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Symposium: Transcatheter aortic valve implantation **· Open Access ·**

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Minimally invasive aortic valve surgery

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Abstract

Aortic valve disease is a prevalent disorder that affects approximately 2% of the general adult population. Surgical aortic valve replacement is the gold standard treatment for symptomatic patients. This treatment has demonstrably proven to be both safe and effective. Over the last few decades, in an attempt to reduce surgical trauma, different minimally invasive approaches for aortic valve replacement have been developed and are now being increasingly utilized. A narrative review of the literature was carried out to describe the surgical techniques for minimally invasive aortic valve surgery and report the results from different experienced centers. Minimally invasive aortic valve replacement is associated with low perioperative morbidity, mortality and a low conversion rate to full sternotomy. Long-term survival appears to be at least comparable to that reported for conventional full sternotomy. Minimally invasive aortic valve surgery, either with a partial upper sternotomy or a right anterior minithoracotomy provides early- and long-term benefits. Given these benefits, it may be considered the standard of care for isolated aortic valve disease.

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1 Introduction

Minimally invasive aortic valve surgery (MI-AVS) is increasingly being adopted by cardiac surgeons worldwide, and in some centers is becoming the standard of care.[1] The primary disease process for which patients are referred for aortic valve replacement (AVR) remains to be aortic stenosis. This population is generally older and therefore more likely to have concomitant co-morbidities compared to the mitral valve disease population. As such, AVR plays a central role in MI-AVS. Improvements of the technique allow for expanded indications and improved outcomes.

Since the first reported AVR occurred through a right thoracotomy in 1993,[2] a variety of techniques have been described, including; parasternal,[3] infra-axillary,[4] lower hemi-sternotomy and transverse sternotomy.[5,6] Today, MI-AVS is performed primarily via upper mini-sternotomy (MS) or right anterior thoracotomy (RT) incisions (Figure 1).

2 Patients selection and preoperative planning

For patients requiring isolated valve surgery, the specific incision is tailored on the basis of comorbidities, morphology of the valve, patient-specific anatomy and the surgeon's preference. Most patients with a primary indication for aortic valve surgery are amenable to a MI-AVS approach, however, it is worthwhile to consider contraindications or relative contraindications. Caution should be applied to patients with severe chest wall deformities, such as pectus excavatum and kyphoscoliosis, this can be considered both a relative contraindication depending on the severity of the abnormality.

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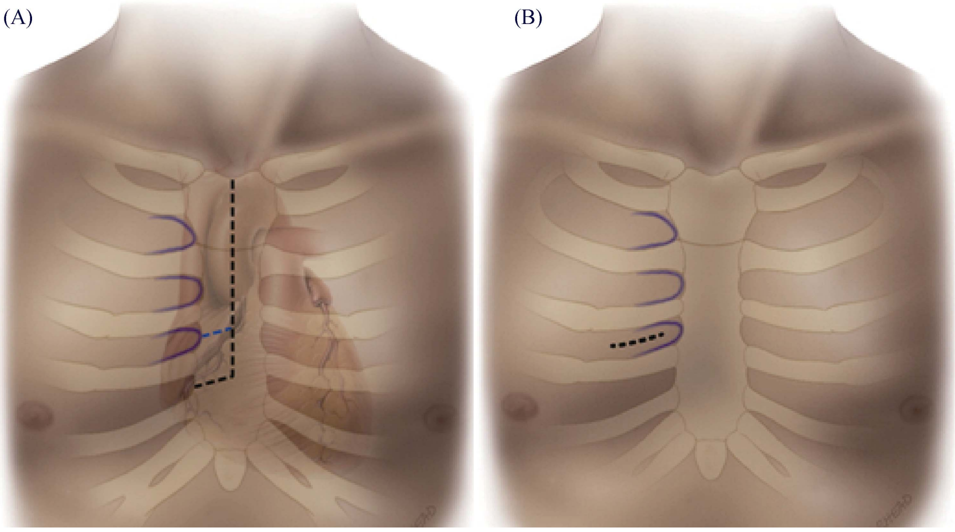

Figure 1. Schematic drawing showing the skin incision required for the J mini-sternotomy into the right fourth or third intercostal space (A) and for the right anterior thoracotomy incision in the third intercostal space (B).

