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Role of Microwave Ablation in Treatment of Lung Tumors

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Abstract

Background: Image-guided percutaneous thermal ablation is a common excellent alternative option for treatment of non-operable primary and metastatic lung tumors. These techniques are based on heating effect on the tissue around a percutaneous applicator causing coagulative necrosis of the tumor cells. Microwave Ablation (MWA) is a commonly used locoregional interventional procedure in treatment of pulmonary tumors with satisfactory outcome.

Aim of Study: The aim of the study was to evaluate the role of CT-guided microwave ablation of inoperable lung tumors.

Subjects and Methods: This study was carried out at Diagnostic & interventional Radiology Department, Goethe University Hospitals, Frankfurt, Germany during the period from April 2017 to March 2020, included 40 patients with 52 lung malignant lesions, underwent CT-guided microwave ablation. All patients were subjected to complete clinical examination, pre-procedural laboratory investigations & imaging evaluation. Post ablation follow-up by chest CT was done after 24 hours, three, six, nine months, one year and every 6 months onwards to determine treatment response. Patients were either adequately ablated (no residual tumor activity) or had local progression (residual tumor activity).

Results: Forty-four malignant lesions (84.6%) showed complete response to treatment and 8 lesions (15.4%) had local progression (residual activity). The median time to local tumor progression was 8.3 months. The median survival was 32 months for patient underwent MWA according to the Kaplan-Meier test. The overall survival rate at 1, 2, and 3 years was 97.5%, 90%, and 82.5%, respectively. Successful tumor ablation was significantly more frequent for lesions with a maximal axial diameter of 3cm or smaller (p=.0001). There were no deaths during the procedure and the mortality rate within 6 months after ablation was 0%. Early postablation complications included pneumothorax (13.5%), pulmonary hemorrhage (9.6%) and postablation syndrome (3.85%), Pleural Effusion (3.85%), Hemoptysis (3.85%). Manual evacuation was done in 3 cases out of 7 sessions complicated by pneumothorax. No significant long-term complications were detected.

Conclusion: Percutaneous CT-guided microwave ablation therapy for management of pulmonary tumors is safe and effective minimally invasive option and can improve local tumor control and survival rate in patients who are not candidate for surgical resection.

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Key Words: *Microwave ablation (MWA) – Radiofrequency ablation (RFA) – CT-guided – Local tumor control – Lung tumors – Non-Small Cell Lung Cancer (NSCLC).*

Introduction

LUNG cancer remains the leading cause of cancer death. Pneumonectomy or lobectomy with hilar and mediastinal lymph node sampling is the gold standard treatment and offers the best option for curing stage 1/2 Non-Small Cell Lung Cancer (NSCLC) **[1,2]**.

Unfortunately, only 15% of patients present with stage 1/2 disease, and many of these do not meet the pulmonary physiologic criteria for lobar resection. In addition to lung cancer, pulmonary metastases are present in 25-30% of patients dying from all types of cancer. For some patients with oligometastatic pulmonary disease, metastectomy is associated with an improvement in survival. External beam radiation traditionally has been offered as the alternative to surgical resection for NSCLC or pulmonary metastatic disease. Unfortunately, the five-year survival following radiation for stage 1 and 2 NSCLC remains low at 15-20%, with local recurrence being the most common type of failure **[1-3]**.

Thermal ablation offers a therapeutic option to improve local tumour control and survival in patients with early-stage NSCLC or with limited metastatic disease from non-lung primaries, who are not candidates for surgical intervention, either because of poor cardiopulmonary reserve, anatomic

constraints limiting resection, failure of traditional therapies or refusal of operative approaches [4].

Tumor heating ablation under the guidance of image has been proved to be one treatment method with definite effects [5], and the method of treating inoperable pulmonary malignancies with Microwave Ablation Therapy (MWA) is one of the new minimally invasive techniques popular in recent years [6].

Electromagnetic waves were used in Microwave Ablation (MWA) to produce tissue heating effects and would result in a much larger zone of active heating when compared with that of Radiofrequency Ablation (RFA), which made percutaneous microwave ablation therapy (MWA) a more precise and more reliable method in treating malignancies in many tissues [7-9].

MWA produce more tissue heating with larger ablation zone than radiofrequency ablation due to its greater convection profile in lung and less severe heat sink effects. Furukawa et al., also found that tissues around the electrodes changed immediately after MWA, that is fibrosis and thickening of collagenous fiber [10]. The ablated pulmonary tissues would be replaced by scar fibrous tissues after 6 months [10].

MW ablation therapy is a safe therapeutic tool for the treatment of primary and metastatic pulmonary neoplasms. The efficacy of treatment is determined mainly by pre-ablation tumour size and location in relation to the hilum [4].

The purpose of the current study was to evaluate the efficacy of microwave ablation in treatment of inoperable pulmonary tumors.

Patients and Methods

This study is a prospective interventional study. The study was approved by the Local Ethical Committee board. It was carried out in institute of Diagnostic and Interventional Radiology, Johann Wolfgang Goethe/Frankfurt University Hospital, Frankfurt am Main, Germany, during the period from April 2017 to March 2020.

A total of 40 patients with 52 primary (9) and metastatic lung lesions (Colon carcinoma (19), Breast carcinoma (10), HCC (6), RCC (4), Endometrial carcinoma (2), Parotid carcinoma (2)). (Table 12), ranging from 0.5 to 5cm (Table 7) were included in this study and underwent CT-guided microwave ablation. They were (19) males and (22) females, their ages ranged from 34 to 83 years (mean age ± SD is 63.8± 14.6 years). (Tables 1,2) Figs. (1,2).

Inclusion criteria:

1- Patients have lost the opportunity of surgical resection (inoperable) or cannot endure surgical treatment because of other diseases.

