

Review

Is not yet time to properly learn endoscopic mitral valve repair?

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ABSTRACT

Minimally invasive mitral valve surgery (MIMVS) was developed in the 1990s, but a systematic adoption of this procedure has been somewhat limited. The minimally invasive approach to the mitral valve has several advantages: a fewer blood transfusions, less pain, shorter ventilation time, shorter length of intensive care unit and hospital stay, earlier return to normal activities, lower risk of wound infections and cosmetic improvements. Despite the mentioned benefits, MIMVS was largely criticized because it is technically more complex and requires a long learning curve. Within the surgical complexity the most challenging aspect appears to be the possible development of serious complications.

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Todavía no es el momento adecuado para aprender cirugía mitral endoscópica?

RESUMEN

La cirugía mitral mínimamente invasiva (CMIVMli) fue desarrollada en los años 90, aunque la adopción sistemática de este procedimiento ha sido ligeramente limitada. El abordaje a la válvula mitral mínimamente invasiva tiene diversas ventajas: menor cantidad de transfusiones de sangre, menor dolor, menor tiempo de ventilación, menor estancia en la unidad de cuidados intensivos, retorno más temprano a las actividades normales, menor riesgo de infección de heridas, y mejoras cosméticas. A pesar de los beneficios mencionados, la CMIVMli ha sido ampliamente criticada debido a que es técnicamente más compleja y requiere una gran curva de aprendizaje. Dentro de la complejidad quirúrgica, el aspecto más difícil parece ser el posible desarrollo de complicaciones graves.

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Palabras clave:

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Introduction

Valvular heart disease (VHD) was not considered as a very serious problem in developed countries cardiovascular medicine for a long time: for that reason, almost 50% of VHD patients did not receive an appropriate treatment. Degenerative valve disease is the most common form of valvular heart disorder in Europe and in the U.S., whereas the incidence of rheumatic disease is predominant in developing countries and therefore worldwide.

Degenerative valve disease affects elderly people, as the world population ages the predominance of patients referred for surgery with VHD will likely be over 80'. The prevalence of VHD is around 2.5%: the mitral regurgitation (MR) is the most common and the aortic stenosis the second one.¹

Patients with MR may be asymptomatic for many years. When choosing the best treatment strategy, the following aspects need to be tackled:

- Natural history of the disease, including the presence of symptoms
- Preoperative determinants of postoperative outcome
- The morphology of the mitral valve
- Operative Risk for the individual patient in a specific center

Urgent surgery in MR is only required for patients with acute severe regurgitation as in case of chordal or papillary muscle rupture.

Chronic MR surgery however is indicated today to symptomatic patients with severe primary mitral regurgitation. Besides, a LVEF $\leq$ 60% or LVESD $\geq$ 45 mm, atrial fibrillation (AF) and a systolic pulmonary pressure $\geq$ 50 mmHg predicts a worse postoperative outcome, independent of the symptomatic status, becoming triggers for surgery in asymptomatic patients. There is strong evidence nowadays² showing that when AF is present, it is already a marker of negative prognosis and therefore an earlier indication is recommended. Watchful waiting is a safe strategy in asymptomatic patients with severe primary mitral regurgitation not related to flail and without any other surgical indications. However, require a very strict follow-up and echo assessment.

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Main text

It is commonly accepted that valve repair is the ideal treatment when the likelihood of a successful and durable repair is over 95% and the expected operational mortality rate is less than 1%. It was demonstrated that mitral valve repair provides better short- and long-term outcomes.³ When valve repair is not an option (for technical reasons), a mitral valve replacement with a strategy of preservation of the sub-valvular apparatus should be adopted. In the case of a functional MR,⁴ the optimal surgical approach remains controversial: mitral valve (MV) repair with an undersized complete ring to restore leaflet coaptation and valve competence has been for long time the preferred technique. However, valve replacement may be considered in the present day, mainly in patients with echocardiographic risk factors for residual or early recurrent mitral regurgitation.⁵

Full median sternotomy has been the standard cardiac surgery approach for over 50 years, providing an excellent exposure of the heart and great vessels and allowing central cannulation for cardiopulmonary bypass (CPB). Nevertheless, this approach is not appealing from the cosmetic point of view, requiring close to 3 months to complete the healing of the sternal fracture. In addition, it encompasses a considerable risk of sternal wound infection in some aged population.

