Anaesthetic considerations for robotic-assisted cardiac surgery

Y Mehta*, D Arora, V Jain

Abstract

Introduction
Robotic-assisted surgery is increasingly being used in various surgical specialties to decrease blood loss, surgical stress and to improve cosmesis. Over past two decades it has become popular in cardiac surgery as well. Various cardiac surgical procedures like valve surgery, coronary artery surgery and congenital repair procedures can be done with robotic help. Anaesthetic management in these procedures is also challenging that involves fast tracking, knowledge of thoracic and cardiac anaesthesiology.

Conclusion
In conclusion, robotic assisted cardiac surgery has a promising future. With the development of 3D technology cardiac surgery can be done with good clinical results. Anaesthetic considerations should aim for one lung ventilation, haemodynamic stability, fast tracking and good analgesia.

Introduction
From the earliest days of cardiac surgery till date, surgical approach has been through traditional routes such as sternotomy or thoracotomy. The need for reducing the overall mortality and morbidity has led to newer innovations and ideas in minimally invasive cardiac surgery. Robotic-assisted cardiac surgery (RACS) is one such modality which has developed in the past two decades. Robotic-assisted procedures are increasingly used in various surgical specialties, with the aim to decrease blood loss, decrease surgical stress and at the same time improve cosmesis.

Since its inception, RACS has found its role mainly in coronary artery bypass grafting (CABG) surgery, mitral valve repairs (MVR) and atrial septal defect (ASD) closures. Of late, procedures such as Maze procedure for atrial fibrillation, intracardiac tumour resection and some congenital heart surgeries such as patent ductus arteriosus (PDA) ligation and transatrial repair of Tetralogy of Fallot have also been done with robotic assistance. Continued improvements in surgical telemanipulation systems and intelligent robotic-enhanced instruments have made it possible to perform RACSs with pin-point precision. This review focuses on anaesthetic considerations in RACS. The anaesthesiologist dealing with such patients should have knowledge of cardiac/thoracic anaesthesia and intraoperative transesophageal echocardiography (TEE).

History
History of robotic-assisted surgeries dates back to mid-1980s when PUMA 60 robot was used for taking neurosurgical biopsy. PRODOC and ROBODOC were used later in urology and orthopaedic surgeries. ROBODOC was the first robotic system approved by Food and Drug Administration (FDA). Use of robots in cardiac surgeries started in 1998 when Carpentier et al. performed first robot-assisted MVR. Loumet et al. performed the world’s first totally endoscopic robotic CABG (TECAB) in 1998.

* Corresponding author
Email: yatinmehta@hotmail.com
Institute of Critical Care and Anesthesiology, Medanta-The Medicity, Gurgaon, Haryana, India

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er Motion Inc., Santa Barbara, CA), a voice-activated robotic endoscope, and the comprehensive master–slave surgical robotic systems, Da Vinci (Intuitive Surgical Inc., Mountain View, CA) and Zeus (Computer Motion Inc., Santa Barbara, CA). Zeus robotic system consists of three interactive arms and a 2-D visualisation system. The system lacks articulated wrist and allows 5 degrees of freedom inside the chest cavity. The Da Vinci system (Figures 1 and 2), the most commonly used robotic-assisted system for TECAB, is essentially a computer-enhanced surgical telemanipulation system, which has an integrated 3-D visualisation which can be magnified up to many times and a robotic wrist which allows articulated motion with 7 degrees of freedom of movement. The Da Vinci system essentially has three components: the first is the surgeon’s console from where the surgeon controls the robot from a remote location. The console also has a three-dimensional viewer. The second component is a visioning platform that consists of video equipment to display images of the surgical site. The third component is the robot with three or four arms depending upon the version.

**Discussion**

The authors have referenced some of their own studies in this review. These referenced studies have been conducted in accordance with the Declaration of Helsinki (1964), and the protocols of these studies have been approved by the relevant ethics committees related to the institution in which they were performed. All human subjects, in these referenced studies, gave informed consent to participate in these studies.

