



Case report

MASSIVE SUBCUTANEOUS EMPHYSEMA DURING ROBOT-ASSISTED RECTAL CANCER RESECTION: A CASE REPORT

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ABSTRACT

Purpose. Robot-assisted surgery offers superior structural visualization and dexterity in fixed anatomical landmarks like the deep pelvis. However, prolonged high-pressure pneumoperitoneum and extreme positioning introduce unique anesthetic and soft-tissue ventilation challenges. The aim of our study was to analyze the clinical progression, risk factors, and the efficacy of vacuum-assisted surgical decompression in managing massive iatrogenic subcutaneous emphysema after robotic surgery.

Material/Methods. A 78-year-old male underwent an elective robot-assisted Hartmann's procedure and partial cystectomy. Continuous pneumoperitoneum and Trendelenburg position were maintained. Intraoperative soft-tissue gas tracking and progressive hypercapnia (EtCO₂ e"50 mmHg) were noted. Postoperatively, the patient was transferred to the ICU. Physical and X-ray examinations revealed extensive, bilateral subcutaneous emphysema spanning from the face down to the thighs, without evidence of pneumothorax. Immediate surgical decompression was performed via bilateral pectoral incisions, followed by the application of Negative Pressure Wound Therapy (NPWT).

Results. The implementation of infraclavicular incisions combined with NPWT led to rapid and controlled gas evacuation, preserving tissue viability and improving respiratory compliance. The patient was successfully extubated the next day; resolution of the tissue tension allowed removal of the vacuum dressings on the third postoperative day. Subtotal reduction of the emphysema was achieved by day four, enabling a safe transfer to the surgical ward.

Conclusions. Prolonged high-pressure pneumoperitoneum and wide retroperitoneal dissection during RAS represent crucial cumulative risk factors for massive subcutaneous emphysema. Infraclavicular decompression ("blowholes") combined with NPWT is a highly effective, safe, and expedited therapeutic strategy to ensure airway patency and facilitate early postoperative weaning.

Keywords: robot-assisted surgery, subcutaneous emphysema, pneumoperitoneum, negative pressure wound therapy,

INTRODUCTION

In the 21st century, interventional medicine and surgical sciences have experienced remarkable growth in available technology and equipment. Among these advancements, robot-assisted surgery (RAS) has revolutionized minimally invasive procedures. Originally developed to overcome the inherent technical limitations associated with conventional laparoscopy, robotic platforms have rapidly transformed the landscape of modern visceral and oncological surgery [1].

The concept of integrating robotic systems into surgical practice originally emerged within the framework of military medicine during the 1980s. Over the subsequent decades, this technology has evolved drastically. A significant milestone in this history was in 1998 with the market debut of two innovative platforms: ZEUS (Computer Motion, Inc.) and the da Vinci Surgical System (Intuitive Surgical, Inc.). Although the industry currently offers a diverse range of alternatives from various manufacturers, the da Vinci platform maintains its leading position as the most widely adopted system globally, boasting over 10,000 operational consoles worldwide [2].

Globally, robotic surgery is most extensively utilized in urology and gynecology, where it has become the gold-standard approach, while also expanding into cardiothoracic and head and neck interventions. The indications for RAS in abdominal surgery are extensive, spanning from simple cholecystectomies to highly complex multivisceral resections. However, the most significant benefit of robotic interventions can be observed in narrow, fixed anatomical spaces where surgical maneuverability is severely restricted. Consequently, the primary indications include deep pelvic dissections, such as low anterior rectal resections for rectal cancer. Advanced oncological procedures requiring multivisceral resections (e.g., T4 tumors invading adjacent organs like the urinary bladder). Noncomplex hepato-pancreato-biliary (HPB) surgeries, including the Whipple procedure and anatomical liver resections, bariatric and complex ventral hernia repairs [3].

