NATIONAL INSTITUTE FOR HEALTH AND CARE EXCELLENCE

INTERVENTIONAL PROCEDURES PROGRAMME

Interventional procedure overview of microwave ablation for primary or metastatic cancer in the lung

Cancer can start in the lung (primary) or spread to it from another part of the body (metastatic). In this procedure, a probe is inserted into the lung, directly through the skin of the chest, to send microwaves into the cancer cells. This produces heat, aiming to destroy the cancer (ablation).

Contents

Abbreviations

Word or phrase	Abbreviation
Adjacent lobe invasion	ALI
Confidence interval	CI
Computerised tomography	CT
Fluorodeoxyglucose	FDG
Microwave ablation	MWA
Non-small cell lung cancer	NSCLC
Odds ratio	OR
Radiofrequency ablation	RFA
Visual analogue score	VAS
Standard deviation	SD

Introduction

The National Institute for Health and Care Excellence (NICE) prepared this interventional procedure overview to help members of the interventional procedures advisory committee (IPAC) make recommendations about the safety and efficacy of an interventional procedure. It is based on a rapid review of the medical literature and professional opinion. It should not be regarded as a definitive assessment of the procedure.

Date prepared

This overview was prepared in March 2021 and updated in September 2021.

Procedure name

- Microwave ablation for primary or metastatic cancer in the lung

Professional societies

- British Society of Interventional Radiology
    - Interventional Oncology United Kingdom

- British Thoracic Society
- Royal College of Radiologists
    - Faculty of Clinical Oncology
    - Faculty of Clinical Radiology
- Society of Cardiothoracic Surgeons of Great Britain and Ireland.

Description of the procedure

Indications and current treatment

Lung cancer is one of the most common types of cancer. The symptoms often do not appear until the disease is at an advanced stage, and the prognosis is generally poor. Cancer that begins in the lungs is called primary lung cancer. There are 2 main types of primary lung cancer: small-cell lung cancer (which is fast growing and can spread quickly) and non-small-cell lung cancer (which usually grows and spreads slowly; this includes squamous cell carcinoma, adenocarcinoma and large-cell carcinoma).

Cancer that starts in one part of the body and spreads via the blood stream to the lungs is known as secondary lung cancer (also called metastatic lung cancer or lung metastasis). Common tumours that metastasise to the lungs include breast cancer, colon cancer, prostate cancer, sarcoma, bladder cancer, neuroblastoma and Wilm's tumour.

NICE's guideline on lung cancer describes the treatment of non-small-cell and small-cell lung cancer. The choice of treatment for primary or metastatic cancer in the lung depends on the type, size, position and stage of the cancer, and the patient's overall health. Common treatments for primary or metastatic cancer in the lung include surgery, chemotherapy, radiotherapy, or a combination of these. Other treatments include photodynamic therapy, thermal ablation, immunotherapy, and biological therapy.

What the procedure involves

The procedure is usually done using general anaesthesia, and occasionally using local anaesthesia and sedation. Under imaging guidance, a small probe is advanced through the chest wall and into each targeted lesion. It then delivers high-frequency microwave energy to rapidly agitate water molecules in the tissues. This converts energy into heat, which causes tumour necrosis. Patients with larger tumours or multiple lesions may have multiple pulses of energy delivered within a treatment session or have a staged treatment with multiple sessions.

This procedure aims to destroy tumour cells and create localised areas of tissue necrosis with minimal damage to surrounding normal tissues. Microwave ablation is a minimally invasive procedure with most procedures lasting 1 to 2 hours with only 5 to 10 minutes of active ablation time.

Efficacy summary

Overall survival

Overall survival rate

In a meta-analysis of 3,432 patients (53 studies) with primary and metastatic lung cancer (all stages) undergoing MWA or RFA, the estimated overall survival rates were statistically significantly lower in patients who had MWA than patients who had RFA at:

- 1 year (79% [95% CI 73.7% to 85.0%, I^2=37.7%; 6 studies] compared with 89% [95% CI 85.8% to 92.6%, I^2=75.0%; 25 studies], p=0.003)
- 2 years (52% [95% CI 46.2% to 57.5%, I^2=0.0%; 6 studies] compared with 68% [95% CI 60.6% to 76.1%, I^2=87.0%; 24 studies], p=0.001)
- 3 years (35% [95% CI 26.8% to 42.5%, I^2=7.6%; 3 studies] compared with 56% [95% CI 47.3% to 64.6%, I^2=82.5%; 24 studies], p<0.001)
- 4 years (31% [95% CI 22.9% to 38.8%, I^2=0.0%; 2 studies] compared with 46% [95% CI 36.1% to 55.0%, I^2=64.9%; 13 studies], p=0.020)
- 5 years (16% [95% CI 0 to 35.5%, 1 study] compared with 41% [95% CI 27.3% to 55.2%, I^2=91.0%; 16 studies], p=0.039) (Yuan 2019).

In a systematic review and meta-analysis of 565 patients (7 studies) with primary and metastatic lung tumours (stages 1 to 4) undergoing MWA or RFA, there were no statistically significant differences in the overall survival rates between the MWA and RFA groups at:

- 1 year (OR 0.95 [95% CI 0.63 to 1.44], I^2=7%; 7 studies)
- 2 years (OR 1.00 [95% CI 0.70 to 1.44], I^2=66%; 6 studies)
- 3 years (OR 0.71 [95% CI 0.42 to 1.18], I^2=0%; 5 studies) (Sun 2018).

In a non-randomised comparative study of 101 patients with NSCLC (stages 3b and 4) undergoing MWA or cryoablation, the cumulative overall survival rates at 1, 2 and 3 years were 79%, 52% and 36% for the MWA group and 73%, 40% and 22% for the cryoablation group (Das 2020).

In a non-randomised comparative study of 162 patients with NSCLC (stage 1) undergoing MWA or lobectomy, the overall survival rates at 1, 3 and 5 years after treatment were 100%, 93% and 50% for the MWA group and 100%, 91% and 46% for the lobectomy group (Yao 2018). For all patients, the overall survival was statistically significantly worse with a tumour that was 3 to 5 cm compared with less than 3 cm (p<0.0001) and stage Ib compared with stage 1a (p<0.0001).

In a non-randomised comparative study of 223 patients with NSCLC (stage 1) adjacent to the pericardium (within 1.0 cm from the pericardium according to CT scans) undergoing MWA or wedge resection, the overall survival rates at 1, 3 and 5 years were 92%, 63% and 55% for the MWA group (n=68) and 98%, 84% and 73% for the wedge resection group (n=155) (Hu 2021). After propensity matching, the overall survival rates at 1, 3 and 5 years were 90%, 60% and 55% for the MWA group (n=56) and 100%, 81% and 72% for the wedge resection group (n=56). The differences between the 2 groups were statistically significant before (p<0.001) and after propensity matching (p=0.047). Multivariate analysis of 223 patients showed that T1bN0 stage (HR, 0.506; 95% CI, 0.264 to 0.971; p=0.04), distance from pericardium (HR, 0.192; 95% CI, 0.090 to 0.412; p=0.001) and tumour size (HR, 2.024; 95% CI, 1.038 to 3.948; p=0.039) were independent prognostic factors for a poor overall survival.

In a non-randomised comparative study of 317 patients with NSCLC who had MWA, the overall survival rate at a mean follow-up of 27.2 months was 68% (13/19) in patients with cavitary NSCLC and 57% (171/298) in patients with noncavitary NSCLC (p=0.344; Xu 2021a).

In a non-randomised comparative study of 319 patients with NSCLC who had MWA, the overall survival rate at a mean follow-up of 27.2 months was 47% (16/34) in patients with ALI-NSCLC and 59% (169/285) in patients with non-ALI NSCLC (p=0.172; Xu 2021b).

Overall survival

In the meta-analysis of 3,432 patients (53 studies) who had MWA or RFA, the median overall survival was 25.6 months (95% CI 19.4 to 31.8 months; I^2=91.7%, p<0.001; 6 studies) for the MWA group and 30.9 months (95% CI 26.4 to 35.5 months; I^2=94.1%, p<0.001; 19 studies) for the RFA group (Yuan 2019). The difference between groups was not statistically significant. For pulmonary metastases, the median overall survival was statistically significantly shorter for patients who had MWA (18.7 months [95% CI 12.1 to 25.3 months; 1 study]) than patients who had RFA (34.8 months [95% CI 27.6 to 42.1 months; I^2=57.9%, p=0.027; 7 studies]; p=0.001). For primary lung cancer, there was no statistically significant difference in the median overall survival between the MWA group (24.4 months, 95% CI 16.9 to 31.8 months; I^2=93.5%, p<0.001; 6 studies) and the RFA group (28.4 months, 95% CI 20.9 to 35.8 months; I^2=91.8%, p<0.001; 8 studies).

In the non-randomised comparative study of 101 patients who had MWA or cryoablation, the median overall survival was 27.5 months (95% CI 22.8 to 31.2 months) for the MWA group and 18.0 months (95% CI 12.5 to 23.5 months) for the cryoablation group; the difference was not statistically significant between groups (p=0.07) (Das 2020). For patients with tumour diameter ≤3.0 cm, the median overall survival was 30.0 months in the MWA group and 26.5 months in the cryoablation group (p=0.39). For patients with tumour diameter more than 3.0 cm, the median overall survival was 24.5 months and 14.5 months, respectively (p=0.04).

In the non-randomised comparative study of 162 patients who had MWA or lobectomy, there was no statistically significant difference in the mean overall survival between the MWA and lobectomy groups (5.97±0.33 years [95% CI 5.32 to 6.62 years] compared with 5.81±0.26 years [95% CI 5.31 to 6.32 years], p=0.608) (Yao 2018).

In the non-randomised comparative study of 317 patients who had MWA, the median OS was 14.0 months in patients with cavitary NSCLC and 17.0 months in patients with noncavitary NSCLC (p=0.133; Xu 2021a). The Kaplan-Meier method revealed no association between the presence of cavities and OS in patients with NSCLC who had MWA (24.0 months compared with 36.0 months; p=0.843).

In the non-randomised comparative study of 319 patients who had MWA, the median OS was 15.5 months in patients with ALI-NSCLC and 17.0 months for patients with non-ALI NSCLC (p=0.394; Xu 2021b).

Disease- or progression-free survival

Disease- or progression-free survival rate

In the meta-analysis of 3,432 patients (53 studies) who had MWA or RFA, the estimated progression free survival rate was statistically significantly higher in the MWA group than the RFA group at 3 years (56% [95% CI 41.1% to 70.9%, 1 study] compared with 33% [95% CI 19.2% to 47.0%, I^2=87.9%; 9 studies], p=0.028) (Yuan 2019). There were no statistically significant differences in the estimated progression free survival rates between groups at 1 year (65% [95% CI 37.1% to 92.4%, I^2=88.4%; 2 studies] compared with 62% [95% CI 50.4% to

74.4%, I^2=89.7%; 12 studies], p=0.876) and 2 years (43% [95% CI 1.5% to 84.7%, I^2=94.3%; 2 studies] compared with 32% [95% CI 22.0% to 41.5%, I^2=76.3%; 10 studies], p=0.601).

In the non-randomised comparative study of 101 patients who had MWA or cryoablation, the cumulative progression-free survival rates at 1, 2 and 3 years were 41%, 18% and 7% for the MWA group, and 36%, 11% and 4% for the cryoablation group (Das 2020).

In the non-randomised comparative study of 162 patients who had MWA or lobectomy, the disease-free survival rates at 1, 3 and 5 years after treatment were 98%, 80% and 37% for the MWA group and 98%, 82% and 30% for the lobectomy group (Yao 2018).

In the non-randomised comparative study of 223 patients who had MWA or wedge resection, the progression-free survival rates at 1, 3 and 5 years were 82%, 57% and 38% for the MWA group (n=68) and 92%, 74% and 58% for the wedge resection group (n=155) (Hu 2021). After propensity matching, the progression-free survival rates at 1, 3 and 5 years were 80%, 54% and 36% for the MWA group and 89%, 66% and 56% for the wedge resection group. The differences between the 2 groups were statistically significant before (p=0.004) and after propensity matching (p=0.029). Multivariate analysis of 223 patients showed that MWA (HR, 2.26; 95% CI, 1.52 to 3.35; p<0.001), distance from pericardium (HR, 0.318; 95% CI, 0.166 to 0.608; p=0.001), and tumour size (HR, 2.045; 95% CI, 1.239 to 3.374; p=0.005) were significant factors for poor progression-free survival.

Disease- or progression-free survival

In the meta-analysis of 3,432 patients (53 studies) who had MWA or RFA, the median progression free survival was 8.4 months (95% CI 3.6 to 13.2 months; I^2=51.4%, p=0.128; 3 studies) for the MWA group and 14.6 months (95% CI 10.2 to 19.0 months; I^2=94.5%, p<0.001; 11 studies) for the RFA group (Yuan 2019).

In a non-randomised comparative study of 115 patients with primary and metastatic lung cancer undergoing MWA or RFA, there was no statistically significant difference in the mean disease-free survival between the MWA group (424.8±371.5 days) and the RFA group (333.1±313.2 days; p=0.16) (Aufranc 2019).

In the non-randomised comparative study of 101 patients who had MWA or cryoablation, the median progression-free survival was 11.0 months (95% CI 9.5 to 12.4 months) for the MWA group and 10.0 months (95% CI 7.5 to 12.4 months) for the cryoablation group; the difference was not statistically significant between groups (p=0.36) (Das 2020). For patients with tumour diameter of 3.0

cm or less, the median progression-free survival was 11.0 months for the MWA group and 13.0 months for the cryoablation group (p=0.79). For patients with tumour diameter more than 3.0 cm, the median overall survival was 10.5 months and 7.0 months, respectively (p=0.04).

