

Percutaneous Lung Ablation Combined with Video-Assisted Thoracic Surgery Guided by Three-Dimensional Reconstruction in the Treatment of Multiple Pulmonary Nodules

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Abstract: *Background:* With the wide application of lung cancer screening, the detection rate of multiple pulmonary nodules (MPNs) has increased annually. However, the optimal therapeutic strategy for MPNs has not achieved a consensus. This study aims to report a novel hybrid technique for the treatment of MPNs.

Methods: A total of 8 patients received CT-guided lung microwave ablation combined with video-assisted thoracic surgery from March 2020 to March 2023. Three-dimensional reconstruction was conducted to distinguish the precise localization, predict the resection extent, and conduct the optimal operation procedure for each lung nodule. The clinicopathological characteristics as well as surgical complications and short-term outcomes were recorded.

Results: 8 patients with a total of 18 nodules were treated by our hybrid technique. Two patients had a FEV1% Pred lower than 90%. The nodules treated by surgery were confirmed as malignant by pathological results with a median size of 9mm. The median size of the nodules treated by ablation was 6mm. The median ablation power used for the nodules was 45 W (range, 40–50W). The ablation time was 5min. The median distance between nodules to pleura was 31mm (range 19-56mm). This hybrid technique did not increase the rate of complication and prolonged hospital stay. During the short term of follow-up, no recurrence occurred in the patients.

Conclusions: We present our experience of percutaneous lung ablation combined with video-assisted thoracic surgery guided by three-dimensional reconstruction in the treatment of multiple pulmonary nodules. This technique provides a minimally invasive and personalized therapy for patients with MPNs.

Keywords: Multiple pulmonary nodules, lung microwave ablation, video-assisted thoracic surgery.

INTRODUCTION

With the wide application of lung cancer screening, the detection rate of pulmonary nodule has increased annually. More than 50% of patients are diagnosed with multiple pulmonary nodules (MPNs) [1]. The pulmonary nodules presenting as ground glass opacities (GGO) were usually suspected as synchronous multiple primary lung cancers (SMPLCs) [2]. The optimal therapeutic strategy for multiple pulmonary nodules has not achieved a consensus. Surgeons' judgment should consider the numbers, size and locations of the nodules as well as the pulmonary functions of patients [3]. Although surgical resection is recommended as the treatment of predominant and peripheral nodules, the appropriate treatment for residual nodules especially deep in the lung remains controversial.

As an effective alternative to surgery, image-guided percutaneous lung ablation has achieved significant progress in recent years [4]. Radiofrequency ablation (RFA), microwave ablation (MWA) and cryoablation (CA) are the most widely used in the treatment of small-sized lung tumors [5]. Thermal ablation induced tumor cells coagulative necrosis and proved to be effective and minimally invasive. Thermal ablation seems as a complement to surgery for patients with limited pulmonary functions [6]. Therefore, in our center, we performed percutaneous lung ablation combined with video-assisted thoracic surgery guided by three-dimensional reconstruction in the treatment of multiple pulmonary nodules. We reported our experience and evaluated the safety and short-term outcomes of this technique.

MATERIALS AND METHODS

Patients

This study was approved by the Institutional Ethics Committees of the Affiliated Hospital of Fudan University (Xiamen Branch). From March 2020 to March 2023, 8 patients were simultaneously treated with CT-guided lung microwave ablation combined with

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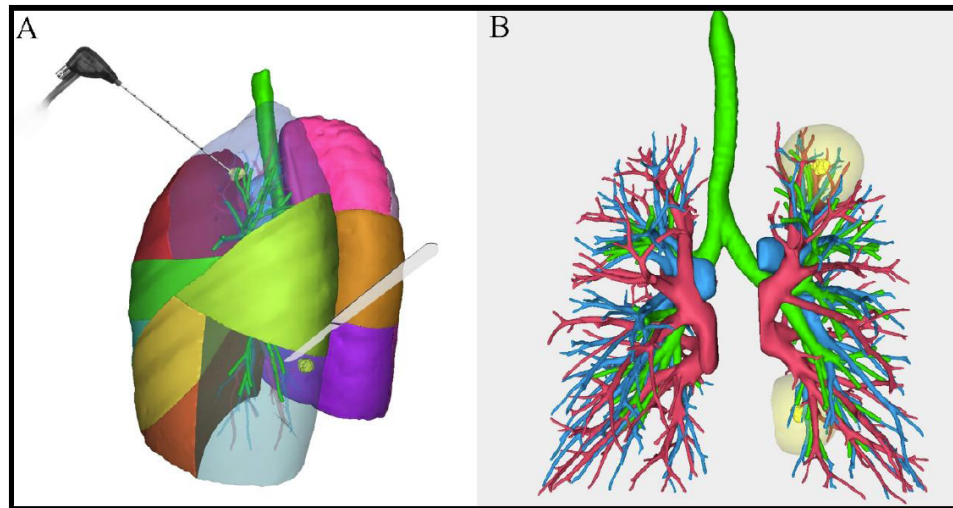


