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ORIGINAL ARTICLE

Needlescopic-assisted thoracoscopic pulmonary anatomical lobectomy and segmentectomy for lung cancer: a bridge between multiportal and uniportal thoracoscopic surgery

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Abstract

Purpose Needlescopic instruments allow us to perform complex laparoscopic procedures, which are almost painless and scarless postoperatively; however, their utilization in thoracoscopic surgery has been limited to minor procedures, including bullectomy and sympathectomy. We present our initial experience of performing thoracoscopic anatomical lung resection via a single utility incision with additional needlescopic working ports and compare the operative results with those of uniportal video-assisted thorascopic surgery (VATS).

Methods We reviewed data on 75 consecutive patients with lung cancer, who underwent anatomical lung resections, including lobectomy and segmentectomy, between February 2015 and September 2017. Of the 75 patients, 39 underwent uniportal VATS (uniportal group), and 36 underwent needlescopic-assisted VATS (n-VATS group). We compared the peri- and postoperative outcomes of the two groups.

Results The clinical characteristics did not differ significantly between the groups, except in the ages of the patients. The n-VATS group had a shorter operation time (mean 159.3 min vs. 198.8 min, $P=0.023$) and lower intraoperative blood loss (mean 40.9 mL vs. 143.2 mL, $P=0.047$). Two major pulmonary arterial bleeding events and one conversion to thoracotomy occurred in the uniportal group.

Conclusion Uniportal VATS can be performed more efficiently and safely with the assistance of additional needlescopic ports and instruments, without compromising the benefits of less postoperative pain and early recovery.

Keywords Needlescopic · Uniportal · Anatomical resection · Lung cancer

Introduction

Anatomical pulmonary resection is the standard surgical treatment for lung cancer, including lobectomy and segmentectomy [1, 2]. Although technically demanding, anatomical lung resections can be performed thoracoscopically via three to four thoracic incisions in most institutions. In recent years, the promotion of uniportal video-assisted thoracoscopic surgery (VATS) has greatly changed the preferences of many thoracic surgeons when they undertake anatomical lung resections [3, 4]. The potential advantages of uniportal VATS include a lower risk of intercostal neuralgia, better cosmesis, and a direct surgical view [5, 6]. While on-line videos and hands-on wet laboratory courses offer advice and highlight ways to master uniportal VATS techniques to ensure that the entire procedure can be done using a single incision [7, 8], there is still some reluctance about introducing surgical assistance to the uniportal VATS system, because inserting additional instruments through the same intercostal incision could disrupt the operator and the person controlling the camera. Needlescopic instruments with diameters of 2–3 mm have been used commonly as adjuncts to traditional laparoscopy or single-port laparoscopic surgery (SILS) [9, 10], and may reduce postoperative pain, minimize scarring, and promote rapid recovery [11]. Needlescopic-assisted thoracoscopic surgery has been available since the early 2000s [12], but it has been limited to minor procedures,

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such as sympathectomy for palmar hyperhidrosis and simple lung wedge resections [12–14].

After practicing conventional uniportal VATS for 1 year, we started incorporating additional needlescopic ports and instruments into our uniportal VATS system to provide better surgical assistance and cooperation, anticipating that the favorable postoperative outcomes associated with uniportal VATS would be retained. We describe the techniques involved in this variant approach to uniportal VATS, and compare the safety and the short-term results of pulmonary anatomical resections using conventional uniportal VATS with those using needlescopic-assisted VATS.

Methods

Study design and patients

We began performing uniportal VATS for anatomical lobectomy and segmentectomy for lung cancer in 2015. In December 2016, we introduced the needlescopic-assisted VATS program, using additional needlescopic instruments to assist the uniportal VATS surgeons when they performed anatomic lung resections. We analyzed data from patients who underwent anatomical lung resections using a single utility incision with additional needlescopic ports (n-VATS group) between December 2016 and September 2017. The control group comprised patients who underwent standard uniportal VATS for anatomical lung resections between February 2015 and December 2016 (uniportal group). All of the procedures were performed by one thoracic surgical team that used the same clinical protocols, care patterns, and perioperative orders. The study was approved by the research ethics committee at the National Taiwan University Hospital, Hsin-Chu Branch, Hsin-Chu City, Taiwan (Approval number: 106-032-E).