2- Patients with primary or metastatic pulmonary tumor (Table 12).

3- Metastases after pneumonectomy or recurrent metastases after surgical resection.

4- Number of lesions less than 5 or lesion diameter less than 5cm.

5- Patient refusing to undergo surgery.

6- Histopathological confirmation of malignancy (Table 4).

7- Adequate baseline bleeding profile including the following laboratory values:

   a- Platelet count >75,000/cc.

   b- International normalizing ration <1.5.

   c- Prothrombin time <15 seconds.

   d- Activated Partial Thromboplastin Time (PTT) <45 seconds.

Exclusion criteria:

1- Uncontrolled primary malignancy (active disease or metastases to other organs).

2- Patients with serious failure of the function of important organs (heart, liver, lung, and kidney).

3- Patients with hilum lesions and companied by larger cavity.

4- Patients with central-type pulmonary malignancies and companied by severe obstructive pneumonia, patients with cancer involving main bronchus.

5- Patients with pulmonary malignancies transferred to neck and thoracic vertebra.

6- Patients with pulmonary diffuse metastatic lesions.

7- Lesions more than 5, diameter more than 5cm.

8- Septicemia and coagulopathy (International Normalized Ratio (INR) > 1.8, or a platelet count >75,000/ml).

All patients were subjected to the following:

1- *Pre-ablation assessment and patient preparation for ablation:*

The assessments of patients who are candidates to microwave ablation were performed by the inter-

ventional radiologist in conjunction and the referring physician. The self-referred patients were assessed by a thoracic multidisciplinary tumor board including interventional radiologist, thoracic surgeons, pulmonology and medical oncology physicians.

A comprehensive clinical history was then taken including previous imaging, biopsy, operations, treatment plans and medications.

Physical examination was performed; recent imaging studies reviewed, and the indications, risks, complications and benefits of the procedure were discussed with the patients in detail.

Before ablation, malignancy has to be confirmed histologically to patients whom diagnosed as early-stage primary lung cancer (non-small-cell) with no lymph node metastasis and not candidates for surgery as a result of associated comorbidity. Diagnosis is confirmed using endoscopy, transbronchial biopsy or percutaneous biopsy.

Histological confirmation is often unnecessary if lesion morphology is typical for patients with pulmonary metastases who are not candidates for curative resection of metastases or those with a limited number of pulmonary metastases, as part of palliative care.

Pre-procedural laboratory investigations including complete blood count and coagulation profile that consisted of bleeding time, Partial Thromboplastin Time (PTT) and International Normalized Ratio (INR) were performed prior to the ablation procedure.

Anticoagulant or antiplatelet medications were stopped from 3 days to one week before the procedure to avoid the risk of bleeding. Repeat coagulation profile studies were performed before the procedure to verify normal coagulation prior the ablation procedure. Prophylactic antibiotics were not routinely given.

Patients underwent CT scanning in the supine position immediately before treatment to confirm the number and size of lesions. The ablation parameters, including applicator length, and number, as well as the position of the patient and site of puncture, were planned on the basis of tumor size and anatomical location.

2- *Microwave ablation procedure:*

Lung microwave ablations were performed using CT fluoroscopic guidance (Somatom Sensation 64; Siemens, Erlangen, Germany using the following parameters: 5-mm collimation, 30mAs, 120kV, and 5-mm section thickness) with Covidien microwave system "EmprintTM Ablation System with ThermosphereTM Technology, Medtronic, USA".

The ablation procedure was performed under complete aseptic conditions. Combination sedation and analgesia with fentanyl citrate (1 [redacted] per kilogram of body weight) and midazolam hydrochloride (0.010-0.035mg/kg) were administered in a stepwise fashion under guidance of the interventionist until the patient was drowsy and tolerating the pain associated the ablation procedure.

Continuous electrocardiography, pulse oximetry, and blood pressure monitoring was done throughout the procedure.

The patient was positioned on the CT table according to the location of the lesion to achieve the shortest accessible path to the lesion in the position most tolerable to the patient either in supine, prone or lateral position.

Pre-ablation CT chest without contrast was done to locate the lesion to be ablated.

All ablation procedures were performed by using microwave antennae (shaft length, 15, 20 or 30cm; radiating section, 3.7cm). Ablation time was recorded for all procedures. The antenna was introduced in a stepwise manner achieving an optimal zone of overlapping ablation ensuring that there was an adequate safety margin around the ablated lesions. The duration of ablation ranged from 5-30 minutes.

The Covidien microwave applicators (antennae) were applied through a single pleural puncture. Applicator location was visualized by using CT fluoroscopy to ensure optimal positioning of the radiating part of the antennae within the lesion.

The criteria for optimal entrance planning were based on the location of the lesion and its relation to the pleura, major bronchi, and pulmonary blood vessels. Adequate skin disinfection of the area of skin entry was performed, followed by injection of 10ml of local anaesthetic 0.5% mepivacaine (Scandicain, AstraZeneca, Wedel, Germany).

Periodic CT fluoroscopic scanning of the tumor was performed to reassess adequate positioning of the applicator and to monitor associated complications. Treatment was continued as long as required and safely tolerated. If complications occurred because of the microwave ablation, the severity and extent of the complications determined termi-

nation of the ablation session and appropriate intervention if required.

To prevent seeding of malignant cells in the needle track during removal of the needle electrode and to induce local hemostasis of the electrode track, needle track coagulation was routinely performed at the end of the procedure using ablation thermal energy during withdrawing the needle Figs. (3,4).

