Current concepts for minimally invasive mitral valve repair

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ABSTRACT

Minimally invasive mitral valve repair is based on several procedural concepts. Recently, three of them have been intensively discussed: aortic occlusion strategy, use of Goretx-Neo-Chordae to repair mitral valve regurgitation and feasibility and efficacy of the minithoracotomy approach in mitral valve treatment of patients after previous cardiac surgery. Twenty years of experience in minimally invasive mitral valve repair have enabled high-volume centers to present valid data and give their recommendations. Transthoracic aortic clamping with ante- and retrograde cardioplegia in the primary setting and hypothermic fibrillation in reoperative setting are currently favoured means of myocardial protection. Neo-chordae concept of mitral valve repair has gained general recognition and has become the technique of choice for many surgeons. The excellent results of minimally invasive mitral valve repair must be considered whenever already available or any new transcatheter techniques are offered.

Keywords: mitral valve repair, minimally invasive, aortic clamping, myocardial protection, hypothermic ventricular fibrillation.

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INTRODUCTION

The number of surgeries performed using less-invasive techniques has increased dramatically over the last two decades. While the minimally invasive approach has become the standard of care for many surgical procedures in the thoracic, abdominal and pelvic cavities, this shift was initially slower in cardiac surgery, since most heart operations are very complex, requiring not only cardiopulmonary circulation but also outstanding precision to achieve successful results. Advancements in diagnostic tools, development of specific cardiac endoscopic instruments, the introduction of peripheral cardiopulmonary bypass circuitry systems and novel surgical techniques have enabled cardiac surgeons to start operating on the heart through very small incisions. Among the different areas of cardiac surgery, the minimally invasive approach has gained particular popularity in the field of mitral valve (MV) treatment. After initial reports in late ‘90s suggesting that the right-sided minithoracotomy approach to MV can be used with relative safety and efficacy, high volume centers have recently presented their excellent results based on
their experiences on thousands of patients (1-4). The minimally invasive approach was shown to provide at least equivalent results to those achieved via sternotomy with both in-hospital mortality and stroke rates under 1% in isolated MV disease (5). Providing the option of a small incision with favourable cosmetic effect without the disadvantage of inferior durability or surveillance drives further development of minimally invasive access and changes the treatments paradigms in favour of patient treatment at earlier disease stage before adverse effects of MV disease appear.

Minimally-invasive MV repair is based on several procedural concepts, which have undergone significant development since this technique was applied for the first time in animals in the early ‘90s and several years later in humans (1, 6). This article briefly describes three methods, which have been frequently discussed in the literature recently:

1) internal and external aortic occlusion;
2) use of Goretx-Neo-Chordae to repair MV regurgitation;
3) feasibility and efficacy of the minithoracotomy approach in MV treatment of patients after previous cardiac surgery.

**Aortic occlusion**

Effective and non-traumatic occlusion of the ascending aorta is a challenging procedure that requires experience, especially in the settings of atherosclerotic changes and fragile aortic walls in older patients. Due to improvements in the diagnostic radiology, we can identify patients at increased risk for aortic cross-clamp complications preoperatively and adjust the treatment strategy accordingly. Iatrogenic aortic rupture or dissection, a potential fatal complication of cross-clamp injury, is a catastrophic disaster, which may lead to death or serious neurologic complications, even in the operating room.

Fortunately, these serious complications only occur sporadically during open-heart procedures (7, 8). The first endoscopic MV procedures were performed by applying endoluminal aortic clamping with an endoaortic balloon (1, 9).

This promising approach, however, was disappointing at first, leading to fatal aortic injury in a significant number of patients (1, 2). However, careful patient selection and numerous modifications to the endoaortic balloon have led to better results, such that it has become a feasible concept of aortic occlusion. Nevertheless, surgeons partially accepted it, since the incidence of aortic dissection due to balloon occlusion still ranges between 0.3-1.4% (9-11).

The unfavourable results of aortic endovascular occlusion have led Chitwood and coworkers to develop a clamp that can be introduced through intercostal spaces and, if carefully applied under video assistance, enables a secure grasp of the aorta (12). Potential problems, which may occur when the ascending aorta is clamped, are injury to the aorta, the main or right pulmonary artery and the left atrial appendage.

