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EDITORIAL

State of the Art Review: Videoscopic Minimally Invasive Mitral Valve Surgery. Trekking to a Totally Endoscopic Operation.

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"Nothing will ever be attempted if all possible objections must be first overcome"

–Samuel Johnson

"Difficulties mastered are opportunities won"

–Winston Churchill

All Aboard-Minimally Invasive Cardiac Surgery-A Reality!

In the last several years patients and surgeons alike have become energized by the potential for correcting various forms of heart disease with minimally invasive surgery (MIS). Despite rapid, multiple advances in minimally invasive techniques in other surgical specialties, cardiac surgeons have lagged behind in developing minimal access methods. However, with circumspect reticence, less invasive cardiac surgery is now emerging and rapid advances are being made both in Europe and the United States. Despite controversy, in only two years, many cardiac surgeons have learned to both replace and repair valves and graft coronary arteries through small incisions with increasing safety and expertise [Baldwin 1998, Verrier 1998, Lytle 1996].

What has catapulted these efforts into a worldwide momentum? Advances in cardiopulmonary perfusion, cardiac arrest techniques, instrumentation, and intra-cardiac visualization have hastened this technologic shift. Cardiac MIS remains in constant flux with changes and improvements being introduced almost on a daily basis. The simultaneous development of the Internet and arrival of the Information Age has widened this effort immensely [Chitwood 1996]. Dendritic connective roots have sprouted internationally, and the field has evolved much more rapidly than ever would have been possible in former years. Daily global forum discussions, via surgeon-driven communication networks such as The Heart Surgery Forum™ and CTSNet, have aided greatly in developing minimally invasive cardiac surgery. Clearly, the Internet has allowed us to communicate our successes and failures in real time and more rapidly than ever before possible. Vibrant discussion and excited interactions between surgeons, anesthesiologists, and industry engineers at the NewERA conference in Palm Springs this past January typified the innovative spirit present within our specialty today. Major surgical societies such as the American Association for Thoracic Surgery, European Association for Cardio-Thoracic Surgery, and Society of Thoracic Surgeons are recognizing the importance of these new techniques and serve as expert peer review platforms, as do their counterpart journals. The international quality in the development of minimally invasive cardiac surgery also resounds through the new International Society for Minimally Invasive Cardiac Surgery (ISMICS). This organization is a direct outgrowth of the excitement and curiosity of surgeons worldwide who want to find safe, new treatment methods with less operative trauma.

Despite earlier widespread skepticism, several centers already have shown that minimally invasive approaches to cardiac valve surgery can achieve less morbidity and more rapid recovery [Loulmet 1998, Chitwood 1997, Cosgrove 1996, Cohn 1997a, b, Koenertz 1996]. Intra-operative myocardial preservation has been shown to be excellent during most of these operations [Schwartz 1997]. Newer endovascular aortic occlusion techniques offer promise. However, early complications and costs have limited the expanded use of these innovative methods [Schwartz 1997, Mohr 1998]. Although minimally invasive methods may vary between centers, with patient cohorts and techniques remaining disparate, early results are encouraging. Nonetheless, long-term benefits still need to be defined. Most cardiac surgeons are carefully awaiting analyzed data before adopting a lesser invasive philosophy. It is my belief that enough data now exists to show that by the turn of the century, minimally invasive approaches will supplant or at least modify most current valve operations, especially for isolated valvular disease. Presently, several leading academic centers including New York University, Brigham and Women's Hospital, Loma Linda University, the Cleveland Clinic Foundation and our group at the East Carolina University School of Medicine now prefer minimally invasive techniques as the standard approach for single primary valve disease as well as selected reoperations. Thus, a new era in cardiac valve surgery appears to be upon us. Where

Table 1. Micro-mitral Operation

Current Patient Selection
Suitable Candidates
•Patients with Primary Mitral Valve Disease
•Reoperative Mitral Valve Patients
•Obese or Large Patients
•Elderly patients
Unsuitable Candidates
•Repair Candidates with Significant Anterior Leaflet Prolapse
•Highly Calcified Mitral Annulus
•Multiple Valve Operations
•Severe Pulmonary Hypertension especially with a small right coronary
•Significant Untreated Coronary Disease
•Severe Peripheral Atherosclerosis

will the trek towards minimally invasive valve surgery lead? What will be the role of endoscopic or closed chest operations? Will there ever be a "Totally Endoscopic" valve operation?