Figure 1: A: a schematic diagram about this hybrid surgery. B: Three-dimensional reconstruction shows the specific spatial location and safe resection range for all the pulmonary nodules.

video-assisted thoracic surgery in our institute. Patients had ≥ 2 pulmonary nodule suspected of lung cancer on preoperative CT scans. Three-dimensional reconstruction was performed before surgery as previously described [7]. Three-dimensional reconstruction distinguished the precise localization of each lung nodule, which facilitated the lung cancer multidisciplinary team to conclude a personalized therapeutic strategy for each patient. The schematic diagram of this hybrid surgery was shown in Figure 1. Patient characteristics included age, gender, histological result, smoking history, lesion size, location, surgical procedure and complications.

Surgical Procedure

MWA was performed using the MTC-3C MWA system (VisonChina Medical Devices R&D Center). All the operations were performed by two radiologists and two experienced thoracic surgeons. The patient was

placed on the CT scanning table in the most suitable position in our hybrid operating room. Local anesthesia with 1% lidocaine was administered at the puncture site. Under the guidance of CT and three-dimensional reconstruction, the puncture was performed according to the predetermined direction and angle. The ablation antenna was adjusted with CT monitoring. The schematic diagram is shown in Figure 2. After completion of the MWA, a CT scan was performed to evaluate the ablation zone and the occurrence of ablation-related complications. A minimum margin of at least 5 mm was considered as sufficient ablative margin. After the procedure, video-assisted thoracic surgery (VATS) was performed to treat the predominant and peripheral lesions.

Follow-Up and Outcomes

All patients received regular follow-up examinations after surgery. X-ray was performed before discharge

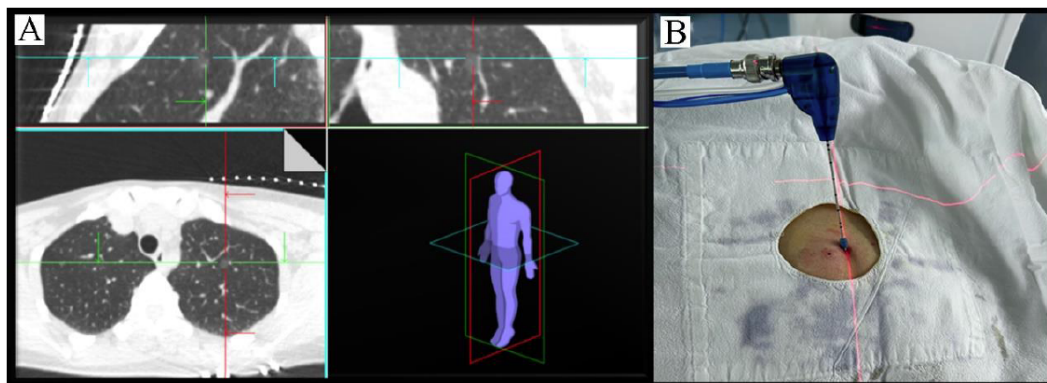


Figure 2: A: The patient was placed on the computerized tomography machine, using CT image reconstruction combed with three-dimensional reconstruction to determine the best puncture path. B: A schematic diagram about the percutaneous lung ablation.

and one month after surgery. Chest CT scan was reviewed generally every 3 months for 2 years after surgery, and every 6 months for 2-5 years after surgery.

Statistical Analysis

Statistical analysis was performed using SPSS version 25.0. Continuous variables were expressed as median (range) and categorical variables were expressed as counts and percentages.