Minimally invasive mitral valve surgery with “sternal sparing” strategies was introduced in the mid-1990s. It is valuable to avoid a full sternotomy as it uses smaller and alternative chest wall incisions, to reduce complications and aims to preserve the outcomes of the standard approach. The minimally invasive approach to the mitral valve has the advantages of fewer blood transfusions, less pain, shorter ventilation time, shorter length of intensive care unit and hospital stay, earlier return to normal activities, lower risk of wound infections and cosmetic improvements.

Despite these benefits, some surgeons argue that the reduced access and the difficult exposure of the surgical area makes minimally invasive MV surgery (MIMVS) more challenging. Additionally, the set-up for the minimal invasive technique is more time consuming and is usually limited to centers with extensive expertise.⁶

The major challenge for the centers that have adopted this procedure was to step out from the comfort zone of a safe and very well-established procedure and embark a new revolutionary procedure in the setting of mitral repair. The main deterrents against adopting a minimally invasive approach were:

1. Time consuming and poor visualization.
2. Not reliable complete myocardial and cerebral protection.
3. Technically more demanding.
4. Difficult de-airing.
5. Increased risk of reoperation for bleeding.
6. Risk of vascular complications.

Nevertheless, over the years, there has been a great development in lesser invasive techniques for heart valve surgery. These advances involve several smaller chest wall incisions: a right parasternal incision, transecting sternotomy, J-sternotomy (mini-sternotomy) and right mini-thoracotomy.

Cosgrove and Navia⁷ used a 10 cm right parasternal incision to expose the aortic and mitral valves. The technique included the resection of the third and fourth costal cartilages and sometimes sacrifice of internal mammary artery. This technique does not have a widespread use. Instead, the mini-sternotomy method, described by Svensson et al.⁸ offers a good exposure of the mitral and aortic valves and can easily be enlarged to full sternotomy when necessary. Nowadays this approach is more often used for aortic than for mitral surgery.

The right mini-thoracotomy (RMT) approach is performed through a small 4–6 cm right lateral incision, inframammary in men and in the sub-mammary crease in women, that is used to access the thorax through the fourth or third intercostal space. An alternative skin incision for mini-thoracotomy is the peri-areolar ‘nipple-cut’, which is safe, efficient and cosmetically appealing.⁹ In the RMT approach there is no sternal incision or fracture of the ribs. The surgeon inserts the surgical instruments through the incision with an excellent direct or video assisted visualization of the mitral valve. Additionally, the mini-thoracotomy approach has a cosmetic advantage over sternotomy, particularly in women. With this technique, the patient is connected to CPB by cannulation of the femoral artery and vein through the groin.^{10,11}

When needed a percutaneous jugular vein cannulation for bi-caval drainage and a catheter for endo-pulmonary venting and retrograde cardioplegia can be used and are useful tools to have in the armamentarium. Some authors advocate central cannulation of ascending aorta with a moderately bigger and superior approach to avoid retrograde arterial flow.¹² A trans-esophageal echocardiography (TEE) is always mandatory to confirm the optimal location of cannulas and to check the cardiac cavity as well as ventricular performances. We introduced in our center this approach in 1999, using a setup that included the use of fluoroscopy and trans-esophageal echo, to properly place the cannulas and catheters. We report the first 100 patients with mitral repair or replacements with 2% of mortality and less than 1% of neurological complication.¹³

Several different set ups were adopted in many centers regarding CPB, including strategies of aortic occlusion, the use of video-assistance and the adoption of robotics to perform the procedure.