3- *Post ablation follow-up protocol:*

- A spiral control CT of the thorax immediately following the intervention serves directly for the final evaluation and for the detection of possible complications.
- A thorax radiograph in two positions was performed 6h after the procedure.
- Follow-up CT was performed at the following periods:
  - a- 24h post ablation: As the first control study post ablation to assess further morphological changes, and in order to exclude remote post ablation complications before patient discharge.
  - b- 4-6 weeks post ablations.
  - c- 3, 6, 9- and 12-months post ablation and finally at 6-months intervals using multi-detector row helical CT scanner (SOMATOM Sensation 64, Siemens, Erlangen, Germany; 30mAs/120 kV/5mm slice thickness).

Both unenhanced and contrast material enhanced chest CT scanning was performed. CT protocol was: (100mL of Omnipaque was administered at a flow rate of 2-3mL/sec. Image acquisition began 30 seconds after contrast agent injection).

- Patients with unclear response were additionally evaluated using PET-CT to determine and exclude any residual metabolic activity in the ablation bed.
- Response to treatment is considered when the ablated lesion decreased in size over time with no contrast uptake and local progression either due to residual or recurrent disease was considered when the lesion became of larger size or expressed morphological changes in its shape such as protrusion or, irregular, nodular or eccentric focus arising from the margin in addition to denovo focus showing contrast uptake (>15HU). A thin symmetric rim of peripheral enhancement of less than 5mm wide observed up to 6 months after ablation was considered a sign of benign peritumoral enhancement. This determining factor was based on evaluating parameters used by previous lung ablation studies in our hospital and from different institutes.

4- *Re-ablation of lesions failed after initial ablation:*

Re-ablation of lesions that did not respond to initial microwave ablation therapy was performed after clinical justification and exclusion of systemic tumor spread. Re-ablation of the initially non-responsive lesions was performed between 1 month and 12 months after the initial ablation. Re-ablation was performed in 4 lesions out of 8 failed lesions post MWA. Secondary tumor control post re-ablation revealed 50% (2/4) secondary success rate post MW ablation with no evidence of tumor residual or recurrence within 3 to 9 month follow-up period after re-ablation.

Statistical analysis:

- Analysis of data was done using SPSS version (SPSS version 25) (Statistical Package for the Social Sciences) (IBM, 2017).
- Radiological evaluation of pre-procedural, intra-procedural, and post-procedural CT images was done. The minimum follow-up period for all patients involved in the study was 6 months.
- Survival times were calculated using the Kaplan-Meier.
- The log-rank test (Cox-Mantel χ^2 value) was used to determine the significance of differences between patient survival rates.
- p-value of less than 0.05 was considered to indicate a statistically significant difference for all analyses.

Results

A total of 40 patients with 52 lung malignant lesions were included in this study (Table 3). They were 9 primary and 43 metastatic lesions (Table 4). Forty-four lesions (84.6%) showed complete response to treatment and eight lesions (15.4%) had local progression (residual activity) during the follow-up period ranging from 6 to 36 months (Table 5), Figs. (3,4).

The median time to local tumor progression was 8.3 months. The overall median survival was 32 months for patient underwent MWA according to the Kaplan-Meier test. The overall survival rate at 1, 2, and 3 years was 97.5%, 90%, and 82.5%, respectively (Table 6) & Fig. (5).

The median survival time for local control group was 32 months. The median survival time for local progression group was 26 months.

The survival rate is significantly higher with local control group than local progression group using Log Rank test (p=0.025) Fig. (6).

Successful tumor ablation was significantly more frequent for lesions with a maximal axial diameter of 3cm or smaller than for lesions greater than 3cm in maximal axial diameter (p=.018). (Table 7).

There was a statistically significant relation between the mean volume of lesions before ablation and treatment outcome post ablation with larger tumor volume before ablation in local progression group than responsive group (0.028) (Table 8). Also there was significant relation between lesion location in relation to lung hilum and treatment outcome with better outcome seen in peripheral lesions (p=0.019) (Table 9).

There was no significant relation between lesion location in relation to pulmonary vessels and the shape of the lesions before ablation with treatment outcome (p=0.341 & p=0.168 respectively) (Tables 10,11).There was no significant relation between different pathological type of primary or secondary pulmonary tumor and treatment outcome (Table 12).

Early postablation complications included pneumothorax (13.5%), pulmonary hemorrhage (9.6%) and postablation syndrome (3.85%), Pleural Effusion (3.85%), Hemoptysis (3.85%). There were no deaths during the procedure and the mortality rate within 6 months after ablation was 0%. No significant long-term complications were seen (Table 13). Conservative management was done in 4 cases & manual evacuation was done in 3 cases out of 7 sessions complicated by pneumothorax and no intercostal tube was inserted (Table 14).

There was significant risk factors associated with development of pneumothorax during ablation procedure as patient age with more liability in patients above 60 years (p=0.027), comorbid lung disease as emphysema (p=0.041), preablation tumor size with more occurrence of pneumothorax in lesions of tumor size <3cm (p=0.016), location of lesions with high incidence in lower lung lesions (p=0.045) and needle track traversing aerated lung parenchyma for a distance >2.6cm (p=0.018) and traversing a major pulmonary fissure by ablation needle (p=0.036) (Table 15).

Table (1): Gender distribution of studied patients.

Gender	Frequency	Percent
Male	19	47.5
Female	21	52.5
Total	40	100.0

Table (2): Age distribution of studied patients.

Age	Frequency	Percent
31-40	2	5
50-41	5	12.5
60-51	6	15
70-61	13	32.5
80-71	11	27.5
81-90	3	7.5
Total	40	100

Table (3): Number of lesions per patient.

