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APPLICATION OF DIFFERENT MINI-INVASIVE TECHNOLOGY IN CARDIAC SURGERY

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Abstract
In the modern era of cardiac surgery, most operations have been performed via midline sternotomy using artificial circulation. However, this paradigm is changing as minimally invasive techniques are increasingly utilized in cardiovascular surgery. Advances in patient assessment, instrumentation, and operative techniques have allowed surgeons to perform a wide range of complex operations through smaller incisions and, in some cases, without artificial circulation. Given that patients desire less invasive surgeries and the literature supports reduced blood loss, shorter hospital stays, less postoperative pain, and better cosmetic outcomes, minimally invasive cardiac surgery should be widely practiced. In this article, we review the incisions and approaches currently used in minimally invasive cardiovascular surgery.

Keywords Cardiac surgery, minimally invasive surgery, valve surgery.

INTRODUCTION

Along with the broader surgical community, cardiovascular surgery is in the process of constant evolution of techniques in the 1990s the world first became aware of minimally invasive valve surgery, which has influenced virtually all types of cardiac surgery performed today,which has been an evolution for cardiologists[1]. With the increasing patient interest in minimally invasive procedures, it is more important than ever for surgeons to keep abreast of the most common minimally invasive techniques in cardiac surgery.

In this article, we will review the most commonly used incisions and approaches, focusing on aortic valve, mitral valve, and aortocoronary bypass procedures[3].

Hemisternotomy

Minimally invasive accesses to the aortic valve can be performed using a wide range of incisions, with the most commonly used access being the hemisternotomy, usually J-shaped to the right fourth intercostal space. In this method, a midline incision is made at the sterno-manubrial junction and extended 4-5 cm downward [2]. The necessary exposure of the sternum can be achieved without enlarging the skin incision by undermining the soft tissues both above and below. A standard sternal saw is then used to divide the sternum along the midline to its smooth curve and entrance into the fourth intercostal space. Although extending the incision to the fourth intercostal space is the most common approach, the specific intercostal space used can and should be customized to the patient[4]. For example, suitable exposure may be possible using the third intercostal space in a lean patient, whereas the fifth space may be required in an obese patient. Aortic root exposure is also possible with a sternotomy in the fifth intercostal space, making this access useful in a wide range of aortic valve and aortic root surgeries. After crossing the sternum and dissecting the mediastinal tissues, a vertical pericardiotomy is performed and the edges of the pericardium are sutured to the skin. This allows complete anterior retraction of the mediastinum and maximizes exposure of the aorta[5].

One advantage of the hemisternotomy is that it allows a variety of cannulation strategies, from fully central to purely peripheral. Columbia University uses standard centrally placed cannulas for the ascending aorta and right atrium, as well as drainage of the right superior pulmonary vein and, if desired, a retrograde catheter for cardioplegia[7]. This method is the same as that used in total sternotomy surgery; it minimizes the number of new techniques that must be learned to perform the procedure successfully. Exposure and visualization can be maximized by withdrawing the venous cannula inferolaterally, suturing through the chest wall with a needle hook, using low-profile aortic cross-clamps, and placing the patient in a steep reverse Trendelenburg position. Despite this, cannulation can also be performed through the femoral artery and vein by placing a pulmonary artery vent or retrograde cardioplegia catheter peripherally from the neck. Completely peripheral cannulation minimizes potential obstructions in the operative field, but requires considerable experience on the part of the anesthesia and perfusion teams[9].

Some reports suggest that taking cannulation to the periphery of the field provides adequate visualization and workspace without the additional technical challenges associated with peripheral cannulation. Once cannulation is achieved, the remainder of the operation is performed in a standardized manner[10].

Right anterior thoracotomy

Another minimally invasive access to the aortic valve is the right anterior thoracotomy. This operation is more commonly used in mitral valve surgery, in addition it can also be used in aortic valve surgery, which avoids sternotomy, and provides less exposure as the aortic root and valve are more difficult to see and reach from this angle. Right anterior thoracotomy usually requires more sophisticated and active monitoring via esophageal echocardiography at least for peripheral cannulation and in some cases for peripheral insertion of retrograde cardioplegia catheters or pulmonary vein ventilation[11].

The technique of right anterior thoracotomy is performed using a 4-6 cm long incision is made along the medial surface of the right third intercostal space, dissecting the underlying tissue and entering the pleural cavity[12]. Because of the medial incision, ligation of the right internal mammary vessels is usually required at this stage, and separation of the third or fourth rib from the sternum may be necessary to ensure adequate exposure. The pericardium is then opened anteriorly from the diaphragmatic nerve and a pericardiotomy is performed to the diaphragm below and to the pericardium above. A cannula for antegrade cardioplegia is inserted directly through the primary incision, and a transthoracic aortic transverse clamp is inserted through the stab incision, after which the disconnected rib is sutured to the sternum. The surgeon should consider the frequent need for rib-cartilage disarticulation and rib fractures that are associated with this access[13].

