Surgical Aortic Valve Replacement Management Options

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Abstract

Background: There are three Surgical Techniques for aortic valve replacement: Conventional sternotomy and valve replacement, Minimally Invasive Surgical Aortic Valve Replacement and Right Anterior Mini Thoracotomy. Median sternotomy was introduced by Milton in 1897 and has since become the standard incision in cardiac surgery allowing for access to the mediastinum and pleural cavities. Physicians remain reluctant to recommend AVR for elderly patients more than 80 years of age or those considered very high risk. Instead, many patients are continued on medical management or undergo a balloon aortic valvuloplasty. Unfortunately, these conservative therapies provide minimal or short-lasting symptomatic relief to the patient, eventually leading to restenosis of the aortic valve or sudden death. RAT avoids sternotomy and is associated with a limited skin incision. However, the operative field is smaller and the aortic valve sits deeper within the wound. Exposure is enhanced by minimizing cannula traffic within the incision via peripheral access, coupled with strategic placement of pericardial sutures. This approach is typically performed with a 4–6 cm incision through the second or third intercostal space

Keywords: Aortic Valve Replacement

Introduction

Abnormalities of the cardiac valves can cause an obstruction to flow (valve stenosis), a leakage backward (valve regurgitation), or both. These abnormalities can usually be detected on physical examination with a stethoscope, as the turbulent blood resulting from valve stenosis or regurgitation will cause a heart murmur. Echocardiography, a noninvasive test that creates a sonar-like picture of the heart, is a common test used in patients with suspected or known aortic valve disease. Echocardiography can reliably confirm the presence and severity of the aortic valve disease, as well as determine the response of the left ventricle to the extra workload on the heart. **(1).**

Clinical evaluation of Aortic valve stenosis:

i- History:

Aortic stenosis usually has an asymptomatic latent period of 10-20 years, and symptoms develop gradually. Exertional dyspnea is the most common initial complaint, even in patients with normal LV systolic function, and it often relates to abnormal LV diastolic function. In addition, patients may develop exertional chest pain, effort dizziness, easy fatigability, and progressive inability to exercise. Ultimately, patients experience one of the classic triads of chest pain, heart failure, and syncope, **(1).**

ii- Physical examination:

For aortic stenosis, a systolic ejection murmur can often be heard best over the right sternal border at the second intercostal space. This murmur will peak early during systole when the disease is mild, and as severity increases will peak later, it also tends to radiate to the carotid arteries along with a slowly rising carotid upstroke. Auscultation often reveals a sustained apical impulse as well. In severe disease states, a thrill can sometimes be palpated over the carotid arteries and aortic area. Additional physical exam findings due to complications and sequelae of aortic stenosis include those associated with heart failure and left ventricle remodeling, such as third and fourth heart sounds, pulmonary crackles, jugular venous distention, and pedal edema**(2).**

iii- Investigations

1-Chest X-ray:

Insights from the clinical routine affirm the observation that the chest x-ray is one of the initial imaging diagnostics in symptomatic patients with an undiagnosed aortic valve stenosis as these patients usually present with symptoms such as angina pectoris or dyspnea which need to be further investigated. The radiological findings are dependent on the stage of the disease and may be missing in the initial phase due to sufficient compensatory mechanisms. **(3)**

However, in an advanced stage of the disease, cardiomegaly with an enlargement of the cardiac silhouette resulting from a left ventricle hypertrophy due to an increased afterload and an enlargement of the left atrium on the antero-posterior view may be detected. Furthermore, signs of heart failure, such as pulmonary venous congestion can be present. Although there are numerous signs that may indicate the presence of a relevant AS the chest X-ray remains a nonspecific tool in the diagnosis of AS and therefore plays a subordinate role. The ESC guidelines therefore do not suggest the use of a chest X-ray as a sufficient tool. **(4)**

2- Electrocardiography (ECG) :

In some cases, patients with AS may present electrocardiographic findings such as a left axis deviation as well as a positive Sokolow-Lyon index (Sv1 + RV5 or 6 > 3.5 mV) as an expression of a left ventricular hypertrophy. Further optional signs such as left branch bundle blocks, T-wave negativations and ST depressions can also be present. However, the ECG is not a sufficient diagnostic tool to detect or quantify any AS. (**5)**