Number of lesions	Patients number	Total lesions
Single lesion	32	32
Two lesions	4	8
Three lesions	4	12
Total	40	52

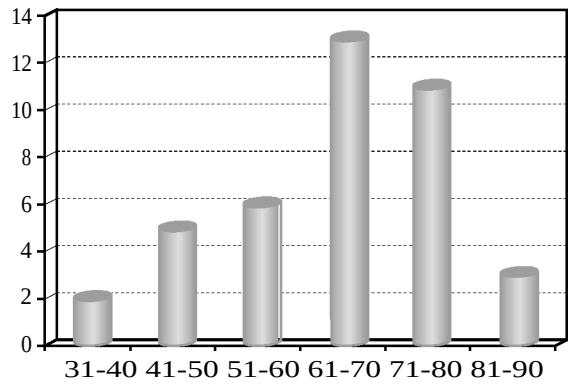

Fig. (1): Age distribution of studied patients.

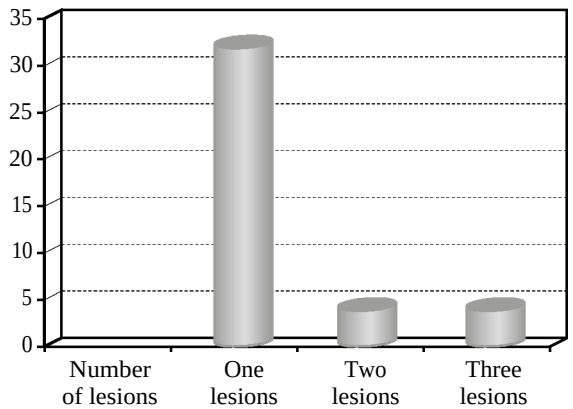

Fig. (2): The number of lesions per patients.

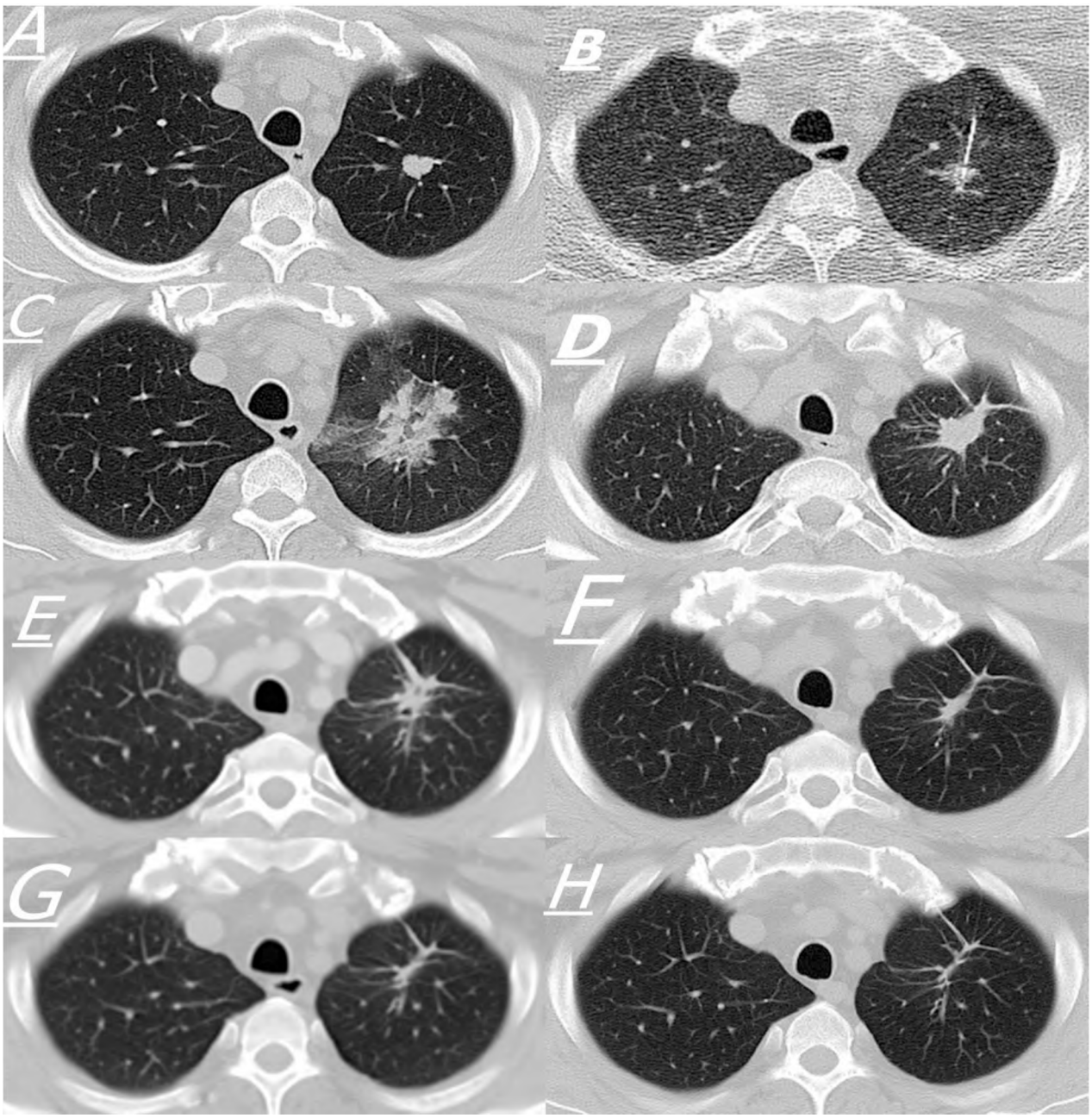

Fig. (3): (A-H): Microwave ablation of lung metastases from renal cell carcinoma in 69 years old male patient. (A) Left upper lung lesion measuring 1.1 X 1.4cm. (B) Ablation needle inside the lesion during microwave ablation process. (C) Ablation zone 24 hours after microwave ablation in the form of ground glass opacity exceeding the lesion with safety margin. (D-H) Serial CT images at 1, 3, 6, 9, 12 months after ablation respectively after ablation showing regression of lesion with progressive scaring denoting complete resolution.