Robot-assisted surgery represents a significant advancement in the field of minimally invasive interven-

tions. Robotic platforms provide high precision during surgical maneuvers, enabling the operating surgeon to execute complex tasks with submillimeter accuracy. This minimizes tissue damage and optimizes surgical outcomes. The precise control of instruments combined with high-definition, 3D stereoscopic visualization contributes to reduced tissue trauma and a lower incidence of associated perioperative complications [4]. This is achieved through digital motion scaling, which enhances fine motor skills and eliminates the “fulcrum effect” characteristic of conventional laparoscopy. Furthermore, the system filters physiological tremors and prevents involuntary, abrupt movements. The platform also allows for more ergonomic and anatomical control of the instruments, which accurately mimic the movements of the human wrist via EndoWrist technology. Consequently, this facilitates delicate procedures in narrow or otherwise poorly accessible anatomical zones where conventional techniques face some limitations. The ability to maintain the camera in a stable, tremor-free position further enhances the surgeon’s precision and control over the surgical field [5].

Minimized tissue trauma can lead to a significant reduction in perioperative blood loss, reducing the requirement for allogeneic blood product transfusions and mitigating the associated risks of allergic, immunological, transmissible, and various other transfusion-related complications [6].

The smaller incisions required for robotic interventions yield numerous secondary benefits for patients, including reduced postoperative pain, minimal cutaneous scarring, and a lower risk of surgical site infections. The cosmetic advantages provided by such procedures are particularly popular among patients, along with the reduced postoperative discomfort they experience [7]. The limited size of the incisions ensures minimal exposure of internal tissues to the external environment, thereby reducing the likelihood of exogenous contamination. This is particularly crucial in high-volume, complex surgeries where a postoperative infection could lead to severe systemic complications [8]. Minimized tissue trauma also decreases the requirement for perioperative opioid and non-opioid analgesics, consequently limiting their associated adverse drug reactions. Infiltrative blocks play a significant role here, with the TAP (Transversus Abdominis Plane) block being one of the most widely utilized approaches in this regard [9]. Furthermore, reduced surgical stress limits the systemic inflammatory response, resulting in lower plasma concentrations of pro-inflammatory mediators such as interleukin-6 and monocyte chemoattractant protein-1, high levels of which are associated with secondary tissue and organ injury [10].

Despite the numerous advantages of robotic surgery over laparoscopic and conventional techniques, certain limitations exist that necessitate a specific perioperative approach. Each component of the equipment is exceptionally bulky, requiring significant space

within the operating room. In smaller facilities, this can prove to be a limiting factor, hindering the implementation of robotic platforms. The large size of the robot’s chassis makes it difficult to position due to the potential for collisions with other equipment, the assisting staff, or the patient themselves. Encroachment into the workspace of the anesthetic team is almost inevitable. The anesthesiologist must be aware that the size of the robot can complicate maneuvering and access to the patient in the operating room. Proper patient positioning on the operating table prior to the start of the procedure is of critical importance, as altering the configuration of the table is impossible once the robotic arms are docked and fixed. The operating room personnel must be specifically trained for timely emergency undocking and removal of the robot from the patient in the event of a critical issue, such as the need for cardiopulmonary resuscitation or an urgent conversion to open surgery [11].

A significant portion of robotic surgery is performed in non-physiological positions, including extreme Trendelenburg, the lithotomy position and lateral decubitus with hyperflexion of the operating table, among others. This predisposes the patient to injuries of cutaneous, bony, and nerve structures; therefore, the prevention of positional injuries is an obligatory part of preoperative preparation [12]. These positions also exert a substantial impact on the cardiovascular, respiratory, renal, and other organ systems. Current robotic systems still lack tactile feedback (haptic feedback) from the instruments. Consequently, surgeons rely solely on visual cues to modulate the amount of tension and pressure applied to the tissues. Adequate visual assessment in this scenario is essential to avoid collateral injury to the patient [13].

