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Video-assisted thoracoscopic surgical wedge resection using multiplanar computed tomography reconstruction-fluoroscopy after CT guided microcoil localization

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Abstract

Background: When early-stage lung cancer is diagnosed, the recommended treatment is anatomical resection using video-assisted thoracoscopic surgery (VATS) or robotic lobectomy. However, nonanatomical resection, known as wedge resection (WR), which is performed to diagnose pulmonary nodules, can be problematic for clinicians performing VATS or robotic-assisted thoracic surgery (RATS). The purpose of this study was to evaluate the safety and effectiveness of VATS WR using multiplanar computed tomography reconstruction (CT MPR)-fluoroscopy after CT guided microcoil localization to achieve complete pulmonary nodule resection.
Methods: Between January 2016 to December 2020, the medical records of patients who underwent CT-guided microcoil localization for suspicious malignant pulmonary nodules and VATS WR with CT MPR and intraoperative fluoroscopy were retrospectively reviewed.
Results: All 130 patients successfully underwent CT-guided localization. The success rate of VATS WR with CT MPR-intraoperative fluoroscopy was 98.5%. Mean operation time was 58 min (range 50–84 min). The postoperative complication rate was 3.1%, and no major postoperative complications were reported. The mean postoperative length of hospital stay was 4.7 days (range 4–8 days).
Conclusions: VATS WR using CT MPR-fluoroscopy after CT guided microcoil localization is a safe and highly effective approach for complete pulmonary nodule resection. However, even in uniport VATS or recently performed robotic surgery, localization and resection of nonvisible, nonpalpable pulmonary nodules is a challenging problem. Consequently, satisfactory outcomes can be expected if this technique is used for suspicious malignant pulmonary nodule resection.

KEYWORDS
computed tomography multiplanar reconstruction, fluoroscopy, pulmonary nodule, video-assisted thoracoscopic surgery, wedge resection

INTRODUCTION

The framework for modern video-assisted thoracoscopic surgery (VATS) was established in 1992 by Landreneau et al.[1] after which VATS has been progressively used as a minimally invasive method for thoracic surgery. Compared to conventional VATS, the use of single-port VATS is increasing.[2,3] Additionally, with the increase in technology advancements and innovations, robotic-assisted thoracic surgery (RATS) has been performed as an alternative to VATS in lung cancer surgery.[4–6]

Multiple methods have been developed with VATS to overcome the limitations caused by digital palpation of the lung parenchyma to achieve accurate and efficient pulmonary nodule resection. As a result, a number of pulmonary nodule localization methods have been used. Traditionally, the hook wire has been used by practitioners for computed tomography (CT)-guided localization prior to VATS.[7] However, this approach has disadvantages such as wire dislodgement and pleural pain during and after insertion.[8] Therefore, the hook wire approach has recently been replaced by microcoils for localization.[9,10]

When early-stage lung cancer is diagnosed, the recommended treatment is anatomical resection such as VATS or robotic lobectomy.[11] However, nonanatomical resection, known as wedge resection (WR), which is performed to diagnose pulmonary nodules, can be problematic for VATS or RATS.[12,13]

However, with advances in multidetector CT technology, high-quality multiplanar reconstruction (MPR) images have been provided. MPR images provide computed images from the scanned volume and incorporate spatial resolution. In general, MPR images are helpful for lesions that cannot be accurately evaluated on axial plane images.[14]

Therefore, the purpose of the current study was to evaluate the safety and effectiveness of VATS WR for complete pulmonary nodule resection. The approach utilized CT-guided microcoil localization that was performed first, followed by VATS WR with CT MPR and intraoperative fluoroscopy.

METHODS

Patients

The institutional review board approved this retrospective study. Data was acquired through a retrospective chart review method. The need for written informed consent was waived. Between January 2016 and December 2020, patients with suspicious malignant pulmonary nodules who underwent CT-guided microcoil localization followed by VATS WR with CT MPR-intraoperative fluoroscopy were included.

The inclusion criteria were as follows: ground glass opacity (GGO) nodules, ≤30 mm in maximal pulmonary nodule long-axis diameter, and nodules less than 3 cm from the surface of the lung.

