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Review Article

Advances in uniportal video-assisted thoracoscopic surgery for non-small cell lung cancer

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Abstract

Lung cancer has the highest incidence and mortality rates among all cancers, both globally and in China. In clinical oncology, lung cancers can be divided into small-cell lung cancer and non-small-cell lung cancer (NSCLC). Currently, radical resection is an important clinical method for NSCLC treatment, and video-assisted thoracoscopic surgery (VATS) occupies a major role in lung cancer surgery, especially owing to its minimally invasive character. In particular, since the initial report of uniportal video-assisted thoracoscopic surgery (uniportal VATS) in 2004, rapid advances have been made, and this surgical procedure is now extensively applied in clinical practice. The aim of this comprehensive review is to provide a summary of the recent advances in the application of uniportal VATS for NSCLC.

Keywords: uniportal video-assisted thoracoscopic surgery, minimally invasive surgical oncology, video-assisted thoracoscopic surgery, lobectomy, lung cancer

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History and definition of uniportal VATS

Thoracoscopy was first reported by the Swedish surgeon Jacobaeus [1, 2]. In 1910, he inserted a rigid cystoscope into the thoracic cavity of a patient and performed simple maneuvers within the thoracic cavity for the diagnosis of pleural conditions under direct vision through the cystoscope. However, VATS was not further developed at that time, owing to limitations in technology and surgical instruments. Since the rapid development of surgical instruments in the 1990s, which was of epoch-making significance for minimally invasive surgery, the VATS technique also rapidly developed and matured, and became increasingly applied for radical resection of the lung cancer [3-10]. Conventionally, multiportal approaches have been used for VATS, the most common being the triportal approach. With the continuous advocacy of the concept of minimally invasive surgery, maturation of the VATS technique, and sustained improvements in the research and development of surgical instruments, thoracic surgeons have started to explore the uniportal VATS approach on the basis of conventional multiportal VATS [11].

In 2004, Rocco et al. first reported the use of uniportal VATS in the diagnosis of the chest diseases [12]. In 2011, Spanish surgeon Gonzalez-Rivas reported the first case of uniportal VATS lobectomy, which represented a milestone in the development of uniportal VATS [13]. Since then, the technique has been increasingly adopted worldwide and has been used in many complex thoracic procedures [14-25]. Uniportal VATS has been developed on the basis of multiportal VATS, which includes the biportal, triportal, and four-port approaches. The most common approach is the triportal technique, in which three incisions are performed at different locations on the thoracic wall in accordance with surgery requirements, forming the observation port, utility port, and auxiliary port; the entire surgery is performed using a thoracoscope [26]. During the uniportal VATS procedure, a single incision is performed for the placement of the video camera and surgical instruments, as well as the execution of the entire surgical procedure [27]. Based on the definition of conventional multiportal VATS, uniportal VATS is considered a technique that allows the surgical procedure to be performed entirely with thoracoscopic instruments under thoracoscopic view through a single port in the thoracic wall, under the premise that rib spreading is not performed [28].

Technical features of uniportal VATS

During the uniportal VATS procedure, all thoracoscopic instruments are introduced in the thoracic cavity using a single small incision. Therefore, the procedure is prone to mutual interference among instruments, and the surgical plane projected on the operative vision is relatively small [29]. As such, the uniportal approach has several unique technical features as described below.

Surgical incision

Incision site in uniportal VATS is dependent on the location of the lesion within the thoracic cavity [30]. Generally, the incision is performed at a short distance away from the lesion, in order to provide room for the maneuver

and operation of instruments within the thoracic cavity, and to reduce the likelihood of mutual interference among instruments. Therefore, a detailed assessment of the patient's chest CT scan and other imaging examination results should be performed before the procedure to confirm the status of lesion [31]. In general, the incision is placed between the anterior axillary line and the midaxillary line, over the fourth to sixth intercostal space; other researchers have performed the procedure via a subxiphoid incision. Incision length is an important factor that affects the uniportal VATS procedure. The smaller the incision, the smaller the range of motion for instruments, and the greater the likelihood of mutual interference [32]. In general, the incision length for uniportal VATS is 2–4 cm; however, it may be appropriately increased to 5 cm for complex surgeries, such as sleeve bronchoplasty or pulmonary arterioplasty [33]. The incision location and size for uniportal VATS are variable; flexible adjustments should be made based on the location of the lesion and the used surgical instruments. Selection of an appropriate incision is a key factor to the increased efficiency of the uniportal VATS procedure. With thoracoscopic instruments and surgical techniques improvement, the selection of incision location and size for future uniportal VATS procedures may be further optimized [34].