Technical challenges related to the robotic system can arise during the course of the surgical intervention. These may include malfunctions of the robotic arms, communication issues between the surgeon and the console, or mechanical obstructions during the procedure. There is always a probability of surgical complications occurring, such as a vascular incident or non-surgical events that would necessitate rapid access to the patient. Therefore, the entire operating team must undergo periodic training to manage such critical situations, ensuring patient safety and the successful completion of the operation [8].

Lastly, the costs of acquiring and maintaining robotic surgical systems can be substantial. This financial barrier can present a serious challenge for smaller hospitals and healthcare facilities with limited budgets, thereby restricting the wider adoption of robotic surgery [14]. There is a tangible variability in the learning curve depending on the type of intervention and the surgeon’s prior experience in laparoscopy. It can range from 8–12 procedures for cholecystectomies to over 300 for highly specialized cardiothoracic procedures [15]. Continuous education and ongoing training are of decisive importance; thus, particularly during the initial developmen-

tal phase of a given center, robotic surgery is typically associated with longer operative times and higher hospital costs [16].

The robotic system cannot replace the surgeon, it merely enhances the precision of their actions. The presence of a robotic system is no guarantee of success in the absence of knowledge and skills on the part of the team [13].

Anesthetic Challenges in Robotic Abdominal Surgery:

While the robotic platform offers clear ergonomic advantages for the operating surgeon, it introduces a unique constellation of pathophysiological challenges for the anesthesia care team. The combination of a prolonged high-pressure carbon dioxide (CO₂) pneumoperitoneum and a steep Trendelenburg position induces profound alterations in patient homeostasis, requiring vigilant monitoring and tailored ventilatory strategies.

- Cardiovascular alterations:

The establishment of an intra-abdominal pressure (IAP) above 12–15 mmHg via CO₂ insufflation triggers immediate hemodynamic shifts. The compression of the abdominal venous system initially increases venous return, but a subsequent reduction in preload can occur due to vena cava compression. Concurrently, systemic vascular resistance (SVR) rises significantly because of the mechanical compression of the aorta and the neuro-humoral release of vasopressin and catecholamines. When combined with a steep Trendelenburg positioning, these changes drastically elevate cardiac workload and myocardial oxygen consumption, posing a substantial risk to elderly patients or those with pre-existing cardiovascular comorbidities, such as atrial fibrillation [17].

- Respiratory Mechanics and Gas Exchange:

The respiratory system bears the heaviest impact of this combined approach. The steep head-down tilt causes a cephalad displacement of the diaphragm by the abdominal viscera, which is further exacerbated by the pressure of the pneumoperitoneum. This dual mechanical barrier leads to a drastic reduction in functional residual capacity (FRC) and a significant drop in pulmonary compliance, leading to increased peak inspiratory pressures (P_{peak}). The rapid development of widespread dependent atelectasis, which severely impairs gas exchange by increasing intrapulmonary shunt and worsening ventilation-perfusion mismatch (V/Q mismatch). Furthermore, the continuous absorption of CO₂ across the peritoneal surface creates a state of systemic hypercapnia and respiratory acidosis, necessitating an aggressive compensatory increase in minute ventilation, which further elevates the risk of ventilator-induced lung injury (VILI) [18].

Choosing the optimal ventilatory strategy is essential for ensuring an uneventful intraoperative course and mitigating both intra- and postoperative pulmonary morbidity. Key determinants in this setting include tidal volume, inspiratory pressures, and the titration of Positive End-Expiratory Pressure (PEEP). Over the past few

decades, a variety of mechanical ventilation approaches have been designed to limit iatrogenic lung injury, a concept broadly defined as “lung-protective ventilation.” While a deep comprehension of respiratory physiology serves as the cornerstone for these clinical decisions, the ideal configuration of ventilatory parameters continues to be a matter of ongoing controversy [19].