The need for coronary revascularization is not a contraindication to MI-AVS, and isolated lesions can be managed percutaneously, either before or after MI-AVS depending on clinical presentation. Emergency operations for acute aortic dissection are preferably performed through a full sternotomy because of the unpredictability of this condition. Reoperations are considered a relative contraindication for MI-AVS. If patients are selectively chosen (i.e., avoiding previous bypass surgery) and accurately planned, MI-AVS cam still be performed.

Standard preoperative cardiac workup for MI-AVS is similar to conventional AVR. This includes chest radiography, coronary angiography, routine laboratory studies and echocardiography. In a patient with a history of stroke or transient ischemic attack, duplex scanning of the carotid and vertebral arteries is warranted.

Cardiac CT is often required, usually for patients with previous cardiac surgery, chest wall irradiation and all those being considered for right anterior thoracotomy.[7] This exam provides much precious information such as the location of the aortic valve in the chest, anatomy of the valve, degree of calcification, size of the ascending aorta, distance between the posterior sternal table and right ventricle in redo surgery, in addition to aiding cannulation and cross-clamp strategies.

3 Operative techniques

Several minimally invasive approaches have been developed for AVR.[5] However, the most frequently adopted techniques are: (1) right anterior mini-thoracotomy (RT) and (2) upper mini-sternotomy (MS) with its variations (T-, J-, L-, reversed C-, S- and inverted V-shape).

4 Mini-sternotomy

Conduct of the operation for MS is similar to that of a full sternotomy aortic valve surgery, using standard instruments and procedures (Figure 2).

A 5–8 cm vertical skin incision is made just caudal to the sternal angle. The upper sternum is divided through a J-shaped incision with an oscillating saw, down to either the 3rd or 4th right intercostal space depending on the patient body habitus. The pericardium is opened vertically and pericardial sutures are affixed 1–2 cm lateral to the skin edge. Doing so enhances exposure by displacing the aorta and heart anteriorly and cranially. The operative field is insuf-

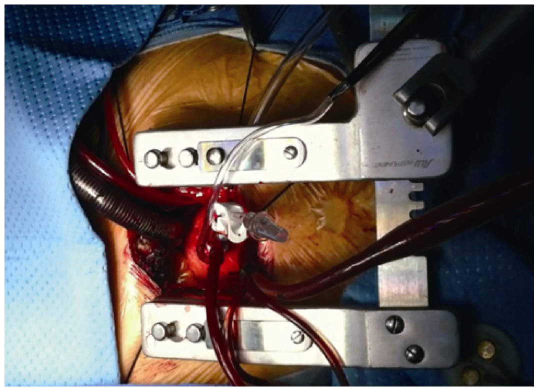

Figure 2. View of the intraoperative field in a partial upper mini-sternotomy.

flated with carbon dioxide delivered through a catheter via a separate stab incision (later used for chest tube insertion).

MI-AVS can be performed with either central or femoral cardiopulmonary bypass (CPB). Axillary arterial cannulation is used selectively for those patients requiring ascending aorta replacement or in the presence of severe aortic calcification.

To further increase the operative field, percutaneous femoral venous cannulation may be considered. The right common femoral vein is punctured via Seldinger technique and a venous cannula with multiple openings is advanced with its tip positioned 2 cm into the superior vena cava under transesophageal echo (TEE) guidance.

Delivery of cardioplegia can be performed using both antegrade and retrograde routes, similar to conventional aortic valve replacement. Left ventricular distension is prevented by intermittent antegrade aortic root venting. After CBP is initiated, the aorta is occluded with a standard aortic cross-clamp. Other low-profile clamps can be used to maximize working space. A transverse aortotomy is placed slightly higher to facilitate its closure and visualization at the end of operation.

The valve is replaced in standard fashion. Temporary epicardial wires are fixed to the decompressed right ventricle before the aortic cross-clamp is removed. Because the surface of the heart is not readily accessible, de-airing demands meticulous attention to detail and is monitored using TEE. Finally, surgical hemostasis is ensured, a single pericardial drain is placed and the chest is closed using steel wires.