Surgical techniques

Standard uniportal VATS

The operating room standard set-up consisted of two monitors: one positioned in front of the patient and one, behind. The uniportal surgeon and the camera were positioned on the patient's ventral side. A 10-mm, 30° angled high definition video-thoracoscope was used for all of the operations. Regular double-hinged VATS and minimally invasive surgical instruments (Scanlan® International, Inc., Saint Paul, Minnesota, USA) were used. In most cases, a 3–4 cm incision was made in the fifth or sixth intercostal space on the anterior axillary line, which gave good access to the hilar structure and mediastinal lymph nodes. A lung grasper with a ratchet was used to retract the lung and provide better exposure. To dissect the hilar area, we used an angled-hook electrocautery and energy device. A curved long suction device was used for countertraction and blunt dissections. Curved or angled double-hinged dissectors were used to loop the pulmonary vessels and bronchus, and a flexible endoscopic stapler was used to divide the vessels and the bronchus. The resected lung segment was removed through the incision in a retrieval bag. For patients with primary lung cancer, staging mediastinal lymph node dissections were performed. After the operation, a chest tube (28 F) was placed through the lowest incision.

Needlescopic-assisted uniportal VATS

The uniportal surgeon and the camera-operator were positioned on the patient's ventral side and the needlescopic assistant was positioned on the patient's dorsal side (Fig. 1a). Once the uniportal system was set up, two additional needlescopic ports were created for the needlescopic instruments (Minilaparoscopy®; Karl Storz SE & Co. KG, Tuttlingen, Germany or BJ needle®, Niti-On Co., Chiba, Japan) (Fig. 1b). A simple wedge resection for pathological analyses can be performed easily using the needlescopic graspers before the anatomical resection proceeds (Fig. 2a). The anatomical resections usually began with dissections around the hilar area to expose the vascular structures. Adequate exposure of the hilar area was achieved with the instrument that was inserted through the uniport. A double-hinged curved dissector could also be used to separate the hilar vessels and the surrounding tissues and perivascular sheath. The sheath and lung tissue were opened using hook electrocautery

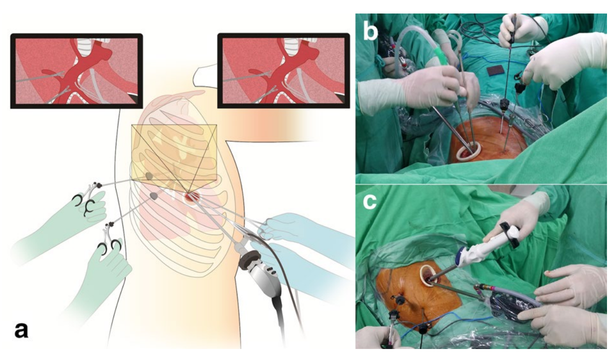

Fig. 1 Surgical set up for needlescopic-assisted uniportal video-assisted thoracoscopic surgery (VATS): **a** the uniportal surgeon (blue) and the camera-operator were positioned on the ventral side, and the needlescopic assistant (green) was positioned on the dorsal side of the patient, **b** Needlescopic instruments (Minilaparoscopy®; Karl Storz SE & Co. KG, Tuttlingen, Germany or BJ Needle®, Niti-On Co., Chiba, Japan) were used through additional needlescopic ports to perform the uniportal surgery, **c** the needlescopic instruments can guide the endostapler without involving the instruments from the utility incision, apart from the thoracoscope

