Original Article

Retrospective cohort study on the correlation analysis among peri-procedural factors, complications, and local tumor progression of lung tumors treated with CT-guided microwave ablation

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Background: Despite adherence to guidelines, recurrence of lesions remains possible in lung tumor microwave ablation (MWA) even when termination is enabled by 5–10 mm ground glass changes. Limited evidence exists regarding the correlation between timely management of perioperative complications (including pneumothorax, pleural effusion, hemorrhage, cavity formation, and infection) and local tumor progression. This retrospective study aimed to investigate the relationship among peri-procedural factors, complications, and local tumor progression in 164 cases of lung tumors treated with computed tomography-guided MWA (CT-MWA), and improve the local prognosis and reduce the complication rate of CT-guided lung tumor ablation.

Methods: We reviewed 164 consecutive patients who underwent CT-MWA at Fudan University Shanghai Cancer Center's Minimally Invasive Therapy Center for lung cancer from September 2019 to May 2020. Correlative analysis was performed between peri-procedural factors, complications and outcomes (local tumor progression rates). Patients who have had prior surgery or previous MWA were excluded. Ablation was the first treatment of choice, and all patients who have had other treatments were excluded. Patients were followed every 3 months with CT. Outcomes of ablation including complications and local tumor progression were evaluated. Peri-procedural factors included demographical factors, tumor features, ablation parameters, management of intra-procedural pneumothorax, and CT features. Complications included pneumothorax, post-procedural refractory infection, and pleural effusion.

Results: The study included 98 males and 68 females, with an average age of 56.1 years. Local tumor progression rate was negatively correlated with intra-procedural management of pneumothorax (R=–0.550, P=0.0003) and Hounsfield unit (HU) difference between HU before and after procedure (R=–0.855, P=0.006), and positively correlated with the average HU value of immediate post-procedural CT at the measurement points (R=0.857, P=0.00002). The correlation analysis results also showed a positive correlation between infection after procedure and pneumothorax (R=0.340, P=0.0001).

Conclusions: A greater difference between HU before and after the procedure or a decrease in CT values immediately after ablation may predict a higher rate of local complete ablation. Prompt management of intraoperative pneumothorax may lower local tumor progression rates and decrease incidence of post-procedural infection.

Keywords: Complication; prognosis; computed tomography values (CT values); lung tumor; microwave ablation (MWA)

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Introduction

Computed tomography-guided microwave ablation (CT-MWA) has been shown to be a safe and effective technique for local tumors (1), with the best complete ablation rates of 80–90% obtained from tumors <3 cm (2). With the advantages including a shorter procedure time and less 'heat sink' effect, MWA has become one of the most popular minimally invasive techniques (3). Local tumor progression was reported to be related to a larger number of lesions and a larger tumor size (4). While many proceduralists who perform lung ablation expect to see a zone of ground glass opacity (GGO) surrounding the tumor after ablation. The relationship between CT features of the ablation zone/tumor and local tumor progression remains unknown.

Currently, GGO surrounding the ablation zone is used to assess for technical effectiveness. The guidelines suggest that complete ablation can be achieved when the ground glass change surrounding the lesion measures 5–10 mm, allowing for the termination of the ablation (5). The presence or recurrence of lesions may still occur despite strict adherence to these requirements during MWA of lung tumors. The immediate pathological changes in a tumor after MWA may indicate the treatment response or long-term prognosis. Many radiomic studies have reported that quantitative features from medical images have the potential to indicate the treatment response and prognosis (6-8). The convective effect and low heat deposition of microwave thermal radiation in the lung can lead to heat gasification after ablation, potentially impacting the local density of lung tumors and resulting in changes to CT values. Hence, CT figures hold promise as predictive factors for local tumor progression although the relationship between Hounsfield unit (HU) value.

MWA carries a significant risk of complications. The incidence rates of pneumothorax vary widely, ranging between 8.5% and 63% (9). Most patients with pneumothorax are managed conservatively without intervention (9), with 0.8–15% receiving closed thorax drainage (10). The incidence of pleural effusion is approximately 1–60%, and about 1–7% of patients require puncture or catheter drainage (11). The frequency of hemorrhage during MWA varies between 3% and 8% (12), mostly manifested by hemoptysis and hemothorax. The formation of cavities is another significant complication of lung ablation. There is limited evidence indicating whether timely management of these perioperative complications are related to local tumor progression.

Highlight box

Key findings

- The Hounsfield unit (HU) difference may predict the local ablation condition. Managing pneumothorax may reduce tumor progression and infection.

What is known and what is new?

- Despite adherence to guidelines, recurrence of lesions remains possible in lung tumor microwave ablation even when termination is enabled by 5–10 mm ground glass changes. Limited evidence exists regarding the correlation between timely management of perioperative complications (including pneumothorax, pleural effusion, hemorrhage, cavity formation, and infection) and local tumor progression.
- A greater difference between HU before and after the procedure or a decrease in computed tomography (CT) values immediately after ablation may predict a higher rate of local complete ablation. Prompt management of intraoperative pneumothorax may lower local tumor progression rates and decrease incidence of post-procedural infection.