Video-assisted Minimally Invasive Mitral Valve Surgery: The Micro-Mitral Operation

In February of 1996, Carpentier performed the first video-assisted mitral valve operation using ventricular fibrillation [Carpentier 1996]. Three months later, our group at East Carolina University School of Medicine (ECU) performed a videoscopic mitral valve replacement using cardioplegic arrest, which appears to have been the first such operation performed in the United States [Chitwood 1997b]. Since that time, we have performed a total of sixty-two minimally invasive video-assisted mitral valve replacements or repairs. To denote the small atrial incision (only 3 centimeters) and intra-cardiac instrument manipulation using videoscopic guidance, we have coined the phrase "Micro-mitral" operation [Chitwood 1997b]. An overview of our surgical technique and results in our initial 31 patients were published previously [Chitwood 1997a, b]. There have been no operative deaths and only one late death from arrythmia. Of these patients, 55% underwent repairs, most of which were less complex than in our transsternal series. Both blood transfusion and ICU requirements have been markedly reduced when compared to our sternotomy cases. Hospital length of stay has averaged only 3.5 days for Micro-mitral patients. There have been few major complications and after our initial learning curve each procedure can now be performed with similar effort to traditional sternotomy based operations. However, the minimally invasive approach does require approximately one hour more of total operative time. At our institution we have had no perfusion mishaps and no incidences of retrograde aortic dissections. Table 1 shows our present inclusion and exclusion criteria.

In previous publications we have outlined the principles of patient positioning, intubation, cannulation, and cardiopulmonary perfusion used at our center for performing the Micro-mitral operation (see Figure 1, ◉) [Chitwood 1997a, b]. In this inaugural issue of The Heart Surgery Forum™ multimedia journal, we can now illustrate from the surgeon's visual perspective each key step in the sequence of this new operation using video clips from an actual surgical case. The CD-ROM enclosed within the front cover of this issue provides the same view of the procedure as seen through the endoscope during an actual Micro-mitral procedure. (To view the enclosed surgical movies, please follow the disk insertion and loading instructions inside the front cover).

The Micro-mitral operation begins with cardiopulmonary bypass established through femoral arterial and venous cannulas inserted under direct vision using the Seldinger technique. The heart is accessed through a 6 centimeter right lateral minithoracotomy (or "instrumentation port") made in the 4th intercostal space at the anterior axillary line. In a number of patients we have been able to avoid femoral venous cannulation by inserting a single stage cannula directly into the right atrium and utilizing vacuum assisted venous return. For patients with severe aorto-iliac disease, we have been able to directly cannulate the distal ascending aorta and perform anterograde arterial perfusion. Either a 5-mm two-dimensional endoscopic rod-lens camera system with screen monitor or a Vista three-dimensional digital camera with a head-mounted display is used for intracardiac visualization and guidance of instrument manipulation. Aortic cross clamping is performed through the intact chest wall using a special transthoracic clamp with sliding rod design (Scanlan International, Inc., St. Paul, MN) (see Figure 2, ◉). Standard anterograde cardioplegic arrest is used for myocardial preservation. Valve excision, suture placement, valve or annuloplasty ring seating, and knot tying are performed with videoscopic visualization and instrumentation.

The video presentation on the accompanying CD-ROM disk fully illustrates a recent mitral valve replacement using the Micro-mitral technique in a woman with pulmonary hypertension (65/35 mm Hg) secondary to severe calcific mitral stenosis (valve area 0.7 cm^2 and trans-valvular gradient of 18 mmHg). The initial movie segment shows the intercostal incision with mild interspace retraction using the Thora-Lift® device (US Surgical Corp, Norwalk, CT). A standard anterograde cardioplegia needle is inserted into the anterior surface of the aorta near the cardiac base facilitated by videoscopic guidance. The transthoracic cross-clamp is inserted through a tiny (4 millimeter) third intercostal space incision and positioned carefully using videoscopic direction. The immobile "prong" of the clamp is carefully passed posterior to the aorta and across the transverse sinus, with special attention to avoid injury to the right main pulmonary artery. The video clip accompanying this editorial clearly illustrates the technique of clamp application and videoscopic inspection of the final position. The insertion of the cardioplegia needle and positioning of the clamp takes no longer than five to eight minutes and we have not experienced any clamp injuries.

Exceptional visualization of the mitral valve and subvalvar apparatus is provided by the endoscopic camera or the Vista digital viewing system. For most cases, we have used a standard 5-mm thoracoscope with 3 chip camera inserted

through a 4th interspace port. The left atrium is entered through a small (3 centimeter) incision just in front of the superior pulmonary vein. This incision may seem quite small when compared to the generous atriotomy typical of transsternal mitral surgery, but endoscopics and digital camera systems provide the illumination and magnification to make the cardiac anatomy more visible than ever before. Retraction of the left atrial roof and inter-atrial septum is performed with a ribbon retractor for thin patients or a trans-thoracic retractor in the anterior chest wall for corpulent patients. Patient size has not been a factor in selection of Micro-mitral candidates.