3- Echocardiography :

Is the tool of choice for confirming the diagnosis of aortic valve stenosis. It is highly valuable for assessing the left ventricular ejection fraction, the valve morphology, the opening movement of the valve and the wall thickness. Furthermore, a semi-quantitative assessment of the extent of valve calcification can be performed as. The severity of aortic valve stenosis is quantified with the help of doppler measurement .Three parameters are needed to classify the aortic valve stenosis: peak transvalvular velocity (Vmax), mean pressure gradient (Pmean) and aortic valve area (AVA). **(6)**

Table 1. Classification of Aortic Stenosis Severity

Classification	Transaortic velocity (m per second)	Mean pressure gradient (mm Hg)	Aortic valve area (cm^2)
Normal	< 2.0	< 10	3.0 to 4.0
Mild	2.0 to 2.9	10 to 19	1.5 to 2.9
Moderate	3.0 to 3.9	20 to 39	1.0 to 1.4
Severe	≥ 4.0	≥ 40	< 1.0

Table (1): The severity of aortic stenosis according to echocardiographic criteria, **(7).**

Clinical evaluation of Aortic valve regurge:

i-History:

Acute aortic regurgitation

The typical presentation of severe acute AR includes sudden, severe shortness of breath; rapidly developing heart failure; and chest pain if myocardial perfusion pressure is decreased or an aortic dissection is present.

Chronic aortic regurgitation

Patients with chronic AR often have a long-standing asymptomatic period that may last for several years. A compensatory tachycardia may develop to maintain a large forward stroke volume, leading to a decreased diastolic filling period, presentation of severe chronic AR includes shortness of breath, fatigue ,chest pain.**(7)**

ii-Physical examination:

Aortic regurgitation when acute and/or severe can be suspected when the patient has a wide pulse pressure, and a low pitched early diastolic murmur is auscultated again over the right sternal border at the second intercostal space. Accentuated P2 may also be noticed due to elevated pressures in the pulmonary vasculature. Chronic aortic regurgitation may illicit a blowing diastolic decrescendo murmur with a positive correlation between the duration of murmur and the severity of the disease. Often auscultation of a laterally and inferiorly displaced apical impulse is present and sustained. Often there is the phenomenon of Corrigan pulse (water hammer), a bounding and forceful pulse that rapidly increases and collapses. **(8).**

Other less common physical exam findings include the de Musset sign, which is subtle head bobbing with a pulse, as well as the Quincke sign and Muller sign (pulsations on the fingernails and uvula, respectively). Similar physical exam findings to aortic stenosis can also be seen late in disease progression. **(8).**

Acute aortic regurgitation will present differently depending on the etiology. If a patient presents with tearing severe chest pain along with physical exam findings such as variation in blood pressure between the right and left extremities, consider aortic dissection as a cause. If the patient presented with a history of streptococcal infection along with fevers, swollen and tender joints, skin nodules, new onset of rash, then rheumatic heart disease would be high on the differential**(9).**

Chronic aortic regurgitation and late in disease progression of aortic stenosis symptoms generally fall into two categories; heart failure and decreased coronary and systemic perfusion. Overtime increased pressures in the left ventricle lead to congestive heart failure; patients may complain of pedal edema, shortness of breath, orthopnea, paroxysmal nocturnal dyspnea, and exertional dyspnea. **(8).**

iii-Diagnosis:

1-Chest X-ray:

Chest X-ray findings associated with aortic regurgitation may include left ventricular enlargement, cardiomegaly, prominent aortic root with valvular calcification, prosthetic valve dislodgement, or aortic dilation. If aortic regurgitation is severe, signs of pulmonary edema may also be present. The ESC guidelines therefore do not suggest the use of a chest X-ray as a sufficient diagnostic tool.**(3)**

2-Electrocardiogram (ECG or EKG):

An ECG can detect enlarged chambers of your heart, heart disease and abnormal heart rhythms, may show repolarization abnormalities with or without QRS voltage criteria of LV hypertrophy, left atrial enlargement, and T-wave inversion with ST-segment depression in precordial leads. However, the ECG is not a sufficient diagnostic tool to detect or quantify any AR. **(10)**

3-Echocardiogram:

Transthoracic echocardiography with Doppler color-flow is the most useful tool for the diagnosis of AR. The jet width and vena contracta width on Doppler color-flow are used to qualitatively assess the severity of AR, whereas the regurgitant volume, regurgitant fraction, and regurgitant orifice area are used for the quantitative assessment, **(10).**

Grading of Aortic Regurgitation Severity

Quantitative Parameters

	Mild	Moderate		Severe
RVol (ml/beat)	<30	30-44	45-59	≥ 60
RF (%)	< 30	30-39	40-49	≥ 50
EROA (cm^2)	<0.10	0.10-0.19	0.20-0.29	≥ 0.30

. AR = aortic regurgitation; EROA = effective regurgitant office area; LV = left ventricle: LVOT = left ventricular outflow tract; R Vol = regurgitant volume; RF = regurgitant fraction

2

There are three Surgical Techniques for aortic valve replacement: (11)

- Conventional sternotomy and valve replacement
- Minimally Invasive Surgical Aortic Valve Replacement
- Right Anterior Mini Thoracotomy

1-Standard Sternotomy

- Median sternotomy was introduced by Milton in 1897 and has since become the standard incision in cardiac surgery allowing for access to the mediastinum and pleural cavities, **(12)**
- Through this approach, the surgeon can see the entire heart and control the whole operative field visually and tactically. Cardiac surgery through standard sternotomy is safe, efficient and is the gold standard for surgical treatment of all congenital and acquired heart diseases resulting in low failure rates and excellent proven long-term outcomes.**(13).**

Indications :

In patients with multiple extra-cardiac co-morbidities as hepatic and renal patients, minimally invasive approaches may increase the overall operative risk, because longer cross clamp-, bypass- and surgery times compared to conventional AVR have been described**.** Conventional aortic valve replacement (AVR) via complete median sternotomy is a safe and feasible procedure with low risk for patients providing excellent long-term outcome **.(14)**

Disadvantage :

Mean mediastinal drainage and mean blood transfusions per patient were higher following full sternotomy compared to ministernotomy. Mechanical ventilation time was significantly longer in full sternotomy patients . However, they did find significantly higher intraoperative blood loss with standard sternotomy.ministernotomy has not only important cosmetic advantages but also beneficial effects on blood loss and transfusion, postoperative pain, reduced ventilation time, and, eventually, sternal stability.**(15)**

Technique :

Incision*:*

The Suprasternal notch and xiphoid are marked as shown in**.** The incision must be a median and vertical line between the sternal notch and the tip of the xiphoid process. The midline can be easily incised with cautery between these two landmarks by dividing the subcutaneous tissue and the underlying pectoral fascia between the fibers of the pectoralis major muscle,**.** The periosteum is divided and bleeding points are cauterized with the electrocautery, **(15).**

The sternal periosteum is then separated, while at the same time cauterizing bleeding points. Identification and division of the transverse venous arch in the jugulum is mandatory to avoid bleeding. The interclavicular ligament of the sternal notch, which is located at 0.5cm below the surface, is divided next with the cautery. The third step is blunt digital dissection of the posterior side of the sternum from the underlying sternoclavicular ligament. The final step before sawing is blunt digital dissection of the xyphoid process from the underlying tissue of the diaphragm. Blunt digital dissection carries no risk and ensures the blade of the sternal saw doesn‘t come in contact with the underlying tissue. The sternum is usually divided from top to bottom by using a sternal saw, **(16).**

