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Safety and feasibility of a novel chest tube placement in uniportal video-assisted thoracoscopic surgery for non-small cell lung cancer

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Abstract

Background: The type and placement of chest tube for patients undergoing uniportal video-assisted thoracoscopic lobectomy remains controversial. The aim of this study was to assess the efficacy and safety of a novel technique in which a pigtail catheter was used alone as the chest tube and placed near the incision for chest drainage after uniportal video-assisted thoracoscopic lobectomy and extended lymphadenectomy.

Methods: A total of 217 patients undergoing uniportal video-assisted thoracoscopic lobectomy were retrospectively reviewed and divided into two groups. In group A, a 12-Fr pigtail catheter with several side ports was placed next to the uniportal wound. In group B, a conventional 20-Fr chest tube was placed through the uniportal wound itself. Postoperative complications related to chest tube placement and patients' subjective satisfaction were compared between the two groups. Postoperative pain management effect and other clinical outcomes such as duration of chest drainage and postoperative stay were also compared.

Results: There were 112 patients in group A and 105 patients in group B. A significantly lower incidence of wound complications was found in group A postoperatively ($p = 0.034$). The pain score on coughing in group A was significantly lower than that in group B on postoperative day two (POD2) ($p = 0.021$). There was no significant difference of other clinical outcomes such as duration of chest drainage and postoperative stay as well as major complications between the two groups.

Conclusion: Placing a 12-Fr pigtail catheter alone next to the uniportal wound for chest drainage might be effective and safe after uniportal video-assisted thoracoscopic lobectomy and extended lymphadenectomy.

KEYWORDS
pigtail catheter, postoperative chest drainage, uniportal video-assisted thoracoscopic surgery, wound complication

INTRODUCTION

Video-assisted thoracoscopic surgery (VATS) has become the reasonable modality with its efficacy in the treatment of non-small cell lung cancer (NSCLC) for decades.[1,2] Recently, a uniportal VATS technique has emerged as an even less invasive alternative to the conventional multiportal approach with faster recovery and shorter hospital stay.[3,4] However, how the chest tube should be placed in uniportal VATS remains controversial, and no agreement has been reached to date.[5,6] Unlike wedge lung resection, radical surgery for NSCLC urges cutting off blood vessels as well as airways and systematic dissection of the lymph nodes, which may result in postoperative bleeding and air leakage.[7,8] Therefore, postoperative chest tube drainage might be necessary in NSCLC,[9] including uniportal VATS.

Yang Xua, Jing Luob, and Qi-Yue Gec contributed equally to this study.

Some studies have tried to explore how to place the chest tube in the same incision of the VATS procedure, but theoretically it may disturb healing of the incision.[5,10] On the other hand, a few of studies have attempted to place the conventional chest tube into the thoracic cavity through a new incision nearby, which can produce less effect on the operative incision but might lead to new trauma and risk.[6] In this study, we applied a novel technique in which a pigtail catheter was used alone as the chest tube and placed near the incision for chest drainage in uniportal VATS. We aimed to evaluate the safety and feasibility of this novel technique and compare it to a conventional technique which places the conventional chest tube inside the surgical incision.

METHODS

Patients

In order to minimize selection bias, we retrospectively reviewed the database of consecutive patients who underwent uniportal VATS lobectomy and extended lymphadenectomy by a single surgical team (YS) from July 2016 to December 2019 at our department. All patients were evaluated as suitable for uniportal VATS preoperatively and no intraoperative conversion to multiportal VATS or open thoracotomy occurred in these patients. The exclusion criteria are listed as follows: An American Society of Anesthesiologists (ASA) physical status classification greater than 3; presence of thoracic surgery history and chest wall trauma; and patient records lacking sufficient information for analysis. Before March 2018, a conventional 20-Fr chest tube was placed inside the incision for thoracic drainage at our department. After that, the novel technique of chest tube placement with a 12-Fr pigtail catheter to place near the incision for thoracic drainage was applied in patients undergoing uniportal VATS lobectomy. The patients were divided into two groups with one group of 112 cases (group A), using the novel technique of chest tube placement; and the other group of 105 cases (group B), using conventional chest tube placement. Patients were instructed how to assess their pain using a visual analog scale (VAS) of 0–10 cm (0 cm: no pain, 10 cm: worst pain imaginable) after surgery. The correct way to cough was taught to the patients before surgery and they were repeatedly trained to ensure effective implementation after surgery and true VAS scores at the state of coughing.