What is the implication, and what should change now?

- The treatment's effectiveness can be enhanced by monitoring CT HU differences, adjusting the needle position, and modifying ablation termination time during the operation. Timely management of pneumothorax has the potential to reduce tumor progression and infection incidence.

In this study, a retrospective analysis was conducted to investigate the correlation among peri-procedural factors including imaging characteristics of ablation zone, complications (such as hemorrhage, pneumothorax, pleural effusion, pulmonary infection, etc.), and the local outcomes [complete response (CR), incomplete response (ICR), and progressive disease (PD)]. The study is expected to contribute significantly to reducing complications in CT-guided lung tumor ablation techniques, improving local prognosis, and providing new insights for radiomics research in CT-MWA. We present this article in accordance with the STROBE reporting checklist (available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-1799/rc).

Methods

CT-MWA procedures

(I) Pre-procedural preparation: a chest CT and enhanced CT were completed before procedure to determine the gross tumor region (GTR), measure the size of the lesion (maximum diameter of the cross-section under the pulmonary window), and evaluate the anatomical relationship between the lesion and adjacent organs (blood vessels, trachea, heart, etc.). The best puncture site and puncture route were determined according to the CT results; ablation needle size, number, and parameters were planned.

(II) Puncture: after local anesthesia, the needle was advanced to the predetermined position in the lesion under the guidance of CT. The ablation needle was passed through the center of the largest cross-section of the lesion, with the needle tip extending beyond the tumor by 0.5–1 cm.

(III) Ablation: ablation was performed at previously set parameters, such as power and time. When the GGO area in the post-ablation target zone (PTZ) extended the boundary of the pre-ablation lesion by more than 5 mm, the ablation was terminated. Each lesion used one probe.

(IV) Management of complications: intra-procedural and post-procedural vital signs were monitored, and complications such as pneumothorax, pleural effusion, pulmonary inflammation, and bleeding were treated.

Study population

A total of 164 patients who underwent CT-MWA for primary or secondary lung cancer at the Minimally Invasive Therapy Center of Fudan University Shanghai Cancer Center from September 2019 to May 2020 were enrolled. The criteria for inclusion were as follows: (I) ≤3 unilateral pulmonary lesions (≤5 bilateral pulmonary lesions), maximum diameter of ≤3 cm in multiple metastases, and maximum diameter ≤5 cm in unilateral metastases; (II) no extensive extrapulmonary metastases (except for bone metastases after systemic therapy or radiotherapy); and (III) no severe coagulopathy or lung failure. Patients who have had prior surgery or previous MWA were excluded. For all patients, CT-MWA was the first choice of all treatments after assessment from a tumor board that allocates the patients into the best practice, and all patients who have had other treatments were excluded.

Data collection, follow-up, and radiologic assessment

Information mainly including demographic data, procedure details, and CT results were collected from electronic records which were well protected by researchers. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the ethics committee of the Minimally Invasive Therapy Center, Fudan University Shanghai Cancer Center (No. KS(Y)21316). The requirement for informed consent was waived due to the retrospective nature of this study. Patients were followed every 3 months with CT to determine patterns of recurrence and efficacy of ablation. Treatment response was captured and defined as follows: (I) CR (*Figure 1A*): (i) lesion disappearance; (ii) complete cavity formation; (iii) fibrosis or scarring; and (iv) solid nodules were reduced or did not change or increase, and CT showed no contrast-enhancement. (II) ICR (*Figure 1B*): (i) partial reduction or enlargement of the lesion (<20%), contrast-enhanced CT signs or positron emission tomography (PET)-CT indicating current metabolic activity of the tumor; (ii) part of the lesion showed cavity or fibrosis, and there were contrast-enhanced CT signs or PET-CT indicating current metabolic activity of the tumor. (III) PD (*Figure 1C*): (i) enlargement lesion size ≥20%, CT contrast-enhanced signs or PET-CT suggesting metabolic activity; and (ii) presence of new GGO or nodules around the ablated lesion, contrast-enhanced CT signs or PET-CT suggestive of tumor metabolic activity.

