ORIGINAL ARTICLE

Leaflet Resection versus Chordal Replacement for Degenerative Mitral Regurgitation: Long-term Outcomes According to the Technique Used

Reparación valvular mitral resectiva vs. implante de neocuerda en la insuficiencia mitral de origen degenerativo: resultados en el seguimiento alejado según la técnica quirúrgica utilizada

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ABSTRACT

Background: Mitral valve repair (MVR) is the technique of choice for the treatment of degenerative mitral regurgitation (MR). Leaflet resection has demonstrated excellent mid-term and long-term outcomes, but there are still disagreements in the literature at the moment of choosing between resection or conservative techniques.
Objective: The primary outcome was to compare the durability of MVR and freedom from reoperation of the quadrangular and triangular leaflet resection techniques versus chordal replacement in degenerative MR. The secondary outcome was to analyze the results of the surgical techniques, the incidence of early postoperative complications and a composite outcome of mortality, reoperation or progression to significant MR in this population.
Methods: We conducted a retrospective cohort study in patients with degenerative MR undergoing MVR (leaflet resection or chordal replacement) between January 2005 and December 2017. A total of 154 patients were included: 78 in the leaflet resection group and 76 in the chordal replacement group. Ten patients underwent both procedures and were excluded from the analysis.
Results: Mean age was 66.4±13.9 years (p=0.3) A minimally invasive approach was used in 29.8% of cases. Mortality at 30 days was 1.2% in the leaflet resection group vs. 1.3% in the chordal replacement group (p=0.31), and it was 2.4% vs. 1.3%, respectively, in the long-term follow up (p=0.62). Cardiopulmonary bypass time was longer in the chordal replacement group (160.3±51.3 minutes vs. 130.4±42.4 minutes, p <0.001), as well as the number of anterior leaflet (17.1% vs. 3.8%, p=0.007) and both leaflet repairs (17.1% vs. 3.8%, p <0.001). At the long-term follow-up, freedom from reoperation was 97.4%, freedom from significant MR was over 90% and survival at 7 years was 97.4% in the entire cohort. Atrial fibrillation was the most common complication (5.8%).
Conclusions: Both techniques had excellent and similar results in terms of mortality, freedom from reoperation and freedom from significant MR.

Key Words: Mitral Valve Repair - Neochord Implantation - Degenerative Mitral Valve Disease

RESUMEN

Introducción: La reparación de la válvula mitral (RM) es actualmente la técnica de elección para el tratamiento de la insuficiencia mitral (IM) de origen degenerativo. La RM resectiva ha demostrado excelentes resultados en el mediano y largo plazo; no obstante, todavía hay discrepancias en la bibliografía sobre la técnica ideal en la reparación entre técnicas resectivas o conservadoras.
Objetivos: Principal: comparar la durabilidad de la RM y la sobrevida libre de reoperación en la IM de origen degenerativo con la técnica de resección cuadrangular/triangular vs. la de implante de neocuerdas. Secundario: analizar los resultados técnico-quirúrgicos, las complicaciones posoperatorias tempranas y el punto final combinado de mortalidad, reoperación y/o progresión a la IM significativa de los pacientes sometidos a reparación de la IM.
Material y métodos: Estudio de cohorte retrospectivo, incluyendo pacientes en los que se efectuó RM a causa de IM grave de origen degenerativo (técnica resectiva o neocuerdas) durante el período enero de 2005 a diciembre de 2017. Los 154 pacientes incluidos se dividieron en dos grupos: grupo resectivas (aquellos sometidos a cirugías resectivas; n=78) y grupo neocuerdas (aquellos sometidos a implante de neocuerdas; n=76). Diez pacientes tuvieron ambos procedimientos y fueron excluidos del análisis.
Resultados: El promedio de edad de los pacientes fue de 66,4 ± 13,9 años (p=0,3). En el 29,8% de ellos pudo realizarse un abordaje miniinvasivo. La mortalidad a los 30 días fue de 1,2% en el grupo resectivas vs. 1,3% en el grupo neocuerdas (p=0,31), y en el seguimiento alejado fue de 2,4% vs. 1,3%, respectivamente (p=0,62). Los tiempos de circulación extracorpórea fueron superiores en el grupo neocuerdas (160,3 ± 51,3 minutos, vs. 130,4 ± 42,4 minutos, p <0,001), al igual que las reparaciones anteriores (17,1% vs. 3,8%, p= 0,007) y bivalvares (17,1% vs. 3,8%, p <0,001). Considerando la totalidad de pacientes evaluados en el seguimiento alejado, la sobrevida libre de reoperación alcanzó el 97,4% y la sobrevida libre de IM ≥ moderada superó el 90%, con una sobrevida global a 7 años de 97,4%. La complicación más frecuente fue la fibrilación auricular (5,8%).
Conclusiones: Ambas técnicas tuvieron excelentes resultados, los que fueron similares en términos de mortalidad, sobrevida libre de reoperación y libre de IM ≥ moderada.

