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Research Article

Preventing and Managing Intraoperative Catastrophic Bleeding in Robotic Lung Cancer Lobectomy: "Life-Saving Strategies"

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Abstract

Background: Robot-assisted thoracic surgery offers significant advantages, with the surgeon operating from a console via 3 D Visulisation instead of standing at the operating table. However, this setup necessitates thorough preparation to handle bleeding emergencies, as the console surgeon may require time to reach the operating table. Although the incidence of massive intraoperative bleeding during robotic thoracic surgery is generally low [1], the potential consequences can be catastrophic if not managed optimally. This study aims to analyze bleeding events occurring during robotic lobectomies at our center and present our therapeutic approach in cases of significant bleeding.

Method: This retrospective study focuses on a single center and spans from October 2018 to July 2023, involving 220 patients who underwent robotic lobectomy for lung cancer. Among them, intraoperative bleeding occurred in seven cases. These events were carefully analyzed, and appropriate steps for management were undertaken. We excluded robot-assisted wedge resections from the study, as well as any conversions to thoracotomy that occurred for reasons other than intraoperative catastrophic bleeding, such as those related to oncological or technical considerations. Patient baseline characteristics, including gender, age, BMI (body mass index), and respiratory function, were collected and analyzed. Operative time, from the time of skin incision to the time of skin closure, including docking of the robotic system, was recorded. Additionally, the type of procedure, histology, tumor localization, and pathological results were carefully documented and analyzed. We defined catastrophic intraoperative bleeding events as bleeding events that demand emergency management due to their life-threatening nature. In these scenarios, we considered both the continuation of robotic surgery and the option of performing a thoracotomy as potential approaches [2]. Data collection and management were conducted seamlessly through a prospective database. The study employed observational analysis, and data were described using absolute and relative (%) frequency for categorical data, and mean and range for continuous data.

Results: Between October 2018 and July 2023, 220 robotic lobectomies were performed. Among them, significant intraoperative vascular injury occurred in seven patients, leading to a conversion to thoracotomy in three cases. In four Cases, we were able to manage the bleeding robotically. The left side of the lung was affected in four cases (3 Upper and 1 Lower lobe) and therefore the left side was more frequently. The other three cases were two right Upper lobe and one middle lobeinjury. Patients with intraoperative bleeding experienced a longer total operative time than those without such complications. Two patients with massiv bleeding (2/7; 42,8%) required packed red blood cell transfusions.

Conclusion: Intraoperative catastrophic bleeding events are unpredictable occurrences that can even happen to experienced surgical teams. Given the widespread use of robotic technology for anatomical lung resections, it is imperative for all units performing such surgeries to have a clear and well-known plan to deal with such situations. These strategies are crucial for saving lives and improving clinical outcomes. In cases of massive bleeding, initial compression of the bleeding site for several minutes, maintaining a calm demeanor, and providing time to prepare for thoracotomy are recommended approaches to handle these critical situations effectively

Keywords: Bleeding; RATS; Robotic lobectomy; Thoracic; VATS

Introduction

The field of robot-assisted interventions in thoracic surgery has been experiencing continuous growth. This upward trend is be attributed to the numerous advantages offered by robotic technology, including improved visualization through 3D imaging, highly maneuverable instruments, and the fulcrum effect that minimizes postoperative pain at trocar sites, leading to better recovery for patients. Additionally, the oncological outcomes of robot-assisted operations are comparable to those of open and Video-Assisted Thoracoscopies (VATS) [2]. However, despite these benefits, major vascular injury and bleeding remain significant concerns in robotic lung surgery. Such complications are considered the most feared among surgeons and could act as major deterrents for the further adoption of minimally invasive surgery [1]. The literature on this specific topic remains relatively limited. Nevertheless previous publications, such as those published by by Cao and Cerfolio, outline strategies for managing intraoperative bleeding in robotic lung surgery [1,3]. The primary objective of this study is to analyze and present the frequency and outcome of bleeding incidents during da Vinci-assisted robotic pulmonary surgery at our department. By shedding light on these critical aspects, we hope to contribute to the enhancement of safety and efficiency in robotic lung resections.