In the non-randomised comparative study of 162 patients who had MWA or lobectomy, there was no statistically significant difference in the mean disease-free survival between the 2 groups (5.57±0.39 years [95% CI 4.81 to 6.34 years] compared with 5.16±0.26 years [95% CI 4.66 to 5.67 years], p=0.672) (Yao 2018).

In the non-randomised comparative study of 317 patients who had MWA, the median PSF was 9.0 months in patients with cavitary NSCLC and 13.0 months for patients with noncavitary NSCLC (p=0.180; Xu 2021a).

In the non-randomised comparative study of 319 patients who had MWA, the median PSF was 12.0 months in patients with ALI-NSCLC and 13.0 months for patients with non-ALI NSCLC (p=0.329; Xu 2021b).

Recurrence

In a systematic review of 985 (12 studies) with NSCLC and metastatic lung cancer undergoing MWA, the estimated local recurrence rates ranged from 9% to 37% (11 studies; 25% or greater in 4 studies and less than 25% in 7 studies) (Nelson 2019). Actuarial analysis showed that the local recurrence rates were 18%, 33% and 40% within 1 year in 3 studies and 12% and 34% within 2 years in 2 studies. There was a strong relationship between local recurrence rate and tumour size, and 7 studies found a statistically significantly higher likelihood of local recurrence with larger tumours, with the most frequent cut-off value being 3 cm.

In the non-randomised comparative study of 115 patients who had MWA or RFA, there were no statistically significant differences in total recurrences (33% [27/81] compared with 30% [24/79], p=0.82), local recurrences (3.7% [3/81] compared with 7.6% [6/79], p=0.32) and distant recurrences (29.6% [24/81] compared with 22.8% [18/79], p=0.42) between the MWA group (mean follow up, 471±299 days) and the RFA group (mean follow up: 505.8± 308 days) (Aufranc 2019).

In the non-randomised comparative study of 101 patients who had MWA or cryoablation, there was no statistically significant difference in the recurrence rate at the ablation sites (residual disease) at 6 months postablation between the MWA group (27%, 15/56) and the cryoablation group (24%, 11/45; p>0.05) (Das 2020). For disease progression at 3 years postablation, metastases in lobes were reported in 73% (41/56) of patients who had MWA and 76% (34/45) of patients who had cryoablation; metastases at both the ablative and a distant site were described in 13% (7/56) and 13% (6/45), respectively. The difference in disease progression rate was not statistically significant between the 2 groups.

In the non-randomised comparative study of 162 patients who had MWA or lobectomy, the local and distant recurrence rates were 11% (6/54) and 61% (33/54) of patients who had MWA and 6% (7/108) and 64% (69/108) of patients who had lobectomy (Yao 2018). There was no statistically significant difference in the recurrence rate between the 2 groups (p=0.544).

In the non-randomised comparative study of 223 patients who had MWA or wedge resection, the cumulative local tumour progression rates at 1, 2 and 5 years were 13%, 23% and 29% for the MWA group (n=68) and 4%, 5% and 5% for the wedge resection group (n=155) (Hu 2021). After propensity matching, the cumulative local tumour progression rates at 1, 2 and 5 years were 11%, 22% and 25% for the MWA group and 4%, 5% and 5% for the wedge resection group. The differences between the 2 groups were statistically significant before (p<0.001) and after propensity matching (p=0.027). In the same study, the cumulative intrapulmonary distant recurrence rates at 1, 2 and 5 years were 5%, 19% and 35% for patients who had MWA and 3%, 18% and 31% for patients who had wedge resection (Hu 2021). After propensity matching, the cumulative local tumour progression rates at 1, 2 and 5 years were 9%, 24% and 38% for the MWA group and 6%, 27% and 36% for the wedge resection group. The differences between the 2 groups were not statistically significant before (p=0.126) and after propensity matching (p=0.327).

In the non-randomised comparative study of 317 patients who had MWA, there was no statistically significant difference in the local recurrence rate at a mean follow up of 27.2 months between patients with cavitary NSCLC (16%, 3/19) and patients with noncavitary NSCLC (22%, 64/298; p=0.765; Xu 2021a).

In the non-randomised comparative study of 319 patients who had MWA, there was no statistically significant difference in the local recurrence rate at a mean follow up of 27.2 months between patients with ALI-NSCLC (29%, 10/34) and patients with non-ALI NSCLC (21%, 59/285; p=0.244; Xu 2021b).

Safety summary

Overall complications

The rate of overall complications was 21% for the MWA group and 27% for the RFA group in the systematic review of 565 patients (7 studies which compared these techniques) and the difference between the 2 groups was not statistically significant (Sun 2018).

Major complications were reported in 13% of patients (9/68) who had MWA and 19% of patients (30/155) who had wedge resection in the non-randomised comparative study of 223 patients (Hu 2021).

Overall procedure-related complications were reported in 28% (22/80) of patients in the retrospective case series of 80 patients with primary and metastatic lung cancer undergoing MWA (Li 2016). Of these complications, 41% (9/22) were considered major and 59% (13/22) minor (Li 2016).

Grade 2 complications were statistically significantly lower in patients who had MWA (11% of tumours, 9/81) than patients who had RFA (25% of tumours, 20/79; p=0.03) in the non-randomised comparative study of 115 patients (Aufranc 2019). There were no statistically significant differences in grade 1 and 3 complications between the 2 groups (grade 1 complications, 16% compared with 23%, p=0.28; grade 3 complications, 4% compared with 1%, p=0.32).

The rate of overall complications was 58% (11/19) in patients with cavitary NSCLC and 35% (103/298) in patients with noncavitary NSCLC (p=0.040) in the non-randomised comparative study of 317 patients who had MWA (Xu 2021a).

Mortality

Death was reported in 2 patients who had MWA and there were no treatment-related deaths in patients who had RFA in the meta-analysis of 3,432 patients (53 studies) (Yuan 2019).

Periprocedural mortality was reported in 1 patient (1 study) in the systematic review of 985 patients (12 studies) (Nelson 2019). This event was caused by ventricular tachycardia 2 days after the procedure.

The overall mortality rate was statistically significantly lower in the MWA group than the lobectomy group (p=0.008; exact data were not reported), especially with severe complications (p<0.0001), in the non-randomised comparative study of 162 patients (Yao 2018).

Pneumothorax

Pneumothorax was reported in 34% (95% CI 23.8% to 44.8%, n=217, at risk 760) of patients who had MWA and 34% (95% CI 25.9% to 43.1%, n=1,117, at risk=2,614) of patients who had RFA in the meta-analysis of 3,432 patients (53 studies) (Yuan 2019). Severe pneumothorax (grade 3 or 4) that needed intervention was described in 11% (95% CI 4.5% to 19.7%, n=73, at risk=587) and 12% (95% CI 6.8% to 19.1%, n=535, at risk=2,735) respectively. There were no statistically significant differences between groups (all p>0.05).

Pneumothorax was reported in 15% of patients who had MWA and 20% of patients who had RFA in the systematic review of 565 patients (7 studies) (Sun 2018).

The rates of pneumothorax that needed thoracostomy ranged from 1% to 15% in 10 studies, and in 8 of these studies the rates were between 5% and 15% in the systematic review of 985 patients (12 studies) (Nelson 2019).

Pneumothorax (excluding voluntary pneumothorax, induced to protect high-risk organs) was reported in 25% (20/81) of tumours that were treated by MWA and 41% (32/79) of tumours that were treated by RFA (p=0.049) in the non-randomised comparative study of 115 patients (Aufranc 2019). Of these events, 29 needed drainage (MWA, n=9; RFA, n=20; p=0.03).

Pneumothorax was reported in 41% (23/56) of patients who had MWA compared with 38% (17/45) of patients who had cryoablation (p=0.74) in the non-randomised comparative study of 101 patients (Das 2020). Of these events, 7 (13% of procedures) in the MWA group and 5 (11% of procedures) in the cryoablation group needed the use of a chest tube drainage.

Pneumothorax was reported in 7 patients who had MWA and no patients who had lobectomy in the non-randomised comparative study of 162 patients (Yao 2018). Of the 7 patients in the MWA group, 3 patients needed closed thoracic drainage while all had intrathoracic drainage after surgery.

Pneumothorax was reported in 16 patients in the MWA group and chest tube required at discharge in 11 patients in the wedge resection group in the non-randomised comparative study of 223 patients (Hu 2021). Of the 16 patients who developed pneumothorax in the MWA group, 5 events were classified as major complications and 11 events as self-limited pneumothorax.

Pneumothorax was reported in 13 patients after MWA in the retrospective case series of 80 patients (Li 2016). Of these 13 patients, 3 patients developed severe pneumothorax and subsequently received chest tube insertion for 5 to 6 days. They were then discharged without obvious sequelae.

Pneumothorax was reported in 39% (9/23) of patients with invasive pulmonary aspergillosis secondary to MWA in a retrospective review of lung MWA database of 1,596 patients with lung tumours (Huang 2018).

A large hydropneumothorax and left upper lobe collapse were present in 1 patient who had MWA in a case series of 6 patients with lung tumours (Harvey 2019). This patient was admitted to hospital for 8 days and had the insertion of an intercostal catheter. In the same study, infected hydropneumothorax was reported in 1 patient about 6 weeks after MWA for lung tumours. The patient had intercostal catheter insertion and a course of intravenous vancomycin and tazocin because of superimposed infection of the sero-pneumothorax. The catheter was removed 16 days after admission, and the patient discharged without residual symptoms.

Pneumothorax was reported in 58% (11/19) of patients with cavitary NSCLC and 29% (86/298) of patients with noncavitary NSCLC (p=0.008) in the non-randomised comparative study of 317 patients who had MWA (Xu 2021a).

Pneumothorax was described in 53% (18/34) of patients with ALI-NSCLC and 27% (77/285) of patients with non-ALI NSCLC (p=0.002) in the non-randomised comparative study of 319 patients who had MWA (Xu 2021b). The risk of pneumothorax increased when patients who had NSCLC also presented with ALI (hazard ratio [HR] 2.867, 95% CI 1.256 to 6.548, p=0.012) and emphysema (HR 9.891, 95% CI 5.538 to 17.665, p<0.001).

Pleural effusion

Pleural effusion was reported in 10% (95% CI 1.5% to 22.4%, n=103, at risk=68,760) of patients who had MWA and 5% (95% CI 2.5% to 8.5%, n=163, at risk=2,558) of patients who had RFA in the meta-analysis of 3,432 patients (53 studies) (Yuan 2019). Severe pleural effusion (grade 3 or 4) that needed intervention was described in 0.3% (95% CI 0.0% to 1.4%, n=9, at risk=682) and 0.6% (95% CI 0.0% to 1.7%, n=31, at risk=2,297) of patients, respectively. There were no statistically significant differences between groups (all p>0.05).

Pleural effusion was reported in 2% of patients who had MWA and 3% of patients who had RFA in the systematic review of 565 patients (7 studies) (Sun 2018).

Pleural effusion was described in 2 studies, including 3% in 1 study and 7% in another study in the systematic review of 985 patients (12 studies) (Nelson 2019).

Pleural effusion was reported in 25% (14/56) of patients who had MWA compared with 18% (8/45) of patients who had cryoablation (p=0.38) in the non-randomised comparative study of 101 patients (Das 2020). All events were asymptomatic.

Pleural effusion was reported in 2 patients who had MWA in the non-randomised comparative study of 223 patients (Hu 2021).

Pleural effusion was reported in 2 patients at 24 hours after MWA in the retrospective case series of 80 patients (Li 2016).

Delayed pleural effusion was present in 1 patient at 26 days after MWA for right upper lobe sub-pleural adenocarcinoma in the case series of 6 patients (Harvey 2019). The patient had intercostal catheter placement which drained more than 1 litre serous fluid and her symptoms resolved.

Pleural effusion was reported in 5% (1/19) of patients with cavitary NSCLC and 6% (18/298) of patients with noncavitary NSCLC in the non-randomised comparative study of 317 patients who had MWA (Xu 2021a).

Pleural effusion happened in 6% (2/34) of patients with ALI-NSCLC and 2% (5/285) of patients with non-ALI NSCLC (p=0.247) in the non-randomised comparative study of 319 patients who had MWA (Xu 2021b).

Haemorrhage

Intra-alveolar haemorrhage was reported in 3% (2/81) of tumours that were treated by MWA and 8% (6/79) of tumours treated by RFA (p=0.16) in the non-randomised comparative study of 115 patients (Aufranc 2019).

Intra-pulmonary haemorrhage was reported in 34% (n=19) of patients who had MWA compared with 24% (11/45) of patients who had cryoablation (p=0.30) in the non-randomised comparative study of 101 patients (Das 2020). Of these events, 3 patients developed symptomatic haemorrhage (hypotension) and stabilised following fluid resuscitation.

Bleeding (severe complication) was reported in 1 patient in both the MWA and lobectomy groups in the non-randomised comparative study of 162 patients (Yao 2018). Both patients needed a thoracotomy.

Massive extra-pleural haemorrhage was present in 1 patient who had MWA for lung metastasis from colorectal carcinoma in the case series of 6 patients (Harvey 2019).

Haemothorax

Haemothorax was reported in 18% of patients who had MWA in 1 study in the systematic review of 985 patients (12 studies) (Nelson 2019).

Haemothorax was reported in 2 patients who had MWA in the non-randomised comparative study of 223 patients (Hu 2021).

Haemoptysis

Haemoptysis was reported in 5% of patients who had MWA and 6% of patients who had RFA in the systematic review of 565 patients (7 studies) (Sun 2018).

Haemoptysis was described in 2 studies, including 6% in 1 study and 7% in another study in the systematic review of 985 patients (12 studies) (Nelson 2019).

Mild haemoptysis was reported in 18% (10/56) of patients who had MWA compared with 16% (7/45) of patients who had cryoablation (p=0.80) in the non-randomised comparative study of 101 patients (Das 2020).

Haemoptysis was reported in 7 patients at 24 hours after MWA in the retrospective case series of 80 patients (Li 2016).

