class II, whereas 82 (53.6%) and 8 (5.2%) were in classes III and IV, respectively. Ninety-four patients (61.4%) were in sinus rhythm, 56 (36.6%) were in atrial fibrillation, and 3 (2%) had a permanent pacemaker.

Preoperative echocardiography showed moderate MR in 8 (5.2%) and severe MR in 145 (94.8%). Left ventricular function was good in 122 patients (79.7%), moderate in 28 (18.3%), and poor in 3 (2%). The mechanism of MR as per the Carpentier classification[2] was type I lesions in 32 patients (20.9%), type II in 109 (71.2%), type III in 2 (1.3%), while 10 patients (6.5%) had mixed type (I and II) lesions.

Using intraoperative transoesophageal echocardiography, the pathology was reported as bileaflet in 41 patients (26.8%), anterior leaflet in 17 (11.1%), posterior leaflet in 67 (43.8%), and annular dilatation in 28 (18.3%). In addition, the anterior leaflet prolapse pathology involved A1 segment in 2 cases (1.3%), A2 in 43 (28%), A3 in 8 (5.2%), A1+A2 in 2 (1.3%), and A2+A3 in 3 (2%). Posterior leaflet prolapse involved P1 pathology in 2 patients (1.3%), P2 in 65 (42.5%), P3 in 5 (3.3%), P1+P2 in 7 (4.6%) and P2+P3 in 17 (11.1%).

Degenerative heart disease was found in 123 patients (80.4%), ischaemic in 10 (6.5%), endocarditis in 6 (3.9%), congenital in 5 (3.2%), and rheumatic in 9 (5.9%). Two patients had an atrial septal defect, 1 a patent *foramen ovale*, 1 an atrioventricular canal, while 1 had a subaortic ventricular septal defect. Coronary angiography showed coronary artery disease in 41 patients (26.8%). The mean Euroscore was 4.9 ± 2.1 (range 2-13), while the Parsonnet score was 12.6 ± 6.8 (range 5-32).

Surgical technique

Intraoperative transoesophageal echocardiography was performed in all patients. All operations were performed through median sternotomy. After full heparinisation, cardiopulmonary bypass was established by cannulating the ascending aorta and, separately, the superior and inferior *vena cava*, using bicaval cannulae. The patient's temperature was lowered to 30° C. The mitral valve was accessed via a superior transseptal approach in 137 (89.5%) cases and in the remainder via a transatrial approach. The E2E technique was the first choice and was performed with and without annuloplasty in 45 (29.4%) and 34 (22.2%) cases, respectively. E2E repair was performed using double-layer approximation and application of a 5-0 polypropylene suture with pericardial buttons, creating two orifices. Ring annuloplasty alone was performed in 36 patients (23.5%) and leaflet exclusion/plication in 53 patients (34.6%). Triangular exclusion was performed in the cases where we were able to achieve valve competence by excising less than 15% of the anterior or 30% of the posterior prolapsed leaflet. Concomitant E2E repair and leaflet plication were performed in 15 patients (9.8%). The Cosgrove-Edwards Annuloplasty System (Models 4600/4625) was used in all cases where annuloplasty was employed. The mean size of the ring was 33.5 ± 2.4 mm (range 28-38). Valve competence was assessed in all patients by forced saline injection into the left ventricle during cardioplegic arrest. Transoesophageal echocardiography was used after discontinuation of cardiopulmonary bypass to assess the integrity and function of the mitral valve. The mean cross-clamp time was 53.4 ± 14.5 min (range 32-102) for E2E repair without annuloplasty, 80.2 ± 16.8 min (range 58-123) for E2E repair with annuloplasty, and 78.5 ± 19.9 min (range 47-131) for other types of mitral repair. In addition, the mean cross-clamp time was 67.4 ± 18.1 min (range 32-131) for the isolated mitral repair cases and 84.8 ± 21.8 min (range 50-128) for the combined cases. The pericardium was closed in all isolated valve cases.

