AORTIC VALVE SURGERY: MINIMALLY INVASIVE OPTIONS

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Abstract

Minimally invasive aortic valve surgery has not been adopted by a significant proportion of cardiac surgeons despite proven benefits. This may be related to a high learning curve and technical issues requiring retraining. In this review, we discuss the data for minimally invasive aortic valve surgery and describe our operative technique for both ministernotomy and anterior thoracotomy approaches. We also discuss the advent of novel sutureless valves and how these techniques compare to available transcatheter aortic valve procedures.

Introduction

Minimally invasive cardiac surgery for the aortic valve (MIAVS) has been shown over the past decade to be a viable and often superior approach to standard aortic valve surgery.[1-9] However, its penetration into the cardiac surgical community has been less than optimal due to multiple issues, including required surgeon training and the inaccurate perception that transcatheter aortic valve replacement (TAVR) will eventually minimize the need for such techniques.

Since the takeoff of laparoscopic cholecystectomy in 1990, different perfusion strategies and approaches to the aortic valve have been described, making minimally invasive cardiac surgery a philosophy of less surgical trauma rather than one specific technique. The first aortic valve surgery (AVS) was done in 1912 and the first replacement in 1960; 33 years later, Rao and Kumar performed the first MIAVS in 1993.[10-12] As with cardiac surgery in general, early pioneers were faced with significant resistance and skepticism. However, the standard of care continued to evolve to provide noninferior or superior outcomes with less morbidity, less pain, and less cost.

Performance of Minimally Invasive Aortic Valve Surgery

There is a significant body of literature reporting and comparing the performance of minimally invasive valve surgeries. Reports of minimally invasive mitral valve surgery (MIMVS) are larger in number, but their results seem to be reflected almost exactly in reports of MIAVS. One of the largest and earliest series from the Brigham and Women's Hospital was done by Soltesz et al.,[13,14] who reported 890 cases that underwent MIAVS via ministernotomy. The procedure was safe and effective, with complication rates comparable to national averages for conventional AVS (cAVS) and a 30-day mortality rate of 2%. Of the total population, 157 were aged 80 years and older and had a mortality rate of 1.9%; 34 of these octogenarians had reoperations and zero mortality. The authors concluded that the benefits of MIAVS might be even more pronounced in higher-risk patients.

A meta-analysis of randomized controlled data included only 220 patients from four studies.[15] This analysis demonstrated trends towards the expected benefits of minimally invasive surgery, i.e., blood loss and length of stay, but the small number did not allow for statistical significance to be reached. Most of what we know comes from retrospective studies. Two meta-analyses by Murtaza and Brown included heterogeneous data and demonstrated noninferior safety and efficacy but did not show objective superiority other than patient appeal.[16,17] It is interesting that both of these meta-analyses included 26 eligible studies, and that the first reported 3 of 26 studies as having > 100 MIAVS while the other reported 4 of 26 having > 100 MIAVS. Enhanced outcomes in higher-volume centers have been repeatedly shown in cardiac surgery, and this is especially true with technically advanced procedures such as mitral repair and MIMVS.[13,18-22]

Data from larger studies suggest an advantage to MIAVS in addition to patient appeal. Mihaljevic et al.[4] reported results of 526 patients undergoing MIAVS and found significantly fewer strokes (2% vs 5%, $P = 0.01$), myocardial infarctions (0% vs 2%, $P < 0.01$), and length of stay (LOS) (median 6 vs 7 days, $P < 0.01$) compared to 516 patients undergoing cAVS. There was also a significantly higher rate of discharge to home as opposed to rehabilitation or nursing home. Sharony et al.[23] came to the same advantageous results regarding LOS and discharge to home in their report of 438 MIAVS procedures. In addition, Doll et al.[24] reported a significant mortality benefit and a lower incidence of respiratory failure among 176 MIAVS procedures.