The success rates of CT-guided localization and of VATS WR were assessed. In addition, procedure-related complications, postoperative complications, operation time, and postoperative length of hospital stay were assessed.

VATS WR success was defined as complete excision of the nodule using VATS without conversion to thoracotomy. Operation time was defined as the time required for VATS WR to remove the pulmonary nodule in the operating room, and the time for diagnosis of the frozen section was included in the operation time.

CT-guided localization and multiplanar reconstruction

An intervention radiologist (YG) with 18 years of experience performed CT-guided localization as described in a previous study.[15] Briefly, patients were placed on a CT table in a suitable position (supine, prone, or lateral) to obtain the shortest needle insertion route for initial CT scan. Next, a coaxial needle with a 20-G trocar tip (Medax Medical Devices) was introduced percutaneously into or near the pulmonary nodule. If the needle tip was confirmed at the planned site, the inner stylet of the needle was removed, and the microcoil (MWCE-35-3-4, diameter: 3 mm; 0.018 inch diameter, 30 mm, fiber-coated, stainless steel; Cook) was inserted through the trocar. All CT images were obtained using a 128-detector row CT scanner (Somatom Definition AS+; Siemens Medical Solutions). Follow-up CT was performed to identify the exact location of the microcoil and any procedure-related complications, such as pneumothorax or hemorrhage. The cross-sectional data were reconstructed with 1 mm thickness at 0.5 mm intervals. The thin-section reconstructed images were transferred to a workstation (Aquarius Intuition) and were processed in the sagittal and coronal planes (Figure 1). The MPR of CT images was interfaced to a picture archiving and communications system (PACS-Marosis; Infinitt). After undergoing CT-guided localization, patients were transferred to the operating room for VATS WR.

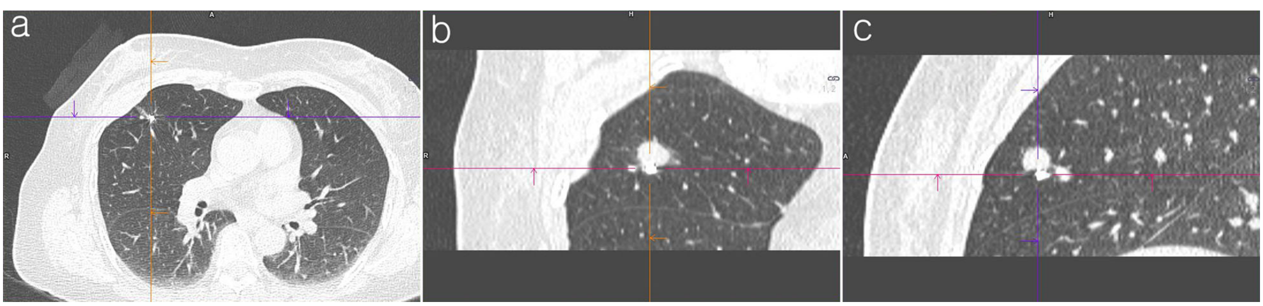

FIGURE 1 Multiplanar CT image reconstruction. A microcoil was inserted beside the target nodule. (a) Axial, (b) coronal, and (c) sagittal reconstructed images

Surgical procedure

One thoracic surgeon (SW) with 16 years of experience performed VATS WR. After evaluation of the MPR of CT images, patients were placed in the lateral decubitus position and were ventilated with a double-lumen endotracheal tube while under general anesthesia, as described in a previous paper.[15] Three-port thoracoscopy was performed using two 5 mm ports and one 12 mm port under intraoperative fluoroscopy (Figure 2).

Statistical analysis

Results are presented as frequencies (percentages) for categorical variables and as mean ± standard deviation with range for continuous variables. Statistical analysis was performed with SPSS software, version 21.0 (IBM Institute).

RESULTS

A total of 130 patients were enrolled in this study consisting of 79 males (60.8%) and 51 females (39.2%). Patient age ranged from 43 to 82 years (mean 63 years). Lung nodules had a mean maximal transverse diameter of 12.0 ± 17.2 mm (range 4.5–29 mm). The mean distance from the pleura to superficial nodule margins was 9.0 ± 13.1 mm (range: 0–28 mm). Patient and nodule characteristics are summarized in Table 1.

