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Anesthetic Considerations in Robotic-Assisted Gynecologic Surgery

[Alan D. Kaye](#), MD, PhD,^{*} [Nalini Vadivelu](#), MD,[†] [Nitin Ahuja](#), MBBS,[‡] [Sukanya Mitra](#), MD,[‡] [Dan Silasi](#), MD,^{||} and [Richard D. Urman](#), MD[§]

^{*}Departments of Anesthesiology and Pharmacology, Louisiana State University Health Sciences Center, New Orleans, LA

[†]Department of Anesthesiology, Yale School of Medicine, New Haven, CT

[‡]Department of Anesthesiology, Chandigarh Government Medical College, Chandigarh, India

^{||}Department of Obstetrics and Gynecology, Yale School of Medicine, New Haven, CT

[§]Department of Anesthesiology, Brigham and Women's Hospital, Boston, MA

Address correspondence to [Alan D. Kaye, MD, PhD](#), Professor and Chairman, Department of Anesthesiology, Louisiana State University School of Medicine, 1542 Tulane Ave., Room 656, New Orleans, LA 70112, Tel: (504) 568-2319, Fax: (504) 568-2317, Email: akaye@lsuhsc.edu

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Abstract

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Background

Robotic-assisted surgery has evolved over the past 2 decades with constantly improving technology that assists surgeons in multiple subspecialty disciplines. The surgical requirements of lithotomy and steep Trendelenburg positions, along with the creation of a pneumoperitoneum and lack of direct access to the patient all present management challenges in gynecologic surgery. Patient positioning requirements can have significant physiologic effects and can result in many complications.

Methods

This review focuses on the anesthetic and surgical implications of robot-assisted technology in gynecologic surgery.

Conclusion

Good communication among team members and knowledge of the nuances of robotic surgery have the potential to improve patient outcomes, increase efficiency, and reduce complications.

Keywords: *Anesthesia, gynecologic surgical procedures, robotics, surgical procedures—minimally invasive*

INTRODUCTION

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Recent advancements in surgical procedures have led to greater emphasis on minimally invasive techniques with the goal of improving patient outcomes and satisfaction while decreasing surgical morbidity and mortality. Robotic-assisted surgery, the latest innovation in the field of minimally invasive surgeries, first came into medical practice in 1999.¹ The basic principle behind this technology is that the robot teleports the surgeon to the operating site and enables operation on the patient from an ergonomic console using 3-dimensional vision and autonomous control of wristed laparoscopic surgical instruments.^{2,3} Advantages of robotic-assisted surgery include improved precision and enhanced accuracy of movement, both of which translate into potential benefits for patients.^{4,5}

Laparoscopic surgery, introduced in the late 1980s, had certain limitations, such as loss of typical 3-dimensional vision, reduced surgeon coordination, and greatly limited touch.¹ Robotic technology overcame many of these obstacles as the technology improved over the years.⁶ The da Vinci Surgical System mimics a human wrist and includes 3 distinct pieces: a console, a surgical cart with 4 arms (2 representing a surgeon's left and right arms, 1 arm to hold and position the

The steep Trendelenburg position provides the optimal exposure of the pelvis and the lower abdomen.¹⁸ Placing the patients in this position for extended periods can lead to significant physiologic consequences. For example, the downward movement of the diaphragm by abdominal contents and pneumoperitoneum can decrease pulmonary compliance and functional residual capacity, cause pulmonary edema, and exacerbate ventilation/perfusion mismatch.^{16,26,27} Additional effects on the cardiopulmonary system are discussed in the next section. These effects may further complicate clinical management of patients with underlying chronic lung disease or the morbidly obese. By pushing the trachea cephalad, Trendelenburg position can lead to displacement of the endotracheal tube by pushing it further in, resulting in mainstem intubation.²⁸

Steep inclination of 25-45 degrees for a prolonged period can lead to upper airway and brain edema¹ and an increase in intracranial pressure and cerebral blood flow. To preserve cerebrovascular homeostasis, normocarbica should be maintained. Previous studies have also shown that the steep Trendelenburg position for long hours during gynecologic procedures has led to postoperative vision loss.²⁰ Also, facial engorgement and edema are quite substantial. These physiological changes led Molloy²³ to hypothesize that under anesthesia in steep Trendelenburg position, cerebrovascular and ophthalmic circulatory autoregulation do not prevent increases in intraocular pressure (IOP) and decreases in ocular perfusion pressure (OPP), which is mean arterial pressure (MAP) minus IOP. The Malloy study showed that even under anesthesia, cerebrovascular and ophthalmic circulatory autoregulation do not prevent complications such as increased IOP.²³

