ORIGINAL ARTICLE

Experience on minimally invasive mitral valve repair in one single center

Oscar A. Prior-González, MD[1], Juan C. Rendón-Isaza, MD[1], Juan S. Jaramillo-Isaza, MD[1], Jose J. Escobar-Matallana, MD[1], Alberto A. Quintero-Gómez, MD[1], Luz E. Pérez-Jaramillo, MD[2], and Lizeth D. Saldaña-Morales, MD[1]

[1] Department of Cardiovascular Surgery, [2] Department of Epidemiology and Statistics, Clínica CardioVID. Medellín, COLOMBIA.

Background. **Mitral valve repair is the gold standard for the treatment of degenerative mitral valve insufficiency. When compared to replacement, repair shows less perioperative mortality, better survival and less long-term morbidity and mortality.** ***Material.*** **A retrospective cohort was performed including all the patients that underwent minimally invasive mitral valve repair in our center. The patients were collected out of a database done in the cardiovascular surgery department. A follow-up was completed, via phone call or inpatient hospital visit, searching for primary endpoints: late mortality, freedom from reoperation and functional classification.** ***Results.*** **A descriptive analysis of the studied variables was done in a population of 159 patients between the years 2013 and 2019. The average age was 55 years (±12,2), 73,6% were men. Severe mitral regurgitation was reported in 84,3%, the etiology was fibroelastic degenerative in 59,1. Neochordae were implanted in 42,8% of the patients. The average of mechanical ventilation was 7 hours (± 8,1), intensive care unit length of stay 3,92 (±11,91) days and total in hospital stay was 7,63 (±17,78) days. Arrythmias presented in 15,7%, heart failure in 3,8%, and stroke in 2,5%. Our mitral valve repair rate was 97.4%. 96,6 % survival rate at 6,68 years, 98,1% freedom from reoperation, 87,3% of patients were on NYHA I classification.** ***Conclusion.*** **Minimally invasive mitral valve repair can be performed safely with short and long-term good results. The failure rate of mitral valve repair is extremely low, especially in experimented surgeons. Mitral valve repair can be done in a low volume center with outstanding results.**

Key words: **Minimally invasive cardiac surgery; Mitral valve; Mitral valve repair.**

Introducción. **La reparación de la válvula mitral representa el estándar de oro actual para el tratamiento de la insuficiencia mitral degenerativa. Cuando se compara con el reemplazo, la reparación demuestra menos mortalidad perioperatoria, mejor supervivencia y menor morbilidad.** ***Métodos.*** **Estudio observacional de cohortes retrospectivo. Se incluyen todos los pacientes sometidos a reparo mitral mínimamente invasivo que se tomaron de una base de datos realizada por el servicio de cirugía cardiovascular. Se realiza seguimiento vía llamada telefónica o en consulta en búsqueda de mortalidad, ausencia de reoperación y clase funcional.** ***Resultados.*** **Se realizó un análisis descriptivo de las variables en una población de 159 pacientes durante los años 2013-2019. Promedio de edad de 55.1 años (±12,2), el 73,6% fueron hombres. Se reporta un grado de insuficiencia mitral severa en el 84,3%, La etiología fue en 59.1% degenerativa fibroelástica. Al 42,8% de los pacientes se les implantó neocuerdas. El tiempo de ventilación mecánica promedio fue de 7 horas (±8,1), estancia en UCI de 3,92 (±11,91) y estancia hospitalaria de 7,63 (±17,78). No hubo mortalidad a 30 días. Se reportan arritmias en 15,7%, accidente cerebrovascular en el 2,5%. La tasa de plastia exitosa fue del 97.4%. a largo plazo, libertad de mortalidad de 96,6% a 6,68 años. Libertad de reoperacion de 98,1%. El 87,3% de los pacientes en clase funcional I.** ***Conclusiones.*** **La reparación valvular mitral mínimamente invasiva se puede realizar de forma segura con resultados alentadores a corto y largo plazo. La tasa de fallas de las reparaciones es muy baja, especialmente en manos de cirujanos experimentados. La cirugía de reparación valvular mitral se puede realizar con excelentes resultados en un centro de bajo volumen.**

Palabras clave: Cirugía cardiaca minimamente invasiva; Válvula mitral; Válvula mitral, reparación.