Multiple improvements have taken place in video assistance strategy over the last years, such as full HD, 30° or 120° camera or today's full 3D vision.¹⁴

The thoraco-scope does not only provide an additional excellent vision along with magnification, but it also improves lighting of the surgical field. In addition, allows a full involvement of all the team in OR. The fully video-assisted thoracoscopic procedure for a MV disease is technically challenging, and its application is currently restricted to a handful of experienced surgeons because it requires a lengthy learning curve. Robot-assistance was introduced in 1998 for the surgery of mitral valve¹⁵ and represented a major advance in cardiac surgery, giving a better exposure to the mitral valve. Preliminary robotic systems consisted of a robotically voice-controlled endoscopic camera (AESOP; Computer Motion, Santa Barbara, CA, USA) with the use of long shafted equipment to perform surgery.¹⁶ Further development with the ZEUS (Computer Motion, Santa Barbara, CA, USA) and Da Vinci Robotic system (Intuitive Surgical, Sunnyvale, CA, USA) enabled 3D visualization and robotic telemanipulation with robotic ‘arms’ that simulated a natural wrist (with an augmented rotation) and finger movements, allowing to work inside the chest.¹⁷ It goes without saying that, robotic MV surgery is more technically challenging and expensive than standard minimally invasive surgery. Collective data from experienced centers in recent studies¹⁸ comparing 3 group of conventional surgery, minimally invasive approaches and Robotic-Assisted surgery, confirms that the latter offers with respect to conventional surgery: reduced blood loss, lower risk of incisional infection and AF, shorter hospital length of stay, quicker return to normal activities, and a superior cosmetic result. The robotic approach is usually associated with longer procedural times compared with the other techniques; requiring 27–45 min of additional cross clamp time and 36–77 min more of cardiopulmonary bypass time. The increase in procedural times between conventional, mini and robotic surgery is directly proportional to the operational complexities. Nevertheless, no big evidence exists today regarding a clear superiority of Robotic assisted surgery versus current minimally invasive approaches.

As anticipated, there are different techniques to occlude the aorta and protect the heart: transthoracic clamp (TTC) and endo-aortic balloon occlusion (EABO). Using the TTC technique, the aorta is occluded through a transthoracic direct clamp inserted through an additional port or directly through the working incision. A separate line into the ascending aorta is used for delivering cardioplegia. EABO technique, on the contrary, is based on the use of an endoluminal balloon catheter inserted through the femoral artery, that provides both aortic occlusion and cardioplegia. The main concerns about the use of the EABO technique is the risks associated to vascular complications and neurological events, a learning curve and a limited use in case of small arterial vessels. The incidence of neurological and vascular complications is directly related to the surgeon's experience and to a proper patient selection based upon anatomy and clinical history.¹⁹ EABO is extremely useful in case of redo or when the ascending aorta is difficult to reach. It also allows a true "keyhole surgery". Beside minimally invasive procedures, its use has been advocating in challenging surgeries for pseudo-aneurysm of ascending aorta.²⁰ TTC is cheaper and more conventional but assumes the risk of arterial wall damage, and bleeding from pulmonary artery, left atrial appendage or cardioplegia insertion site, which is always necessary.

Kowalesky et al., comparing endo-balloon and transthoracic clamp technique, in a recent meta-analysis²¹ suggested:

1. Endo-balloon clamping was associated with a significant increase in the relative risk of vascular complications and leg ischemia. Complications occurs more frequently when surgeons have an initial experience with endo-balloon and lack an adequate learning curve, which is mandatory.
2. There were no significant differences in cross-clamp and cardiopulmonary bypass timing using both techniques.
3. There was no significant difference in the occurrence of cerebrovascular accidents, mortality, and acute kidney injury between endo-balloon and transthoracic clamping.
4. Better pre-operative patient evaluation is crucial to predict complications with femoral cannulation and perfusion.