Both groups had the same management and patient selection protocols. The patients were followed-up using a chest X-ray or chest computed tomography (CT) at 1, 3, 6 months and every 6 to 12 months postoperatively. Brain magnetic resonance imaging (MRI), bone radionuclide scanning and positron emission tomography (PET)/CT would be used for detailed examination when necessary, or if relevant clinical symptoms appeared. If some patients could not return to our hospital for the follow-up, we advised the patients to perform the same assessments at local medical institutions or by phone visit. At 6 months after surgery, all patients returned to the outpatient department for regular postoperative follow-up and accomplished an incision subjective satisfaction rating scale at that time. This scale included degree of pain during removal of the chest tube, wound complication or other causes impeding incision recovery, influence on upper limb movement on the surgical side, incision impact on quality of life and degree of chronic pain from the incision. Each of the five aspects in the scale included four ratings, of which one was very, two was equal, three was slightly, and four was not. The higher the score, the better the subjective satisfaction. All patients were followed-up during a median follow-up period of 16 months. Surgical and postoperative outcomes between the two groups were compared and analyzed, retrospectively. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013) and the Harmonized Tripartite Guideline for Good Clinical Practice from the International Conference on Harmonization. This study was reviewed and approved by the Institutional Review Board of the Jingling Hospital (approval no. 2016NZKY-026-03). All patients enrolled into the study completed the informed consent form.

Surgical procedure of uniportal VATS for NSCLC

Under general anesthesia with double-lumen endotracheal tube intubation for selective one lung ventilation, the patient was placed in the lateral position on the healthy side. After sterilization and draping procedure, a minimal skin incision was located between the midaxillary and the anterior axillary lines on the fourth or fifth intercostal space according to the position of the interlobar fissure and hilus. The length of the incision was 3–5 cm, and a wound protector was placed. The camera was normally kept on the upper edge of the wound protector which was placed in the incision unless some adjustments were necessary. Lobectomy resection with radical lymphadenectomy was performed in all patients in this study including those with a confirmed preoperative diagnosis of NSCLC and whose frozen section showed malignancy after a wedge resection. The targeted lobes were resected along the fissures using endostaplers (Echelon 45 Endopath stapler; Ethicon Endosurgery Corp.). In particular, 1.1 mm-high stapler like ECR45W (Ethicon Endo-surgery, LLC) was used specially when the resected tissue was thin (such as the edge of the fissure) and 2.0 mm-high stapler like ECR45G or 1.8 mm-high stapler like ECR45D (Ethicon Endo-surgery, LLC) were applied for thicker lung tissue (such as the middle area of the fissure). In the lymph node dissection, an ordinary metal endoscopic suction with side holes on the tip was used to "grasp" the target structure because of its suction capacity. Then, an electrocoagulation hook (EcH), which acts as a dissector and sealer, was used for precise excision and hemostasis. An ultrasonic

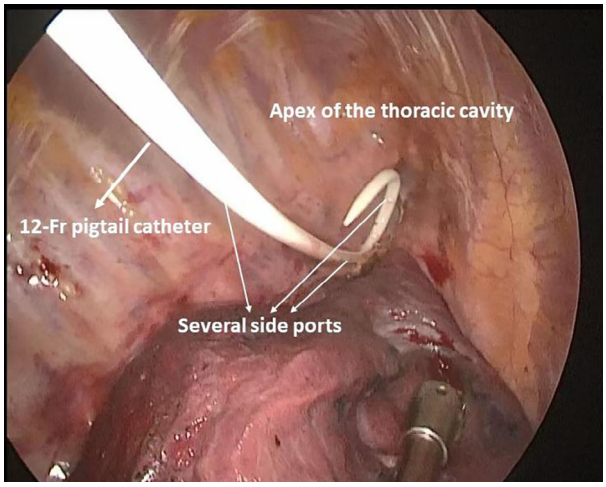

FIGURE 1 A 12-Fr pigtail catheter with several side ports was placed under thoracoscopic guidance for appropriate positioning upon the apex of the thoracic cavity.