Table (4): Type of lesion: (Primary or secondary).

Type of lesion	Frequency	Percent
Primary	9	17.3
Metastatic	43	82.7
Total	52	100.0

Table (5): Treatment outcome.

Outcome	Frequency	Percent
• Local tumor response (control)	44	84.6
• Local tumor progression (recurrence or residue)	8	15.4
Total	52	100.0

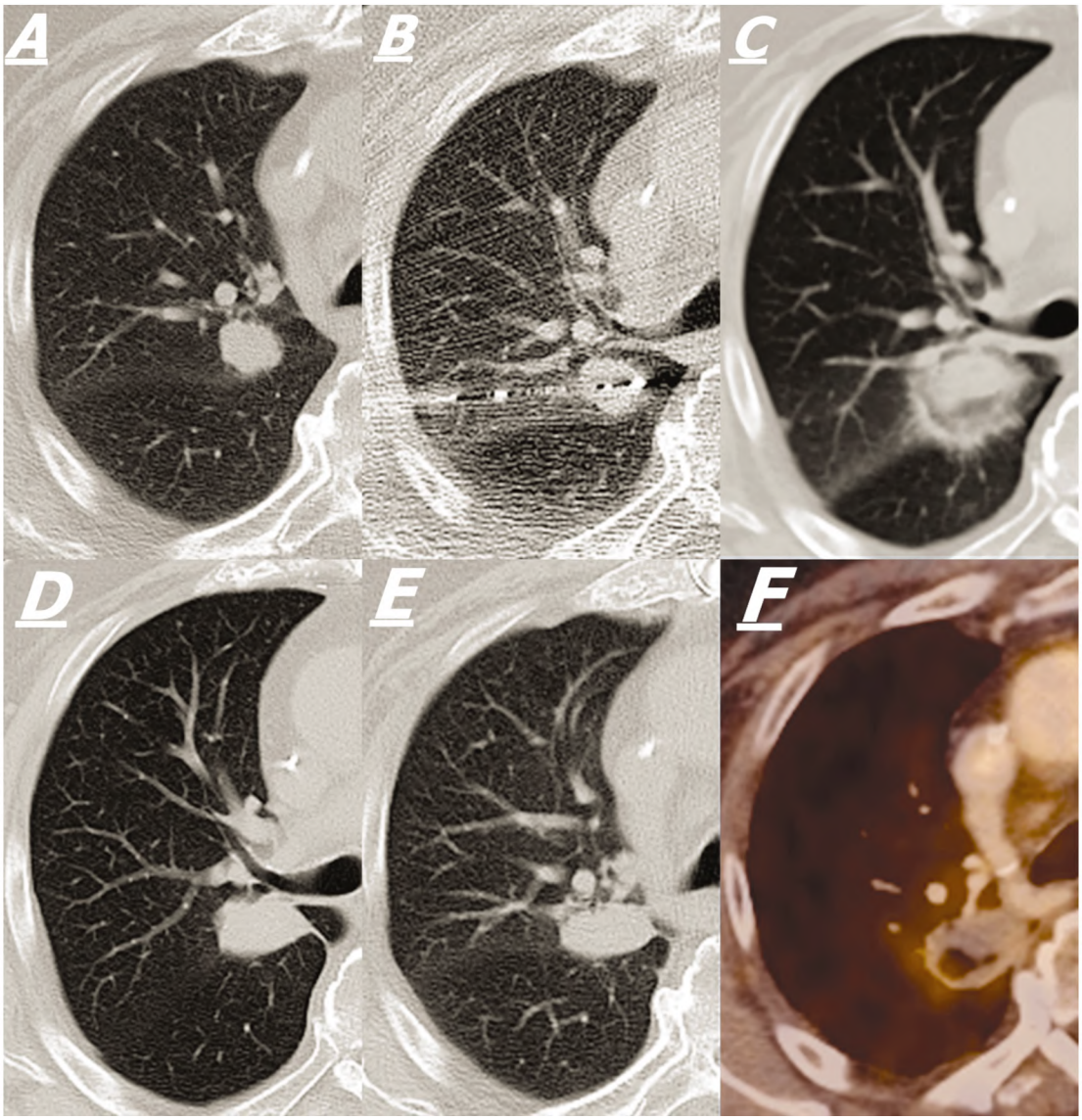

Fig. (4): (A-F): Microwave ablation of colorectal metastases of 75 years old male. (A) CT image show lesion measuring 2.1 X 2cm seen posterior segment right upper lung lobe. (B) Ablation needle inside lesion during ablation procedure. (C) Ablation zone of ground glass opacity covering the lesion. (D) CT follow-up after 3 months showing no contrast enhancement of the lesion. (E) CT follow-up after 3 months showing no contrast enhancement of the lesion. (F) PET-CT scan after 9 months showing no metabolic activity of ablated lesion denoting complete response.