Surgical instruments

A high-definition camera is an essential device in the uniportal VATS procedure, as it provides a wider operating space and increases convenience of operation. Future development and maturation of flexible thoracoscopy will further reduce the impact of the thoracoscopic camera on surgical instruments handling [35].
As a small incision is used, elongated instruments should be primarily used in uniportal VATS in order to maximize space at incision site and to reduce the likelihood of mutual interference among instruments. Long-handled double articulating instruments, which have the advantage of longer operating distance, may be used to reduce the impact of smaller incisions on the open-close actions of instruments [36]. During uniportal VATS procedure, instruments are inserted through a small hole nearly parallel to the thoracoscope into the thoracic cavity, and are converged on the operative field, which greatly reduces the surgical plane. With the use of curved instruments with distal articulation, such as curved suckers and curved electrocautery hooks, the surgical plane can be increased [37].

Visual perception and surgical planes

For triportal VATS, the observation port, utility port, and auxiliary port form a triangle, and instruments point towards the same operating area from three different directions, which results in less mutual interference. However, as the image plane and both surgical planes are at certain angles to one another, the surgeon's judgment of depth may be affected, especially when fine manipulations are performed [37]. For uniportal VATS, the rigid thoracoscope and surgical instruments point towards the same operating area in a nearly parallel fashion, and the image and projective planes basically overlap each other. This provides an excellent perception of depth, and the angle of

view is similar to direct vision in conventional open surgery [37]. In addition, the parallel insertion of thoracoscopic instruments also facilitates maneuvers, which are more similar to those performed during conventional open surgery, thus enabling surgeons to perform finer manipulations.

Application of uniportal VATS in thoracic procedures

Due to the operating limitations of uniportal VATS, this approach was mainly used for mediastinal lymph node biopsies, local resections of pulmonary tissue, and diagnosis of pleural conditions during early stages of development [12]. Rocco et al. reported the development of uniportal VATS, in which the procedure was used in the diagnosis and treatment of 644 patients over a decade [38]. Of 644 performed procedures, 329 were diagnostic procedures for pleural conditions, 14 were performed for pre-thoracotomy exploration for lung cancer, 186 were performed for local resections of pulmonary tissue, and 115 were performed for miscellaneous conditions [38]. Conversion to thoracotomy or multiportal VATS was 3.7%, the incidence of postoperative complications was 2.8%, and perioperative mortality was 0.6% [38]. The experience reported by Rocco et al. suggested that uniportal VATS had a larger scope of application in thoracic surgery and that the procedure was relatively safe [38]. As the experience was only based on data up to 2010, uniportal VATS was primarily used for minor thoracic procedures during the study period. However, with the enhancement of the VATS technology, accumulation of surgical experience, and improvements to surgical instruments, the scope of application of uniportal VATS has gradually expanded [11].

The first case of uniportal VATS lobectomy was reported by Spanish surgeon Gonzalez-Rivas and colleagues [13]. As lobectomy requires the dissection of the hilar structures in order to obtain free access to pulmonary arteries, pulmonary veins, and bronchi, as well as the dissection of interlobar fissures, the procedure maneuvers are more complex. Due to mutual interference among instruments during the uniportal VATS procedure, high levels of surgical skills are required. Following the report of the first case of uniportal VATS lobectomy, uniportal VATS was gradually introduced into the realm of complex thoracic surgeries, and medical institutions around the world started to explore the use of uniportal VATS for complex procedures, such as lobectomy and radical lung cancer resection. In 2013, Gonzalez-Rivas and colleagues reported a two-year experience on uniportal VATS lobectomy [39]. Of 102 attempted procedures, 97 uniportal VATS procedures were successfully completed, and conversion to thoracotomy or multiportal VATS was necessary in five cases, resulting in a conversion rate of 4.9% [39]. The mean surgical time was 154.1 ± 46 minutes, and the median duration for which a chest tube was in place was 2 days [39]. Postoperative complications occurred in 14 patients; however, no postoperative 30-day mortality was reported [39].