Concomitant procedures included the following: 5 (3.3%) patients underwent intracardiac defect closure; 13 (8.5%) radiofrequency ablation of atrial fibrillation; 41 (27.6%) coronary artery bypass grafting; and 3 (2%) left ventricular aneurysm repair. The mean number of the grafts was 2.4 ± 1.2 (range 1-5). One valve and four combined cases were urgent. Operative details are listed in Table 1.

Data collection and statistical analysis

The data were collected retrospectively, using the in-house "cardex" database, clinical notes, and correspondence with the patients' general practitioners. All patients had a transthoracic echocardiogram (TTE) prior to discharge and when they attended

Table 1. Operative details of mitral valve repair.

Details	Number (%)
Approach to mitral valve:	
Transatrial	137 (89.5%)
Transseptal	16 (10.5%)
Type of repair:	
E2E:	79 (51.6%)
with ring annuloplasty	45 (29.4%)
without ring annuloplasty	34 (22.2%)
and leaflet plication	15 (9.8%)
Leaflet exclusion or plication	53 (34.6%)
Ring annuloplasty	36 (23.5%)
Mean ring size (mm)	33.5 ± 2.4 (28-38)
Concomitant procedures:	
CABG:	41 (27.6%)
Mean number of grafts	2.4 ± 1.2 (1-5)
Intra-cardiac defect closure:	5 (3.3%)
ASD	2 (1.3%)
PFO	1 (0.6%)
VSD	1 (0.6%)
AVC	1 (0.6%)
LV aneurysm plication	3 (2%)
AF ablation	13 (8.5%)

AF – atrial fibrillation; ASD – atrial septal defect; AVC – atrioventricular canal; CABG – coronary artery bypass grafting; E2E – edge-to-edge technique; LV – left ventricular; PFO – patent *foramen ovale;* VSD – ventricular septal defect.

their first outpatient visit. Follow-up information was obtained during the period from March 2006 to July 2006 by review of the clinical notes or telephone interviews with all patients.

The patients were divided into two groups: the isolated valve and the combined group (coronary artery revascularisation or intracardiac defect closure). Values of continuous variables were expressed as mean ± standard deviation with ranges in parentheses. Continuous variables were compared using t-tests and one-way analysis of variance (ANOVA), whereas categorical variables were compared by means of the chi square (χ^2) test. Survival was calculated by Kaplan-Meier analysis. For all analyses, a p-value <0.05 was considered statistically significant. Univariate analysis of risk factors was performed with Cox proportional hazards regression. Data were analysed using SPSS 13.0 for Windows statistical software.

Results

The mean hospital stay was 8.1 ± 3.7 (range 4-25). The mean Intensive Care Unit (ICU) stay was 1.5 ± 1.5 days (range 0-15). There was no in-hospital mortality in the isolated mitral valve repair group, whereas 2 patients died in the combined group as a result of ischaemic pathology. New onset atrial fibrillation requiring conversion to SR occurred in 26 patients (17%), while there were respiratory infections in 10 (6.5%), gastrointestinal complications in 3 (2%), renal problems in 6 (4%), postoperative bleeding in 2 (1.4%), cerebral vascular accident in 1 (0.7%), and renal failure/bowel ischaemia/ cerebral vascular accident in 1 (0.7%).

Ninety-four patients (61.4%) remained in sinus rhythm postoperatively, while 56 (36.6%) were in atrial fibrillation. Postoperatively, 144 patients (94.1%) were in NYHA class I, 7 (4.6%) in class II, and 2 (1.4%) in class III. All patients had a TTE during their postoperative hospital stay or at their first appointment in the outpatients' clinic. Mitral stenosis was detected neither immediately after surgical intervention nor later; at the last follow up (TTE), MR was absent or mild in 139 patients (90.9%), moderate in 10 (6.5%), and severe in 4 (2.6%). The overall left ventricular function was good in 128 patients (83.6%), moderate in 22 (14.4%) and poor in 3 (2%). The differences between the preoperative and postoperative clinical data are shown in Table 2.

All patients were under cardiological follow up and the development of late MR assessed by routine TTE. Four patients underwent re-operation during the follow-up period. The causes of re-operation were severe MR in 3 patients and endocarditis in 1. The

Table 2. Preoperative and postoperative clinical data.