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Corresponding author: Dr. Oscar A. Prior-González
email: dr.prior@gmail.com

Mitral valve disease (MVD) is the second most common clinically significative form of valvular defect on adults [1]. In the United States, MVD is the most frequent type of valvular disease in adults older than 55 years

[2]. Today, degenerative mitral insufficiency is the illness that more affects the population, in around 2% [1-4]. The most frequent finding in patients with degenerative disease is valve prolapse due to elongation or chord rupture. This can result in several degrees of insufficiency because of the malcoaptation of the leaflets during ventricular contraction [1-5]. Mitral valve repair (MVr) is the gold standard for the treatment of mitral valve insufficiency (MVI) [6,7]. When compared to mitral valve replacement (MVR), the repair is more physiologic and spares the complications related to a prosthetic valve [5,8]. It provides less perioperative mortality, better survival, better preservation of the left ventricle function after surgery [4,6,9] and less long-term morbidity [4]. If patients with chronic degenerative disease undergo operation early before symptoms and before ventricular changes occur, the outcome is quite superior [1,10]. Early intervention improves survival and the likelihood of MVr success in comparison to watchful waiting [10].

Minimally invasive cardiac surgery (MICS), aroused on the last decade of 20th century [11] and has become the standard approach in many European and north American centers [12]. On the early 90´s [13], the uprising interest on general laparoscopic surgery encouraged the evaluation of new minimally invasive techniques for their use on cardiac surgery [14]. Minimally invasive mitral valve repair (MIMVr) is an area of growing interest [15]. This techniques pursues to achieve safety and effectiveness similar or superior to conventional surgery [1,14-17]. Several advantages of MIMVr over conventional surgery have been proved [9] including similar quality, long-term durability, freedom from reoperation, other concomitant procedures, less surgical trauma, reduction of blood transfusions, less postoperative pain, mechanical ventilation time, ICU stay and in-hospital stay. Surgical recovery is faster and the cosmetic results are advantageous, with a great patient satisfaction in terms of wound scaring and faster return to daily activities [1,5,6,8,9,14-19]. Sternal wound infection and dehiscence are virtually dismissed, which are correlated with high morbidity and mortality, especially in risk groups like obese, diabetic patients and those with chronic obstructive pulmonary disease. Because of its less invasive nature, this scope results to be a valuable alternative in selected patients. This study describes our experience and results in MIMVr.

MATERIAL

A retrospective cohort that included all the patients that underwent MIMVr in our center was performed. The study was conducted from May 2013-October 2019. Patients older than 18 years were included. The patients were collected of a database done in the cardiovascular surgery department. The data was placed on an Excel spreadsheet (Office 2019, institutional license). The variables for descriptive analysis were interpreted in statistical software SPSS version 22 (institutional license).

In the present study, different demographic variables were considered: age, genre, comorbidities, body mass index; clinical variables like the grade of severity of the insufficiency, preoperative ventricular function, etiology of the valve disease; variables related with the surgical procedure and the technique like the type of minimally invasive approach, cannulation, myocardial protection, mechanism of insufficiency, involved leaflets, chord rupture. Surgical technique details are described like the type of ring used and its size, use of neochords, valve resection techniques or other additional procedures. aortic crossclamp and bypass times, conversion to sternotomy. Postoperative variables such as time in intensive care unit, in-hospital stay, complications, 30-day mortality and freedom from MVI on the transthoracic echocardiography were considered. We defined successful repair as the absence of mitral insufficiency or mild/trace insufficiency, with adequate leaflet coaptation. A follow-up survey was done, the patients on this series were called by phone or data were gathered from the electronic charts if the patient was consulted the last six months on our center. A Kaplan-Meier analysis was done, in order to determine freedom from mortality and freedom from reoperation rates. Patients were questioned about their functional classification using the NYHA score (New York Heart Association) [20].

