Robotic mitral valve replacements with bioprosthetic valves in 52 patients: experience from a tertiary referral hospital

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Abstract

OBJECTIVES: Robotic mitral valve replacement (MVR) emerged in the late 1990s as an alternative approach to conventional sternotomy. With the increased use of bioprosthetic valves worldwide and strong patient desire for minimally invasive procedures, the safety and feasibility of robotic MVRs with bioprosthetic valves require investigation.

METHODS: Between January 2013 and May 2017, 52 consecutive patients underwent robotic MVRs using the da Vinci Si surgical system (Intuitive Surgical Inc., Sunnyvale, CA, USA). Their mean age was 55.1 ± 13.8 years, and mean EuroSCORE II was 2.25% ± 1.25%. Among the enrolled patients, 32 (61.5%) patients presented with preoperative atrial fibrillation, 6 (11.5%) patients had experienced embolic stroke and 5 (9.6%) patients had undergone previous cardiac surgery. The operations were performed using cardiopulmonary bypass (CPB) under an arrested heart status.

RESULTS: Five porcine valves and 47 bovine valves were implanted. A total of 38 (73.1%) patients received concomitant cardiac procedures, including 26 Cox-maze IV procedures, 12 tricuspid valve repairs and 5 atrial septal defect repairs. The mean aortic cross-clamp and CPB times were 141.3 ± 34.3 min and 217.1 ± 42.0 min, respectively. There was no operative mortality. During the mean follow-up of 29 ± 15 months, no prosthesis degeneration was noted. The average left atrial dimension exhibited a significant decrease from 51.4 ± 11.5 mm to 42.6 ± 10.1 mm.

CONCLUSIONS: Robotic MVR with bioprosthetic valves is safe, feasible and reproducible. Mid-term results are encouraging. Both aortic cross-clamp and CPB times can be improved with experience.

Keywords: Robotic mitral valve replacement • Robotic cardiac surgery • Minimally invasive • Bioprosthetic valve

INTRODUCTION

Mitral valve replacement (MVR) can improve survival in patients with severely irreparable mitral pathologies, such as rheumatic mitral stenosis, subvalvular fibrosis with leaflet tethering, infectious leaflet destruction and prosthetic valve degeneration [1]. In general, mechanical valves are recommended for younger patients and bioprosthetic valves for older patients. However, a lower age cut-off and the increasing use of bioprosthetic valves have become new trends in recent decades mainly due to the improved surgical outcomes of reoperative MVR, satisfactory long-term durability of current-generation bioprostheses and increasing experience of transcatheter valve-in-valve procedures [2–6]. According to the guidelines of the European Society of Cardiology and European Association for Cardio-Thoracic Surgery in 2017, bioprosthetic valve is recommended in patients of any age, for whom anticoagulation therapy is contraindicated, cannot be managed appropriately or is not desired [1].

Robotic MVR emerged in the late 1990s as an alternative approach to conventional sternotomy. When compared with the conventional sternotomy approach, minimally invasive techniques can provide significant benefits in terms of cosmetic appearance, decreased postoperative pain, lower blood transfusion rate and faster return to daily activities [7–12]. Both Gao et al. [11]...
and Senay et al. [12] reported excellent outcomes on robotic MVR with mechanical valves. However, limited data are available on robotic MVR with bioprosthetic valves due to the challenges involved in valve implantation. With the increase in the use of bioprosthetic valves worldwide [2] and strong patient desire for minimally invasive procedures [13], the safety and feasibility of robotic MVRs with bioprosthetic valves require investigation. Thus, the aim of this retrospective cohort study was to analyse initial experiences and mid-term clinical outcomes in our tertiary referral hospital.

PATIENTS AND METHODS

Between January 2013 and May 2017, 200 robotic cardiac surgeries were performed at the Chi Mei Medical Center using the da Vinci Si surgical system (Intuitive Surgical Inc., Sunnyvale, CA, USA). Of them, 52 consecutive patients underwent robotic MVR with bioprosthetic valves. The following patients were excluded from the analysis: patients requiring an additional cardiac procedure on the aortic valve, aorta or coronary arteries; those previously operated on the right chest and those with pulmonary infection. All surgical procedures were performed by a single console surgeon, as well as a table surgeon. Preoperative workup included transthoracic echocardiography and computed tomographic angiography of the chest, abdomen and pelvis. In addition, coronary angiography was indicated for patients with the potential for coronary artery disease. Tricuspid valve repairs were performed in patients with moderate-to-severe secondary tricuspid valve regurgitation. The radiofrequency Cox-maze IV procedure was performed in patients with persistent atrial fibrillation. Left atrial appendage obliteration was performed in patients with atrial fibrillation since July 2015. The hospital’s institutional review board approved the study protocol.