The success rate of the CT-guided localization procedure was 100%. The asymptomatic pneumothorax occurred in 32 patients (24.5%), and the pulmonary parenchymal hemorrhage occurred in 30 patients (23.1%). No major microcoil localization-related complications were noted. The success rate of VATS WR was 98.5%. Two patients required conversion to standard thoracotomy due to diffuse pleural adhesion. None of the microcoils were dislodged.

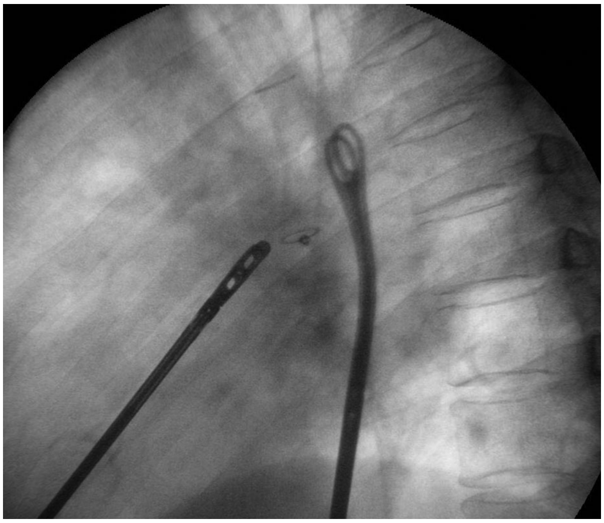

FIGURE 2 Intraoperative fluoroscopy for localization

TABLE 1 Baseline characteristics

Variables	*n* (%)
Mean age (years)	63
Sex	
Male	79 (60.8)
Female	51 (39.2)
Nodule	
Mean size (mm)	12.0 ± 17.2 (range: 4.5–29)
CT findings	
Pure ground-glass opacities (GGO)	23 (17.7)
Part-solid	40 (30.8)
Solid	67 (51.5)
Mean distance (mm)[a]	9.0 ± 13.1 (range: 0–28)
Pathological diagnosis	
Benign	98
Primary lung cancer	9
Adenomatous hyperplasia	2
Adenocarcinoma in situ	6
Adenocarcinoma	1
Metastasis	23

[a]Mean distance is the distance from the pleura surface to the superficial margin of the nodule.

The mean time between coil insertion and surgery was 62.5 min (range 40–130 min), and mean operation time was 58.2 min (range 50–84 min). The diagnostic rate of resected pulmonary nodules was 100%. The postoperative complication rate was 3.1%, comprising three cases of pneumonia and one case of bleeding. Patients with pneumonia recovered with the appropriate antibiotic treatment, and the patient with bleeding was observed and recovered spontaneously. No major postoperative complications were noted. The mean postoperative length of hospital stay was 4.7 days (range 4–8 days) (Table 2).

A summary of the pathological diagnosis of excised specimens was 98 benign, nine lung cancer, and 23 metastatic specimens (seven colon cancer, four lung cancer, three renal cell carcinoma, three breast cancer, two rectal cancer, two hepatocellular carcinoma, one thyroid cancer, and one cervical cancer). Treatment of nine lung cancer patients was discontinued with WR because consent was not received from the patients in advance. Surgical margins of all wedge resection specimens were negative microscopically.

DISCUSSION

In our study, we evaluated the safety and effectiveness of VATS WR using CT MPR-fluoroscopy after CT guided microcoil localization for achieving complete pulmonary nodule removal. The following major findings were

TABLE 2 Computed tomography coil localization and video-assisted thoracoscopic surgery (VATS) wedge resection (WR) results

Variables	*n* (%)
Success of localization	130 (100)
Success of VATS, WR	128 (98.5)
Postprocedure complications	
Pneumothorax	32 (24.5)
Hemorrhage	30 (23.1)
Mean operation time, WR (min)	58 (range: 50–84)
Postoperative complications, WR	4 (3.1)
Mean postoperative length of stay (day)	4.7 (range: 4–8)

identified. (i) The VATS WR success rate was 98.5%, (ii) mean operation time was 58 min, (c) postoperative complication rate was 3.1%, and (d) mean postoperative length of hospital stay was 4.7 days.