Palabras claves: Reparación valvular mitral - Implante de neocuerda - Enfermedad mitral degenerativa

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Abbreviations

MVR	Mitral valve repair	**CABGS**	Coronary artery bypass graft surgery
MR	Mitral regurgitation	**ASD**	Atrial septal defect
LVEF	Left ventricular ejection fraction	**AVB**	Atrioventricular block
PCS	Previous cardiovascular surgery	**KF**	Kidney failure
CPB	Cardiopulmonary bypass	**MV**	Mechanical ventilation
AVR	Aortic valve replacement	**MI**	Myocardial infarction
AF	Atrial fibrillation	**MICS**	Minimally invasive cardiac surgery

INTRODUCTION

Mitral valve repair (MVR) has demonstrated excellent mid-term and long-term outcomes and constitutes the treatment of choice in patients with severe mitral regurgitation (MR). (1, 2) The procedure is feasible in at least 90% of patients with degenerative mitral valve disease. (3)

Several techniques have been described for MVR, with better results compared with mitral valve replacement, including the absence of prosthesis-related complications and longer-term survival. (4) However, the rates of severe recurrent MR and the durability of the repair are the issues most discussed in the literature. The evaluation of the long-term results of these techniques (leaflet resection versus chordal replacement) is important to decide which surgical approach will be used.

A systematic functional approach to mitral valve reconstruction was introduced by Carpentier in 1969. (5) In 1983, he published his experience of mitral valve repair using the French correction, providing sufficient leaflet coaptation and excellent long-term results. One of the most important techniques proposed by Carpentier was quadrangular resection. Only 11% of the patients underwent reoperation due to residual or recurrent MR 10 to 20 years after surgery. (6) However, a few potential disadvantages of resection techniques have been postulated, as impaired leaflet mobility and decrease in the coaptation surface which is thought to be essential for a longstanding and good repair result. Therefore, new techniques have been developed over the years to reduce resection and the need for sliding or plication annuloplasty. In the following years, the term of a "respect rather than resect" approach was coined, and expanded polytetrafluoroethylene (ePTFE) neochords were developed as a support for the free edge of the prolapsed valve, based on the initial experiences of Frater (7) and David. (8) The use of premade ePTFE loops (loop technique) was introduced to facilitate the chordal replacement proposed by von Oppell and Mohr (9) particularly when MVR is performed through a minimally invasive cardiac surgery (MICS). This technique was initially described to repair anterior leaflet prolapse, and was thereafter extended to the other segments with excellent results; freedom from mitral reoperation was 95% and 88% patients had MR<2+ at 10 years. (10)

The primary outcome of the present study was to compare the durability of MVR and freedom from reoperation of the quadrangular and triangular leaflet resection techniques versus chordal replacement in degenerative MR. The secondary outcome was to analyze other measures of the surgical technique results: early postoperative complications and a composite outcome of mortality, reoperation or progression to significant MR in this population.

