Journal of Medical and Surgical Urology

ISSN: 2168-9857

OPEN ACCESS Freely available online

Review Article

Anesthetic Considerations in Robotic Surgery: A Comprehensive Review

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ABSTRACT

Recent advancements indicate a surge in demand for minimally invasive surgical techniques, with robot-assisted procedures gaining prominence due to their ability to address limitations of traditional laparoscopic methods. However, the introduction of robotic surgery may necessitate adjustments in patient positioning and logistical arrangements for staff and equipment, challenging conventional approaches to anesthesia care. Despite these considerations, the innovative impact of robotic technology holds promise for transformative therapeutic enhancements. To enhance patient safety and deliver superior anesthesia care, anesthesiologists must grasp the fundamental aspects of robotic surgical systems and stay informed about these evolving developments.

Keywords: Robotic surgery; Anesthesia; Perioperative preparation; Intraoperative management; Postoperative care; Robotic systems; Advantages; Limitations

INTRODUCTION

Robotic surgery has emerged as a transformative technology in modern surgical practice, offering surgeons enhanced precision, dexterity, and visualization compared to traditional approaches [1]. This technological advancement has revolutionized various surgical specialties, including urology, gynecology, general surgery, and thoracic surgery. The integration of robotic systems, such as the da Vinci Surgical System, has facilitated complex procedures and led to improved patient outcomes [2]. However, the success of robotic surgery relies not only on the technological sophistication of the systems but also on meticulous preoperative planning, intraoperative management, and postoperative care.

In recent years, there has been a growing interest in understanding the specific considerations and challenges faced by anesthesiologists in the context of robotic surgery. Anesthesia plays a crucial role in ensuring patient safety, optimizing surgical conditions, and facilitating a smooth perioperative course. Therefore, it is imperative to examine the unique implications of robotic surgery on anesthesia practice.

This article aims to provide a comprehensive review of the anesthetic considerations in robotic surgery, encompassing the technological aspects of robotic systems, the advantages and applications of robotic surgery, as well as the limitations and technical challenges encountered. By synthesizing current literature and clinical insights, this review seeks to offer practical guidance to anesthesiologists and surgical teams involved in robotic procedures, ultimately contributing to improved patient care and surgical outcomes.

LITERATURE REVIEW

Robotic surgical systems: Overview, advantages, and technical challenges

Robotic systems, such as the da Vinci Surgical System, are widely used in a variety of surgical specialties. They consist of a control console where the surgeon operates, and a robotic unit with miniaturized articulated arms equipped with surgical instruments. These systems offer high-definition 3D visualization and magnification, as well as enhanced dexterity and precision [1]. Robotic surgery offers many advantages, including better visualization thanks to the 3D camera, reduced surgeon fatigue, fewer post-operative complications, faster recovery and shorter hospital stays for patients [3,4]. In addition, it enables complex procedures with increased precision, paving the way for less invasive interventions and improved surgical outcomes.

However, robotic surgery is not without its limitations and challenges. High costs, a learning curve for surgeons, maintenance issue and system availability are all obstacles to their widespread adoption [5,6]. In addition, complications specific to robotic surgery, such as thermal injury and system malfunctions, require appropriate monitoring and management.

Preoperative anesthetic considerations

Preanesthetic patient evaluation prior to robotic surgery: A

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Received: 20-Mar-2024, Manuscript No. MSU-24-30284; **Editor assigned:** 22-Mar-2024, PreQC No. MSU-24-30284 (PQ); **Reviewed:** 05-Apr-2024, QC No. MSU-24-30284; **Revised:** 12-Apr-2024, Manuscript No. MSU-24-30284 (R); **Published:** 19-Apr-2024. DOI: 10.35248/2168-9857.24.13.343

Citation: Hafiani H, Choubhi M, Ameur A, Bensghir M, Abou Elalla K (2024) Anesthetic Considerations in Robotic Surgery: A Comprehensive Review. Med Surg Urol. 13:343.

comprehensive preanesthetic evaluation is essential to assess the patient's overall health status and to identify any potential risks or contraindications for anesthesia. Schrijvers et al., provide valuable guidelines regarding pulmonary gas exchange during robot-assisted surgery in Trendelenburg position, offering insights into optimizing preanesthetic assessment to ensure adequate respiratory function and oxygenation during the procedure [7].