Materials and Methods

This retrospective study spans from October 2018 to July 2023 and includes 300 lobectomies for lung cancer performed at our department. Of these, 220 were robot-assisted thoracic surgery(RATS) lobectomies. Patients with benign lesions were excluded from the study. Intraoperative bleeding events were meticulously documented, and decisions regarding either proceeding with the robot or converting to thoracotomy were recorded. Patients who underwent conversion to thoracotomy due to other difficulties, such as adhesions, were excluded from the analysis.

Oncological Workup

For cases of bronchial carcinoma or highly suspicious lung cancer, an extensive oncological workup was performed in all patients. This workup involved a whole body PET-CT scan to assess the extent of the disease. For mediastinal staging, we employed either endobronchial ultrasound-guided fine-needle aspiration biopsy (EBUS FNA) or mediastinoscopy. Additionally, a brain MRI was routinely conducted to exclude the presence of cerebral metastases. At our institution, absolute contraindications for robotic surgery encompass tumor characteristics like central vascular invasion, locally advanced T4 lesions, Pancoast tumors, and tumors exceeding 10 cm in size.However, we have achieved successful robotic resections in cases involving tumor invasion into the chest wall, prior thoracic surgery, and post-induction chemotherapy or Chemoimmunotherapy.

Surgical Steps

All robotic lung resections in this study were performed using the da Vinci surgical system X® (Intuitive, Sunnyvale, CA, USA). The surgical procedure follows a well-defined sequence.

Patient Positioning

The patient is placed in a lateral decubitus position. Controlled bronchoscopy is performed to visualize the airway, and a double-lumen endotracheal tube is used to achieve single lung ventilation. Carbon dioxide is routinely used at 8 mm Hg to depress the diaphragm and collapse the lung, providing a clear operating field. Bipolar forceps and Cadiere forceps are used to mobilize the lung parenchyma and improve exposure of the hilar elements, making the surgical site more accessible. The Maryland bipolar forceps was employed to dissect the structures, facilitating precise and controlled tissue separation.

Robot Setup

After introducing the trocars in 8^{th} intercostal space, the Da Vinci X Robot Surgical System is introduced into the surgical field from over the patient's head. The robotic instruments are utilized as follows: the first robotic arm is equipped with the Maryland bipolar forceps, and the second robotic arm carries the camera. The fenestrated bipolar forceps is inserted into arm 3, and the cardiere forceps is placed in the fourth arm posteriorly. The assistant port is positioned in triangulation behind the camera port and the anterior robotic port, typically in the 9th or 10th intercostal space [4] .

All surgeries commence with the initial mobilization of the pulmonary ligament, followed by the removal of lymph nodes from stations 9, and then 8, and 7 for both sides. For the right side, lymph nodes 4 and 2 are removed, and for the left side, lymph nodes 5 and 6 are excised [4]. In the second step, the vessels are exposed and carefully divided. Finally, the bronchus is dissected and managed accordingly. The duration of each surgery was thoroughly documented, starting from the first incision to the final suture, encompassing the entire surgical procedure from skin to skin. Comprehensive patient data, including gender, age, FEV1 (forced expiratory volume in 1 second), Body Mass Index (BMI), and histological type of lung cancer, were meticulously recorded. A single surgeon performed all surgeries, and perioperative morbidity was documented to assess any potential complications during the surgical process.

Results

Between October 2018 and July 2023, 220 patients RATS lobectomies for bronchial carcinoma using the Da Vinci Robot X system. During the study period, intraoperative bleeding was observed in sseven patients, of whom three necessitated a conversion to thoracotomy. The average age of patients experiencing intraoperative bleeding was 72 years, with a mean FEV1 (forced expiratory volume in 1 second) of 1, 85 liter. The mean body mass index of these patients was 21, 4 kg/m². It is noteworthy that patients with intraoperative bleeding had a higher frequency of upper lobe resections on the left side. The total operative time was longer in patients with intraoperative bleeding (211 vs. 169 minutes), and the 90 day perioperative mortality rate was 0,45 %(1/220). Postoperative complications were documented includind pulmonary fistula, pneumonia, and persistent effusion.