With gradual refinement and popularization of uniportal VATS lobectomy, many medical centers have

reported results on uniportal VATS for radical lung cancer resection in the recent years. The Shanghai Pulmonary Hospital in China recently reported the experience on uniportal VATS procedures in the largest available sample size study performed at a single institution [40]. A total of 1063 patients were included in this study, and a broad variety of procedures were performed, including sleeve lobectomy, lobectomy, segmentectomy, wedge resection, and synchronous bilateral thoracic surgery. Conversion to thoracotomy was 4.6%, median length of ICU stay was 1 day, postoperative complication rate was 5.6%, and perioperative mortality was 0.

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Case report - Thoracic oncologic

Single-port video-assisted thoracoscopic lobectomy

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Abstract

The video-assisted thoracoscopic surgery (VATS) approach to lobectomy for non-small cell lung cancer varies among hospitals. Although three to four incisions are usually made, the operation may be successfully carried out using only two incisions with similar results. We observed that for lower lobes the second incision could be eliminated in selected cases. We describe a case report of a 74-year-old female operated by a single-port approach for a lower-lobe VATS lobectomy.

Keywords: Thoracoscopy/video-assisted thoracoscopic surgery; Lobectomy; Lung cancer surgery

1. Introduction

Video-assisted thoracoscopic surgery (VATS) is an emerging technology in minimally-invasive surgery which provides painless surgery with short recovery time. This report describes a minimally-invasive technique for VATS lower lobectomies with a single-port approach.

2. Clinical summary

A 74-year-old female consulted for cough and hemoptysis. A computed tomography (CT)-scan revealed a mass in the lower lobe of the left lung with bronchiectasis. The bronchoscopy showed a mass in segments 8, 9 and 10 of the left bronchus. The biopsy revealed a carcinoid tumour. The patient was proposed for VATS lobectomy.

3. Surgical technique

The patient was placed in a right-lateral decubitus position. A 4-cm incision was made in the fifth intercostal space in the anterior position just inferior to the breast and pectoralis major. We introduced the 10-mm thoracoscope into the lower part of the incision and explored the chest cavity. A complete fissure was found. Digital palpation confirmed the presence of a mass in left lower lobe. We inserted the instruments through the upper part of the utility incision to start the dissection. The first step was to dissect the artery in the fissure, holding the lower lobe with a ring forceps positioned above the dissector. To staple the artery, we changed the camera to the upper part of the utility incision and inserted the staplers below the camera (Fig. 1a). For inferior pulmonary vein and bronchus the thoracoscope was placed again in the inferior part of the incision. This was the most common camera position during the operation (Fig. 1b) (Video 1).

We completed the lobectomy stapling the anterior fissure with the optic placed below the stapler. The lobe was removed in a protective bag and a systematic lymph node dissection finished the procedure (Video 2). A single chest tube was placed in the posterior part of the utility incision (Fig. 2). The total surgery time was 80 min.

The chest tube was removed on the second day and the patient was discharged home in 48 hours with no complications in the chest X-ray.

The pathological examination revealed a 3-cm typical carcinoid tumour with no lymph node involvement (a total of nine lymph nodes were studied).

4. Discussion

There is no standardized technique for the VATS approach, though most centres use a utility incision measuring about 3–5 cm and generally positioned in the anterior chest wall. Most surgeons then add two other ports (one for the optics and another at posterior level) [1].

We began performing VATS lobectomies in the department in June 2007. Up to September 2010, we undertook 209 major pulmonary resections by VATS. Since February 2009, we started to do VATS lobectomies using only two ports [2]. We used a double-port technique as described by Burfeind and D'Amico [3].

In our literature review, we have found no reports of lobectomies performed through a single incision. Since 2004, Rocco et al. have published different articles on the single-port VATS technique [4] for diagnostic and therapeutic procedures, though not including lobectomies.

