WHITE PAPER

Considerations for the anesthesia team during robotic-assisted surgery

Anesthesia

Robotic-assisted surgery and the anesthesiology team

Physiological considerations

The number of robotic-assisted surgeries continues to grow because of its important clinical benefits. As with any technology, it must be considered within the framework of the entire surgical team and other key surgical equipment.

Robotic surgery

Robotic surgery or robot-assisted surgery allows surgeons to perform many types of complex procedures with higher degree of precision, better visualization of tissues, flexibility and control than is possible with conventional techniques. The robotic system has been used in a range of surgical specialties including bariatric, obstetric surgery and cardiothoracic surgeries but is often associated with urological surgeries including prostatectomies (RALP) and cystprostatectomies. Despite its cost and large size, there are advantages to working with a robotic system. It allows for better visualization of the surgical field when compared to standard laparoscopic surgery and can filter natural hand tremors of the surgeon and can scale movements for fine precision work[1]. It continues to evolve to new applications with the upper extremities and functionally within the OR with boom-mounted options.

Robot-assisted surgery with the da Vinci® Surgical System (Intuitive Surgical Inc, Sunnyvale, CA, USA) or similar systems may offer benefits to patients through the use of minimally invasive techniques, which may result in reduced blood loss, reduced blood transfusion, fewer complications, reduced postoperative pain, shorter hospital stays, and reduced recovery times. Surgeons may also benefit through improved ergonomics (for example, three-dimensional visualization and freedom, and intuitiveness of movement-enabled eye-hand coordination that may be lost in laparoscopic surgery), potentially resulting in better surgical performance. Robot-assisted surgery is, however, associated with high capital and operating costs.[2]

As with any new technology, there must be a cohesive and holistic approach to change management and consideration of the needs of the entire surgical team when adopting a robotic system. The focus of this whitepaper examines the needs of the anesthesiology team, the requirement of the anesthesia machine including delivery of anesthetic agent and management of the patient.

The technology

The robot generally consists of three main components: a master console, a robotic surgical manipulator, and a visualization tower. Seated in the master console, the surgeon has the ability to control the surgical manipulator. Communication can be challenging between team members so microphones and speakers are used to enhance communication between the surgeon and the surgical team.

For the anesthesia team, they must be prepared to handle new challenges. Anesthetic concerns for patients undergoing laparoscopic and robotic surgery differ from those for patients undergoing open abdominal surgery. They include the physiologic effects of the pneumoperitoneum, absorption of CO_2, and invasion of anesthetic workspace[1,3].

Critical physiological issues for the anesthesiologist and anesthesia machine during the robotic surgery include:

1. Extreme positioning, associated with the steep Trendelenburg position, will lead to a reduced functional residual capacity and lung compliance.
2. Laparoscopic surgery will increase intra-abdominal pressure during pneumoperitoneum.
3. Duration of surgery — very often long cases lead to accumulation of anesthetic agent in fatty tissue[1].

Patient positioning

Positioning is the most critical part of any robotic-assisted surgery. Robotic surgery relies on patients in a steep or reverse Trendelenburg position which allows gravity to position intra-abdominal organs for robotic surgery. The steep Trendelenburg position which is defined as 30° to 40° in the head down position. Without proper patient positioning, patient outcomes may be compromised. In urologic surgery, a steep Trendelenburg positon is used to provide optimal exposure of the pelvis and lower abdomen[4].

It is also essential that the patient remain absolutely still. After the robot has been placed, movement from the patient could lead to tearing or puncturing of the viscera[1].

Placing the patient in this position for extended periods can lead to physiologic consequences. The downward movement of the diaphragm by abdominal contents and pneumoperitoneum can decrease pulmonary compliance, functional residual capacity, cause pulmonary edema, and exacerbate ventilation/perfusion mismatch. In addition, it can also increase mean arterial pressure as well as systemic vascular resistance[1]. In susceptible patients, this can lead to hypoxia so an appropriate ventilation strategy is required. These effects may further complicate clinical management of patients with co-morbidities including underlying chronic lung disease or the morbidly obese. Steep inclination for a prolonged period, ranging from 25° to 45°, can lead to upper airway and brain edema.[4] Airway edema increases the risk of postoperative respiratory complications including the need for reintubation[5]. Cerebral edema can result in delayed awakening and confusion. Current strategies for management include limiting time in steep Trendelenburg and limiting abdominal insufflation pressure[6].