Main consumables and equipment

Disposable water-cooled MWA needle and MTC-3C

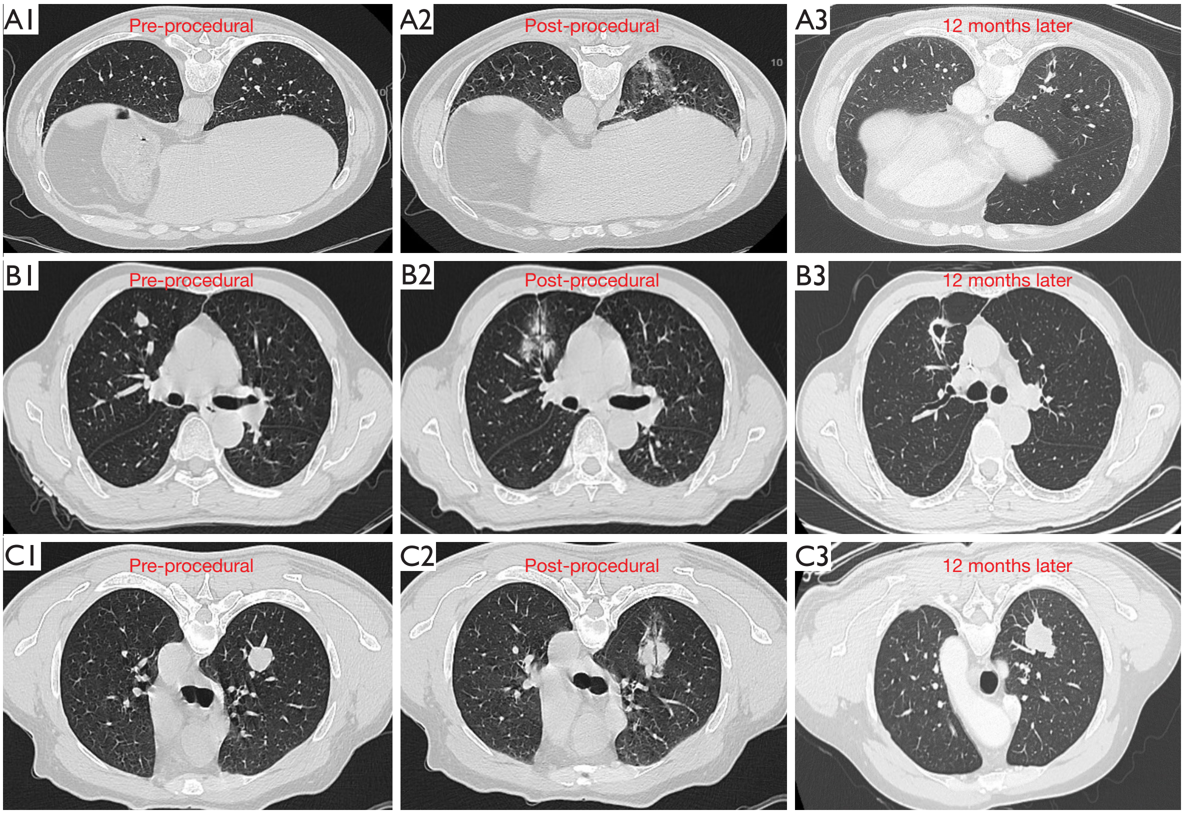

Figure 1 CT features of CR, ICR, PD. (A) CT features of CR: (A1) tumor lesion of CR (pre-ablation); (A2) HU of the ablation zone decrease significantly; (A3) the ablation zone form fibrosis and cavity. (B) CT features of ICR: (B1) tumor lesion of ICR (pre-ablation); (B2) HU decrease of the ablation zone is not significant; (B3) residual lesions can be observed surrounding the ablation zone. (C) CT features of PD: (C1) tumor lesion of PD (pre-ablation); (C2) HU of the ablation zone increase significantly; (C3) local tumor progression was observed during follow-up. CR, complete response; ICR, incomplete response; PD, progressive disease; CT, computed tomography; HU, Hounsfield unit.

MWA therapy instrument (Viking Jiuzhou Medical Device City Research and Development Center, Nanjing, China); Optima CT670 64-Row 128-Slice Spiral CT (GE Company, Boston, MA, USA).

Statistical analysis

The statistical processing was conducted using the software SPSS 20.0 (IBM Corp., Armonk, NY, USA). Measurement data were presented as $\bar{x}$±s, and data were compared using the two independent samples *t*-test. Frequency (%) was used to present enumeration data, and enumeration data were compared using the chi-square test or Fisher exact probability method. The Pearson correlation coefficient was utilized to conduct correlation analysis on two sets of measurement data that conformed to a normal distribution. The Spearman's rank correlation coefficient was used to analyze the correlation between two sets of measurement data that did not follow a normal distribution. The Kruskal-Wallis test was employed to conduct statistical analysis among several sets of measurement data that were not normally distributed. Rank data or count data were analyzed using the rank-Spearman correlation coefficient. Two count data (categorical variables) were subjected to the chi-square test to determine the number of column associations. Statistical significance was considered when $P \leq 0.05$.

Results

Demographic results (Table 1)

The study included 98 male and 68 female participants

Table 1 Baseline characteristics

Baseline characteristics	Values
Gender	
Male	98
Female	68
Age (years)	56.1 [21–76]
Pathological type	
Colorectal cancer	52
Non-colorectal cancer	112
Tumor location	
Right lung	94
Left lung	70
Tumor size (cm)	
≤1	82
>1, ≤3	70
3–5	12
Ablation power (W)	50 [35–60]
Ablation time (min)	7.6 [3–14]

Values are presented as n or median [range].