METHODS

We conducted a retrospective cohort study at Hospital Italiano de Buenos Aires in patients with degenerative MR undergoing MVR. Between January 2005 and December 2017, 712 mitral valve surgeries were performed in patients with degenerative and non-degenerative MR: 465 were mitral valve replacements and 247 were mitral valve repairs. This retrospective analysis included all the patients (n=154) undergoing MVR due to degenerative MR using leaflet resection or chordal replacement. Follow-up was performed by reviewing the electronic medical records and by telephone contact. Patients who required conversion to mitral valve replacement or those undergoing both techniques (leaflet resection or chordal replacement) were excluded from the analysis. Patients who had active endocarditis of the mitral valve or cardiogenic shock at the moment of surgery were also excluded.

The following MVR techniques were evaluated:

- Triangular or quadrangular resection of the involved segment and reconstruction with TiCron (Medtronic Inc., USA) or Cardionyl sutures.
- Chordal replacement with PTFE sutures (Gore-Tex) that were sutured to the papillary muscle to support the prolapsing segments.

The following variables were recorded: age, sex, presence of hypertension and smoking habits, preoperative functional class, cardiopulmonary bypass (CPB) time, aortic cross-clamp (ACC) time, and associated procedures. The following perioperative complications were considered: prolonged mechanical ventilation (MV) in patients extubated 48 hours after the procedure, atrioventricular block (AVB) requiring definite pacemaker, postoperative stroke, acute kidney failure (KF) (elevation of creatinine level + 1 from baseline value or need for hemodialysis), and reoperation for bleeding. Early postoperative mortality was defined as death within 30 days of surgery.

The quality of MVR was qualified as "successful", "acceptable" or "failed" when MR on the echocardiogram was trivial to mild MR (1+/ 2+), mild to moderate (2+/3+) or moderate to severe (3+/4+), respectively.

The durability of mitral valve repair and freedom from reoperation were considered in the absence of residual moderate (+3) or greater post-operative MR, determined by

echocardiography, and/or in the absence of need for mitral reoperation due to severe regurgitation.

Statistical analysis

Consecutive sampling was used to include all the patients who met the eligibility criteria. Continuous variables were expressed as mean and standard deviation, or median and interquartile range, according to the distribution, and categorical variables as absolute and relative frequencies. A Kaplan-Meier curve was built to show the incidence of the outcome in each group during the follow-up period and was compared with the log-rank test. A multivariate Cox proportional hazard analysis was performed to identify those factors associated with the final outcome. A two-tailed p value <0.05 was considered statistically significant.

All the statistical calculations were performed using STATA 13 (StataCorp LP, College Station, TX) software package.

Ethical considerations

The study was conducted following the recommendations for research studies in human subjects and current legal regulations. An informed consent was not required because the study was a review of medical records and no data that would allow patient's identification were reported (except in the case of missing data, when a telephone call was made). The investigators implemented measures to protect the privacy and confidentiality of all the information according to the Argentine Personal Data Protection Law 25,326.

RESULTS

Preoperative characteristics

The preoperative characteristics are detailed in Table 1. Mean age was 66.4±13.9 years and the proportion of men was lower in the leaflet resection group (46.15% vs. 63.1%; p=0.034). The preoperative NYHA functional class was significantly worse in these patients compared with the chordal replacement group (2.56±0.8 vs. 2.05±0.7; p <0.001) and this difference was directly associated with the fact that nowadays patients undergoing surgery have fewer symptoms or are asymptomatic. (11).

Surgical and postoperative characteristics

The minimally invasive approach was less common and the cardiopulmonary bypass time was lower in the leaflet resection group (6.4% vs. 53.9%; p <0.001, and 130.4 ± 42.4 min vs. 160.3 ± 51.3 minutes; p <0.001, respectively), a usual finding in this type of approach.

