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The Feasibility and Advantages of Subxiphoid Uniportal Video-Assisted Thoracoscopic Surgery in Pulmonary Lobectomy

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Abstract

Background Uniportal video-assisted thoracoscopic surgery (VATS) lobectomy has emerged as a promising and exciting approach for minimally invasive thoracic surgeries. However, nearly all reported uniportal VATS lobectomies are performed via an intercostal route, and chest wall trauma remains an issue. Here, we report the use of a novel uniportal VATS technique involving a subxiphoid route for pulmonary lobectomies.

Methods We retrospectively analyzed perioperative data for patients who underwent subxiphoid uniportal and traditional three-port VATS lobectomies from January 2016 to January 2017 at our hospital.

Results During the study period, 37 patients successively underwent subxiphoid uniportal VATS lobectomies, including three synchronous bilateral pulmonectomies; 68 patients underwent traditional three-port VATS. There were no surgical or 30-day postoperative mortalities, and no significant between-group differences were found in the number of retrieved lymph nodes, number of explored nodal stations, blood loss, drainage time, postoperative complications, or length of hospital stay. Operative time was longer in the subxiphoid uniportal VATS group than in the traditional three-port VATS group ($P < 0.001$). Visual analog scale (VAS) pain scores after surgery were significantly lower in the subxiphoid uniportal VATS group ($P < 0.05$).

Conclusions Subxiphoid uniportal VATS lobectomy is a safe and feasible surgical procedure associated with reduced surgical trauma and postoperative pain as well as improved cosmetic results compared with traditional VATS. Moreover, this procedure is better suited for patients receiving synchronous bilateral pulmonectomy. Further long-term follow-up analyses involving more patients are ongoing.

Trial registry number ClinicalTrials.gov NCT03051438.

Introduction

Rapid technological progress has decreased the invasiveness of thoracic surgeries, as well as the duration of postoperative rehabilitation [1]. Since 2010, uniportal video-assisted thoracoscopic surgery (VATS) lobectomy has become a new area of exploration and evolution for minimally invasive thoracic surgery [2]. Because of excellent results, uniportal VATS lobectomy is becoming increasingly accepted [3, 4]. We started using this surgical procedure in 2015 [5]. However, nearly all reported uniportal VATS lobectomies were performed via an intercostal

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route, and intercostal incisions can result in postoperative intercostal neuralgia and chronic thoracotomy pain [6]. Here, we report the use of a novel uniportal VATS technique involving a subxiphoid route for pulmonary lobectomy prevents these outcomes and better preserves pulmonary function. This study aims to assess the feasibility and applicability of the subxiphoid uniportal VATS approach for pulmonary lobectomy and to compare perioperative outcomes of subxiphoid uniportal and traditional three-port VATS lobectomies.

Materials and methods

Data acquisition and follow-up

We retrospectively analyzed the results of patients who underwent subxiphoid uniportal or traditional three-port VATS lobectomy between January 2016 and January 2017 at our hospital. None of these patients had received neoadjuvant therapies prior to surgery. Institutional Review Board (IRB) approval and patient consent were obtained. The retrospective study was registered at ClinicalTrials.gov (NCT03051438). Pre-, peri-, and postoperative outcome variables and patient details were collected via patient inquiry and clinical assessment.

Surgical technique

General aspects

Both subxiphoid uniportal and traditional three-port VATS lobectomies were performed under general anesthesia. A double-lumen endotracheal tube and single-lung ventilation were utilized. Required surgical equipment included Echelon Flex endoscopic articulating linear cutters (Ethicon Endo-Surgery, Somerville, NJ, USA), long curved endoscopic surgical instruments with double articulations and curved suction (Yundi, Wuxi, China), and a 10-mm 30° thoracoscope (Storz Medical AG, Tägerwilen, Switzerland).

Traditional three-port VATS technique

Traditional VATS lobectomies were completed using the three-port technique, which involves three incisions and an operative field that is visualized onscreen via a video thoracoscope [7].