Figure 2 The CT screenshot displays the long axis of the ablation needle post-lung tumor ablation, with 0.05 cm on both sides of the tumor center serving as the measurement point (indicated by a red dot and measuring at 0.05 cm^2). The red dots represent the tumor center, while the black dot on either side indicates CT value measurements. The arrow indicates the focal area of the tumor. L, left; R, right; CT, computed tomography.

with an average age of 56.1 years (range, 21 to 76 years). Among them, there were 52 patients diagnosed with colorectal cancer, 20 patients with hepatocellular carcinoma, 15 patients with lung cancer, 9 patients with nasopharyngeal carcinoma, and 68 patients with other types of cancers; 94 tumor lesions were in the right lung and 70 were in the left lung. A total of 82 tumor lesions measured ≤1 cm in diameter, 70 measured ≤3 cm, and 12 measured 3–5 cm. The average ablation power was 35–60 W, and the average ablation time was approximately 7.6 minutes (range, 3 to 14 minutes). The mean follow-up time of lesions was 31 months.

CT-MWA outcomes of complications and the local effective rate

Among the 164 patients, pneumothorax occurred in 58 patients (35.4%), post-procedural pulmonary infection in 15 cases (9.1%), and pleural effusion in 20 cases (12.2%). There was no hemorrhage, serious, or fatal adverse events. Local CR was achieved in 90, local ICR in 56, and local PD in 18 lesions. The local effective rate, which is the composite of CR and ICR, reached 89% over a mean follow-up time of 31 months.

A positive correlation of local tumor progression with average immediate posto-procedural CT value, and a negative correlation with difference between pre- and post-procedural CT value

As illustrated in *Figure 2*, A thickness of 1.25 mm was chosen for thin-slice CT. The CT screenshot displayed a long axis of the ablated lesion, with the needle at two points (a red dot measuring 0.05 cm^2) 0.05 cm bilateral to the tumor center. As illustrated in *Figures 3,4*, the local tumor progression exhibited a positive correlation with the average value of immediate post-procedural CT at the measurement points (R=0.857, P=0.00002) (*Figure 3*) and a negative correlation with the difference between pre- and post-procedural CT values (R=−0.855, P=0.006) (*Figure 4*). The average value of immediate post-procedural CT at the measurement point was predominantly negative in the CR group, positive in the PD group, and either positive or negative in the ICR group. The CR group had the greatest difference in CT value between pre- and post-procedural measurements; the PD group had the smallest difference; the ICR group exhibited a moderate difference. By conducting pairwise comparisons between groups, the average value of immediate post-procedural CT and the difference between pre-MWA and post-MWA showed statistically significant differences between the CR group and ICR group, the CR group and PD group, and the ICR group and PD group (the average value of immediate post-

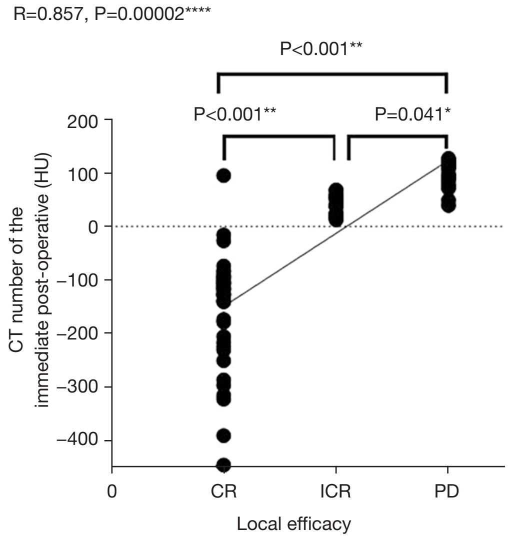

Figure 3 The relationship between local efficacy and HU of immediately post-procedural CT. The local tumor progression exhibited a positive correlation with the average value of immediate post-procedural CT at the measurement points (R=0.857, P=0.00002). The average value of immediate post-procedural CT at the measurement points was predominantly negative in the CR group, positive in the PD group, and either positive or negative in the ICR group. By conducting pairwise comparisons between groups, the average value of immediate post-procedural CT showed significant statistical differences between the CR group and ICR group, the CR group and PD group, and the ICR group and PD group (the average value of immediate postoperative CT: P<0.001, P<0.001, P=0.041). CT, computed tomography; CR, complete response; ICR, incomplete response; PD, progressive disease; HU, Hounsfield unit.

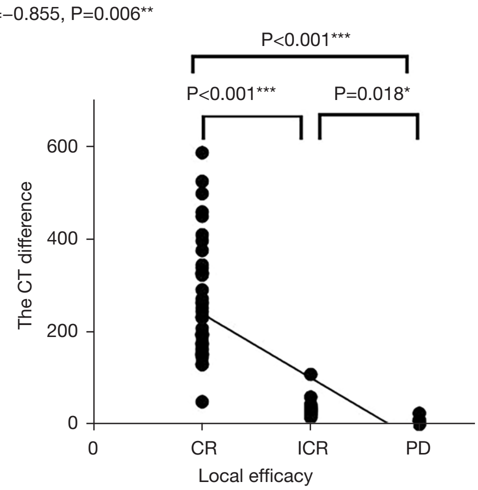

Figure 4 The relationship between local efficacy and the HU difference before and after procedure. The local prognosis exhibited a negative correlation with the difference between pre- and post-procedural CT values (R=−0.855, P=0.006). The CR group had the greatest difference in CT value between pre- and post-procedural measurements; the PD group had the smallest difference; the ICR group exhibited a moderate difference. By conducting pairwise comparisons between groups, the difference between pre-MWA and post-MWA showed significant statistical differences between the CR group and ICR group, the CR group and PD group, and the ICR group and PD group (CT value difference: P<0.001, P<0.001, P=0.018). CT, computed tomography; CR, complete response; ICR, incomplete response; PD, progressive disease; HU, Hounsfield unit; MWA, microwave ablation.