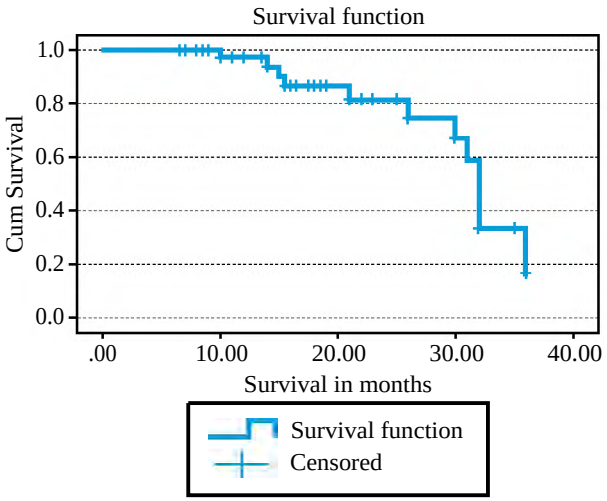

Fig. (5): Kaplan-Meier curve of the overall survival rate of all patients treated with MWA.

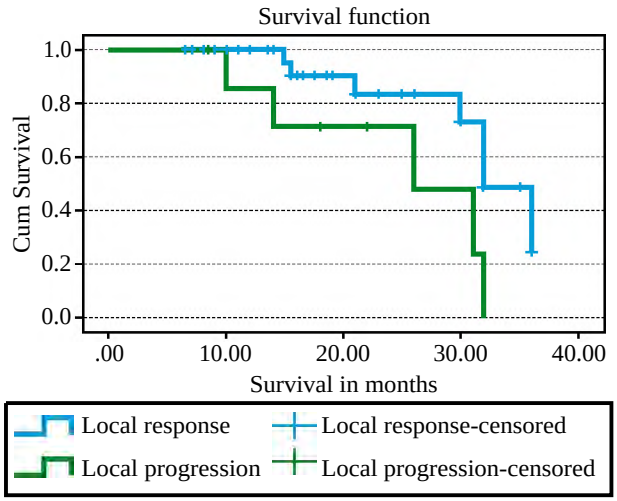

Fig. (6): Kaplan-Meier curve of the survival rate of local response (Blue line) and local progression (Green line) groups treated with MWA.

Table (6): Means and medians for survival time.

Local control	Mean[a]				Median			
	Estimate	Std. Error	95% confidence interval		Estimate	Std. Error	95% confidence interval	
			Lower Bound	Upper Bound			Lower Bound	Upper Bound
Local response	31.379	1.740	27.790	34.789	32.000	2.018	28.054	35.946
Local progression	24.619	3.611	17.541	31.698	26.000	8.042	10.273	41.763
Overall	29.683	1.569	26.609	32.758	32.000	.521	30.979	33.021

a: Estimation is limited to the largest survival time if it is censored.

Table (7): Size of lesions before ablation.

Size range	Treatment outcome		*p*-value
	Local response	Local tumor progression	
Less than 3cm	41	3	0.018*
3 to 5cm	3	5	
Total	44	8	52

Table (8): Volume of lesions before ablation.

	Treatment outcome		*p*-value
	Local response	Local tumor progression	
Mean tumor volume (cc)	1.2	4.8	0.028*
Range of tumor volume (cc)	0.1-13.9	0.3-61.3	

Table (9): Location in relation to lung hilum.

	Treatment outcome		*p*-value
	Local response	Local tumor progression	
Central	2	5	0.019*
Peripheral	42	3	
Total	44	8	52

Table (10): Location in relation to pulmonary vessels.

Relation to pulmonary vessels (within 5mm)	Treatment outcome		*p*-value
	Local response	Local tumor progression	
No	29	5	0.341
Yes	15	3	
Total	44	8	52

Table (11): Shape of the lesions.

Tumor margin	Treatment outcome		*p*-value
	Local response	Local tumor progression	
Coarse irregular	28	5	0.186
Fine irregular	16	3	
Total	44	8	52

Table (12): Pathology of different types of pulmonary lesions and its influence on ablation outcome.

Tumor type	Treatment outcome		Total	*p*-value
	Local response	Local tumor progression		
Bronchial carcinoma	8	1	9	0.41
Colon carcinoma	17	2	19	0.42
Breast carcinoma	8	2	10	0.34
HCC	5	1	6	0.41
RCC	3	1	4	0.39
Endometrial carcinoma	2	0	2	0.51
Parotid adenocarcinoma	1	1	2	0.68
Total	44	8	52	

Table (13): Complications occurred during the microwave ablation therapy.

Complication	Frequency per session	Percent
Pneumothorax:	(7/52)	(13.5)
Mild	4/7	57.1
Moderate	3/7	42.9
Severe	0/9	0.0
Pulmonary hemorrhage	(5/52)	9.6
Pleural effusion	(2/52)	3.85
Hemoptysis	(1/52)	1.9
Surgical emphysema	(1/52)	1.9
Postablation syndrome	(1/52)	1.9
Pulmonary infection	(0/52)	0.0
Burn at the site of the ablation punctures	(0/52)	0.0
Death during the procedure	(0/52)	0.0
Total ablation session with complication	(17/52)	32.65

Table (14): Management of pneumothorax complicating ablation therapy.

Management method	Frequency	Percent
Conservative management	(4/7)	57.1
Manual evacuation	(3/7)	42.9
Intercostal chest tube	(0/9)	0.0

Table (15): Risk factors for development of pneumothorax in patients treated by MWA.

Risk factors	Pneumothorax		*p* value
	Yes	No	
Age:			
>60	5	22	0.027*
<60	2	11	
Gender:			
Male	4	15	0.43
Female	3	18	
Underlying emphysema:			
Yes	4	19	0.041*
No	3	26	
Tumor size:			
<3cm	4	40	0.016*
>3cm	3	5	
Tumor location:			
Upper lung zone	2	27	0.045*
Lower & middle zones	5	18	
Ablation track length traversing aerated lung:			
0-2.5cm	2	39	0.018*
>2.6cm	5	6	
Ablation needle traversing major pulmonary fissure:			
Yes	2	1	0.036*
No	5	45	

Discussion

Lung cancer is a major cause of cancer-related death worldwide. Lobectomy is the standard treatment for early stage lung cancer. However, many patients with lung cancers are not fit for lobectomy because of poor pulmonary reserve, associated comorbidities, or other risk factors **[11]**. These patients are usually treated in a multidisciplinary fashion, with systemic therapies and radiation therapy being the most commonly used modalities. However, all these treatments rarely provide a cure or good long-term survival outcomes **[12]**.