This case shows the possibility to do a VATS lobectomy with only one incision. It is probably that this procedure

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Figure 1 The first report of uniportal VATS lobectomy

The 1-year overall and 1-year disease-free survival for patients with lung cancer were 98% and 96% respectively, which indicated excellent short-term efficacy. The study further illustrates the safety and feasibility of the uniportal VATS technique when applied in thoracic procedures, and indicates the high value of the procedure in clinical applications [40]. Chung et al. reported that, compared to conventional triportal VATS, uniportal VATS lobectomy resulted in shorter surgical time, less intraoperative bleeding, and shorter postoperative hospital stay for patients [41]. When lymphadenectomy is performed with VATS, a greater number of dissected lymph nodes can be achieved with uniportal VATS for radical lung cancer resection, in comparison to triportal VATS. Shen et al. from Zhongshan Hospital of Fudan University in China conducted a propensity score matching study to compare the safety and feasibility of uniportal VATS and triportal VATS for NSCLC treatment [42]. The study found no statistical differences in surgical time, number of dissected lymph nodes, intraoperative bleeding, and length of postoperative hospital stay between the two approaches [42]. The rate of conversion to thoracotomy for the uniportal VATS group was 1%, which was similar to that of the triportal VATS group (2%) [42]. Additionally, no statistical differences were found in postoperative complications between the two groups [42]. For the uniportal VATS group, the time taken for lobectomy was shorter, but the time taken for lymphadenectomy was longer in comparison to the triportal VATS group. This can be explained by the proximity of the incision to the hilum and a larger extent of lymphadenectomy, which is more difficult than the dissection of lymph nodes [42]. In addition, the study also indicated that the accumulation of a certain volume of cases was required for the transition from triportal VATS to uniportal VATS [42]. The use of surgical staplers is possibly the most difficult maneuver in this procedure. However, for surgeons with prior experience in a large number of thoracoscopic procedures, the learning curve was shorter. In addition, this study reported that surgeons could achieve a stable level of competence after 15 cases.

In addition to lobectomy, there have been other attempts to gradually introduce the uniportal VATS approach into more complex thoracic procedures. Through the analysis of 43 patients with locally advanced NSCLC who had undergone uniportal VATS procedures, Spanish researcher Gonzalez-Rivas and colleagues found longer surgical time in these patients compared to patients with early stage NSCLC [43]. However, no significant differences were found in postoperative complications, duration for which a chest tube was in place, and length of hospital stay. In addition, the number of dissected lymph nodes was higher in patients with locally advanced NSCLC, which indicates that the uniportal VATS approach can be used for the treatment of these patients [43]. The 30-month survival rate was 90% for patients with early stage NSCLC, and 74% for those with locally advanced NSCLC [43].

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Single-port video-assisted thoracic surgery in 1063 cases: a single-institution experience[†]

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Abstract

OBJECTIVES: Single-port video-assisted thoracic surgery (VATS) technique has been used for thoracic diseases. There was no report about single-port VATS in large series. Outcomes following single-port VATS were analysed to determine its efficacy and safety.

METHODS: From June 2012 to June 2014, 1063 single-port VATSs were performed by four surgeons. Patient demographics, perioperative parameters, histopathology and outcomes were analysed.

RESULTS: There were 1063 patients (524 men and 539 women). The median age was 56.1 ± 8.7 years (range, 15–86 years). Lobectomy was performed in 569 patients, segmentectomy in 162, wedge resection in 264, pleural biopsy in 7, drainage of effusion in 20, pleural tumour resection in 5, mediastinal tumour resection in 54, mediastinal tumour biopsy in 2, bilobectomy in 7, sleeve lobectomy in 3 and pneumonectomy in 2. Synchronous bilateral single-port VATS was performed in 27 cases, whereas metachronous bilateral single-port VATS was performed in 5 cases. Pathological diagnoses included primary lung cancer in 635 cases, metastatic lung cancer in 19, mediastinal tumour in 56, pleural disease in 32 and benign pulmonary conditions in 353. Fifteen intraoperative vascular injuries were identified in 15 patients. The total conversion rate was 4.6%. The average operation time was 135 ± 31 min (range, 30–230 min), and the average blood loss was 117 ± 47 ml (range, 50–2000 ml). The median intensive care unit stay was 1 day (0–4 days). The postoperative hospital stay was 6.2 ± 2.6 days on average. There was no operative death, and operative complications occurred in 59 patients (5.6%). The 1-year overall survival and 1-year disease-free survival for the primary lung cancer group were 98 and 96%, respectively.