procedural CT: P<0.001, P<0.001, P=0.041, respectively) (*Figure 3*); CT value difference: P<0.001, P<0.001, P=0.018, respectively (*Figure 4*). Thus, the total ablation rate in patients with negative average values of immediate post-procedural CT after ablation was significantly higher than that in those with positive values. A larger difference between pre- and post-procedural CT values indicated a higher rate of complete local ablation. *Figure 5* displays a 61-year-old male patient with sigmoid carcinoma with lung metastasis. *Figure 6* shows a 60-year-old male patient with lung metastasis of sigmoid carcinoma. Both patients showed a decrease in CT values after ablation, and subsequent CT reexamination revealed that the ablation lesion had transformed into fibrous tissue. Contrastingly, if the average value of immediate post-procedural CT was positive, and the pre- and post-procedural CT values were similar, the lesion was more likely to remain or recur.

Post-procedural refractory pulmonary infection was positively correlated with pneumothorax

We observed that 58 (35%) patients had intra-procedural pneumothorax needing chest tube drainage. Of 58 patents needing chest tube, 36 (62%) patients received immediate chest tube drainage, and 22 (38%) patients was given supplemental oxygen after procedure. As a result, none of patients with chest tube developed infection, but 13 (59%) cases of patients without chest tube developed post-procedural pulmonary infection. According to the correlation analysis, there was a positive correlation between intra-procedural pneumothorax and post-procedural

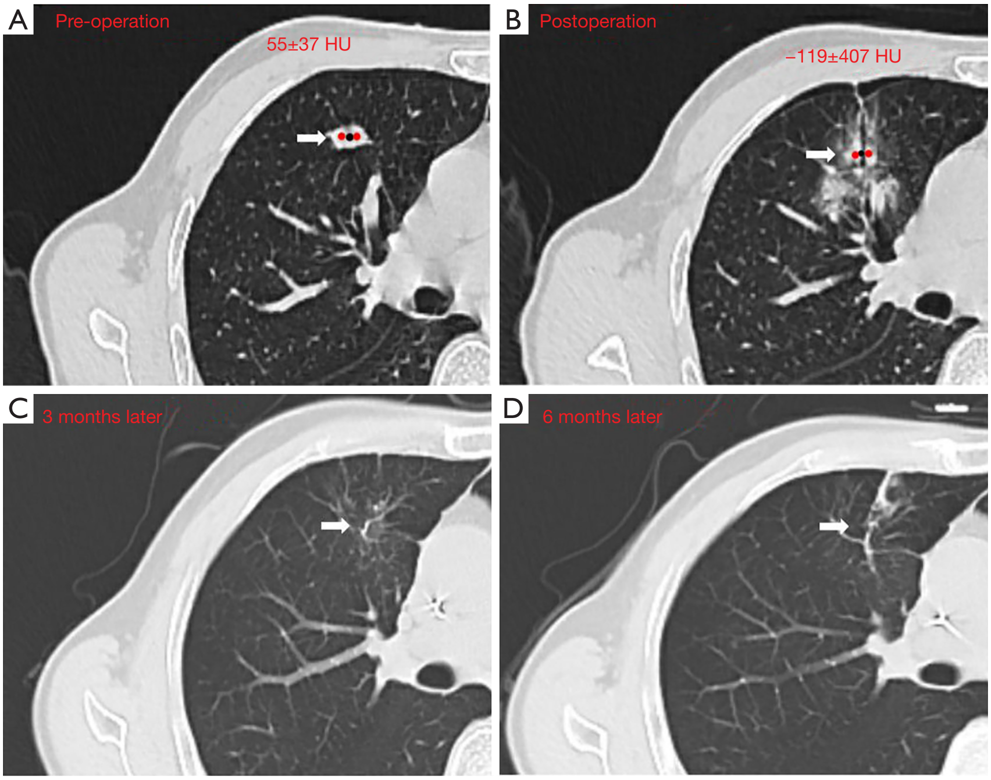

Figure 5 A 61-year-old male patient with sigmoid carcinoma with lung metastasis: (A) the average CT value at the measurement points before ablation was 55±37 HU; (B) the average CT value at the measurement points after ablation was −119±107 HU; (C) CT reexamination 3 months after surgery showed fibrous strips in the ablation lesions; (D) CT reexamination 6 months after surgery showed fibrous strips in the ablation lesions. The red dots represent the tumor center, while the black dots on either side indicate CT value measurements in (A,B). The arrow indicates the focal area of the tumor. HU, Hounsfield unit; CT, computed tomography.

lung infection (R=0.340 and P=0.0001) (*Table 2*). Linear regression analysis indicated a significant difference in the post-procedural lung infection between the two groups with and without immediate treatment of intra-procedural pneumothorax (*F*=22.824, P=0.0003; *Table 3*).