Subxiphoid uniportal VATS technique

Patients were placed in a supine position, and the operating table was adjusted as needed to elevate the appropriate side of the body for surgery (Fig. 1). Both the surgeon and the assistant stood contralaterally to the surgical lung so that the same visual field was obtained, enhancing surgical coordination. A single incision approximately 4.0 cm in length was made below the xiphoid process. The incision was transverse and for bilateral lung surgeries and tilted in the direction of the operative costal arch for unilateral lung surgeries (Fig. 1a–d). The skin, subcutaneous tissue, and rectus abdominis insertion at the costal arch were cut. During single-lung ventilation, the tunnel close to the deep surface of the costal arch was bluntly dissected with a finger, and the pleural cavity was entered above the diaphragm (Fig. 1e). A plastic wound protector (Demai, Guangzhou, China) was placed in the incision to provide optimal exposure. The procedures required bimanual instrumentation with paired surgical instruments that crossed at incision sites (Fig. 1f).

Our surgical procedures followed classic principles of pulmonary resections, and similar to mediastinal lymphadenectomies for lung cancer, we were often required to dissect individual veins, arteries, and lobar bronchi. Of key concern was adequate exposure of the lung, which was mandatory for every step. For a subxiphoid uniportal VATS approach, an endostapler was the most convenient tool for ligating bronchi, incomplete