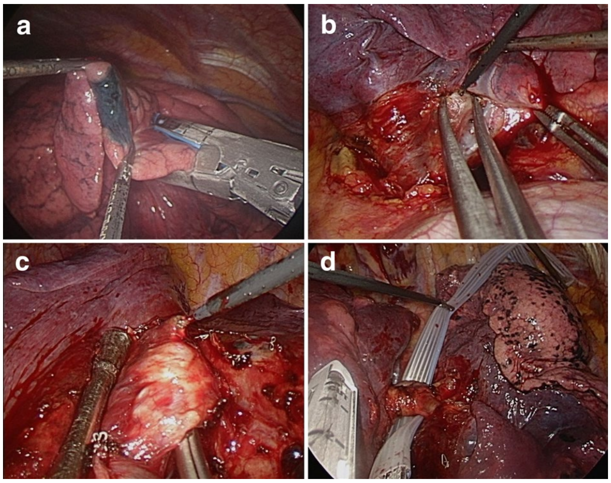

Fig. 2 Modified techniques for uniportal video-assisted thoracoscopic surgery under needlescopic assistance: **a** wedge resection of the dye-localized lesion, **b** opening the sheath and lung tissue using a uniportal curved dissector and needlescopic hook electrocautery, **c** opening the peribronchial sheath with needlescopic electrocautery when performing segmentectomy, **d** a Penrose drainage tube was pulled through to guide the passage of the endostapler safely through the pulmonary vessel

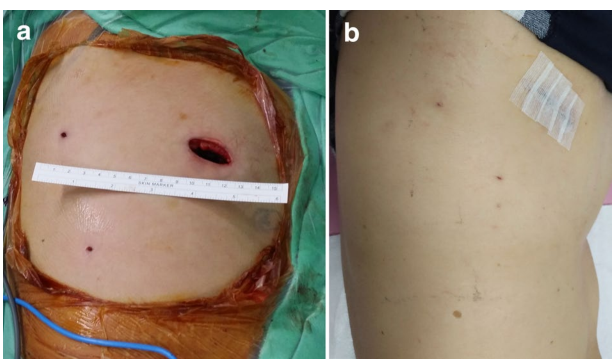

Fig. 3 Appearance of the needlescopic wounds: **a** before wound closure. **b** Only a pinhole-like scar remained at the puncture site 2 weeks after surgery

with countertraction provided by a needlescopic grasper and a two-handed surgical maneuver (Fig. 2b, c). With the assistance of the needlescopic instruments, a Penrose drainage tube could be pulled through to guide the anvil of the endostapler and ensure its safe passage through the pulmonary vessels and bronchus (Fig. 2d). Usually, this critical step could be performed without using the instruments from the utility incision; hence, only the endostapler and camera remained (Fig. 1c). When the operation was completed, the needlescopic puncture site was closed with one simple stitch or a topical skin adhesive (Fig. 3a), and only a pinhole-like scar remained at the puncture site 2 weeks after surgery (Fig. 3b).

Postoperative care

In general, the same protocol was used to manage both groups postoperatively. Postoperative patient-controlled analgesia comprised intravenous morphine (1 mg/mL). Additional analgesics, including oral nonsteroidal analgesic agents and acetaminophen, were administered once the patients had resumed oral intake 2–4 h after the operation. Chest radiography was performed either immediately after the operation or the following morning. The chest tube was removed in both groups if there were no air leaks and the drainage was < 200 mL within a 24 h period. All postoperative complications were recorded. Prolonged air leaks were defined as those that lasted for > 5 days. Major pulmonary artery (PA) bleeding was defined as PA bleeding episodes with an estimated blood loss of > 500 mL, which usually required direct surgical repair.

Outcome variables and data analysis

Data on the patients' demographics, hospital stay, chest drainage duration, complications, and surgical results were collected from the institution's database, surgical notes, and medical and nursing records. The postoperative pain intensity was evaluated using a visual analog scale, on which 0 represented no pain and 10 represented intractable pain [15]. All of the continuous variables are presented as means and standard deviations (SDs). The demographic and clinical data from the different surgical groups were compared using an independent *t* test or Fisher's exact test, as appropriate. Wilcoxon rank-sum tests were applied to the non-normally distributed continuous variables.

