Anesthesia for Robotic Thoracic Surgery (Da Vinci Decoded)

Mostafa S. ElAdawy[a], Dharmendra Agrawal[b]

Departments of [a]Cardiothoracic Anaesthesia, [b]Thoracic, Freeman Hospital, Newcastle upon Tyne, UK

Correspondenceto Mostafa S. Eladawy, MD, DESA, AFSA, MSc, Department of Cardiothoracic Anaesthesia, Freeman Hospital, High Heaton NE77DN, Newcastle upon Tyne, Freeman Hospital NE3 1AN, Newcastle Upon Tyne, UK. Tel: 0191 213 9494; e-mail: mostafa.eladawy@nuth.nhs.uk

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The da Vinci Surgical System is a robotic surgical system made by the American company Intuitive Surgical. Approved by the Food and Drug Administration (FDA) in 2000, it is designed to facilitate surgery using a minimally invasive approach, and is controlled by a surgeon from a console. Robotic surgery has gained popularity worldwide recently in different surgical domains, the mastering of robotic manipulation by the surgeons has been a challenging when it first emerged but training and practice led to improvement in both the efficiency and efficacy of surgical techniques.

The idea of anesthesia for robotic thoracic surgery could be frightening to anesthetists who have never done it before, but learning the technical difficulties and the specific considerations will help building the confidence towards a safe anesthetic management.

In this overview we will discuss the interaction between the robot and the patient, patient position, anesthetic management, expected complications and troubleshooting them.

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Introduction

Minimally invasive surgery involving the thoracic cavity continues to increase. With the introduction of robotic systems, particularly the da Vinci robot system (Intuitive Surgical Inc., Sunnyvale, California, USA), a team of experienced anesthetists is required to manage those patients undergoing these specific procedures.

The management of the robotic thoracic surgical patient requires the knowledge of minimally invasive surgery techniques involving the chest, familiarity with the da Vinci robot surgical system, management of one-lung ventilation techniques with double-lumen tubes or bronchial blockers, along with flexible fiberoptic bronchoscopy techniques [1].

The da Vinci robotic surgical system provides three-dimensional video imaging plus a set of telemanipulated flexible effector instruments. The system consists of three major components: a console for the operating surgeon, a patient-side cart with four interactive robotic arms, and a vision cart including optical devices for the robotic camera [2].

Patient positioning is important and proper positioning prevent complications such as nerve or crashing injuries while the robotic system is used.

The anesthetist must be able to recognize the hemodynamic effects of carbon dioxide (CO_2) insufflation in the chest and be alert to the potential for conversion to open thoracotomy [3].

This review provides an overview of the anesthetic implications for the use of the robotic system in patients undergoing robot-assisted surgery through the thoracic cavity.

The experience in Newcastle upon Tyne

Robotic surgery possesses the potential to become the standard of care for the surgical treatment of lung cancer and mediastinal lesions. It provides quality of surgery and radicality of resection.

The technical features of the new robotic system are magnification of vision up to 10 times, tremor filter, and an impressively wide range of instruments. The new models Xi innovative overhead architecture and the lowered diameter of the trocar (8 vs. 12 mm) resulted in a reduction of arm collisions and less trauma to the patient. Robotic staplers have been introduced recently.

We performed the first UK robotic lobectomy at Freeman Hospital with a da Vinci Si system under the guidance of our proctor from PISA in April 2014.

As the program has matured, we developed a team of thoracic surgeons, anesthetist, nurse practitioner, and scrub staff for robotic cases. We have adopted a safe patient-centered program with clinical and risk governance structures in place. We developed guideline including training, competency for surgeons and indications and contraindication of procedures.

The maturation and continued development of thoracic robotic surgery has also allowed operative times to be more efficient. A case that would have taken all day is now possible for us to do with an operating time of 90 min.

We managed thorough dissection of lymph nodes and a precise assessment of lymph node involvement in the patients with lung cancer. This information is critical to getting an accurate prognosis and guiding treatment decisions. Our robotic surgical repertoire has also expanded and we have also performed resection of mediastinal masses notably thymectomy including in those with myasthenia gravis. This has meant that we do not need to perform a sternotomy.