fissures, and blood vessels due to the operative angle. Small vascular branches were difficult to divide using an endostapler. Thus, vascular clips were used in these cases. Resected tissue specimens were collected in a protective bag, and mediastinal lymphadenectomy was performed for all lung cancer patients. At the end of the operations, a U-shaped suture surrounding the chest tube was placed to close the drainage spout after extubation (Fig. 1d), and the wound was infiltrated with ropivacaine (Naropin, AstraZeneca AB, Sweden).

Upper lobectomy

Right and left upper lobectomies were performed by first dividing the artery and then the vein. The corresponding pulmonary fissure was ultimately stapled when the bronchus was transected (Fig. 2). Procedures for subxiphoid uniportal VATS of the left lung sometimes caused compression of the heart that leads to premature ventricular contraction; to overcome this problem, long curved endoscopic surgical instruments with double articulations and curved suction were used, and we attempted to minimize pressure on the heart. All patients tolerated the entire procedure well, with no instances of severe intraoperative arrhythmia.
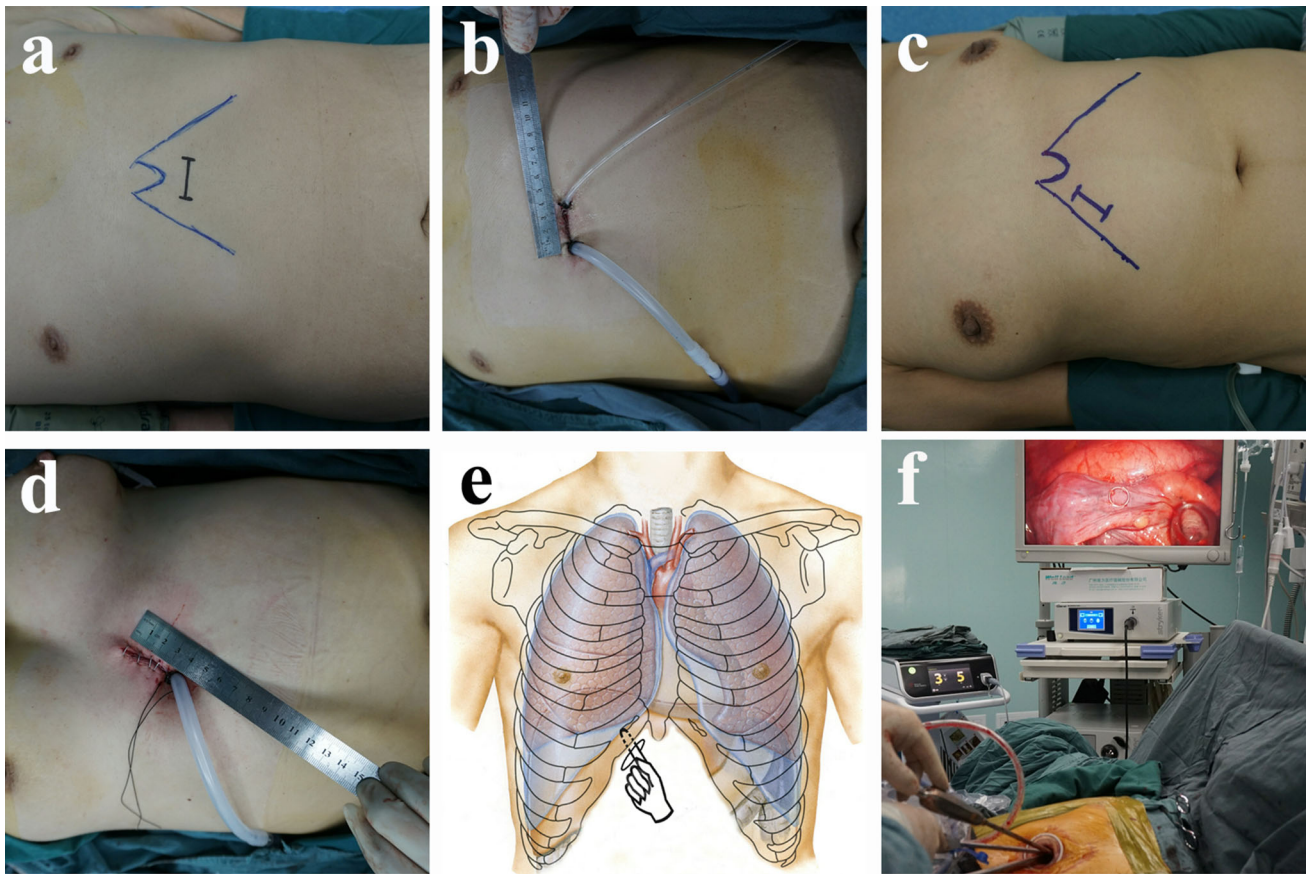
Fig. 1 The incision for subxiphoid uniportal VATS lobectomy. **a** The transverse incision just below the xiphoid process. **b** The chest tube for bilateral lung surgery. **c** The incision is tilted in the direction of the operative costal arch. **d** The chest tube for unilateral lung surgery.

