Needlescopic video-assisted wedge resection combined with the subcostal trans-diaphragmatic approach for undetermined peripheral pulmonary nodules

著者	Oda Makoto, Matsumoto Isao, Takizawa Masaya, Waseda Ryuichi, Suzuki Mitsutaka, Ishiyama Yasuhiro, Abe Takatoshi, Ishikawa Norihiko, Watanabe Go
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Needlescopic video-assisted wedge resection combined with the subcostal trans-diaphragmatic approach for undetermined peripheral pulmonary nodules

Makoto Oda · Isao Matsumoto · Masaya Takizawa · Ryuichi Waseda · Mitsutaka Suzuki · Yasuhiro Ishiyama · Takatoshi Abe · Norihiko Ishikawa · Go Watanabe

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Abstract

Background Reduced mortality from lung cancer by computed tomography (CT) screening facilitates the use of video-assisted thoracic surgery (VATS) lung wedge resection to obtain a definite diagnosis and to treat tiny nodules. The authors evaluated their initial experience using novel needlescopic VATS wedge resection combined with the subcostal trans-diaphragmatic (SCTD) approach for managing undetermined peripheral pulmonary nodules.

Methods Between 2009 and 2012, 35 patients who had 36 operations underwent needlescopic VATS wedge pulmonary resection with the SCTD approach. Preoperative percutaneous CT-guided marking of the nodule was performed. Two 3-mm miniports were placed in the thorax for the thoracoscopic camera and minigrasper. Just anterior to the 10th rib, a 2-cm subcostal incision was made, and a 12- or 15-mm port was placed trans-diaphragmatically into the chest cavity. Wedge resection of the lung was performed with endostaplers introduced through a subcostal port.

Results The median tumor size was 1.1 cm. Localization of the tumor was widely distributed. The mean operation time was 51 min, and the mean blood loss was 4.2 mL. No patients required conversion to thoracotomy, and one patient required conversion to conventional VATS. Additional thoracic ports were placed in five patients, and the needlescopic incision was extended to 15 mm in one patient. The median duration of chest drainage was 1 day. Additional analgesia was not required for 22 patients and was used for less than 1 day for three patients, less than 2 days for seven patients, and less than 3 days for seven patients. The pathologic diagnosis of the nodules was malignant for 28 patients and benign for 8 patients. On postoperative day 7 or at admission, 34 patients were free of postoperative neuralgia.

Conclusions Needlescopic VATS wedge pulmonary resection combined with the SCTD approach is both safe and feasible and offers the specific advantages of minimal invasiveness and good cosmetic outcomes.

Keywords Lung cancer · Minimally invasive surgery · Needlescopic surgery · Subcostal trans-diaphragmatic approach · Video-assisted thoracic surgery · Wedge pulmonary resection

Video-assisted thoracic surgery (VATS) wedge resection has been widely performed for many different lung diseases, including pneumothorax, as well as for undetermined pulmonary nodules. Clear advantages of VATS over open wedge lung cancer resection have been found in terms of both acute clinical outcomes and hospital costs [1]. Furthermore, the National Lung Screening Trial showed that lung screening with the use of low-dose computed tomography (CT) reduces mortality from lung cancer [2] and appears to facilitate the use of VATS lung wedge resection to obtain a definite diagnosis and treat tiny nodules.

The Danish Lung Cancer Study Group also reported that CT screening appears to facilitate the use of VATS in 84 % of lung cancer operations, and in their study, all benign

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M. Oda (✉) · I. Matsumoto · M. Takizawa · R. Waseda · M. Suzuki · Y. Ishiyama · T. Abe · N. Ishikawa · G. Watanabe
Department of General and Cardiothoracic Surgery, Kanazawa University, 13-1 Takaramachi, Kanazawa, Ishikawa 920-8641, Japan
e-mail: odamak@med.kanazawa-u.ac.jp

nodules could be removed by VATS [3]. In these situations, thoracic surgeons desire further less invasive VATS wedge resection.

With the advancement of instruments and techniques for VATS procedures, needlescopic VATS has been performed and shows better cosmetic results as well as less postoperative neuralgia than conventional VATS for primary spontaneous pneumothorax [4–6] and peripheral lung nodules [7]. In these procedures, ports 10 mm or larger require the use of endostaplers and larger instruments through the intercostal space for lung resection. Also, extension of the skin incision and intercostal space is sometimes required to remove resected bulky tissue from the thoracic cavity. Therefore, some degree of intercostal nerve damage still is inevitable, even in needlescopic VATS wedge pulmonary resection via the intercostal space.