Positioning is more than patient positioning — one must consider the position of robotic unit as well

Because positioning is key when considering robotic surgery, the surgical staff should also assess the position of robotics unit itself, the size of it within the OR space, and its positioning in relation to the patient. Future generations are expected to include boom-mounted options. Regardless, the robotic system occupies a large space and spatial restriction may reduce access to the patient.

The implication to the anesthesiologist is that this could mean an obstructed view of the patient, especially when considering the steep Trendelenburg position.

Insufflation of gas

Laparoscopy requires creation of a pneumoperitoneum by insufflation of gas, usually carbon dioxide (CO_2), to open space in the abdomen for visualization and surgical manipulation. CO_2 insufflation can be performed blindly using a Veress needle, or by placement of a port under direct vision through a small subumbilical incision. The gas source is connected to the needle or port. Intra-abdominal pressure (IAP) is monitored as gas is insufflated, aiming for a pressure ≤15 mmHg to minimize physiologic effects. For laparoscopic prostatectomy, which is performed in steep Trendelenburg position, the European Association for Endoscopic Surgery recommends IAP below 12 mmHg[7].

Vigilance in monitoring and meticulous management is essential to prevent wide pathophysiological changes associated with procedures.[3] To prevent hypercapnia, close intraoperative monitoring of end-tidal CO_2 ($ETCO_2$) or arterial partial pressure of CO_2 ($PaCO_2$) is essential.[8]

Getinge's solutions that support anesthesia-related challenges during Robotic Surgery

Atelectasis

Anesthesia-induced lung collapse is a well known entity observed in approximately 90% of patients undergoing general anesthesia. This collapse begins at the induction of anesthesia and persists several hours after the end of the surgery. There is a close relationship between atelectasis and post-operative pulmonary complications (PPCs). Therefore, an appropriate ventilation setting during mechanical ventilation for general anesthesia may reduce intra-operative atelectasis, with beneficial effects in the post-operative period.[9]

The steep Trendelenburg head-down position, and relatively long duration of CO_2 pneumoperitoneum (generally more than three hours), can result in an increased risk of intraoperative hypoxia and postoperative atelectasis. In addition, an increase of $PaCO_2$ can be difficult to control. Furthermore, with patients who are elderly and have difficult management of intraoperative oxygenation, the risk of postoperative pulmonary complications are increased. Extreme care should be taken to consider the needs of these patients.[8]

Lung Recruitment Maneuvers:

Lung recruitment maneuvers are ventilatory strategies that aim to restore the aeration of normal lungs:

- Improves lung mechanics.
- Improves oxygenation.
- Decreases the risk of developing ventilator-induced lung injury (VILI).

Lung-protective ventilation strategies, including recruitment maneuvers (RM), shows lower incidence of atelectasis, PPCs, and hospital mortality.[9]

Maintaining positive end-expiratory pressure (PEEP) has been known to improve intraoperative oxygenation and lung mechanics. PEEP impedes the venous blood return from the lower extremities and decreases cardiac output, but this effect is likely to be negated by the extreme Trendelenburg position.

In some situations the anesthesia machine should be capable of setting a PEEP more than 35 cmH_2O to be able to reach the necessary pressure during RM to recruit a collapsed lung. Individualizing the PEEP after RM will allow the alveolus to stay open and prevent atelectasis.[9]

An automatic lung recruitment tool on the anesthesia unit will give the clinician an easy and reproducible way of managing and monitoring the effect of the maneuver *(see Figure 1)*. The automatic lung recruitment function, available in the Flow-e and Flow-i, performs a stepwise increase in peak pressure and PEEP to reach a target level set by the clinician. This stepwise approach is to apply a gentle maneuver for the patient and limit the negative effect of hemodynamic compromise.