A negative correlation between intra-procedural management of pneumothorax and local tumor progression

The correlation between intra-procedural management of pneumothorax and local tumor progression was significant (R=−0.550 and P=0.0003) (*Figure 7*). There was a significant difference in the local tumor progression between the two groups with and without intra-procedural management of pneumothorax (*F*=25.090, P=0.016; *Table 4*). Prompt management of intraoperative pneumothorax may lower local tumor progression rates.

Discussion

In this study, the results showed that a greater HU difference between pre- and post-procedural CT values or a decrease in CT values immediately after ablation predicted a higher rate of local complete ablation. In addition, correlation analysis results indicated a positive correlation between post-procedural refractory infection and pneumothorax, and a negative correlation between intra-procedural management of pneumothorax and local tumor progression.

Local MWA technique has grown in popularity recently as a precise and minimally invasive therapy for lung tumors. However, the incidence of pneumothorax after ablation remains high at approximately 8.5–63% (13). It has been shown that most cases of pneumothorax are self-limiting and can be treated conservatively with oxygen inhalation, whereas only 13–20% of cases require chest

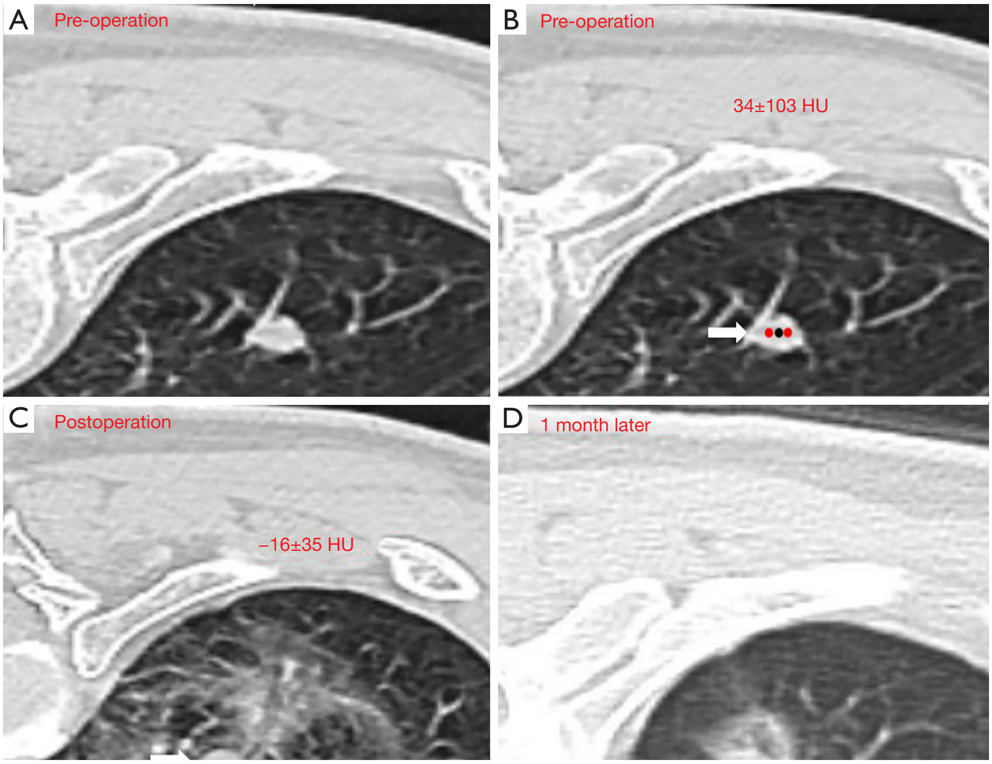

Figure 6 A 60-year-old male patient with lung metastasis of sigmoid carcinoma: (A) a solid nodule 0.9 cm × 0.9 cm × 1.0 cm was seen in middle lobe of right lung; (B) the average CT value at the measurement points before ablation was 34±103 HU; (C) the average CT value at the measurement points after ablation was −16±35 HU; (D) CT reexamination 1 month after surgery showed that the ablation lesion was fibrous strips. The red dots represent the tumor center, while the black dot on either side indicates CT value measurements in (B). The arrow indicates the focal area of the tumor. HU, Hounsfield unit; CT, computed tomography.

tube drainage (14). In our study, we discovered that intra-procedural management of pneumothorax was negatively correlated to the local tumor progression rate of lung lesion ablation. The relationships may involve the following mechanisms: (I) intra-procedural pneumothorax results in sudden and conspicuous compression of the lung, leading to the displacement of the lung and the tumor, which impairs accuracy of the puncture and efficacy of the ablation. Although several studies have shown that artificial pneumothorax before puncture was helpful to relieve pain and avoid damage of vital organs adjacent to the tumor (15-18), concerns remain that pneumothorax increases local pulmonary motion, making tumors more likely to displace during puncture and ablation, resulting in impairment of ablation efficacy. Considering the low incidence of vital organs damage, ablation efficacy was felt to overweigh the relatively little discomfort during surgery for patients with malignant tumors. (II) The occurrence of intra-procedural pneumothorax reduces the convective effect of lung ablation and increases the heat-sink effect, reducing efficacy of the ablation. In addition, intra-procedural pneumothorax caused discomfort for patients. Therefore, pneumothorax should be managed during operation.