Ninan and Dylewski [8] reported port-access robot-assisted pulmonary lobectomy without utility thoracotomy combined with the subcostal trans-diaphragmatic (SCTD) approach. With this approach, a SCTD incision was made for access to the pleural cavity. The potential advantages of this procedure are no size limits for tumors extracted, ability to maintain carbon dioxide (CO_2) insufflation, and no necessity for insertion of larger instruments through intercostal port sites [8].

To minimize intercostal nerve damage in VATS, we developed needlescopic VATS wedge pulmonary resection combined with the SCTD approach for undetermined pulmonary nodules using two 3-mm intercostal ports for a videoscope and a mini-endograsper and one 15- or 12-mm SCTD port for endostaplers and instruments larger than 3 mm in diameter. We report our initial experience with this novel procedure for managing undetermined peripheral pulmonary nodules.

Materials and methods

Patients

Needlescopic VATS wedge pulmonary resection combined with the SCTD approach began in September 2009 at Kanazawa University Hospital. Between September 2009 and May 2012, 36 operations were performed for 35 patients, who underwent needlescopic VATS wedge pulmonary resection with the SCTD approach at Kanazawa University Hospital for undetermined pulmonary nodules suspected to be primary or metastatic lung cancer. Of the 36 operations, 33 (92 %) were performed between September 2010 and May 2012. The medical records of all patients who underwent needlescopic VATS combined with the SCTD approach were retrospectively reviewed.

The indications for this procedure were pulmonary nodules located in the peripheral one-third of the lung that measured less than 2 cm in diameter and nodules suspected to be primary or metastatic lung cancer that required wedge resection for purposes of diagnosis, treatment, or both. If the nodule was suspected to be primary lung cancer, pure or nearly pure ground glass opacity (GGO) nodules that could be managed by wedge resection as a radical operation were included for this procedure (Fig. 1A). If the nodule suspected to be lung cancer was not a GGO lesion, only high-risk patients who did not tolerate radical pulmonary resection, such as segmental or lobar resection, were included.

Before the operation, all the patients underwent preoperative evaluation with a thoracoabdominal CT scan including a high-resolution image of the primary tumor with or without positron emission tomography and a pulmonary function test.

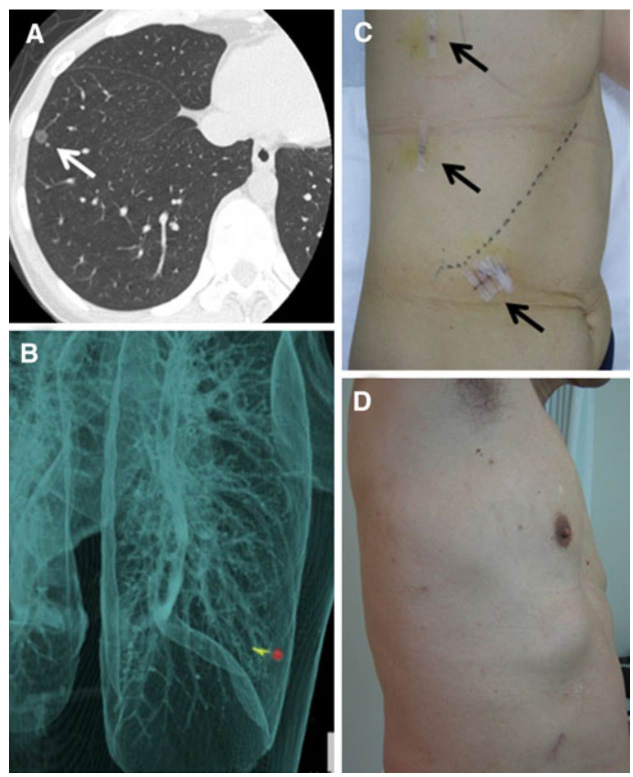

Fig. 1 **A** Preoperative chest computed tomography (CT) scan of a 36-year-old woman showing a tiny ground glass opacity nodule (*arrow*) in S8 of the right lung. **B** Three-dimensional X-ray of a 36-year-old woman after percutaneous pulmonary marking of the nodule under CT guidance. **C** Skin wounds of a 36-year-old woman on postoperative day 7 indicating two 3-mm puncture wounds and one 2-cm subcostal wound. **D** Skin wounds of a 66-year-old man 2 months after the operation. The patient had diffuse pleural adhesions, and three 3-mm ports were placed in addition to the standard ports. It is difficult to identify the five 3-mm puncture wounds on the thorax in this image

Surgical technique

On the same day as the operation, preoperative percutaneous CT-guided marking of the pulmonary nodule was performed with a 21-gauge marking needle (Guiding-Marker System, Hakko, Tokyo, Japan) to achieve nontactile pulmonary wedge resection (Fig. 1B). Patients were positioned in the lateral decubitus position under general anesthesia with single-lung ventilation provided by a double-lumen endotracheal tube combined with epidural anesthesia.