RESULTS

Patient Characteristics

A total of 8 patients received CT-guided lung microwave ablation combined with video-assisted thoracic surgery from March 2020 to March 2023 in our center. The detailed Clinicopathological characteristics

Table 1: Patient Characteristics

Variables	N
Total number of patients	8
Total number of pulmonary nodules	28
Age	
≤60	5
>60	3
Gender	
Male	1
Female	7
Smoking status	
Yes	1
No	7
Comorbidity	
Diabetes mellitus	2
hypertension	1
FEV 1% Pred	
>90	6
80-90	2
Previous lung resection	
Yes	2
No	6
Number of pulmonary nodules per patient	
2	5
3	0
≥4	3
Nodule characteristics	
GGO	15
sub-solid nodule	12
solid nodule	1

are shown in Table 1. The median age was 51.5 years old. There is one man and seven women. The male patient has a ten-year smoking history. Three patients had comorbidities, including 2 with type II diabetes mellitus and 1 with hypertension. Two patients had a FEV1% Pred lower than 90% owing to previous lung resection. The 8 patients had 28 pulmonary nodules with 15 GGOs, 12 sub-solid nodules and one solid nodule.

Surgical Procedure and Pathological Results

A total of 18 nodules were treated by ablation combined with video-assisted thoracic surgery. The surgical procedure and pathological results are shown in Table 2. The nodules treated by surgery were confirmed as malignant by pathological results with a median size of 9mm. The median size of the nodules treated by ablation was 6mm. The median ablation power used for the nodules was 45 W (range, 40–50W). The ablation time was 5min. The median distance between nodules to pleura was 31mm (range 19-56mm). One patient received S6 segmentectomy in the left lower lobe first and was treated by ablation for the nodules in the right lower lobe 3 days after operation. Two patients had complications which were subcutaneous emphysema and fever caused by encapsulated pleural effusion. The complications were discharged after symptomatic treatment. The mean postoperative hospital stay was 5.4 days. Therefore, the hybrid therapy did not increase the rate of complications and prolonged hospital stay.

Follow-Up

All patients received regular follow-up examinations after surgery. The median period of follow-up was 38 months (range 24-60 months). No recurrence occurred in the patients. We present the ablation follow-up chart of patient 2 in Figure 3.

DISCUSSION

With the advance of medical imaging and people becoming more health conscious, the proportion of early-stage lung cancer is increasing [8]. Video-assisted thoracic surgery is considered the most efficient treatment for early-stage lung cancer. Although Lobectomy was considered as standard procedure. Recent studies have revealed that sublobar resection was not inferior to lobectomy for a tumor size less than 2cm [9]. Sublobar resection was considered an optimal therapy for peripherally located ground glass dominant lung tumor and preserved more pulmonary function

Table 2: Surgical procedUre

Patient ID	video-assisted thoracic surgery				CT guided lung microwave ablation			complica tion	Postoper ative hospital stay (day)
	location	size (mm)	Surgical procedure	pathology	location	size(mm)	Distance to pleura (mm)		
1	RLL	8	Wedge	MIA	RUL	6	36		3
2	LLL	9	Lobectomy	IAC	LUL	7	56	Subcutan eous emphyse ma	9
3	LLL	9	segmentectomy	IAC	RLL	8	21	Fever	12
					RLL	5	31		
4	LUL	8	Wedge	MIA	LUL	5	29		3
5	LUL	7	segmentectomy	IAC	LLL	5	35		4
6	LLL	15	Wedge	IAC	LLL	10	36		4
7	RML	18	Lobectomy	IAC	RUL	6	30		4
	RLL	10	Wedge	IAC					
8	LUL	17	segmentectomy	IAC	LLL	4	19		4

RUL, right upper lobe; RML, right middle lobe; RLL, right lower lobe; LUL, left upper lobe; LLL, left lower lobe; AIS: adenocarcinoma in situ; MIA: minimally invasive adenocarcinoma; IAC: invasive adenocarcinoma cancer.