Operations performed on the mitral valve

Right parasternal access for minimally invasive mitral valve surgery has been used by some authors. A few years later, other cardiac surgeons performed via right-sided thoracotomy, where alternative approaches such as hemisternotomy, left thoracotomy and right minithoracotomy were developed; of these, right-sided minithoracotomy is the most widely used in current clinical practice[14].

Right minithoracotomy

Right minithoracotomy is recognized as the most commonly used incision in minimally invasive mitral valve surgery and is now the standard minimally invasive access in most centers. Several retrospective studies have evaluated outcomes after mitral valve surgery via right minithoracotomy[15]. Benefits including a better view of the valve, reduced risk of infection due to the well-vascularized superior pectoralis muscle and lack of sternal separation, shorter hospitalization. stay, less postoperative bleeding, and less postoperative pain[16].

To access the mitral valve through right-sided minithoracotomy, an inframammary incision of 4-6 cm in length along the mid axillary line is made for primary access and supplemented with stab incisions if necessary [17]. This primary incision is made 1-2 cm below the nipple in men and approximately 1 cm above the breast crease in women, followed by soft tissue dissection directed cranially to the chest wall to allow access to the chest cavity through the fourth intercostal space. The incision is usually made medially to minimize the working distance to the valve, but not as medially as in aortic valve surgery, shifting the incision slightly laterally results in a wider view of the valve but at the expense of greater surface distance. The ideal location to maximize working distance and visualization of the valve can be altered according to the surgeon's preference. Once the primary incision is made, stab incisions are used to introduce accessory instruments[18].

In our practice, two small puncture incisions are made a few intercostal spaces below the main incision to guide the carbon dioxide insufflator and suction pump during the procedure and the pleural drainage tube afterward. If desired, a 5 or 8 mm videoscope can be introduced through one or more incisions, both of which are located along the anterior axillary line. To improve exposure of the heart, the right hemisphere of the diaphragm is withdrawn downward by suturing its tendinous dome and bringing it to the skin through the seventh to eighth interval with a needle-hook apparatus[19].

The pericardium is then opened, starting a few centimeters anteriorly from the right diaphragmatic nerve, and the pericardiotomy is continued down to the diaphragm and up to the ascending aorta. The anterior edge of the pericardium is withdrawn with sutures to the medial aspect of the skin incision, and the posterior edge is withdrawn with sutures brought to the skin with a needle hook. A transthoracic Chitwood clamp is then inserted through the stab wound in the third interval along the right medial axillary line and prepared for possible atrial retraction by inserting a retractor through the chest wall medial to the primary incision. This retractor may be self-retaining, as in devices that attach directly to the chest wall with screw clamps, or may be held in place with table clamps [20]. Although cannulation during artificial circulation can be performed in a completely peripheral fashion. Similar to minimally invasive aortic surgery, the use of central cannulation minimizes both the amount of new techniques required to adopt the entire procedure and the expertise required of other members of the surgical team, such as anesthesia and perfusion. In particular, the avoidance of peripheral arterial cannulation and endoaortic balloon occlusion not only simplifies and shortens the procedure, but also eliminates the risk of complications such as retrograde aortic dissection, retroperitoneal hemorrhage, and lower extremity ischemia[21].

In minithoracotomy, cannulas for aortic, superior vena cava, antegrade cardioplegia, and retrograde cardioplegia can be placed centrally through the primary incision, leaving only the inferior vena cava cannula to be placed peripherally. Some surgeons perform a multistage venous cannula through the femoral vein using the Seldinger technique under PEE control, supplementing if necessary with a standard rectangular cannula inserted through the primary incision into the superior vena cava. In reviewing the various literature, we believe that although this degree of central cannulation reduces the technical complexity and simplifies the entire process, it still creates the potential for difficulty in visualization or movement during the procedure. Other authors believe that cannulation involves a fully peripheral and hybrid design, with the aortic and venous cannulas placed in the periphery and the cannulas for antegrade and retrograde cardioplegia remaining in the center[22].