e The tunnel close to the deep surface of the costal arch was bluntly dissected with a finger. **f** The surgeon performed the operation with bimanual instrumentation; in particular, a pair of surgical instruments that were crossed at the incision site was utilized

Middle lobectomy

Right middle lobectomies were performed in the following sequence: division of the anterior portion of the major fissure, the vein, the bronchus, the artery, and the remaining fissure. Only when the fissure was complete was the artery divided before the bronchus (Fig. 3a–c).

Lower lobectomy

For right and left lower lobectomies, the procedure was easier when the division of the fissure was complete. When the fissure was incomplete and no arteries were visible in the fissure, lobectomy was performed from bottom-to-top, with the fissure stapled last (Fig. 3d–f).

Pulmonary ground-glass opacities and small nodules

Ground-glass opacities (GGOs) and small nodules can be difficult to palpate through a subxiphoid incision.

Therefore, preoperative CT-guided puncture positioning was used to pinpoint the positions of pulmonary lesions (Fig. 1f).

Statistical analysis

Categorical variables were expressed as percentages, and continuous variables were expressed as mean ± standard deviation. Variables were compared using Student's t test, Chi-squared test, or Fisher's exact test. Data were analyzed using SPSS 17.0. P values < 0.05 were regarded as statistically significant.

Results

Patient characteristics

Between January 2016 and January 2017, 37 patients were successfully treated via subxiphoid uniportal VATS
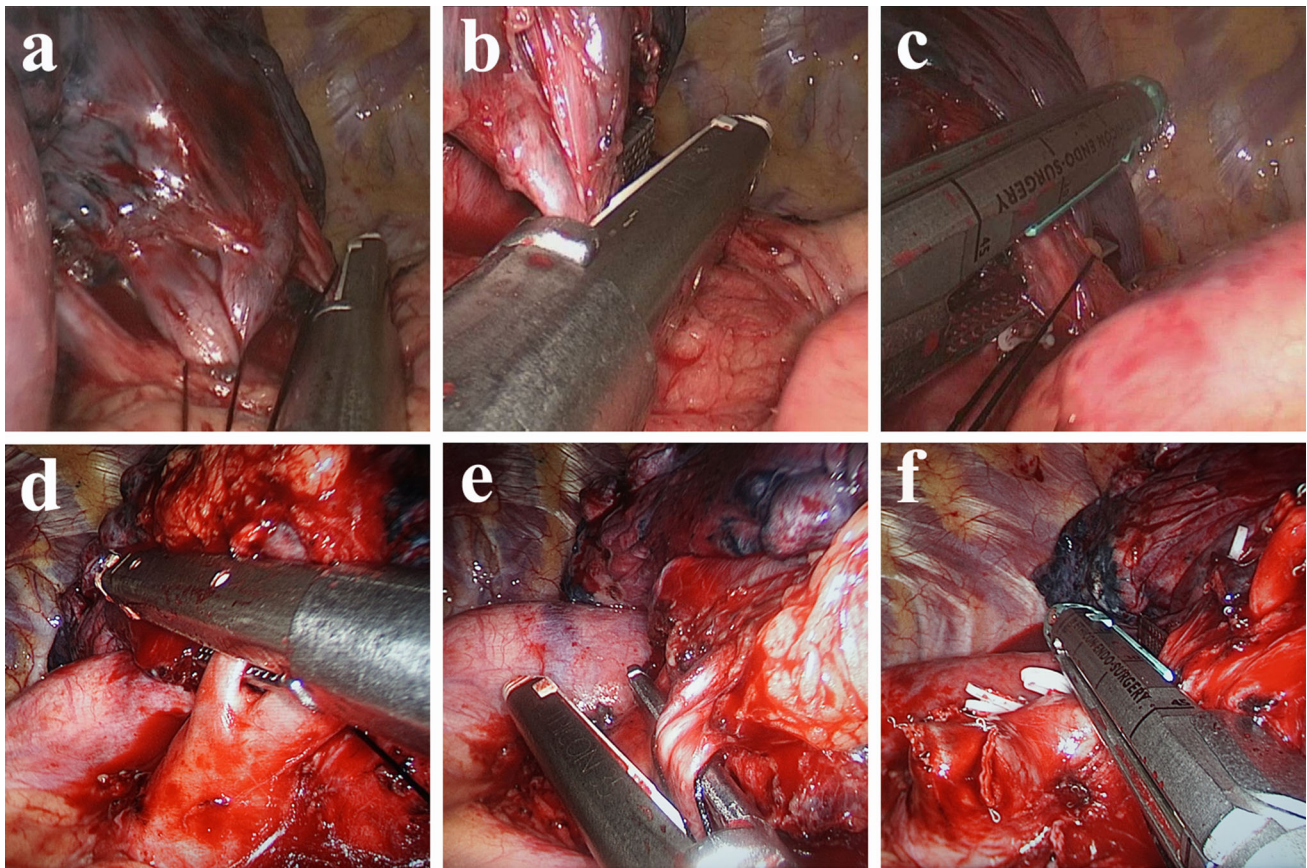
Fig. 2 Upper lobectomy via subxiphoid uniportal VATS. **a** Treatment of the right upper lobar artery. **b** Treatment of the right upper lobar vein. **c** Treatment of the right upper lobar bronchus. **d** Treatment of the left upper lobar artery. **e** Treatment of the left upper lobar vein. **f** Treatment of the left upper lobar bronchus

lobectomy, including three synchronous bilateral pulmonectomies for the following purpose: (1) radical right upper lobectomy for carcinoma with left upper lobe wedge resection; (2) radical right lower lobectomy for carcinoma with left upper lobe wedge resection; (3) radical left upper lobectomy for carcinoma with right lower lobe wedge resection. A total of 68 patients underwent traditional three-port VATS. There were no surgical or 30-day postoperative mortalities. All patient characteristics and lobectomy combinations are presented in Table 1. Postoperative pathologic diagnoses included both primary lung cancers and benign conditions (Table 2). Primary lung cancers were classified by pathologic stages (stage I, II, III, or higher; Table 3).