Results

We reviewed the data from 75 patients with lung cancer, who underwent anatomical lung resections, including lobectomy and segmentectomy, between February 2015 and September 2017. Of these patients, 39 underwent uniportal VATS (uniportal group) and 36 underwent needlescopic-assisted VATS (n-VATS group). Table 1 summarizes the patients' demographic data and baseline characteristics. The patients in the uniportal group were significantly older than those in the n-VATS group (60.9 ± 11.3 years vs. 54.4 ± 13.2 years; $P = 0.025$), which might reflect the fact that younger patients in the later period of our cohort received computed tomography screening for lung cancer. The groups were comparable with regard to other demographic data, including sex, mean body mass index, comorbidities, and preoperative lung function. Primary lung cancer was the most common indication for pulmonary anatomical resection in the uniportal (97.4%) and n-VATS (94.4%) groups. There were no significant

Table 1 Patient demographics and baseline characteristics

	Uniportal (*n* = 39)	n-VATS (*n* = 36)	*P*
Age, years	60.9 ± 11.3	54.4 ± 13.2	0.025
Sex (female)	30 (76.9%)	23 (63.9%)	0.215
Height, cm	158.1 ± 8.1	159.9 ± 7.5	0.321
Weight, kg	58.8 ± 8.9	62.6 ± 9.7	0.081
BMI, kg/m^2	23.4 ± 3.0	24.4 ± 3.3	0.182
Smoking	4 (10.3%)	7 (19.4%)	0.289
Comorbidity			
Extrathoracic malignancy	4 (10.3%)	7 (19.4%)	0.289
Hypertension	10 (25.6%)	8 (22.2%)	0.556
Diabetes mellitus	3 (7.7%)	4 (11.1%)	0.497
Cardiac diseases	2 (5.1%)	4 (11.1%)	0.354
FVC (% of prediction)	104.9 ± 15.8	104.1 ± 17.8	0.847
$FEV_{1.0}$ (% of prediction)	103.8 ± 22.4	102.7 ± 18.2	0.820
Nodule size, cm	1.5 ± 0.8	1.5 ± 1.0	0.854
Tumor location (lobe)			0.338
Right upper	13 (33.3%)	15 (41.7%)	
Right middle	6 (15.4%)	2 (5.6%)	
Right lower	5 (12.8%)	4 (11.1%)	
Left upper	8 (20.5%)	12 (33.3%)	
Left lower	7 (17.9%)	3 (8.3%)	
Pathology			0.508
Primary lung cancer	38 (97.4%)	34 (94.4%)	
Metastatic lung tumor	1 (2.6%)	2 (5.6%)	

BMI body mass index, *FVC* functional vital capacity, *$FEV_{1.0}$* forced expiratory volume in 1 s

differences between the groups in tumor size, lesion distribution, or final pathology.

Table 2 presents the operative results. The mean (± SD) operation time in the uniportal group was significantly longer than that in the n-VATS group (198.8 ± 86.8 min vs. 159.3 ± 55.4 min; $P = 0.023$), and the mean (± SD) intraoperative blood loss was significantly lower in the n-uniportal group (40.9 ± 56.7 mL) than that in the uniportal group (143.2 ± 298.1 mL; $P = 0.047$). Major PA bleeding occurred in two patients from the uniportal group, requiring conversion to open thoracotomy to control bleeding in one. There was no perioperative mortality. The uniportal and n-VATS groups were comparable with respect to the mean numbers of dissected N1 (3.9 ± 3.8 vs. 4.7 ± 5.2; $P = 0.442$) and N2 (9.9 ± 7.7 vs. 8.0 ± 5.8; $P = 0.257$) lymph nodes. Three patients (7.7%) in the uniportal group and one patient (2.8%) in the n-VATS group had prolonged air leaks. There were no differences between the uniportal and n-VATS groups in mean postoperative intensive care unit stay (1.5 ± 2.0 days vs. 1.1 ± 2.0 days; $P = 0.328$), mean hospital stay (7.1 ± 3.2 days vs. 6.5 ± 2.2 days; $P = 0.342$), or the mean duration of an indwelling chest drainage tube (5.6 ± 2.8 days vs. 5.0 ± 1.8 days; $P = 0.271$). Although two additional wounds were created for the needlescopic instruments, the patients in the two groups reported comparable pain levels on postoperative days 1, 3, and 5, and on the day of discharge.