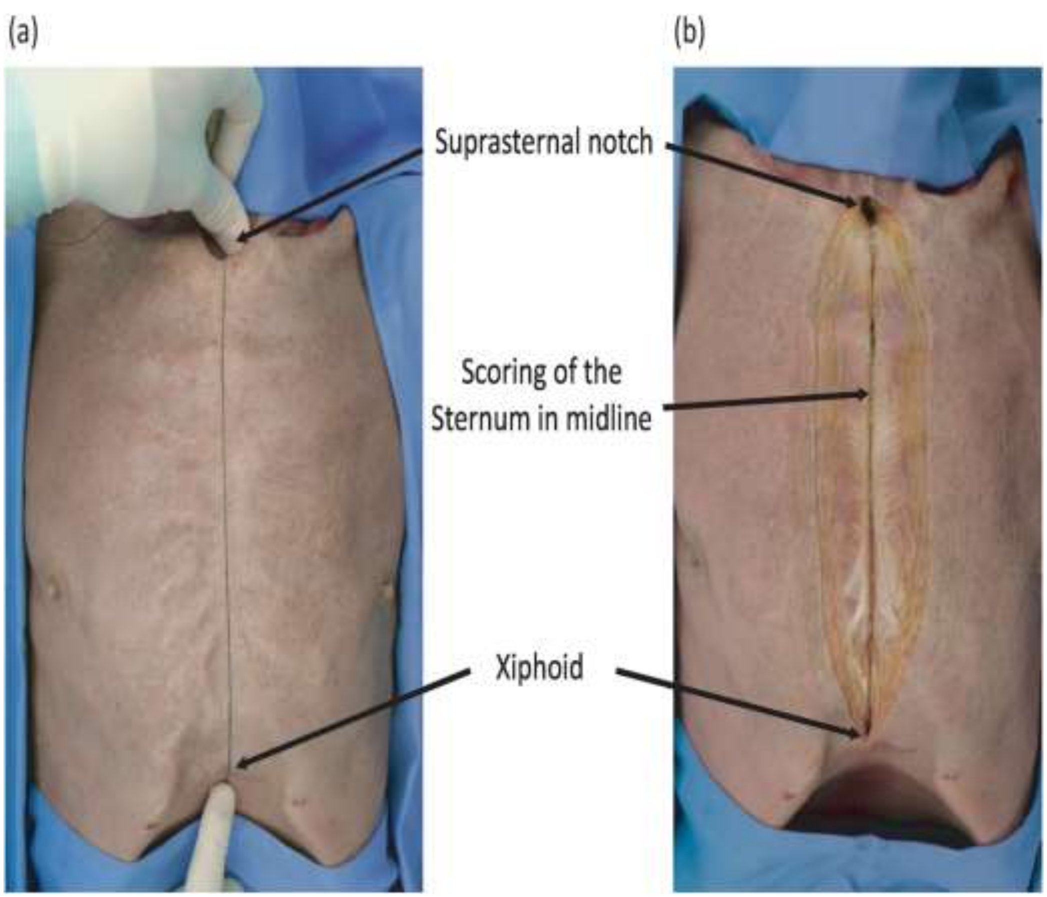


Figure (1): Identifying the xyphoid (A) and sternal notch (B) before incision,

(17). **(**

(a)

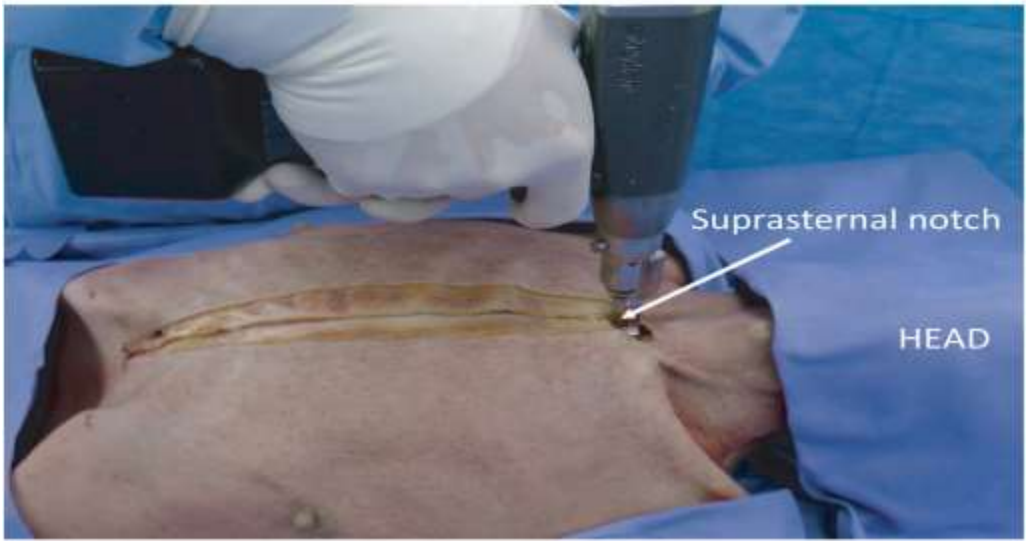
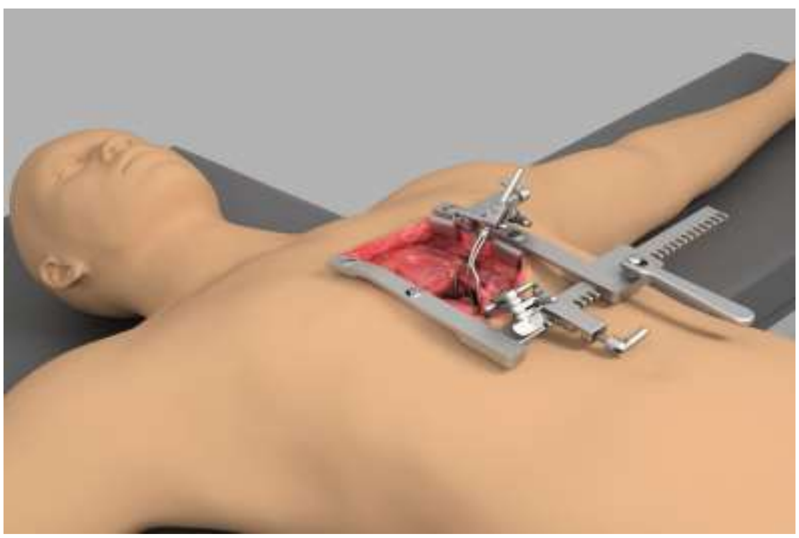