Surgical outcomes

In both the subxiphoid uniportal and three-port VATS groups, one procedure required conversion to conventional open thoracotomy because of dense adhesions and bleeding. The conversion rates were 2.70% and 1.47%, respectively. Both converted procedures were completed safely, and no inpatient deaths occurred. There were no significant between-group differences in blood loss, number of retrieved lymph nodes, number of explored nodal stations, drainage time, or length of hospital stay. Operative time was longer in the subxiphoid uniportal VATS group compared with the traditional three-port VATS group ($P < 0.01$; Table 4). Three patients (8.11%) in the subxiphoid uniportal VATS group and six patients (8.82%) in the traditional three-port VATS group experienced postoperative complications ($P > 0.05$; Table 5).

Visual analog scale pain scores

The intensity of postoperative pain was scored using a 10-cm vertical visual analog scale (VAS) [8]. The mean VAS scores at 24 h, 48 h, 72 h, 1 week, and 1 month after surgery were 3.27 ± 1.46, 3.14 ± 1.52, 2.35 ± 1.29, 1.97 ± 0.54, and 0.79 ± 0.35, respectively, for the subxiphoid uniportal VATS group; the scores were 7.69 ± 1.32, 6.26 ± 1.28, 4.65 ± 1.63, 2.31 ± 0.75, and
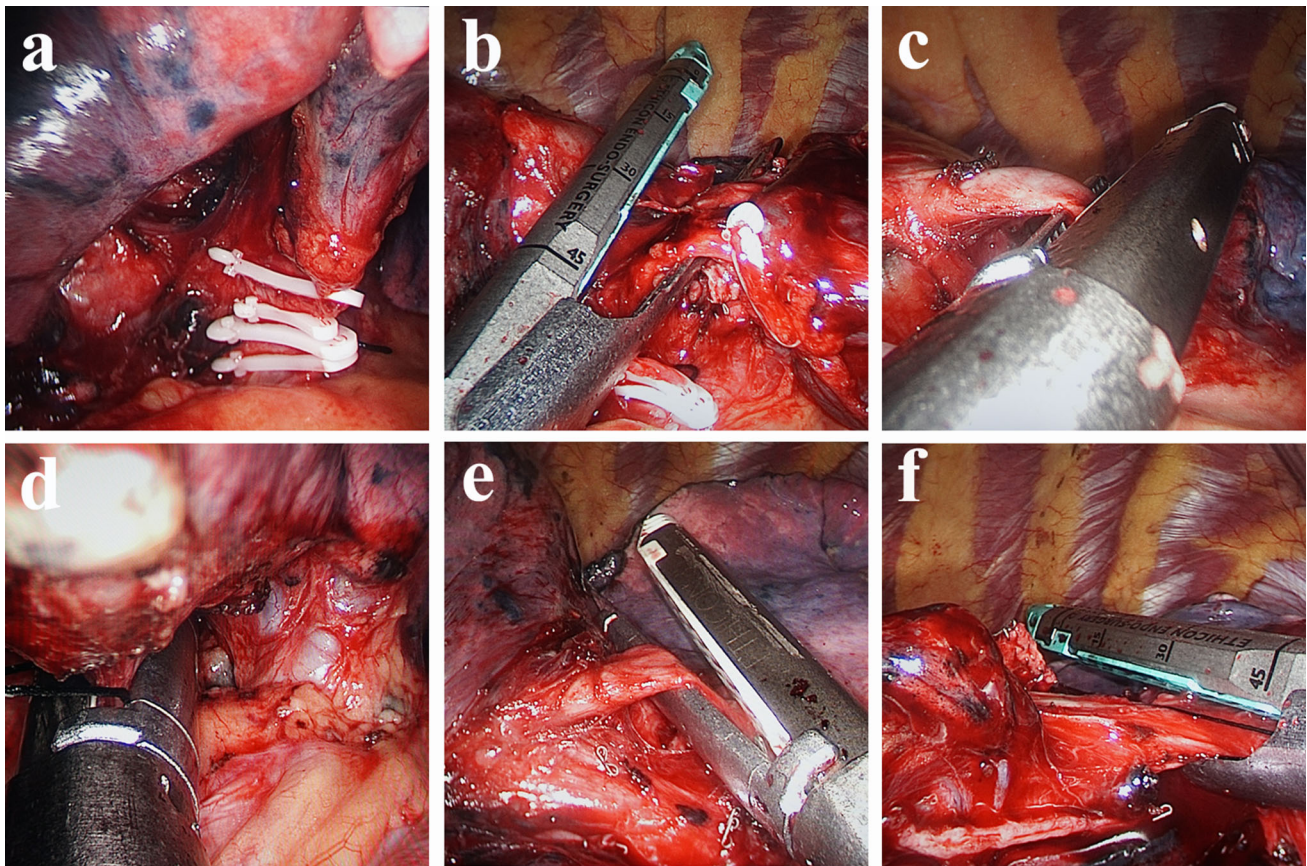
Fig. 3 Middle and lower lobectomy via subxiphoid uniportal VATS. **a** Treatment of the right middle lobar vein. **b** Treatment of the right middle lobar bronchus. **c** Treatment of the right middle lobar artery. **d** Treatment of the right lower lobar vein. **e** Treatment of the right lower lobar artery. **f** Treatment of the right lower lobar bronchus

