

Minimally Invasive Aortic Valve Surgery

Nezafati MH^{1*}, Kahrom M¹ and Pouya Nezafati¹

¹Department of Cardiovascular surgery, Ghaem Hospital, Mashhad University of Medical Sciences, Iran

***Corresponding author:** Nezafati MH, Department of Cardiovascular surgery, Ghaem Hospital, Mashhad University of Medical Sciences, Mashhad, Iran, Email: mhnezafati@yahoo.com

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INTRODUCTION

Minimally-invasive cardiac valve surgery represents a recent and remarkable paradigm shift. Traditionalists were originally opposed to such procedures, asserting smaller incisions lead to dismal exposure and unsatisfactory outcomes. The marvelous results of current conventional valvular surgery set high standards for the development and implementation of new strategies and less invasive techniques, especially considering an aging population with increased comorbidities, operative risks and quality of life expectations.

In the past two decades minimally invasive cardiac valve surgery has been catching up with a mission for better cosmetic outcome with minimal invasiveness. The phrase “minimally invasive cardiac surgery” alludes to “any procedure not performed with a full sternotomy or cardiopulmonary bypass (CPB) support”. Accordingly, minimally invasive cardiac surgical techniques should not be described in terms of a distinct method, but it composes a philosophy in surgical approach which aims to minimize the extent of surgical invasion.

Over the last decades, as a consequence of the progressive aging of the general population, the number of aortic valve operations due to degenerative aortic valve diseases has dramatically increased. Aortic valve replacement (AVR) was performed for decades through a median sternotomy with direct central cannulation for cardiopulmonary bypass.

The enthusiasm to perform minimally invasive aortic valve surgery dates back to the last decade of the twentieth century. A remarkable evolution in surgical techniques was heralded by the first minimally invasive AVR performed by Cosgrove and Sabik in 1996 using parasternal approach [1]. In 1997 Bennetti and colleagues [2] explained the right thoracotomy approach. This was followed by partial upper ministernotomy approach for both adult and pediatric cases described in 1998 by Gundry and colleagues [3]. A transverse sternotomy method was also briefly employed but quickly rejected due to unsatisfactory morbidity and mortality rates [4]. Currently the two most popular approaches are the partial upper ministernotomy and the right thoracotomy technique with full sternotomy now the incision of choice in the minority of isolated aortic valve cases.

With the appearance of minimally-invasive aortic surgery and significant expansion in popularity, several new observations regarding the treatment of patients with isolated or combined valve diseases and also complex aortic root surgeries have arisen and during the past 20 years, many cardiac surgeons worldwide have reported their outcome data with promising results [5-11].

ADVANTAGES OF MINIMALLY INVASIVE AORTIC VALVE SURGERY

Smaller incisions indisputably offer various postoperative benefits, the most tangible being improved cosmesis and esthetically pleasing scar. However, one of major concerns regarding minimally invasive approach was a reasonable concern about the “trade-off” of limited exposure of surgical incision versus safety of the prevailing approach through the full sternotomy.

Due to the limited mediastinal dissection and minimal spreading by the chest retractor, postoperative pain, likelihood of atrial fibrillation (AF) and reliance on narcotic pain medication in the first 2-3 days following surgery will be reduced [12]. Avoiding a full sternotomy should contribute to improved postoperative stability of the sternum, reduction in deep sternal wound infection and eliminating the risk of sternal non-union.

Minimally invasive aortic valve surgery (MIAVS) shows a mortality rate similar to that with conventional sternotomy [13] and can be safely performed in patients aged more than 80 years with acceptable morbidity and mortality rates [14,15]. Due to the reduced size of the operative field and, therefore, less potential sites of bleeding, such as the sternum and pericardium [16], patients receive fewer blood and blood product transfusions, and are discharged from the ICU and hospital earlier than those with sternotomy [17].

Of note, there is also a significant benefit in terms of pulmonary function, earlier extubation, facilitating early mobilization, increasing patient’s satisfaction, better use of healthcare resources, ease of rehabilitation and return to full activity and productivity.