To date, we have performed 197 robotic operations including 167 major lung resections. We have developed our technique and so pioneered the world's first use of the subxiphoid approach in robotic thoracic surgery published in May 2016 on CTSNet. The utility subxiphoid port was used in major lung surgery for stapling the structure, removal of lobs, and for intercostal drain placement.

Day-one pain scores after robotic surgery (RATS) in our practice were low compared with VATS. In the last 100 major lung resections, we used subxiphoid utility port in 97 cases. It helped in reduction of pain in postoperative period and resulted in faster recovery and early hospital discharge. The 16 (16%) patients declared a pain score at rest of 0 (visual analog score 1–10), 32 (33%) patients scored 1, 32 (33%) patients scored 2, and 17 (18%) patients scored 3.

The incidence of long-term neuropraxia was only in 17 (8.6%) patients in comparison with 62% in other approaches.

The average hospital stay after robot-assisted surgery was initially 4 days. With the continuous experience and use of subxiphoid utility port, it reduced to 2 days in the last 97 patients. We observed that recovery after robotic surgery is quick. The average time is 2 weeks with fewer complications.

Future advances

The new innovative features is a fluorescence-detection tool (the injection of indocyanine green; by applying the intraoperative near-infrared fluorescence imaging system, the surgeon is able to clearly identify the vessels and the intersegmental line during segmentectomy or to detect neoplasms.

Preoperative investigations

Routine preoperative investigations for thoracic surgery included ECG, full blood count, coagulation profile, kidney functions, liver functions, chest radiography or computed tomography scan of chest if available, and pulmonary functions tests ideally including KCO and TLCO.

Other investigations can be requested according to the patient preoperative condition like echocardiography, carotid Doppler, or other imaging modalities for different parts of the body.

Selection criteria

As the robot-assisted thoracic surgery is still in its uprising learning curve, the operative time is expected to be longer than normal for conventional surgery, and so preferably the patient should be reasonably fit before the procedure with expected adequate tolerance of one-lung ventilation and hemodynamic compromise.

Preoperative management

The preparation and execution of robotic thoracic surgery involves a large team including surgeons, scrub nurses, anesthetists, and anesthetic assistants. Ideally, the team initially consists of the same regular members for maximum harmony until the system is well established.

All members of the team have to undergo sufficient training to be familiar with the equipment, identify and troubleshoot particular problems, and bail out procedures; this should be through advanced planning and rehearsal to determine designated roles, theater layout, and required equipment [1].

According to the patient condition and the anesthetist preference, it is advised to premedicate patients 2 h before surgery with lansoprazole 30 mg, gabapentin 300 mg, and loaded with maltodextrin drink as part of the enhanced recovery protocol.

Monitoring

In addition to conventional monitoring (ECG, pulse oximetry, temperature, $ETCO_2$, and spirometry), all patients undergoing robot-assisted thoracic lobectomy should have an arterial line inserted in the operative side. The anesthesiologist must be ready for the potential of conversion to an open thoracotomy.

A central line access is recommended but not essential, it offers the advantage of monitoring Central Venous pressure (CVP) during CO_2 insufflation reflecting the effect on intrathoracic pressure and rapid delivery of intravenous infusions. It should be inserted on the operative side and all lines must be connected to long extension lines for ease of access.

One liter of warmed plasmalyte should be connected to a wide bore cannula through an extension with three-way tap. Restrictive fluid strategy is usually advised assuming no major blood loss.

A urinary catheter is recommended if the procedure is expected to last longer than 2–3 h.

Intraoperative management

Positioning of the patient for a robotic lobectomy includes placing the patient over a bean bag in a maximally flexed lateral decubitus position with the elevated arm slightly extended, so that the thoracic cavity can be accessed and no damage to the arm occurs during manipulation of the robotic arms. Prewarmed assorted gel pads can be used underneath arms and a wedge for head and arms (Figs 1 and 2).

