Minimally Invasive Valve Surgery: When Less Is More

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Sternotomy has been the gold standard in cardiac surgery and generally provides and unobstructed view of the heart. However, expertise in this traditional method may no longer suffice for the professional survival of cardiac surgeons, We must consider minimally invasive approaches to treating diseases of the heart. As such, the focus of this article will be on the past, present, and future of mini-valve surgery.

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INTRODUCTION

Sternotomy has been the gold standard in cardiac surgery and generally provides an unobstructed view of the heart. This is the currently used method in which all surgeons are trained and perform cardiac surgery across the world. However, expertise in this traditional method may no longer suffice for the professional survival of cardiac surgeons. Owing to mounting evidence of fast recovery and cosmetic appeal, percutaneous approaches mostly spear-headed by cardiologists, including transcatheter aortic valve replacement and MitraClip, are replacing traditional methods. This transition may threaten the role of surgeons in treating diseases of the heart. To remain relevant, we must acknowledge patient demand for less intrusive procedures and proactively learn and adopt new effective technologies into our practices. In addition to percutaneous procedures, minimally invasive valve surgery (mini-VS) is the much-needed paradigm shift for our continued central role in patient care.

Since the first minimally invasive valve surgery, critics and skeptics have argued that it was less effective relative to traditional full sternotomy procedures. They reasoned that the smaller incision results in a smaller operating field of vision as well as space and thus hinders surgical execution. They have claimed that minimally invasive surgery required conforming the patient to the procedure. With the development of new techniques and experience, mini-VS has proven to be equivalently effective to sternotomy-based approaches and applicable to almost all cardiac pathologies. mini-VS represents a potentially new area of expertise for surgeons to remain relevant.

In order to provide patients with the most effective standard of care, cardiac surgeons must learn to adapt to the changing technological landscape. In addition to staying active on learning percutaneous technologies, they must consider adopting minimally invasive approaches widely to treat diseases of the heart, namely minimally invasive aortic valve surgery (mini-AVS) and minimally invasive mitral valve surgery (mini-MVS). As such, the focus of this article will be on the past, present, and future of mini-valve surgery.

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PAST: HISTORY AND EVOLUTION

Ludwig Rehn conducted the first successful heart surgery on September 9, 1896, in Frankfurt, Germany.[1,2] A self-taught surgeon, he overcame the widely held pessimism of the period on the possibility of heart surgery and successfully performed a cardiorrhaphy on a 22-year-old man who had been stabbed 2 days earlier. By 1907, Rehn[3] accumulated 124 cases of heart suture repair with 60% mortality rate.[1] His work dispelled the notion that cardiac

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wounds were mortal and any surgical intervention impossible.[1]

Theodore Tuffier conducted the first successful valve surgery in 1912 by using his fingers to reach the stenotic aortic valve of a 26-year-old male patient.[4] The first successful mitral valve operation was a mitral valvulotomy using a teratomy knife; this was conducted by Elliott Carr Cutler at Brigham and Women's Hospital (Boston, MA) in 1923 on a female patient with mitral valve stenosis.[5-7] The first multivalvular operation was consecutive closed mitral commissurotomy and tricuspid commissurotomy by Trace et al[8] in 1952, followed by a combined mitral and tricuspid commissurotomy by Brofman in 1953.[9] The same year, John Gibbon conducted the first successful open heart surgery using his Model II heart-lung machine on a 18-year-old woman with a large secundum atrial septal defect.[10] Disheartened by subsequent failed operations, Dr Gibbon soon gave up open heart surgery, but his machine enabled to continue work by others, including Lillehei et al[11] who successfully repaired multiple valvular lesions with cardiopulmonary bypass (CPB) and right thoracotomy.[10]

Since Rehn's first cardiac surgery, major advancements in aortic and mitral valve surgeries have been achieved by applying developments in other medical fields to cardiac surgery, improving techniques and tools, and incorporating imaging and automated assistance during surgery to enable mini-AVS and mini-MVS.

Open cardiac surgery was implemented soon after the development of the heart-lung machine by John Gibbon in the early 1950s, whereby diseased valves could be repaired by annuloplasty or replacement with prosthetic mechanical valves.[10,12] New techniques for mitral annuloplasty emerged during the 1960s,[13-15] along with the invention of annuloplasty rings during the 1970s.[16,17]

The first trials of minimally invasive techniques in cardiac surgery occurred after the success of the laparoscopic cholecystectomy in the early 1990s. In 1993, Rao and Kumar[18] successfully conducted the first minimally invasive aortic valve replacements in 2 female patients through a right anterior thoracotomy. Soon thereafter, Cosgrove et al[19] at the Cleveland Clinic Foundation reported on mini-AVS or mini-MVS via right parasternal incision in 50 patients in 1996,[20] followed by documentation from Cohn et al[21] (Brigham and Women's Hospital) on minimally invasive aortic and mitral repair or replacement via right parasternal incision or ministernotomy in 1997. Both groups reported higher patient satisfaction and a reduced need for blood transfusions, suggesting the potential benefits of minimal invasive surgery compared with conventional median sternotomy.[21,22]

In 1997, a new system called Port Access (Heartport Inc, Redwoods, CA) revolutionized minimally invasive cardiac surgery. Port Access was a system composed of special catheters, cannulas, and long-shafted surgical instruments that enabled heart surgery through small intercostal incisions (ie, ports) combined with an endovascular cardiopulmonary system; this enabled cardiac surgery to become even less invasive. Initial trials demonstrated a high morbidity and mortality due to a steep learning curve, which was partially resolved with increased training and incorporation of video assistance.[23,24] Although the company eventually failed, Port Access represents the birth of the minimally invasive cardiac surgical approaches we know today.

Incorporation of video and robotic assistance greatly improved the initial success of mini-surgical procedures. In 1996, Carpentier et al[25] first used video assistance in mitral valve repair via minithoracotomy. Chitwood et al also incorporated video assistance into mini-MV repair and replacement surgeries, along with percutaneous transthoracic aortic occlusion, retrograde cardioplegia, and peripheral arterial perfusion.[26,27] In 1998, Falk et al[28] reported successful solo surgeries with voice-controlled robot assistance using 3-dimensional video incorporation (AESOP 2000; Computer Motion, Santa Barbara, CA) into the Port Access system.[24] The same year, Carpentier et al[29] became the first surgeons to conduct open heart surgery using the da Vinci telemanipulation system (Intuitive Surgical, Sunnyvale, CA).

Overall, mini-VS has numerous benefits relative to full sternotomy valve surgery. The patient experience is significantly more positive; studies consistently note improved cosmesis,[30] less pain and discomfort,[21,30-34] reduced need for postoperative analgesics,[21] and shorter hospital length of stay with quicker return to normal activity.[21,27,31,34-38,40] Some benefits also may translate to cost savings.[20,21,27,36] Patients also experience reduced incidence of wound infection,[37,39] less blood loss,[27,34,38] reduced need for blood transfusions,[21,28,35,37,39] and less need for reexploration[27] or reoperation[27,36,38,40,41,43] because of bleeding. Relative to sternotomy, mini-VS is also safe and beneficial in elderly patients.[37,44] Of note, there are no significant differences between the 2 methods in mortality rate[31,36,37,39-41,43] or incidence of atrial fibrillation (AF).[27,34,38,40-42,]

PRESENT: TECHNIQUES AND APPROACHES

mini-VS is not a single surgical technique or procedure, but rather a different philosophy with a