Two relatively large propensity score matching studies have been reported. Johnston et al.[25] reported results from 832 pairs of matched patients undergoing either cAVS or MIAVS via ministernotomy (MS) and found no difference in mortality (0.96% vs 0.96%, 95% CI, $P > 0.9$), stroke (1.3%, 95% CI, $P > 0.9$), myocardial ischemic events (0.48% vs 0.36%, 95% CI, $P = 0.7$), or renal failure (0.72% vs 0.84%, 95% CI, $P = 0.8$). The MIAVS-MS group showed superiority with significantly lower drain output at 24 hours, fewer transfusion requirements, lower pain scores, and shorter LOS ($P < 0.001$ for each). Gilmanov et al.[26] reported another propensity study of 182 matched pairs undergoing cAVS or MIAVS via MS or anterior thoracotomy (TH). They similarly found no difference in either mortality (1.64% vs 1.64%, 95% CI, $P = 1.0$) or postoperative complications, with the MIAVS group having significantly shorter time on mechanical ventilation (median 7 vs 8 hours, 96% CI, $P = 0.02$), less postoperative atrial fibrillation (AF) (21% vs 31%, 95% CI, $P = 0.04$), and decreased blood transfusions (medians 1 vs 2 units, 95% CI, $P = 0.04$).

It is not surprising that the benefits reported with MIAVS are a reflection of those reported with MIMVS. It is intuitive that less surgical trauma would lead to less bleeding, less pain,

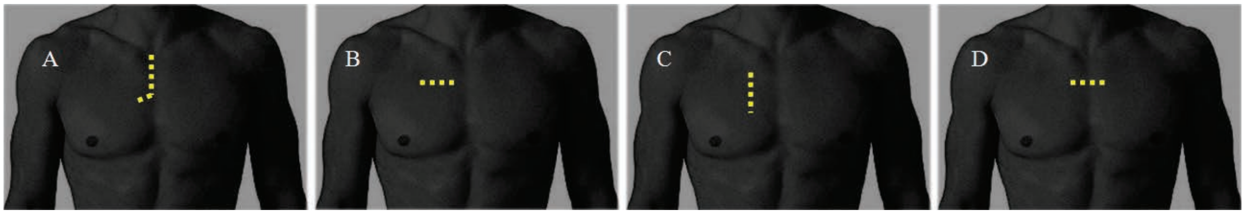

Figure 1. Various minimally invasive approaches for direct access to the aortic valve. (A) Upper (J) ministernotomy. (B) Right anterior minithoracotomy. (C) Right parasternal incision (abandoned). (D) Transverse sternotomy (abandoned).

and less systemic stress. Also, a smaller incision would lead to decreased respiratory impairment and better cosmesis. Less pain and analgesic requirements is almost uniform in all studies that reported pain scoring.[1,6] Casselman et al. reported 94% of their patients undergoing MIMVS as having no or mild postoperative pain and 99.3% as being esthetically pleased with their scar.[27] One concern with MIVS is a questionable association with stroke. Although this has been mostly reported with mitral valves, multiple confounders make interpretation of the exact cause less straightforward.[28,29] Proposed culprits included endoaortic balloon occlusion and inadequate deairing and femoral artery cannulation.[30-32] On the other hand, Le Pietra et al.[33] analyzed 1,501 MIVS patients and did not show this association. Until a randomized controlled trial is conducted to put this concern to rest, we are inclined towards transthoracic aortic clamping, removal of air under transesophageal echocardiographic (TEE) guidance, and recommending cannulation strategy dependent upon the surgeon's experience and comfort level.

The significant advantages of MIAVS have also been demonstrated in higher-risk groups. Reports of MIAVS in the morbidly obese, the elderly, and in reoperative cases have all demonstrated excellent results.[34-37] A recent meta-analysis of reoperative AVS cases concluded that the MIAVS is equally safe and effective even in patients with a challenging dissection.[38] In summary, there is a uniform demonstration of noninferior safety and efficacy of MIAVS compared to cAVS as well as a known cosmetic appeal and patient satisfaction. Less uniformly and predominantly in higher-volume centers, there is a benefit of decreased blood transfusions, respiratory insufficiency, and length of stay, with more patients being discharged home as opposed to rehabilitation or nursing homes. It is noteworthy that in two studies including patients who underwent MIVS as their second cardiac surgery, patients experienced less pain and a much faster recovery compared to their previous full sternotomy.[9,39]

Technique

Several approaches for MIAVS have been described (Figure 1). The parasternal and transsternal approaches were abandoned early on as they resulted in lung herniation and disfigurement and were difficult to switch to a full sternotomy if needed. At our centers we use both the upper J hemisternotomy and the right anterior minithoracotomy. The former has the advantage of allowing access to the aorta, which is very familiar to cardiac surgeons, as well as minimal requirement of specialized instrumentation. The anterior minithoracotomy has the advantages of postoperative sternal stability as well as evidence suggesting that this approach is less invasive, demonstrates less transfusions, respiratory insufficiency, and atrial fibrillation, and results in lower length of stay.[40,41] However, a recent meta-analysis did not support these advantages.[42] The following describes the most commonly performed ministernotomy and minithoracotomy approaches (Figure 3).