In this study, we found that a greater decrease in CT value was related to a higher rate of CR, whereas a smaller decrease may imply a higher risk of local recurrence. This phenomenon might be attributed to histological changes in the ablation zone. After ablation, local tissue underwent coagulation necrosis, destruction of cell structures, and local alveolar vaporization, all decreasing CT values. A more complete ablation suggested a more obvious tissue shrinkage and local gasification, and thus a greater decrease in CT value. Liu *et al.*, Chetan *et al.*, and Alexander *et al.* reported that the mean density and the mean CT values both decreased in the ablation zone (19-21), which is consistent with our results. Several studies have suggested

Table 2 Correlation analysis results

Factors	Gender	Age	Pathological type	Tumor location	Tumor size	Ablation power	Ablation time	Pre-procedural CT value	The immediate post-procedural CT value	CT difference	Local tumor progression	Pneumothorax	Post-procedural infection	Pleural effusion
Gender														
R	1	0.121	−0.012	−0.024	0.025	−0.041	−0.039	0.108	−0.112	0.112	−0.071	−0.053	−0.076	−0.087
P	–	0.277	0.917	0.828	0.822	0.715	0.726	0.333	0.317	0.315	0.523	0.636	0.499	0.439
Age														
R	0.121	1	−0.061	0.078	−0.165	0.063	−0.05	0.116	−0.045	0.059	−0.019	0.025	0.149	0.078
P	0.277	–	0.586	0.485	0.138	0.573	0.653	0.299	0.691	0.6	0.863	0.825	0.183	0.486
Pathological type														
R	−0.012	−0.061	1	−0.058	−0.052	−0.085	0.008	−0.169	−0.094	−0.001	−0.063	−0.099	−0.089	−0.066
P	0.917	0.586	–	0.604	0.64	0.446	0.944	0.128	0.403	0.992	0.574	0.377	0.426	0.553
Tumor location														
R	−0.024	0.078	−0.058	1	−0.113	−0.149	−0.083	−0.057	0.087	−0.191	−0.071	0.123	0.081	−0.055
P	0.828	0.485	0.604	–	0.311	0.181	0.461	0.612	0.437	0.085	0.525	0.272	0.47	0.623
Tumor size														
R	0.025	−0.165	−0.052	−0.113	1	0.442	0.511	−0.008	0.035	−0.016	0.106	0.03	−0.132	0.07
P	0.822	0.138	0.64	0.311	–	0.001**	<0.001**	0.944	0.756	0.888	0.341	0.787	0.236	0.529
Ablation power														
R	−0.041	0.063	−0.085	−0.149	0.442	1	0.218	0.066	−0.1	0.176	0.059	0.098	−0.067	0.103
P	0.715	0.573	0.446	0.181	0.001**	–	0.049*	0.558	0.373	0.114	0.596	0.38	0.548	0.359
Ablation time														
R	−0.039	−0.05	0.008	−0.083	0.511	0.218	1	−0.2	−0.074	0.086	−0.091	0.022	−0.015	−0.106
P	0.726	0.653	0.944	0.461	<0.001**	0.049*	–	0.072	0.508	0.443	0.414	0.841	0.897	0.345
Pre-procedural pulmonary infection														
R	−0.133	0.003	−0.062	0.136	−0.104	−0.047	−0.037	−0.11	0.185	−0.21	0.228	0.214	0.698	0.183
P	0.233	0.976	0.579	0.222	0.352	0.675	0.739	0.324	0.095	0.058	0.039*	0.054	<0.001*	0.1
Pre-procedural CT value														
R	0.108	0.116	−0.169	−0.057	−0.008	0.066	−0.2	1	0.267	0.306	−0.216	−0.097	0.043	0.017
P	0.333	0.299	0.128	0.612	0.944	0.558	0.072	–	0.015*	0.005**	0.052	0.386	0.701	0.883

Table 2 (*continued*)

Table 2 (*continued*)

