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Anesthetic Challenges in Robotic Assisted Laparoscopic Radical Prostatectomy

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Abstract

Robotic assisted laparoscopic radical prostatectomy (RALRP) has emerged as a preferred surgical approach for the treatment of prostate cancer due to its minimally invasive nature and enhanced surgical precision. Patient positioning, including the prolonged Trendelenburg position, poses challenges related to respiratory and hemodynamic management. The creation and maintenance of pneumoperitoneum can lead to physiological changes, necessitating close monitoring and appropriate fluid management. The management of pain during and after surgery requires a multimodal approach. Post-operative care requires vigilant monitoring and management to prevent complications and facilitate recovery. Future advancements in anesthesia technology, including precision medicine, enhanced monitoring, automation, and pharmacological innovations, hold promise for further improving anesthetic care in RALRP.

Keywords: anesthetic management, patient positioning, pneumoperitoneum, robotic assisted laparoscopic radical prostatectomy

Key points

- Robotic assisted laparoscopic radical prostatectomy is a minimally invasive surgical procedure using the da Vinci surgical system to remove the prostate gland in patients with localized prostate cancer.
- Anesthesiologists play a critical role in addressing challenges such as patient positioning, ventilation, hemodynamic stability, fluid management, and pain control.

Introduction

Robotic assisted laparoscopic radical prostatectomy (RALRP) is a minimally invasive surgical procedure that combines laparoscopic surgery with robotic assistance to remove the prostate gland in patients with localized prostate cancer. During RALRP, the patient is placed under general anesthesia. Small keyhole incisions are made in the abdomen, and carbon dioxide gas is used to create a working space. Robotic arms equipped with specialized surgical

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instruments are inserted through these incisions, controlled by the surgeon from a console in the operating room.

Anesthesiologists play a critical role in addressing the specific challenges posed by RALRP, such as patient positioning, ventilation, hemodynamic stability in the prolonged Trendelenburg position, fluid management, and pain control. Through careful monitoring and management of vital signs, including blood pressure, heart rate, oxygen saturation, end-tidal carbon dioxide levels, and collaboration with the surgical team, an anesthesiologist ensures positive patient experience during the surgery, despite challenges in equipment placement and administration due to limited space and the presence of the robotic system.[1]

Understanding RALRP

The DaVinci® surgical system, developed by Intuitive Surgical, Inc. in Sunnyvale, California, is a pioneering robotic platform widely utilized in the medical field. With over 800 robots installed worldwide, it stands as the leading robotic system in common practice today. This surgeon-driven system boasts either 3 or 4 arms, offering remarkable Endo wrist capabilities and granting surgeons a three-dimensional visualization of the surgical field. Despite some criticisms regarding its functionality and potential areas for improvement, this system has undeniably revolutionized the landscape of robotic surgery.[2]

One prime example of its transformative impact is in the realm of treating localized prostate cancer through a state-of-the-art procedure known as RALRP. This technique harnesses the precision of robotics and minimally invasive methods, primarily relying on the Da Vinci Surgical System for its success. RALRP presents a host of advantages over traditional surgical approaches, including enhanced surgical precision, minimized blood loss, shorter hospital stays, and expedited recovery periods.[3]

Men diagnosed with localized prostate cancer, especially those classified as having low to intermediate risk, a favorable life expectancy, and no contraindications for surgery, find RALP to be a particularly suitable treatment option. The procedure itself entails creating small abdominal incisions to insert trocars, with robotic arms controlled by a skilled surgeon via a console offering a three-dimensional view of the surgical field. This meticulous approach allows for the careful dissection of the prostate gland, and in some cases, potential lymph node removal when deemed necessary.[4]

One of the most striking features of the robotic system is its ability to enhance surgical precision, significantly reducing the risk of damage to crucial nerves responsible for urinary and erectile function. While there are inherent risks associated with any surgical procedure, including temporary urinary incontinence, erectile dysfunction, bleeding, and the potential for infections, RALRP offers compelling benefits. These include excellent cancer control outcomes, accelerated post-operative recovery, and promising long-term survival rates for patients diagnosed with localized prostate cancer. In essence, the DaVinci surgical system and RALRP together exemplify the evolution of

surgical technology, ushering in a new era of medical care that prioritizes precision, patient outcomes, and quality of life.[5]