RESULTS

We conducted a descriptive analysis of the mentioned variables in a population of 159 patients between 2013 through 2019. Normality was previously determined with Kolmogorov-Smirnov test because the population was greater than fifty patients. The average age was 55.1 years (± 12.2), 73.6% were men. The comorbidities presented were hypertension in 40.9%, dyslipidemia in 8.2%, atrial fibrillation in 6.9% and coronary disease in 1.3% (**Table 1**). The left ventricle ejection fraction (LVEF) was 60.45 (± 8.53), with severe

Table 1. Demographic variables (n=159)

VARIABLE	
Age, mean (SD)	**55.1 (± 12.2)**
Gender, n (%)	
Male	**117 (73.6)**
Female	**42 (19)**
BMI, mean (SD)	**24.49 (± 4.98)**
Comorbidities, n (%)	
Asthma	**2 (1.3)**
Hypertension	**65 (40.9)**
Dyslipidemia	**13 (8.2)**
Endocarditis	**1 (0.6)**
Cigarrete smoking	**12 (7.5)**
Atrial fibrillation	**11 (6.9)**
Rheumatic fever	**2 (1.3)**
Hypothyroidism	**4 (2.5)**
Coronary artery disease	**2 (1.3)**
Others	**16 (6.1)**

SD: Standard deviation BMI: Body Mass Index

Table 2. Clinical and preoperative data (n=159)

VARIABLE	
LVEF, mean (SD)	60,45 (± 8,53)
Mitral valve regurgitation, n (%)	
Moderate	8 (5)
Severe	134 (84.3)
Moderate-severe	17 (10.7)
Etiology, n (%)	
Fibroelastic	94 (59.1)
Endocarditis	7 (4.4)
Functional	3 (1.9)
Mixomatous (Barlow, mixed)	55 (34.6)
Chordae tendinae prolapse, n (%)	138 (95.2)
Type of prolapse, n (%)	
Posterior	111 (69.8)
Anterior	12 (7.5)
Both	22 (13.8)
Chordae tendinae rupture n (%)	77 (48.4)

LVEF: Left ventricle ejection fraction SD: Standard deviation.

mitral regurgitation in 84.3%, followed by moderate-severe in 10.7%, and moderate regurgitation in 5%. The etiology was 59.1% degenerative fibroelastic, 34.6% myxomatous (Barlow, mixed, others), 4.4% endocarditis, and 1.9% as functional. Ninety five percent of the patients presented valve prolapse and the most common prolapse was on the posterior leaflet in 69.8%. Seventy-seven (48.4%) patients also had rupture of chordae tendinae (**Table 2**). The most common approach was thoracotomy in 65,6% and in 6.3% was periareolar. Femoral venoarterial cannulation was done in 81.7%, femoral venoarterial and venous yugular in 13.7%, and in 3.9% femoral venoarterial and superior vena cava. Del Nido cardioplegia was preferred in 67.6% followed by Custodiol® in 31%. Neochords were implanted in 42.8% of patients (**Table 3**). Forty-four (27.7%) patients underwent either triangular or quadrangular resection (**Fig. 1**), and 111 (48.2%) for neo-chords (**Fig. 2**). Other procedures were done in 13.7% of patients: 6.3% patent foramen ovale or atrial septal defect closure, 2.5% tricuspid valve repair, and in 1.9% maze procedure. Cross-clamping time mean time was 100.4 min (±31.4 min), cardiopulmonary bypass time 145.48 min (±41.6 min). The mean for mechanical ventilation was 7 hours (± 8.1 hours), ICU length of stay of 92 hours (±11.91 hours) and in-hospital length of stay 763 (±1778). Immediately after the end of cardiopulmonary bypass, transesophageal echocardiography was performed, revealing successful repair in 99% of the cases. A last transthoracic echocardiography was done before discharge of the patients and the rate of repair was 97.8%. There was no mortality reported at 30 days. The most frequent complications were arrhythmias in 157%, heart failure in 3.8% and stroke in 2.5% (**Table 4**). The follow-up of the patients was 6.8 years, and achieved by 130 out of 159 patients (81.76%). The rest of the patients did not answer the call or stopped going to consultation. There were 3 cardiac deaths. One patient died in a car accident. It was found that at 5.3 years, 96,6% of the patient were alive, with an average of survival of 6.68 years (CI 96%; 6.56-6.81) (**Fig. 3**). 98.1% of the patients remained free of reoperation at the time of the follow-up (**Fig. 4**). Three

Table 3. Surgical procedure variables (n=159)

VARIABLE	
Successful mitral valve repair, n (%)	155 (97.48)
Conversion to sternotomy, n (%)	4 (2.5)
Approach, n (%)	
Thoracotomy	145 (6.6)
Periareolar	14 (6.3)
Neochords, n (%)	111 (42.8%)
Resection, n (%)	
Triangular	44 (27.7)
Cuadrangular	2 (1.3)
Other	17 (10.7)
Concomitant procedure, n (%)	7 (13.7)
Aortic cross-clamp in minutes, mean (SD)	100.48 (± 31.4)
Cardiopulmonary Bypass time in minutes, mean (SD)	145,48 (± 41.6)

SD: Standard deviation.