One skin puncture was made, usually on the middle axillary line in the seventh intercostal space. The first 3-mm thoracoport (Endopath 3-mm Access Needle; Ethicon Endo-Surgery, Cincinnati, OH, USA) was placed, and a 3-mm high-definition videothoracoscope was inserted through the port (Fig. 2A; Video 1).

Just anterior to the 10th rib, a 2-cm subcostal skin incision was made. The diaphragm was reached by blunt dissection, and a 15-mm port (Versaport Plus Bladeless 15-mm-Long Trocar; Covidien, Mansfield, MA, USA, or VersaStep Plus Standard 15 mm; Covidien) for the first 19 patients or a 12-mm port (Endopath XCEL Bladeless Trocar, Ethicon Endo-Surgery; or Versaport Plus Bladeless 12-mm-Long Trocar, Covidien; or VersaStep Plus Standard 12 mm; Covidien) for the final 17 patients was placed trans-diaphragmatically into the chest cavity under visualization by the videothoracoscope inserted through the intercostal 3-mm port (Fig. 2B).

The second 3-mm thoracoport for the 3-mm needlescopic instruments (Olympus, Tokyo, Japan) was placed in the appropriate intercostal space, depending on the tumor location, to grasp the lung securely for wedge resection of the lung (Fig. 1C). Insufflation of CO_2 (pressure, 8 mmHg; flow, 10 L/min) introduced through a subcostal port was maintained until the lung was well deflated (Video 2).

Wedge resection of the lung was performed with an endostapler introduced through a subcostal port targeting the marking needle placed preoperatively (Fig. 2C; Video 3). The resected lung was inserted into a removal bag and withdrawn trans-diaphragmatically through the subcostal incision (Video 4). The sample was split open in the operating room to ensure the presence of the entire nodule and the metallic coil and then was sent to a pathologic laboratory for immediate analysis and confirmation of a safe resection margin.

After hemostasis was secured and no air leakage from the lung was ensured, a 5-mm flexible polyurethane multichannel drain (Nippon Sherwood, Tokyo, Japan) or a 19-Fr Blake drain was inserted through the subcostal incision (Video 4). The drains were placed to the water seal. The punctured skin incisions for the 3-mm ports were closed only with skin tape (Steri-Strip Skin Closures, 3M, Tokyo, Japan). For the subcostal skin incision, the diaphragm was not closed, and the subcutaneous muscle was closed with two or three stitches (Video 4). After the subcuticular suture, the skin was closed with skin tape (Fig. 1C).

Postoperative care

Epidural anesthesia was used for 3 days after the operation. Oral nonsteroidal analgesics were routinely administered