Characteristics	Preoperative Number (%)	Postoperative Number (%)
MR grade:	145 (94.8%)	4 (2.6%)
Severe	8 (5.2%)	10 (6.5%)
Moderate	–	139 (90.9%)
No or mild		
LVEF:		
Good (>50%)	122 (79.7%)	128 (83.6%)
Moderate (30-50%)	28 (18.3%)	22 (14.4%)
Poor (<30%)	3 (2%)	3 (2%)
NYHA class:		
I	15 (9.8%)	144 (94.1%)
II	48 (31.4%)	7 (4.6%)
III	82 (53.6%)	2 (1.4%)
IV	8 (5.2%)	0 (0%)
Heart Rhythm:		
SR	94 (61.4%)	94 (61.4%)
AF	56 (36.6%)	56 (36.6%)
New-onset AF*		26 (17%)
PPM	3 (2%)	3 (2%)

AF – atrial fibrillation; LVEF – left ventricular ejection fraction; MR – mitral regurgitation; NYHA – New York Heart Association; PPM – permanent pacemaker; SR – sinus rhythm. *Converted to SR.

mean freedom from re-operation for this specific group of patients was 37.3 ± 24.6 months (range 18-73). Three patients had simple annuloplasty, having undergone a plain E2E technique without annuloplasty at the initial repair. The patient with endocarditis underwent mitral valve replacement with a mechanical prosthesis (he was in full-time employment as a scaffolder until he had the bout of endocarditis). The vegetations were located on the E2E suture but not on the mitral ring. The four patients had an uneventful recovery and postoperative TTE showed trivial or no mitral regurgitation.

Currently, 147 patients are alive. There were 4 late deaths from unrelated causes. Mean follow up was 34.3 ± 25.1 months (range 0-105).

Statistics

There was no significant difference between the E2E and other techniques in terms of postoperative hospital stay (p=0.8), morbidity rate (p=0.51), left ventricular function (p=0.85), mitral regurgitation (p=0.090) and NYHA status (p=0.39). The use of the E2E technique with concomitant annuloplasty was strongly associated with a better postoperative MR status (p<0.001), but not with NYHA status (p=0.21), postoperative left ventricular function (p=0.46), postoperative hospital stay (p=0.59) or morbidity rate (p=0.51), when compared to E2E without ring annuloplasty. There was a statistically significant difference between E2E and other techniques with respect to the mean cross-clamp time (p=0.001). There was no significant difference between the underlying mechanism of the MR (anterior or posterior leaflet or bileaflet failure) and the postoperative mitral valve status in the E2E repair cases (p=0.73). In addition, there was a significant difference between the valve-only and the combined group with respect to Euroscore (p=0.001), mean cross-clamp time (p=0.001), ICU stay (p=0.012), postoperative hospital stay (p=0.006), and survival (p=0.033). The overall survival of the two groups is shown in Figure 1. There was no significant difference between the transatrial and transseptal approaches with regard to the incidence of new postoperative dysrrhythmias (p=0.4).

Finally, the univariate analysis showed that significant variables for no or trivial MR postoperatively were E2E with annuloplasty (p=0.001), and ring annuloplasty (p=0.001), but the difference was borderline when the preoperative MR status was taken into account (p=0.066).

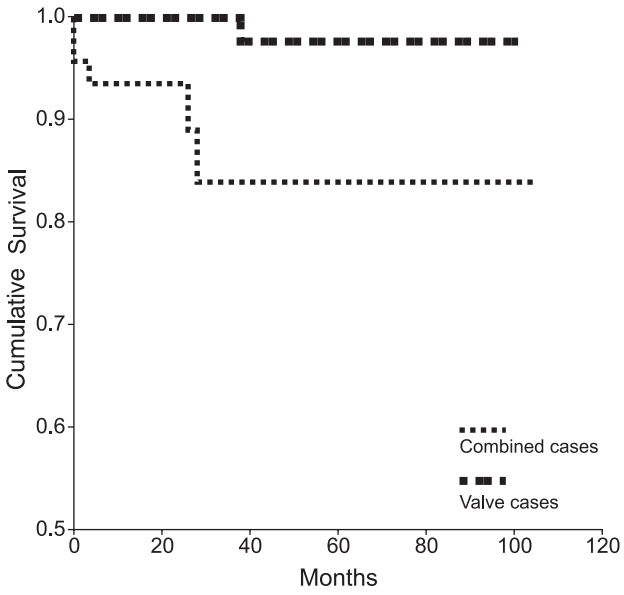

Figure 1. Cumulative survival of isolated valve cases and combined cases.