Table 4. Postoperative variables and complications (n=159)

VARIABLE	
Mechanical ventilation time in hours, mean (SD)	7 (± 8.1)
Intensive care unit time, in days, mean (SD)	3.92 (± 1191)
Total in-hospital stay, in days, mean (SD)	7.63 (± 17.78)
Complications, n (%)	32 (20.12)
Type of complication, n (%)	
Superficial wound infection	3 (1.9)
Arrhytmias	14 (8.8)
Hepatic laceration	2 (1.3)
Perioperative MI	1 (0,6)
Heart failure	3 (1.9)
Systolic Anterior Motion	1 (0.6)
Prolonged mechanical ventilation	3 (1.9)
Stroke	1(0.6)
Reoperation for bleeding	4 (2.5)
30-day mortality, n (%)	0 (0)

SD: Standard deviation MI: Myocardial infarction.

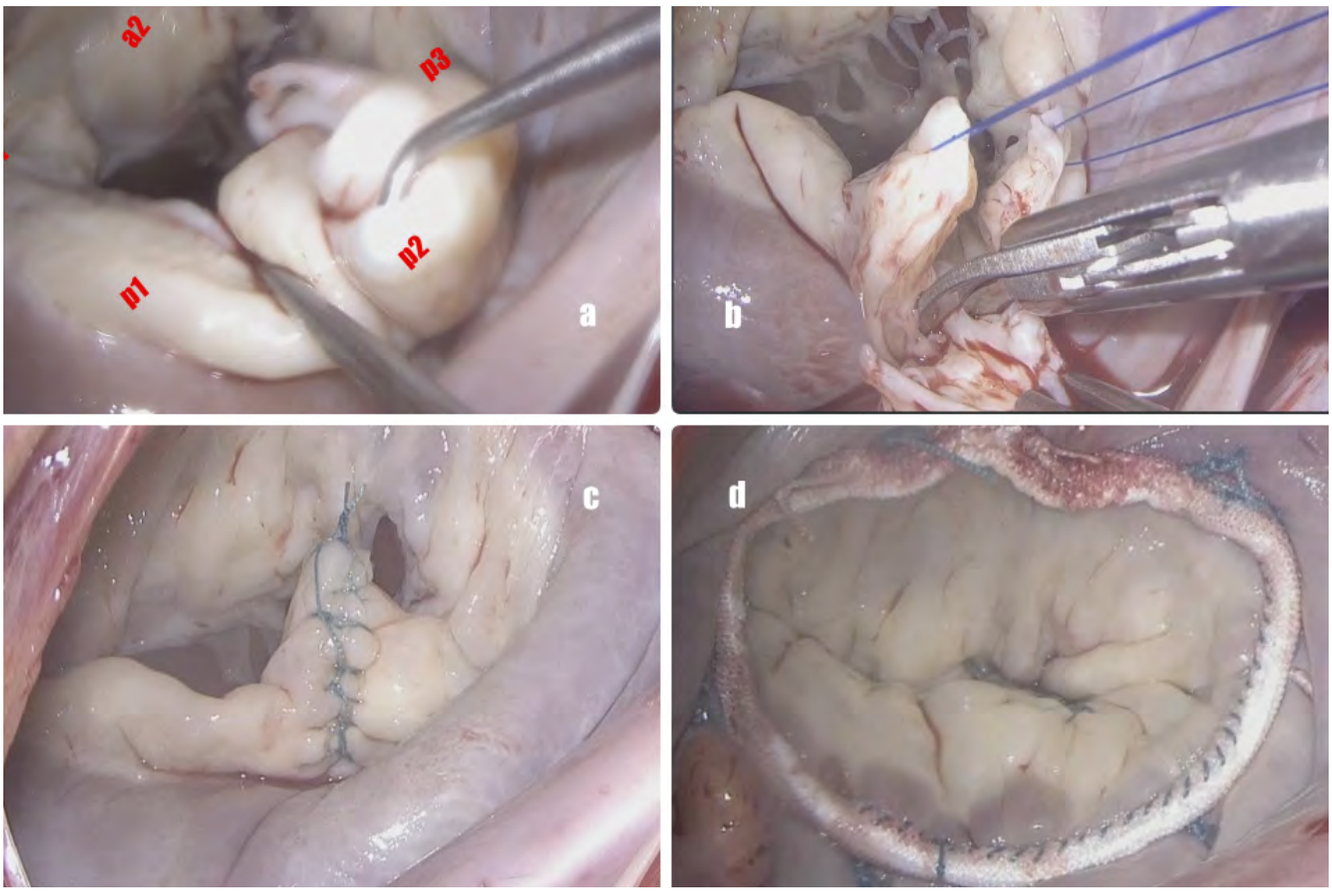

Figure 1. Triangular resection. A: Surgical inspection of mitral valve. Myxomatous leaflet with excess tissue and p2 prolapse. B: Triangular resection of p2. C: Leaflet closure with running suture. D: Complete repair.

patients required another heart surgery. One of the patients developed acute endocarditis after a community acquired pneumonia which caused perforation of the anterior leaflet; other patient had a tear in the neo-chords insertion site at the papillary muscle. On average, the patients had a freedom from reoperation period of 1,432 days (IC 95%, 1402-1463). Of the 130 interviewed patients, 126 were alive. We performed a questionnaire to determine the functional classification according to NYHA score finding that 110 patients (87.3%) were on Class I and 16 patients (12.7%) were on class II. There were no patients in classes III or IV.

DISCUSSION