Haemoptysis was reported in 13% (3/23) of patients with IPA secondary to MWA in the retrospective review of lung MWA database of 1,596 patients (Huang 2018).

Haemoptysis was reported in 6% (2/34) of patients with ALI-NSCLC and 2% (7/285) of patients with non-ALI NSCLC (p=0.247) in the non-randomised comparative study of 319 patients who had MWA (Xu 2021b).

Fistula

Bronchopleural fistula was reported in 1 patient (1 study) in the systematic review of 985 patients (12 studies) (Nelson 2019).

Bronchopleural fistula was reported in 4% (3/81) of tumours that were treated by MWA and 1% (1/79) of tumours treated by RFA (p=0.32) in the non-randomised comparative study of 115 patients (Aufranc 2019).

Bronchial fistula and bronchocutaneous fistula from the post-MTA cavity were found at 1 week after MWA for local tumour recurrence in a case report of 1 patient with lung adenocarcinoma (pT1aN0M0) in the right upper lobe. This patient had segmental resection and post-surgical radiation therapy prior to MWA (Ramos-Bossini 2021).

Air embolism or leak

Asymptomatic air embolism was reported in 1 patient after introduction of the microwave antenna in the retrospective case series of 80 patients (Li 2016). This patient recovered completely without permanent morbidity.

Prolonged significant air leak with direct pleural thermal damage was present in 1 patient who had MWA for a 10 mm right upper lobe nodule in a case series of 6 patients (Harvey 2019). The patient had a 22-day admission for management, including right-sided intercostal catheter insertion and subsequent video-assisted thoracoscopic surgery with debridement of inflammatory exudate and adhesions.

Subcutaneous emphysema

Subcutaneous emphysema was reported in 2% of patients who had MWA and 3% of patients who had RFA in the systematic review of 565 patients (7 studies) (Sun 2018).

Subcutaneous emphysema surrounding the puncture point of MWA was reported in 1 patient in the retrospective case series of 80 patients (Li 2016). This patient was readmitted 11 days after discharge and had antibiotic and analgesic treatment.

Cardiac complications

Arrhythmia was reported in 3 patients who had MWA and atrial fibrillation in 12 patients who had wedge resection in the non-randomised comparative study of 223 patients (Hu 2021).

Mild pericardial effusion was reported in 3 patients and thickening of pericardial layers in 3 patients who had MWA in the non-randomised comparative study of 223 patients (Hu 2021).

Infection

Infection was reported in 7 patients who had MWA compared with 5 patients who had cryoablation (p=0.83) in the non-randomised comparative study of 101 patients (Das 2020).

Infection was reported in 2 patients who had MWA and 10 patients who had lobectomy in the non-randomised comparative study of 162 patients (Yao 2018). The difference between groups was not statistically significant (p=0.204).

Invasive pulmonary aspergillosis

The rate of invasive pulmonary aspergillosis secondary to MWA was 1.4% (23/1,596) of patients in the retrospective review of lung MWA database of 1,596 patients (Huang 2018). Of the 23 patients who developed invasive pulmonary aspergillosis after lung MWA, 6 patients died as a consequence (2 died of sudden massive haemoptysis and 4 died of infection), with a mortality rate of 26%. Pleural effusion was reported in 44% (10/23) of these patients. The most common finding of chest CT was pulmonary cavitation (87%, 20/23).

Pneumonia

Pneumonia was described in 2 studies, including 3% in 1 study and 7% in another study in the systematic review of 985 patients (12 studies) (Nelson 2019).

Pneumonia was reported in 5% (1/19) of patients with cavitary NSCLC and 3% (8/298) of patients with noncavitary NSCLC in the non-randomised comparative study of 317 patients who had MWA (Xu 2021a).

Lung abscess

Grade 2 abscess was reported in 1 patient in 1 study in the systematic review of 985 patients (12 studies) (Nelson 2019).

Lung abscess was reported in 2 patients in the retrospective case series of 80 patients (Li 2016). The local abscess was drained percutaneously with CT guidance, and the patients had intravenous antibiotics and were discharged 5 days and 9 days later, respectively.

Other complications

Atelectasis

Atelectasis was reported in 13% (3/23) of patients with invasive pulmonary aspergillosis secondary to MWA in the retrospective review of lung MWA database of 1,596 patients (Huang 2018).

Rib fracture

A single right lateral rib fracture with associated FDG hypermetabolism was present in 1 patient 3 months after MWA for lung tumours in the case series of 6 patients (Harvey 2019).

Intercostal artery injury

Intercostal artery injury was reported in 1 patient in the retrospective case series of 80 patients (Li 2016).

Skin burns

Significant skin burns were reported in 2 studies, including the rate of grade 2 burns being 2% in 1 study and of grade 3 burns being 2% in 1 study and 6% in another study in the systematic review of 985 patients (12 studies) (Nelson 2019).

Skin burn was reported in 4% (2/56) of patients who had MWA and no patients who had cryoablation (p=0.20) in the non-randomised comparative study of 101 patients (Das 2020).

Postablation syndrome

Postablation syndrome was reported in 4% (2/56) of patients who had MWA compared with 2% (1/45) of patients who had cryoablation (p=0.69) in the non-randomised comparative study of 101 patients (Das 2020).

Postablation syndrome was reported in 70% (16/23) of patients with invasive pulmonary aspergillosis secondary to MWA in the retrospective review of lung MWA database of 1,596 patients (Huang 2018).

Postablation syndrome was described in 5% (1/19) of patients with cavitary NSCLC and 9% (28/298) of patients with noncavitary NSCLC in the non-randomised comparative study of 317 patients who had MWA (Xu 2021a).

Fever

Fever was reported in 4 patients who had MWA and 9 patients who had lobectomy in the non-randomised comparative study of 162 patients (Yao 2018). The difference between groups was not statistically significant (p=0.838).

Fever was reported in 2 patients at 24 hours after MWA in the retrospective case series of 80 patients (Li 2016).

Pain

Mean intraprocedural pain VAS scores were 6.01±2.06 in the MWA group compared with 2.43±1.39 in the cryoablation group (p=0.001) in the non-randomised comparative study of 101 patients (Das 2020).

Pain was reported in 7 patients in the retrospective case series of 80 patients (Li 2016). Of these 7 patients, 5 patients had mild chest pain and 2 patients developed severe pain during the ablation procedures, not relieved by intravenous injection of 5 mg morphine sulfate. These 2 patients recovered completely without permanent morbidity.

Pain was statistically significantly lower in patients who had MWA (n=5) than patients who had lobectomy (n=29; p=0.01) in the non-randomised comparative study of 162 patients (Yao 2018).

Chest pain was reported in 26% (5/19) of patients with cavitary NSCLC and 30% (90/298) of patients with noncavitary NSCLC in the non-randomised comparative study of 317 patients who had MWA (Xu 2021a).

The evidence assessed

Rapid review of literature

The medical literature was searched to identify studies and reviews relevant to Microwave ablation for primary or metastatic cancer in the lung. The following databases were searched, covering the period from their start to 7 September 2021: MEDLINE, PREMEDLINE, EMBASE, Cochrane Library and other databases. Trial registries and the Internet were also searched. No language restriction was applied to the searches (see the literature search strategy). Relevant published studies identified during consultation or resolution that are published after this date may also be considered for inclusion.

The inclusion criteria were applied to the abstracts identified by the literature search. Where selection criteria could not be determined from the abstracts the full paper was retrieved.

Inclusion criteria for identification of relevant studies

Characteristic	Criteria
Publication type	Clinical studies were included. Emphasis was placed on identifying good quality studies. Abstracts were excluded where no clinical outcomes were reported, or where the paper was a review, editorial, or a laboratory or animal study. Conference abstracts were also excluded because of the difficulty of appraising study methodology, unless they reported specific adverse events that were not available in the published literature.
Patient	Patients with primary or metastatic cancer in the lung.
Intervention/test	Microwave ablation.
Outcome	Articles were retrieved if the abstract contained information relevant to the safety and/or efficacy.
Language	Non-English-language articles were excluded unless they were thought to add substantively to the English-language evidence base.

List of studies included in the IP overview

This IP overview is based on 6,329 patients from 3 systematic reviews and/or meta-analyses (Yuan 2019; Sun 2018; Nelson 2019), 6 non-randomised comparative studies (Aufranc 2019; Das 2020; Yao 2018; Hu 2021; Xu 2021a, 2021b), 2 case series (Li 2016; Harvey 2019), 1 case report (Ramos-Bossini 2021) and 1 review of review of lung MWA database (Huang 2018).

Other studies that were considered to be relevant to the procedure but were not included in the main summary of the key evidence are listed in the appendix.

Summary of key evidence on microwave ablation for primary or metastatic cancer in the lung

Study 1 Yuan ZH (2019)

Study details

Study type	Meta-analysis
Country	Not reported for individual studies
Recruitment period	Database searched: 2010 to 2017
Study population and number	n=3,432 (53 studies; MWA in 12 studies compared with RFA in 41 studies) Patients with primary and metastatic lung cancer (all stages)
Age and sex	Overall age and sex: not reported
Patient selection criteria	Inclusion criteria: patients had lung cancer, including primary or metastatic cancer, of all stages and all subtypes; the studies reported clinical outcome after MWA or RFA; the studies reported survival status after treatment (at 1, 2, 3, 4, and 5 years); the studies were either prospective or retrospective RCTs and non-RCTs. Exclusion criteria: studies that were not directly relevant to MWA and RFA, such as cryoablation and laser ablation for treating lung cancer; duplicate publications; literature focusing on the outcome of the treatment without survival data.
Technique	MWA and RFA
Follow-up	5 years
Conflict of interest/source of funding	Conflict of interest: none Funding: This work was supported by Beijing Talents Project; Funding for High-Level Talents in Beijing Municipal Health System (Grant No. 2014-3-088); National Major Scientific Instruments and Equipment Development Project (Grant No. ZDYZ2015-2); Beijing Natural Science Foundation (Grant No. 7142078); National Twelve-Five Key Technology Support Program (Grant No. 2012BAI15B08); Beijing You'an Hospital Hepatic Disease & HIV Fund (Grant No. 20150203), and the National Natural Science Foundation of China (Grant No. H1617/81472328).

Analysis

Study design issues: This meta-analysis evaluated the clinical outcomes of MWA and RFA for treating lung cancer. This meta-analysis was done based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement. A comprehensive literature search was done in 5 databases. Two researchers conducted the literature screening and data extraction independently and all disagreements were discussed and resolved by consensus.

Meta-analysis was done by combining the results of the selected articles with overall survival, progression-free survival, local tumour progression-free survival and complete ablation data. The population survival progress for each study was modelled to the reported survival times (at 1, 2, 3, 4 and 5 years as reported). Subgroup analyses by tumour size or number were not done because the relative data extracted from the eligible studies were inadequate.

Study population issues: The Newcastle-Ottawa Scale and Quality Appraisal Tool showed that the included studies were considered high quality. Certain evidence of publication bias was shown in the RFA group (p=0.015) but not in the MWA group (p=0.361). The sample size of the included studies reporting on MWA was limited, which can lead to false-positive or false negative conclusions (risk of random errors). The studies used different patient inclusion eligibility criteria (such as tumour size, lesion number, age and follow-up). This might have influenced the consistency of effects across the included studies and led to interstudy heterogeneity.

Key efficacy findings

- Number of patients analysed: 3,432 (53 studies; MWA in 12 studies compared with RFA in 41 studies)

Complete ablation rate:

- MWA: 81.1% (95% CI 75.8% to 86.0%; I^2=65.7%, p<0.001; 8 studies, n=640)
- RFA: 86.1% (95% CI 78.5% to 92.4%; I^2=88.0%, p<0.001; 16 studies, n=585)

Median progression free survival:

- MWA: 8.4 months (95% CI 3.6 to 13.2 months; I^2=51.4%, p=0.128; 3 studies, n=164)
- RFA: 14.6 months (95% CI 10.2 to 19.0 months; I^2=94.5%, p<0.001; 11 studies, n=429)

Median local tumour progression free survival:

- MWA: 31.5 months (95% CI 19.0 to 44.0 months; I^2=57.2%, p=0.097; 3 studies, n=184)
- RFA: 22.0 months (95% CI 11.8 to 32.2 months; I^2=0.0%, p=0.755; 4 studies, n=109)

Median overall survival:

- MWA: 25.6 months (95% CI 19.4 to 31.8 months; I^2=91.7%, p<0.001; 6 studies, n=469)
- RFA: 30.9 months (95% CI 26.4 to 35.5 months; I^2=94.1%, p<0.001; 19 studies, n=738)
- No statistically significant difference

Estimated median overall survival for primary lung cancer:

- MWA: 24.4 months (95% CI 16.9 to 31.8 months; I^2=93.5%, p<0.001; 6 studies, n=430)
- RFA: 28.4 months (95% CI 20.9 to 35.8 months; I^2=91.8%, p<0.001; 8 studies, n=333)

Estimated median overall survival for pulmonary metastases:

- MWA: 18.7 months (95% CI 12.1 to 25.3 months; 1 study, n=183)
- RFA: 34.8 months (95% CI 27.6 to 42.1 months; I^2=57.9%, p=0.027; 7 studies, n=270)
- P=0.001

Results of meta-analysis for overall survival rate, progression-free survival rate and local tumour progression-free rate