Optimization of physiological state before surgery: Optimizing the patient's physiological state before robotic surgery is crucial for enhancing perioperative outcomes and reducing the risk of complications. Scott et al., discuss the role of preoperative carbohydrate-enriched drinks in improving patients' physiological status prior to surgery [8]. These strategies aim to minimize the metabolic stress response, maintain euglycemia, and enhance perioperative energy reserves, thereby promoting better recovery and postoperative outcomes in robotic surgical patients.

Planning specific anesthetic management for robotic surgery: Tailoring anesthetic management to the unique demands of robotic surgery requires careful planning and consideration of various factors. [1]. delve into the specifics of anesthetic management for robot-assisted laparoscopic surgery, offering insights into preoperative planning strategies tailored to the intricacies of robotic surgical procedures. This includes considerations such as patient positioning, pneumoperitoneum management, and hemodynamic optimization, aiming to ensure safe and effective anesthesia delivery throughout the surgical intervention.

Anesthetic techniques and pharmacological agents

General anesthesia *vs.* regional anesthesia in robotic surgery: Robotic surgery offers a unique setting where both general anesthesia and regional anesthesia techniques can be utilized based on the patient's condition and the surgical procedure. Corcione et al., provide comprehensive insights into the considerations for selecting between general and regional anesthesia in robotic abdominal surgery [9]. General anesthesia offers advantages such as rapid onset, controlled airway management, and immobility, which are particularly beneficial for complex procedures requiring precise surgical manipulation. On the other hand, regional anesthesia techniques, such as epidural or spinal anesthesia, provide effective analgesia and can potentially reduce the need for intraoperative opioids, thereby facilitating early recovery and postoperative pain management. Understanding the nuances of each approach is essential for anesthesiologists to tailor their anesthetic plan to the individual patient's needs and the specific requirements of the robotic surgical procedure.

Utilization of multimodal analgesia techniques: Effective postoperative pain management is essential for optimizing patient comfort and facilitating early mobilization and recovery following robotic surgery. Batley emphasize the importance of multimodal analgesia strategies in achieving superior pain control while minimizing opioid-related adverse effects [10]. Multimodal analgesia combines various analgesic modalities, including opioids, Non-Steroidal Anti-Inflammatory Drugs (NSAIDs), acetaminophen, and regional anesthesia techniques, to target different pain pathways and provide synergistic pain relief. By utilizing multiple agents with complementary mechanisms of action, anesthesiologists can achieve adequate pain control with lower opioid doses, thereby reducing the incidence of opioid-related side effects such as nausea, vomiting, sedation, and respiratory depression. Moreover, multimodal analgesia promotes Enhanced Recovery After Surgery (ERAS) protocols by facilitating early ambulation, reducing length of hospital stay, and improving overall patient satisfaction.

Specific pharmacological considerations in robotic surgery patients: Robotic surgery patients may present unique pharmacological challenges due to factors such as preexisting comorbidities, intraoperative hemodynamic changes, and postoperative complications. Pramanik highlight the importance of individualized pharmacological management strategies tailored to the specific needs of robotic surgical patients [11]. Factors such as renal function, hepatic metabolism, drug interactions, and respiratory status should be carefully considered when selecting and dosing pharmacological agents. Additionally, intraoperative monitoring and vigilant postoperative care are essential to identify and manage potential drug-related adverse events promptly. By addressing these specific pharmacological considerations, anesthesiologists can optimize perioperative care and enhance patient safety in robotic surgery.

Intraoperative anesthetic management

Patient positioning and monitoring: During robotic surgery, meticulous patient positioning is essential to provide optimal exposure for the surgical field while ensuring patient safety and comfort. Proper positioning helps facilitate surgical access and minimizes the risk of nerve injuries, pressure ulcers, and other positioning-related complications. Additionally, continuous monitoring of vital signs, including blood pressure, heart rate, oxygen saturation, and end-tidal carbon dioxide, is imperative to promptly identify and address any intraoperative hemodynamic fluctuations or adverse events.

Several studies have emphasized the importance of appropriate patient positioning and vigilant intraoperative monitoring in robotic surgery. For instance, Schrijvers et al., discuss the challenges associated with maintaining adequate pulmonary gas exchange during robot-assisted surgery in Trendelenburg position, highlighting the need for continuous monitoring of respiratory parameters to prevent hypoxemia and hypercapnia [7]. Similarly, underscore the significance of meticulous patient positioning to optimize surgical outcomes and minimize the risk of intraoperative complications in robotic-assisted radical prostatectomy [12].