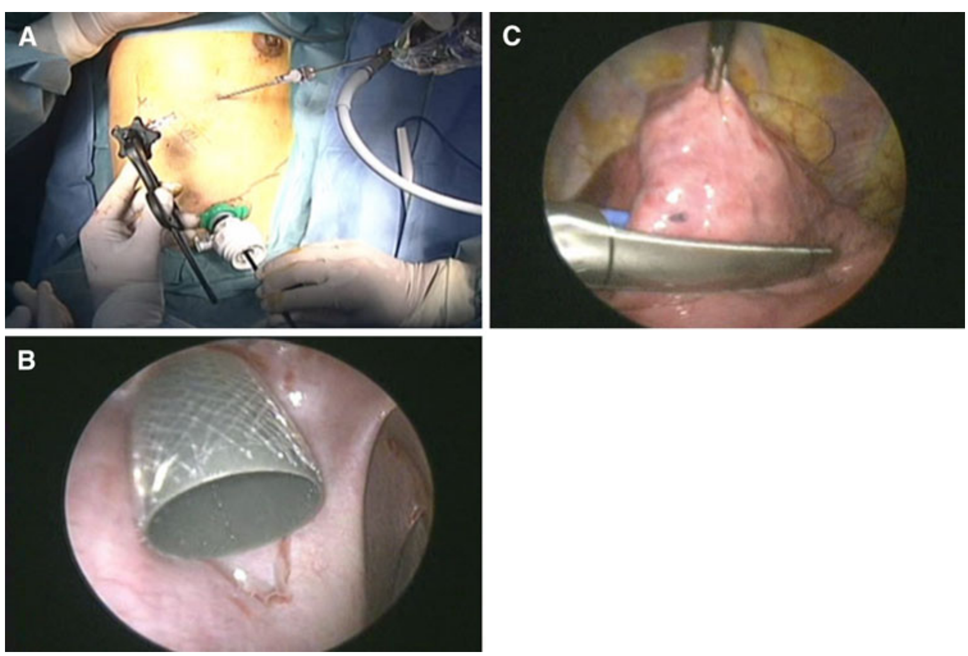

Fig. 2 **A** Standard positioning of three ports, including two 3-mm ports and one 12- or 15-mm port in needlescopic video-assisted wedge resection combined with the subcostal trans-diaphragmatic approach. **B** Trans-diaphragmatic 12-mm port placement viewed under a videothoracoscope inserted through a 3-mm intercostal port. **C** Inside view of a wedge pulmonary resection performed using long staplers introduced through a 12-mm subcostal port

until patients were discharged. A chest roentgenogram was taken immediately after the operation in the operating room and every day until 1 day after removal of the 5-mm multichannel drain or the 19-Fr Blake drain. The drain was removed if no air leaks were present and if drainage was not bloody and chylous, without consideration for the volume of the effusion. An air leak was defined as prolonged when it lasted longer than 5 days. All postoperative complications were recorded.

Results

Between September 2009 and May 2012, 35 patients underwent 36 operations for needlescopic VATS wedge pulmonary resection combined with the SCTD approach for undetermined pulmonary nodules. Table 1 summarizes the patient characteristics. There were 16 men (44.4 %) with a median age of 62.5 years. The suspected preoperative diagnosis was lung cancer for 29 patients (80.6 %) and metastatic lung cancer for 7 patients (19.4 %). The median tumor size was 1.1 cm.

Localization of the resected tumor was widely distributed. In bilateral sides, S7 and S10 nodules were not included. Preoperative pulmonary function test results are listed in Table 1.

Table 2 summarizes the intra- and postoperative characteristics. The mean operation time was 51 min, and the mean blood loss was 4.2 mL with no blood loss after the first patient. None of the patients required conversion to a thoracotomy, and one patient required conversion to a conventional VATS. Only the first patient who underwent this procedure had a blood loss of 150 mL from the staple line just after pulmonary resection using an endostapler under insufficient deflation of the lung. This patient was converted to conventional VATS, with two 3-mm ports exchanged for 5.5- and 12-mm ports. Additional thoracic ports were placed in five patients because of lymph node biopsy for one patient with one additional 3-mm port, lymph node biopsy for two patients with one additional 5.5-mm port, better grasping of the lung in one patient with one additional 3-mm port, and diffuse pleural adhesion in one patient with three additional 3-mm ports (Fig. 1D). One needlescopic incision was extended to 15 mm in one patient because of marker needle dislocation requiring manipulation of the nodule.

No mortality and no hospital deaths occurred. Postoperative complications included air leakage prolonged for more than 5 days in one patient and prostatitis requiring a 17-day hospital stay for one patient. No diaphragmatic hernia was observed after the operation. The median duration of postoperative chest drainage was 1 day, and the median postoperative hospital stay was 8 days. Additional analgesia, including occasional pushing of epidural analgesia and use of nonsteroidal suppositories, was not required for 22 patients and was used less than 1 day for three patients, less than 2 days for seven patients, and less than 3 days for seven patients.

The pathologic diagnosis of the nodules was malignancy for 28 patients and other benign lesions for 8 patients. Among 27 primary lung cancer nodules in 23 patients, Noguchi's classification [9] was type A for 16 patients, type B for 3 patients, and type C for 6 patients. Two nodules larger than 2 cm in diameter could not be applied to this classification. On postoperative day 7 or at admission (if admission was earlier than postoperative day 7), 34 patients were free of postoperative neuralgia, and 2 patients had occasional neuralgia.