Repair of the posterior leaflet was more frequent in the leaflet resection group (92.3% vs. 65.7%), but the number of procedures of anterior leaflet repair (3.8% vs. 17.1%; p= 0.007) and repair of both leaflets (3.8% vs. 17.1%; p <0.001) was lower in this group. Ten patients who underwent both procedures, corresponding to anterior and posterior leaflet prolapse with resection of the posterior leaflet and chordal replacement in the anterior leaflet, were excluded from the analysis. The other intraoperative and postoperative results are shown in Table 2.

Complications and mortality

Mean follow-up was 3.7±3.4 years and was completed in 91% of the cases. In-hospital mortality was 1.29% without differences between both groups.

Atrial fibrillation was the most common complication (5.8%). Reoperation for bleeding was 3.8% in the leaflet resection group vs. 1.3% in the chordal replacement group (p=0.32). The complications developed in the postoperative period and during follow-up are shown in Table 3.

The proportion of trivial to mild residual MR in the early postoperative period was similar with both techniques. The proportion of patients with moderate to severe MR in the immediate postoperative period was 2.6% for all the patients and corresponded to 5% of the patients on the chordal replacement group and none in the leaflet resection group (p=0.04).

Freedom from the composite outcome of mortality, reoperation or progression to significant MR during follow-up was 83.8% with no significant differences in the curves. Freedom from reoperation was 97.4% (99% in the leaflet resection group vs. 96% in the chordal replacement group) and freedom from moderate MR (3+/4+) was 89% (89.8% in the leaflet resection group vs. 88.2% in the chordal replacement group) (Table 4) (Figs. 1-2).

Table 1. Preoperative characteristics of the patients undergoing mitral valve repair

Variable	Mean ± SD or n (%)			
	Total	Leaflet resection	Chordal replacement	p
Patients	154 (100)	78 (50.6)	76 (49.3)	
Age (years)	66.4±13.9	67.4±13.3	65.3±14.4	0.3
Age (median, years)	70	71	67.5	0.3
Male sex	84 (54.5)	36 (46,15)	48 (63.1)	0.034
NYHA	2.31 ± 0.8	2,56 ± 0.8	2.05 ± 0.7	<0.001
Smoking habits	42 (27.7)	16 (20.5)	26 (34.2)	0.056
Hypertension	100 (64.9)	54 (69.2)	46 (60.5)	0.26
LVEF <60%	13 (8.4)	8 (10.25)	5 (6.5)	0.46
PCS	5 (3.2)	3 (3.84)	2 (2.6)	0.67

NYHA: New York Heart Association; LVEF: Left ventricular ejection fraction; PCS: Previous cardiovascular surgery.

DISCUSSION

At long-term follow-up, freedom from reoperation was 97.4%, freedom from more than moderate MR was above 90% and survival at 7 years was 97.9% in the entire cohort.

The discrepancy between the rate of reoperation and the incidence of significant MR indicates that not all patients with significant MR after MRV require surgery during the follow-up period.

Gillinov et al. (1) demonstrated that prolapse of both leaflets, anterior leaflet prolapse and failure to perform an annuloplasty are the most significant risk factors for failure of MVR regarding recurrence of MR during follow-up.

Leaflet resection techniques have demonstrated favorable and durable hemodynamic results at late follow-up; yet, anatomic and physiologic changes in the mitral valve have been described with this approach. The approximation of the tissue remnant after the resection increases tissue stiffness and decreases its mobility. However, resection could be considered the technique of choice, particularly in degenerative mitral valve prolapse with a great proportion of redundant tissue, as it reduces the possibility of systolic anterior motion (SAM). This requires the use of the sliding technique to reduce the anterior-posterior distance of the posterior leaflet and prevent SAM.