Discussion

In this series of mitral valve repair we used three main means of reconstruction. They included Alfieri's E2E technique, triangular exclusion, and ring annuloplasty. We did not use quadrangular resections, sliding plasty, or artificial chordae. There is no doubt that the "French correction" paper laid down solid foundations for mitral valve repair.[2] The majority of the correction techniques prior to the introduction of the Alfieri E2E technique relied on the integrity of the anterior leaflet to maintain mitral valve competence.[6] The techniques to fashion artificial chordae gained popularity, particularly for the correction of anterior leaflet prolapse.[10] Different techniques have been published for the insertion of these chordae.[11] This underlines the fact that these techniques are operator dependent. In contrast, the E2E technique is a simple and reproducible method.[7] It has been a superb tool in our experience for the correction of anterior as well as posterior leaflet prolapse, supporting Alfieri's results.[8] The E2E is a quick technique and reduces the cross-clamp time. This technique is our choice because of its simplicity and the excellent results in our experience. It is not limited to specific situations, as described by Kherani et al.[12]

We found that E2E with ring annuloplasty had better outcomes. This is similar to Alfieri's findings.[13] Gillinov et al pointed out that mitral annuloplasty re-

models the annulus, maintains leaflet coaptation and stabilises the repair over the time.[14] As E2E repair reduces the effective mitral valve area, creating two orifices, we do not undersize the annulus in order to improve competence. Our average annulus size in this series was 34 mm. We strive to achieve valve competence with the Alfieri E2E stitch on its own. Ring annuloplasty is mentioned as one of the options of the "French correction" and was performed in all cases where annular dilatation was responsible for the MR. We used ring annuloplasty mainly to support the repair and not to correct the shortfalls of the suture repair. We used the Cosgrove-Edwards ring exclusively in this series. It has the main advantage of avoiding the insertion of sutures into the anterior mitral annulus and it supports the repair adequately. We did not try to use the E2E technique as a bailout for badly executed repair. Clearly, if the E2E technique is used in such a context it is not going to rectify a poor repair.[13,15]

In our practice, no quadrangular resections were employed. We relied mostly on triangular exclusion, whether the pathology was in the anterior or the posterior leaflet.[16] This technique allows modification of the repair, unlike the case of resection where there is no opportunity to do so. It is the concomitant plication of the mitral annulus in the context of quadrangular resection of the posterior leaflet that predisposes towards systolic anterior motion pathology.[17] We used triangular exclusion and E2E without a single case of systolic anterior motion.

As for the surgical approach, we used the transseptal one in the majority of patients in this series. It provided unrivalled access to the mitral valve. This approach allows the assessment of the mitral valve without excessive traction. It allows the assistant a good view of the mitral valve reconstruction steps. None of our patients required pacemaker insertion. The safety of this approach has been supported by other groups.[18] This superior transseptal approach entails more atrial incisions, which could predispose to bleeding and dysrhythmias.[19] However, we did not notice an increased incidence of such complications in our patient population.

The quality of our patients' life at mid-term was excellent, with 94% of patients in NYHA class I, while we found no significant difference in NYHA status between E2E with and without annuloplasty. Although E2E repair has a more restrictive surface at rest than classical repair, it shows the same improvement in clinical status and the same exercise tolerance as classical repair.[20]

Although our study was a retrospective one, the use of the in-house analytical clinical database, clinical notes and correspondence with patients' family doctors or general practitioners, who maintain the detailed medical history of their patients, helped us to minimise this limitation, as our data were correct and accurate in all areas examined.

Our study demonstrates that the above techniques, beyond the "French correction", are associated with excellent early- and mid-term outcomes. They simplify the repair procedure, especially when combined with other procedures. These techniques were applied with no mortality in the isolated mitral valve repair group and low mortality in the combined group.

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