	MWA			**RFA**			
Outcomes	**No. of studies**	**Heterogeneity**	**Estimate (95% CI)**	**No. of studies**	**Heterogeneity**	**Estimate (95% CI)**	**P**
Overall survival							
1 year	6	I^2=37.7%, p=0.155	79.3 (73.7 to 85.0)	25	I^2=75.0%, p<0.001	89.2 (85.8 to 92.6)	0.003
2 years	6	I^2=0.00%, p=0.691	51.9 (46.2 to 57.5)	24	I^2=87.0%, p<0.001	68.3 (60.6 to 76.1)	0.001
3 years	3	I^2=7.6%, p=0.339	34.6 (26.8 to 42.5)	24	I^2=82.5%, p<0.001	56.0 (47.3 to 64.6)	<0.001
4 years	2	I^2=0.0%, p=0.458	30.9 (22.9 to 38.8)	13	I^2=64.9%, p+0.001	45.5 (36.1 to 55.0)	0.020
5 years	1	NA	16.0 (0 to 35.5)	16	I^2=91.0%, p<0.001	41.3 (27.3 to 55.2)	0.039
Progression-free survival							
1 year	2	I^2=88.4%, p=0.003	64.8 (37.1 to 92.4)	12	I^2=89.7%, p<0.001	62.4 (50.4 to 74.4)	0.876
2 years	2	I^2=94.3%, p<0.001	43.1 (1.5 to 84.7)	10	I^2=76.3%, p<0.001	31.7 (22.0 to 41.5)	0.601
3 years	1	NA	56.0 (41.1 to 70.9)	9	I^2=87.9%, p<0.001	33.1 (19.2 to 47.0)	0.028
4 years	NA	NA	NA	6	I^2=70.1%, p=0.005	22.8 (11.6 to 34.0)	NA
5 years	NA	NA	NA	5	I^2=92.5%, p<0.001	31.3 (10.1 to 52.6)	NA
Local tumour progression-free survival							
1 year	3	I^2=87.9%, p<0.001	84.6 (72.9 to 96.3)	11	I^2=99.2%, p<0.001	73.0 (45.2 to 100.8)	0.451
2 years	2	I^2=81.9%, p=0.019	68.5 (51.8 to 85.1)	10	I^2=97.8%, p<0.001	62.1 (38.4 to 85.8)	0.665
3 years	2	I^2=15.1%, p=0.278	72.2 (64.5 to 79.9)	9	I^2=97.9%, p<0.001	62.2 (37.2 to 87.2)	0.454
4 years	1	NA	74.1 (67.0 to 81.2)	4	I^2=97.1%, p<0.001	53.4 (15.4 to 91.4)	0.294

5 years	1	NA	48.0 (23.8 to 72.2)	4	I^2=78.8%, p=0.003	64.2 (42.3 to 86.1)	0.331

Key safety findings

Adverse events for MWA and RFA:

	MWA				RFA				
Adverse events	**No. of events**	**No. at risk**	**Proportion (%)**	**95% CI (%)**	**No. of events**	**No. at risk**	**Proportion (%)**	**95% CI (%)**	**P**
Pneumothorax	217	760	33.9	23.8 to 44.8	1,117	2,614	34.3	25.9 to 43.1	0.957
Pneumothorax (grade 3 or 4) needs intervention	73	587	11.0	4.5 to 19.7	535	2,735	12.3	6.8 to 19.1	0.797
Pleural effusion	103	68,760	9.6	1.5 to 22.4	163	2,558	5.2	2.5 to 8.5	0.428
Pleural effusion (grade 3 or 4) needs intervention	9	682	0.3	0.0 to 1.4	31	2,297	0.6	0.0 to 1.7	0.517

Death: 2 deaths were reported in the MWA group and no treatment-related deaths happened in the RFA group.

Study 2 Sun YD (2018)

Study details

Study type	Systematic review and meta-analysis
Country	Australia (n=1), China (n=2), Italy (n=1), Germany (n=2) and US (n=1)
Recruitment period	Database searched: inception to 2018
Study population and number	n=565 (7 studies; MWA, n=319; RFA, n=246) Patients with primary and metastatic lung tumours (stages 1 to 4)
Age and sex	Mean 57 to 74 years; 66% (376/565) male; tumour size, mean 2.35 to 3.46 cm
Patient selection criteria	Inclusion criteria: prospective or retrospective articles without ethical issues; the research content is consistent with the research topic; evaluate patient pain through internationally accepted pain scoring criteria (such as VAS, numeric rating scales, verbal rating scales); and the required data results should be reported from the article or can be derived. Exclusion criteria: reviews, editorials, case reports, conference abstracts and letters; the data contained in the article is duplicated; studies using animal models (such as swine and rabbit) or unrelated studies to the objectives of our analysis; missing data or insufficient data; and when the same study was reported twice, data from the most recent study with the largest sample size were extracted for relevant results.
Technique	MWA and RFA
Follow-up	3 years
Conflict of interest/source of funding	Conflict of interest: none. This study was funded by Natural Science Foundation of Shandong Province (No. ZR2017MH095).

Analysis

Follow-up issues: One patient was lost to follow up in 1 study (Maxwell et al., 2016).

Study design issues: This systematic review and meta-analysis investigated the differences between MWA and RFA, focusing on evaluating the difference in the overall survival rate and safety of thoracic cancer. This study was carried out according to the Preferred Reporting of Systematic Reviews and Meta-Analyses recommendations. A systematic literature search was done in 5 databases.

Three researchers independently identified relevant studies and extracted data in a standardized data extraction form. Data were pooled using odds ratios. A fixed effects model was used.

Study population issues: Seven comparative studies were included but no randomised studies identified. After methodological quality assessment, most of the included studies were high quality. All patients had lung tumours (stages 1 to 4).

Key efficacy findings

- Number of patients analysed: 565 (7 studies; 319 MWA compared with 246 RFA)

0.5-year overall survival: OR 0.99 (95% CI 0.52 to 1.89), I^2=0% (5 studies; 186 MWA and 176 RFA)

1-year overall survival: OR 0.95 (95% CI 0.63 to 1.44), I^2=7% (7 studies; 319 MWA and 246 RFA)

2-year overall survival: OR 1.00 (95% CI 0.70 to 1.44), I^2=66% (6 studies; 295 MWA and 218 RFA)

3-year overall survival: OR 0.71 (95% CI 0.42 to 1.18), I^2=0% (5 studies; 156 MWA and 119 RFA)

Publishing bias: Linear regression analysis (Egger's test) of the funnel plot did not identify any significant graphics or statistical bias (p=0.872).

Key safety findings

Incidence of treatment complications

Treatment	Total complications		Haemoptysis		Pleural effusion		Pneumothorax		Subcutaneous emphysema	
	Rate	P	Rate	P	Rate	P	Rate	P	Rate	P
MWA	21.05%	P=0.321	4.68%	P=0.756	2.34%	P=0.651	14.62%	P=0.352	2.34%	P=0.651
RFA	27.46%	X^2=0.987	6.34%	X^2=0.96	2.82%	X^2=0.205	19.72%	X^2=0.866	2.82%	X^2=0.205

There was no statistically significant difference in the incidence of complications between the 2 groups.

Study 3 Nelson DB (2019)

Study details

Study type	Systematic review
Country	Not reported for individual studies
Recruitment period	Database search performed: 2017
Study population and number	n=985 (1,336 nodules; 12 studies) Patients with NSCLC and metastatic lung cancer
Age and sex	Age and sex: not reported; tumour size, mean 1.2 to 3.8 cm
Patient selection criteria	Inclusion criteria: articles that used microwave ablation to treat primary or secondary lung malignancies; outcomes of interest included local recurrence or adverse events; English-language; broad definitions of local failure, such as local recurrence and local control rates, were included. Exclusion criteria: case series with fewer than 30 treated lesions; non-peer-reviewed publications, such as those found in conference proceedings.
Technique	MWA
Follow-up	9 to 47 months
Conflict of interest/source of funding	This study was funded by generous philanthropic donations from the Family and anonymous donors as well as departmental support. Two authors disclose a relationship with Neuwave Medical; 1 author with Galil Medical, Jounce Therapeutics, Merit Medical, and Abbvie.

Analysis

Follow-up issues: Reported follow-up was often short and only 3 of the 12 studies had a mean or median follow-up greater than 2 years. Four of 12 studies were truncated early, with a mean or median follow-up less than 1 year.

Study design issues: This systematic review analysed published literature on the efficacy of MWA for the treatment of lung malignancies. The primary outcome was local recurrence (defined in an intent-to-treat fashion and included technical failures seen at the first follow-up CT scan). This study was done in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.

A comprehensive literature was done in 6 databases. After screening the collected titles and abstracts for compliance with the eligibility criteria, all articles were assessed using the Critical Appraisal Skills Programme criteria for cohort studies.

Study population issues: All studies were retrospective and overall, the methodologic quality of each article was poor. There was a lack of consensus in terms of reporting local recurrence: some studies reported the likelihood of a patient having a local recurrence at any of their treated sites, and others reported local recurrence per treated nodule. None of the included studies, that reported risk of failure per nodule treated, showed evidence of incorporating hierarchal regression or other methods to account for nonindependence of multiple metastatic tumours within the same patient.

Because of the perceived heterogeneity in the included studies - clinical, methodologic, and in terms of outcomes - meta-analyses were not conducted.

Key efficacy findings

Number of patients analysed: 985 (1,336 nodules; 12 studies)

Procedure characteristics and clinical outcomes

Study	MHz	Histology	No. of patients (nodules), accrual	Mean tumour size	Follow up (months)	Local recurrence or technical failure	Other findings
Wolf (2018)	915 MHz	Primary NCSLC metastatic	50 (82), 2003 to 2006	3.5±1.6 cm	10	26% (13/50) local recurrence per patient 67% 1-year free from local recurrence 5% (3/66) sessions technical failure	Size >3 cm predicted failure (p=0.01)
Lu (2012)	915 MHz	Primary NCSLC metastatic	69 (93), 2005 to 2008	2.2±1.7 cm	18	22% (15/69) local recurrence per patient 16% (15/94) local recurrence per nodule 19% (9/47) <3cm local recurrence 8% (1/12) 3 to 4 cm local recurrence 50% (5/10) >4 cm local recurrence	Size >4 cm predicted failure (p=0.039)
Vogl (2011)	915 MHz	Metastatic	80 (130), 2007 to 2010	-	9	26.9% (35/130) local recurrence per nodule 18% (24/130) technical failure 18% (20/110) <3 cm local recurrence 75% (15/20) >3 cm local recurrence	Size >3 cm (p<0.001) and central location (p<0.002) predicted failure
Vogl (2013)	915 MHz	Primary NCSLC metastatic	57 (91), 2009 to 2011	1.8±0.8 cm	10	37% (21/57) local recurrence per patient 33% (30/91) local recurrence per module	Size >1.55 cm (p<0.01), irregular

						7% (7/9) technical failure 60% 1-year freedom from local recurrence	shape (p<0.01), pleural contact (p=0.02), less than 26 J/mm^3 (p<0.001) predicted failure
Zheng (2014)	2.45 GHz	Primary NCSLC metastatic	184 (253), 2011 to 2013	-	-	-	-
Zheng (2016)	2.45 GHz	Primary NCSLC metastatic	183 (203), 2011 to 2013	3.4±2.0 cm	34	19% (35/183) local recurrence per patient 14% (26/183) technical failure 82% 1-year freedom from local recurrence 76% 2-year freedom from local recurrence 74% 3-year freedom from local recurrence 74% 4-year freedom from local recurrence	Emphysema (p=0.02) and tumour size (p<0.001) predicted failure
Wei (2014)	2.45 GHz	Advanced NSCLC	39 (39), 2010 to 2013	3.8 cm	11	26% (10/39) local recurrence	-
Vogl (2016)	2.45 GHz	Metastatic colorectal	47 (103), 2008 to 2014	Range 0.5 to 5 cm	>24	12% (12/103) local recurrence per nodule at 2 years 0/103 technical failure	Central lesions (within 5 cm of hilum) predicted failure (p<0.001)
Yang (2017)	2.45 GHz	Stage 1 NSCLC	104 (104), 2008 to 2014	2.4±1.3	47	23% (24/104) local recurrence 36% (10/28) >3.5 cm local recurrence 18% (14/76) <3.5 cm local recurrence	Size >3.5 cm predicted failure (p=0.009)
Egashira (2016)	2.45 GHz	Primary NCSLC metastatic	44 (93), 2012 to 2014	1.2 cm	15	9% (8/93) local recurrence per nodule 6% (6/93) technical failure	-

Zhong (2017)	2.45 GHz	NSCLC	113 (113), 2013 to 2015	3.1 cm (0.7 to 6)	18	16% (18/113) local recurrence per patient 6% (2/35) early-stage local recurrence 21% (16/78) late-stage local recurrence 26% (15/57) >3 cm local recurrence 5% (3/56) <3 cm local recurrence	Advanced stage (p=0.047) and size >3 cm (p=0.002) predicted failure
Ko (2016)	915 MHz	NSCLC metastatic	15 (32), 2013 to 2016	1.35 cm	15	16% (5/32) per nodule local recurrence	-

Estimated local recurrence rates: 9% to 37% (25% or greater in 4 studies; less than 25% in 7 studies; less than 15% in 2 studies).

- Actuarial analysis of local recurrence rates: 18%, 33% and 40% within 1 year in 3 studies and 12% and 34% within 2 years in 2 studies.
- There was no identified relationship between follow-up and local recurrence rate.

Relationship between local recurrence and tumour size: a strong relationship was found.

- Seven studies found a statistically significantly higher likelihood of local recurrence with larger tumors, with the most frequent cut-off value being 3 cm.
- Among the 5 studies that did not report a higher likelihood of local recurrence with larger tumors, 2 had median tumor sizes that were very small, at 1.2 and 1.4 cm. These 2 studies also showed favorable outcomes, with local recurrence rates of 9% and 16% by the end of the study duration.

Other identified predictors of failure include central location, irregular shape, pleural contact, use of suboptimal energy settings, emphysema and advanced-stage disease.

Key safety findings

Pneumothorax requiring thoracostomy: 1% to 15% (10 studies; 5% to 15% was reported in 8 of 10 studies)

Significant skin burns (2 studies): grade 2 burns, 1.5% (1 study); grade 3 burns, 1.5% to 6% (2 studies).

Single bronchopleural fistula: n=1 (1 studies)

Single periprocedural mortality: n=1 (0.5% of patients; 1 study), this event was caused by ventricular tachycardia 2 days after the procedure.