Intraoperative Bleeding and Treatment Strategy

The console surgeon swiftly assessed the situation, carefully evaluating both the source and severity of the bleeding. When dealing with peripheral bleeding from the branches of the pulmonary artery, our standard approach involves robotic management. We utilize cardiere forceps to effectively clamp the bleeding vessel whenever feasible.

However, in instances of bleeding from the central pulmonary artery, we opt for a more invasive approach. In such cases, we consider a thoracotomy

Among the catastrophic complications observed, bleeding from the pulmonary artery or vein was the most common. The main factors contributing to intraoperative bleeding were adhesions and adherent lymph nodes near the pulmonary vessels. Additionally, anatomical variations of the vessels resulted in unexpected vascular injuries. The bleeding events were mostly observed during vessel dissection or vessel transection with the stapler.

Management of Catastrophic Bleeding

Immediate action was taken in response to catastrophic bleeding, with a direct thoracotomy being performed promptly and blood transfusions administered. An experienced thoracic surgeon was summoned for assistance. The initial step involved compressing the bleeding vessel with a sponge to achieve hemostasis. The compression was executed by either the assistant or the console surgeon and lasted approximately 15 minutes. This time was utilized to prepare for the thoracotomy, provide instructions to the entire surgical team, and arrange all the necessary instruments and additional surgical staff for support. In the second step, a thoracotomy was performed, and the pulmonary artery was centrally controlled. The vascular injury was successfully repaired using Prolene 5-0. In two patients, bleeding was effectively halted by applying clips openly.

Discussion

Travis published "the 7 P's:" preparation, pressure, patience, poise, products, partner, and Prolene. Among these, the first critical move appeared to be applying pressure on the bleeding vessel [5]. These results highlight the importance of effective management and preparedness to handle catastrophic bleeding events during robotic lung resections. The prompt and coordinated response of the surgical team is essential in managing such life-threatening situations, ensuring patient safety, and achieving positive clinical outcomes. In certain challenging cases, especially when dealing with extreme adhesions and fibrosis surrounding the pulmonary artery, intrapericardial control of the pulmonary artery may be necessary. In such instances, carefully opening the pericardium and using vessel loops and bulldog clamps to gain proximal control of the pulmonary artery could be helpfull.

Roll of bedside assistant

The role of the bedside assistant in robotic lung surgery is crucial and highly important for the success of the procedure. The assistant plays a critical role in fluid instrument exchange and maneuvers at the robot-patient interface. Therefore, proper training and familiarity with the procedure are essential for the assistant.They should be prepared to quickly apply pressure to the bleeding vessel with a sponge and maintain this pressure until the surgeon decides whether to continue robotically or switch to open surgery. Readily having a sponge at hand in such situations is important for achieving swift hemostasis. Clear communication between the surgeon and the assistant in the operating room is mandatory to ensure a safe and efficient operation. The assistant must be able to understand the nuances of the surgeon's actions and be prepared to anticipate their needs during the surgery. The assistant should promptly clear the bleeding area by using suction to improve visibility. Furthermore, the assistant have to maintain composure and ensure clear communication with the surgeon during this critical phase. In the event that a conversion to open surgery becomes necessary, they should be prepared to remove the robotic arms as required. Moreover, they have to be well prepared and proactive in providing support to the surgical team during this transition. The assistant's skills, attentiveness, and ability to collaborate seamlessly with the surgeon are pivotal factors in effectively managing intraoperative bleeding and other critical scenarios during robotic lung surgery. Their contributions significantly enhance the overall success and safety of the procedure.