Additionally, financial and survival advantages have been described for the minimally invasive over conventional AVR with sternotomy. Consequently, minimally invasive surgery for aortic valve pathologies has become a standard technique in many centers all over the world due to its proven benefits. With improving in surgeons' skill and shorter duration of CPB time, these operations might benefit the patients more than standard procedures because of more favorable outcomes and fewer cerebral and pulmonary complications so should be considered part of the routine armamentarium of cardiac surgeons in the modern era [18].

PATIENT SELECTION

Patient selection for MIAVS is of paramount importance to avoid complications, and suitability for this procedure is evaluated on an individual basis. Overall, 85-90% of patients are proper candidate for a minimally invasive approach. Most patients with a primary indication for aortic valve surgery are amenable to a MIAVS approach, so a designation of indications or relative contraindications is worthwhile. This suitability greatly depends on the surgeon preference and expertise, heart function, chest anatomy and co-existing medical conditions. Another important issue that needs to be considered is whether a mechanical or a tissue valve is more suitable for the patient.

Special attention should be paid to patient body habitus (obesity, chest deformity), medical conditions (trauma or previous chest surgery) as well as aortic valve and root anatomy (degree of valve calcification, aortic aneurysm and concomitant mitral pathology). Presence of porcelain aorta and the need for coronary revascularization is usually a contraindication to MIAVS, although hybrid percutaneous coronary stenting or even right coronary bypass grafting at the time of MIAVS might be considered. Surgery for emergent situations such as acute proximal aortic dissection or endocarditis is routinely performed through a full sternotomy.

Relative contraindications to this approach include poor ejection fraction, very short or very long ascending aorta, small aortic root in elderly patients requiring root enlargement, and last but not the least lack of availability of transesophageal echocardiography (TEE) as a standard measurement [19].

All other patients, including those requiring multi-valve or redo operations, aortic root surgery and even those with atrial fibrillation or elderly patients with severe comorbidities, are potential candidates for a MIAVS. Routine application of MIAVS along with early conversion when mandatory, and careful attentiveness of patients with potential contraindications results in excellent early and late results that are at least similar to conventional sternotomy and possibly better.

IMAGING

Standard preoperative cardiac imaging workup for MIAVS has included plain chest radiography, echocardiography and coronary angiography. Selective obtaining of three-

dimensional (3D) reconstruction of multidetector computed tomographic angiography (CTA) gives the surgeon precise information about the kind of incision to use and helps planning the safe conduct of minimally invasive aortic valve surgery [20]. This leads the surgeon to uncover the anatomy before the procedure and to ratify the proper location and extent of the incision. The proximity of the cardiac structures to the incision is of value if central cannulation of aorta and right atrial appendage is to be used. This can help decision making regarding how low to take a partial sternotomy or which intercostal space to choose for anterior thoracotomy. Additionally, CTA is a valuable tool in illustrating the presence and course of anomalous coronary arteries and patent bypass grafts. It is also more advantageous than cardiac catheterization in delineating the size and extent of ascending aortic aneurysm and coarctation.

Transesophageal echocardiography (TEE) plays an important role during MIAVS in discerning problems that require prompt correction. Detailed assessment of the cardiac anatomy and function helps in the confirmation of definitive diagnosis and the success of surgical procedure. Furthermore aortic and venous cannulations are out of direct vision of the surgeon and proper positioning of the cannulae during MIAVS is usually impossible without the aid of TEE. Intra-operative TEE helps in the navigation of the guide wire and appropriate positioning of the cannulae, coronary sinus cannulation, antegrade and retrograde cardioplegia delivery and enables real-time evaluation of cardiac valves, ventricular function and filling, intra-cardiac deairing, weaning from cardiopulmonary bypass and adequacy of the surgical treatment. Application of Intra-operative TEE for early diagnosis of perioperative problems potentially improves the outcome of patients managed with MIAVS [21].

ANAESTHETIC MANAGEMENT

With progressive improvement of surgical procedures, the protocol of anesthesia managements also requires to be amended to facilitate the surgical technique. During MIAVS, the alteration in positioning of the patient demands changes in anesthesia protocols. Special attention should be paid to bony eminences as pressure points to prevent nerve compression and injury. Using cotton pad or roll in axilla is an effective prevention for brachial plexus injury.

