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Anesthetic Management of Robotic Assisted Cardiac Surgery

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Abstract

INTRODUCTION

In the past decade, the image of cardiac surgery has been totally changed by the evolution of a number of technologic advances, most notably the development of minimally invasive techniques, including minimally invasive direct coronary artery bypass (MIDCAB), off-pump coronary artery bypass (OPCAB), and minimal access valve surgery. But all these techniques have their limitations and did not improve overall mortality of cardiac patients comparing to the standard bypass technique.

Minimally invasive cardiac surgery has recently moved one step forward by the introduction of computerized tele-micromanipulator which is also known as the surgical robot. Using that device, surgeons can manipulate small instruments, which are inserted through small chest incisions, while he or she is away from the patient, achieving many of the technical manoeuvres previously possible only with open exposure.

Since the introduction of robotic surgery in our hospital, it became part of cardiac surgery. Robotics is bringing minimally invasive techniques to operations that otherwise would require extensive incisions and long recovery times when done by standard open-chest methods. It offers the potential for minimal scarring, dramatically reduced recovery times, less suppression of the body's immune system, reduced transfusion requirement and reduction in stress response compared to open procedures ([1]). Using robotics, the surgeons have been able to utilize minimally invasive techniques for harvesting the left internal mammary artery (LIMA) for coronary artery bypass.

The Da Vinci Surgical System (Intuitive Surgical, Inc. of Sunnyvale, CA), consists of two primary components, the surgeon's viewing and control console and the surgical arms that are used to perform the surgery. These pencil-sized instruments, equipped with tiny, computer-enhanced mechanical wrists, are designed to duplicate and enhance the dexterity of the surgeon's forearm and wrist at the operative site through entry ports less than one-half inch in diameter (Figure 1).

Figure 1

Anesthesia for Robotic cardiac surgery requires special consideration. As left internal mammary artery (LIMA) harvesting is done on a beating heart in a normothermic patient, myocardial protection becomes a challenge. In off-pump coronary artery bypass grafting ischemic preconditioning has been used for myocardial protection if the target coronary vessel is not totally occluded ([3]). One lung ventilation (OLV) and carbon dioxide insufflation (Capnothorax) is required during LIMA harvesting. OLV can reduce cardiac output, increase pulmonary vascular resistance and produce hypoxia and hypercarbia ([4]). Direct access to the heart is impossible during the robotic procedures; therefore, external defibrillator pads are positioned prior to induction to anesthesia ($_5$). The position of the pads will have to be changed depending on the surgical approach ($_1$). In certain cases where pacing may be required, a transvenous pacing wire is inserted along with the pulmonary artery catheter ($_5$).

In this report, we present our initial experience with ten patients who underwent cardiac surgery by the new Da Vinci Surgical System.

PATIENTS AND METHODS

Ten patients ASA class III and IV were enrolled in this initial experience for harvesting of the LIMA. All CABG patients presented with a significant stenosis of the LAD artery (>50% stenosis) requiring surgical revascularization after difficulties to dilate and stent in cardiac catheter laboratory (CCL) due to various reasons. None of these patients had the following: ejection fraction less than 40%, severe noncardiac conditions, severe peripheral vascular disease, myocardial infarction within 7 days before the procedure, previous thoracic surgery, calcified or diffuse disease in the LAD coronary artery or pulmonary function test less than 50% than expected.

The patients were premedicated with lorazepam 2 mg orally the night before and 90 minutes before induction of anesthesia. All cardiac medications were continued up to the day of surgery. Patient monitoring consisted of standard electrocardiogram leads II and V_5, a right radial artery catheter placed under local anesthesia before induction, pulse oximetry, capnography, BIS monitor, urinary catheter and nasopharyngeal and rectal temperature. Induction of anesthesia was performed with midazolam, 0.1 mg/kg, sufentanil 1-1.5 mcg/kg and rocuronium 0.9 mg/kg to facilitate endotracheal intubation. When the BIS reading dropped below 50, tracheal intubation was performed with a left-sided Robertshow double-lumen endotracheal tube (DLT) in 5 patients while in the rest the trachea was intubated with Univent tubes with left lung deflation during LIMA dissection with left-sided surgical approach. Fiberoptic bronchoscopy (FOB) was used for all cases to confirm the position of either DLT or Univent tube. After tracheal intubation, patients were ventilated with a FiO2 0.5/air. End-tidal carbon dioxide (EtCO2) was displayed continually by capnography with ventilation adjusted to ensure partial pressure of 35 to 45 mmHg.

A 9F introducer was placed in the right internal jugular vein through which Swan–Ganz catheter was introduced. A transesophageal echocardiography (TEE) probe was then placed. The patients were positioned supine with the left arm above the head and a slight lateral tilt by rotating the table 30° toward the right side. Anesthesia was maintained with infusions of sufentanil and Midazolam to maintain BIS reading around 50. Continuous infusion of Rocuronium 10 μg/kg/min was maintained till the end of surgery.

