Video-atlas on robotically assisted mitral valve surgery

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Introduction

Mitral valve surgery is the most commonly performed robotically-assisted cardiac surgical procedure. The robotic approach evolved from minimally invasive mitral valve surgery, which was performed via right mini-anterolateral thoracotomy either under direct vision or with endoscopic visualization. The da Vinci™ Surgical System (Intuitive Surgical Inc., Sunnydale, CA) has been used in several robotic cardiac surgical centers to successfully perform mitral valve surgery. This system uses high-definition three-dimensional camera imaging and Endowrist™ (Intuitive Surgical, Sunnydale, CA) instruments, which allow for motion in six degrees of freedom. When compared with minimally invasive mitral valve surgery, the robotic-assisted approach enables unparalleled visualization of the mitral valve apparatus, tremor-free movements, ambidexterity, and avoidance of the fulcrum effect of using long-shafted endoscopic instruments. The 2 to 3 cm lateral working port incision allows for less pain, quicker recovery, and reduced length of stay when compared with sternotomy.

This video article provides a detailed description of our current approach to performing complex mitral valve surgery using the da Vinci™ system.

Operative technique

The patient is positioned supine on the operating table (*Video 1*). After induction of anesthesia, the patient is intubated with either a double lumen endotracheal tube or bronchial blocker, allowing for right lung isolation. A 17 French venous drainage cannula is introduced via the right internal jugular vein and advanced to the superior vena cava/right atrial junction. A Swan-Ganz catheter is also introduced.

Three-dimensional transesophageal echocardiography (TEE) is then performed on each patient. The mitral valve pathology can be carefully evaluated, and high-quality three-dimensional images are used to produce a topographic model of the valve. This allows formulation of a careful and highly accurate repair plan, before making any incisions.

The patient is then positioned right side up, 30° from horizontal. A 3 cm incision is made in the 4th intercostal space, directed medially from the anterior axillary line (AAL). This working port incision is used for both access and camera insertion. Access to the pleural cavity is attained. We use an Alexis™ (Applied Medical, Rancho Santa Margarita, CA) soft tissue retractor, which aids greatly in exposure. A single pledgeted stitch can be placed in the central tendon of the diaphragm and used to retract the diaphragm inferiorly via a stab incision in the chest wall. However, this step is not needed in most cases and can be a potential site of bleeding. Robotic arm trocars are introduced, the first for the right arm in the 5th intercostal space at the anterior axillary line, the second for the left arm in the 3rd intercostal space slightly anterior to the AAL, and the third for the dynamic atrial retractor in the 4th intercostal space, two finger breadths from the mid-clavicular line. In addition to standard monitoring devices, defibrillator pads are placed. Sonometric pads are placed on both lower legs to measure oxygen saturation in the right leg after arterial cannulation.

We then expose the right femoral artery and vein for cannulation. After heparinization, a 17 or 19 French Biomedicus™ (Medtronic, Minneapolis, MN) cannula is used for arterial inflow, and a 22 to 25 French Biomedicus™ venous drainage cannula is placed, followed by placement visualization using TEE. In cases of small femoral artery or aortoiliac

atherosclerosis, we cannulate the right axillary artery using a side arm graft cannula.

The da Vinci™ system is then docked. The camera can be introduced either via the working incision in the 4th intercostal space or via a separate trocar placed medial to the working incision. Cautery scissors are used to open the pericardium, after identifying the phrenic nerve. This incision should be made 3 to 4 cm anterior to the phrenic nerve and should extend from the SVC pericardial reflection to the diaphragm. We then place a superficial pledgeted pursestring suture (3-0 Goretex™) in the anterolateral surface of the ascending aorta, and secure a cardioplegia cannula at this site. The Chitwood crossclamp (Scanlon International, Minneapolis, MN) is introduced via a stab incision in the posterior axilla, and used to carefully cross-clamp the ascending aorta. Cold Brettschneider crystalloid cardioplegia is used to arrest the heart. In re-operative cases or in cases with extensive ascending aortic atherosclerosis, we use hypothermic (26 ℃) fibrillatory arrest as our myocardial protection strategy.