Donahoe et al.[9] reported that conventional VATS resection after CT-guided microcoil insertion is a safe and effective procedure for diagnosing and treating malignant pulmonary nodules. In that study, the VATS resection success rate was 93%, the operation time was 68.8 min, and the postoperative complication rate was 8%. In comparison, in our study, the VATS success rate was higher, the operation time was shorter, and the postoperative complication rate was lower. MPR is a post-processing technique for creating new images that can be used as a supplemental approach to axial images for detecting lesions and to optimize surgical planning. Surgeons without basic training in cross-sectional imaging have difficulty evaluating normal anatomical structures and lesions on axial CT images but are more familiar with the anatomy viewed in the coronal plane. Consequently, MPR of CT images can enhance operator confidence.[16] Therefore, the reason for the difference in the study results could be attributable to whether the imposing reconstruction image, such as the coronal plane image, was referenced when the surgical plan was designed.[14]

Since the introduction of uniportal VATS in 2000,[17] uniportal VATS lobectomy, segmentectomy, and pneumonectomy approaches have been reported.[18,19] Uniportal VATS is advantageous because it only involves one intercostal space, so postoperative pain can be reduced, and rapid recovery can be achieved. In a previous study[12] of 46 patients who underwent uniportal VATS WR with intraoperative fluoroscopy, the operation time was 105 min, postoperative complication rate was 8.7%, and mean postoperative length of hospital stay was 4.6 days. A longer operation time and more postoperative complication rates were reported compared with our study. This is probably because anatomic resection was performed mainly with uniportal VATS and was relatively straightforward, but WR, which requires pulmonary nodule resection, has not yet been performed in a large series because of its high degree of difficulty and complex operative techniques.[13,20] Furthermore, CT MPR was not used with the surgical procedures. Therefore, in the future, a prospective study is needed to compare the diagnostic accuracy and therapeutic efficacy of uniportal and convention VATS pulmonary WR.

The robotic Da Vinci surgical system is a relatively new minimally invasive technique in thoracic surgery. Although the disadvantage of the robotic system is the equipment is expensive, it is advantageous due to the three-dimensional high-definition visualization, superior range of motion, and better maneuverability of instruments[5] and has been proposed as an alternative to VATS. Previous studies[5,21] have reported that robotic-assisted thoracoscopy with the Da Vinci surgical system for lobectomy were both feasible and safe. However, most studies[22–24] have previously reported a longer operation time for RATS compared to VATS lobectomy. In addition, in a study of VATS and RATS that was conducted to compare hospital costs and clinical results in 15 502 patients, Swanson et al.[25] reported that RATS WR (3.26 vs. 2.86 h; $p = 0.0003$) was associated with higher hospital costs and longer operating times compared with VATS. Although preparation of the robotic surgery system lengthens the robotic operation time, nonanatomic resection such as segmentectomy or WR has technical and anatomical limitations.[26] Therefore, we believe that RATS can overcome these limitations if pulmonary nodule localization, CT MPR, and intraoperative fluoroscopy are performed.

The number of benign nodules among the pulmonary nodules included in this study is too high compared to other previously reported papers. The reason for this may be due to the exclusion of patients undergoing concomitant lobectomy for primary lung cancer.

Our study had several limitations. First, this was a retrospective study and included a relatively small number of patients. Our results should be further validated in a prospective trial with a greater number of cases. Second, this study was conducted at a single institution. Furthermore, one intervention radiologist (YG) with 18 years of experience performed all CT-guided localizations, and one surgeon (SW) with 16 years of experience performed all VATS WR, introducing the possibility of various biases. A large-scale multicenter study is needed to confirm our findings.

In conclusion, VATS WR using CT MPR-fluoroscopy after CT guided microcoil localization is safe and highly effective for complete pulmonary nodule resection. However, even in uniportal VATS or recently performed robotic surgery, localization and resection of nonvisible, nonpalpable pulmonary nodules remains challenging. Therefore, satisfactory outcomes can be expected if this technique is used for suspicious malignant pulmonary nodule resection.

CONFLICT OF INTEREST

The authors declare no competing interests.

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