Surgical technique

After the induction of general anaesthesia, patients were intubated smoothly as usual. A central venous catheter and a 6.5-Fr introducer sheath were placed into the right internal jugular vein. Patients were positioned in the supine position with the right chest elevated approximately 30° and the right arm tucked at the side. External defibrillator pads were placed properly. A multi-plane transoesophageal echocardiography probe was inserted before incision to confirm the severity of the valvular heart disease. A 2-cm oblique right groin incision was made for peripheral cannulation. After systemic heparinization, cardiopulmonary bypass (CPB) was established under transoesophageal echocardiography guidance. The patient’s femoral artery was cannulated for systemic retrograde perfusion. Adjunctive distal femoral perfusion was achieved using an 8-Fr arterial cannula (Medtronic, Minneapolis, MN, USA). Bicaval venous drainage was initiated through the right internal jugular vein and femoral vein.

The da Vinci Si robotic patient cart approached the patient perpendicularly from the left side. A 12-mm camera port (Xcel Bladeless Trocar, Ethicon Inc., Somerville, NJ, USA) was initially introduced into the right 4th intercostal space (ICS) on the midclavicular line. A right robot arm port (8 mm) was placed in the right 6th ICS on the anterior axillary line. A right assisted robot arm was placed in the right 5th ICS on the parasternal border. A left robot arm port (8 mm) was placed in the right 2nd ICS on the midclavicular line. A 3-cm horizontal incision was fashioned in the right 4th ICS with a retractor (Tesan Surgical Innovations, Houston, TX, USA) as a working port (Fig. 1A). A transthoracic Chitwood cross-clamp (Scanlan International, Minneapolis, MN, USA) was placed at the right 4th ICS and midaxillary line. A cardioplegia venting catheter (14G BD Angiocath) was inserted through the right 2nd ICS on the parasternal border and directly into the ascending aorta. A 4-0 prolene loop was superficially sutured on the proximal part of catheter. Then, it was snared by 2-0 Ti-Cron sutures with Teflon pledges on the ascending aorta. After aortic cross-clamping (ACC), myocardial protection was achieved using an antegrade cold crystalloid cardioplegia of histidine-tryptophan-ketoglutarate solution (30 ml/kg; Custodiol HTK; Köhler Chemie GmbH, Bensheim, Germany).

Standard MVR techniques were performed. The left atrium was opened parallel to the interatrial groove. The mitral valve was exposed using a dynamic atrial retractor. A flexible drainage catheter was placed in the left superior pulmonary vein to obtain a clear operative field. For patients with Barlow’s deformity and dilated cardiomyopathy, bileaflet preservation was performed; for patients with rheumatic mitral stenosis, posterior mitral leaflet preservation was performed; and for patients with infective endocarditis and prosthesis degeneration, the diseased valve was excised. Initially, 2-0 double-armed Ti-Cron sutures (Covidien Inc., Dublin, Ireland) were anchored to the annulus with Teflon...
Follow-up

Data were obtained until September 2017. All patients were first evaluated 2 weeks after the operation. Further clinical follow-up was conducted through biannual visits to the outpatient clinic and phone contact. Vitamin K antagonists were used as anticoagulants in the 1st 3 months after bioprosthetic valve implantation, then discontinued unless patients had other indications for anticoagulation. Serial echocardiographic data were recorded to evaluate the bioprosthesis function, heart function and remodeling of the left atrium and left ventricle. All patients received echocardiography follow-up at least once in this review. In each patient undergoing a Cox-maze IV procedure, the 12-lead electrocardiogram was investigated every 3 months, and a routine 24-h Holter was arranged annually or at any time when the patient was symptomatic.