It has been our general policy to leave as many chordae tendinae as possible during mitral replacement, either open or endoscopic, to preserve diastolic ventricular contour and systolic ventricular function. In the case presented in this multimedia editorial, the leaflets of the calcific, stenotic mitral valve were excised videoscopically, including the anterior chords. Supra-annular pledgeted mattress sutures were placed using a specialized needle holder with short jaws to prevent needle slippage. Odd angled needle positioning is often required in videoscopic mitral surgery, especially for left fibrous trigone/commissure area sutures. After preplacement of all sutures, the threads are passed through a 29-mm prosthesis extracorporeally, and then the valve is slid down the suture bundle into position against the annulus. The prosthetic sewing ring is tightened against the annulus and knots secured using a knot tying instrument specially designed for valve implantation (Scanlan International, Inc., St. Paul, MN). Lastly, air is displaced from the left atrium, pulmonary veins, and ventricle by carbon dioxide insufflation. After left atrial closure, evacuation of residual air is performed by aortic root venting monitored by transesophageal echocardiography.

A Trek to Totally Endoscopic Cardiac Operations

Surgeons reviewing this work and that of others will have to be the judge as to the possibility and widespread application of a truly endoscopic mitral valve operation. Several talented surgeons are already on this journey. Dr. Vanermin in Aalst, Belgium, Dr. Mohr in Leipzig, and Dr. Reichenspurner in Munich have had similar successes and are comfortable with video-assisted mitral surgery. Moreover, surgeons here at the East Carolina University School of Medicine have performed "video-directed" or completely endoscopic mitral valve replacements working solely through a three-dimensional camera with a head-mounted display. Further enabling technology is just around the corner, including robotic surgical instruments with scaled motion and tremor suppression, flexible intracardiac articulating robotic arms, voice-activated camera manipulation, and improved three-dimensional visualization and display technologies. Recently, Professor Fredrich Mohr at the Herzcentrum in Leipzig, Germany reported solo videoscopic mitral operations with a thoracoscopic camera controlled by robotics [Mohr 1998]. These same authors have also performed experimental robotically assisted coronary anastomoses and mitral valve repairs. On May 21, 1998, Drs. Carpentier and Loulmet at Broussais Hospital in Paris performed the world's first truly robotically assisted mitral valve operation in a human patient using the Intuituve Surgical system. The following week (May 28, 1998) Professor Mohr performed four mitral operations using the same flexible "wrist-like" device. I was present in Leipzig to assess the capabilities of this adjunctive instrumentation in preparation for trials in the United States. The Intutitive robot features a control console in which the surgeon immerses him/herself in images of the surgical field projected from an endoscope onto an enclosed viewing screen. The surgeon "operates" by manipulating a pair of intra-corporeal surgical arms using discrete finger-tip sensors and controllers while seated at the console across the room from the patient. The arms of this system contain mechanical "wrists" which allow natural motions and exceptional degrees of freedom of the intra-corporeal instruments. Although modifications in electronics and mechanics must be made with a view toward miniaturization, it is clear to me that robotic instrumentation such as the Intuitive system may provide the bridge to truly endoscopic cardiac operations

Thus, within the last two years cardiac MIS has developed from a random concept to efficacious application. The current enthusiasm of surgeons worldwide, combined with "light-speed" technologic development and communications, appears to be propelling us toward even less traumatic and possibly "micro-invasive" cardiac operations in the future. Yes, the spirit of innovation for better patient care is in the air! The modern technical revolution in cardiac surgery is evolving so rapidly that traditional multipatient clinical trials have not been performed and most information remains anecdotal. Just recently, some series of patients are beginning to be collected and analysis of these data should be enlightening.

We must continue to ask ourselves are these new methods really benefiting our patients through reduced trauma, fewer complications, more rapid recovery, or better long-term results when rigorously compared to traditional operations? Our results must have both a compassionate and statistical meaning. To protect these end points for minimally invasive cardiac surgery, a healthy mix of scientific skepticism and wisdom must be exercised through discussion forums, society meetings, and especially peer reviewed journals like The Heart Surgery Forum™ and the Annals of Thoracic Surgery. Yes some of us believe that "micro-invasive" reconstructive cardiac surgery will become a reality. However, the trek up Mt. Everest is far from over;we have only just arrived at "base camp".

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