Current consensus guidelines strongly support the use of low tidal volumes, specifically calibrated to 6–8 mL/kg of predicted body weight, to prevent alveolar overstretching and volutrauma. Nonetheless, a low-tidal-volume approach carries an inherent risk of progressive microatelectasis, a phenomenon significantly accelerated by the cephalad diaphragmatic shift during carbon dioxide pneumoperitoneum and steep head-down tilt. To counteract this, the concurrent implementation of PEEP is vital to preserve alveolar stability, enhance oxygenation, and maintain functional residual capacity, which ultimately facilitates earlier postoperative extubation following extended minimally invasive procedures. The implementation of alveolar recruitment maneuvers (ARMs) plays an exceptionally critical role in optimizing pulmonary function during robot-assisted procedures, particularly in the obese patient population [20].

CASE PRESENTATION

A 78-year-old male patient was presented in University Hospital St. Marina – Varna for an elective robot-assisted Hartmann’s procedure combined with a partial cystectomy due to an advanced rectal carcinoma with transmural invasion into the urinary bladder. The surgical intervention was performed under general inhalation anesthesia using a lung-protective ventilation strategy with a PEEP maintained at 5 mmHg. The total operative duration was 6 hours, during which a steep Trendelenburg position and high-pressure carbon dioxide pneumoperitoneum were continuously maintained for 5 hours. Extensive pelvic and retroperitoneal dissection was required to achieve complete tumor clearance, resulting in the opening of retroperitoneal fascial planes. Intraoperatively, the anesthesia care team noted clinical signs strongly suggestive of developing subcutaneous emphysema, accompanied by a progressive, significant rise in end-tidal carbon dioxide (EtCO₂) levels – up to 50 mmHg. This required immediate adjustments in ventilatory parameters, utilizing compensatory hyperventilation to manage the respiratory acidosis induced by continuous CO₂ absorption.

In the postoperative period, the patient was transferred to the Clinic of Anesthesiology and Intensive Care for advanced monitoring and treatment. The patient was admitted to the intensive care unit (ICU) while still intubated and under sedation, and was therefore placed on mechanical ventilation under a BiPAP (Bilevel Positive Airway Pressure) regime. Physical examination revealed an extensive, massive subcutaneous emphysema involving the face, chest wall, bilateral upper extremities, abdomen, and extending down to the thighs, as shown on Figure 1.

Fig. 1. The patient in the early postoperative period.



An emergency bedside chest X-ray was performed, which visualized severe bilateral subcutaneous emphysema spanning across the anterior chest walls, axillary regions, and the neck Figure 2. Crucially, the radiograph demonstrated no evidence of pneumothorax or pneumomediastinum, confirming an extrapulmonary etiology of the gas tracking.

Fig. 2. X-ray image after surgery.



Following an urgent consultation with a thoracic surgeon, an immediate surgical decompression was performed under local anesthesia. The procedure involved bilateral pectoral skin incisions, approximately 5 cm in length, to allow passive evacuation of the entrapped gas. Following manual expression of the subcutaneous CO₂, negative pressure wound therapy (NPWT / vacuum dress-

ings) was applied to the incision sites to facilitate continuous drainage and tissue decompression, as shown in Figure 3. The patient's respiratory mechanics and clinical status improved rapidly following the intervention. On the second postoperative day, the patient met all weaning criteria, was successfully extubated, and supplemental oxygen therapy via a face mask was initiated under effective spontaneous breathing. On the third day, the vacuum dressings were removed due to a significant and visible reduction in the subcutaneous emphysema. On the fourth day, a follow-up evaluation by the thoracic surgical team confirmed a subtotal resolution of the soft-tissue gas tracking. Consequently, the patient was safely transferred to the Department of Surgery in stable condition. On the same day, the bilateral pectoral skin incisions were treated with antiseptics, primarily closed, and covered with sterile dressings. The subsequent postoperative course remained uneventful.

Fig. 3. The same patient on the second postoperative day.