Preoperative consideration

Patients should receive a clear and detailed explanation of the RALRP procedure. They should be aware of potential risks and complications, and the decision to undergo RALP should be made in consultation with a qualified urologist or oncologist based on individual circumstances and cancer staging. Preoperative visits with the anesthesia team establish rapport and address concerns. Providing written materials in plain language can serve as helpful references. Implementing anxiety-reducing techniques and supportive communication can alleviate preoperative anxiety. Premedication, such as anticholinergics, benzodiazepines, or opioids, may be necessary, especially for anxiety patients.

The anesthesiologist relies on patients' information regarding previous surgeries, allergies, medications, chronic medical conditions, and reactions to anesthesia or drugs. A thorough physical examination is conducted to assess the patient's overall health, including signs of respiratory compromise, cardiovascular disease, or physical limitations that may impact patient positioning or airway management during RALRP. Laboratory tests, such as blood tests, electrocardiogram, chest X-ray, and pulmonary function tests, help evaluate baseline organ function and detect any underlying abnormalities to guide anesthesia decisions. Airway assessment assists in planning for potential difficulties and selecting the appropriate approach.

Anesthetic considerations for patients with comorbidities require a comprehensive and individualized approach. Patients with decompensated heart failure, significant arrhythmias, or severe valvular heart disease should have their surgery delayed or canceled to manage their heart condition first. Patients with cardiovascular stents, even when taking anticoagulants and antiplatelet drugs, are at risk of stent thrombosis. Patients with severe chronic obstructive pulmonary disease are at an increased risk during surgery due to higher airway pressures during mechanical ventilation. Precautions are necessary in patients with lung bullae, which could potentially rupture and complicate the procedure.[6] Positioning on the operating table can also be challenging to prevent neurological injury.[7] The patient's medical history includes hypertension, cardiorespiratory disease, diabetes, and medications that can affect blood pressure or heart rate, should be evaluated. Adequate intravenous access using multiple large-bore peripheral intravenous catheters is typically placed to accommodate rapid fluid administration and possible blood transfusion before the procedure.[8]

Intraoperative challenges

Open and collaborative communication between the anesthesia and the surgical team is essential in RALRP. The expertise of the anesthesia team, particularly those experienced in robotic surgery anesthesia, is crucial for selecting the appropriate technique. General

anesthesia is commonly used for RALRP, inducing unconsciousness, providing pain relief, muscle relaxation, and control of physiological parameters. Patients are also intubated using an endotracheal tube to secure the airway and ensure adequate oxygenation and ventilation throughout the procedure. In some cases, a combination of general and regional anesthesia may be employed.

Positioning

Proper patient positioning and access to the surgical site are essential for optimal visualization, precise instrument manipulation, maintain patient safety and comfort, and successful completion of the procedure. The lithotomy position is commonly used for RALRP. In this position, the patient lies supine with their legs raised and flexed at the hips and knees, supported by stirrups. However, some surgeons prefer the supine position with bilateral hip abduction, which can also provide adequate exposure and access for the procedure. Access ports are inserted into the patient's abdomen to facilitate the insertion of robotic instruments and the camera used in RALRP. These ports are typically placed in specific locations to optimize instrument movement.