As direct vision and complete access to the heart is limited during minimally invasive procedures; consequently, external defibrillator pads are positioned prior to induction to anesthesia. The position of the defibrillator pads have to be fashioned based on the surgical approach. In special situations where cardiac pacing may be necessary, a transvenous pacing wire is inserted through superior vena cava (SVC) along with the pulmonary artery catheter.

Prolonged single-lung ventilation, complex surgical instrumentation as well as limited exposure and access for immediate intervention pose a great challenge for the anesthesiologist. Sometimes, conversion to full sternotomy may be necessary and the vigilant anesthesiologist should be ready to manage these problems.

Anesthesiological protocol of patients undergoing MIAVS requires the understanding of the pathophysiology of underlying cardiac disease (e.g. aortic stenosis or regurgitation) and their hemodynamic implications. A comprehensive cardiovascular monitoring consisted of standard electrocardiogram leads II and V5, invasive blood pressure (BP) monitoring by catheterization of the radial or femoral artery placed under local anesthesia before induction, central venous cannulation for measurement of the central venous pressure (CVP), peripheral veins cannulation to administer fluid and drugs, pulse oximetry, capnography, bispectral index monitor, urinary catheter, nasopharyngeal and rectal temperature and in selected patients, a pulmonary artery catheterization (PAC) may be required to monitor filling pressures, pulmonary artery pressures, venting or pacing cardiac chambers and continuous monitoring of cardiac output (CO).

According to the fast-track protocol of minimally invasive cardiac surgery, all patients can be extubated successfully within 3-4 hours in post operative recovery room after evaluation of the basic vital parameters, hemodynamics and acceptable criteria of extubation.

CARDIO PULMONARY BYPASS (CPB)

An important event in the advancement of MIAVS is the parallel evolution in perfusion technology. As the shifting towards MI cardiac surgery progressed, improvements were made to minimize cannulae size and using non-kinking materials to maximize operative field. Arterial access can be achieved by central cannulation of aorta or peripheral cannulation through the axillary or femoral artery. Numerous options are also available for venous cannulation, directly through the right atrium or with bicaval access, achieving superior and inferior vena cavae cannulation, either directly or percutaneously from the femoral or internal jugular veins with or without vacuum-assisted drainage [22]. Vacuum-assisted venous drainage (negative pressure approximately -40 to -60 mmHg) represents a major advance in CPB technology, which enables satisfactory venous drainage through small caliber cannula especially in patients with higher body surface area (BSA) requiring a higher flow rate on CPB [23].

Although, CPB through femoral perfusion reduces the 'clutter in a relatively small operative field', but its application is quite unusual in our current practice, being reserved only for special situations. The retrograde perfusion is not a physiological one, and several drawbacks have been described with peripheral arterial cannulation, including increased incidence of vascular complications and perioperative stroke [22].

Myocardial protection strategy can be achieved via administration of cardioplegia either antegrade from anaortic cannula or retrograde from the coronary sinus via transjugular catheterization combined with transthoracic or endovascular aortic balloon occlusion [24]. The port access technique is a system with promising results that combines endovascular balloon aortic occlusion with antegrade cardioplegia administration. However, it has been related with higher rates of retrograde aortic dissection, as well as the previously stated risks of peripheral arterial cannulation [25,26].

Conventional mobilization of the heart is hardly possible with the minimally invasive access since, volume overload of the left heart and de-airing remains a major concern. A venting catheter can be inserted via the right superior pulmonary vein (RSPV) or pulmonary artery (PA) to empty the left ventricle, decrease backflow of blood, and to improve visualization of the aortic root. In our experience, continuous flooding of the operative field with CO₂ at a flow of 0.5–1.0lit/min in all patients, antegrade aortic root venting and meticulous air surveillance by TEE can eliminate significant gaseous emboli.

SURGICAL TECHNIQUES

To date, various types of incisions have been described for MIAVS including right anterior thoracotomy [2] and different ministernotomy approaches such as an upper reversed T incision [27], a right side partial sternotomy [28], an upper J incision [29,30], an S-shaped partial sternotomy [31], a right parasternal incision [32,33], a lower half ministernotomy (T incision) [34], an L-shaped incision [35], a reversed Z-shaped sternotomy [36], an I-shaped ministernotomy [37] and a reversed C-shaped ministernotomy [38].