The table is positioned in V shape with the midthorax at the top to open up the ribs and put the bean bag under the patient's side opposite to the umbilicus to have a horizontal line of shoulder, ribs, flank, and hips. A hip strap is applied to maintain the patient position (Fig. 3).

Once the robot is in position there will be limited access to the endobronchial tube, drapes with a see through window must be placed over the patient's face. A lower body warmer should be applied after positioning.

Theater layout will have to be adapted so that the patient faces the anesthetic machine. The robot will be at the head end.

Patients undergoing robotic lobectomy or lung surgeries must have a lung isolation device to achieve one-lung ventilation. In the majority of these cases, a left-sided Double Lumen Tube (DLT) is indicated and optimal

Figure 1

Da Vinci robotic system console.

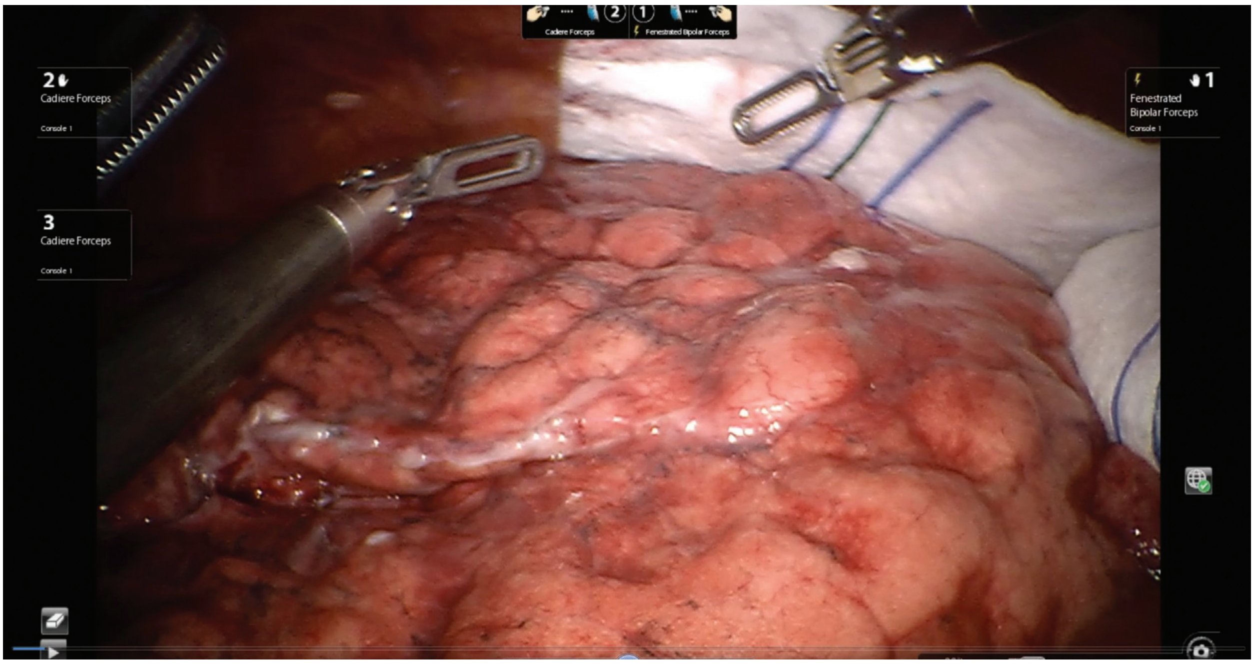
Figure 2

Da Vinci robotic system arms.

Figure 3

Anesthesia setup for thoracic surgery in robotic approach.

Figure 4



View from inside the robotic console.

position achieved with the flexible fiberoptic bronchoscope [4]. In a few cases in which the airway is deemed to be difficult, an independent bronchial blocker should be used, and optimal position is achieved with the use of a fiberoptic bronchoscope [5]. Long ventilator tubing should be used as the anesthetic machine will be situated far away from the patient (Fig. 4).