5 Right anterior mini-thoracotomy

In RT, the operative field is smaller and the aortic valve may sit deeper compare to the mini-sternotomy. Exposure is enhanced by minimizing cannula traffic within the incision, coupled with strategic placement of pericardial sutures. Before skin incision, peripheral cannulation is performed. A small oblique incision (4 cm) is made over the groin to expose the common femoral vessels anteriorly and a 4–0 polypropylene purse-string sutures are placed. The femoral vein is first cannulated using the Seldinger technique and a multi-hole venous cannula is advanced with its tip positioned 2 cm into the superior vena cava under TEE guidance. Using the same percutaneous technique, the common femoral artery is cannulated and its tip is positioned within the external iliac artery to avoid obstructing the internal iliac artery. Much like the upper mini-sternotomy approach, direct aortic cannulation is the current preference in some centers (Figure 3).[8]

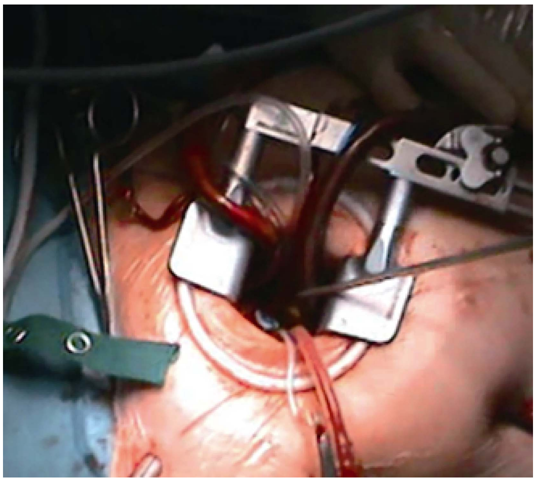

Figure 3. Right anterior mini-toracotomy for AVR. AVR: aortic valve replacement.

A 4–6 cm skin incision is made over the right third intercostal space near the sternal border. A soft tissue retractor is inserted into the wound followed by a rigid retractor. Pericardiotomy is performed 3–4 cm anterior and parallel to the phrenic nerve, extending inferiorly towards the diaphragm and superiorly to the pericardial reflection. The pericardium is retracted by passing sutures through the chest wall away from the incision. The operative field is insufflated with carbon dioxide gas. The ascending aorta is clamped with a low-profile aortic cross-clamp and antegrade cold crystalloid or blood cardioplegia is delivered directly into the ascending aorta by a needle vent catheter.

The aortic valve is replaced in usual fashion, however, longer handled instruments are utilized. Temporary epicardial pacing wires may be placed before the aortic cross-clamp is removed. Once weaned from bypass, the femoral cannulae are removed. A small chest drainage tube is inserted in the right pleural space through a separate intercostal space. The pericardium is approximated and the chest incision is closed routinely.

6 Minimally invasive *vs*. conventional sternotomy aortic valve surgery

Superiority of the minimally invasive approach, either MS or ST, over conventional aortic valve replacement has not been demonstrated yet. There is no consistent prospective studies published so far that can detect superiority of one of the approach over the other and identify patients who can benefits the most.

Recent studies have demonstrated that MI-AVS is as safe as standard sternotomy, moreover it is associated with improvement in certain post-operative outcomes such as reduced length of stay,[9] post-operative bleeding,[10] mechanical intubation time,[10] and wound dehiscence.[11]

The significantly lower use of blood products may also justify the reduction in renal failure reported in a recent meta-analysis.[12] The incidence of new onset atrial fibrillation (AF) after MI-AVS as compared to conventional AVR is a controversial topic due to the conflicting literature available on the matter.[8] Furthermore, economic benefits have been reported for the minimally invasive against conventional sternotomy AVR.[13]

Although MI-AVS has several positive outcomes, it is associated with longer aortic cross-clamp, CPB and operating times.[10]

With regard to long term outcomes, Merk, *et al*.[14] reported that MI-AVS was associated with an absolute increase in postoperative survival of 7.5% and 4.9% at five and eight years respectively, when compared to conventional AVR surgery. Glauber and colleagues also demonstrated excellent survival in MI-AVS patients three years postoperatively (96% *vs*. 88% for conventional AVR), but this difference did not reach statistical significance;[8] similarly one of the most experienced center in Europe also confirmed a good survival rate at 5-, 10- and 15-year, respectively of 83.8% ± 1.1%, 69.4% ± 1.7% and 47.8% ± 4.7%.[15]