Minimally invasive mitral valve surgery by means of thoracotomy was developed initially with the aim of performing surgical techniques similar to a conventional sternotomy, but with reduced perioperative mortality and faster recovery. In 1996, Carpentier performed the first video assisted MIMVr through an anterior minithoracotomy [13,14,16,21]. Shortly thereafter, the first video assisted MVR was done, using a transthoracic aortic clamp, named the Chitwood clamp [9,19]. In 1997, Mohr performed MIMVS with the port access technology and for the first time with 3D videoendoscopy [11]. Since then, the viability for MIMVr was established, for selected patients in specialized centers [16]. Over the last years, different MICS centers reported their experience in MVr with promising results. Most of these results suggest that MIMVS provide excellent, safe and reproducible mitral valve exposure with results comparable to those with conventional approaches [13]. Currently, American and European valvular disease management guidelines recommend mitral valve repair over replacement for correction of mitral insufficiency in specialized centers with a success rate of at least 95% and mortality rates below 1% [2-4,22]. Several studies confirm that repair compared to replacement confers more survival, better left ventricular function and greater freedom from endocarditis, thromboembolism and anticoagulant-related bleeding [23]. Surgery may result in complete correction of mitral regurgitation and normalization of valve morphology, and therefore represents the only curative treatment strategy for patients with mitral valve insufficiency [6]. There has always been great doubt in regards to the ability of a surgeon to perform the same quality of MVr through a "limited vision" approach compared to the sternotomy approach, which presumably has a negative impact on long-term results [11]. Our institution is one of the leading regional centers in MICS and has grown in experience for MVr. Reconstructive valve