Table 2 Operative results

	Uniportal (*n* = 39)	n-VATS (*n* = 36)	*P*
Operation time (min)	198.8 ± 86.8	159.3 ± 55.4	0.023
Blood loss (ml)	143.2 ± 298.1	40.9 ± 56.7	0.047
Major PA bleeding	2 (5.1%)	0 (0.0%)	
Conversion to thoracotomy	1 (2.5%)	0 (0%)	
Total lymph nodes dissected (No.)	13.9 ± 9.2	12.2 ± 9.0	0.448
N1	3.9 ± 3.8	4.7 ± 5.2	0.442
N2	9.9 ± 7.7	8.0 ± 5.8	0.257
Prolonged air leak	3 (7.7%)	1 (2.8%)	0.379
Postoperative chest drainage (day)	5.6 ± 2.8	5.0 ± 1.8	0.271
Postoperative ICU stay (day)	1.5 ± 2.0	1.1 ± 2.0	0.328
Postoperative hospital stay (day)	7.1 ± 3.2	6.5 ± 2.2	0.342
Postoperative pain scale score			
POD 1	1.8 ± 1.3	1.9 ± 1.1	0.736
POD 3	2.3 ± 1.1	2.6 ± 0.6	0.132
POD 5	1.7 ± 1.2	1.7 ± 0.9	0.974
Discharge day	2.0 ± 1.0	2.0 ± 0.6	0.891

PA pulmonary artery, *ICU* intensive care unit, *POD* postoperative day

There were 72 patients with primary lung cancer in our series: 36 (94.7%) in the uniportal group and 30 (88.2%) in the n-VATS group had adenocarcinomas. Table 3 shows the pathological tumor types and tumor stage distributions in the two groups.

Table 3 Pathology results of the primary lung cancer

	Uniportal (*n* = 39)	n-VATS (*n* = 36)
Primary lung cancer	38	34
Pathology		
Adenocarcinoma	36 (94.7%)	30 (88.2%)
Squamous cell carcinoma	2 (5.2%)	1 (2.9%)
Carcinoid tumor	0 (0.0%)	2 (5.8%)
Sarcomatoid carcinoma	0 (0.0%)	1 (2.9%)
Staging		
IA	29	23
IB	6	4
IIA	1	3
IIB	0	1
IIIA	2	2

Discussion

Debate continues about whether the term “single-incision VATS” is more accurate than “uniportal VATS”, because the word “port” is synonymous with “trocar”, which is not used in the context of uniportal VATS [16]. However, the term “uniportal” has prevailed in descriptions of the same approach featuring the same access point for optics and instruments, and provides a direct surgical view that preserves the depth and three-dimensions of the intraoperative visualization [17]. Conventional three-port VATS consists of a “baseball diamond” configuration with the camera inserted into the lower port and the instruments for both hands inserted through the anterior and posterior ports. Needlescopic VATS was previously described as a variant of three-port VATS, which uses 3-mm needlescopic instruments, a scope replacing the original 10-mm camera port and posterior port, and a technique similar to that of traditional three-port VATS, but with a more restricted visual field and lower level of brightness [18]. Our technique differs from the general concept of three-port VATS and its variants and comprises uniportal VATS with its unique geometric and ergonomic appeal, coupled with the assistance of two needlescopic instruments via additional needlescopic trocar ports.

Initially, needlescopic surgery was not widely adopted for common laparoscopic procedures, because the strength and durability of the instruments could limit tissue manipulation [11]. After refinement over several years, a 3-mm needlescopic grasper can now be used to manipulate a variety of intraabdominal organs, including inflamed or thickened gallbladder walls, because of improvements in the instrument’s rigidity and the well-designed fenestrated jaw. The new generation of 2-mm instruments (BJ needle®, Niti-On Co.) also permits more secure grasping with less bending of the shafts than previous 2-mm instruments [19]. However, consideration must be given to the increased risk of tissue damage associated with the use of needlescopic graspers with such fine tips, especially when manipulating vulnerable lung tissue. During hilar dissections, we prefer to grasp the hilar sheath instead of directly grasping the lung parenchyma or a lymph node. Otherwise, using the needlescopic graspers to hold peanut gauze that gently moves the parenchyma through friction on the visceral pleura may be a better method for manipulating lung tissue.