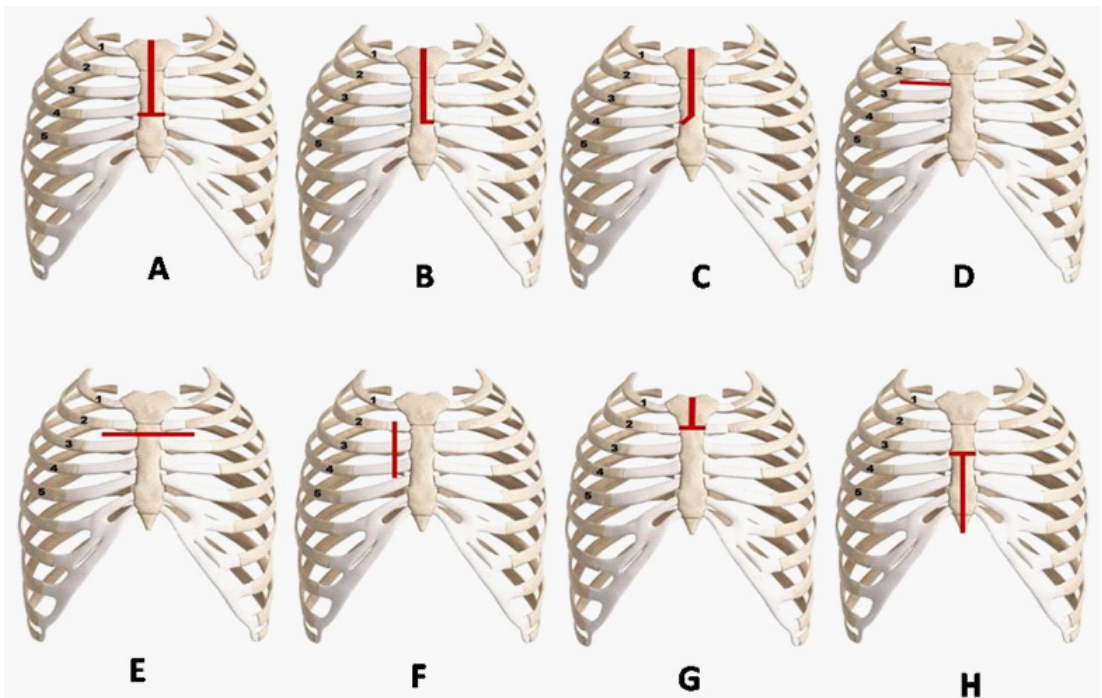


Figure 1: Incisions for minimally invasive aortic valve replacement. Inverted T partial sternotomy (A), L-hemisternotomy (B), J-hemisternotomy (C), right anterior thoracotomy (D), transverse sternotomy (E), right parasternal incision (F), manubrium-limited sternotomy (G), lower half sternotomy (H).

The Upper Hemisternotomy Approach

Currently, this is definitely the most popular of all minimal access approaches to the aortic valve. Under general anesthesia, with the patient in supine position, we perform a 5-6 cm midline skin incision started at the level of the junction between the manubrium and the sternum body, extending downward. The sternum is divided vertically and then transected horizontally at the level of the right 3rd or 4th intercostals space, forming a reversed L shape sternotomy taking care to avoid injury to the right internal mammary artery. The level of the sternal division depends greatly on body habitus, the presence or absence of chronic obstructive pulmonary disease (COPD), and whether the heart lies transversely or longitudinally within the chest.

Following the creation of a J-sternotomy, a small Finochietto-type retractor is placed between the sternal edges, through which the pericardium is opened longitudinally. Cardiopulmonary bypass is established by direct cannulation of the distal ascending aorta and right atrium (Figure 2). Once CPB has been achieved, the aorta is directly cross-clamped and the heart can be arrested with the direct delivery of antegrade cardioplegia. The aorta is then opened transversely and the valve exposed. Aortic valve or full root replacement or repair is accomplished as it would be in the case of a standard median sternotomy according to the surgeon's preference.