After cannulation of the patient and initiation of artificial circulation, mitral valve exposure can be started with dissection of Sondergaard's sulcus. Once the aorta is clamped, the left atrium is opened and the anterior left atrium and septum are retracted forward using one of the types of retractors described above. One technique that helps to maximize visualization is to place a retraction suture mainly using 3-0 monofilament, approximately one centimeter from the P3 portion of the mitral annulus in the inferior wall of the left atrium[23]. This suture is then led out of the left atrium, behind the inferior vena cava (through the oblique sinus) and out of the thorax laterally. This serves both to drain the excess inferior wall of the left atrium away from the valve and to improve the view of the inferior valve. Other work by cardiac surgeons where used a similar technique placing the transthoracic retractor as close to the sternum as possible to prevent the left atrium from sliding off the retractor and away from the surgeon. Paying special attention to the left internal mammary artery, which may be injured by this maneuver, the valve is approximated a few centimeters by placing several thick sutures on the posterior aspect of the mitral annulus, as is done during annuloplasty, and attaching them to the surgical band. After detection, valve repair or replacement is performed in the standard way of valve replacement, the atriotomy is closed in the standard way and cardiac dehiscence is performed under ChEE monitoring[24].

There is much debate about de-aeration in minimally invasive surgery, which consists of using carbon dioxide insufflation in each case followed by an extensive de-aeration protocol performed under the supervision of a PEE that involves positioning the patient in deep Trendelenburg during aortic unclamping, aggressive cardiac volume loading, positive pressure ventilation to clear pulmonary venous air, and alternating left and right table positions to remove air trapped beneath the interventricular septum. After de-aeration, electrodes for cardiac pacing are placed, local nerve blockade is applied, and the chest is closed[25].

Robot-assisted mitral valve surgery

The history of foreign colleagues in the development of telemanipulation technology in the 1990s paved the way for robotic valve surgery, and in 1998 Karpente i Mor independently reported the first cases of robotic mitral valve plasty. The technique evolved rapidly, and over the next 2 years Mexmnesh and colleagues performed the first closed endoscopic mitral valve plasty, Grossi and colleagues performed posterior leaflet repair, and Chitvud and colleagues performed posterior leaflet resection followed by reconstruction. and colceal annuloplasty[26]. In addition to the potential benefits of minimally invasive surgery, numerous groups have reported additional benefits of robotic surgery, including three-dimensional visualization, ambidextrous, tremor filtration, motion scaling, and even smaller incisions. Results after robotic mitral valve surgery in a prospective multicenter phase II trial involving 112 patients showed an 8% incidence of postoperative grade 2 mitral regurgitation and a 5.4% reoperation rate. Columbia University Medical Center used in the first US trial of robotic-assisted mitral valve surgery and is currently performing the procedure developed by Professor Chitwood via a 5-6 cm right submammary minithoracotomy that enters the chest through the fourth intercostal space[27]. This incision is similar to that used in the previously described minithoracotomy, and intrathoracic preparation in our center is performed in the same manner. As discussed previously, cannulation for artificial circulation can be peripheral or central. Aortic occlusion can be performed either by transthoracic aortic clamping or by endo-aortic balloon with continuous carbon dioxide insufflation in the operating field. Usually, two robotic arms are inserted into the chest through 10-mm trocar incisions[13]. The right instrument is inserted 4-6 cm lateral to the thoracotomy site in the fourth or fifth intercostal space, and the left instrument is placed medial and cranial to the right instrument in the second or third intercostal space. A distance of 6 cm is maintained between the levers, and the alignment of the levers with the valve plane is optimized to allow unrestricted movement of the instruments[17].

A stereoscopic endoscope with a 30 degree angle of view is inserted through the medial part of the thoracotomy, leaving the remaining part of the incision as a working port for the assistant on the patient's side. If desired, the third arm can also be used as a dynamic retractor. When the patient is on artificial circulation, the left atrium is accessed by a left atriotomy through the interatrial sulcus and the valve is exposed using a transthoracic intraatrial retractor. Valve repair, atriotomy closure, disconnection from artificial circulation, de-aeration and closure can then be performed in the usual way[23].

Aortocoronary bypass

Aortocoronary bypass remains the gold standard for coronary revascularization and is still predominantly performed via median sternotomy with little change in the overall invasiveness of the procedure[11].This is due to several factors that complicate this procedure when performed through small incisions, including the technical requirements of delicate vessel dissection and suturing, the difficulty of exposing multiple regions of the heart, internal thoracic arteries, and aorta, and the long operative time. Despite these problems, experience with minimally invasive aortocoronary bypass surgery is growing[17].

CONCLUSIONS

In summary, since the 1990s, minimally invasive techniques have been used for a wide range of cardiac surgeries. Over the past two decades, numerous sources have demonstrated the feasibility, safety and efficacy of minimally invasive cardiac surgery and supported its integration into clinical practice. The Vakhidov Republican Specialized Scientific and Practical Medical Center for Surgery is one of the leading centers for the treatment of congenital and acquired heart defects, where all methods of operative cardiac surgical treatment available to modern medicine are offered. Excellent technical equipment, as well as highly qualified specialists provide the best conditions that guarantee an individual and optimal approach to the treatment of each patient.

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