**Surgical technique**

**TECAB**

TECAB can be performed on both an arrested heart (AHTECAB) and on a beating heart (BHTECAB). Surgical technique for an AHTECAB involves creating a capnothorax by collapsing the left lung and insufflating carbon dioxide. Endoscopic harvesting of left internal mammary artery and sometimes right internal mammary artery (RIMA) is performed. An endo-aortic occlusion balloon catheter (EAC) is advanced into the aortic root under TEE guidance. After the internal mammary arteries are prepared, cardiopulmonary bypass is initiated and the patient is systemically cooled. The endo-occlusion balloon is then inflated in the ascending aorta, isolating the coronary arteries from the systemic circulation and delivering the cardioplegia through it. Cardioplegic arrest is induced with antegrade cardioplegia solution delivered via the aortic root through the distal channel of the EAC.

**Totally endoscopic coronary artery bypass on the beating heart**

Availability of endoscopic suction stabilisers has made BHTECAB possible. Newer generations of robotic systems include a suction stabiliser that can be inserted as a robotic instrument and is controlled by the surgeon from the console. The endostabiliser inserted through the subcostal port immobilises the target vessel and then a suture, a U clip or very recent anastomotic device can be used for completing the anastomoses.

**Robotic-assisted mitral valve repairs/atrial septal defect repair**

In 2002, FDA approved Da Vinci robotic system for MVR, although MVR with robotic assistance started way back in 1998 when Carpenter first used Da Vinci robotic system to repair mitral valve. Port access technique, along with robotic assistance, has been used for ASD closure. Other congenital defects can also be corrected with robotic assistance.

**Patient selection for robotic-assisted cardiac surgery**

Patient selection should include patients who can tolerate one lung ventilation (OLV) for a prolonged period of time. Patients with chronic pulmonary diseases, cor pulmonale, severe pulmonary hypertension and patients having dense pleural adhesions must be excluded. Patients having room air hypercarbia (>50 mmHg) and hypoxia (PaO2 <65 mmHg on room air), active bronchopasm and major emphysematous bullae may not tolerate the hypercarbia, potential hypoxia and barotrauma resulting from OLV and carbon dioxide insufflation. In addition, patients for TECAB, with intramyocardial left anterior descending (LAD) artery or calcified and small vessels should be excluded. Coagulopathy, if present, should be addressed preoperatively. Patients having severe peripheral vascular disease with anticipated difficult femoral cannulation also are poor candidates for robotic cardiac surgeries. Patients with unstable angina, recent myocardial infarction or haemodynamically unstable patients should preferably be managed with median sternotomy. Patient’s spine should also be examined for feasibility of neuroaxial block. Peripheral pulse should be examined, and any history of claudication should also be noted. Doppler evaluation of major vessels of lower limbs should also be done for size of the femoral vessels.

**Patient positioning**

Proper patient positioning is of utmost importance in robotic cardiac surgery as even slightest of changes in patient or instrument panel position are not possible once the robotic arms are inside the patient’s chest. Patients are positioned supine with a slight lateral tilt with the arm on the side of chest ports being suspended from a support at the level of the head. Proper arm positioning is crucial to prevent any inadvertent nerve plexus injury. However, patient should also be prepared for emergency sternotomy and thoracotomy as conversion to sternotomy may be required in 3–5% of patients.

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Physiological changes during robotic-assisted cardiac surgery

Respiratory

Prolonged periods of OLV, which is usually required during robotic cardiac surgery, along with capnothorax, can cause significant hypoxaemia during the operative period. The mean duration of 196.8 ± 67 min of OLV has been reported by some authors. OLV causes an increase in V/Q mismatch along with an increase in shunt fraction and a large alveolar arterial oxygen gradient. These changes can be significantly exaggerated in obese patients and smokers who have limited respiratory reserve. In-sufflation pressures should be continuously monitored as capnothorax can become a tension pneumothorax. Insufflation of CO₂ should be maintained at 2–3 L per minute to maintain intrapleural pressure less than 10 mm Hg. Some amount of hypoxia and hypercarbia is always expected during OLV, but it should not be allowed to reach a level at which oxygenation at tissue level is hampered and there is a marked increase in pulmonary arterial pressure (PAP). Positive end expiratory pressure (PEEP) should be applied to the ventilated lung along with the continuous positive airway pressure (CPAP) to the non-ventilated lung if required.

Cardiovascular

CO₂ insufflation into the chest to create capnothorax causes a decrease in systemic venous return and thereby resulting in a decreased cardiac output (CO) and increased central venous pressures (CVP), mean PAP and pulmonary capillary wedge pressure (PCWP). Moreover, there will be decrease in mixed venous oxygen saturation (SvO₂).