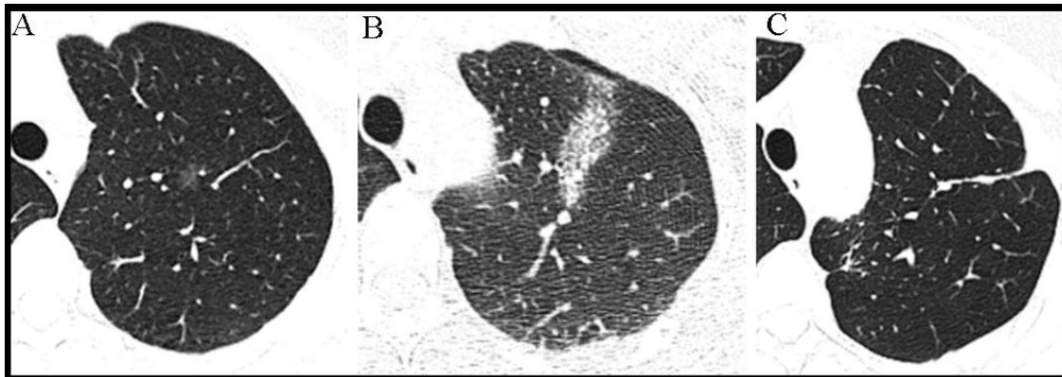


Figure 3: Shows the same patient's lung nodule. **A**, preoperative. **B**, during ablation. **C**, 48 months after ablation.

[10, 11]. More than 50% of patients are diagnosed with multiple pulmonary nodules (MPNs) at the initial CT scan. The multiple pulmonary nodules presenting as ground glass opacities (GGO) were considered as synchronous multiple primary lung cancers rather than intrapulmonary metastasis [12]. The clinicians faced the dilemma that no standard strategy for the management of the MPNs. The currently accepted strategy is to resect the predominant lesion and ongoing follow-up of the residue lesions. However, patients may feel extreme anxiety about the residue lesions in case of gradual enlargement. The cerebral blood flow of the right insula decreased in patients with pulmonary nodules under anxiety state [13]. The detection of pulmonary nodules can affect the physical and mental health of patients, and perioperative anxiety is common [14]. So how to develop an individualized treatment plan for these patients?

As an alternative to surgery, lung ablation and stereotactic body radiotherapy (SBRT) can treat the primary and metastatic pulmonary malignant lesions for patients without the opportunity to receive surgery due to advanced age, and poor pulmonary function [15]. Lung ablation could achieve nearly 96.0% and 67.1% OS rates at 1 and 3 years for patients with stage IA NSCLC [16]. Han *et al.* reported that MWA had similar rates of 3-year OS for patients with GGO and a dramatically lower cost and shorter hospital stay compared with surgery [17]. Considering the advantages of lung ablation, recent studies attempted to combined VATS and lung ablation in the treatment of MPNs. Harrison *et al.* reported a personalized treatment strategy combining wedge resection and ablation for patients with multiple pulmonary metastases [18]. Qu *et al.* shared their experience in the treatment of multiple ground glass opacities by

electromagnetic navigation bronchoscopy-guided microwave ablation combined with uniportal video-assisted thoracoscopic surgery [19]. However, a need for more clinical practice to prove the safety and efficacy of lung ablation combined with VATS. Therefore, in the present study, we reported our experience and evaluated the safety and short-term outcomes of this technique in our center. We perform CT-guided lung microwave ablation combined with video-assisted thoracic surgery for 8 patients with MPNs. All the nodules treated by VATS were confirmed as malignant by pathological results. This hybrid technique did not increase the rate of complications and prolonged hospital stay. During the follow-up, no recurrence occurred in the patients. Moreover, this is the first reported hybrid technique based on the three-dimensional reconstruction technology. Three-dimensional reconstruction is widely used in the preoperative evaluation and instruction of the segmentectomy of lung nodules [20]. Three-dimensional reconstruction distinguished the precise localization, predicted the resection extent and conducted the optimal operation procedure for each lung nodule. It can also predict the residual lung function and propose the proper position, appropriate puncture site, direction, and angle. Three-dimensional reconstruction facilitated the lung cancer multidisciplinary team to conclude a personalized therapeutic strategy for each patient. There are some limitations of our present study. Firstly, this is a retrospective study with a short-term follow-up. Second, the small size of our cohort. Therefore, a prospective larger cohort with long-term follow-up still must be validated.

CONCLUSIONS

In conclusion, we present our experience of percutaneous lung ablation combined with video-assisted thoracic surgery guided by three-dimensional reconstruction in the treatment of multiple pulmonary nodules. This technique provides a minimally invasive and personalized therapy for patients with MPNs.

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CONFLICT OF INTEREST

The Authors declare that there are no relevant financial competing interests to report.

AUTHOR'S CONTRIBUTION

BRC and RFW designed and performed the study. CXD and ZLH compiled the literature search. ZYL, TZ and ZHW extracted the original data. GYY and YXZ performed the statistical analysis. JG and HF processed the related figures and tables. BRC, RFW and HF drafted the manuscript. All authors approved the final manuscript.

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