An extremely important caveat for MI-AVS worth mentioning is the conversion rate to sternotomy. One study found that in expert hands, this drops to as low as 0.3%.[15]

7 Minimally invasive mini-sternotomy *vs*. mini-thoracotomy

Recently, an increasing number of studies in the literature have been comparing sternotomy versus RT or MS, but there is a lack in understanding as to whether there are significant differences between these two minimally invasive approaches.[16]

A recent Bayesian meta-analysis conducted by Phan, *et al*.[16] included seven randomized controlled trials and ten propensity-score matched observational studies showing that 30-day mortality, stroke, reoperation for bleeding and wound infection were comparable between the MS and the RT approach. The only difference found was a longer CPB and cross-clamp durations of a RT approach compared to MS, but that did not result in different operative and post-operative outcomes.

Other authors have reported that the RT approach was significantly associated with improved post-operative outcomes over MS, however sutureless technologies were used in the series.[17] In fact, recent reports described positive impact of sutureless and rapid deployment AVR on immediate postoperative outcomes,[18] especially when MIAVR was performed;[19] however robust evidence is lacking on long-term outcomes.[20]

8 The role of minimally invasive techniques in surgical AVR within the setting of TAVI

Conventional surgical AVR remains the gold standard treatment for patients requiring AVR.

Nevertheless, catheter-based procedures such as TAVI (trans aortic/apical/femoral valve implantation), are recommended so far only in patients at high-risk for surgical AVR. The procedures have recently started to be considered even in the lower-risk groups.

As an example, the PARTNER II trial aims to evaluate outcomes in patients with aortic stenosis and with The Society of Thoracic Surgeons (STS) score of 4%–6% undergoing conventional aortic valve replacement and TAVI.[21] Patients with concomitant coronary artery disease will be randomized to percutaneous coronary intervention plus TAVI versus coronary artery bypass graft surgery plus AVR. Similarly, the Surgical Replacement and Trans-catheter Aortic Valve Implantation (SURTAVI) trial will include patients older than 70 years with an STS score of 3%–8%.[21]

Nevertheless, TAVI should, at present, be reserved only for high-risk patients or in particular conditions (e.g., porcelain aorta), whereas MI-AVS may be regarded as potential first line treatment. In a context of very old patients, the performance of MI-AVS was found to be excellent, even when MI-AVS was carried out in patients with very high EuroSCORE.[21]

9 The expanding role of sutureless / fast release valves

The potential benefits of minimally invasive valve surgery may be enhanced by the use of the sutureless / fast release valve technologies. As highlighted before, the main drawback of MI-AVS lies in the increased CPB and cross clamp time. Sutureless valves in fact aim to reduce operative time by using rapid valve deployment techniques. In the TRITON trial, the CPB and cross-clamp times were 75 min and 46.6 min respectively.[21] The use of Perceval S and ATS 3f Enable has demonstrated similar reduction in bypass times of less than 30 min. Comparison with STS data shows a 60% decrease in operative time, which might reduce the effects on myocardial ischemia and hypoxia.[21]

10 Clinical perspectives

Since minimally invasive aortic valve surgery may confer better outcomes than standard sternotomy, an increasing effort to offer such an approach to high-risk patients should be encouraged. Potentially, these high risk patients are the ones who may benefit the most as demonstrated, for example, as in the case of mitral minimally invasive surgery.[22,23] The use of sutureless technologies also has to be encouraged since it may reduce the operative time.

11 Conclusions

Current evidence suggests that MI-AVS is associated with excellent early and late outcomes that are at least comparable to full sternotomy. At present, MI-AVS is performed primarily via mini-sternotomy or right anterior thoracotomy incisions. The mini-sternotomy affords the surgeon a "familiar exposure" and may not require special instruments, and thus reducing the learning curve compared to a mini-thoracotomy approach. Continual improvements facilitated by the development of sutureless or rapid deployment prostheses in addition to continuing popularity can make minimally invasive valve surgery a staple for future cardiac surgery.

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