Figure (2): Electric sternal saw activated by foot pedal, **(17).**

Retraction:

The sternum is retracted slowly and progressively in order to avoid fractures. Initially the sternum will be retracted manually until there is enough room to insert a Finochietto retractor. Towels can be placed around the sternal edges for bleeding control and protection from retraction trauma. During retraction the sternopericardial ligaments are freed passively from the posterior surface of the sternum**, (17).**



2- Minimally invasive Aortic valve surgery:

Figure (3): Gradual opening of the sternum with Finochietto retractor. **(17). (MIAVS)**

Physicians remain reluctant to recommend AVR for elderly patients more than 80 years of age or those considered very high risk. Instead, many patients are continued on medical management or undergo a balloon aortic valvuloplasty. Unfortunately, these conservative therapies provide minimal or short-lasting symptomatic relief to the patient, eventually leading to restenosis of the aortic valve or sudden death.**(18)**

As a result, new techniques and technologies have been developed to enhance these outcomes, particularly in high-risk complex patients. As in other fields of medicine, a trend towards minimally invasive surgery has swept into cardiac surgery to achieve better results for the patients with the same quality as conventional median sternotomy**(19)**

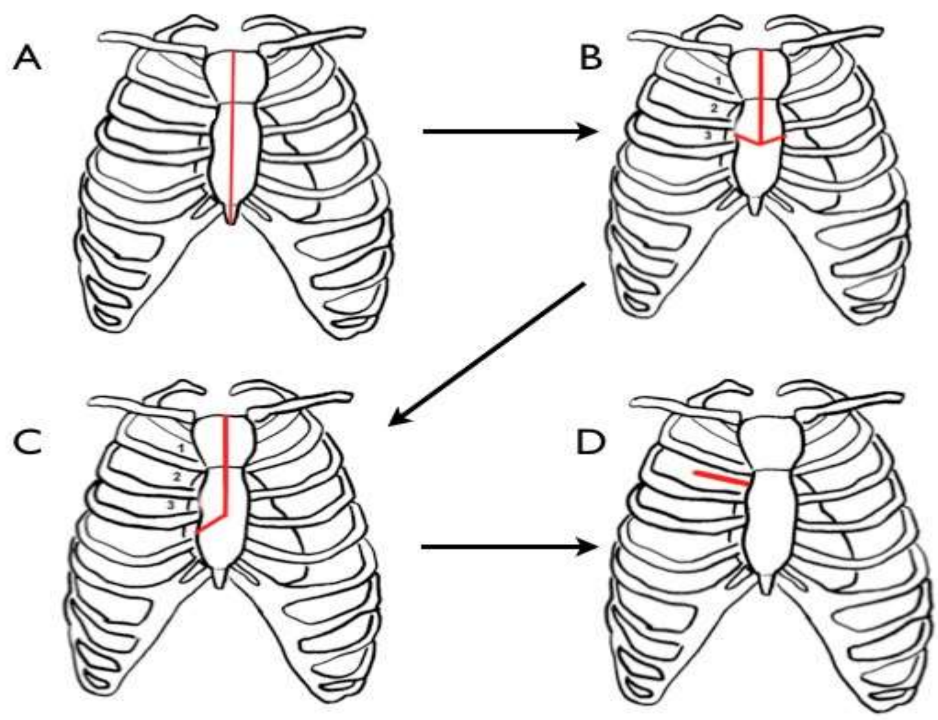
Approaches

Several minimally invasive approaches (including the right parasternal approach, upper and lower ministernotomy (MS), V-shaped, Z-shaped, inverse-T, J-, reverse-C and reverse-L partial MS, transverse sternotomy and right minithoracotomy,) have been developed for AVR since 1993 **(20**)

Minimally invasive aortic valve replacement (MIAVR) requires a coordinated effort by the surgeon, perfusionist, anaesthesiologist, cardiologists and nurses to achieve the best clinical outcomes. Intraoperative transesophageal echocardiography (TEE) is used routinely. A pulmonary artery catheter is employed based on patient risk and the specific operation. **(21)**

1- **J-shaped Mini-sternotomy for AVR:**

Upper J mini-sternotomy offers a great exposure of the superior mediastinal structures, and it is a viable option for performing MIAVR with the use of conventional instruments. Owing to its similarity to a full midline sternotomy, the process of achieving a J-shaped upper mini-sternotomy itself is relatively easy**. (21).**



Figure(4) A: Full sternotomy incision; B: Hemi upper sternotomy with 'T' incision; C: Upper hemisternotomy with 'J' incision; D: Non-sternal incision – right anterior mini-thoracotomy. 1,2,3 intercostal spaces.

Surgical technique of J-shaped mini-sternotomy:

This is the most common incison used for surgeons for MIAVS, may be the best approach for less-experienced surgeons. **(19)**