Adverse events

Study	Adverse events (common terminology criteria for adverse events grade 2 or above)
Wolf (2018)	8/66 sessions grade 2 pneumothorax 4/66 sessions haemoptysis 1/66 sessions grade 2 skin burn 1/66 sessions grade 3 skin burn
Lu (2012)	4/69 patients grade 2 pneumothorax 1/69 patients grade 3 pneumothorax 5/69 patients haemoptysis
Vogl (2011)	1/130 lesions grade 2 pneumothorax
Vogl (2013)	-
Zheng (2014)	42/204 sessions complications 31/204 sessions grade 2 pneumothorax 1/204 sessions grade 3 pneumothorax 6/204 sessions grade 2 pleural effusion 6/204 sessions pneumonia 1/204 sessions grade 2 abscess 1/204 sessions grade 5 ventricular tachycardia (death 41 hours after procedure)
Zheng (2016)	-
Wei (2014)	7/39 sessions grade 1 or 2 haemothorax 3/39 sessions grade 2 pneumothorax
Vogl (2016)	10/125 sessions grade 2 pneumothorax
Yang (2017)	18/129 sessions grade 2 pneumothorax 9/129 sessions grade 2 pleural effusion 1/129 sessions bronchopleural fistula
Egashira (2016)	7/62 sessions grade 2 pneumothorax (primary NSCLC) 1/62 sessions grade 2 pneumothorax (metastatic)
Zhong (2017)	8/113 pneumonia
Ko (2016)	1/15 patients grade 2 pneumothorax 1/15 patients grade 3 skin burn

Study 4 Aufranc V (2019)

Study details

Study type	Non-randomised comparative study (retrospective)
Country	France (single centre)
Recruitment period	2013 to 2018
Study population and number	n=115 (MWA, n=61 [79 tumours]; RFA, n=54 [81 tumours]) Patients with primary and secondary lung tumours
Age and sex	MWA: mean 68.1 years; 50% (27/54) male; tumour size, mean 1.71±0.83 cm RFA: mean 67.4 years; 47% (29/61) male; tumour size, mean 1.31±0.51 cm
Patient selection criteria	Inclusion criteria: patients with primary or secondary lung tumour; patients considered inoperable because of clinical, functional or biological data, with an estimated life expectancy greater than 6 months, for whom the decision of curative thermal ablation treatment was made in a multidisciplinary meeting; in the event of tumour recurrence, patients had MWA or RFA. Exclusion criteria: simultaneous extra-thoracic or thoracic lesions inaccessible with thermal ablation at the time of treatment; contraindication for general anaesthesia; severe coagulopathy or no stop of anti-platelet therapy prior to treatment.
Technique	For both MWA and RFA, the intervention was done under CT fluoroscopy (BrightSpeed^{TM}, General Electric Healthcare). A biopsy was done during treatment when the tumour histology was not known. MWA: a microwave generator and a 16-G probe (AMICA MWA System^{TM}; Hospital Service) were used, with 40 W power (range: 20 to 80 W). RFA: a generator (RF 3000TM, Boston Scientific) and a 14 G needle electrode with a co-axial system (LeVeen CoAccessTM, Boston Scientific) were used, with a range of 25 to 180 W.
Follow-up	MWA: mean 471 days (SD 299); RFA, mean 505.8 days (SD 308)
Conflict of interest/source of funding	None

Analysis

Study design issues: This retrospective study compared MWA with RFA in the percutaneous treatment of primary and secondary lung tumours. The primary endpoints were local recurrence during follow-up and the incidence of complications during and following thermal ablation. The retrospective nature and the selection criteria between MWA and RFA led to selection bias. The survival data were biased by the absence of some parameters such as the differentiation between primary and secondary tumours and the concomitant use of other treatments.

All procedures were done by 1 of 3 interventional radiologists with 7-, 10- and 15-years of experience in percutaneous thermal ablation. RFA was favoured because authors had more experience with this technique.

MWA was selected when a tumour >25 mm, when the tumour was near a vessel greater than 3 mm in diameter, or when there were multiple lesions to treat (at least 2 lesions in the same lung).

Study population issues: There were no significant differences between the 2 groups in terms of age and sex distribution. Of the 160 tumours treated, there were 41 (41/160; 25.6%) primary lung tumours and 119 (119/160; 74.4%) lung metastases. Before treatment, the mean diameter of the tumours was 17.1±8.3 mm (range 5 to 36 mm) in the MWA group and 13.1±5.1 mm (range 4 to 27 mm) in the RFA group (p<0.001). Several sessions with multiple ablations were done: 17 (17/81; 21%) for MWA and 15 (15/79;19%) for RFA.

Key efficacy findings

- Number of patients analysed: 115 (MWA, n=61 [79 tumours]; RFA, n=54 [81 tumours])

Procedure parameters and recurrences

	MWA (n=81)	RFA (n=79)	P value
Ablation dates			
Ablation duration (minutes)	7.5±4.5 (1 to 20)	15.4±6.6 (2 to 45)	<0.001
Ablation volume (cm^3)	30.2±35.9 (1.9 to 243.8)	24.1±21.7 (2 to 97.8)	0.20
Ablation short diameter (cm)	2.8±1.1 (1 to 7)	2.7±0.9 (1.3 to 4.6)	0.36
Technical success	100% (81/81)	100% (79/79)	1
Recurrences	33% (27/81)	30% (24/79)	0.82
Local recurrences	3.7% (3/81)	7.6% (6/79)	0.32
Distant recurrences	29.6% (24/81)	22.8% (18/79)	0.42
Time before recurrence (days)	297.4±259 (37 to 1,024)	306.8±223 (30 to 745)	0.89
Disease-free survival (days)	333.1±313.2 (37 to 1,227)	424.8±371.5 (30 to 1,471)	0.16
Length of hospital stay (days)	4.7±4.6 (2 to 5)	4.5±3.7 (1 to 25)	0.76

Of the 9 local recurrences, 5 were treated with RFA, 2 with MWA and 1 with cryotherapy, with good local control. The remaining recurrence presented as a diffuse disease, with no indication for local curative treatment. For patients who had RFA, there were 18 distant pulmonary or extra-pulmonary recurrences.

No differences in sphericity indexes were found between tumours in the MWA groups (0.60±0.13; range 0.33 to 0.88) and those in the RFA group (0.64±0.15; range 0.34 to 0.94) (p=0.16).

A linear relationship was found between small-diameter ablation zone at 1 month after MWA and the duration of the procedure at 40 W (R^2=0.6157).

Key safety findings

No deaths were attributed to thermal ablation. No deaths occurred during the 30 days following thermal ablation.

complications

	MWA (n=81)	RFA (n=79)	P value
Total pneumothorax	24.7% (n=20)	40.5% (n=32)	0.049
Low abundance pneumothorax	8.6% (n=7)	12.7% (n=10)	0.57
Exsufflated pneumothorax	4.9% (n=4)	2.5% (n=2)	0.68
Drained pneumothorax	11.1% (n=9)	25.3% (n=20)	0.03
Intra-alveolar haemorrhage	2.5% (n=2)	7.6% (n=6)	0.16
Bronchopleural fistula	3.7% (n=3)	1.2% (n=1)	0.32
Grade 1 complications	16% (n=13)	22.7% (n=18)	0.28
Grade 2 complications	11.1% (n=9)	25.3% (n=20)	0.03
Grade 3 complications	3.7% (n=3)	1.2% (n=1)	0.32
Grade 4, 5 and 6 complications	0%	0%	>0.99

The most common complication was pneumothorax (excluding voluntary pneumothorax, induced to protect high-risk organs).

Study 5 Das SK (2020)

Study details

Study type	Non-randomised comparative study (retrospective)
Country	China (single centre)
Recruitment period	2011 to 2016
Study population and number	n=101 (MWA, n=56; cryoablation, n=45) Patients with NSCLC (stage 3b or 4)
Age and sex	MWA: mean 59.1 years; 60.7% (34/56); tumour size, mean 2.9 cm Cryoablation: mean 57.7 years; 57.8% (26/45) male; tumour size, mean 2.6 cm
Patient selection criteria	Inclusion criteria: patients were histologically or cytologically diagnosed with stage 3b or 4 NSCLC according to the 8th edition of the Tumor-Node-Metastasis classification and had an Eastern Co-operative Oncology Group performance status of 0 or 1; tumours were considered to be surgically inoperable and unresponsive to standard chemotherapy or radiotherapy; patients had ≤3 lesions per hemithorax and with the largest lesion diameter ≤5.0 cm. Exclusion criteria: age <18 years; uncontrolled malignant pleural effusion; symptomatic brain metastases; life expectancy ≤3.0 months; history of current extra pulmonary malignancies or previous malignancies within the last 5 years; and inadequate haematologic, hepatic or renal function.
Technique	All procedures were done under local anaesthesia. MWA: Under CT guidance, the MWA instrument used was a KY-2000 microwave multi-function therapeutic instrument (Kangyou Medical Co., Ltd.) with 14- to 20-gauge microwave antennas and an output power of 50 to 80W. For lesions <3.0 cm in diameter, 1 antenna was inserted, whereas 2 antennas were inserted for lesions >3.0 cm. Cryoablation: An argon-based CA delivery system (AccuTarget MediPharma Co. Ltd.) was used with 14- to 18-gauge cryoprobes. For lesions ≤3.0 cm in diameter, 1 cryoprobe was inserted, whereas 2 cryoprobes were used for lesions >3.0 cm.
Follow-up	3 years
Conflict of interest/source of funding	None

Analysis

Follow-up issues: Patients were followed up postablation as outpatients, with CT scans performed at 1, 3 and 6 months and subsequently every 6 months.

Study design issues: This retrospective study compared the safety and efficacy of MWA with cryoablation for NSCLC. The primary outcome measures were technical success, clinical effectiveness (defined as local disease control), safety and overall survival. Irregular focal enhancement of the lesion >15 Hounsfield units compared with the initial postablation non-enhanced lesion was considered as a sign of local tumour progression. A circumferential rim of enhancement ≤0.5 cm around the ablation zone at 6 months postablation was considered to indicate benign peritumoral enhancement. Biopsies were not routinely done during follow-up. Therefore, this study lacked histopathological proof of treatment success.

Study population issues: There were no statistically significant differences in baseline clinicopathological characteristics between groups.

Variable	**MWA**	**Cryoablation**	**P value**
Pathology			0.52
ADC	76.8% (n=43)	73.3% (n=33)	
Non-ADC	23.2% (n=13)	26.7% (n=12)	
Stage			0.77
3b	57.1% (n=32)	60.0% (n=27)	
4	42.9% (n=24)	40.0% (n=18)	
Tumour size, cm			0.95
≤3.0	57.1% (n=32)	57.8% (n=26)	
>3.0	42.9% (n=24)	42.2% (n=19)	
Mean tumour diameter, cm	2.9 (range 0.8 to 5.0)	2.6 (range 0.9 to 5.0)	
Tumour distance from pleura, cm			0.83
≤1	35.7% (n=20)	37.8% (n=17)	
>1	64.3% (n=36)	62.2% (n=28)	
Tumour distance from vessel, mm			0.78
≤3	28.6% (n=16)	31.1% (n=14)	
>3	71.4% (n=40)	68.9% (n=31)	
Metastases, n			0.38
1	44.6% (n=25)	53.3% (n=24)	
≥2	55.4% (n=31)	46.7% (n=21)	

Key efficacy findings

- Number of patients analysed: 101 (MWA, n=56; cryoablation, n=45)

Clinical outcomes

Clinical outcome	**MWA (n=56)**	**Cryoablation (n=45)**	**P value**
Median ablation time, minutes	7 (range 5 to 10 minutes)		

Initial technical success (no detectable enhancement in the initial postablation CT scan)	92.86% (n=52)	93.33% (n=42)	
Re-ablation within a 6-month period	7.14% (n=4)	6.67% (n=3)	
Recurrence at the ablation site (residual disease) at 6 months postablation	26.78% (n=15)	24.44% (n=11)	>0.05
Recurrence 3 years postablation			>0.05
Metastases in lobes	73.21% (n=41)	75.55% (n=34)	
Metastases at both the ablative and a distant site	12.50% (n=7)	13.33% (n=6)	
Overall survival			
Cumulative overall survival rate at 1 year	78.57%	73.33%	
Cumulative overall survival rate at 2 years	51.78%	40.00%	
Cumulative overall survival rate at 3 years	35.71%	22.22%	
Median overall survival time, months	27.5 (95% CI, 22.8 to 31.2)	18.0 (95% CI, 12.5 to 23.5)	0.07
For patients with tumour diameter ≤3.0 cm, median overall survival time, months	30.0	26.5	0.39
For patients with tumour diameter >3.0 cm, median overall survival time, months	24.5	14.5	0.04
Progression-free survival			
Cumulative progression-free survival rate at 1 year	41.07%	35.55%	
Cumulative progression-free survival rate at 2 years	17.85%	11.11%	
Cumulative progression-free survival rate at 3 years	7.14%	4.44%	
Median progression-free survival time, months	11.0 (95% CI, 9.5 to 12.4)	10.0 (95% CI, 7.5 to 12.4)	0.36
For patients with tumour diameter ≤3.0 cm, median progression-free survival time, months	11.0	13.0	0.79
For patients with tumour diameter >3.0 cm, median progression-free survival time, months	10.5	7.0	0.04