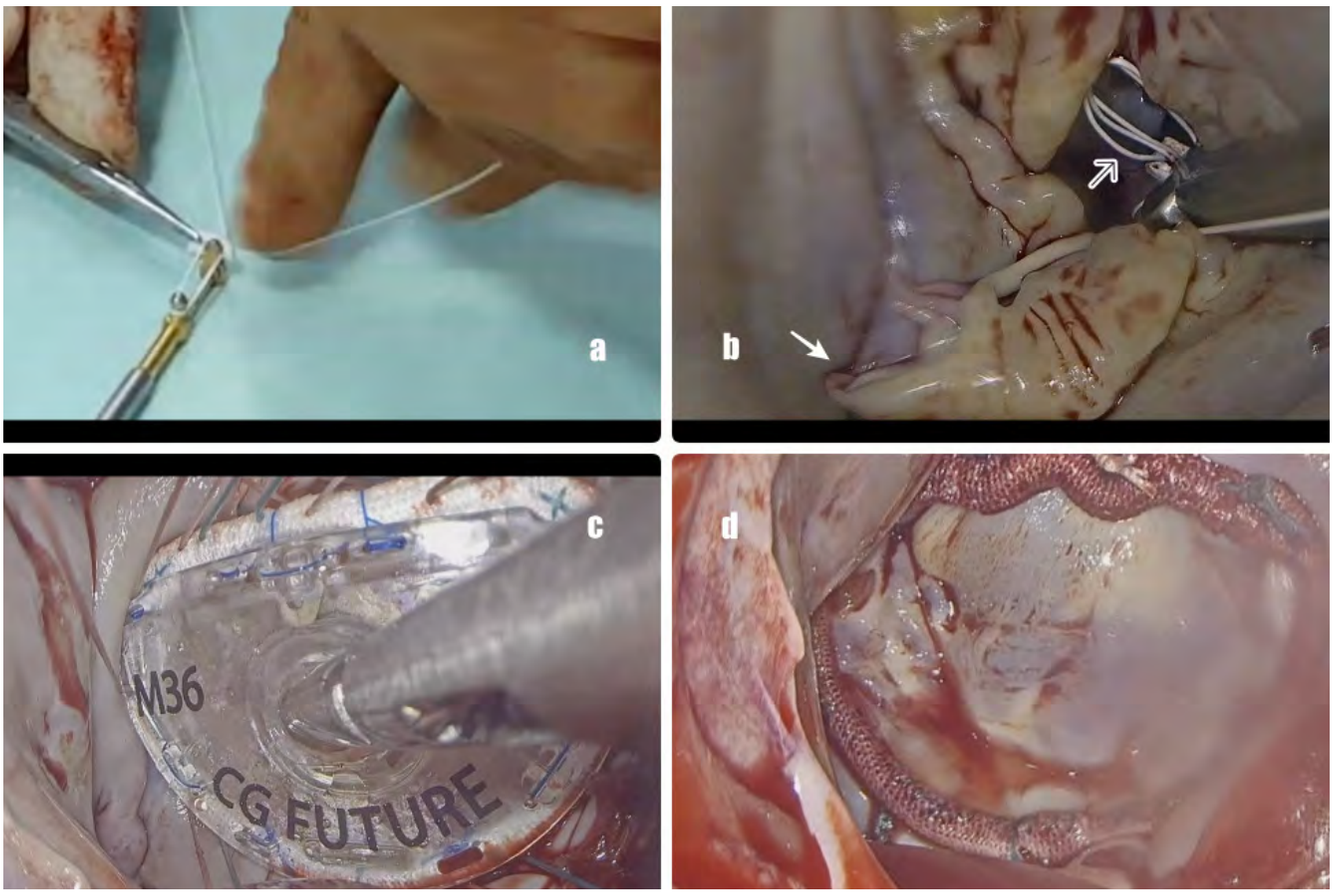

Figure 2. Mitral valve repair with neo-chords. A: After direct measurement of the distance between the papillary muscle and the prolapsed leaflet, PTFE neo-chords are fashioned with the Leipzig technique. B: White arrow points at a ruptured chordae tendinae at p2, hollow arrow points at the neo-chords sutured to the papillary muscle head. C: Placement of a semirigid annuloplasty ring. D: Complete repair.

surgery is a system of integral analysis of the valve, based on three basic principles: the restoration or conservation of the total mobility of the leaflets, creating an enhanced coaptation surface and remodeling of the ring to provide an optimal orifice area. Today, these techniques are easier and reproducible, allowing the mitral valve to be more accessible for repair. Prolapse of the posterior leaflet is the most common finding in patients with isolated mitral regurgitation and can be corrected by triangular resection, a simple, quick and reproducible technique. Currently, valve preservation is favored, "respect rather than resect" as Perier et al. [24] mention in their paper, where they use artificial neo-chords to repair posterior leaflet prolapse, which is also the chosen technique for the management of anterior leaflet prolapse [24]. In our series, 42.8% of the repairs were done using neochords according to the Leipzig technique [25] **(Fig. 2).** Ring annuloplasty increases the success of the repair. We performed annuloplasty in all repairs, comparable to other groups. The repair rate was high, as reported in other series [7.9]. In our institution, all patients with MVI candidates for MICS are intervened by this approach. Pre-surgical analysis with transesophageal echocardiography and a systematic and thorough surgical examination of the valve are important strategies to obtain a high percentage of repair. Gammie et al. [26] reported significantly higher rates of repair in the minimally invasive vs. conventional approach (85% vs. 67%). Our perception is that mitral valve visualization is much better with this approach. We believe that the high rate of successful repair is enough evidence that the minimally invasive approach did not affect the probability of repair and that the choice of procedure was more influenced by valvular pathology than by the surgical approach itself [11].