Table 1 Patient characteristics

Variable	Frequency (n = 36)
Age (years)	62.5 (14–85) 60.3 ± 14.8
Gender (males)	16 (44.4)
Height (cm)	160.5 (147–183) 160.4 ± 9.1
Weight (kg)	57.0 (33–87) 57.2 ± 11.7
Nodule size (cm)	1.1 (0.5–2.5) 1.0 ± 0.6
Nodule location (segment)	
Right S1	4 (11.1)
S2	2 (5.6)
S3	7 (19.4)
S4	2 (5.6)
S6	4 (11.1)
S8	2 (5.6)
S9	2(5.6)
Left S1 + 2	1 (2.8)
S4	2 (5.6)
S5	2 (5.6)
S6	3 (8.3)
S9	5 (13.9)
Suspected preoperative diagnosis	
Primary lung cancer	29 (80.6)
Metastatic lung cancer	7 (19.4)
Pulmonary function test	
FEV1 (L)	2.5 (1.4–4.5) 2.6 ± 0.6
FEV1.0 (%)	76.3 (56.7–95.7) 75.2 ± 9.0
DLCO (%)	81.1 (49.3–121.5) 81.4 ± 16.8

Continuous data are shown as median (range) and mean ± standard deviation, categoric data as number (%)

FEV1 forced expiratory volume in 1 s, *FEV*1.0 % forced expiratory volume % in 1 s; *DLCO* diffusing capacity for carbon monoxide

Discussion

In the current study, needlescopic VATS wedge pulmonary resection combined with the SCTD approach for undetermined peripheral pulmonary nodules was successful. The advantages of this needlescopic operation are less invasiveness, less pain, and better cosmetic outcomes.

We recently performed VATS pulmonary resections using the SCTD approach for various chest diseases. This approach is divided into four categories depending on the skin incisions in the intercostal spaces other than the SCTD port as follows: wedge resection, segmental or lobar resection, robot-assisted lobectomy [10], and hybrid VATS. In our standard SCTD approach, the thoracoports and skin incision in the intercostal spaces comprise two 3-mm miniports in wedge resection, three 5-mm ports in segmental or lobar resection, three robotic ports plus one 5-mm port in robotic lobectomy [10], and a 6- to 8-cm access wound in hybrid VATS.

Several approaches to minimize postoperative pain in VATS have been reported recently, such as complete port-accessed lobectomy by the muscle-sparing method [11], the transcervical approach with one intercostal 5-mm thoracoscopic camera port [12], single-port video-assisted thoracoscopic lobectomy [13], the microthoracoscopic one-port method [14], and uniportal VATS using a single-incision laparoscopic surgery port [15]. However, these procedures are not widely used because of their technical difficulties.

Our procedure has no serious technical disadvantages such as a limited field of vision as in single-port video-assisted thoracoscopic lobectomy [13] or a prolonged operation time as in the transcervical approach with one intercostal 5-mm thoracoscopic camera port [12].

Intrathoracic VATS sometimes requires extension of the wound and intercostal space for extraction of the resected tissue. In our procedure, when the resected tissue is extracted from the thorax out of the body, extension of the wound and intercostal space is not required. The diaphragm is naturally opened when the resected tissue is extracted from the thorax, and no closure of the diaphragm is required. Although diaphragmatic hernia is a possibility with this procedure, we believe that the risk is extremely low because the space between the diaphragm and subcostal incision is very small, and the peritoneal cavity is not usually opened. It is not necessary to enter the abdominal cavity using this approach, and we did not open the peritoneum in any of the patients who recently underwent this procedure. For these reasons, we do not close the diaphragmatic defect.

In advancing toward the diaphragm after the subcostal incision and subcutaneous muscle division, careful dissection of the tissue just posterior to the rib is important to avoid incidental peritoneal opening. No diaphragmatic hernia occurred in more than 70 patients treated via our approach including wedge resection, segmentectomy, and lobectomy of the lung.

Our approach facilitates the handling of an endostapler without interfering with other devices or the camera. To avoid the hip bone and to prevent disturbance of the insertion and handling of the staplers, the patient should be sufficiently bent at the lumbar portion in the lateral decubitus position. Long endostaplers, not usually used in VATS but used in bariatric surgery, were especially useful for managing upper lobe lesions and could easily reach the target lesion. A contraindication to this approach is dense pleural adhesions.

Localization of the resected tumor was widely distributed. Only S7 in the right lung and S10 in the bilateral lungs were not resected. Either S10 or the posterior segment of the lower lobe was apparently the most difficult segment to reach from the subcostal port for the use of staplers. If sufficient lung depression can be achieved, wedge resection of S10 is possible. Although S7 is not difficult to resect, no patients had S7 nodules.