Recently, many studies have adopted thermal ablation, including RFA and MWA, for treatment of tumors. Kwan et al., reported no difference in Overall Survival (OS) following sub-lobar resection or thermal ablation for comparable elderly patients with stage I non-small cell lung cancer **[11]**.

Several studies have evaluated the safety and efficacy of CT-guided MWA in lung cancer patients **[12]**. This procedure is now proved to be an important tool in the treatment of primary and secondary lung tumors which offers patients a repeatable, effective, safe and low-cost treatment for lung malignancies either after or concurrently with radiotherapy or systemic therapy. The NSCLC guideline published by National Comprehensive Cancer Network (NCCN) recently suggested that ablation could be an option for patients with unresectable stage IA NSCLC, selected patients with multiple pulmonary lesions and those with tumor recurrence in the lung **[13]**.

Both microwave and Radiofrequency ablations have same benefits, however MWA has some more advantages including; less time needed for procedure, higher temperature for target lesions, cellular necrosis volumes are bigger, option to use multiple antennae, accessibility to lesions in proximity to vascular structures less than 3mm in diameter and/or having cystic components with less incidence of the heat-sink effect as well as less intraprocedural pain **[14]**.

In our prospective study, we revealed the safety, efficacy, and prognostic value of MWA for treatment of inoperable lung tumors and whether lesions characteristics can affect the ablation efficacy/ success rate or not through prospective approach.

In the current study about 84.4% of the ablated lesions showed complete local response while 15.6% of lesions showed local tumor progression either due to due to tumor residue or recurrence. Ierardi et al., showed that 29% (9/31) of lesions showed local recurrence after treatment on follow-up with the rest of lesions 71% (22/31) showed no residual tissue on follow-up **[14]**. Also, Vogl et al., stated that 73.1% (95/130) of lesions showed complete successful ablation while 26.9% (35/130) of lesions had failed ablation either related to residual tumor or recurrent disease during follow-up **[15]**. In their study on 69 patients, Lu et al., showed local progression occurred in 15 cases (21.74%) on his study in 69 cases with pulmonary malignancy **[16]**. Also, Zheng et al., found that the local progression rate was 19.1% (35 of 183) during their retrospective study of MWA in 183 patients **[17]**. Healey et al., found among the 108 patients with single lung malignancy, that primary technical success was achieved in 80% (n=86) while the 22 patients had residual tumor on follow-up **[18]**.

The percentage of progressive disease in our study and these other studies is more or less the same. In the other hand the complete local tumor response showed difference in percentage of lesions achieving complete response among different studies, this can be due to difference in assessment methods of defining local tumor response as in our study it is considered mainly with change in ablated

lesions morphological characters not only according to contrast enhancement of the tissue.

The mean time of tumor progression/detection was 8.3 months (range: 3-12 months). The median survival rate of the patients who underwent MWA was 32 months. No procedure related mortality occurred. The overall one, two, three years survival rates were 97.5%, 90% and 82.5% respectively. Higher survival rates were detected in patients with tumor free-state after successful ablation and local tumor control in comparison to patients with local progression. This difference in survival rates was statistically significant (p=0.038). This may reflect the clinical significance of ablation therapy of pulmonary neoplasms in the improvement of patients' survival.

The current study showed that there was no statistically significant relation between the ablation outcome and both of tumor origin either primary or metastatic as well as the pathological type of metastatic disease and this conclusion is supported by Vogl et al., Healey et al., and Ierardi et al., as they also found no significant relation between pathological type of pulmonary tumor and treatment outcome. Perhaps this attributed to the inclusion of multiple histopathologic subgroups with a small sample size of some histopathologic types **[14,15,18]**.

The results of the microwave ablation procedure were primarily determined by the preablation lesion size. The primary determinant for successful ablation is the achievement of an adequate ablation zone and associated safety margins. This is to ensure eradication of marginal microscopic tumor infiltration in the surrounding parenchyma **[15]**.

In the current study about 84.6% of the ablated lesions were less than or equal to 3cm in size while 15.4% of ablated lesions were from 3 to 5cm in size and this result are the same as that of Vogl et al., 2011 on microwave ablation of pulmonary metastases, which showed that 84.6% ablated lesions were less 3cm in size **[15]**. Also, Maxwell et al., reported that 80% ablated lesions were up to 3cm **[19]**.

Our results together with these studies showed that higher percentage of pulmonary lesions were less than or equal to 3cm in size but differ in the percentage that could be attributed to the difference in sample size in each individual study. Moreover, we found significant relation between pre-ablation lesion size and treatment outcome (p=0.018) with successful tumor ablation was significant statistically higher with lesions of maximal axial diameter up to 3cm (93.2%) in comparison to lesions of more than 3cm in maximal axial diameter (37.5%) and this was the same finding of these forementhioned studies. This may reflect that, the achievement of an adequate ablation zone covering the whole lesion including a safety margins is extremely important to ensure adequate ablation of lung lesions.

Central and perihilar lesions had a significantly higher incidence of recurrence after ablation. This could be attributed to the "current-sink effect" caused by pulmonary arteries, which are larger and more aggregated at the hilum or the center of the lung **[15]**.