Statistical methods

Continuous variables are summarized as means ± standard deviation or medians (ranges). Categorical variables are summarized as frequencies (percentages). The EuroSCORE II was calculated using an online calculator. ACC and CPB times were analysed using a non-linear regression model ($r^2$) to assess learning period effects. Moreover, isolated MVRs and complicated MVRs with concomitant procedures were analysed separately. The unpaired, 2-tailed Student’s t-test was used to measure differences between preoperative and postoperative transthoracic echocardiography findings. All statistical analyses and graphs were performed and created using the SPSS software, version 23.0 (IBM, Armonk, NY, USA).

RESULTS

Baseline characteristics

Demographic characteristics of the study patients are listed in Table 1. Their mean age was 55.1 ± 13.8 years, and mean EuroSCORE II was 2.25% ± 1.25%. The patients were classified as New York Heart Association (NYHA) functional Class II (25.0%), Class III (61.5%) and Class IV (13.5%). A total of 26 (50%) patients had significantly elevated N-terminal pro-brain natriuretic peptide level (>900 pg/ml). Among the enrolled patients, 32 (61.5%)...
patients presented with preoperative atrial fibrillation comprising 4 with paroxysmal atrial fibrillation, 26 with persistent atrial fibrillation and 2 with permanent atrial fibrillation. Six (11.5%) patients had experienced embolic stroke and 5 (9.6%) had previously undergone cardiac surgery, including prosthesis degeneration \((n = 2)\), prosthetic valve endocarditis \((n = 1)\), coronary artery bypass grafting \((n = 1)\) and 1 mitral valve repair failure \((n = 1)\). Rheumatic mitral valve disease was the most common pathology in our patient group.

### Operative data

All 52 patients underwent successful robotic MVRs with bioprosthetic valves. Of these, 5 (9.6%) patients received the Hancock II tissue valves (Medtronic), and 47 (90.4%) patients received the Carpentier-Edwards PERIMOUNT Magna Mitral Ease Heart Valves (Edwards Lifesciences, Irvine, CA, USA). The size distribution of the bioprosthesis is presented in Table 2, with 69% of the patients receiving 27 or 29 mm valves. Three patients were intended for robotic mitral valve repairs and then converted to valve replacements, including 2 patients with Barlow’s deformity and a patient with infective endocarditis. A total of 38 (73.1%) patients received concomitant cardiac procedures, including 26 Cox-maze IV procedures, 16 left atrial appendage obliterations, 12 tricuspid valve repairs and 5 atrial septal defect repairs. Intraoperative transoesophageal echocardiography confirmed satisfactory bioprosthesis function in all patients. The operative data are summarized in Table 2.

The mean ACC and CPB times were 141.3 ± 34.3 min and 217.1 ± 42.0 min, respectively. Both ACC and CPB times improved significantly with experience according to the chronological date of the procedure \(r^2 = 0.297, P < 0.001\) and \(r^2 = 0.417, P < 0.001\), respectively. In addition, subgroup analyses of isolated MVRs and complicated MVRs with concomitant procedures yielded similar learning curves (Fig. 3).

### Clinical outcomes

Postoperative outcomes and complications are presented in Table 3. There was no operative mortality. The median length of stay in the intensive care unit was 20 (interquartile range 16–45) h, and the median hospital stay was 7 (interquartile range 5–12) days. Prolonged ventilation was implemented for 7 (13.5%) patients. However, no patients required long-term mechanical ventilation. Three (5.8%) patients received high-volume red blood cell transfusion (>2 units). Intra-aortic balloon pumping was established in 2 (3.8%) patients for the temporary support of myocardial stunning. One (1.9%) patient was converted to sternotomy for sudden bleeding from the left atriotomy after weaning from CPB.

During the mean follow-up of 29 ± 15 months, 4 (7.7%) patients had late mortality. The death in 3 patients was related to non-cardiac causes, and the other patient died due to dilated ventricular hypertrophy.

#### Table 2: Operative data \((n = 52)\)

| Perfusion time (min), mean ± SD | ACC | 141.3 ± 34.3 |
| Bioprostheses type, \(n\) (%) | Hancock II | 5 (9.6) |
| | Magna Ease | 47 (90.4) |
| Valve sizes (mm), \(n\) (%) | 25 | 3 (5.8) |
| | 27 | 14 (26.9) |
| | 29 | 22 (42.3) |
| | 31 | 9 (17.3) |
| | 33 | 4 (7.7) |
| Concomitant procedure, \(n\) (%) | Cox-maze IV operation | 26 (50) |
| | LAA obliteration | 16 (30.8) |
| | ASD closure | 5 (9.6) |
| | TV repair | 12 (23.1) |

ACC: aortic cross-clamp; ASD: atrial septal defect; CPB: cardiopulmonary bypass; LAA: left atrial appendage; SD: standard deviation; TV: tricuspid valve.