There was no 30-day mortality on our series (Table 4). Perier et al. [24] reported a very low mortality (0,8%) within the first 30 postoperative days, very similar to McClure et al. [27] who reported 3 deaths (0,4%). The conversion rate to sternotomy was low (2.5%), as reported by the Leipzig group, of barely 1.4% [11]. This was due to the presence of severe pleural adhesions on the right side or complications that could not be controlled through the mini thoracotomy incision. In our series, there was a patient with failure of the MVr, transesophageal echocardiography indicated systolic anterior motion of the mitral valve, we converted to sternoto-

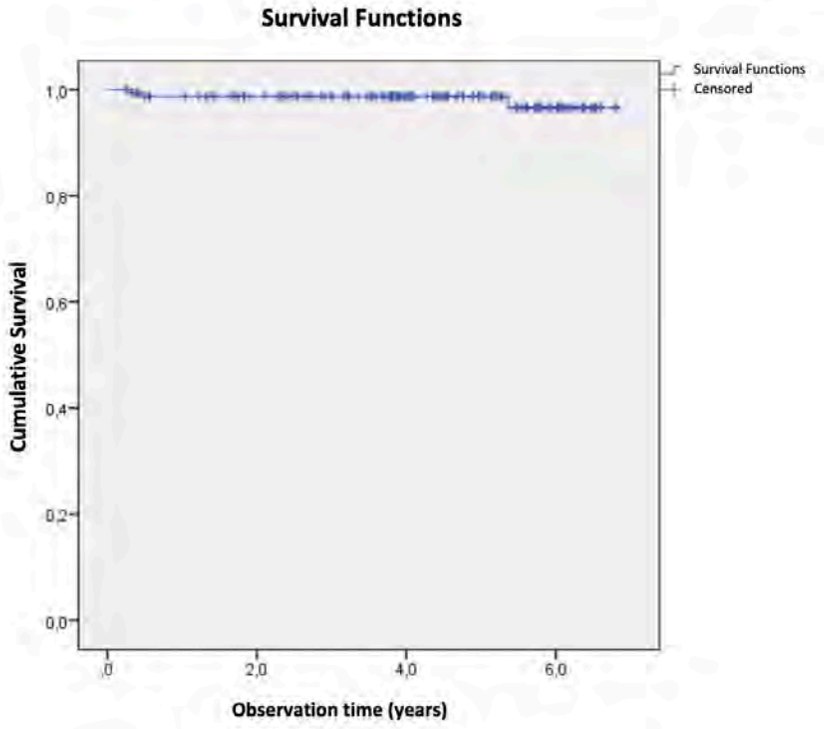

Figure 3. Kaplan-Meier analysis of global survival rate posterior to minimally invasive mitral valve repair in a 6.8-year period.