Patients were prepared and draped as for conventional cardiac surgery, permitting sternotomy in case of need. After exclusion of the left lung, the first port (camera) was placed in the fourth left intercostal space at the level of the midclavicular line. Carbon dioxide was insufflated into the left pleural space so as to obtain an intrapleural pressure of 5 to 10 mmHg and to allow exploration of the pleural cavity with two-dimensional (0°) endoscope. The second port (right instrument) was placed through the fourth left intercostal space at the level of the anterior axillary line. The third port (left instrument) was placed in the sixth left intercostal space also at the level of the anterior axillary line. The surgical arms of the Intuitive Surgical System were positioned through the ports into the thoracic cavity, and LIMA dissection was started using a three-dimensional (30°) endoscope, electrocautery, and a grasper. The capnothorax was continued at a pressure of 5 to 10 mmHg, and the LIMA was dissected from the first costal cartilage to the fifth intercostal space. Collateral branches of the LIMA were divided by electrocautery, and after full heparinization, the distal end of the LIMA was divided between the clips. At this stage, the instruments and surgical arms were removed from the thoracic cavity. A slandered sternotomy incision was performed and LIMA to LAD anastomosis was completed under direct vision on a beating heart. Other grafts were performed using a vein grafts from the saphenous vein.

At the end of the procedure, the double-lumen tubes were changed to single lumen while Univent tubes were left in place after pulling the blocker. Then, the patients transferred to the ICU where the trachea was extubated later on the same day.

RESULTS

Ten male patients who underwent LIMA were studied. Mean age was 55.2±6.5 years. Mean time for endoscopic LIMA harvesting was 64.3±13.4 minutes. Setup time for the system (sterile draping, port placement) was 50-65 minutes. No intraoperative complications related to port placement were encountered and there were no mechanical failures of the robotic system.

In 7 patients, the procedure could be completed. The number of grafts for each patient ranged between 1-3 grafts with a mean of 2.3±0.82. In 3 patients, the LIMA was discarded for low flow. In those patients, a vein graft was placed on the beating heart. Transit time flow measurement was performed in all patients documenting graft patency in the operating room. Postoperative ECG and cardiac enzyme levels were within normal limits. No mortality was reported in this series during the hospital course. All patients were discharged home free from chest pain 4-7 days after surgery.

DISCUSSION

After extensive trials in animals and cadavers a prototype of robot system was introduced into clinical practice in May 1998 ([6], [7]). The Endo-Wrist technology enhances and optimized hand-eye alignment, indexing, and tremor filtering resulting in greatly facilitated tissue handling. The high-resolution 3-dimensional image display provides a detailed view of all anatomic details, allowing for precise tissue manipulation ([8]). The advantages of the da Vinci system include integrated three-dimensional visualization and a robotic wrist that provides articulated motions with 7 degrees of freedom (DOF) of movement inside the chest cavity. This feature seems to be most advantageous in LIMA harvesting and complex microsurgery ([9]).

Conventional endoscopic instrumentation was performed in LIMA harvesting on a series of patients with no conversions to the standard approach ([10]). Good results were also reported using the Harmonic Scalpel (Ethicon Endo-surgery, Cincinnati, OH) combined with conventional thoracoscopy for LIMA dissections. Mohr et al were the first to use the da Vinci Robotic system and the AESOP system for ITA harvesting and CABG surgery ([7]). Loulmet was the first to report a totally endoscopic coronary artery bypass graft (TECABG) surgery that occurred in June 1998. Shortly thereafter, Reichenspurner performed RAVE-CABG surgery, including endoscopic LIMA harvesting with a combination of minithoracotomy and endoscopic anastomosis using the ZEUS robotic system. Cichon and Kappert also have reported their experience with unilateral and bilateral endoscopic LIMA harvesting ([10]).

It is well known that the most crucial part of CABG procedure is the construction of an excellent coronary anastomosis. The success of revascularization ultimately depends on the technical quality of the grafts that provide the ischemic regions of the heart with adequate blood flow. For this reason, the quality of robotically assisted versus manual coronary anastomoses has been compared by several groups. Currently, no significant differences in the quality of the anastomoses performed using conventional versus robotic techniques were found([11]).

So far, in coronary artery surgery, the predominant procedures have been single-vessel revascularizations of the LAD artery using LIMA. At present, multivessel revascularization is hampered by the difficulties of exposing the posterior wall of the left ventricle. This fact suggests the need for endoscopic exposure devices and endoscopic vacuum-assisted stabilizers. Eventually, the trend of development should evolve towards beating-heart multivessel totally endoscopic operations, because this procedure involves minimal access and avoidance of CPB ([12]).

In conclusion, our initial experience shows that robotic assistance is an enabling technology that allows the performance of endoscopic LIMA harvesting. Anesthesiologists should have both, thoracic and cardiac anesthesia skills to cope with this technology. Maximum cooperation is needed between the surgical and anesthesia team during robotic cardiac surgical procedures.

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