#### Figure 3: Exponential regression curve for changes in (A) aortic cross-clamp time and (B) cardiopulmonary bypass time according to the chronological data for robotic MVRs. Aortic cross-clamp time: \(y\) (min) = 210.14x\(^{-0.142}\); \(r^2 = 0.297, P < 0.001\) and cardiopulmonary bypass time: \(y\) (min) = 320.6x\(^{-0.136}\); \(r^2 = 0.417, P < 0.001\). MVR: mitral valve replacement.
heart failure, and cardiomyopathy. A total of 26 patients underwent the Cox-maze IV procedure; freedom from atrial tachyarrhythmia was 89%, 90% and 88% at 6, 12 and 24 months, respectively. Freedom from atrial tachyarrhythmia off all antiarrhythmic drugs was 81%, 86% and 82% at 6, 12 and 24 months, respectively. Postoperative complications included re-expansion for bleeding in 1 (1.9%) patient, stroke in 1 (1.9%) patient, reversible neurological injury in 2 (3.8%) patients, low cardiac output syndrome in 1 (1.9%) patient, unilateral pulmonary oedema in 4 (7.7%) patients and permanent pacemaker implantation 1 year after surgery in 1 (1.9%) patient. No instances of myocardial infarction, phrenic nerve palsy, wound infection, limb ischaemia, aortic dissection or new haemodialysis were observed in our group. There was no prosthetic degeneration or the need for reintervention.

**Echocardiography outcomes**

Postoperative echocardiography outcomes were compared with the preoperative data (Table 4). A significant decrease of 51.4 ± 11.5 mm to 42.6 ± 10.1 mm (P < 0.001) occurred in the dimension of the left atrium. No difference was found in the preoperative and postoperative left ventricular ejection fraction values: 65.5% ± 10.8% (preoperatively) vs 66.4% ± 10.4% (postoperatively) (P = 0.61). Right ventricular systolic pressure decreased from 37.2 ± 19.3 mmHg to 31.8 ± 15.8 mmHg, but the decrease was not significant (P = 0.10). Mean transprosthetic pressure gradient was 3.64 ± 3 mmHg in the postoperative follow-up.

**DISCUSSION**

According to the Society of Thoracic Surgeons Adult Cardiac Surgery Database, the use of bioprosthetic valves has dramatically increased, whereas the use of mechanical valves is in decline [2]. From the majority of centres in North America, the use of mitral bioprostheses has increased from 32% in 2000 to 63% in 2007. Moreover, the patients receiving bioprosthetic valves are increasingly young. Gammie et al. [2] concluded that improved surgical outcomes in reoperative mitral valve surgery and the satisfactory long-term durability of current-generation bioprostheses have probably contributed to this fundamental shift. In addition, activity constraints and complex monitoring protocol for anticoagulation therapy and the risks of thromboembolic and bleeding events have affected the rejection of mechanical valves by patients [14].

Minimally invasive mitral valve surgery (MIMVS) includes partial sternotomy, right anterolateral thoracotomy, right mini-thoracotomy, endoscopic-assisted mini-thoracotomy and robot-assisted surgery. MIMVS is beneficial in terms of cosmetic appearance, reduced postoperative pain, lower blood transfusion rate, shorter length of hospital stay and faster return to daily activities [7–12]. There has been an increased interest in MIMVS in recent decades. Using data from a nationwide surgical database (Japan), Nishi et al. [13] have demonstrated that the rate of MIMVS has increased from 5.7% in 2008 to 15.6% in 2012. More recently, in a retrospective cohort of 1257 patients undergoing robotic mitral valve surgery, Murphy et al. [10] reported a significant rate of acceptance of robotic mitral valve surgery: an increase from 46% in the 1st year of its institution to more than 90% in the last 3 years. However, despite the marked growth of MIMVS, most included in previous reports have been mitral valve repair procedures [7–10], whereas our series focused on valve replacement.