Trendelenburg position may be utilized during RALRP to displace the intestines cephalad, creating additional space and facilitating access to the pelvic organs. Steep reverse Trendelenburg positioning, with the head elevated and the feet lowered, may be used to displace the small bowel away from the operative field. The degree of Trendelenburg tilt is typically adjusted based on the surgeon's preference and the patient's tolerability.[9] However, it can present challenges in terms of preventing complications associated with prolonged positioning, managing the airway, and maintaining stable hemodynamics. It is important to ensure patient comfort and helps reduce the risk of nerve injuries during the procedure, such as brachial plexus injury, common peroneal, lateral femoral cutaneous or obturator nerve.[10]

Monitoring

Continuous monitoring of the patient's vital signs during RALRP, including blood pressure, heart rate, oxygen saturation, end-tidal carbon dioxide levels, and temperature, is crucial. Typically, blood pressure is maintained within an appropriate range based on the patient's condition, preoperative assessment, age, cardiac function, and comorbidities. Proper fluid management is vital to maintain fluid balance, optimize tissue perfusion, and minimize complications. Close monitoring of anesthetic depth, guided by clinical assessment and anesthesia monitoring devices, is crucial to maintaining stable hemodynamics and ensuring sufficient perfusion to vital organs during RALRP.[11]

Pneumoperitoneum

Pneumoperitoneum, the insufflation of carbon dioxide gas into the abdominal cavity can create an increased intra-abdominal pressure, and a working space for the surgical procedure. Adequate pressure is usually maintained between 12 to 15 mmHg. This can lead to various physiological changes and potential complications. Pneumoperitoneum

can indeed induce hemodynamic changes, leading to increased systemic vascular resistance, decreased venous return, and subsequent decreases in cardiac output and blood pressure. Therefore, it is essential to monitor parameters such as blood pressure, heart rate, central venous pressure, and cardiac output. It is advisable to minimize the use of excessive Trendelenburg or steep reverse Trendelenburg positions during RALRP to mitigate further hemodynamic instability.[12]

Pneumoperitoneum can impact respiratory function by decreasing lung compliance, impairing ventilation-perfusion matching and reducing functional residual capacity. Subsequently, ensuring proper ventilation with appropriate tidal volumes and respiratory rates is important. Careful monitoring of end-tidal carbon dioxide ($ETCO_2$) levels and arterial blood gas (ABG) analysis helps assess ventilation adequacy. The use of positive-end expiratory pressure (PEEP) can help maintain alveolar recruitment, improve oxygenation, and counteract the reduction in lung compliance. Periodic lung recruitment maneuvers, such as sustained inflation or intermittent increases in PEEP, may be performed to optimize lung function.[13]

Pneumoperitoneum can affect cardiovascular and cerebrovascular dynamics. Therefore, maintaining hemodynamic stability, optimizing fluid status, and ensuring appropriate blood pressure are crucial to support organ perfusion, including cerebral perfusion. Avoiding excessive head-down or head-elevated positions can help prevent cerebral perfusion abnormalities. Gradual and controlled deflation of the Zpneumoperitoneum at the end of the procedure helps minimize abrupt changes in intravascular volume and cardiovascular dynamics. Additionally, pneumoperitoneum can cause postoperative pain and discomfort. Effective pain management strategies should be implemented to ensure patient comfort and facilitate early mobilization. This may include multimodal analgesia techniques, such as a combination of systemic analgesics, regional anesthesia techniques, and non-pharmacological interventions.

Adjusting the ventilator settings

It is generally recommended to use lower tidal volumes to prevent excessive distention of the abdomen and reduce the risk of hemodynamic compromise. A tidal volume of 6-8 mL/kg of ideal body weight is typically appropriate. The respiratory rate of 12-16 breaths/min is commonly used to maintain $ETCO_2$ between 35-45 cmH_2O. It is essential to avoid excessively high respiratory rates. PEEP helps maintain lung volume and oxygenation by preventing alveolar collapse during expiration. Start with a PEEP of 5 cmH_2O and adjust as needed to maintain adequate oxygenation and avoid compromising hemodynamics.[14]

Trendelenburg position can potentially lead to the displacement of the endotracheal tube. To address this situation and ensure proper ventilation, the following steps include proper alignment of patient's head, and the confirmation of endotracheal tube. Once the correct tube position is confirmed, securely fasten the endotracheal tube in place using appropriate securing devices. This will prevent any unintended displacement.[15] After pneumo-

peritoneum is released, ensure that an endotracheal tube is repositioned to the appropriate depth based on the patient's size and the distance between the teeth and the carina.

