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REVIEW

Anaesthesia for robotic surgery

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S U M M A R Y

Robot assisted surgeries are associated with smaller incisions, less scarring, less morbidity and a shorter hospital stay. But anaesthesiologists need to be aware of the challenges of robotic surgery and the changes in surgical technique. Longer duration of surgery, limited access, prolonged insufflation of carbon dioxide and extremes of position are some of the changes which need to be tackled with expertise to avoid complications. In addition different surgical specialities have their own requirements, from the steep Trendelenburg position in radical prostatectomy and other pelvic surgeries, to one lung ventilation and capnothorax in robotic cardiothoracic surgery. This review focuses on the anaesthetic challenges faced in robotic surgery in different surgical specialities and their management.

1. Introduction

A robotic device used in surgery today is a powered, computer controlled manipulator that can be programmed to move, position tools and carry out a wide array of tasks. The robots lack independent motions or pre-programmed actions. A more accurate descriptor for these devices is a computer enhanced telemanipulator. The surgeon is "teleported to the operative site" as if he is in the operative field. The robot does not replace the surgeon but instead performs and enhances the precision of the surgeon's hands.[1]

In April 1997, the first robot assisted surgery was performed using the da Vinci system.[1] Since then, tens of thousands of robotic procedures have been performed with more than 2585 da Vinci systems installed in over 2025 hospitals worldwide.[2]

Minimally invasive surgery with laparoscopy provides benefits of reduced postoperative pain, shorter hospital stay, faster postoperative recovery and improved patient satisfaction.[1] Robotic surgery is a further advancement in the field of minimally invasive surgery and gives improved operative field visibility, three dimensional imaging, elimination of motion reversal (the surgeon controls the movement of the instrument tip directly rather than controlling the instrument handle which would require movement in the reverse direction), filtering of resting tremors (the system can recognize the natural hand tremor of the surgeon and remove it) and motion scaling.[3] Motion scaling can be adjusted from a 1:1 up to 5:1 ratio. This means that 5 inches of hand motion can be translated to 1 inch of surgical instrument motion.[1]

2. The robots

There are two surgical robotic systems in commercial use today: Zeus Surgical system (Computer Motion) and the da Vinci surgical system (Intuitive Surgical).[1]

The da Vinci system has 3 parts: console, instrument tower and robot with 4 arms (the original da Vinci robot had 3 arms).[1] At the console the surgeon controls the robotic arms and the Endo-Wrist instruments which are designed with 7 degrees of freedom (one more than the human hand). The surgeon is able to view the operating field with a 3 dimensional high definition vision system. The foot pedals control movement and focussing of the camera, disengagement of the robot instruments and controlling electrocautery. The second component consists of the tower which contains video equipment to record and display for the surgical field for the rest of the operating team. The third component is the robot itself which consists of 4 arms of which one holds the video telescope and the others perform manipulations. The Zeus system also consists of a control console where the surgeon operates the robot. It has a voice activated camera and the robotic arms are attached to the table itself. The robotic arm allows only 5 degrees of motion.[1]

3. Anaesthetic concerns with robotic surgery

At the present time robotic surgery has found widespread application in the field of urology, gynaecology, otolaryngology, cardiac, thoracic, paediatric and general surgery.

Anaesthesia for robotic surgery presents multiple challenges to the anaesthesiologist primarily due to the presence of the large and bulky robot. The robot is rigidly fixed to its trocar insertion sites and over the patients abdomen and chest (in abdominal and pelvic

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surgeries), or encroaching over the patients head, chest and abdomen (in thoracic and head neck surgeries). This invasion of the anaesthetic workspace leads to limited access to the patient's airway, monitoring devices and intravascular lines.[4]

The procedure is likely to be prolonged especially in the initial part of the learning curve and usually involves prolonged carbon dioxide (CO_2) insufflation. This together with the extremes of positions results in haemodynamic and respiratory compromise.

The robot is also a serious impediment to resuscitation, in case of sudden cardiovascular collapse. The surgical team should be capable of removing the trocars and moving back the robot in less than 1 min[4] as the table or patient cannot be moved until the trocars are removed from the patient's body cavity.

3.1. Anaesthesia

A large bore intravenous access with long extension tubings is usually established post-induction as gaining intravenous access once the procedure has started is difficult. Inadequate muscle relaxation can lead to the patient bucking and pushing, causing the bowel to obscure the surgical field along with the risk of inadvertent injury and should therefore be avoided.