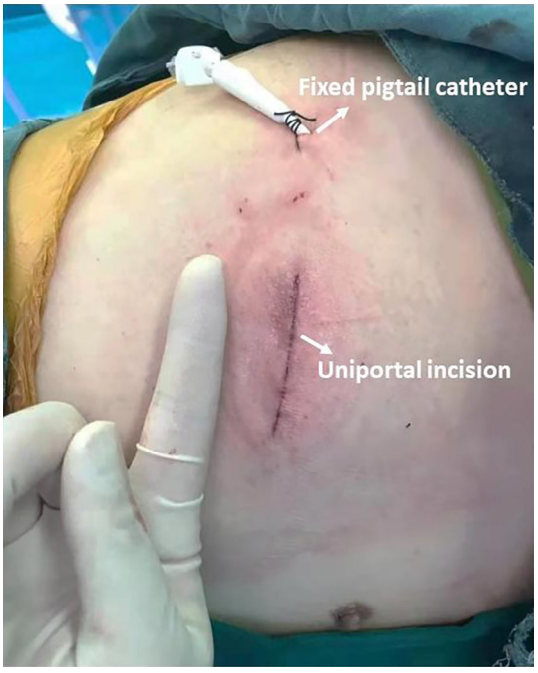

FIGURE 2 The pigtail catheter was securely attached to the chest wall by only one silk thread and the uniportal incision was closed cosmetically in group A.

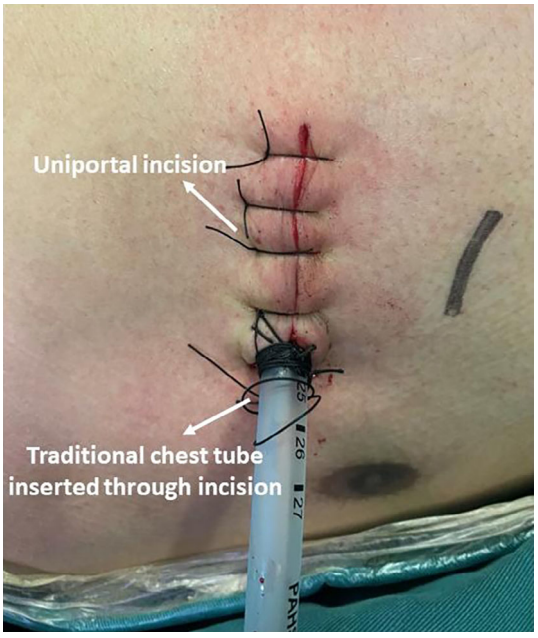

FIGURE 3 A conventional 20-Fr chest tube was placed through the uniportal wound itself and attached tightly to the surface of the skin in group B.

scalpel (US), which produces reliable and durable ligation of small lymphatic or blood vessels, was used as a blunt dissector, sealer, and clamper. We avoided grasping the target lymph nodes directly as possible, and the operation type was applied to all patients in both groups. After the lymph nodes were dissected, a saline submersion test was carried out to examine continuous bleeding as well as air leakage (by reventilation of the lung applying a peak pressure of 22 cmH_2O), and any problems were solved before the end of surgery.

Technique of chest tube placement

In group A, a 12-Fr pigtail catheter was placed next to the uniportal wound at the same intercostal space under thoracoscopic guidance for appropriate positioning upon the apex of the thoracic cavity. Several side ports were distributed along the pigtail catheter for a better drainage of pleural effusion (Figure 1). After the confirmation of no bleeding from the puncture hole of the drainage tube inside the thoracic cavity, the pigtail catheter was securely attached to the chest wall by only one silk thread. For the uniportal wound, the muscle layer and subcutaneous tissue were interrupted sutured with surgical braided thread, and the skin was closed using a skin adhesive for medical incision (Figure 2). In group B, a conventional 20-Fr chest tube was placed through the uniportal wound under thoracoscopic guidance for appropriate positioning upon the apex of the thoracic cavity. At the muscular layer and subcutaneous tissue, both sides of the chest tube were tightly sutured with silk threads leaving just enough space for the tube to be removed. The other muscle layer and subcutaneous tissue were approximated with an intermittent suture technique using a single 2–0 braided synthetic suture. After the skin level was sewn together, the chest tube was attached tightly to the surface of the skin (Figure 3). Patients were transferred to the intensive care unit of our department after replacing the double lumen tube to single lumen tube and extubated after completely waking up.

