Editorial

New era of "resection of the carina and lower trachea"

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Introduction

It has been more than half a century since Abbott reported their experience on carinal resection and reconstruction (1). Tracheal surgery still remains challenging despite improvements in surgical and anesthetic techniques, resulting in thoracic surgeons exploring a new era of "resection of the carina and lower trachea" (2). Minimally invasive thoracic surgery has been widely extended for the resection of peripheral early stage lung cancer. Video-assisted thoracoscopic surgery (VATS) lobectomy and sublobar resection have become a common procedure. Complete resection and reconstruction of the carina or trachea with VATS and airway management remain challenging. Only few reports of VATS tracheal or carinal resection and reconstruction have been published (3-8). Li and colleagues examined the feasibility of VATS in the treatment of benign and malignant diseases involving the carina and trachea, and made comparisons with relevant techniques (3). They evaluated 12 patients undergoing VATS carinal or tracheal procedures from multiple centers. They analyzed clinical characteristics, operative details, and the postoperative course of VATS tracheal surgery. Li and colleagues concluded that VATS resection and reconstruction of the carina or trachea are appropriate and that these procedures are safe. Interestingly, there was no hospital mortality or major morbidity rates in this study. These findings were compared without bias with the previously reported postoperative mortality and morbidity rates after open thoracotomy (9,10). Although VATS tracheal surgery was a feasible procedure in their article (3), there are several limitations of VATS tracheal or carinal procedures. When compared with open thoracotomy techniques, VATS procedures are typically more challenging because of the steep learning curve, inadequacy of palpation and direct vision, and the need for the surgeon to adjust to a 2D monitor view (11). Another limitation of VATS is the concern of performing sufficient oncological resection and safe reconstruction. Therefore, tumors involving the trachea or carina require good arrangement with the anesthesiologist during airway resection, proper airway management and reconstruction, and preoperative planning. In this editorial, we would like to discuss the requirements and improvements to solve these limitations of minimally invasive tracheal surgery.

Requirement for minimally invasive tracheal surgery

The role of anesthesia and airway management during tracheal surgery includes several considerations of tube management without interference with the surgical field and ventilation with appropriate oxygenation. Definitive intraoperative strategies varied and are discussed and detailed in relation to the specific surgical procedures. We can classify three types of airway management according to the resection type: (I) single lumen left endobronchial tube; (II) cross-field ventilation; (III) high-frequency jet ventilation (HFJV).

A right bronchial resection with partial carinal reconstruction could be performed by an endobronchial tube directed into the left main bronchus (6). Since the single lumen endobronchial tube is smaller than the double lumen tube, the single lumen tube can be introduced through a distal bronchus, without interfering with the lateral cartilaginous or membranous portion of the anastomosis. Using this approach, there is no need for ventilation or a cross-field tube. The key principle in dealing with this situation is to ensure matching of anastomosis orifices between the bronchial opening and the tracheal or carinal opening after resection. In contrast, this procedure is very difficult when total tracheal and carinal procedures are required. In the case of tracheal and carinal resection, cross-field ventilation is a generally accepted strategy to manage the airway. VATS procedures are usually performed through three ports. If cross-field ventilation is required, an endobronchial tube is introduced through either one of operation ports or an additional port is added to prevent the tube from interfering with the instruments used for the anastomosis (5). This is an example of cross-field ventilation method. Once the tracheal lesion is resected, the ventilation method changed to cross-field ventilation by introducing an additional endobronchial tube into the main bronchus through either the operation port or an additional port. As usual, the anastomosis is initiated from the posterior wall advancing to the anterior wall, working around the cross-field endobronchial tube. Once posterior wall anastomosis is completed, the cross-field endobronchial tube is removed and the original endotracheal tube is forwarded distal over the anastomosis. The rest of the anterior wall anastomosis is then completed. This approach enables the patient to have stable vital parameters, and gives the surgeons more confidence to complete the procedure. To avoid interference caused by the cross-field ventilation system, HFJV is useful in VATS tracheal reconstruction. Essentially, with HFJV there is no need for any additional ports or incisions. HFJV is frequently performed via the lumen of the blocker tube with a deflated balloon placed in the main bronchus during each anastomosis. Therefore, HFJV allows the surgeon to perform VATS carinal surgery. For this reason, HFJV is preferred in tracheal operations that require a small operative area and a short anastomotic time. HFJV is also useful as an additional source of oxygen, delivering oxygen to the contralateral lung, maintaining adequate oxygenation with cross-field ventilation through the left side. The vital signs are maintained and pulse oximetry confirms that oxygen saturation is normal during HFJV.

In terms of the surgical proposal, one key proposal is to establish tension-free anastomosis, even in open thoracotomy procedures (12). This process requires careful preoperative simulation and planning with bronchoscopy and computed tomography scans to ensure the length of the anatomic resection required. Both proximal and distal airways were mobilized until tension-free anastomosis can be achieved. The other key factor is to ensure minimal size mismatch between the two anastomosing orifices by either reducing or enlarging the proximal orifice. VATS for tracheal or carinal surgery is more complex. Effective traction using endoscopic devices has been useful for reducing the anastomotic tension. Some authors recommend using the interrupted sutures to allow better size matching, less ischemia of anastomosis and to prevent loosening and entanglement of the sutures (13). Other authors used both continuous and interrupted suturing, for the membranous and cartilaginous portions of the bronchus (14). The advantages of this hybrid approach are that the continuous sutures avoid tangling the ends and shortening anastomosis time, and the interrupted sutures prevent anastomosis leak and stricture often caused by continuous suturing. On the other hand, placing interrupted sutures using a VATS approach can be more complex and time-consuming than using a running suture. The use of continuous running sutures provides a better operative view and has been proven safe and effective in VATS (6,15).