CONCLUSIONS: Our findings indicate that single-port VATS for thoracic diseases is safe and feasible.

Keywords: Video-assisted thoracic surgery • Single-port • Minimally invasive surgery

INTRODUCTION

The single-port video-assisted thoracic surgery (VATS) technique was first reported by Rocco *et al*. [1]. Since 2004, Rocco has published several articles on the single-port VATS technique for diagnostic and therapeutic purposes [2–5]. Gonzalez-Rivas *et al*. developed the single-port technique for VAT major pulmonary resections in 2011 [6–9], and reported the first series for major pulmonary resections in 2013 [10]. Hsu *et al*. [11] reported the first multi-institutional single-port VATS study in anatomical resection for primary lung cancer. Ng *et al*. [12] reported that the early survival outcomes after single-port VATS were satisfactory. Wang *et al*. [13] reported that the perioperative outcomes in single-port approach were comparable with those of the multiple-port approach in a propensity-matched study.

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The potential advantages of the single-port VATS include less postoperative pain, fewer paraesthesias and better cosmetic results [10–15]. However, there are still controversies regarding the safety, mortality and morbidity of single-port VATS. This study was designed to assess the safety and feasibility of single-port VATS.

MATERIALS AND METHODS

The study protocol was reviewed and approved by the Ethics Committee of Shanghai Pulmonary Hospital, and the informed consent was obtained from all patients. Between June 2012 and June 2014, 1063 single-port VATSs were performed by four senior surgeons at the Thoracic Department of Shanghai Pulmonary Hospital, Shanghai, China. In the same period, 2476 thoracic surgical procedures were performed by the same surgeons; hence, in a 2-year period, single-port VATS was performed in 42.9% of the patients. A full medical record review was conducted to obtain

Figure 2 The largest series of uniportal VATS

Advantages and shortcomings of uniportal VATS

The major advantages of uniportal VATS are reduced postoperative pain, reduced incidence of thoracic wall dysesthesia, and improved aesthetics. Using this approach, the risk of intercostal nerve injury is lower. As a metal trocar is not used, the risk of trocar compression on the periosteum and intercostal nerves is eliminated, thereby reducing postoperative pain and thoracic wall numbness in patients. The reduction in the number of incisions reduces the surgical trauma to the thoracic wall and facilitates psychological acceptance of the uniportal VATS procedure. The subjective opinion regarding the smaller extent of trauma from the procedure

makes it easier for patients to regain positive emotional status postoperatively, and allows a faster return to normal life and work activities. Therefore, the uniportal VATS procedure can reduce physical and mental trauma in patients, thus achieving the purpose of minimally invasive treatment.

However, it should also be noted that uniportal VATS procedure has disadvantages. As the camera and all surgical instruments are inserted and removed from the same utility port, inadvertent mutual interference will occur and affect the surgical procedure. The reduced surgical plane also requires a reasonable surgical route to be planned in order to avoid repeated maneuvers during the procedure. In addition, compared to multiportal VATS approach, there are certain difficulties in the promotion of uniportal VATS. Although some studies have indicated that a long learning curve for uniportal VATS is not expected if the multiportal VATS approach has been mastered, differences may exist in the understanding and mastery of surgical concepts and techniques. Therefore, optimization and formulation of standards regarding the surgical instruments and technology for uniportal VATS are necessary to facilitate the promotion of this technique. In addition, although the safety and feasibility of uniportal VATS in thoracic procedures have been successively reported by many studies, as standards have not been established yet, differences in surgical instruments, surgical techniques and concepts of uniportal VATS still exist among different medical institutions, and careful assessment is also required for the short- and long-term prognosis of this approach. Further exploration of the clinical application value of the uniportal VATS approach in thoracic surgery requires a larger sample size and clinical studies with a higher level of evidence.

Conflict of interest

The authors have no potential conflicts of interest to disclose.

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