In our set up, the assistant who uses the needlescopic instruments usually sees the same images as the uniportal surgeon (Fig. 1a); however, when the operating field is moved to perform procedures on the lower lobe and the subcarinal nodal dissections, the “mirror image” can become problematic for the assistant [20, 21]. Therefore, we sometimes use an image converter, as described in similar laparoscopic surgery settings [22, 23], to reverse the mirror image on the assistant’s monitor (Fig. 4).

The findings from studies of uniportal/single-incision VATS show the superiority of this technique for reducing postoperative pain and paresthesia over conventional multiportal VATS for lobectomies for lung cancers [24, 25] and for surgery to treat pneumothorax [26, 27]. In these series, 5-mm instruments were the thinnest used in the multiport system; therefore, the use of needlescopic instruments in a multiport system needs to be compared with their use in a uniportal system. Our series is the first to compare needlescopic-assisted thoracoscopic surgery with uniportal thoracoscopic surgery. The postoperative pain scores in our study groups were comparable and lower than the average scores reported from previous investigations on uniportal surgery [3]. The findings of a randomized trial demonstrated that preemptive local anesthesia can reduce the postoperative wound pain associated with needlescopic VATS [28], but this was not administered to our patients.

Specific training for uniportal VATS has been highlighted to ensure safety and maintain the radical nature of the treatment [29]. Thoracic surgeons generally begin with conventional multiportal VATS, then progress to two-port VATS, and eventually, to uniportal VATS, with enough practice incorporated to accommodate a stepwise progression in technical expertise. Some experts suggest changing from open surgery to uniportal VATS directly after the specialized training course, which includes tips and tricks for uniportal VATS; however, not many of these techniques can be acquired confidently by inexperienced surgeons. To address

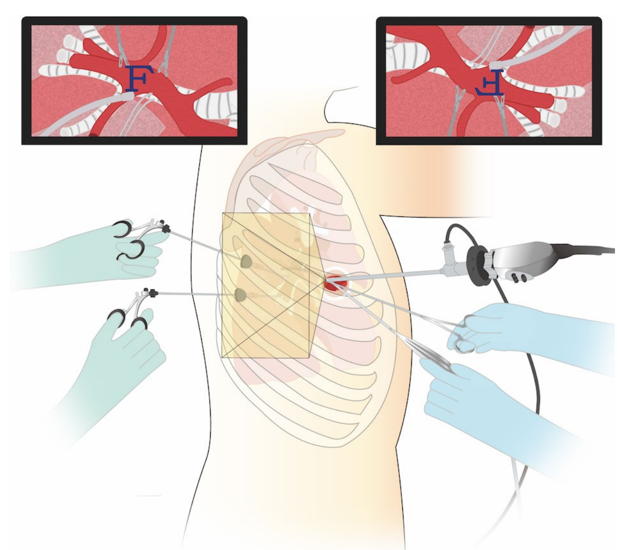

Fig. 4 An image converter produces reversed mirror images on the assistant’s monitor to overcome the “mirror image” issue when operating on the lower field of the thorax

this, needlescopic assistance could be used as a bridging technique for surgeons who are undergoing training in uniportal VATS because more assistance is available when it is needed, which minimizes the surgeons' levels of stress. In some situations, surgeons can use an assistant's needlescopic instruments as a grasper in the left hand; for example, when performing exposure and countertraction during the hilar dissection and when pulling the drainage tube to guide the endostapler. This is especially so when the assistant is not familiar with the procedure and tissue manipulation or when the surgeon is still learning how to perform uniportal VATS. In addition to helping overcome the learning curve, needlescopic assistance could expand the indications for uniportal VATS, as it did for SILS [19].

We acknowledge that this was a retrospective study and that the comparisons were based on historical control operations. The improved operative outcomes of the n-VATS group could be attributed to the learning curve of our surgical team, especially in relation to the operation time. However, our results suggest that uniportal VATS can be performed more efficiently and safely with additional needlescopic assistance for lung cancer surgery. Further prospective research that incorporates a randomized design is needed to rigorously test this treatment strategy.

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Compliance with ethical standards

Conflict of interest Drs. Huan-Jang Ko, Xu-Heng Chiang, Shun-Mao Yang, and Ming-Chi Yang have no conflicts of interest or financial ties to disclose.

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