New indication of extracorporeal life support (ECLS) for airway surgery

Even though current airway management is reasonable for VATS tracheal surgery, we should consider more ideal airway management during minimally invasive surgery. The traditional approach of cross-field ventilation and HFJV are sufficient for most oncological airway surgery cases, however current airway management has limitations in extended resections and complex reconstructions. Recently, ECLS has become a valuable and a secure choice for complex surgical cases in patients with near-total occlusion of the airways to support respiratory functions during complex therapy. In fact, we have increasingly used ECLS for major airway surgery, endoscopic airway intervention, acute respiratory failure, lung transplant surgery as well as a bridge to lung transplantation (16-19). One of the important indications of ECLS in airway management is intense and emergency situations when conventional ventilation procedures are difficult during the surgery. Initiated ECLS with awake induction can be performed safely and may prevent this critical complication in critical patients. After ECLS initiation, general anesthesia can be applied and airway tumor elimination or resection can be performed under safer controlled conditions.

Mechanical circulation ECLS, such as cardiopulmonary bypass, has been widely used in the past for complex tracheobronchial construction and for the resection of complex thoracic malignancies. Extracorporeal membrane oxygenation (ECMO) technology has developed considerably over the last few decades and has become the favored supporting alternative for ECLS at most institutions that frequently perform airway surgery with airway management. The use of ECMO has several advantages in these complex airway surgical cases. ECMO provides an unhindered, tubeless operation field like further accurate resection and reconstruction. Therefore, ECMO could be useful for VATS and airway surgery. If ECLS is required during airway surgery, veno-venous (V-V) ECMO is the first choice for airway surgery. It accomplishes the support of pulmonary function with effective oxygenation and CO_2 removal. Generally, V-V ECMO is managed via a two-cannula system, however recently single-cannula V-V ECMO has been more popular, allowing single vessel access instead of a femoro-femoral or a femoro-jugular insertion. With the increasing experience of single lumen cannulas in other respiratory failure diseases such as acute respiratory distress syndrome (ARDS) and lung transplantation, these single lumen cannulas have demonstrated as an interesting less-invasive choice (16). We have confirmed the use of single lumen V-V ECMO facilitates interventions leading to more definitive airway security (16). This technique can facilitate a meticulous, unhurried, safe, complete surgical reduction of lesions in the carina and main stem bronchi. In most cases, airway surgery can be safely performed by experienced teams without ECLS support. However, there are some circumstances where airway management is predictably very difficult, nearly impossible, or out of control especially during VATS. ECLS is an effective tool for the thoracic surgeon when performing extended airway surgery or endoscopic airway manipulation in crucial airway obstructions.

Potential role of robot assisted thoracic surgery (RATS) for airway surgery

Due to increasing experience in VATS lung resection, VATS bronchoplastic surgery is currently being attempted in experienced centers (3-8), though it has not been widely applied owing to technique difficulty. When performing VATS, the lack of depth perception and counterintuitive movement make surgeons uncomfortable when dealing with critical structures. To overcome this problem, RATS has been proposed as an alternative in minimally invasive thoracic surgery. There are several practical advantages of RATS over VATS in lung cancer surgery, including a clear three-dimensional vision of the surgical field with greater accuracy with EndoWrist technology, thus allowing surgeons to virtually perform an operation as if using their own hands. The robotic surgical system is designed for open surgery and promotes minimally invasive techniques as the robotic instruments provide accurate movements. Therefore, RATS is considered a feasible procedure for many complex thoracic operations.

Lately, several authors reported the feasibility of RATS bronchoplasty (15,20,21). These authors showed that the RATS bronchoplasty is technically possible to perform for central-type lung cancer patients. In addition, double-sleeve lobectomy including bronchoplasty and angioplasty for central-type lung cancer has also been performed by RATS (21,22). The pulmonary artery is weaker than the bronchus, so much more attention should be paid when performing the pulmonary artery anastomosis. The enhanced view and EndoWrist technology both help make every stitch very precise during angioplasty. To our knowledge, there has been only one report of successful robotic-assisted tracheal resection to date (23). Jiao *et al.* performed totally robotic-assisted non-circumferential tracheal resection and running reconstruction with coverage of anastomosis by anterior mediastinal fat flap (23). They mentioned that the RATS tracheal resection and reconstruction using robotic two-arm can be completed easily similar to the general open approach. Based on these studies, RATS may become a better option than VATS for trachea surgery. However, there are still some disadvantages of RATS, including higher hospital costs, loss of haptic feedback, longer set-up times, and concern regarding the management of accidental intraoperative bleeding (24,25). Additionally, there are only limited number of reports on the utilization of RATS for airway surgery compared to VATS and conventional thoracotomy surgery. The technical aspects and perioperative complications as well as long-term benefits of RATS airway surgery is not clear and should be identified in further clinical trials.

Conclusions

In conclusion, we agree that VATS resection and reconstruction of the carina or trachea are safe and feasible procedures in selected patients with well-prepared airway management. Although these procedures should be restricted to skilled VATS surgeons in the beginning, we believe that in future these procedures may be approved as regular approaches during tracheal surgery. Furthermore, RATS tracheal surgery may become a popular approach for well-trained robotic surgeons. These minimally invasive methods may present a new alternative strategy for the treatment of tumors of the trachea and carina. Further prospective randomized studies focusing on the comparison of feasibility and safety of minimally invasive surgery will be necessary for exploring the new era of "resection of the carina and lower trachea".

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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