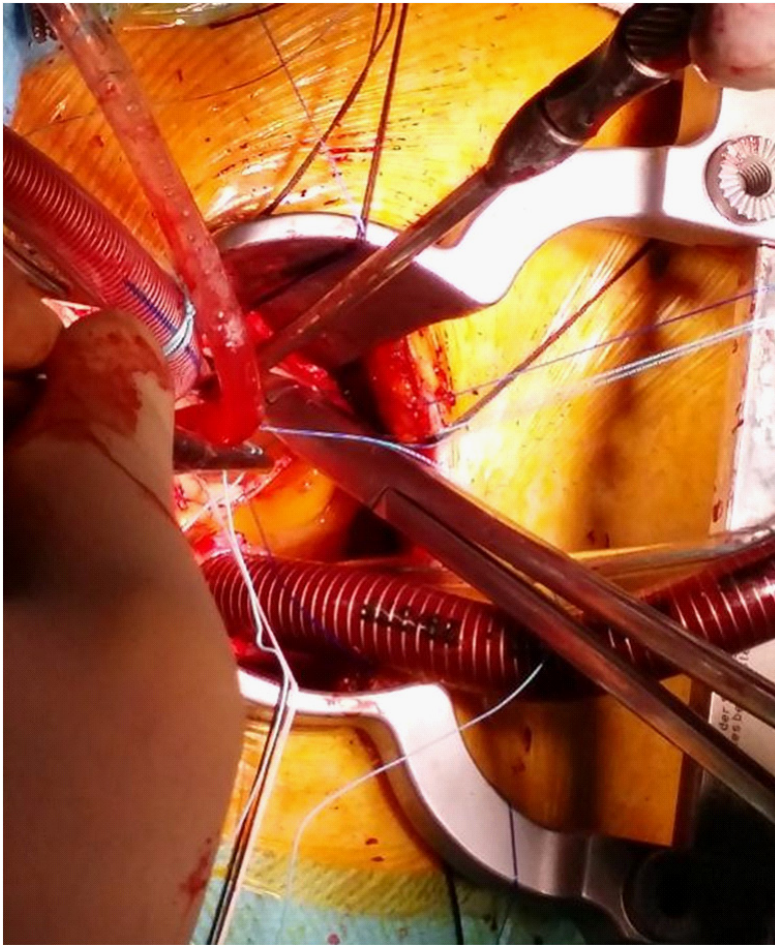


Figure 2: Intra-operative photo showing upper J-shaped hemisternotomy with central cannulation.

After closure of the aortotomy, pericardial drain, atrial and ventricular pacing wires are placed on CPB to improve exposure and access to heart structures and avoiding injury. Deairing is then performed under guidance of TEE and the aortic cross-clamp removed. After weaning from CPB, decannulation and protamine administration, the previously inserted chest tube is positioned in the pericardium and another in the right pleural space. Although the right pleural cavity can be preserved intact but we preferentially open this cavity as it enables drainage of pericardial cavity into the pleural space. The drains are placed towards the right side to ensure they are not trapped on sternal closure and the partial sternotomy is re-approximated with sternal wires and the incision closed (Figure 3) [39-41].



Figure 3: Post-operative photograph of incision.

Right Anterior Thoracotomy Approach

This approach is the second, most frequently used after upper hemisternotomy. A 4–6 cm right anterior thoracotomy incision is made in the right second intercostal space just lateral to the costo-manubrial junction, without rib resection. The pericardium is then opened and CPB is established by central or femoral venous and arterial cannulation. Upon the initiation of cardiopulmonary bypass, the aorta is cross clamped through the incision, under direct vision and the heart arrested with cardioplegia as described above. Oblique aortotomy is performed and extended into the mid portion of the noncoronary cusp. Occasionally, placing the annular sutures near the right coronary cusp is difficult with this approach, and the annulus must be pulled into view in order to improve the visualization [42]. The rest of the procedure is practically routine as for any other minimally invasive aortic valve surgery.