Technique for chest tube removal and incision care

The chest tube was removed when there was no leakage for 12 h and the volume of drainage was less than 200 mL/24 h, as well as the confirmation of neither air leakage nor residual pneumothorax on the chest x-ray.[11] First, the patients were placed in the semilateral position. After preparation of the patient's exercise for breath, the tube was smoothly removed at the pause of respiration.[12] In group A, small surgical gauze was used to cover on the minimal skin incision, and neither additional tying nor suture procedure was needed because the puncture hole for the pigtail catheter was so small. In group B, at the same time of the chest tube was totally pulled out, the reserved suture which was placed during surgery were used to close the incision. Postoperative incision disinfection was performed every 2 days, and sutures were routinely removed on the 12th to 14th day after operation. However, if incision fat liquefaction occurred, part of the sutures would be opened in advance

TABLE 1 Baseline characteristics of patients in both groups.

Variables	Group A ($n = 112$)	Group B ($n = 105$)	p-value
Age (years)	59.57 ± 9.02	60.82 ± 8.73	0.301
Gender			0.247
Male	52 (46.4%)	57 (54.3%)	
Female	60 (53.6%)	48 (45.7%)	
ASA classification			0.918
1	11 (9.8%)	12 (11.4%)	
2	85 (75.9%)	79 (75.2%)	
3	16 (14.3%)	14 (13.4%)	
BMI (kg/m^2)	23.11 ± 3.19	23.20 ± 3.22	0.836
Hypertension	26 (23.2%)	22 (20.9%)	0.688
Diabetes	14 (12.5%)	11 (10.5%)	0.641
Hyperlipoidemia	12 (10.7%)	9 (8.6%)	0.594
Pulmonary function[a]			
FVC (L)	2.58 ± 0.56	2.64 ± 0.63	0.458
FEV1 (L)	2.29 ± 0.64	2.38 ± 0.58	0.280
Arterial blood gas analysis[a]			
PaO_2 (mmHg)	95.57 ± 10.67	97.28 ± 11.25	0.252
$PaCO_2$ (mmHg)	38.94 ± 5.41	39.13 ± 5.23	0.793
Location			0.789
Right upper lobe	36 (32.1%)	32 (30.5%)	
Right middle lobe	16 (14.3%)	13 (12.4%)	
Right lower lobe	22 (19.6%)	16 (15.2%)	
Left upper lobe	18 (16.1%)	21 (20%)	
Left lower lobe	20 (17.9%)	23 (21.9%)	
Histological			0.520
Squamous cell carcinoma	26 (23.2%)	30 (28.6%)	
Adenocarcinoma	79 (70.5%)	71 (67.6%)	
Others	7 (6.3%)	4 (3.8%)	
Pathological stage			0.914
IA	14 (12.5%)	18 (17.1%)	
IB	17 (15.2%)	16 (15.2%)	
IIA	26 (23.2%)	19 (18.1%)	
IIB	32 (28.6%)	30 (28.6%)	
IIIA	15 (13.4%)	14 (13.3%)	
IIIB	8 (7.1%)	8 (7.6%)	

Note: Data are presented as mean ± SD or *n* (%).

Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index; FVC, forced vital capacity; FEV1, forced expiratory volume in 1 s.

[a]The pulmonary function and arterial blood gas analysis were tested and recorded preoperatively.

TABLE 2 Surgical and postoperative outcomes.