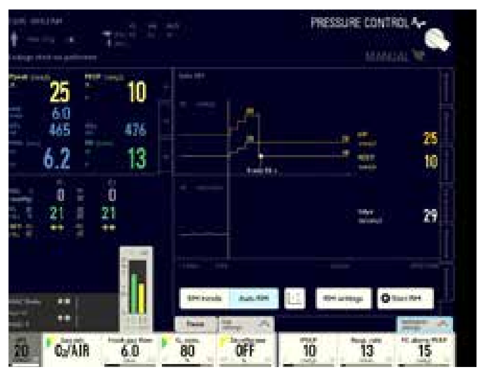

Figure 1 Automatic lung recruitment tool.

There will be an intentional increase in tidal volume during a stepwise increase in alveolar pressure to recruit partly collapsed lung tissue. It is extremely beneficial if the anesthesia machine is able to compensate for the sometimes drastic changes in tidal volume — if not, there is a risk that the ventilation system will be empty and result in the stoppage of ventilation, e.g. a bellow system will be flat/empty.

The importance of keeping the PEEP after a recruitment maneuver is described by Prof. Hedenstierna in "Mechanisms of Atelectasis in the Perioperative Period." The article concludes that doing a RM, and not applying a PEEP after the maneuver, will lead to an increase of atelectasis.[10]

Anesthesia machines capable of delivering high-inspiratory flow, and pressure both peak and continuously, will help manage the ventilation of patients with high resistance and/or low lung compliance (e.g COPD, asthmatics, crushing chest trauma, neonatal patients, bariatric surgery).[11]

Sustainability and safety

The global trend is to use more low-flow anesthesia and reduce the FGF to the basic needs of patients. This is both related to the consumption of oxygen/volatile agent and the waste of volatile agent, which has a negative environmental and economical effect. Low-flow anesthesia may be associated with the risk of delivering a hypoxic mixture to the patient. Having a safety system like Getinge's active O_2Guard installed on the anesthesia machine reduces the risk of this situation occurring.[12]

An additional beneficial effect of low-flow anesthesia is that it raises the overall heat and moisture content in the inhaled gases. This makes it easier to maintain the patient's body temperature, and humidity, in a safe way and eliminates the need for an external active humidifier.[13]

Depth of anesthesia

During extreme positioning and recruitment maneuvers, it is important to monitor the changes in agent concentration. The agent concentration is measured at the Y-piece and analyzed internally by the gas analyzer. The end tidal concentration is continuously measured and displayed on the interface and used for the calculation of the MAC (Minimal Alveolar Concentration) value. The MAC value is age correlated and works like an indicator if the patient is being under or over anesthetized. In addition, another beneficial parameter displays the calculated value in the target organ, the brain (MAC Brain), and additionally supports the dosage of volatile agents. Given that robotic assisted surgery may extend the overall operating time, and thus also the anesthetic exposure, these tools can calculate concentration and enable decisions regarding the start of weaning in a more monitored way.

Conclusion

The number of robotic-assisted surgeries continues to grow because of its important clinical benefits. As with any technology, it must be considered within the framework of the entire surgical team and other key surgical equipment — specifically the anesthesia team and anesthesia machine. Proper selection of the anesthesia machine can support and help manage key robotic surgery implications. Elements including recruitment maneuvers and high inspiratory/expiratory flow, in addition to individualized PEEP adjustments to help offset atelectasis and other potentially life-affecting conditions, should be considered as part of the evaluation process.

Getinge Flow-e Anesthesia Delivery System

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Indications for use: The indication for Flow-i, Flow-c, and Flow-e Anesthesia Systems are administering inhalation anesthesia while controlling the entire ventilation of patients with no ability to breathe, as well as in supporting patients with a limited ability to breathe. The system is intended for use on neonatal to adult patient populations. The system is intended for use in hospital environments, except MRI environments, by healthcare professionals trained in inhalation anesthesia administration.

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