In our experience, the time of aortic cross clamp are longer with this approach as compared to the hemisternotomy technique discussed above. In patient candidate for isolated aortic valve surgery in whom sternotomy should to be avoided at all costs, such as those with heavily irradiated sternum or who are disabled and routinely ambulate with the use of shoulder crutches,

this procedure seems to be beneficial. This approach enables early ambulation in these patients with their crutches and eliminates the risk of sternal dehiscence.

Drawbacks of this technique include; possible right internal mammary artery (RIMA) injury, scarring and disfigurement of right breast in females, long learning curve and poor exposure in re-operative aortic valve replacement. In cases of poor exposure, conversion to full sternotomy or extending the incision across the sternum with a transverse sternotomy would be feasible and safe.

Right Parasternal Incision

The right parasternal approach was the first step into the world of minimally invasive aortic valve surgery, but It soon gave way to the more versatile and straightforward upper ministernotomy technique [1].

Briefly, a 6-10 cm vertical skin incision is made in the right parasternal area overlying the second, third and fourth costal cartilage. These costal cartilages are completely excised, right internal mammary artery is ligated and divided and the pericardium is opened longitudinally. After systemic heparinization, the cardiopulmonary bypass is begun by central or peripheral venous and arterial cannulation. Upon the initiation of cardiopulmonary bypass, the aorta is cross-clamped through the parasternal incision. An oblique hockey stick incision is made in the aorta and extending down to the noncoronary cusp. The aortic valve replacement or repair is then performed with the standard techniques.

Occasionally, right parasternal incision is complicated by lung herniation which is physiologically disturbing, cosmetically disfiguring and necessitates second operation for mesh closure of the defect [43].

Manubrium-Limited Sternotomy Approach

Manubrium-limited sternotomy is a legitimate technique. Most of popular techniques that gain access through a midline incision still divide a remarkable segment of the sternum body up to 3-4 intercostal spaces [16].

In our experience, although this approach utilizes the minimum-required working space to perform aortic valve surgery, but creates a pleasing scar while ensuring that the sternum body remains stable and intact. We perform a manubrium-limited incision from the sternal notch to the second intercostal space. The manubrium is divided vertically in the midline and then transected horizontally in both directions at the level of the manubrio-sternal junction, creating a V-shape sternotomy taking care to avoid injury to the right and left internal mammary arteries. Cardiopulmonary bypass is established by direct arterial cannulation of the distal ascending aorta and percutaneous venous cannulation through the femoral vein guided by TEE. The rest of the procedure is performed as standard technique. Sternal closure is accomplished with two wires in the manubrium and two wires from the body of the sternum up to the manubrium [16].

Transverse Sternotomy Approach

There are some anecdotal reports for use of this approach at the beginning of minimally invasive aortic valve surgery. Because both of mammary arteries are sacrificed, this incision never gained much popularity and was therefore quickly abandoned.

Briefly, an 8-10 cm transverse clamshell like incision is made across the midline, the sternum being transected horizontally at the level of the second or third intercostal space along with ligation and division of both internal thoracic arteries. A small retractor is placed between the sternal edges and the pericardium is opened longitudinally. After systemic heparinization, cardiopulmonary bypass is established by direct cannulation of the distal ascending aorta and right atrium. Insertion of venous cannula to right atrial appendage can be performed via a separate stab incision made over the fourth right intercostals space in the mid-clavicular line (this incision is then used to insert a drain at the end of the operation) [4]. The rest of procedure is performed routinely as discussed in other MIAVS before. The sternotomy is closed with two interrupted loops of stainless steel wire.

Lower Half Sternotomy Approach

The lower half sternotomy is a multi-purpose minimally invasive approach that enables reasonable visualization and direct access to the aortic root and all surfaces of the heart. An 8-10 cm in length midline skin incision is made from xiphoid process extending up to the third intercostal space. Then the sternal body is divided transversely at the level of the third interspace forming a T shape sternotomy and leaving the upper half of the sternum body intact. Special care is taken to avoid injury to the right and left internal mammary arteries. A pediatric retractor is placed between the lower sternal edges and a longitudinal pericardiotomy is made. Opening the right pleural space and removal of thymus remnants would make an additional exposure.