Minimally invasive mitral valve surgery (MIMVS) was developed in the 1990s, but a systematic adoption of the technique has been somewhat limited. MIVS has become a treatment for many patients with MV insufficiency: in the United States, its use has increased from 11.9% in 2004 to 20.1% in 2008 and in Germany, from 13.1% in 2004 to 45.2% in 2013 and to more than 50% in 2017.²²

An increasing number of patients choose for a minimally invasive surgery because of the observed advantages: pain reduction and quicker recovery has been demonstrated in several studies. Other reported benefits of a minimal invasive approach include less bleeding, reduced atrial fibrillation, decreased wound infections, and shorter hospital stay. This technique has also shown a low morbidity and mortality²³ in comparison to big series of standard mitral surgery approaches. Its use could be specially interesting in the setting of redo surgeries. Full sternotomy in re-operation for valve diseases can be technically challenging particularly in cases of patent coronary graft or enlarged right cavities. MV redo surgery with a minimally invasive approach is a valid alternative allowing less surgical trauma, pain, blood loss and need for transfusions, which translates into reduced length of hospital stay.²⁴

Despite the mentioned benefits, minimally invasive mitral valve surgery was largely criticized because it is technically more complex and requires a long learning curve. Within the surgical complexity the most challenging aspect appears to be the possible development of serious complications associated with peripheral cannulation: retrograde aortic dissection is a rare but life-threatening complication that may arise from this cannulation method. Heart-Port World Wide Registry reported aortic dissection in 11 of

610 patients undergoing Port-Access surgery, a number that was superior to the incidence of aortic dissection after conventional cardiac surgeries.²⁵

In 1998, Mohr et al.²⁶ published a preliminary study revealing serious complications in a series of 48 patients who underwent minimally invasive surgeries and EABO: hospital mortality rate was 9.8%, transient ischemic attack rate was 7%, acute retrograde aortic dissection was reported in 3.9% of patients, and 5.8% of patients required reoperation for para-valvular leakage. Aortic dissection events were probably caused by the guide wire transit that created an intimal tear, increased by retrograde flow that led to a complete vessel dissection. It is fair to say that the rate of these complications at the very early stage of their experience was related to the limited surgeon and team expertise with the Port-Access system, the difficult use of Fluoroscopy and TEE during the placement of catheters and the quality of the device being extremely stiff and inflexible at that time. The same team published in the following years^{27–29} several reports, with TTC, of excellent long-term results with a low rate of complications and drastically decreased conversion to sternotomy. After these initial studies the real efficacy and safety of minimally invasive approach and of the EABO were evaluated with very few randomized trials and several meta-analysis or propensity score matched investigations.

In 2005, Dogan and colleagues³⁰ published the first prospective randomized study about video-assisted Port-Access technique, comparing it to standard surgery: in this study Port Access technique was reported to be more time consuming, even if the differences were not statistically relevant. The CPB and cross-clamp time were similar. An important result was that no patient demonstrated clinical evidence of myocardial ischemia, indicating a similar quality of myocardial protection in both techniques. Furthermore, no permanent neurologic deficit was described. Before this study, Schneider and colleagues³¹ had reported a similar experience, not observing significant differences in the stroke rates between patients undergoing Port Access or conventional surgery. It is important to point out that before randomization the surgical team at that time had a very limited experience with the minimally invasive port access technique, and some of the technical problems reported in these series may be attributed to the learning curve.

In 2010, Gammie and coauthors³² with their analysis of STS database reported a markedly higher rate of permanent perioperative stroke in patients who underwent minimally invasive surgeries compared to the conventional sternotomy group. Supplementary analyses demonstrated:

1. Threefold higher risk of stroke for MIVS performed without aortic occlusion (on beating- or fibrillating-heart).
2. Femoral cannulation was not independently related to increased risk of stroke.