Both techniques are used in our centers and are adapted to the echocardiographic, hemodynamic and anatomic characteristics of the patient. (12)

There are no large randomized trials comparing both techniques. Only one prospective randomized trial published by Falk et al. (13) compared the use of both techniques in 129 patients and reported good

Table 2. Intraoperative and postoperative results in patients undergoing mitral valve repair

Variable	Mean±SD or n (%)			
	Total (n=154)	Leaflet resection (n 78)	Chordal replacement (n=76)	p
Video-assisted minimally invasive surgery	46 (29.8)	5 (6.4)	41 (53.9)	<0.001
CBP time (min)	145±49.5 (75-412)	130.4±42.4 (75-252)	160.3±51.3 (80-412)	<0.001
ACC time	104.6±34.3 (56-248)	95±29.2 (60-208)	111.7±34.7 (62-248)	0.002
Posterior leaflet repair	126 (81.8)	72 (92.3)	50 (65.7)	<0.001
Anterior leaflet repair	16 (10.3)	3 (3.8)	13 (17.1)	0.007
Repair of both leaflets	16 (10.3)	3 (3.8)	13 (17.1)	<0.001
Associated procedures				
AVR	12 (7.7)	12 (15.3)	0	0.01
Tricuspid valve surgery	15 (9.7)	9 (11.5)	6 (7.8)	0.45
Ascending aorta surgery	8 (5.1)	5 (6.4)	3 (4)	0.49
CABGS	26 (16.8)	19 (24.3)	7 (9)	0.12
Closure of ASD	3 (1.9)	0	3 (3.9)	0.076
Surgery for AF	21 (13.6)	9 (11.5)	12 (15.7)	0.44
Days of hospitalization (median-IQR)	7 (6-9)	7 (6-9)	6.5 (5-8)	0.033

CPB: Cardiopulmonary bypass; ACC: Aortic cross-clamp. AVR: Aortic valve replacement; CABGS: Coronary artery bypass graft surgery; ASD: Atrial septal defect; AF: Atrial fibrillation. IQR: Interquartile range.

Table 3. Postoperative complications in patients undergoing mitral valve repair

Variable	n (%)			
	Total (n=154)	Leaflet resection (n 78)	Chordal replacement (n=76)	p
Atrial fibrillation	9 (5.8)	3 (3.8)	6 (7.8)	0.28
AVB	3 (1.9)	3 (3.8)	0 (0)	0.97
KF requiring hemodialysis	1 (0.6)	1 (1.2)	0 (0)	0.52
Reoperation for bleeding	4 (2.5)	3 (3.8)	1 (1.3)	0.32
Posoperative MI	1 (0.6)	0 (0)	1 (1.3)	0.31
Postoperative stroke	1 (0.6)	1 (1.2)	0 (0)	0.32
Prolonged MV	12 (7.7)	6 (8)	6 (8)	0.96

AVB: Atrioventricular block requiring definite pacemaker; KF: Kidney failure; MI: Myocardial infarction; MV: Mechanical ventilation.

Table 4. Outcome of patients undergoing mitral valve repair during follow-up

Variable	n (%)			
	Total (n=154)	Leaflet resection (n 78)	Chordal replacement (n=76)	p
30-day mortality	2 (1.29)	1 (1.2)	1 (1.3)	0.31
Mortality during follow-up	3 (2.1)	2 (3)	1 (1)	0.62
Reoperation on the mitral valve during follow-up	4 (2.6)	1 (1)	3 (4)	0.3
Severity of MR during follow-up				
MR ≤ trivial to mild	130 (84.4)	70 (89.7)	60 (78.9)	0.065
MR mild to moderate	7 (4.5)	0 (0)	7 (9)	0.006
MR ≥ Moderate (++/+++)	17 (11)	8 (10.2)	9 (11.8)	0.75

MR: Mitral regurgitation

Fig. 1. Freedom from reoperation, mortality and progression during long-term follow-up