In the current study about 86.5% of the lesions were peripherally located and 13.5% of the lesions are centrally located in relation to lung hilum with a statically significant relation between lesion location in relation to lung hilum and treatment outcome (p=0.019) with better outcome seen in peripheral lesions (93.3%) than central lesions (28.6%).

Vogl et al., showed that 77% were peripherally located while 23% were centrally located with significant relation with ablation outcome and more successful ablation for peripheral lesions than for centrally located lesions (p=.002) **[15]**. Healey et al., stated that only 20 lesions out of the 108 lung lesions were centrally located while 28 were middle and 59 peripheral masses **[18]**.

These studies together with our study concluded that most of ablated lesions were peripherally located with statistically significant relation with treatment outcome beside difference in percentage between studies and difference in individual lung preference.

Although side effects and complications related to percutaneous thermal ablation can occur **[20]**, in the present study MWA related complications were observed in 32.65% of cases, none of which were considered life threatening for the patients. This data reinforces the concept that MWA of lung tumors is a safe procedure when performed by trained experts.

In most large studies the incidence of pneumothorax after MWA vary widely, ranging between 8.5-63% and are similar to those reported after RFA, ranging between 11% and 67% **[15,21-27]**. In our study 13.5% (7/52) of sessions were complicated by pneumothorax during MWA and this going with the range results of these studies but our low percentage could be due to high experienced interventional radiologists whom did the procedure as

well as for good selection of cases through our multidisciplinary tumor team and considering the technique low invasive one.

There have been various studies that described the management of pneumothorax complicating a variety of thoracic interventions, particularly lung biopsy and thoracic ablation therapy **[22,28-32]**.

Our cases were managed conservatively and with manual air evacuation by 5F or 10F catheters, but no intercostal tube was placed. The main cause for pneumothorax seems to be associated with the insertion of the antenna and not with the thermal effect of the ablation **[33]**.

In the current study, significant risk factors associated with the development of pneumothorax, they were: (A) Age of more than 60 years, (B) Underlying emphysema, (C) Lesions smaller than 3cm, (D) Basal pulmonary lesions, (E) Traversing aerated lung parenchyma in the needle track for a distance >2.6cm, and (F) Crossing a major pulmonary fissure in the track of ablation. These results are comparable to other studies, who agreed that tumors located in the lower parts of the lungs (higher mobility), the traversal of lung fissures and lung emphysema are also associated with an increased pneumothorax risk **[26,34-36]**.

Delayed pneumothorax should be guarded adequately post ablation. However, we didn't experience any delayed pneumothorax post MWA.

Pulmonary hemorrhage can occur by damaging an intrapulmonary or intercostal blood vessel. An intrapulmonary hemorrhage appears as a rapidly expanding GGO starting from the antenna and can be associated with hemoptysis; however, the hemorrhage is usually self-limiting, and no action is needed **[33]**. In the current study; only 9.6% of patient had peri-procedural pulmonary hemorrhage. They were self-limited and didn't need intervention.

This study had some limitations; the small sample size, the studied patients is heterogeneous, including primary and metastatic pulmonary tumors with variable histological types and tumor dimensions which may affect ablation outcome in addition to the short time of study with short imaging follow-up despite being prospective in nature which may affect the survival results of patients.

Conclusion:

Microwave ablation therapy is a safe effective minimally invasive tool for treatment of pulmonary tumors and considered a useful option in the multimodality treatment of patients with in-operable lung cancer. Compared to RFA, it creates larger, more spherical and less time-consuming ablation zones and is less susceptible to the heat sink effect with same complication rate. The efficacy of treatment is determined mainly by preablation tumor size and location in relation to the hilum.

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دور الإجتثاث بالميكروويف فى علاج آورام الرئة

المقدمة: يعتبر سرطان الرئة من الآسباب الرئيسية للوفاة ويعتبر إستئصال جزء من الرئة جراحياً الحل المثالى لعلاج سرطان الرئة. للآسف ١٥٪ من المرضى لا يمكن علاجهم جراحياً. كما آنه تقريباً ٢٥-٣٠٪ من وفيات السرطان بسبب سرطان الرئة. يعتبر العلاج الإشعاعى بديلاً للجراحة لكن ١٥-٢٠٪ فقط من المرضى يعيشون لمدة ٥ سنوات. العلاج بالكى الحرارى يعتبر حل رائع لعلاج سرطان الرئة وبديل مناسب للمرضى الذين لا يمكن التدخل فيهم جراحياً آو يعانون من قصور فى وظائف القلب والرئة. يعتبر علاج سرطان الرئة بالحرق الحرارى من الطرق الحديثة الواعدة. تستخدم آجهزة الميكروويف الموجات الكهرومغناطيسية لحرق الآورام بمساحة آكبر وكفاءة آعلى مقارنة بالتردد الحرارى ويعتبر الكى بالميكروويف من الطرق الآمنة ذات المضاعفات القليلة لعلاج سرطان الرئة والتى تحسن معدلات الحياة لدى هؤلاء المرضى.

الهدف من البحث: يهدف البحث إلى تقييم إستخدام الكى بالميكروويف فى علاج سرطان الرئة.

المواد وطرق البحث: آجريت هذه الدراسة بقسم الآشعة بمستشفيات جامعة جوته - فرانكفورت - آلمانيا الإتحادية للمرضى الذين يعانون من آورام الرئة ولا يمكن علاجهم جراحياً.

النتيجة: وجد آن الكى بالميكروويف مؤثر وفعال فى علاج سرطان الرئة الذى لا يمكن علاجه جراحياً مع معدل قليل من المضاعفات غير الخطيرة ويعتبر حجم الورم قبل الكى وكذلك موقعة فى الرئة من آهم العوامل التى تحدد نسبة نجاح العلاج.