Furthermore, aortic cross-clamping requires a purse-string suture on the ascending aorta for antegrade cardioplegia delivery and aortic root venting, which can lead to bleeding from this cannulation site. Mohr and colleagues reported, in one of the largest published series of patients undergoing minimally invasive MV surgery, that bleeding was the most common indication for conversion to sternotomy (13). The authors concluded that the Chitwood clamp should be placed very carefully and under ongoing visual examination of the ascending aorta and the left atrial appendage. In case of any difficulties in placing the clamp, early full sternotomy should be considered.

Studies comparing both endovascular aortic occlusion and transthoracic cross-
clamping are limited. A 12-year experience from the East Carolina University and University of Pennsylvania (479 patients with endovascular aortic occlusion vs 573 patients with transthoracic aortic clamping) revealed that the incidence of aortic dissection and strokes was higher when endoaortic occlusion was applied, even though this difference was not statistically significant (1.5% vs 0.4%, p = 0.09; 2.7% vs 1.2%, p = 0.08) (14). Similarly, Reichenspurner et al. reported higher incidence of bleeding in patients who underwent aortic endoclamping (6/60 vs 1/60) and recommended the use of the transthoracic clamp for initial surgery and endovascular aortic occlusion for redo endoscopic MV surgery (15). In contrast, Loforte et al. did not find iatrogenic dissection or intraoperative bleeding in a series of 138 patients (93 transthoracic aortic clamping vs 45 endoaortic balloon occlusion) (16). Further studies are necessary to provide an ultimate recommendation on the strategy of aortic occlusion. Whenever aortic clamping is judged to be unsafe due to adhesions or severe atherosclerosis, hypothermic fibrillation as a means of myocardial protection may be an alternative. This method has received particular attention recently, when minimally invasive MV surgery was expanded to patients with previous sternotomy. Chitwood et al. (1996-2006, 167 redo cases) used hypothermic fibrillation in 77% of these patients without serious complications necessitating sternotomy and with no cerebrovascular accidents (17). Similarly good results were presented by the Leipzig group (18). They operated on 181 patients with previous cardiac surgery, avoiding aortic clamping in 77% of their patients with an acceptable postoperative stroke rate of 3.8%. Hypothermic fibrillation seems to be a safe alternative to aortic cross-clamping and endovascular occlusion.

**Goretex neo-chordae with premeasured loops in MV repair**

MV repair achieves better results compared with valve replacement therapy (19, 20), and is thus the procedure of choice for almost all types of mitral regurgitation. There is a variety of MV repair techniques available. Leaflet resection achieves excellent results when used to treat prolapse of the posterior leaflet, the most common pathology (4, 21). As far as more complex valve regurgitation is concerned, other techniques must be applied, like chordal shortening transposition, papillary muscle sliding plasty, papillary muscle shortening, commissural plication, remodeling ring annuloplasty or Alfieri edge-to-edge repair (21). These techniques allow surgeons to perform reconstructive surgery in almost all patients with MV regurgitation. Recently, more attention has been paid to the construction of neo-chordae using PTFE sutures (Gore-Tex, W.L. Gore & Associates, Flagstaff, AZ), which was introduced 20 years ago by David et al. (22).

This technique provided excellent results, but did not obtain broad clinical acceptance due to difficulties in achieving a reproducible neochordal length. This difficulty was even more pronounced when surgeons tried to apply this technique via a minimally invasive approach. In 2000, Mohr et al. introduced the “loop technique” to address these limitations, which consisted of a pre-manufactured pledget with 4 single 5-0 Gore-Tex loops (23). The pledget was sutured to the papillary muscle and the ends of the loops were then fixed to the leaflet segments. The length of the loops was chosen according to the distance measured between edge of normal non-prolapsing segment and the tip of the papillary muscle. In treatment of anterior leaflet prolapse, the most common neo-chordae length is 21 mm. Loops used for repair of
the posterior leaflet are usually 14 mm in length. Neo-chordae undersizing is more reasonable than oversizing, because in non-beating hearts, the distance between the reference non-prolapsing segment free edge and the papillary muscle may easily be overestimated.