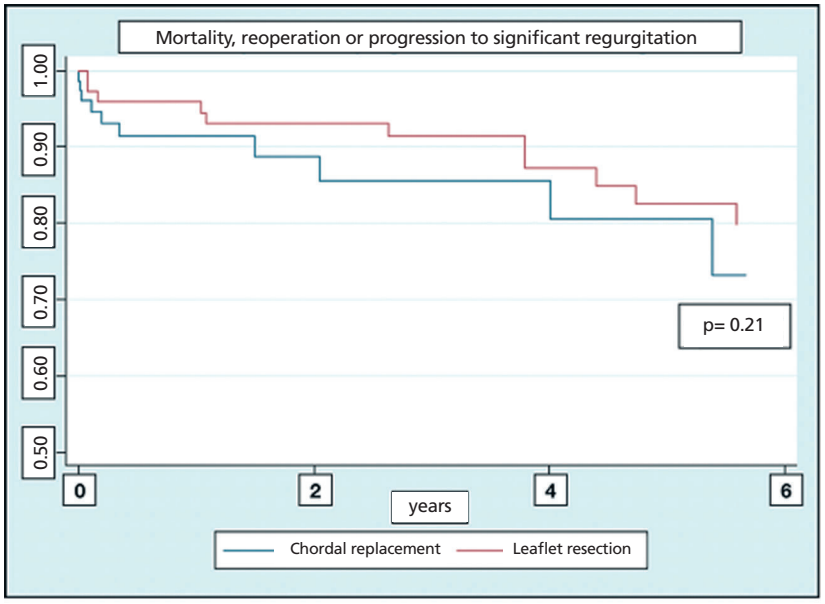
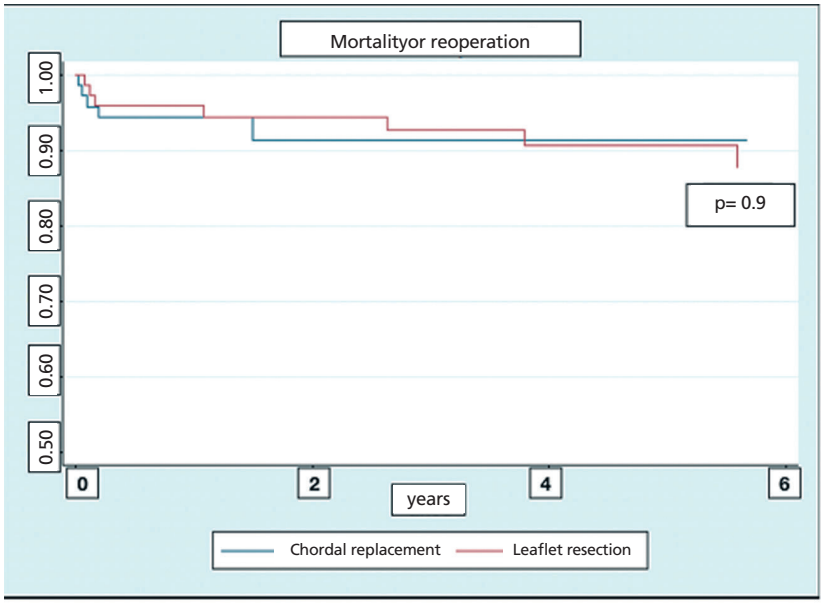


Fig. 2. Freedom from reoperation or mortality during long-term follow-up



echocardiographic results and low morbidity and mortality using both the conventional approach and MICS. However, no advantage of one technique over the other was detected.

A recent meta-analysis including 1,926 patients, compared both techniques and reported no significant differences in terms of mortality, successful repair and recurrent MR during follow-up. Yet, chordal replacement was associated with greater freedom from reoperation and higher postoperative left ventricular function compared with leaflet resection. Probably, as chordal replacement does not involve any disruption of the ventriculo-annular continuity, it preserves ventricular function. (14-16)

Study limitations

The limitations of this study are associated with the methodological design of an observational and retrospective single-center study.

CONCLUSIONS

Resection techniques and chordal replacement to repair degenerative mitral valve regurgitation have excellent and similar results in terms of mortality and freedom from reoperation and from significant MR. Therefore, at the moment of planning MVR, the surgeon can choose the technique that best suits the characteristics of each patient.

Conflicts of interest

None declared. (See authors' conflicts of interest forms on the website/Supplementary material).

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