Hypothermia

Prolonged bypass time, which is expected during robotic surgery along with infusion of fluids and effects of capnothorax, all contribute to hypothermia, which can cause difficulty in achieving haemostasis and can lead to postoperative shivering and delayed extubation. Maintaining the operating room temperature with proper air conditioning and use of ambient air warmers and fluid warmers can help in preventing hypothermia. Pulmonary artery (PA) catheter blood temperature can be reliably used to monitor core temperature.

Peri-operative anaesthetic management

A routine pre-anaesthetic evaluation should be done and specific emphasis should be given to respiratory system examination as these patients would require a prolonged period of OLV. Pulmonary function tests (PFT) should be performed, with proper optimisation using bronchodilators and steroids in case PFTs are found to be abnormal.

Cardiac medications including beta blockers, statins, nitrates and calcium channel blockers should be continued throughout the peri-operative period. ACE inhibitors should be omitted on the day of the surgery for postoperative prevention of hypotension. Anti-platelets such as clopidogrel should be stopped at least 5–7 days before surgery. Aspirin may be continued in the peri-operative period.

Routine monitoring includes ECG, end-tidal CO₂ concentration, pulse oximetry, CVP, invasive arterial pressure monitoring, temperature monitoring and urine output.

PA catheterisation is highly desirable as it not only helps in monitoring CO, PAP, CVP and PCWP but also gives vital information about the peripheral oxygen delivery through SvO₂ measurement.

TEE has a significant role in minimally invasive cardiac surgery to check the placement of various cannulae as well as monitoring of myocardial ischaemia and cardiac functions. Moreover, de-airing of the heart can be better monitored with TEE in view of the space constraint.

Induction and maintenance of anaesthesia

Main anaesthetic considerations are fast-tracking and adequate analgesia in the postoperative period. Induction of anaesthesia is usually with thiopentone or etomidate, depending upon the patient’s haemodynamic status along with fentanyl and vecuronium as a muscle relaxant. A left-sided double lumen tube or a bronchial blocker through a single lumen tube is used for facilitating one-lung ventilation. Position of the tube or blocker should always be confirmed by fibreoptic bronchoscope. Anaesthesia is maintained with isoflurane and supplemental doses of fentanyl and vecuronium.

Regional analgesia

Regional analgesia particularly thoracic paravertebral block (PVB) supplementing general anaesthesia has been used in minimally invasive cardiac surgery. The advantage of PVB is minimal haemodynamic disturbance with no risk of epidural haematoma. The technique includes a posterior approach to the paravertebral space to block the intercostal nerves as they exit the intervertebral foramina. The epidural needle is walked above or under the transverse process to puncture the superior costal rib transverse ligament to lie in the paravertebral ‘gutter’. The sympathetic chain is very close to the somatic nerves in the paravertebral space, and bilateral sympathetic block may occur with PVB. We have used this technique in patients undergoing robotic-assisted cardiac surgery.
robotic cardiac surgery and found it comparable with the epidural technique\(^1\). Ultrasound is also being used for performing the block.

Other regional techniques such as thoracic epidural analgesia (TEA)\(^2\) and intercostal nerve block have also been used in these patients. For TEA antiplatelet agents should be stopped at least 5 days prior to surgery.

**Conclusion**

With advances in robotic technology, improved 3-D vision, advanced 3-D echocardiograph and effective simulation platforms for training and operative planning, the future of RACS looks promising. Hybrid approaches will remain an integral part of robotically assisted CABG. Most studies on robotic cardiac surgeries have shown promising results with lesser postoperative complications, shorter hospital stay and comparable results with conventional approaches.

The emphasis is on improving current methods and developing new devices for suture-less anastomosis. Future systems might include the ability for a surgeon to programme the surgery and merely supervise as the robot performs most of the tasks.

**Abbreviations list**

ASD, atrial septal defect; CABG, coronary artery bypass grafting; CO, cardiac output; CVP, central venous pressures; EAC, endo-aortic occlusion balloon catheter; MVR, mitral valve repairs; OLV, one lung ventilation; PA, pulmonary artery; PAP, pulmonary arterial pressure; PFT, Pulmonary function tests; PWCP, pulmonary capillary wedge pressure; RACS, TEA, thoracic epidural analgesia; TEE, transesophageal echocardiography.

**References**


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