Ministernotomy

In this approach, the patient is positioned in a supine position, defibrillator pads are applied, and the entire sternum and groin are prepped and exposed. Access into the chest is made through a 6- to 8-cm upper J sternotomy extending into the right-third intercostal space. This incision provides excellent exposure to the entire legnth of the aorta and superior mediastinum. The right mammary vessels are occaisionally ligated. Retrograde cardioplegia catheter via coronary sinus may be placed by the anesthesiologist under TEE guidance. Alternatively, many surgeons are using del Nido cardioplegia via antegrade approach for initial arrest, which may obviate the need for retrograde cardioplegia altogether.

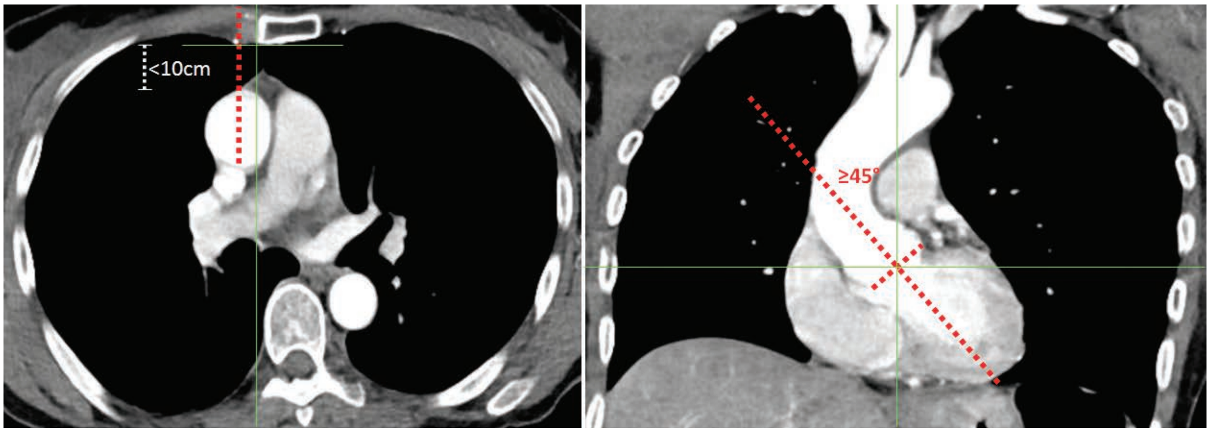

Figure 2. Preoperative evaluation for aortic valve access via a right anterior minithoracotomy. Criteria as described my Miceli et al.[43,44] (1) Half of the aorta should lie to the right of the right sterna border at the level of the pulmonary valve. (2) Angle between the axis of the aortic valve and the vertical axis should be > 45°. (3) Distance between the ascending aorta and the sternum is < 10 cm.

Figure 3. Postoperative scars after aortic valve replacement through a ministernotomy (left) and anterior minithoracotomy (right).

The pericardium is suspended to the skin edges, elevating the ascending aorta into the field. Access for cardiopulmonary bypass is obtained through standard direct aortic cannulation and percutaneous femoral venous cannulation, with the latter positioned under TEE guidance. We use a CygNet® (Vitalitec International, Inc., Plymouth, MA) transthoracic aortic clamp for the ascending aorta. The left side is vented via a right superior pulmonary vein and an aortic root vent, and continuous carbon dioxide insufflation is maintained. An aortotomy is made to expose the valve in an angle that is familiar to all cardiac surgeons. The valve excision and replacement is carried out under direct vision in the the usual fashion.

Minithoracotomy

With this approach, a computed tomography (CT) scan of the chest can be obtained for preoperative planning, especially during the early phase of the learning curve. Miceli et al.[43] described criteria for patient minithoracotomy approach selection. They recommended that three criteria be fullfilled (Figure 2): (1) On an axial image at the level of the pulmonary valve, at least half of the aorta should be to the right of the right sternal border; (2) On the image, the aorta should be less than 10-cm deep to the sternum; and (3) The angle between the aortic valve axis and the vertical axis should be 45 degrees or more. With sufficient experience, virtually all anatomic variants can be addressed, even without a preoperative CT scan.