Key safety findings

Adverse events associated with the procedures

Adverse events	MWA (n=56)	Cryoablation (n=45)	P value
Pneumothorax	41.1% (n=23)	37.8% (n=17)	0.74
Grade 1, asymptomatic	28.6% (n=16)	26.7 (n=12)	
Grade 2, symptomatic requiring chest tube	12.5% (n=7)	11.1% (n=5)	
Intra-pulmonary haemorrhage	33.9% (n=19)	24.4 (n=11)	0.30
Grade 1, mild symptoms; intervention not indicated	28.6% (n=16)	24.4% (n=11)	
Grade 2, moderate symptoms (hypotension); medical intervention indicated	5.4% (n=3)	0	
Pleural effusion	25.0% (n=14)	17.8% (n=8)	0.38
Grade 1, asymptomatic; clinical or diagnostic observations only	25.0% (n=14)	17.8% (n=8)	
Haemoptysis	17.9% (n=10)	15.6% (n=7)	
Grade 1, mild, <100 ml, intervention not required	17.9% (n=10)	15.6% (n=7)	0.80
Infection	12.5% (n=7)	11.1% (n=5)	0.83
Post-ablation syndrome	3.6% (n=2)	2.2% (n=1)	0.69
Burn	3.6% (n=2)	0	0.20
Complication requiring admission (mean length of stay, 1 to 2 days)	21.4% (n=12)	15.6% (n=7)	0.54

Intraprocedural pain, mean±SD: MWA, 6.01±2.06; cryoablation, 2.43±1.39; p=0.001

Association between occurrence of pneumothorax and intra-pulmonary haemorrhage with MWA and clinical characteristics

	Pneumothorax			**Intra-pulmonary haemorrhage**		
Variable	Yes (41.1%, n=23)	No (58.9%, n=33)	P value	Yes (33.9%, n=19)	No (66.1%, n=37)	P value
Stage			0.24			0.62
3b	19.6% (n=11)	37.5% (n=21)		17.8% (n=10)	39.4% (n=22)	
4	21.4% (n=12)	21.4% (n=12)		16.1% (n=9)	26.7% (n=15)	
Nodule size			0.03			0.04
>3 cm	16.1% (n=9)	41.1% (n=23)		12.5% (n=7)	44.6% (n=25)	
≤3 cm	25.0% (n=14)	17.9% (n=10)		21.4% (n=12)	21.4% (n=12)	
Nodule location (side)			0.18			0.09
Right lung	21.4% (n=12)	41.1% (n=23)		16.1% (n=9)	46.4% (n=26)	
Left lung	19.6% (n=11)	17.9% (n=10)		17.8% (n=10)	19.6% (n=11)	
Nodule location (lobe)			0.07			0.13
Upper and middle	21.4% (n=12)	44.7% (n=25)		17.8% (n=10)	48.2% (n=27)	
Lower	19.6% (n=11)	14.3% (n=8)		16.1% (n=9)	17.8% (n=10)	
Tumour distance from pleura			0.11			0.47
>1 cm	21.4% (n=12)	42.9% (n=24)		19.6% (n=11)	44.7% (n=25)	
≤1 cm	19.6% (n=11)	16.1% (n=9)		14.3% (n=8)	21.4% (n=12)	
Tumour distance from vessel			0.14			0.13
>3 mm	25.0% (n=14)	46.4% (n=26)		19.6% (n=11)	51.8% (n=29)	
≤3 mm	16.1% (n=9)	12.5% (n=7)		14.3% (n=8)	14.3% (n=8)	
Nodule location (region)			0.02			0.03
Central (close to hilum)	21.4% (n=12)	12.5% (n=7)		17.8% (n=10)	16.1% (n=9)	
Peripheral	19.6% (n=11)	46.4% (n=26)		16.1% (n=9)	50.0% (n=28)	
Number of antennas			0.03			0.04
1	16.1% (n=9)	41.1% (n=23)		12.5% (n=7)	44.7% (n=25)	
>1	25.0% (n=14)	17.8% (n=10)		21.4% (n=12)	21.4% (n=12)	

Study 6 Yao W (2018)

Study details

Study type	Non-randomised comparative study (retrospective)
Country	China (2 centres)
Recruitment period	2000 to 2010
Study population and number	n=162 (MWA, n=54; lobectomy, n=108) Patients with NSCLC (stage 1)
Age and sex	MWA: mean 56.65 years; 68.5% (37/54) male; tumour size, mean 3.01 cm Lobectomy: mean 56.11 years; 62.5 (67/108) male; tumour size, mean 2.98 cm
Patient selection criteria	Inclusion criteria: age between 18 and 75 years; radiographically diagnosed staging of 1a or 1b (American Joint Committee on Cancer Seventh Edition staging); negative mediastinal lymph node metastases after mediastinoscopy for patients with radiographic findings suggesting mediastinal lymph node metastases; biopsy-proven NSCLC and no other malignancies within the previous 2 years. Exclusion criteria: patients with 2 stage I synchronous NSCLC primary tumours proven to be pathologically distinct; pulmonary metastasis; small cell lung cancer; other adjuvant therapies received before; severe comorbid medical conditions, severe coagulopathy, etc. who could not tolerate ablation or surgery; and patients who did not fulfil a minimum follow-up time.
Technique	WMA: under conscious sedation, a FORSEA microwave delivery system (Qinghai Microwave Electronic Institute, Nanjing, China) was used. All ablations were performed under a 16-detector guided CT (LightSpeed 16, GE Medical Systems, Boston, MA), with 1 to 5 mm collimation. When the tumour was <3 cm, single-application MWA was done at 50W for 10 minutes through 1 antenna inserted at the centre of the tumour. When the tumour was between 3 and 5 cm, 2 antennas were inserted in parallel at the largest tumour surface 2.0 cm apart with the microwave energy of each at 60W for 10 minutes. Lobectomy: under general anaesthesia, hilum lymph nodes should be dissected with frozen section sampling done to guarantee the isolation of negative hilum lymph nodes. The margin of at least 2 cm of healthy lung tissue was needed. The margin of the tumour should be negative. Chest catheterisation was routinely done during close thoracic incision. After the procedure, patients were observed for a minimum of 2 hours in the post anaesthesia care unit.
Follow-up	5 years
Conflict of interest/source of funding	None

Analysis

Follow-up issues: In the MWA group, the initial follow-up CT was generally done monthly for the first 3 months. In both the MWA and lobectomy groups, follow-up CT was performed every 3 months for the rest of the first year and annually thereafter.

Study design issues: This retrospective study compared the effectiveness and complication between MWA and lobectomy in treating stage 1 NSCLC. The primary outcomes were overall survival, disease-free survival and death. A total of 162 patients achieved 93% power at a 0.05 significance level to detect an equivalence hazard ratio of 1.70. This study was retrospective, which may reduce the reliability of the data. The patient sample was limited, which was insufficient for precise subgroup analysis.

To minimise the effect of potential confounders on selection bias, propensity score matching analysis was performed to adjust for potential biases by selecting factors related to MWA and lobectomy. One-to-two matching between the groups was accomplished using the nearest-neighbour matching method, with a calliper of 0.25. The adjusted comparisons were done by propensity score and were based on data from 54 patients in the MWA group. After adjustment for these factors, the overall survival and disease-free survival rates were recalculated for the 2 groups.

All MWAs were done by 2 authors with 15 to 20 years of experience in interventional radiology. For lobectomy, most were done by 1 author, who had 15 years of experience in open thoracotomy. All the ablation areas that displayed no contrast enhancement were defined as complete ablation. Recurrent disease was defined as the discovery of any new focal enhancement of the soft tissue in CT (more than 15 HU compared with the non-reinforced series) or increased uptake was identified in the PET. If the patients' physical conditions were tolerable, the biopsy result was needed to confirm recurrence. Local recurrence was defined as a recurrence at the margin of the ablation site or the surgery margin. Distant metastasis was defined as newly identified lung cancer metastases other than those within the local recurrence. Major complication was defined as complication with an incidence over 5%. Severe complication was defined as life-threatening complication that needed medical intervention.

Study population issues: There were no statistically significant differences in baseline characteristics (smoking status, clinical staging, histologic type, tumour type and tumours position) between groups. Because mediastinal lymph node dissection or sampling were unable to be done in the MWA group, the patient stage in the MWA group may be underestimated, which may influence the result.

Key efficacy findings

Number of patients analysed: 162 (MWA, n=54; lobectomy, n=108)

Technical success:

- MWA: n=51 after the first session of ablation (Another 3 tumours between 3 and 5 cm showed a residual tumour after 1 month of follow-up. After the second session of ablation, these 3 tumours were completely necrotised, as revealed by the CT scan.)
- Lobectomy: n=108

Overall survival and disease-free survival between MWA and lobectomy

	MWA		**Lobectomy**		
	mean±SD	95% CI	mean±SD	95% CI	P value
Overall survival, years	5.97±0.33	5.32 to 6.62	5.81±0.26	5.31 to 6.32	0.608
Disease-free survival, years	5.57±0.39	4.81 to 6.34	5.16±0.26	4.66 to 5.67	0.672
	Overall survival rate	Disease-free survival rate	Overall survival rate	Disease-free survival rate	
1 year	100%	98.1%	100%	98.1%	
3 years	92.6%	79.6%	90.7%	81.5%	
5 years	50.0%	37.0%	46.3%	29.6%	

In univariate analysis, tumour size (p<0.0001) and clinical staging (p<0.001) were significantly influential for overall survival while other factors were not significant. In multivariate analysis, tumour size (p<0.0001) and clinical staging (p<0.005) were independent prognostic factors for overall survival.

Subgroup analysis of overall survival and tumour size:

- Overall survival was statistically significantly worse with a tumour that was 3 to 5 cm compared with less than 3 cm (p<0.0001) and stage Ib compared with stage 1a (p<0.0001).
- Overall survival between MWA and lobectomy: there was no significant difference in tumour size (<3 cm, p=0.883; 3 to 5 cm, p=0.216) and clinical staging (1a, p=0.883; 1b, p=0.319).

Local or distant recurrence

	MWA	**Lobectomy**	**P value**
Recurrence			0.544
Local recurrence	11.1% (n=6)	6.4% (n=7)	
Distant recurrence	61.1% (n=33)	63.8% (n=69)	
Median recurrence time, years	2.12±0.38 (95% CI 1.36 to 2.89 years)	2.32±0.41 (95% CI 1.50 to 3.17 years)	0.328

Key safety findings

The major and minor complications between MWA and lobectomy

	MWA	Lobectomy	P value
Pneumothorax	7	-	NA
Fever	4	9	0.838
Pain	5	29	0.01
Infection	2	10	0.204
Pleural effusion	-	4	NA
Myocardial ischaemia	-	2	NA
Heart failure (severe complication)	-	2	NA
Atrial fibrillation (severe complication)	-	1	NA
Respiratory failure (severe complication)	-	3	NA
Bleeding (severe complication)	1	1	0.616
Wound discharge	-	1	NA

-, no data; NA, not applicable.
In the MWA group, 7 patients had pneumothorax, including 3 patients who needed closed thoracic drainage, while all patients had intrathoracic drainage after surgery.
Both patients who had bleeding needed a thoracotomy.

All these severe complications were treated in a timely fashion with no related patient death and recovered in 1 month.

The overall mortality rate in the MWA group was lower than in the lobectomy group (p=0.008), especially with severe complication (p<0.0001).

Study 7 Hu H (2021)

Study details

Study type	Non-randomised comparative study (retrospective)
Country	China (single centre)
Recruitment period	2014 to 2018
Study population and number	n=223 (MWA, n=68; wedge resection, n=155) Patients with NSCLC (stage 1) adjacent to the pericardium (within 1.0 cm from the pericardium according to CT scans)
Age and sex	MWA: mean 83.1 years; 64.7% (44/68) male; tumour size, mean 2.3 cm Wedge resection: mean 78.0 years; 66.5% (103/155) male; tumour size, mean 2.5 cm
Patient selection criteria	Inclusion criteria: a small solitary stage I NSCLC (T1a/bN0M0); platelet count ≥50 x 10^9/L; prothrombin time ratio ≥70%; Eastern Cooperative Oncology Group (ECOG) performance status score ≤2; the use of multiphase dynamic CT for pre-treatment assessment; and more than 6-month follow up after treatment. Patients having local ablative treatment were those with lung tumours who refused or were considered unable to tolerate surgical resection and radiotherapy by a multidisciplinary team.
Technique	CT-guided MWA: MWA (2450 MHz MTC-3CA microwave generator; Vision Medical, Nanjing, China) was used, with a power of 20 to 40W, 6 to 8 minutes. After the ablation procedure, all patients were admitted for overnight observation. Wedge rection: video-assisted thoracoscopic surgery and thoracotomy.
Follow-up	MWA: median 45 months (range 4 to 86 months) Wedge resection: median 48 months (range 6 to 90 months)
Conflict of interest/source of funding	None

Analysis

Follow-up issues: After discharge, patients were assessed at 1, 3 and 6 months after the procedure and subsequently after every 6 months.

Study design issues: This study conducted a propensity score matching analysis to retrospectively compare the long-term therapeutic outcomes of wedge resection and MWA as a first-line treatment for stage I NSCLC adjacent to the pericardium. The outcomes included local tumour progression, intrapulmonary distal recurrence (defined as emergence of the recurrent tumour in the lung somewhere other than the area treated with MWA), progression-free survival, overall survival and adverse events (recorded using the common terminology criteria).

The effect of selection bias and confounding factors was reduced by calculating the propensity score using logistic regression and performing 1:1 patient matching.

Study population issues: Baseline characteristics of patients before and after propensity score matching:

Characteristics	**before propensity score matching**			**After propensity score matching**		
	MWA (n=68)	**Wedge resection (n=155)**	**P value**	**MWA (n=56)**	**Wedge resection (n=56)**	**P value**
Age, mean±SD	83.1± -11.3	78.0± -11.8	0.002	82.0± -9.8	78.8± -10.9	0.112
Baseline performance status	80 (60 to 90)	90 (80 to 100)	0.001	80 (70 to 90)	90 (70 to 100)	0.011
Charlson comorbidity index	5 (4 to 6)	3 (1 to 4)	0.001	4 (3 to 5)	4 (2 to 5)	0.015
FVC, median, quartile range (%)	72 (64 to 92)	81 (66 to 97)	0.001	75 (56 to 85)	80 (65 to 88)	0.035
FEVI, median, quartile range (%)	63 (50 to 77)	71 (56 to 86)	0.007	65 (46 to 75)	67 (53 to 79)	0.071
DLCO, median, quartile range (%)	62 (49 to 74)	69 (54 to 82)	0.02	63 (51 to 74)	70 (52 to 82)	0.139

Other issues: Evaluation of the suitable type of surgical approach (thoracotomy or thoracoscopic resection) is a potential factor when choosing the treatment modality.