Outcome	Group A ($n = 112$)	Group B ($n = 105$)	p-value
Length of incision (cm)	3.56 ± 0.28	3.64 ± 0.35	0.636
Surgical duration (min)	126.64 ± 23.42	122.75 ± 20.60	0.197
Intraoperative blood loss (mL)	41.84 ± 14.72	39.66 ± 13.81	0.263
Lymph nodes yield	16.24 ± 2.86	15.87 ± 3.02	0.355
Duration of chest drainage (day)[a]	2.78 ± 0.90	3.02 ± 1.21	0.097
Postoperative stay (day)	3.98 ± 1.14	4.20 ± 1.31	0.187
VAS during rest state on POD1	3.89 ± 0.53	4.01 ± 0.67	0.143
VAS during coughing state on POD1	4.09 ± 0.41	4.25 ± 0.82	0.068
VAS during rest state on POD2	3.38 ± 0.72	3.55 ± 0.79	0.098
VAS during coughing state on POD2	3.91 ± 0.54	4.14 ± 0.89	0.021
PaO2 on POD1 (mmHg)	98.36 ± 13.18	95.58 ± 12.32	0.111
PaO2 on POD2 (mmHg)	97.27 ± 11.43	95.24 ± 10.65	0.178
PaCO2 on POD1 (mmHg)	38.78 ± 7.82	39.04 ± 6.89	0.796
PaCO2 on POD2 (mmHg)	38.17 ± 4.56	39.24 ± 6.17	0.146
FVC (L) on POD1	1.27 ± 0.44	1.24 ± 0.52	0.646
FVC (L) on POD2	1.47 ± 0.31	1.42 ± 0.29	0.221
FEV1 (L) on POD1	0.95 ± 0.31	0.92 ± 0.25	0.435
FEV1 (L) on POD2	1.14 ± 0.25	1.10 ± 0.19	0.188

Note: Data are presented as mean ± SD.
Abbreviations: FVC, forced vital capacity; FEV1, forced expiratory volume in 1 s; POD, postoperative day; VAS, visual analog scale.
[a]The duration of chest drainage by 12-Fr pigtail catheter in group A or conventional 20-Fr chest tube in group B.

for drainage and disinfection if necessary, and a second closure would be applied according to the healing of the fresh tissue in the incision. On the contrary, sutures would be routinely removed at certain time. If the skin, subcutaneous tissue or even muscle layer were detected to be poorly healing at the site where the chest tube was inserted, it would be considered to be incision dehiscence.

Clinical outcomes

The following outcomes were assessed: (1) Postoperative pain scores at rest or coughing state; (2) respiratory function including spirometry values and blood gas analysis on postoperative days (PODs); (3) postoperative complications which may be related to wound and the chest tube placement, including dislodgement of chest tube, paresthesia, subcutaneous emphysema as well as pleural effusion which needed further treatment, and their severity were classified based on the Clavien–Dindo classification;[13] (4) score of the incision subjective satisfaction rating scale; and (5) surgical and postoperative data including length of incision, surgical duration, lymph nodes yield, duration of chest drainage and postoperative stay.

Statistical analysis

IBM SPSS for Windows, version 22.0 (IBM Corporation) was used for all statistical evaluations. Continuous variables are expressed as mean ± SD and were compared using independent samples Student's t-test or Mann–Whitney U test. Shapiro–Wilk test was used to test and verify the normality of the distribution of continuous variables. Categorical variables are summarized as proportions or percentages and were compared using χ^2 test. p-values less than 0.05 were considered statistically significant.

RESULTS

There were 112 patients who received the novel technique of chest placement in group A, and 105 patients who received the conventional technique of chest placement in group B. Baseline characteristics demonstrated no significant difference in both groups in terms of gender, age, body mass index (BMI), diabetes, hyperlipoidemia, pulmonary function and pathological stage (Table 1). Moreover, there was no significant difference between both groups in terms of surgical outcomes including length of incision, surgical duration, blood loss and lymph node yield (Table 2).

Postoperative pain scores at rest or coughing state and pulmonary function as well as arterial blood gas analysis date were compared between the two groups (Table 2). A significantly lower pain score was found in group A than that in group B during coughing state on POD2 (3.91 ± 0.54 vs. 4.14 ± 0.89, $p = 0.021$). There was no significant difference of pain scores between the two groups at the state of rest or coughing on POD1 and the state of rest on POD2. Moreover, there was no significant difference of postoperative

TABLE 3 Complications and patient subjective satisfaction.