Aortic cannulation should be performed directly through the sternotomy incision as high on the ascending aorta as possible. Using small and flexible aortic cannula inserted by needle-guidewire technique allows for safe and controlled cannulation [44]. Venous cannulae can be brought out either through the primary incision or through the right pleural space via a separate stab incision which later become the exit sites for the thoracostomy drains.

To provide the greatest length of ascending aorta for manipulation, a long aortic cross clamp can be passed through a stab incision on the right anterior chest wall and below the clavicle. Aortic valve operation is then performed as it would be in the case of a standard median sternotomy and de-airing is performed in the usual manner with TEE guidance after closure of the cardiac incisions [44].

Aortic Valve Bypass (AVB) Surgery (Apicoaortic Conduit)

Conventional AVR in the elderly patients with critical aortic stenosis (AS) and associated porcelain aorta, prior mediastinitis, multiple previous cardiac or thoracic operations and multiple patent bypass grafts is displeasing to the cardiac surgeon and high risk for the patient. An AVB

(apicoaortic conduit) is a Dacron conduit usually containing a bioprosthetic valve that relieves AS by shunting blood from the left ventricular apex to the descending thoracic aorta [45,46]. The main goal of this technique is to provide a satisfactory outcome with lower morbidity and mortality in high risk patients when compared to the conventional approach, especially by avoiding the use of median sternotomy, cardiopulmonary bypass and aortic clamping.

A left antero-lateral thoracotomy incision is made over the 6th rib. After proceeding to the full heparinization, a partial occlusion clamp is applied onto the distal descending aorta and distal part of conduit is anastomosed end- to-side onto the descending aorta. Insertion of the apical connector to the LV apex is performed using Interrupted pledgeted 2-0 Ethibond mattress sutures [10–12] around the cardiac apex in a circular fashion. Cardiopulmonary bypass is used infrequently and when necessary, only for a brief period of time via femoral cannulation. This procedure can be performed with or without cardiopulmonary bypass and with different types of valves: mechanical, bioprosthetic stented or stentless and homografts at the surgeon's discretion [47].

Transapical Aortic Valve Endoprosthesis Implantation

The transapical aortic valve endoprosthesis implantation is a new technique and under study in various centers around the world [48-50]. This procedure offers to overcome vascular access issues and is performed in a high technology hybrid operative theatre under fluoroscopic and TEE control.

A small left antero-lateral thoracotomy in the fifth intercostal space is performed and a sheath is placed in the left ventricular apex with a double purse-string suture. A guidewire is passed through the aortic valve under TEE and fluoroscopic guidance into the descending thoracic aorta. A self-expanding or balloon-expandable catheter-mounted bioprosthesis with “oversize” of 20% is introduced through a 24F introducer. With the valve situated in correct position, rapid ventricular pacing is done to reduce cardiac output and then the balloon is inflated with maximum pressure of 5 atmospheres and the prosthesis is released.

Heart block may be of some concern in this technique with a 10% need for pacemaker implantations, indisputably due to calcifications that are squeezed into the peri-annular space during valve implantation [49].

Totally Endoscopic Aortic Valve Replacement (TEAVR)

Totally endoscopic aortic valve replacement (TEAVR) aims to lessen surgical chest wall trauma by avoiding costal spreading or sternal fractures. TEAVR seems to be a safe procedure but patient selection should be based on anatomical criteria and tolerance for longer cross clamp and CPB durations, so is actually addressed to intermediate-risk patients. Patient selection criteria also include presence of a sufficient peri-aortic working space to enable management of instruments, ventricular ejection fraction of >45% and finally, absence of significant iliac and femoral artery stenoses [51].

The procedure is performed using four trocars setting (two working ports, a camera trocar, and one trocar for the management of a pulmonary vent). After institution of femoro-femoral CPB, the aorta is cross-clamped using Chitwood clamp. Following delivery of cardioplegia, aortotomy and annular decalcification, the bioprosthetic sutureless valve is implanted through a thoracoscopic trocar under exclusive control of a camera [51]. The totally endoscopic aortic valve replacement (TEAVR) has proven to be technically safe and feasible with the current technology in selected patients with mentioned criteria [52].