Furthermore, the appropriate loops length is strongly influenced by left ventricular size and location of stitches in the papillary muscle.

One decade of experience with the “loop technique” has made possible the analysis of early- and mid-term results on a significant number of patients. Kuntze et al. reported on 522 patients who underwent minithoracotomy and MV repair using premeasured loops, showing excellent results with 99% 30-day survival and 0.6% late cardiac reoperations in a mean follow-up period of 18 months (24). Recently, a prospective randomized trial was performed to compare the neo-chordae technique with leaflet resection for posterior MV prolapse (25).

The authors concluded that the loop technique may be superior to leaflet resection because it resulted in a significantly longer line of leaflet coaptation and might therefore be more durable.

On follow-up, both techniques showed excellent valve function in the majority of patients. The surgical society is currently awaiting long-term follow-up results, which are expected to confirm the efficacy and durability of the pre-manufactured neo-chordae concept in the MV repair.

**Minimally invasive MV repair in patients with previous cardiac surgery**

Operating on MV in patients who have undergone previous cardiac surgery is challenging and associated with an increased rate of perioperative morbidity and mortality. The conventional access through a median sternotomy may lead to mortality of 26% in patients with previous aortic valve replacement (26) and 9%-14% in patients with previous coronary artery bypass grafting (27, 28). Encouraged by their growing experience with minimally invasive techniques, an increasing number of surgeons is opting to apply the minithoracotomy access to reoperative patients. Their interest is also driven by the fact that while good exposure through a sternotomy is challenging, particularly in patients with prior aortic valve replacement, it is not an issue in right-sided lateral minithoracotomy.

Additionally, avoiding extensive dissection, especially in patients with functional coronary artery bypasses, significantly reduces the risk of redo procedures.

When the minimally invasive approach was applied for the first time in patients with previous cardiac surgery, efficient myocardial protection was a challenge. There are several strategies that can be safely adopted in the redo setting. One option is endovascular aortic occlusion as described by Casselman et al. (29). Another is to carefully dissect the ascending aorta away from the pulmonary artery and to clamp the aorta transthoracically. Finally, one method that is currently gaining increasing acceptance is hypothermic fibrillation arrest, which circumvents the need for aortic clamping and cardioplegia delivery.

This technique is especially valuable in case of patent coronary bypasses, but necessitates a competent aortic valve. The concept of hypothermic fibrillation has become the preferred approach due to its simplicity and reliable myocardial preservation (17, 18).

Several centers that have introduced minimally invasive MV surgery have recently reported their results in the reoperative settings. Arcidi et al. presented outcomes of 167 patients with a 30-day mortality of
3% and no conversion to sternotomy or aortic dissection (17). Similarly, excellent results were presented by Seebürger et al. who analysed data of 181 consecutive patients and reported a 6.6% in-hospital mortality and conversion to sternotomy in 3 patients (18).

In both centers, the minimally invasive approach has become the preferred method to correct MV regurgitation in patients with prior cardiac surgery.

CONCLUSION

For two decades, we have borne witness to the ongoing development of minimally invasive MV repair. This technology is based on several concepts, which have proven their superiority over the conventional sternotomy approach. Recently, high-volume centers have published their experiences on minithoracotomy MV repair.

They have given their recommendations for aortic occlusion strategy, presented novel valve repair techniques and proved the feasibility of minimal invasive access in reoperative settings.

At the moment, transthoracic aortic clamping with ante- and retrograde cardioplegia in the primary setting and hypothermic fibrillation in reoperative setting are favoured myocardial protection techniques. The neo-chordae concept of MV repair has gained general recognition and has become the technique of choice for many surgeons. Increasingly, minimally invasive approach is the preferred means to correct MV regurgitation in patients with prior cardiac surgery.

The excellent results of minimally invasive MV repair will have to be considered whenever already available or new transcatheter techniques are offered to a wider group of patients.

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