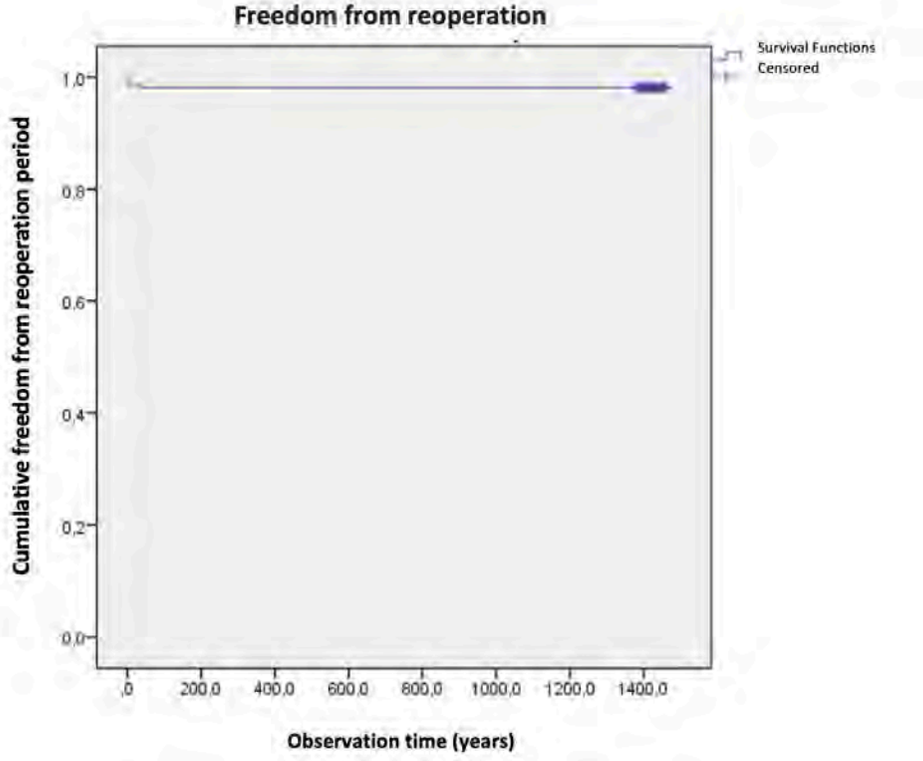

Figure 4. Freedom of reoperation rate after minimally invasive mitral valve surgery in a 6.8-year period by Kaplan-Meier analysis.

my and MVR was performed with a bioprosthesis. The aortic cross-clamping and cardiopulmonary bypass times of our series are longer than in a conventional mitral valve surgery and this is a constant in the reports of MICS. However, this has no implications for patient recovery.

Chikwe et al. [28] in an analysis of the New York State database, evaluated the impact of the number of repairs per surgeon and their success rate. They found that the median of annual mitral valve surgeries per surgeon was 10 cases, and to obtain good results, they determined the volume of cases per surgeon was 25. Surgeons who operated more than 50 cases per year had superior results. On the other hand, the median of mitral valve operations performed by an individual surgeon annually in the United States is 5 per year according to the STS database. This indicates that only in a few centers is possible to reach the goal indicated by the author. This could discourage the rest of the surgeons who try to perform more mitral repairs than replacements [23,28].

However, there are other reports of low-volume centers in which the success rate is comparable to high-volume centers that manage 50 or more surgeries per year. In the report by Giraldo-Grueso et al [29], a 12-year retrospective study is carried out in which a single surgeon performs the MIMVr. They report a series of 200 patients and as a primary endpoint to establish reoperation rate, recurrence of severe mitral regurgitation or death. They report 2 cardiac deaths, freedom of reoperation of 98,4% in a six-year follow-up. Their results show that, despite handling low volumes annual cases, their results are comparable to those reported by world reference MVr centers.

In the follow-up study in this series, survival rates for MVr was 96.6% at 5.3 years, and with freedom from reoperation of 98.1% comparable with those reported in high volume centers [23,28,29]. Although we did not accomplished the suggested recommendations of performing at least 25 mitral repair surgeries per year, the repair rate is high and is consistent with the work of Giraldo-Grueso et al. [29], where they show that, despite the low volume, the repairs are successful in a very high percentage. This success rate is attributed to strict attachment to the guidelines and is consistent with Gillinov´s approach to the topic [23]. He suggests that mitral valve surgery should be a specialty. We count with a multidisciplinary team that facilitates the surgeon a complete analysis. Also, the surgeon has a specific MIMVr training in a high-volume center.

One of the main limitations of this study is its retrospective nature. Second, the patient population is a heterogeneous group with different causes of mitral regurgitation. With regard to the follow-up on the patients, 80% of the total number was reached. The critical assessment of the results of MIMVr has some limitations, based on the shortage of randomized controlled clinical trials and the reliance on single center case series.

As a conclusion, MIMVr is a safe and feasible technique with promising results in short and long term. It is associated with very low conversion rate to a conventional sternotomy. The failure rate of repairs is very low, especially in the hands of experienced surgeons. The times of aortic cross-clamp and cardiopulmonary bypass may be a little longer than with conventional surgery, but the length of stay and recovery of the patient are shorter.

These techniques are a paradigm for the future in terms of cost-effectiveness. Being able to offer the same quality and better aesthetics, less traumatic incisions, with short hospital stay and with less costs than conventional surgery, allows this procedure to be more cost-effective compared to other minimally invasive techniques such as robotic cardiac surgery. The minimally invasive approach is an alternative for the treatment of mitral valve disease with the same long-term results. If a multidisciplinary approach is accomplished, it is more likely to achieve success rates similar to those of high-volume centers.

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