1.11 ± 0.54, respectively, for the three-port VATS group. Postoperative pain scores were significantly lower ($P < 0.05$) in the subxiphoid uniportal VATS group than in the three-port VATS group, confirming an expected advantage of subxiphoid uniportal VATS.

Discussion

The field of thoracic surgery is continually evolving [9]. Since the first uniportal VATS lobectomy was performed by Gonzalez Rivas in 2011, there have been considerable improvements in techniques and reliability [4, 10]. The advantages of uniportal VATS over traditional three-port VATS include less postoperative pain, speedier recovery, and superior cosmetic results [11, 12]. Although postoperative pain and chest wall paresthesias can be reduced with uniportal VATS due to its minimally invasive nature, they often still occur when an incision through the intercostal space is utilized. Technological advances and innovative devices have led to the development of a novel uniportal VATS involving a subxiphoid approach [10]. Initially, this procedure was applied to pneumothorax operations, metastasectomies, and mediastinal tumor resections [11–13]. However, as demonstrated here, the use of novel uniportal VATS approaches for lobectomies has proved quite successful.

In this study, we compared the outcomes of pulmonary lobectomy via subxiphoid uniportal VATS with traditional three-port VATS. We found no significant between-group differences in the number of retrieved lymph nodes, number of explored nodal stations, blood loss, drainage time, postoperative complications, or length of hospital stay. Compared with other reports [14], the average number of resected lymph nodes was lower in our study. This can be explained by our routine performance of en-bloc resection of lymph nodes during mediastinal lymphadenectomy. During our procedures, we dissected and investigated over six stations of lymph nodes during mediastinal lymphadenectomy, including at least three mediastinal lymph node stations. Specifically, in our center, we conventionally dissect stations #2, 4, 7, 9, 10, 11,

Table 1 Baseline patient characteristics

Characteristic	Subxiphoid uniportal VATS (n = 37)	Three-port VATS (n = 68)	P value
Age (Mean ± SD)	54.12 ± 6.43	63.32 ± 7.54	<0.01
Sex (%)			0.174
Male	15 (40.54%)	37 (54.41%)	
Female	22 (59.50%)	31 (45.59%)	
Pulmonary function (Mean ± SD)			
FVC (% predicted)	91.26 ± 11.54	87.13 ± 12.79	0.105
FEV1 (% predicted)	88.83 ± 13.27	82.35 ± 14.42	0.026
MVV (% predicted)	66.26 ± 15.36	71.63 ± 17.16	0.115
Arterial blood gas analysis (Mean ± SD)			
PAO_2 (mmHg)	82.59 ± 10.21	79.75 ± 14.20	0.285
$PACO_2$ (mmHg)	40.87 ± 4.38	42.61 ± 6.12	0.130
SAO_2 (%)	95.76 ± 2.28	94.28 ± 3.71	0.029
Lobectomy (%)			
Right upper	12 (32.43%)	15 (22.06%)	0.245
Right middle	4 (10.81%)	6 (8.82%)	1.000
Right lower	9 (24.32%)	16 (23.53%)	0.927
Left upper	6 (16.22%)	13 (19.12%)	0.712
Left lower	3 (8.11%)	17 (25.00%)	0.035
Left pneumonectomy	0 (0%)	1 (1.47%)	1.000
Synchronous bilateral pulmonectomy[a]	3 (8.11%)	0 (%)	0.077