For patients with S7 nodules, we perform needlescopic VATS wedge resection combined with the SCTD approach. Because upper lobe nodules were the most common sites of resection with this procedure, pneumothorax, a common disease in adolescents that frequently contains bullae in the upper lobe, is a good indication for this procedure with minimal invasiveness and cosmetic benefits.

The maximal diameter of the resected nodules in this series was 2.5 cm, and the maximal diameter was 2.9 cm for 17 lobectomy cases. Although we believe that nodules smaller than 5 cm can be safely resected and extracted from the subcostal skin incision, the indication for this procedure currently is limited to nodules smaller than 3 cm.

We managed tiny nodules with our procedure and performed percutaneous CT-guided marking with a 21-gauge marking needle on the same day as the operation to identify the pulmonary nodules. This enabled surgeons to perform nontactile pulmonary resection. Although pneumothorax and pulmonary hemorrhage are known complications that accompany CT-guided marking with a 21-gauge marking needle, arterial embolism, an extremely rare and occasionally fatal complication, also has been reported [16].

In our series, severe complications were not associated with this procedure, and mild pneumothorax occurred during two operations in the same patient. Although we use an angio-CT scanning system in which real-time images can be seen during the procedure, arterial embolism should be carefully avoided.

We acknowledge that this was a retrospective study with no control group for comparison. Furthermore, although

Table 2 Intra- and postoperative characteristics

Variables	
Operating time (min)	45 (26–110) 51 ± 21
Bleeding (mL)	0 (0–150) 4.2 ± 25
Additional ports or thoracic wound extension	
No additional port	29 (80.6)
3-mm × 1	2 (5.6)
3-mm × 3	1 (2.8)
5-mm × 1	2 (5.6)
Wound extension[a]	1 (2.8)
Conversion to conventional VATS[a]	1 (2.8)
Conversion to thoracotomy	0 (0)
Chest drainage (days)	1.0 (1–6) 1.3 ± 1.1
Chest drainage in 1 day	32 (88.9)
Operative and hospital death	0 (0)
Postoperative hospital stay (days)	8 (3–17) 8.3 ± 2.7
Operation complications	
Air leak >5 days	1 (2.8)
Prostatis	1 (2.8)
Wound infection	0 (0)
Nodule size (cm)	1.0 (0.3–3.5) 1.1 ± 0.6
Pathologic diagnoses of nodules	
Primary lung cancer	23 (63.9)
Metastatic lung cancer	4 (11.1)
Primary and metastatic lung cancer	1 (4.3)
Other benign lesions	8 (22.2)
Additional analgesia	
None	22 (61.1)
<l day	3 (13.6)
<2 days	7 (19.4)
<3 days	4 (11.1)
Neuralgia on postoperative day 7[b]	
Pain free	34 (94.5)
Occasional discomfort	2 (5.6)
Occasional use of analgesics other than routine drugs	0 (0)

Continuous data are shown as median (range) and mean ± standard deviation, categoric data as number (%)

VATS video-assisted thoracic surgery

[a] Same patient

[b] If the patient's hospital stay is shorter than 8 days at discharge

perioperative and long-term pain could not be evaluated prospectively on a regular basis, including the visual analog scale, the results from the use of postoperative additional analgesia and postoperative neuralgia on postoperative day 7 appeared to indicate the decreased invasiveness of our approach.

Although the postoperative hospital stay was long in our series, our clinical protocol states that patients are discharged on postoperative day 10 because of the Japanese social health insurance system [17]. This longer hospital stay offers economic benefits to the hospital. Admission fees are not that expensive for patients, and patients tend to want a longer stay in the hospital. The 5-mm multichannel drain or 19-Fr Blake drain was removed from 89 % of the patients on postoperative day 1, and the patients could be discharged on postoperative day 2 or 3.

We conclude that needlescopic VATS wedge pulmonary resection combined with the SCTD approach is a safe and feasible procedure that offers specific advantages with minimal invasiveness and good cosmetic outcomes. We also believe that this operation can be performed safely by a single subcostal skin incision without a thoracic incision or puncture, due to the development of instruments and videoscopes, through a long subcostal port.

Disclosures Makoto Oda, Isao Matsumoto, Masaya Takizawa, Ryuichi Waseda, Mitsutaka Suzuki, Yasuhiro Ishiyama, Takatoshi Abe, Norihiko Ishikawa, and Go Watanabe have no conflicts of interest or financial ties to disclose.

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