This cohort study pertains to clinical outcomes of robotic MVR with bioprosthetic valves. Although MVR can be performed with satisfactory outcomes using a minimally invasive endoscopic technique [9], robot arms are comparably strong for extensive debridement of a severely calcified annulus. In addition, bioprosthetic valves have a higher profile and a wide, saddle-shaped cuff that are considered technical challenges when implanting them through a small surgical wound. Using advanced robotic equipment, including a dynamic atrial retractor, delicate articulated arms and a 3-dimensional high-definition videoscope, they can be implanted properly without entrapment of stitches. Our current results compare favourably with published standards [7–12]. There was no operative mortality, and late cardiac-related mortality occurred in 1 patient due to irreversible dilated cardiomyopathy. Serial echocardiography demonstrated a significant reduction in left atrial dimension, left ventricular end-diastolic dimension and left ventricular end-systolic dimension.

**Table 3:** Postoperative outcomes and complications (n = 52)

| Complication                                      | Preoperative, n (%) | Postoperative, n (%) |
|---------------------------------------------------|---------------------|----------------------|
| Prosthesis degeneration                            | 0 (0)               | 0 (0)                |
| 30-Day mortality                                   | 0 (0)               | 0 (0)                |
| Late mortality                                     | 4 (7.7)             | 13.5%                |
| Prolonged ventilation (>24 h)                     | 7 (13.5)            |                      |
| Postoperative IABP support                         | 2 (3.8)             | 3 (5.8)              |
| High-volume RBC transfusion (>2 U)                 | 3 (5.8)             |                      |
| Complications                                      | 1 (1.9)             |                      |
| Re-expansion for bleeding                          | 1 (1.9)             |                      |
| Sternotomy conversion                              | 1 (1.9)             |                      |
| Myocardial infarction                              | 0 (0)               |                      |
| Stroke                                            | 1 (1.9)             |                      |
| Reversible neurological injury                     | 2 (3.8)             |                      |
| Unilateral pulmonary oedema                       | 4 (7.7)             |                      |
| Low cardiac output                                 | 1 (1.9)             |                      |
| Phrenic nerve palsy                                | 0 (0)               |                      |
| Wound infection                                    | 0 (0)               |                      |
| Limb ischaemia                                     | 0 (0)               |                      |
| Aortic dissection                                  | 0 (0)               |                      |
| Permanent pacemaker implantation                   | 1 (1.9)             |                      |
| New haemodialysis                                  | 0 (0)               |                      |
| New onset atrial fibrillation                      | 2 (3.8)             |                      |

IABP: intra-aortic balloon pumping; RBC: red blood cell.

**Table 4:** Echocardiographic data (n = 52)

| Variables                        | Preoperative, mean ± SD | Postoperative, mean ± SD | P-value |
|----------------------------------|-------------------------|--------------------------|---------|
| LVEF (%)                         | 66.5 ± 10.8             | 66.4 ± 10.4              | 0.61    |
| LA dimension (mm)                | 51.4 ± 11.5             | 42.6 ± 10.1              | <0.01   |
| LVESD (mm)                       | 32.8 ± 8.3              | 29.8 ± 7.1               | <0.01   |
| LVEDD (mm)                       | 52.1 ± 10.5             | 47.2 ± 8.7               | <0.01   |
| RVSP (mmHg)                      | 37.2 ± 19.3             | 31.8 ± 15.8              | 0.10    |
| Mean TPG (mmHg)                  | 3.64 ± 3                |                         |         |

LA: left atrium; LVEDD: left ventricular end-diastolic dimension; LVEF: left ventricular ejection fraction; LVESD: left ventricular end-systolic dimension; RVSP: right ventricular systolic pressure; SD: standard deviation; TPG: transprosthetic pressure gradient.
Despite the encouraging results achieved following MIMVS, safety issues were frequently raised by critics during its early development. Few centres in Asia launched the robotic programme due to concerns about its safety, complexity and costs [15]. Some reports have also claimed an increased incidence of stroke because of the use of retrograde perfusion by femoral arterial cannulation [16]. In our protocol, cerebral oximeter (INVOS, Medtronic) was used during MIMVS, and no patient experienced intraoperative stroke. Although 1 patient did experience stroke, this was due to low cardiac output syndrome in the postoperative recovery period; 2 other patients had reversible neurological injury during mid-term follow-up. This report revealed that 4 patients experienced right unilateral pulmonary oedema, and none of them required postoperative extracorporeal life support. Unilateral pulmonary oedema is a rare but potentially life-threatening complication after MIMVS through the right side of the chest. The mechanism is thought to be associated with the ischaemia–reperfusion injury to the lung, as well as the general inflammatory response, leading to higher vascular permeability with subsequent pulmonary oedema [17–19]. Moss et al. [19] have made some modifications to reduce the incidence, and we have made similar efforts in our projects. Unilateral pulmonary oedema eliminated within the preceding 2 years may be attributed to the following intraoperative strategies: maintaining adequate arterial inflow, shortening CPB time and implementing pulmonary recruitment manoeuvres.