[a]Synchronous bilateral pulmonectomies included the following surgical procedures: (1) radical right upper lobe cancer surgery and left upper lobe wedge resection; (2) radical right lower lobe cancer surgery and left upper lobe wedge resection; and (3) radical left upper lobe cancer surgery and right lower lobe wedge resection

Table 2 Pathology results

Pathological types	Subxiphoid uniportal VATS (%) (n = 37)	Three-port VATS (%) (n = 68)	P value
Primary lung cancer	30 (81.08%)	53 (77.94%)	0.706
Adenocarcinoma	21 (56.76%)	29 (42.65%)	0.167
Squamous cell carcinoma	9 (24.32%)	19 (27.94%)	0.689
Adenosquamous	0 (0%)	2 (2.94%)	0.539
Large cell carcinoma	0 (0%)	2 (2.94%)	0.539
Carcinosarcoma	0 (0%)	1 (1.47%)	1.000
Benign disease	7 (18.92%)	15 (22.06%)	0.706
Inflammatory granuloma	3 (8.11%)	5 (7.35%)	1.000
Pulmonary cyst	2 (5.41%)	2 (2.94%)	0.923
Tuberculosis	1 (2.70%)	2 (2.94%)	1.000
Pulmonary hamartoma	1 (2.70%)	1 (1.47%)	1.000
Bronchiectasis	0 (0%)	4 (5.88%)	0.332
Lung sequestration	0 (0%)	1 (1.47%)	1.000

There were no significant differences in these results between the groups (all $P > 0.05$)

and 12 during right pneumonectomies, and stations #5, 6, 7, 9, 10, 11, and 12 lymph nodes during left pneumonectomies. Dissection of #7 lymph nodes is often relatively difficult. During our procedures, we pulled the lobes forward along the mediastinum below the bronchus and resected lymph nodes en-bloc. We feel this is an effective

Table 3 Distribution of primary lung cancers by pathologic stage

Stage	Subxiphoid uniportal VATS (%) (n = 30)	Three-port VATS (%) (n = 53)	P value
Stage I	15 (50.00%)	22 (41.51%)	0.455
IA	8 (26.67%)	9 (16.98%)	0.294
IB	7 (23.33%)	13 (24.53%)	0.903
Stage II	12 (40.00%)	24 (45.28%)	0.241
IIA	7 (23.33%)	13 (24.53%)	0.903
IIB	5 (16.67%)	11 (20.75%)	0.650
Stage III or greater	3 (10.00%)	7 (13.21%)	0.936
IIIA	3 (10.00%)	5 (9.43%)	1.000
IIIB	0 (0%)	1 (1.89%)	1.000
IV[a]	0 (0%)	1 (1.89%)	1.000

[a]Isolated brain metastasis following metastasectomy prior to being evaluated for lobectomy

Table 4 Surgical results (Mean ± SD)

Characteristic	Subxiphoid uniportal VATS (n = 37)	Three-port VATS (n = 68)	P value
Operative time (min)	262.15 ± 40.68	151.84 ± 47.12	<0.001
Blood loss (mL)	110.61 ± 23.37	105.34 ± 25.64	0.302
Drainage time (days)	4.72 ± 1.41	5.13 ± 3.27	0.470
Length of hospital stay (days)	9.23 ± 2.94	9.87 ± 3.86	0.382
Number of lymph nodes retrieved (lung cancer patients only)	11.29 ± 3.51	12.68 ± 3.79	0.068
Number of nodal stations explored (lung cancer patients only)	7.22 ± 1.17	7.08 ± 1.83	0.675

Operative time was longer for the subxiphoid uniportal VATS group than for the traditional three-port VATS group ($P < 0.001$)