Pneumoperitoneum

Pneumoperitoneum refers to the presence of air within the peritoneal cavity. Despite other options such as oxygen, helium, argon, and nitrous oxide, carbon dioxide (CO₂) remains the agent most commonly used for creating the pneumoperitoneum because of the problems associated with other gases, such as their combustible nature and the possibility of intravascular embolism on insufflation. Intraperitoneal insufflation with CO₂ is performed in Trendelenburg position when the patient is positioned at an angle of 15-20 degrees. There is also a significant effect on respiratory mechanics. Lung compliance can decrease by more than 50%, and mean pulmonary arterial pressure and pulmonary capillary wedge pressure also decrease.²⁹ In addition, there is an increase in peak inspiratory pressure, plateau pressure, and end-tidal CO₂ tension.¹⁹ The CO₂ insufflation can result in increased postoperative complications in patients with underlying lung disease. For example, patients with conditions such as chronic obstructive pulmonary disease are less efficient in eliminating excessive CO₂ even with increased minute volume of ventilation. This deficiency can lead to postoperative respiratory hypercarbia and acidosis, requiring prolonged mechanical ventilation.^{30,31}

The combination of the steep Trendelenburg position with pneumoperitoneum influences cardiopulmonary physiology in many ways.³² Pneumoperitoneum and a 45-degree Trendelenburg position have been shown to cause 2- to 3-fold increases in left ventricular filling pressures,³³ and cardiac output may decrease.³⁴ Systemic vascular resistance and MAP also increase, whereas renal, splanchnic, and portal flows decrease. Activation of the renin-angiotensin system increases the levels of vasopressin.

PERIOPERATIVE COMPLICATIONS

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The mere availability of robotic surgical capability cannot by itself guarantee a successful surgical program. Teamwork is essential for successful patient outcomes. The anesthesiologist must be ready to deal with the consequences of the steep learning curve, stressed surgeons, and the long duration of most procedures. Also, the anesthesiologist must be prepared to handle new challenges associated with proper patient selection and screening, as well as intraoperative care challenges.^{22,35} Invasion of the anesthetic workspace with the robotic system is almost unavoidable, and anesthesiologists must be aware that the size of the robot might interfere with their ability to quickly access the patient.³⁶ Proper positioning of the patient is a necessary first step for robotic-assisted laparoscopic procedures. Without proper patient positioning and port placement, robotic-assisted procedures are tedious to perform and patient outcomes are compromised.²⁵ The most common complications and their anesthetic implications are summarized in [Table 2](#).

Patient Positioning

Obtaining the proper patient position is a dynamic process that requires the supervision of the surgeon. Not only should the patient be protected from injuries, but the optimal position must also allow for safe docking of the robot as well as for access of the bedside surgeon to the surgical assistant ports.²³ Once the procedure begins, the anesthesiologist and the surgeon are limited in making any changes to or improving the positioning of the patient. Consequently, the anesthesiologist must carefully arrange intravenous access and arterial lines (if required) prior to positioning because access will be limited once the robotic portion of the procedure starts. Bilateral peripheral intravenous access is generally advised.

During the steep Trendelenburg position in gynecologic surgeries, shifting the patient's trunk often leads to suboptimal positioning of the extremities, increasing the risk of nerve injury from stretch and compression. Lower extremity acute compartment syndrome requiring fasciotomy and rhabdomyolysis resulting in renal failure as a result of prolonged intraoperative lithotomy position have been reported.^{37,38}

Groups around the world have suggested methods to prevent patient shifting during the steep Trendelenburg position, including braces, leg suspension, and iliac supports. However, all of these methods can potentially result in nerve injury,³⁹⁻⁴² and the shoulder braces and straps used to prevent the patient from shifting can cause neuropathic injury.³² During robotic-assisted gynecologic surgeries, the trocars and instruments are fixed, so the prevention of patient sliding becomes all the more important. The risk of stretching and tearing of the incisions, which may increase the risk of an incisional hernia, is a concern. Klauschie et al¹⁸ demonstrated for the first time the use of an antiskid foam material for patient positioning. Although they observed small shifts in patient positioning, no clinical neurologic injuries were noted.

Most vulnerable to the head-down extreme position are the cardiac, respiratory, and central nervous systems.¹⁰ Because any intraoperative movement can be catastrophic, muscle relaxation is critical for success. Other complications include unrecognized surgical injury, occult blood loss, and risk of hypothermia.^{1,43}

Cardiopulmonary Complications

As discussed previously, the combination of pneumoperitoneum and steep Trendelenburg causes pulmonary problems such as atelectasis and ventilation-perfusion mismatch.¹ A decrease in the pulmonary compliance and functional residual capacity is observed, but the peak airway pressures increase. White and Freire⁴⁴ demonstrated how subcutaneous emphysema occurs frequently with the steep Trendelenburg position and may contribute significantly to the total amount of CO₂ absorbed in addition to the absorption of peritoneal CO₂ insufflation. Ideally, hyperventilation is the solution to the hypercarbia and respiratory acidosis, but in the steep Trendelenburg position, hyperventilation is limited during robotic surgery by a higher ventilator-inspired pressure. Plus, the abdominal CO₂ insufflation also limits diaphragmatic excursion.²⁷ In this setting, Oğurlu et al⁴⁵ observed lower peak airway pressure and plateau pressure with higher lung compliance with the use of pressure-controlled ventilation. This use of pressure-controlled ventilation—allowing a larger tidal volume for the same inspired pressure—might be particularly useful for patients for whom it is difficult to achieve adequate oxygenation.⁴⁶