Role of an Anesthesiologist

The anesthesiologist plays an essential role in managing massive intraoperative bleeding during robotic surgery. The necessary steps to take include

- **Order blood for transfusion:** The anesthesiologist should ensure that blood is available for transfusion if needed.
- **Volume supplementation and blood pressure maintenance:** It is crucial to control blood loss effectively by administering saline solution to sustain elevated blood pressure and minimize blood loss.
- **Managing arrhythmias:** Addressing arrhythmias, which frequently occur during significant bleeding, is vital. Moreover, it is essential to have a defibrillator on hand and use it if needed. Medications for arrhythmia management should also be easily accessible.
- **Maintain an open airway:** Ensure that the patient's airway remains clear and unobstructed.
- **Provide deep sedation:** It is essential for the patient to be completely relaxed to enable the surgeon to focus solely on managing the bleeding.

The management of blood supply and addressing arrhythmias are key aspects of the anesthesiologist's role in ensuring a successful outcome during robotic surgery with significant intraoperative bleeding.

Advantages of Robotic Surgery

Robotic surgery has several advantages over traditional open surgery, including better visualization in 3D imaging, highly maneuverable instruments, and reduced postoperative pain, leading to better patient recovery. Additionally, the oncological outcomes of robotic surgeries are comparable to open and video-assisted thoracoscopies [6]. However, in cases of severe bleeding, the time it takes to reach the bedside and initiate a thoracotomy can significantly affect the outcome. Thanks to the development of robotic surgery, the number of minimally invasive surgeries has increased overall. The VIOLET study confirmed the superiority of minimally invasive procedures compared to open surgery. Minimally invasive thoracic surgery resulted in less pain compared to open surgery [7]. The oncological outcomes are similar [8]. Due to vascular injury, however, acceptance of minimally invasive surgery is still lacking. More recently, the European Society of Thoracic Surgeons' Minimally Invasive Thoracic Surgery Interest Group reported that 22% of in-hospital mortality cases were associated with major intraoperative complications [9]. As revealed in our observational study, we encountered intraoperative bleeding complications in six patients. Pulmonary artery injuries are rare, but when it does occur it can be catastrophic. Conversely, vein injuries are generally more manageable [10].

Incidence of Intraoperative Bleeding

Cao et al. published a study on the largest series of catastrophic bleedingsevents during robotic lung resection, with a rate of 1.9 % [1]. In this study, the predictors of catastrophic events were a higher clinical stage and a lower FEV1, and the most common event was hemorrhaging from the left pulmonary artery. The authors concluded that, although the incidence of intraoperative failures in robotic surgery is low, it is necessary to establish management strategies to improve clinical outcomes. Velez-Cubian reported an overall conversion rate of 9,6 % and emergency conversion rate of 5% because of bleeding [9]. Cerfolio reported a 4 % rate of major bleeding during robotic lung surgery. The first steps outlined were to perform compression on the vessels to minimize bleeding and to regain calm in the operatingroom [3]. Kent et al. reported bleeding rates of 1.9%, 1.3%, and 1.9% for open thoracotomy, VATS, and robotic surgery, respectively [10]. Interestingly, Louie described the left upper lobe as the predominant site of bleeding from the pulmonary artery [11]. This is consistent with our results. The decisive factor in this treatment was securing the patient's vital functions first, followed by oncological criteria and functionality. Our conversion rate was 1, 3 % (3/220) wich is a little lower than the published conversion rate [1,9,10]. Since the introduction of the robotic program in our hospital, we have consistently reduced the proportion of VATS procedures. Careful examination of preoperative imaging is essential to assess anatomical variants and potential technical challenges, enabling better planning of surgery and preparedness for any eventuality.

Conclusion

This study sheds light on the importance of managing intraoperative bleeding effectively during robotic lung surgery. By developing well-thought-out strategies and involving a skilled surgical team, complications caused by bleeding can be better controlled and treated, leading to improved outcomes in robot-assisted anatomical lung resections. Moreover, it is crucial to highlights the importance of conducting the dissection of the pulmonary artery with utmost care, taking into account risk factors such as lower cardiopulmonary function. The presence of a readily available sponge during surgery holds immense significance, as it allows for immediate compression in case of massive bleeding. It is crucial to maintain a sense of calmness and organization within the surgical team, as this facilitates swift decision making regarding the next steps, which could involve converting to a thoracotomy or pursuing endoscopic robotic repair.

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