Management of pneumoperitoneum: Pneumoperitoneum, created by insufflating carbon dioxide into the peritoneal cavity, is a fundamental aspect of robotic surgery that provides adequate visualization and space for surgical maneuvers. However, maintaining optimal pneumoperitoneum pressure and ensuring adequate ventilation are critical considerations during the intraoperative period. Excessive intra-abdominal pressure can lead to hemodynamic instability, impaired venous return, and compromised respiratory mechanics, necessitating careful monitoring and adjustment of insufflation parameters. Studies have highlighted the anesthetic considerations associated with pneumoperitoneum management in robotic-assisted laparoscopic procedures, emphasizing the importance of maintaining adequate ventilation-perfusion matching and minimizing the risk of intraoperative hypercapnia and acidosis [13]. Additionally, discuss the effects of steep Trendelenburg positioning on intraocular pressure during robotic surgery, underscoring the need for ophthalmological monitoring and appropriate measures to mitigate the risk of ocular complications [14].

Hemodynamic optimization: Achieving hemodynamic stability is paramount during robotic surgery to ensure adequate tissue perfusion and oxygen delivery while minimizing the risk of perioperative cardiovascular events. Hemodynamic optimization strategies may include fluid management, vasopressor or inotropic support, and goal-directed therapy guided by advanced monitoring techniques such as arterial pressure waveform analysis or transesophageal echocardiography.

Research explores the utility of intraoperative Positive End-Expiratory Pressure (PEEP) evaluation using the intratidal compliance-volume profile in optimizing hemodynamic status during robotic surgery [15]. Their findings emphasize the importance of individualized hemodynamic management strategies tailored to the patient's physiological parameters and surgical requirements. Similarly, discuss the challenges and considerations for hemodynamic management in robotic gynecological surgery, highlighting the importance of maintaining perioperative hemodynamic stability to optimize outcomes and minimize perioperative complications [16].

Postoperative care and pain management

Monitoring and assessment of postoperative complications: Following robotic surgery, vigilant monitoring and assessment of postoperative complications are essential for early detection and intervention. This involves continuous monitoring of vital signs, assessment of pain levels, evaluation of surgical site integrity, and detection of potential adverse events such as bleeding, infection, and thromboembolic events. Additionally, close collaboration between anesthesia providers, surgeons, and nursing staff is crucial to ensure timely recognition and management of any postoperative complications.

Studies such as discuss the importance of postoperative pulmonary complications in patients undergoing robotic-assisted gynecologic surgery, emphasizing the need for comprehensive respiratory assessment and pulmonary care strategies [17]. Similarly, highlight the significance of monitoring for respiratory complications in robotic urological surgeries, underscoring the importance of early recognition and intervention to prevent adverse outcomes.

Multimodal pain management strategies: Effective pain management is paramount in enhancing patient comfort and facilitating early recovery following robotic surgery. Multimodal analgesia strategies, which combine various analgesic modalities targeting different pain pathways, have emerged as a cornerstone of postoperative pain management.

These strategies may include the use of opioids, Non-Steroidal Anti-Inflammatory Drugs (NSAIDs), acetaminophen, regional anesthesia techniques, and adjunctive medications such as gabapentinoids and ketamine.

The implementation of multimodal analgesia techniques in managing postoperative pain in patients undergoing robotic urological surgery. Their study highlights the efficacy of combining different analgesic modalities to achieve superior pain control while minimizing opioid-related side effects. Additionally, explore the efficacy of a three-point cuff palpation technique in preventing endobronchial tube migration during robotic pelvic surgeries, emphasizing the importance of optimizing pain management strategies to enhance patient outcomes [18].

Early mobilization and enhanced recovery protocols: Early mobilization and enhanced recovery protocols play a crucial role in promoting faster recovery and reducing the length of hospital stay following robotic surgery. These protocols focus on optimizing perioperative care pathways, including early ambulation, nutritional support, and physiotherapy, to facilitate rapid return to baseline functional status and improve overall patient satisfaction.

Research by Scott et al., [8] emphasizes the importance of early ambulation and oral carbohydrate preload drinks in enhancing recovery following major surgery.

Their study underscores the benefits of implementing enhanced recovery protocols to minimize postoperative complications and expedite recovery in patients undergoing robotic surgery. Additionally, discuss the contemplations of anesthesiologists in robotic surgery, highlighting the role of multidisciplinary collaboration in implementing comprehensive perioperative care pathways to optimize patient outcomes [19].