Anesthetic induction can be done using fentanyl, propofol, and atracurium or propofol Target

Controlled Infusion (TCI) +/− remifentanyl; maintenance can be using either propofol Total Intravenous Anesthesia (TIVA) or inhalational anesthetics in combination with atracurium infusion as long as the robotic arms are locked inside the patient. Remifentanil infusion can be advantageous in expected longer procedures to avoid accumulation of repeated doses of opioids, and intravenous morphine or diamorphine can be given toward the end.

A paravertebral block is usually performed after induction in lateral position to cover the intraoperative period. Typically ∼20 ml of bupivacaine 0.25% with adrenaline 1 : 200.000 is injected at the level of T6–T7 on the side of surgery under ultrasound guidance. A paravertebral catheter is then inserted by the surgeon at the end for postoperative pain control with a loading dose of 15–20 ml of levobupivacaine 0.25% followed by infusion of 10–15 ml/h of bupivacaine 0.1%.

Nerve stimulator should be used at the end to check the depth of muscle relaxation before recovery and extubation.

Postoperative management and pain control

Postoperative recovery should be in specialized post anesthesia care unit and then transferred to high dependency unit (HDU) or a regular ward according to the type of surgery.

A multimodal approach combining Patient Controlled Analgesia (PCA) morphine or fentanyl, paravertebral infusion, and regular paracetamol is usually effective alongside opioid-sparing strategy like gapabentin 300–600 mg or pregabalin 75–150 mg two to three times daily. The paravertebral nerve catheter analgesia is usually left in place until intercostal drains are out or 48–72 h postoperatively whichever comes first.

Intravenous hydration is maintained using plasmalyte given at 1 ml/kg/h until eating and drinking is established.

Perioperative complications

Advantages of using the da Vinci robotic surgical system in thoracic surgery includes a shorter hospital stay, less pain, less blood loss and transfusion, minimal scarring, faster recovery, and probably a faster return to normal activities [6,7], but there are some complications that can occur during or after the procedure, and the awareness of these complications together with good communication among the team helps prevent most of them.

CO_2 insufflation can be challenging. The pressure of insufflation ranges from 5 to 10 mbar, and the effect on intrathoracic pressure varies from decrease in venous return and elevated CVP, decrease in lung compliance needing higher ventilator pressures, up to direct compression of the Superior Vena Cava (SVC) causing profound decrease in CO.

Robotic surgery with the da Vinci robotic surgical system does not allow for changes in patient position on the operating room table once the robot has been docked. Special attention must be given to the elevated arm or head to prevent crushing injuries by the robotic arms. A case report [8] described a brachial plexus injury in an 18-year-old male after robot-assisted thoracoscopic thymectomy. In this report, the left upper limb was in slight hyperabduction.

It is important to keep in mind that hyperabduction of the elevated arm to give optimal space to the operating arm of the robot can lead to a neurologic injury. Close communication between the surgeon and anesthesiologist in relation to the positioning and functioning of the robot is mandatory, and all proper measures must be taken, including the use of soft padding and measures to avoid hyperabduction of the arm. The elevated arm should be protected by using a sling resting device.The conversion to open thoracotomy must be readily available in case of emergency need, mostly owing to uncontrollable blood loss, In the Park *et al.* [9] report, three out of the four cases that needed to be converted had minor bleeding.

Other postoperative complications includes atrial fibrillation, prolonged air leak, pleural effusion, left recurrent laryngeal nerve injury, phrenic nerve injury, and chylothorax.

Conversion to open procedure

This practice should be rehearsed, and all the equipments necessary must be available for immediate use. The anesthetist should have a low tolerance to hemodynamic effects of CO_2 insufflation, respiratory compromise, or bleeding incidences, especially if difficult to control with robotic access. In all the former situations, the anesthetic team must switch to the conventional anesthetic technique for open thoracic surgery, switch off the muscle relaxant infusion, and replace the fluid and blood loss.

Conclusion

Anesthesia for robotic thoracic surgery is a branch of thoracic surgery that is gaining popularity. The thoracic anesthetist should easily be able to manage these procedures with relative ease once orientated to the specific perioperative management and the potential complications. A plan should be put in place in conjunction with the theater team to deal with any of the expected problems.

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Conflicts of interest

There are no conflicts of interest.

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