A pilot study comparing isoflurane with total intravenous anaesthesia (TIVA) with ketamine-midazolam-fentanyl for the maintenance of anaesthesia in patients undergoing robotic radical cystectomy, found that isoflurane was associated with increased plasma concentrations of prothrombin, fibrinogen and aspartate aminotransferase (AST). Recovery was more delayed after TIVA, may be due to the use of ketamine.[5] The long term effects of these physiological changes have however not been studied.

3.2. Monitoring

In addition to routine monitoring (i.e. electrocardiogram (ECG), pulse oximetry, non-invasive blood pressure monitor, temperature, capnography, airway pressures), invasive arterial pressure, central venous pressure and even pulmonary artery pressure may be needed depending on the surgical procedure being performed, comorbidities of the patient and the experience of the surgical team. All lines should be placed prior to positioning as access to the patient is limited once the robot is docked.

If a perioperative cardiovascular emergency arises, trans-oesophageal echocardiography is the most effective means of assessing cardiac function.[6]

3.3. Positioning

The special positions—steep Trendelenburg (pelvic surgeries), lateral decubitus (thoracic surgeries) require that the patient is safely secured to the table, all pressure points are well padded and the robotic arms do not rest on the patient. Body fitting bean bags, gel pads and foam pads have been commonly used for patient positioning.[7] In addition the potential for long operative times requires that special precautions are undertaken to prevent nerve injuries.

3.4. Intraoperative care

After the patient has been positioned but prior to starting the procedure, care should be taken to ensure that the intravenous, central venous pressure and arterial lines (if inserted) are patent and not kinked.

The pulse oximetry probe may need to be repositioned to avoid artifacts or problems in monitoring intra-operatively.

The abdominal cavity is insufflated with CO_2 to a pressure not exceeding 20 mmHg.[3] The steep head low position with pneumoperitoneum, causes the diaphragm and bowel to be pushed up, necessitating that the endotracheal tube position be re-checked to rule out endobronchial intubation.

The robot side cart is brought close to the patient and considering its size there is very limited access to the patient's airway. After the robot is engaged, the position of the patient cannot be changed.

Ventilatory parameters should be adjusted to ensure normocarbia during the procedure as hypercarbia can cause an increase in ICP as well as intraocular pressure.

Hypothermia can occur due to the prolonged operative time and should be aggressively treated using fluid warmers, warming blankets and mattresses.

Though blood loss is significantly decreased with the robotic as compared to open surgery, care should be taken not to miss occult blood loss.

Precautions should be taken to prevent deep vein thrombosis (DVT). Intermittent compression devices or pharmacotherapy for DVT prophylaxis should be administered depending on institutional practice. For patients requiring a prolonged Trendelenburg position combined with lithotomy, thrombo-prophylactic doses of heparin or low molecular weight heparin may be preferred over intermittent compression devices because of reports of compartment syndrome which may be exaggerated with the latter method.[8]

3.5. Postoperative care

A major advantage of robotic surgery is decreased postoperative pain and opioid consumption.

In a study in patients with endometrial cancer, the patients who underwent a robotic assisted procedure required 30% less post-operative pain medication than those who underwent laparoscopic surgery. The authors reported that based on this analysis they no longer used intravenous patient controlled analgesia (IV PCA) and provided narcotics only if oral analgesia was inadequate. Many patients were discharged on the same day with only oral analgesics.[9]

As the positioning of the patient, physiological changes, perioperative management and complications vary with the specific robotic procedures performed, the remaining part of the article contains literature that has been reviewed and described accordingly.

4. Robot assisted surgeries

4.1. Urology

4.1.1. Radical prostatectomy

The da Vinci robot is widely used in urology for radical prostatectomy, radical cystectomy, simple and radical nephrectomy, donor nephrectomy, pyeloplasty and adrenalectomy.

Robot assisted laparoscopic prostatectomy (RALP) has a lower complication rate as compared to open radical prostatectomy. The length of post anaesthesia care unit (PACU) stay and hospital stay was reported to be 30% and 67% shorter in patients who underwent robotically assisted prostatectomy in comparison to open procedures.[10] The steep Trendelenburg position (30–45°) with pneumoperitoneum which is required for this surgery can cause significant cardiovascular, respiratory and cerebrovascular changes especially as the patient population is elderly.

The surgical procedure involves placing the patient in the lithotomy position with arms tucked by the side of the table. Pneumoperitoneum is initiated once the patient is secured and the patient is positioned in a 30–45° Trendelenburg position. Ports are