We then dissect Sondergaard's grove, exposing the entry of the right pulmonary veins into the left atrium, and sharply perform a left atriotomy. A dynamic Endowrist™ atrial retractor is introduced, and the mitral valve is visualized. The robotic arms allow complex repair techniques to be easily implemented, including triangular resections, folding valvuloplasties, neochord placement, chordal transfer, papillary shortening procedures, and of course annuloplasty band placement. We have also successfully performed mitral valve replacements using the da Vinci™ system (*Video 2*). Previously, we tied all suture knots intra-corporeally; however, we now use the Cor-Knot™ suture device (LSI Solutions, Victor, NY) to secure annuloplasty bands and valve prostheses.

We secure a bipolar ventricular pacing wire to the posterior surface of the right ventricle, as well as atrial pacing wires if needed. We generally introduce two drains; a 24 French Blake drain positioned anteriorly along the mediastinum, and a 28 French right angle chest tube postero-lateral to the lung. The drains are tunneled through the chest wall via the prior robotic arm trocar incisions. Patients are generally extubated within a few hours following the procedure. Drains are removed between postoperative days 1 and 2, and pacing wires are removed by postoperative day 3. The average length of stay at our institution is 3 to 4 days.

Comments

Our institution has performed over 800 robotic mitral valve procedures to date. The results for the first 540 cases have been published (1). Of these, 454 patients underwent a lone mitral repair and 86 had a concomitant atrial fibrillation ablation. The average cross clamp and cardiopulmonary bypass times were 116 and 153 minutes respectively in the lone mitral repair patients. The group operative mortality was 0.4%. The mean follow-up period was 351 days (15-946 days), and 2.9% of patients required a reoperation for a failed repair.

Arrest and cardiopulmonary bypass times have improved with ongoing experience. Our institution participated in two subsequent Food and Drug Administration (FDA) investigational device clinical trials, which led to the approval in 2002 of the da Vinci™ surgical system for mitral valve surgery in the United States (2,3). In the first FDA trial, the average cross clamp time was 150 minutes. In the second multi-center FDA trial, the average cross clamp time fell to 126 minutes, and there was little variation in operative time between centers. After implementation of the Cor-knot device, the average cross clamp time has decreased to 94.7 minutes (P<0.02) (4).

In addition to the previously mentioned benefits of using the da Vinci™ surgical system (i.e., improved dexterity, six degrees of freedom, tremor-free movements, ambidexterity, etc.), the system greatly improves operative visualization through the use of three-dimensional high definition imaging. Visualization of the mitral valve in particular is unparalleled when using the da Vinci™ system, compared to minimally invasive or sternotomy approaches.

To date, the smallest incisions for mitral valve surgery have been accomplished when using the da Vinci™ system. Benefits of this decrease in operative stress include less pain, improved cosmesis, quicker return to recovery, and decreased length of stay. Mihaljevic *et al*. reported a decrease in length of stay of 1 day relative to sternotomy and 0.9 days relative to minimally invasive approach for 261 robotically-assisted mitral valve repairs performed between 2006 and 2009 (P<0.001) (5). There were no in-hospital deaths, and neurologic, pulmonary, and renal complications were similar among groups. Similar reductions in length of stay were seen at the University of Pennsylvania, where 39 patients who underwent sternotomy and mitral valve repair or replacement were compared with 26 patients who underwent robotically-assisted mitral valve repair or replacement (6). Patients who underwent robotic-assisted surgery experienced shorter mean duration of postoperative hospitalization (7.1 *vs*. 10.6 days; P=0.04), despite longer cross-clamp and bypass times (110 *vs*. 151 minutes; P=0.0015; 162 *vs*. 239 minutes; P=0.001, respectively). Mean packed red blood cell transfusion was also lower among patients who underwent robotic-assisted mitral valve surgery (2.8 *vs*. 5.0 units; P=0.04).

Relative contraindications to a robotic approach include extensive pleural adhesions, poor pulmonary function, poor ventricular function, aortic regurgitation, and pectus excavatum. Many surgeons prefer the traditional sternotomy in high risk patients with comorbidities such as poor left ventricular function, given the increased operative times associated with robotic surgery historically. However, we have shown that in experienced centers with refined techniques and skilled robotic teams, operative times are comparable to sternotomy, with no increase in risk and shortened length of stay. Improvements in technology and instruments will continue to improve operative times for robotic surgery. We have had success in patients with poor ventricular function, likely owing to the overall decrease in operative stress when compared with sternotomy. However, the sternotomy approach is still preferred in patients with severe pulmonary disease or pulmonary hypertension.

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