DISCUSSION

Complications and adverse events

Respiratory complications: Robotic surgery, while minimally invasive, can still pose risks of respiratory complications, including atelectasis, pneumonia, and respiratory distress. These complications may arise due to factors such as prolonged surgical duration, intraoperative positioning, and the effects of pneumoperitoneum on respiratory mechanics. Prompte recognition and management of respiratory complications are crucial to prevent adverse outcomes and optimize patient recovery [20].

Discuss the considerations for respiratory management in patients undergoing robotic-assisted radical prostatectomy, emphasizing the importance of perioperative lung protective strategies and early postoperative mobilization to minimize the risk of respiratory complications. Similarly, explore the evolution of robotic surgery from both surgical and anesthetic perspectives, highlighting the advancements in respiratory monitoring and management techniques to improve patient safety [21].

Hemodynamic instability: Hemodynamic instability, characterized by fluctuations in blood pressure, heart rate, and cardiac output, can occur during robotic surgery due to factors such as pneumoperitoneum-induced changes in venous return, intraoperative fluid shifts, and the effects of anesthetic agents on cardiovascular function. Close hemodynamic monitoring and proactive management are essential to maintain hemodynamic stability and prevent adverse cardiovascular events.

The anesthetic concerns for robotic-assisted laparoscopic radical prostatectomy, emphasizing the importance of optimizing fluid balance and vasopressor support to mitigate the risk of intraoperative hypotension and hemodynamic instability. Additionally, investigate the preservation of pulmonary gas exchange during robotic surgery in steep Trendelenburg position, highlighting the implications for hemodynamic management and perioperative fluid administration.

Neurological complications: While relatively rare, neurological complications such as peripheral nerve injuries, neuropathies, and cerebral ischemia can occur during robotic surgery due to factors such as patient positioning, prolonged surgical duration, and the effects of anesthetic agents on cerebral perfusion. Vigilant neurological assessment and early recognition of potential complications are essential to prevent long-term neurological sequelae and optimize patient outcomes.

The implications of patient positioning and anesthesia management on neurological outcomes in robotic surgery, emphasizing the importance of maintaining cerebral perfusion and minimizing the risk of nerve injuries. Additionally, Mittal et al., investigate the efficacy of neuroprotective techniques such as three-point cuff palpation to prevent nerve injuries during robotic pelvic surgeries, highlighting the role of anesthesiologists in optimizing perioperative neurological care.[18]

Future perspectives and emerging trends

Advancements in robotic technology: Robotic surgery continues to evolve rapidly with advancements in robotic technology, including improvements in surgical platforms, instrumentation, imaging modalities, and telepresence capabilities. Future developments in robotic technology aim to enhance surgical precision, dexterity, and ergonomics, while also expanding the scope of robotic procedures to include more complex surgeries across various specialties. The potential implications of technological advancements in robotic surgery for anesthetic management, highlighting the need for anesthesiologists to stay abreast of emerging technologies and adapt their perioperative [7].

CONCLUSION

Robotic surgery, with its advantages in terms of precision and rapid recovery, represents a major advancement in modern surgical practice. However, its success relies on comprehensive perioperative management, where anesthesia plays a central role in ensuring patient safety and optimizing surgical outcomes.

In this article, we have examined various aspects of anesthetic considerations in robotic surgery, highlighting the importance of preoperative assessment, intraoperative management, postoperative care, as well as prevention and management of complications. By incorporating evidence-based anesthetic techniques and multimodal analgesia strategies, anesthesiologists can significantly contribute to the success of robotic surgical interventions. Moreover, a multidisciplinary approach involving surgeons, anesthesiologists, and other healthcare professionals is essential to ensure a smooth and secure surgical experience for patients.

The future of robotic surgery appears promising, with technological advancements and innovative anesthetic techniques expected to further enhance patient outcomes and safety. In summary, close collaboration among healthcare team members, proactive adoption of new technologies, and careful attention to perioperative care are crucial to advancing the practice of robotic surgery and providing optimal care to patients.

CONFLICT OF INTEREST

No authors have competing interests.

ETHICAL APPROVAL

As per international standard or university standard written ethical approval has been collected and preserved by the author(s).

AUTHOR CONTRIBUTION

Hamza Hafiani, Khalil Abou Elalaa: Conception, contribution to literature review final draft writing, and critical revision All the authors have participated sufficiently in this work, take public responsibility for the content, and have made substantial contributions to this research.

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