DISCUSSION

• Incidence and clinical relevance:

Subcutaneous emphysema is a common complication of laparoscopic surgery with an incidence rate of 0.43–2.34%. Although ~77% of patients who undergo laparoscopic surgery have grossly undetectable subcutaneous emphysema, airway obstruction can occur due to pharyngeal emphysema when it extends to the neck [21]. While often self-limiting, massive soft-tissue gas tracking can escalate into a life-threatening crisis by compro-

missing airway patency, shifting core hemodynamics, and impairing respiratory mechanics, thus requiring immediate and aggressive clinical management.

- Specific risk factors:

The current case represents a cumulative convergence of nearly all established independent risk factors for severe iatrogenic subcutaneous emphysema:

- Operative duration - an operative time exceeding 3.5 hours is a critical threshold for massive gas absorption. In this case, the continuous 5-hour exposure to CO₂ insufflation provided a prolonged window for progressive tissue dissection.

- Surgical complexity and number of ports - advanced pelvic procedures, such as a robot-assisted colorectal procedure combined with a partial cystectomy, frequently necessitate the placement of 5 or more cannulas and involve multiple attempts at abdominal entry, both of which are strongly correlated with increased fascial laxity and gas leakage.

- Extensive tissue dissection - the invasion of the rectal carcinoma into the urinary bladder required wide-margin pelvic and retroperitoneal dissection. This extensive surgical alteration disrupted the natural anatomical barriers and opened direct pathways into the retroperitoneal spaces [22].

- Pathophysiological mechanisms and the “Pump” effect:

Under the constant pressure gradient of the carbon dioxide pneumoperitoneum (especially if pressures approach or exceed 15 mmHg), the insufflated gas acts mechanically to dissect through the retroperitoneal fascial planes. This tracking is further accelerated by the steep Trendelenburg position. Gaining momentum gravitationally, the gas migrates cephalad from the pelvic cavity through the retroperitoneum and mediastinum, ultimately tracking into the subcutaneous tissues of the chest wall, axillae, neck, and face. The absence of a pneumothorax on the chest radiograph confirms that the gas tracking was entirely extrapulmonary and driven by surgical insufflation rather than alveolar barotrauma.

- Intraoperative hypercapnia as a pathognomonic sign:

A progressive and significant rise in EtCO₂ above 50 mmHg serves as a primary intraoperative warning sign

of systemic gas absorption. In this patient, the rapid rise in EtCO₂ was directly secondary to the massive peritoneal and subcutaneous vascular recruitment of CO₂. When EtCO₂ crosses this threshold, it indicates that the systemic gas absorption has overwhelmed the body’s natural buffering capacity, necessitating immediate compensatory hyperventilation by the anesthesia team to mitigate severe respiratory acidosis [23].

- Therapeutic decompression:

The role of infraclavicular “Blowholes” and NPWT. When massive subcutaneous emphysema causes tissue tension that threatens airway patency or respiratory compliance, active surgical decompression becomes mandatory. The creation of bilateral 5 cm pectoral skin incisions (historically termed “blowholes”) provides an effective escape tract for the entrapped gas. In this case, combining these decompressing incisions with NPWT offered distinct advantages. It maintained a continuous, controlled negative pressure gradient that accelerated gas evacuation, prevented premature closure of the skin edges, ensured sustained decompression, and significantly reduced soft-tissue emphysema within 24–48 hours, facilitating early extubation on the first postoperative day and preventing secondary tissue ischemia [24].

CONCLUSION

While robot-assisted surgery offers numerous proven advantages and has rapidly become a preferred method across various surgical disciplines, its utilization demands a comprehensive understanding of potential perioperative challenges and iatrogenic complications. The physical bulk of the robotic platform severely restricts direct patient access, highlighting the critical need for structured intraoperative checkpoints to monitor patient status, tissue displacement, and ventilatory mechanics. Furthermore, although complications such as subcutaneous emphysema are frequently self-limiting and clinically insignificant, they can occasionally escalate into life-threatening conditions. Ultimately, a vigilant, multidisciplinary approach involving anesthesiologists, surgical subspecialists, and intensive care teams is paramount for the early recognition and successful management of these severe complications, ensuring optimal patient safety.

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