Key efficacy findings

Number of patients analysed: 223 (MWA, n=68; wedge resection, n=155 [video-assisted thoracoscopic surgery, n=85; thoracotomy, n=70])

Therapeutic outcomes

Outcomes	**before propensity score matching**			**After propensity score matching**		
	MWA (n=68)	**Wedge resection (n=155)**	**P value**	**MWA (n=56)**	**Wedge resection (n=56)**	**P value**
Local tumour progression	26.5% (n=18)	5.2% (n=8)				
Cumulative local tumour progression rate at 1 year	13.0%	4.0%	<0.001	11.0%	4.0%	0.027
Cumulative local tumour progression rate at 2 years	23.0%	5.0%		22.0%	5.0%	
Cumulative local tumour progression rate at 5 years	29.0%	5.0%		25.0%	5.0%	
Intrapulmonary distant recurrence	33.8% (n=23)	31.0% (n=48)				

Cumulative intrapulmonary distant recurrence rate at 1 year	5.0%	3.0%	0.126	9.0%	6.0%	0.327
Cumulative intrapulmonary distant recurrence rate at 2 years	19.0%	18.0%		24.0%	27.0%	
Cumulative intrapulmonary distant recurrence rate at 5 years	35.0%	31.0%		38.0%	36.0%	
On 31 December 2018, deaths	29.0% (n=20)	14.8% (n=23)				
1-year progression-free survival rate	82.0%	92.0%	0.004	80.0%	89.0%	0.029
3-year progression-free survival rate	57.0%	74.0%		54.0%	66.0%	
5-year progression-free survival rate	38.0%	58.0%		36.0%	56.0%	
1-year overall survival rate	92.0%	98.0%	<0.001	90.0%	100.0%	0.047
3-year overall survival rate	63.0%	84.0%		60.0%	81.0%	
5-year overall survival rate	55.0%	73.0%		55.0%	72.0%	

Risk factors for therapeutic outcomes: Multivariate analysis of 223 patients showed MWA (HR, 2.26; 95% CI, 1.52 to 3.35; p<0.001), distance from pericardium (HR, 0.318; 95% CI, 0.166 to 0.608; p=0.001), and tumour size (HR, 2.045; 95% CI, 1.239 to 3.374; p=0.005) were significant factors for poor progression-free survival. With respect to overall survival, T1bN0 stage (HR, 0.506; 95% CI, 0.264 to 0.971; p=0.04), distance from pericardium (HR, 0.192; 95% CI, 0.090 to 0.412; p=0.001), and tumour size (HR, 2.024; 95% CI, 1.038 to 3.948; p=0.039) were independent prognostic factors for a poor overall survival.

Subgroup analysis by the distance from the pericardium: For patients with NSCLCs that were contiguous to the pericardium, local tumour progression, progression-free survival and overall survival were better in the wedge resection than in the MWA group (n=33, both p values <0.05). According to the treatment modality, intrapulmonary distant recurrence (p=0.365) and overall survival (p=0.192) were not significantly different in patients with NSCLCs that were close but not contiguous to the pericardium. Significant interaction effects between the treatment group and distance from pericardium were observed for local tumour progression and progression-free survival (p=0.018 and p=0.025, respectively).

Variable	Outcome	The distance classification from pericardium	HR (95% CI)	P value	P value for interaction
Treatment type [Local ablation]	Local tumour progression	Lesions that were contiguous to the pericardium (n=33)	2.15 (1.14 to 3.88)	0.011	P=0.018
		Lesions that were not contiguous to the pericardium (n=35)	1.62 (1.28 to 2.65)	0.015	
	Intrapulmonary distant recurrence	Lesions that were contiguous to the pericardium (n=33)	0.57 (0.24 to 1.65)	0.132	P=0.246
		Lesions that were not contiguous to the pericardium (n=35)	1.43 (0.66 to 3.04)	0.365	
	Progression-free survival	Lesions that were contiguous to the pericardium (n=33)	1.44 (1.23 to 2.27)	0.013	P=0.025
		Lesions that were not contiguous to the pericardium (n=35)	1.52 (0.96 to 2.59)	0.082	
	Overall survival	Lesions that were contiguous to the pericardium (n=33)	2.36 (1.35 to 4.02)	0.012	P=0.082
		Lesions that were not contiguous to the pericardium (n=35)	1.46 (0.31 to 2.18)	0.192	

Key safety findings

No treatment-related deaths were recorded.

MWA:

- Major complications: 13.2% (n=9), including pneumothorax (n=5), pleural effusion (n=2) and haemothorax (n=2).
- Mild complications: (n=20), including arrhythmia (n=3), self-limited pneumothorax (n=11), mild pericardial effusion (n=3) and thickening of pericardial layers (n=3).

Wedge resection:

Major complication: 19.4% (30/155), including chest tube required at discharge (n=11), pneumonia (n=13), empyema (n=3), chylothorax (n=4), and atrial fibrillation (n=12).

Study 8 Li B (2016)

Study details

Study type	Case series (retrospective)
Country	China (single centre)
Recruitment period	2014 to 2016
Study population and number	n=80 (100 malignant lung nodules; 52 patients with primary tumours and 28 with metastases) Patients with primary and metastatic lung tumours
Age and sex	Mean 64.1 years; 61% (49/80) male; tumour size, mean 2.0±0.63 cm
Patient selection criteria	Inclusion criteria: patients with a malignant lung nodule considered suitable for MWA; with histologically proved NSCLCs or metastases; and with significant comorbidities or refusal to surgery. Exclusion criteria: patients with any tumour longest diameter >3 cm, cardiopulmonary dysfunction (forced expiratory volume [FEV] <1 L, FEV1% <50%, MVV <50%, New York Heart Association Class III), international normalized ratio >1.4 or platelet count <50 × 109/L, uncontrolled diabetes mellitus or hypertension.
Technique	Under local anaesthesia, MWA was done using an MWA/resection system (Surblate System, Vision Medical, American) operating at 2.45 GHz, allowing 5 to 120W to be delivered to the tumour through a 17-gauge internally water-cooled antenna. MWA was done percutaneously with 1 antenna introduced into the nodule under the CT guidance (Somatom Perspective 64; Siemens, Erlangen, Germany). Power of 40 to 60W was applied for 3 to 5 minutes for nodules 2 cm or smaller; for nodules >2 cm and <3 cm, this was repeated 2 times after repositioning of the antenna.
Follow-up	30 days of hospital discharge after MWA
Conflict of interest/source of funding	None

Analysis

Follow-up issues: Patients were observed in intensive care unit for 24 hours after MWA and seen in the clinic to assess for clinical outcomes and complications at 30 days after ablation. If in clinically stable condition within 24 hours, patients were discharged home the following day. Every patient with overtly unstable clinical signs was instructed to visit the emergency department for further observation and management after discharge from hospital.

Study design issues: This nonrandomised, single-institution, retrospective study assessed the safety and feasibility within 24 hours of discharge post-percutaneous image-guided MWA for inoperable malignant lung nodules and elucidate the factors predisposing to hospital readmission. The primary aim evaluated the rate of short-term admission and procedure-related complications within 30 days of hospital discharge after MWA for inoperative malignant lung nodules. The secondary aims included evaluation of the factors predisposing to technical success and hospital readmission. The study did not have long-term follow-up for adverse events or survival benefit in patients, and did not intend to assess the treatment effect of thermal ablation. Because of the nature of the study there were underlying biases in patient selection caused by referral patterns.

Satisfactory ablation was defined by the ground-glass opacification surrounding the tumour on CT. All the procedures were performed by 2 interventional radiologists, each with >5 years of experience with thermal ablation, and a technician, and a nurse in a hospital CT room. Intent-to treat analysis was used.

Study population issues: Of the 80 patients, 64 were diagnosed single lesion (80%), 12 double lesions (15%), and 4 triple lesions (5%). All tumours treated were <3 cm in diameter and the patients were in different clinical conditions, so the results regarding the safety and feasibility within 24 h discharge may not be generalisable to large tumours and every patient.

Key efficacy findings

- Number of patients analysed: 80 (100 malignant lung nodules 52 patients with primary tumours and 28 with metastases)

Number of procedures: n=93

Technical success: 94% of ablation sessions (94/100)

Single procedures: n=68

Twice procedures: n=11

Triple procedures: n=1

Mean ablation power: 51.6±9.8 W (range 40 to 60 W)

Median ablation time: 4 minutes (range 3 to 5 minutes)

Mean ablation time per nodule: 4.4±0.9 minutes

Number of patients discharged within 24 hours: 91.3% (n=73)

Microwave ablation treatment algorithm

Size, cm	Ablation, W	Time, minutes	Point, n	Microwave antenna, n
<1	40	3	1	1
1 to 2	40	5	1	1
2 to 3	60	5 (3)	2	1 (2)

Key safety findings

Short-term admission because of intra- and post-operative complications: 8.7% (n=7)

Readmission because of periprocedural complications within 30 days following 24-hour discharge: 3.7% (n=3)

- One patient was readmitted 11 days after discharge with mild subcutaneous emphysema surrounding the puncture point of MWA. Appropriate antibiotic and analgesic treatment were given to the patient.
- Two patients were readmitted to the emergency department 1 week after discharge with lung abscess complicated by dyspnoea and high fever. The local abscess was drained percutaneously with CT guidance, and the patients were treated with intravenous antibiotics and discharged 5 days and 9 days later, respectively.

There were no procedure-related mortalities, but the rate of procedure-related complications was 27.5% (n=22), of which 40.9% (9/22) were major and 59.1% (13/22) were minor.

Types of complications:

- Intraoperative: n=6
- Immediate (within 24 hours): n=13
- Periprocedural (within 30 days): n=3

Major complications:

- Severe pneumothorax: n=3, all needed placement of a chest tube. These patients recovered completely without permanent morbidity.
- Severe pain: n=2, the intolerable pain happened during the ablation procedures, not relieved by intravenous injection of 5 mg morphine sulfate. These patients recovered completely without permanent morbidity.
- Air embolism: n=1, this asymptomatic air embolism confirmed with a few airs in thoracic aorta and heart seen on CT immediately after introduction of the microwave antenna. This patient recovered completely without permanent morbidity.
- Lung abscess: n=2
- Intercostal artery injury: n=1

Minor and adverse events:

- Small pneumothorax: n=10
- Subcutaneous emphysema: n=1
- Flexural effusion: n=2
- Haemoptysis: n=7
- Fever: n=2
- Chest pain: n=5

Study 9 Huang GH (2018)

Study details

Study type	Retrospective review of lung MWA database
Country	China (6 centres)
Recruitment period	2011 to 2016
Study population and number	n=23 (25 lesions) Patients with invasive pulmonary aspergillosis secondary to MWA for primary lung tumours
Age and sex	Mean 64.5 years; 83% (19/23) male; tumour size, mean 3.85±1.50 cm
Patient selection criteria	Inclusion criteria: patients having percutaneous lung MWA during the past 2 months; symptoms of lower respiratory tract infection; confirmed signs of infection at the ablation site by imaging; a positive aspergillus result by sputum smear and culture, smear and culture of aseptic specimens derived from the ablation zone, or galactomannan antigen detection; the initial exclusion of a bacterial infection; poor effect of broad-spectrum antibacterial treatment; proven and probable cases of invasive pulmonary aspergillosis; good efficacy of the appropriate empirical therapy against moulds. Exclusion criteria: infection that occurred more than 2 months after MWA; infection of a non-ablation site; the absence of aforementioned mycological evidence; positive bacterial cultivation results from the original specimen; excellent efficacy following antibacterial treatment.
Technique	The MTC-3C microwave ablation system (Qi Ya Research Institute of Microwave Electronic, Nanjing, China. Registration standard: YZB/country 1408–2003. No: SFDA (III) 20073251059) or the ECO-2450B microwave ablation system (ECO Microwave Electronic Institute, Nanjing, China. Registration standard: YZB/country 1475–2013. No: SFDA (III) 20112251456) was used for MWA. Pre-emptive analgesia was given, and all procedures were done under local anaesthesia. Patients were discharged 3 to 5 days after MWA if they recovered well.
Follow-up	Not reported
Conflict of interest/source of funding	None

Analysis

Study design issues: This retrospective, multicentre review of patients included in a comprehensive lung MWA database was formed by 6 health institutions in China. This study investigated the incidence and clinical and radiologic manifestations of invasive pulmonary aspergillosis in patients who underwent MWA and to analyse the treatment outcomes, mortality rate and possible risk factors.

Proven invasive pulmonary aspergillosis required proof demonstrating the presence of fungal elements in diseased tissue by microscopic analysis or by the culture of sterile material. Probable invasive pulmonary aspergillosis required the presence of a host factor, a clinical criterion and a mycological criterion.

Treatment success was defined as a ≥25% reduction in the diameter of radiological lesions, plus patient survival, improvement of disease-related symptoms, and documented clearance of infected sites. Treatment failure was defined as patient survival with no or minor improvement in disease related symptoms plus a 0 to 25% reduction in lesion diameter, deteriorating disease-related clinical symptoms plus new sites of disease or radiological exacerbation of pre-existing lesions, persistent isolation of mould species from infected sites, or patient death during the prespecified period of evaluation.

Study population issues: All the 23 patients with IPA had histologically confirmed primary lung cancers (11 adenocarcinomas, 10 squamous carcinomas and 2 indeterminate tumours) spanning all TNM stages from 1 to 4 (2 cases of 1a, 4 cases of 1b, 2 cases of 2a, 1 case of 2b, 4 cases of 3a, 5 cases of 3b and 5 cases of 4). Of the 23 patients, 6 patients developed proven invasive pulmonary aspergillosis and 17 developed probable invasive pulmonary aspergillosis.