	Group A ($n = 112$)	Group B ($n = 105$)	p-value
Dislodgement of chest tube	0	0	N/A
Paresthesia	1 (0.9%)	5 (4.8%)	0.110
Wound complication	3 (2.7%)	10 (9.5%)	0.034
Subcutaneous emphysema	2 (1.8%)	7 (6.7%)	0.093
Pleural effusion[a]	5 (4.5%)	2 (1.9%)	0.447
Pneumonia	7 (6.3%)	5 (4.8%)	0.632
Pulmonary embolism	0	1 (0.9%)	0.484
Subjective satisfaction score	12.09 ± 2.59	11.42 ± 2.67	0.062

Note: Data are presented as mean ± SD or *n* (%).
Abbreviation: POD, postoperative day.
[a]Moderate to massive pleural effusion which requires additional drainage after surgery.

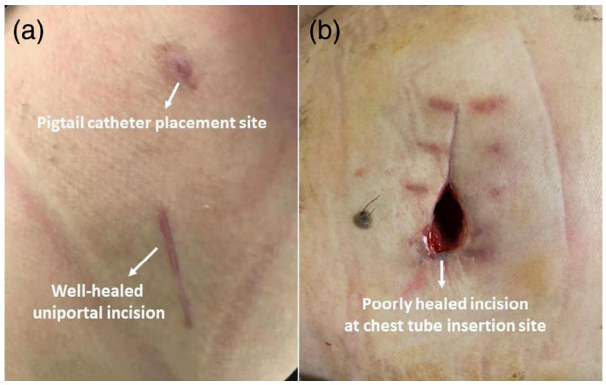

FIGURE 4 (a) The uniportal incision and the pigtail catheter placement site were both well-healed in group A. (b) A patient in group B suffered from poor wound healing at the site where a conventional chest tube was inserted.

forced vital capacity (FVC) and forced expiratory volume in 1 s (FEV1) between the two groups, and arterial blood gas analysis demonstrated normal range of both PaO_2 and $PaCO_2$ levels in two groups on POD1 and POD2. Furthermore, duration of chest drainage and postoperative stay were similar between the two groups, respectively (Table 2).

As shown in Table 3, three patients in group A suffered wound complications (operative incision fat liquefaction), while 10 patients in group B suffered wound complications, including 8 patients who suffered incision dehiscence and two patients who suffered incision fat liquefaction (Figure 4). Based on the Clavien-Dindo classification, the 13 patients with wound complications were all grade I. The incidence of wound complications was significantly lower in group A than that in group B (2.7% vs. 9.5%, $p = 0.034$). There was no dislodgement of the chest tube in both groups during the PODs until the chest tube was removed. The incidence of paresthesia (grade I) was similar between both groups. The two patients suffering from subcutaneous emphysema in group A were both grade I (cured just through intermittently negative pressure suction from pigtail catheter), while one patient in group B was grade IIIa (received extra thoracic drainage for the reason of obstruction in original chest tube) and the other six were grade I. Moreover, the incidence of pleural effusion which needed further treatment (grade IIIa) was also comparable between both groups. There was a trend of higher score of the subjective satisfaction scale about the incision in group A than that in group B, while the difference was not significant (12.09 ± 2.59 vs. 11.42 ± 2.67, $p = 0.062$).

DISCUSSION

In our study, we aimed to assess the safety and feasibility of a novel chest tube placement in uniportal VATS lobectomy for NSCLC. VATS lobectomy was first introduced in 1992,[14] since when it has been increasingly performed as an alternative to thoracotomy due to the minimally invasive nature of the procedure and its many superiorities.[2,15] Recently, uniportal VATS has broadened its application in lung bullectomy, pulmonary wedging, lobectomy and segmentectomy due to less-invasiveness such as less pain and cosmetic reasons over multiportal VATS.[4,16,17]