Positive end-expiratory pressure (PEEP) can help decrease atelectasis. PEEP improves intraoperative oxygenation and lung mechanics, impedes the venous blood return from the lower extremities, and decreases cardiac output, but these effects are likely to be negated by the steep Trendelenburg position. Limiting the amount of CO₂ insufflation causing increased venous congestion in the upper extremity can help prevent facial and airway edema.⁴⁷

Many patients with endometrial cancer are obese and have less efficient ventilation during pneumoperitoneum.⁴⁸ These patients present with further challenges in airway management, and they may be at higher risk of coronary artery disease, pulmonary dysfunction, and diabetes.¹⁷ In general, the hindrance to normal diaphragmatic excursion is substantial when these patients are placed in the steep Trendelenburg position.⁴⁹

With the creation of pneumoperitoneum, immediate gas embolism may occur, and in very rare cases it can cause severe

cardiovascular failure, reduction of pulmonary blood flow, and death. The clinical manifestations generally include a sudden increase followed by a rapid drop in end-tidal CO₂, tachycardia, hypotension, diminished breath sounds in a specific lung field on auscultation, cyanosis, and a classic cardiac murmur (mill-wheel murmur) associated with gas embolization. The mechanism is perceived to be infiltration of insufflated CO₂ into venous/lymphatic channels with pulmonary migration, presumed to occur from rapid insufflation of gas directly into the bloodstream.³⁶ Certain measures to avoid and to treat this complication include rapid removal of pneumoperitoneum, hyperventilation with oxygen, placing the patient in the left lateral decubitus and Trendelenburg positions, cardiopulmonary resuscitation, and potentially aspirating the embolus via a central venous catheter or needle insertion directly into the right ventricle via a substernal approach aimed toward the left shoulder with subsequent therapeutic aspiration of gas.^{36,48} During the procedure, CO₂ should be used for insufflation because of its high diffusion coefficient to minimize the risk of gas emboli.²¹ The anesthesiologist needs to use extreme caution and measure CO₂ levels at the end of exhalation so he/she can adjust the ventilator to remove excess CO₂ and help prevent hypercarbia and acidosis.

Cardiac arrhythmias and vagal reactions secondary to peritoneal distention during insufflation or viscus manipulation and diminished cardiac preload secondary to caval compression can contribute to a catastrophic outcome and asystolic cardiac arrest. Hypoxia or hypercapnia can result in cardiac arrhythmias. The combination of Trendelenburg positioning and elevated intraabdominal compartment pressures predispose a patient to aspiration, potentially resulting in hypoxia and possibly hypercapnia. Theoretically, hypercapnia can also occur from CO₂ absorption during pneumoperitoneum.

Other Complications

Another major anesthetic consideration during robotic-assisted surgery for endometrial cancers is the prolonged anesthesia that accentuates the problems highlighted above by placing a longer challenge on the patient's cardiorespiratory capacity.⁵⁰ Prolonged anesthesia is a key area of concern with all robotic-assisted gynecologic procedures. Because many patients undergoing gynecologic surgery are discharged home the same day, adequate pain control and postoperative nausea and vomiting (PONV) are significant concerns. Multimodal approaches to pain management and appropriate PONV prophylaxis have been shown to decrease length of stay and improve patient satisfaction.^{51,52}

TEAMWORK AND COMMUNICATION

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Given all of the technological aspects of robotic surgery and the potential physiological consequences and risk of morbidity and mortality specific to gynecologic surgeries, the use of robotic surgery simulation programs may afford distinct advantages when preparing personnel for success in the operating room. Simulation has the potential to improve outcomes and reduce complications while enhancing teamwork.⁵³ In addition, good communication among all members of the team, including surgeons, anesthesiologists, and nurses is the key to a safe, effective, and efficient environment. The addition of audio speakers to transmit the surgeon's voice can also improve communication among team members.²²

CONCLUSION

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In 2 short decades, robotic surgery has grown into its own subspecialty. As with other procedures, gynecologic robotic-assisted procedures are associated with potentially serious complications as a result of steep Trendelenburg positioning, creation of pneumoperitoneum, and difficult access to the patient. Common complications include positioning injuries, upper body edema, cardiopulmonary compromise, subcutaneous emphysema, and hypothermia. In a review of the literature, the American Association of Gynecology reported an incidence of 1 in 2,500 cases of asystole and arrest during laparoscopy, reflecting the potential for catastrophic morbidity and mortality.^{54,55}

Teamwork and communication among surgeons, nurses, and anesthesiologists are essential to minimize complications and improve surgical conditions and patient outcomes.

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Footnotes

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The authors have no financial or proprietary interest in the subject matter of this article.

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