In 2011, a meta-analysis (Cheng et al.) including 35 comparative studies compared MIMVS clinical outcomes and resource utilization to conventional open mitral valve surgery. The mortality rate was comparable at 30 days, 1 year, 3 years and 9 years. Some clinical outcomes were significantly improved with MIMVS including atrial fibrillation, chest tube drainage, number of transfusions, sternal infection, time to return to normal activity and scar cosmetic results. However, the 30-day risk of stroke (2.1% vs 1.2%) and aortic dissection/injury (0.2% vs 0%) were significantly increased for MIMVS compared to the standard procedure. Cross-clamp time, cardiopulmonary bypass time, and procedure times were increased with the minimally invasive method but ventilation time and length of stay in intensive care unit and hospital were reduced.³³ A longer CPB and Clamping time is usual in all reports comparing MIMVS and conventional Surgery.

Nevertheless, this does not give the impression to predict a negative clinical impact.

In 2014, a systematic review (Sunderman et al.) and meta-analysis³⁴ investigated more than patients who underwent MV surgery from 45 different studies. An important outcome was that stroke rate (1.7% vs 1.6%) and all-cause mortality up to 30 days was similar in MIMVS and classic MV surgery. Postoperative new AF was inferior in MIMVS group (probably related to reduced right atrial manipulation) and only four patients presented an aortic dissection. The rates of re-exploration and postoperative renal failure were similar in both groups. In contrast to the precedent cited studies, specifically the meta-analysis by Grammie and Cheng and colleagues,³³ this report showed that MIMVS group of patient did not have an increase stroke rate compared with the conventional surgery. The initial negative results were probably the consequence of the learning curve in the centers involved in the earliest reports.

Nevertheless, after more than 20 years from MIMVS introduction, this technique is performed in around 25% of isolated MV surgery. This situation is probably caused by the above-mentioned studies that reported an increased number of negative outcomes. In addition, the transition to MIMVS requires a supplementary training, even for established mitral valve surgeons. Furthermore, the need for different perfusion cannulas, advanced 2D or 3D video-assistance, and surgical instruments require an economical investment to start a MIMVS program.

It is important to remind that adopting any new technique requires a learning curve, so if this point is not considered, the results are not quite realistic. Casselman et al.³⁵ defined the learning curve at 50 consecutive MIVS cases, founding very favorable outcome data associated with MIMVS using EABO. The 30-day mortality rate of a series of 500 patients was 1.4%, the major stroke rate was only 0.8% and no aortic dissections occurred. These results are in big contrast with the precedent literature and the main reason of these differences is that, only in this study, surgeons were all fully experienced with minimally invasive mitral valve surgery (at least 100 patients operated with this technique). Later, in 2018 a multi-center propensity-matched study³⁶ of 1278 patients from England proved that there is no difference between MIVS and sternotomy with regards to reintervention-free survival out to 8 years. In the MIMVS group, patients had a reduced need of blood transfusion and reduced postoperative length of stay.

Conclusion

- CBP and Clamping times of MIMVS uses to be longer than conventional surgery's' in all studies.
- Early and mid-term mortality outcomes are always similar.
- Aortic dissection and neurological outcomes are currently similar (except for the earlier study from Cheng et al.³³ and Gammie et al.³²).
- Rate and durability of repair outcomes are excellent with MIMVS.
- Bleeding and transfusion rates of MIMVS compared to conventional surgery are always reduced.

The use of minimally invasive approaches in mitral valve repair is safe, is useful and allows excellent long-term results.

Besides the fact that CPB and Clamping time appear to be always longer in all reports, the clinical results are excellent in reducing blood transfusion, length of stay and improving postoperative recovery. Earlier concerns related to high rate of neurological negative outcomes and vascular complications are not confirmed in more recent series, where experienced surgeons employ improved material following strict protocols after an adequate learning curve. Good training before embarking in new procedures, especially in MIMVS, is mandatory.

Conflict of interest

The authors declare that they have no conflict of interest.

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