Intraoperative complications

Regular communication among the surgical team, anesthesia team, and operating room staff for the sharing of patient information is essential for the early detection and management of any complications or changes in the patient's condition.[16] The anesthesia team plays a critical role in continuously assessing the patient's hemodynamic stability, oxygenation, ventilation, and proactive management, as well as timely intervention is crucial in managing these situations. Close monitoring of serum electrolyte levels, ABG analysis, and glucose levels, allows for early detection and appropriate correction. The primary challenges for anesthesiologists during robotic surgery are limited intraoperative patient access, insufficient space, and the robot cannot be executed immediately in the event of cardiopulmonary resuscitation and unexpected incidents during surgery.[17]

Complications related to patient positioning, such as nerve injuries, pressure injuries, or vascular compromise, should be promptly identified and addressed. Pneumoperitoneum-related complications include subcutaneous emphysema, pneumothorax, gas embolism, or injury to intra-abdominal organs, are generally rare. However, vigilant monitoring and close observation of the patient's vital signs, end-tidal carbon dioxide levels, oxygen saturation, and surgical field are vital for early recognition of complications. Injury to the urinary tract, including the bladder or ureters, is a potential complication. In severe cases, visceral injury can occur during RALRP.

Postoperative care

Following the procedure, patients are transferred to the post-anesthesia care unit for monitoring and recovery. Adequate pain management after RALRP is crucial for patient comfort and recovery. A multimodal approach is often employed, which may include the administration of medications, and non-pharmacological approaches. Nonsteroidal anti-Inflammatory drugs are effective in relieving mild to moderate pain by reducing inflammation and blocking pain signals. Opioids are potent analgesics used for moderate to severe pain.[18] Antidepressants, anticonvulsants, and muscle relaxants, can help alleviate neuropathic pain, reduce muscle spasm, and modulate pain signaling pathways.

For non-pharmacological approaches, physical therapy techniques like exercises, stretches, and manual therapy, which prove beneficial for improving pain and function, particularly in musculoskeletal conditions. Transcutaneous electrical nerve stimulation employs low-voltage electrical currents to alleviate pain by stimulating nerves.[19] Postoperative recovery is enhanced by early ambulation and respiratory care, crucial for preventing complications, improving lung function, stimulating digestion, and reducing

the risk of postoperative ileus.[20] Ambulation supports deep breathing and effective coughing, preventing atelectasis and ensuring proper oxygenation. Teaching patient's techniques, controlled coughing and chest physiotherapy techniques help to promote the recovery period.

Regular monitoring of vital signs, including heart rate, blood pressure, respiratory rate, pulse oximetry, capnography and temperature, is crucial to detect any signs of physiological instability or early complications. Accurate monitoring of fluid intake and output is essential. Thromboprophylaxis measures, like early ambulation, compression stockings, intermittent pneumatic compression devices, or medications, should be implemented to prevent deep vein thrombosis and pulmonary embolism, with risk assessment tools aiding in identifying higher-risk patients.[21]

Future directions and advancements

Advanced hemodynamic monitoring provides real-time vital parameter data for tailored hemodynamic management, optimized fluid administration, and early instability detection. Point-of-care ultrasound aids in assessing lung and cardiac function, guiding vascular access, and enhancing diagnostic capabilities.[22] Artificial intelligence and Machine learning analyze patient data, offering predictive analytics, personalized risk assessment, and decision support for preoperative planning and anesthesia management.[23]

Conclusion

RALRP has transformed urology by providing surgeons with superior precision and control, posing specific anesthetic challenges in terms of patient positioning, pneumoperitoneum management, fluid balance, pain control, and more. Addressing these challenges demand close teamwork, vigilant monitoring, and a deep understanding of RALRP's unique requirements. The future of RALRP anesthesia looks promising, with precision medicine, advanced monitoring, automation, pharmacological innovations, and multimodal pain management.

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