Unlike lung bullectomy and pulmonary wedging, radical resection of NSCLC needs to cut off blood vessels and airways, which may induce bleeding and air leakage postoperatively, even though these may have been preliminarily examined and solved during surgery.[18] In addition, systematic dissection of the lymph nodes could be related to increased leakage of lymph fluid, and there is a reasonable chance of chylothorax after pulmonary resection, which may lead to pleural effusion.[19] Therefore, postoperative chest drainage appears to be important in lobectomy and lymph node dissection for NSCLC.[9] It facilitates lung re-expansion, allows postoperative pleural effusion evacuation and prevents the development of pneumothorax in case of any air leaks, which may contribute to postoperative recovery.[20] However, there has been no recommended method for wound closure and chest tube placement in uniportal VATS.[21,22] In our institution, uniportal VATS has been introduced since 2015, and the chest tube is usually inserted anteriorly through the incision at the fourth or fifth anterior axillary line and then fixed at the site of the skin incision after the lung resection.[23] However, insertion of chest tube in the operating incision may increase the risk of poor wound healing, especially in the area where the chest tube was placed. Therefore, some studies have tried to fight for better cosmetic wound healing after the placement of chest tube in uniportal VATS. For example, Kim et al. reported a continuous suture anchoring technique using knotless, barbed absorbable suture material which achieved superior outcomes compared to the conventional suture anchoring method in uniportal VATS, while the sample size was too small (only 35 patients included in their study).[5] On the other hand, Palleschi et al.[6] tried to place the chest tube through a newly dedicated tunnel along the chest wall from a 1 cm skin incision approximately on the projection of two

intercostal spaces below the thoracotomy, considering the passage of the chest tube directly through the mini-invasive access may impair the correct reconstruction of muscular plane. The postoperative results were comparable and even superior to the "single incision" approach, due to the possibility of a better reconstruction of the thoracotomy wound several studies. However, the skin incision for chest tube may trigger extra damage to patient's chest wall, which may aggravate the postoperative pain and even impede recovery.[24] In this study, a 12-Fr pigtail catheter was applied to place near the incision for thoracic drainage in patients undergoing uniportal VATS lobectomy, which may contribute to the lower incidence of wound complications than those with conventional chest tube placement. In addition, significant lower pain score was found in patients with this novel technique of chest tube placement during coughing state at POD2, which may demonstrate the advantage of pigtail catheter in postoperative analgesia.

The efficiency of pleural drainage is the key to chest tube application and is significant for postoperative recovery. Kim et al. reported a total 8.6% of patients suffering from mild subcutaneous emphysema after surgery.[5] Yang et al.[10] once placed a 26-Fr tube upward to the apex of the thoracic cavity through an incision at the fourth or fifth anterior axillary incision which might be suitable for drainage of air. However, they found that this may not have been favorable for the drainage of exudate and an additional 8-Fr pigtail catheter was inserted through the seventh intercostal space of the posterior axillary line. In our study, a relatively thicker 12-Fr pigtail catheter with several pores was placed alone upward to the apex of the thoracic cavity without any other conventional chest tube. Moreover, a stapler with specific nail height was applied according to the thickness of lung tissues. Furthermore, at the end of surgery, a saline submersion test was carried out to resolve continuous bleeding as well as air leakage in time. In our study, a similarly low incidence of subcutaneous emphysema was observed in both groups, which may be attributed to the placement of pigtail catheter upward to the apex of the thoracic cavity and the specific application of low-height stapler. The two patients suffering from subcutaneous emphysema in group A were both cured just through intermittently negative pressure suction from pigtail catheter, while one patient in group B received extra thoracic drainage from a 14G catheter (B. Braun Melsungen AG) punctured at the second intercostal space in the midclavicular line, for the reason of obstruction in original chest tube. In this study, five patients in group A and two patients in group B with a large amount of pleural effusion were diagnosed by ultrasound and a 14G catheter (B. Braun Melsungen AG) was placed under ultrasound guidance, usually at the subscapular angular line. The drainage fluid in all patients was pale yellow and transparent, and no red blood fluid was detected. This extra chest tube was routinely applied for adequate drainage for 1 day and removed on the next day. There is no significant difference between the two groups in postoperative pleural effusion which requires additional drainage, though patients with pigtail catheter tend to have a higher risk. These postoperative complications were all less than, or equal to, grade IIIa according to the Clavien-Dindo classification, and there were no grade IV or grade V patients. We supposed that a relatively thick catheter (12-Fr) with several side ports and our specially resection of certain lung tissues with high-height stapler may contribute to this result. Furthermore, some studies reported that a single chest tube inserted through the incision may not be favorable for the drainage of blood, even if using the conventional 26-Fr chest tube.[10] Maezawa et al.[25] demonstrated that an 8 Fr pigtail catheter may achieve a similar effect in treating traumatic hemothorax when compared to a 20 Fr chest tube. In this study, postoperative persistent bleeding in the chest was not encountered in any patient, and we plan to observe the drainage effect of a 12-Fr pigtail catheter in case of postoperative bleeding in further studies. In addition, we have prepared a set of protocols if chest tube drainage is found to be bright red, including monitoring blood pressure, heart rate and other vital signs, and dynamic examination of both hematocrit and hemoglobin. The thoracic drainage fluid would be compared to the patient's peripheral blood and ultrasound might be used to determine whether there was postoperative intrathoracic bleeding. If this condition was suspected, timely open exploration and other active management measures would be applied to ensure the patient's clinical prognosis.