The patient is positioned in a supine position, defibrillator pads are applied, and the whole sternum and groin are prepped and exposed. Access into the chest is made through a 5- to 6-cm transverse anterior thoracotomy entering the second intercostal space (Figure 4). We routinely transect the third costal cartilage and ligate the right mammary vessels. A soft tissue retractor and rib spreader are inserted into the minithoracotomy incision. Pericardial stay sutures are crucial to obtain the necessary exposure. We continue the procedure using femoral arterial and venous access for bypass via limited femoral cut-down. Alternatively, direct aortic and percutaneous femoral venous cannulation may be done. Del Nido cardioplegia is usually administered antegrade into the aortic root or directly into the coronary ostia. Retrograde coronary sinus cannulation can also be performed. A left ventricular vent is inserted into the right superior pulmonary vein, and the aorta is clamped directly through the incision. We proceed with valve excision and replacement in the usual fashion. Drainage tubes are placed in the pericardial sac and pleural cavity. The third rib is then fixed to the sternum with nonabsorbable sutures (Table 1).

Sutureless Valves

A common outcome of minimally invasive cardiac surgery in general is prolonged bypass and clamp times. It is well established that these two variables have been linked to morbidity and mortality. Although this did not translate to a negative outcome

Figure 4. Sutureless aortic valves. (A) The Perceval valve (LivaNova, London, UK). (B) The 3f®-Enable valve (Medtronic, Inc., Minneapolis, MN). (C) The INTUITY valve (Edwards Lifesciences Corp., Irvine, CA).

Figure 5. Oblique anterior minithoracotomy may provide enhanced visualization.

in any of the studies comparing MIAVS to conventional valve surgery, fast-deployment sutureless aortic valves (suAV) have been developed. These valves are deployed after excision of the old calcific valve through either a full sternotomy or via minimally invasive access, MS, or TH. Three valve systems have gained the CE mark and are available in the European market (Figure 5).

Reports from European and Canadian centers demonstrated safety, efficacy, and excellent hemodynamic profiles for both isolated AVS as well as concomitant coronary surgery, and comparative studies showed a noninferior morbidity profile yet with significantly shorter clamp and bypass times.[45,46] The shorter clamp and bypass times have been consistent in all studies regardless of the kind of sutureless valve and the type of access, and the times are often significantly shorter than with sutured valves. A randomized controlled trial comparing suAVR through minimally invasive techniques vs cAVR showed the suAVR group to have significantly shorter clamp times despite being minimally invasive.[47] The outcomes are very promising, however, like with transcatheter valves, long-term outcomes are not yet as rigorously examined as with conventional sutured valves. The Perceval (LivaNova, London, UK) and INTUITY (Edwards Lifesciences Corp., Irvine, CA) valves are in various stages of clinical trials in the United States and pending FDA approval.

Conclusion

Minimally invasive aortic valve surgery carries significant benefits including expeditious recovery as well as decreased transfusion and atrial fibrillation rates. It is, however, far from being widely adopted due to the need for increased surgeon training and patient awareness. Transcatheter aortic valve replacement (TAVR) has clearly been shown to save lives in extreme and high-risk patients and is steadily creeping towards the intermediate-risk patient population. By its very nature, TAVR has both a major advantage and disadvantage. The advantage is that it is less invasive than surgery, and patients will always choose a less invasive, equally effective choice. However, for the time being, surgical AVR (SAVR) will continue to have clear advantages in lower-risk patient populations, including lower paravalvular aortic regurgitation and pacemaker rates and known durability. Importantly, the association between even mild paravalvular leak and mortality has been clearly drawn.[48,49] As cardiac surgeons, we have a duty to compare the best available techniques and technology available for the benefit of our patients. That means that as TAVR technology improves in the coming years, it should be compared whenever possible to the best SAVR technique (i.e., MIAVS). Once MIAVS becomes more common and is incorporated in the training of all cardiac surgeons, only then can an adequately powered trial comparing the best surgical technique to the latest TAVR technology take place.

Conflict of Interest Disclosure: Dr. Ramlawi is a consultant for Medtronic, Inc., Sorin Group, and AtriCure, Inc., has equity in Replicore Inc., and receives research funding from Baxter BioSciences and Medtronic. Dr Lamelas has served as a member of the speakers' bureau for Medtronic, Inc. and On-Q by I-Flow, LLC. He is also the CEO of Miami Instruments.

Keywords: minimally invasive cardiac surgery, valvular heart disease, aortic valve surgery, transcatheter aortic valve surgery

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