Under general anesthesia, with the patient in supine position, we perform a 5-8 cm midline skin incision**,** started one cm below the suprasternal notch, and extending downward. The sternum is divided vertically and then transected horizontally at the level of the right 3rd or 4th intercostal 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 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 **(22).**

Figure (5): Cosmetic mini-sternotomy wound for a male patient, underwent Aortic valve replacement.

2- Right Anterior Mini Thoracotomy (RAT):

RAT avoids sternotomy and is associated with a limited skin incision. However, the operative field is smaller and the aortic valve sits deeper within the wound. Exposure is enhanced by minimising cannula traffic within the incision via peripheral access, coupled with strategic placement of pericardial sutures. This approach is typically performed with a 4–6 cm incision through the second or third intercostal space**. (23)**

Advantages and Disadvantages

Randomised trials comparing conventional sternotomy to MIAVR face formidable challenges because of patient preference, surgeon bias and, importantly, the lack of a standardised surgical approach. Postoperative complications associated with a full sternotomy are practically possible with minimal invasive approach[16] In theory, avoiding full sternotomy should contribute to better post-operative stability of the sternum and thereby prevent deep infection and preserve respiratory function and mobility in the immediate post-operative period. A smaller area of exposed sternal bone marrow and periosteum may also minimise bleeding. Several retrospective studies have shown that MIAVS reduces exposure of surgical trauma to the patient, post-operative pain, blood transfusion, risk of renal failure, times for mechanical ventilation and, therefore, reduces intensive care length of stay. The hospital postoperative length of stay is also diminished. **(24)**

An important fact to emphasise is that the outcome and quality of the procedure are comparable or superior to the conventional open or full sternotomy procedures, including the risks of cerebrovascular events**. (25)**

Another potential disadvantage of MIAVR is the morbidity associated with peripheral cannulation, which may cause wound infection, pseudoaneurysms and neurological events. Nevertheless, the improvements in technique over time has decreased the morbidity of the procedure and allows surgeons to perform the procedure in high risk and elderly patients as more familiar approach and even better-than-predicted survival in this population. However, despite these procedures being potentially more expensive compared with full sternotomy procedures, the benefit is proven and it leads to a reduction in post-operative complications, shorter hospital stay and faster recovery, which should result in lower costs in the long term. **(21)**

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