MINIMALLY INVASIVE ROOT AND ASCENDING AORTA SURGERY

With increasing experience, a large number of concomitant operations have been performed in addition to aortic valve surgery via the upper hemisternotomy approach [53]. This includes patients requiring aortic valve replacement or repair in combination with ascending aortoplasties, aortic root enlargements, aortic root replacements as a Bentall procedure [54,55], aortic root reimplantation as a David procedure [56], ascending aortic replacements (with a cross-clamp) or hemiarch replacements (with circulatory arrest) and Ross procedure [57]. Young patients with a bicuspid aortic valve and associated aortopathy are typically common candidates.

A vigilant review of 3D reconstructed images of the thoracic aorta in relation to the sternum and the rib cage is necessary to understand the details of the patient's anatomy and to plan the exposure through the upper hemi-sternotomy [20,58].

After systemic heparinization, the ascending aorta and the right atrium are cannulated directly via the ministernotomy access. If necessary, selective antegrade cerebral perfusion is achieved by cannulating the innominate artery with or without left common carotid artery [59]. Standard techniques are applied for each planned operation. Of note, paying meticulous attention to ensure complete hemostasis at every step of the minimal access root surgery is a critical strategy.

REDO MINI AVR

Given increasing life expectancies, coupled with improved outcome of modern operations, there are an increasing number of patients undergoing reoperative cardiac procedures. This is especially relevant in patients with previous CABG, where iatrogenic injury to patent bypass grafts during redo sternotomy would be a serious concern [5,60]. Consequently, by avoiding unnecessary tissue dissection, minimally invasive redo AVR may reduce the risk of bleeding and damage to adjacent structures.

Upper hemisternotomy to the 4th intercostal space is a typically used approach [61]. Whenever possible, it is our preference to adopt a central cannulation strategy for CPB, as it is considered to resemble normal physiology more closely. In the presence of patent LIMA graft, myocardial protection during redo mini-AVR is of great importance. The classical policy includes dissection and temporary occlusion of the LIMA pedicle during cardioplegic arrest to avoid cardioplegic solution "washout" and myocardial regional warming. In circumstances that patent LIMA could not be occluded, systemic cooling to 20°C or giving additional systemic potassium (40 mEq) to a goal of 6.0-7.0 mEq/l through the pump are other key strategies [62-64].

PITFALLS AND SAFEGUARDS IN MIAVS

Complications attributed to the minimally invasive procedures are derived from the particularities of the incision itself, physically limited exposure of the entire heart and mediastinum and the complexity of instrument manipulation. The other technical difficulties and challenges to the implementation of minimally invasive procedures are unfavorable anatomy, unsuitable positioning of the patient, incorrect chest incision with less room to manipulate, limited exposure for central cannulation, suboptimal venous return for deloading the heart, difficulties with valve exposure, decalcification and operation, excessive bleeding and deairing of cardiac chambers [19,65].

Conversion of MIAVS to full sternotomy is not only a defeat for the surgeon and the team, but also creates injury to the patient and invariably leads to longer operation and CPB times. Depending on surgeon experience, conversion occurs in 1.8 to 4% of all cases, due to inadequate exposure; bleeding from the right ventricle, coronary sinus, aortotomy or intercostal vessels; and low cardiac output state [19]. The incision can be extended to a full sternotomy in the cases of partial sternotomy or can be either enlarged or converted to a transverse sternotomy in the cases of right minithoracotomy.

Another intrinsic drawback of minimally invasive approaches is the use of femoral cannulation and perfusion which may lead to groin complications (e.g., infections, retrograde arterial dissections or hematoma) and their morbidities imperceptible with conventional technique [65]. Furthermore, due to the poor exposition, inadequate LV de-airing is a major concern during MIAVS, making the use of TEE and continuous flooding of the operative field with CO₂ mandatory, which had minimized air emboli and stroke in reported series.

Finally, it must be highlighted that conventional aortic valve surgery still remains the main and standard approach by most surgeons with satisfactory results. It is faster and the surgeon has direct access to the heart structures if complications occur [66]. Accordingly we strongly advocate that surgeons should use the procedure that they are more familiar with. Forcing a minimally invasive approach at any cost may be harmful in some circumstances.

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