Factors	Gender	Age	Pathological type	Tumor location	Tumor size	Ablation power	Ablation time	Pre-procedural CT value	The immediate post-procedural CT value	CT difference	Local tumor progression	Pneumothorax	Post-procedural infection	Pleural effusion
The immediate post-procedural CT value														
R	−0.112	−0.045	−0.094	0.087	0.035	−0.1	−0.074	0.267	1	−0.737	0.857	−0.017	0.215	0.13
P	0.317	0.691	0.403	0.437	0.756	0.373	0.508	0.015*	–	<0.001**	0.00002****	0.878	0.052	0.245
CT difference														
R	0.112	0.059	−0.001	−0.191	−0.016	0.176	0.086	0.306	−0.737	1	−0.855	−0.067	−0.178	−0.214
P	0.315	0.6	0.992	0.085	0.888	0.114	0.443	0.005**	<0.001**	–	0.006**	0.548	0.109	0.053
Local tumor progression														
R	−0.071	−0.019	−0.063	−0.071	0.106	0.059	−0.091	−0.216	0.857	−0.855	1	0.135	0.191	0.161
P	0.523	0.863	0.574	0.525	0.341	0.596	0.414	0.052	0.00002****	0.006**	–	0.226	0.086	0.147
Pneumothorax														
R	−0.053	0.025	−0.099	0.123	0.03	0.098	0.022	−0.097	−0.017	−0.067	0.135	1	0.340	0.192
P	0.636	0.825	0.377	0.272	0.787	0.38	0.841	0.386	0.878	0.548	0.226	–	0.0001**	0.084
Post-procedural infection														
R	−0.076	0.149	−0.089	0.081	−0.132	−0.067	−0.015	0.043	0.215	−0.178	0.191	0.340	1	0.262
P	0.499	0.183	0.426	0.47	0.236	0.548	0.897	0.701	0.052	0.109	0.086	0.0001**	–	0.018*
Pleural effusion														
R	−0.087	0.078	−0.066	−0.055	0.07	0.103	−0.106	0.017	0.13	−0.214	0.161	0.192	0.262	1
P	0.439	0.486	0.553	0.623	0.529	0.359	0.345	0.883	0.245	0.053	0.147	0.084	0.018*	–

*, P<0.05; **, P<0.01; ****, P<0.0001. CT, computed tomography.

Table 3 The relationship between intraoperative pneumothorax and postoperative infection

Post-procedural infection	Intra-procedural pneumothorax		R	P†	*F*	P‡
	–	+				
–	104	45	0.340	0.0001***	22.824	0.0003***
+	2	13				

***, P<0.001. †, P value of the correlation coefficient; ‡, P value of the chi-square test.

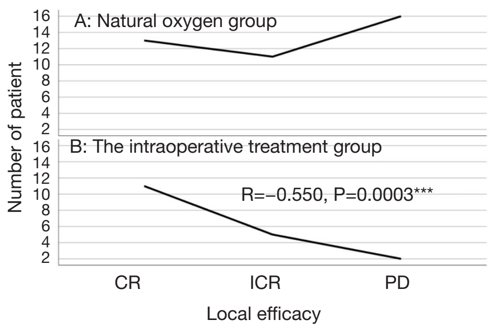

Figure 7 The relationship between local efficacy and different management of intra-procedural pneumothorax. The correlation between immediate treatment of intra-procedural pneumothorax and local effects was R=−0.550 and P=0.0003. Prompt management of intraoperative pneumothorax may lower local tumor progression rates. CR, complete response; ICR, incomplete response; PD, progressive disease.

Table 4 The relationship between intra-procedural pneumothorax management and local effects

Groups	Intraoperative management of pneumothorax		R	P†	*F*	P‡
	–	+				
CR	2	18	−0.550	0.0003***	25.090	0.016**
ICR	5	13				
PD	15	5				

**, P<0.01; ***, P<0.001. †, P value of the correlation coefficient; ‡, P value of the chi-square test. CR, complete response; ICR, incomplete response; PD, progressive disease.

that radiomics analysis using image analysis tools had the potential to recognize recurrence early, but its reliance on particular computer software limited availability in the clinic (22-24). There have also been reports about the utilization of post-ablation CT densitometry to predict recurrence, but added radiation dose conferred by CT densitometry remained a concern (25). Therefore, the post-ablation changes in CT value can be a more available and safer way to predict recurrence and instruct optimal timing of ablation termination. Our results suggest that if there is no difference in immediate post-ablation HU, there is a high rate of ICR or PD suggesting that additional treatment should be considered in that session.

A limitation of this study was the difference in CT scanners, which likely created variability in absolute CT values. In addition, the study included tumor lesions diagnosed with different pathological types, which may have different treatment responses to ablation. Although our results showed a satisfactory local effective rate of 89%, the limitations of this study were its retrospective design, the possibility of selection bias, the length of follow-up and the irregular follow-up due to the inconvenience of travel from remote areas. In addition, our follow-up results lack histological proof of CR.

Conclusions

CT-MWA procedure exerts significant local effects in the treatment of primary or metastatic lung tumors. Intra-procedural pneumothorax may affect the efficacy of this procedure, and immediate CT value may be a predictive index of local tumor progression.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-1799/rc

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://jtd.amegroups.com/article/view/10.21037/jtd-23-1799/coif). B.B.P. serves as Consultant of GE Healthcare, outside the submitted work. The other authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the ethics committee of the Minimally Invasive Therapy Center, Fudan University Shanghai Cancer Center [No. KS(Y)21316]. The need for patient consent was waived because of the retrospective nature of the study.

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