Some studies have demonstrated that thoracic surgery may impair respiratory mechanics as well as gas exchange, which might impede the recovery of patients.[26,27] In this study, spirometry results and arterial blood gas analysis were assessed to evaluate postoperative pulmonary function before the pigtail catheter or conventional chest tube was removed. There was no significant difference in FVC and FEV1 between the two groups on either POD1 or POD2. Arterial blood gas analysis exhibited normal ranges of PaCO2 in two groups and there was no significant difference between them. PaO2 might have had a lower reference value because it depends on oxygen support to some degree. Moreover, other major complications such as pneumonia and pulmonary embolism were also comparable between the two groups, and there was no significant difference in duration of chest drainage or postoperative stay. In addition, we used to find patients paying high attention to their incisions, and the subjective satisfaction of patients with the incision greatly influenced their evaluations with the recovery. Incision healing after uniportal VATS could be affected by various of conditions.[21,22] However, few studies have reported effective methods to evaluate incision satisfaction after uniportal VATS lobectomy. In this study, we creatively designed a subjective satisfaction scale that covered the top five concerns of patients about incision, including degree of pain during the removal of the chest tube, wound complication or other causes impeding incision recovery, influence on upper limb movement on the surgical side, incision's impact on quality of life and degree of chronic pain for the incision. At last, there was a trend of higher subjective

satisfaction score in patients with pigtail catheter than those with conventional chest tube placement, while the difference was not statistically significant. The result showed a comparable great subjective satisfaction about the uniportal VATS incision in both groups, which urged further studies with a large number of samples to confirm.

In conclusion, placing a 12-Fr pigtail catheter next to the uniportal wound at the same intercostal space could provide better wound healing, comparable intrathoracic drainage effect and pulmonary function, and lower postoperative pain level at coughing than inserting a conventional chest tube through the incision itself. We demonstrated that the 12-Fr pigtail catheter alone might be considered as a safe and effective approach for postoperative drainage after uniportal VATS lobectomy and extended lymphadenectomy.

Patients' satisfaction about incision and chest tube were evaluated at 6 months after surgery in our study. However, patients' life quality after 6 months as well as scar assessment of incision were not mentioned, which could cause insufficient evidence to reflect patients' subjective feeling. In the meantime preparations are now underway for a new randomized controlled trial (RCT) to compare the safety and efficacy between 12-Fr pigtail catheter placed next to the uniportal wound and conventional chest tube inserted through the incision.

AUTHOR CONTRIBUTIONS

Conceptualization, Yang Xu; methodology, Jing Luo; software, Yang Xu; validation, Yi Shen, Wei Wei and Zhi-Sheng Jiang; formal analysis, Wei Wei; investigation, Zhuang-Zhuang Cong; resources, Yi Shen, Wei Wei; data curation, Hai-Rong Huang; writing—original draft preparation, Yang Xu, Qi-Yue Ge; writing—review and editing, Yang Xu; visualization, Jing Luo; supervision, Yi Shen; project administration, Zhuang-Zhuang Cong; funding acquisition, Zhuang-Zhuang Cong and Yi Shen. All authors have read and agreed to the published version of the manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare that there are no conflicts of interest.

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