Table 5 Postoperative complications

Complication	Subxiphoid uniportal VATS (%) (n = 37)	Three-port VATS (%) (n = 68)	P value
Pneumonia	1 (2.70%)	2 (2.94%)	1.000
Cardiac arrhythmias	1 (2.70%)	1 (1.47%)	1.000
Prolonged air leak	1 (2.70%)	2 (2.94%)	1.000
Hemothorax	0 (0%)	1 (1.47%)	1.000
Totals	3 (8.11%)	6 (8.82%)	1.000

The overall rate of postoperative complications has no significant differences ($P > 0.05$) between the subxiphoid uniportal VATS and three-port VATS group

approach; as previously noted, the two groups did not differ in the number of retrieved lymph nodes or the number of explored nodal stations.

Besides the number of resected lymph nodes, other surgical outcomes in our center, including blood loss, drainage time, postoperative complications, and length of hospital stay, were mostly in accordance with other published results [15–17]. The positioning of patients and general surgical techniques followed Dr. Chia-Chuan Liu's subxiphoid incision approach [16]. His techniques helped us to adapt to the new approach, and complete the operation proficiently. However, we used some extended laparoscopic instruments to better access to certain surgical regions. Our retrospective study had a limited sample size, and the next step is to expand surgical cases via subxiphoid VATS. These experiences will be summarized in future publications.

In early surgeries at our hospital, we utilized three ports by conventional thoracoscopic access. With increased technical proficiency, we were eventually able to complete the operation using one port through the thoracic cage. Now the majority of thoracic surgeries are performed with single-port VATS at our center. More importantly, we have found that the intensity of postoperative pain following the single-port approach is indeed lower than after the three-port approach. We have compared the results of procedures performed through the thoracic cage using either three ports or one port in a previous study [5]; despite the number of ports, patients continued to experience intercostal neuralgia. Thus, we began to explore uniportal subxiphoid VATS and to investigate advantages of the uniportal approach over the three-port conventional VATS. Because this technique and approach were new to us and synchronous bilateral pulmonectomies were performed in the subxiphoid uniportal VATS group, operative times for this group were somewhat prolonged. Substantially less time will likely be required for subxiphoid uniportal VATS lobectomies with increased experience and enhanced instrumentation. Finally, we found that VAS pain scores were significantly lower after surgery in the subxiphoid uniportal VATS lobectomy group than in the other group. We attributed this difference to decreased incidence of intercostal nerve injury and access trauma.

We have noted several advantages of the uniportal subxiphoid approach in this study. First, there was no limitation of shoulder movement after subxiphoid uniportal VATS, because thoracic integrity was maintained. Second, this approach involves a low risk of pulmonary complications. All the advantages above have overt benefits for enhanced recovery after surgery (ERAS) [18]. Third, for patients with bilateral pulmonary lesions, subxiphoid uniportal VATS allows synchronous bilateral pulmonectomies. Furthermore, compared with other approaches, subxiphoid uniportal VATS has superior aesthetic outcomes, with no visible chest scars.

Subxiphoid uniportal VATS lobectomy may have certain limitations under certain technical conditions. First, it is difficult to use this approach to perform complex thoracic procedures, such as surgeries in patients who have received prior thoracic irradiation and induction therapy, sleeve lobectomies, and vascular reconstructions. Second, bleeding control for vascular injuries may be significantly harder to achieve when using this approach. Third, the heart may be compressed, or arrhythmias may be encountered when passing instruments into the left chest. However, we are convinced that these weaknesses will be overcome with the continuous development of videoendoscopic instruments and endosurgical techniques.

In our study, we retrospectively analyzed the advantages and disadvantages of uniportal subxiphoid VATS in

pulmonectomies compared to traditional VATS. Our recent experience demonstrates that subxiphoid uniportal VATS lobectomy is a safe and feasible surgical procedure with excellent postoperative results, particularly for patients with bilateral pulmonary lesions. However, subxiphoid uniportal VATS lobectomy is a relatively complex procedure, and appropriate expertise and instruments are critical to its success. Moreover, further analyses of subxiphoid uniportal VATS lobectomy should be conducted with more patients to better evaluate the potential and promise of this approach.

Compliance with ethical standards

Conflict of interest The authors declare that there is no conflict of interest.

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