In our series, mean ACC and CPB times were slightly extended, which was mainly attributed to the 73.1% of patients who underwent concomitant procedures. In addition, extensive decalcification in rheumatic mitral stenosis is another reason for the prolonged operative time. Despite the longer operative time, we revealed an improvement after overcoming the learning curve and understanding the applications of new devices. Both ACC and CPB times improved remarkably with experience (Fig. 3). In the last 10 cases, the COR-KNOT device was used for mitral prosthesis fixation, significantly reducing the knotting time from 30 to 6 min.

The development of MIMVS has greatly influenced the surgical techniques and clinical outcomes of reoperative cardiac surgery. Minimally invasive approaches can lower the risk of damage to cardiac structure. Series reports have presented favourable results, with 30-day mortality rates of approximately 3–5% [20–22]. Since our programme was initiated in 2013, we have performed 7 reoperative robotic MVRs, including 5 patients under aortic-clamp arrested heart status (this study) and 2 patients under non-clamping fibrillating heart condition. Average intraoperative blood loss was 300 ml. All patients resumed their daily tasks within a week after the operation. An intracavitary temporary pacing wire was placed into the left ventricular endocardium, which is a standard procedure in our reoperative robotic MVR (Fig. 2). This technique was initially described by Casselman et al. [22] in their endoscopic redo mitral and tricuspid valve surgery. However, slightly different from the ordinary method, we launched an innovative concept to place the intracavitary pacing wire between the mitral annulus and prosthetic suture ring. Thus, the pacing wire does not compromise the leaflet coaptation or damage the prosthesis. In this study, all intracavitary pacing wire functioned well, and they were removed 1 week postoperatively without thromboembolic or bleeding events.

Another important finding of this study is the high rate of concomitant Cox-maze IV procedure performed. Atrial fibrillation rates vary between 30% and 50% among patients undergoing mitral valve surgery, which can increase the risk of stroke and reduce survival. In a randomized control trial, Gillinov et al. [23] demonstrated that patients undergoing the surgical ablation in addition to mitral valve surgery had significantly increased rates of freedom from atrial fibrillation. As with minimally invasive techniques for mitral valve surgery, an increasing trend of interest was noted for the maze procedure. Nifong et al. [24] conducted the 1st and largest study to date evaluating the clinical outcomes following robotic mitral valve repair concomitant with the maze procedure; 96.5% of patients reported freedom from atrial fibrillation without taking antiarrhythmic drugs or warfarin. In our study, sinus rhythm was restored in nearly 90% of patients. Most can discontinue warfarin or downgrade to antiplatelet therapy after the blanking period. In patients with mitral valve disease and atrial fibrillation, our limited experience provides a new perspective for bioprosthesis implantation in combination with aggressive restoration of sinus rhythm.

**Limitations**

This study has the inherent limitations of a retrospective observational data collected from a relatively small population in a single centre. Given that this is not a randomized study, surgeon bias cannot be ignored. Prior to valve replacement, valve repair was attempted. Therefore, only patients with irreparable mitral valve disease underwent valve replacement surgery, which limited the number of cases studied. All patients received at least once echocardiography follow-up after the operation. However, the preoperative echocardiography and postoperative echocardiography were not performed by a single cardiologist. Finally, there was no control group to compare our study group within this series, because, since 2013, most patients have undergone robotic cardiac surgery instead of conventional sternotomy in our institution. Thus, a well-designed study is required to validate the advantages of robotic MVR.

**CONCLUSION**

In conclusion, robotic MVR with bioprosthetic valves is safe, feasible and reproducible with encouraging clinical outcomes. Both ACC and CPB times can improve remarkably with experience. Although the preliminary data suggest acceptable echocardiographic results, a long-term follow-up remains necessary to understand the benefits of robotic MVR with bioprosthetic valves.

**Conflict of interest:** none declared.

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