A total of 25 lesions were ablated including ablation of single (n=21) and double lesions (n=2). Single-spot ablation (1 antenna) was used for tumours with a maximum diameter of ≤3.0 cm while multiple spot ablation (2 antennae) was used for tumours >3.0 cm in diameter.

Key efficacy findings

Number of patients analysed: 23 (25 lesions)

Mean ablation time: 13.70±6.63 minutes (range 4.0 to 28.0 minutes)

Key safety findings

Demographic and clinical characteristics of patients

Characteristics	Patients having MWA (n=1,596)	Patients with invasive pulmonary aspergillosis (n=23)	P value
Smoking history			
Yes	36.8% (n=587)	82.6% (n=19)	<0.001
Smoking index >400	23.9% (n=381)	65.2% (n=15)	<0.001
Underlying disease			
COPD	6.1(n=97)	56.5% (n=13)	<0.001
Cardiovascular disease	17.9% (n=286)	30.4% (n=7)	0.175
Malnutrition	9.6% (n=153)	17.4% (n=4)	0.260
Diabetes mellitus	7.1% (n=113)	8.7% (n=2)	1.000
Hepatitis B virus infection	4.6% (n=74)	4.3% (n=1)	1.000
Perioperative chemotherapy	44.9% (n=716)	65.2% (n=15)	0.027

Complications:

- Postablation syndrome: 69.6% (n=16, which was treated with nonsteroidal drugs when necessary)
- Pneumothorax: 39.1% (n=9, of which 6 needed catheterisation for closed drainage)
- Pleural effusion: 43.5% (n=10, of which 5 had thoracentesis)
- Haemoptysis: 13.0% (n=3, which was managed with the appropriate administration of haemostatic drugs)
- Atelectasis: 13.0% (n=3, no special treatment was needed)

Invasive pulmonary aspergillosis after MWA:1.44% (23/1,596) - of these 23 patients, 22 patients initially had intravenous voriconazole while 1 patient had itraconazole. Twelve patients had adjuvant therapy, including 6 patients had intracavitary lavage for necrotic liquefaction, 5 had thoracic drainage for pleural effusion and bronchopleural fistula, and 1 had bronchial artery embolisation.

- Treatment failure (mortality): 26.1% (n=6, of these patients, 4 died of infection and 2 died of sudden massive haemoptysis)
- Treatment success: 73.9% (n=17, of these patients, 5 died from tumour recurrence or metastasis rather than invasive pulmonary aspergillosis)

Symptoms and laboratory and radiological findings of 23 patients with invasive pulmonary aspergillosis:

- Interval between symptom and MWA: 21.09±10.90 days (range 7.0 to 48.0 days)
- Fever: 95.7% (n=22)
    - ≥39°C: 56.5% (n=13)

  - <39°C: 39.1% (n=9)
- Cough: 100% (n=23)
- Sputum: 95.7% (n=22)
  - ≥100 mL/24 h: 52.2% (n=12)
  - <100 mL/24 h: 43.5% (n=10)
- Haemoptysis: 13.0% (n=3)
- Radiological findings (chest CT):
  - Interval between CT and MWA: mean 28.78±9.56 days (range 13.0 to 54.0 days)
  - Mean size of lesions: 7.36±1.94 cm (range 4.70 to 11.10 cm)
  - Cavitation: 87.0% (n=20)
  - Infiltration: 26.1% (n=6)
  - Nodule: 26.1% (n=6)
  - Consolidation: 21.7% (n=5)
  - Bronchopleural fistula: n=13.0% (n=3)

Study 10 Harvey J (2019)

Study details

Study type	Case series
Country	Not reported
Recruitment period	Not reported
Study population and number	n=6 Patients with lung tumours
Age and sex	Mean 72 years; 67% (4/6) male
Patient selection criteria	Not reported
Technique	MWA
Follow-up	2 weeks to 3 months
Conflict of interest/source of funding	None

Analysis

Study design issues: This study described several potentially life-threatening delayed complications associated with pulmonary MWA.

Study population issues:
Patient 1 with left upper lobe squamous cell carcinoma had radiation therapy and 2 subsequent MWA of local recurrence. The patient was discharged the day after ablation.

Key efficacy findings

Number of patients analysed: 6

All patients had MWA for lung tumours.

Key safety findings

Hydropneumothorax: Seventy-eight-year-old male had radiation therapy for left upper lobe squamous cell carcinoma and 2 subsequent MWA for local recurrence. He presented to the emergency department of his local hospital 5 days following discharge with dyspnoea and increased respiratory effort. CXR showed a large hydropneumothorax and left upper lobe collapse. An intercostal catheter was inserted, and the patient needed an 8-day admission before discharging home.

Delayed pleural effusion: Seventy-three-year-old female had MWA for right upper lobe sub-pleural adenocarcinoma. She developed progressively worsening dyspnoea over 3 weeks after discharge, presenting to the emergency department 26 days post-procedure. CXR showed a moderate volume right-sided pleural effusion. An intercostal catheter was placed and left overnight, draining >1 L serous fluid and her symptoms resolved.

Infected hydropneumothorax: Seventy-seven-year-old female had MWA for lung tumours (squamous cell carcinoma and local recurrence of adenocarcinoma). The patient presented to hospital about 6 weeks postprocedure. CXR showed a right-sided hydropneumothorax, and CT chest was suspicious for a bronchopleural fistula. An intercostal catheter was placed the following day. She received a course of intravenous vancomycin and tazocin due to superimposed infection of the sero-pneumothorax. The ICC was removed 16 days after admission, and the patient discharged without residual symptoms.

Prolonged significant air leak with direct pleural thermal damage: Sixty-seven-year-old male had MWA for a 10 mm right upper lobe nodule. The patient experienced progressive dyspnoea. Admission CXR showed collapse of the right lung with several air-fluid levels extending to the para-hilar region. A right-sided intercostal catheter was placed, however, there was ongoing subsequent air leak. The air leak failed to resolve and 5 days later the patient had video-assisted thoracoscopic surgery with debridement of inflammatory exudate and adhesions; a large focal pleuro-parenchymal burn was revealed. The patient needed a 22-day admission for management.

Rib fracture: Seventy-year-old male with T2N0 right upper lobe adenocarcinoma diagnosed incidentally on CXR following a motor vehicle accident. After radiation therapy, he had MWA for local recurrence. Follow-up PET/CT imaging done 3 months after MWA because of increasing ipsilateral chest wall pain showed a new right lateral 5^{th} rib fracture with associated FDG hypermetabolism.

Massive extra-pleural haemorrhage: Sixty-eight-year-old male had MWA for lung metastasis from colorectal carcinoma. Day 15 post-procedure, the patient presented to the emergency department with sudden, severe chest pain after sneezing. Arterial phase CT showed a large loculated left pleural collection with evidence of active haemorrhage at the site of antenna tract within the chest wall. The patient had angiogram and coiling of an actively bleeding inferior side branch of the 7^{th} left intercostal artery. The patient was discharged with opiate analgesia and planned follow-up with CXR 3 days later. Because of persistent local mass effect, he had video-assisted thoracoscopic surgery for drainage of the large left extra-pleural haematoma and small volume haemothorax. He made an uncomplicated recovery and discharged 3 days postoperatively.

Study 11 Xu (2021a)

Study details

Study type	Non-randomised comparative study (retrospective)
Country	China (single centre)
Recruitment period	2016 to 2020
Study population and number	n=317 (364 MWA procedures; 19 patients with cavitary NSCLC and 298 patients with noncavitary NSCLC) Patients with NSCLC
Age and sex	Mean 68 years; 61.2% (194/317) male; tumour size, mean 3.6±2.2 cm
Patient selection criteria	Inclusion criteria: age >18 years, histopathological results of NSCLC confirmed with the bronchoscope prior to MWA and/or with the biopsies prior to or concomitant with MWA ablation, an Eastern Cooperative Oncology Group score of 0 to 2, and complete clinical and radiological data available. Exclusion criteria: other concomitant therapies such as radioactive seed implantation performed during the MWA procedure, a follow-up of <3 months, and incomplete data.
Technique	MWA: An MTC-3C MWA system (Vison Medical, Nanjing, China) or an ECO-100A1 MWA system (ECO Medical Instrument, Nanjing, China) was used, with a microwave emission frequency of 2,450±50 MHz and an adjustable continuous wave output power of 20 to 80 W.
Follow-up	Mean 27.2 months (SD 11.9)
Conflict of interest/source of funding	Funding: This work was funded by the Central Healthcare Research Fund (No. 2020YB10) and the Clinical and Translational Medical Research Fund, Chinese Academy of Medical Sciences (No. 2020-I2M-C&T-A-021). Conflict of interest: none.

Analysis

Follow-up issues: Patients were followed up at 1 to 5 days, 3 to 4 weeks and then every 2 to 4 months after MWA.

Study design issues: This retrospective study explored the outcomes of MWA in patients with cavitary NSCLC and to compare the prognosis of cavitary and noncavitary NSCLC treated with MW ablation.

Radiological recurrence was assessed by 2 experienced radiologists who were blinded to the clinical information. OS was defined as the interval from the start of MWA to death or the last follow-up. PFS was defined as the interval from the initiation of the MWA procedures to the time of objective progression, including local recurrence and/or metastases, which was evaluated by 3 independent interventional radiologists.

Study population issues: At baseline, a statistically significant difference was found in the presence of emphysema (p=0.030), whereas other variables revealed no differences between patients with cavitary NSCLC and patients with noncavitary NSCLC. Nineteen (6.0%) patients with NSCLC presented with cavities before MWA, with a maximum cavity wall thickness of 10.7±6.2 mm. Synchronous coaxial-cannula biopsy was done for 107 (33.8%) patients, of whom 10 (52.5%) had cavitary NSCLC and 97 (32.6%) had noncavitary NSCLC.

Other issues: There were several limitations. First, it was a retrospective study; thus, patient selection bias might exist. Second, the sample size was limited for patients with cavitary NSCLC. Third, the mean follow-up period was 27.2 months. The long-term evolution of cavitary NSCLC after MWA should be further explored.

Key efficacy findings

Number of patients analysed: 317

Ablation factors:

- Maximum power (W): 55.3±11.2 (cavitary NSCLC, 52.6±12.8; non-cavitary NSCLC, 55.6±11.1; p=0.276)
- Total ablation time (minutes): 10.4±5.8 (cavitary NSCLC, 9.0±4.2; non-cavitary NSCLC, 10.5±5.9; p=0.271)

Clinical outcomes of cavitary and noncavitary NSCLC treated with MWA

Variables	**Overall (n=317)**	**Cavitary NSCLC (n=19)**	**Noncavitary NSCLC (n=298)**	**P value**
Local recurrence	21.1% (n=67)	15.8% (n=3)	21.5% (n=64)	0.765
Status				0.344
Survival	58.0% (n=184)	68.4 (n=13)	57.4% (n=171)	
Mortality	42.0% (n=133)	31.6% (n=6)	42.6% (n=127)	
Median PSF (months)	13.0±10.6	9.0±8.5	13.0±10.7	0.180
Median OS (months)	17.0±10.9	14.0±10.8	17.0±10.9	0.133

New pulmonary metastases were found in 15.8% (n=3) of patients with cavitary NSCLC and in 7.7% (n=23) of patients with noncavitary NSCLC after MWA, and no statistically significant difference was found between the groups (p=0.196). Of these patients with new metastases, 2.2% of patients had secondary MWA.

Extrapulmonary progression after MWA: 26.3% (n=5) of patients with cavitary NSCLC and 24.8% (n=76) patients with noncavitary NSCLC developed extrapulmonary progression after MWA.

The Kaplan-Meier method revealed no association between the presence of cavities and OS in patients with NSCLC treated with MWA (24.0 compared with 36.0 months; p=0.843).

Key safety findings

Complications of cavitary and noncavitary NSCLC treated with MWA

Variables	Overall (n=317)	Cavitary NSCLC (n=19)	Noncavitary NSCLC (n=298)	P value
Complications	35.6% (n=113)	57.9% (n=11)	34.6% (n=103)	0.040
Pneumothorax	30.6% (n=97)	57.9% (n=11)	28.9% (n=86)	0.008
Major complications				
Pneumothorax	13.9% (n=44)	15.8% (n=3)	13.8% (n=41)	
Pleural effusion	1.9% (n=6)	0	2.0% (n=6)	
Bronchopleural fistula	0.3% (n=1)	0	0.3% (n=1)	
Pneumonia	0.6% (n=2)	0	0.7% (n=2)	
Minor complications				
Pneumothorax	16.7% (n=53)	42.1% (n=8)	15.1% (n=45)	
Pneumonia	2.2% (n=7)	5.3% (n=1)	2.0% (n=6)	
Side effects				
Chest pain	30.0% (n=95)	26.3% (n=5)	30.2% (n=90)	
Pleural effusion	4.1% (n=13)	5.3% (n=1)	4.0% (n=12)	
Postablation syndrome	9.1% (n=29)	5.3% (n=1)	9.4% (n=28)	

No MWA associated mortality was found within 30 days after MWA.

Study 12 Xu S (2021b)

Study details

Study type	Non-randomised comparative study (retrospective)
Country	China (single centre)
Recruitment period	2016 to 2020
Study population and number	n=319 (366 tumours; ALI group, n=34; non-ALI group, n=285) Patients with NSCLC
Age and sex	Mean 68 years; 61.4% (196/319) male: tumour size, mean 3.6±2.2 cm
Patient selection criteria	Inclusion criteria: age older than 18 years, confirmed NSCLC patients treated with MWA, Eastern Cooperation Oncology Group score of 0 to 2, and complete clinical and radiological data were available. Exclusion criteria: other concomitant therapies done during the MWA procedure, such as radioactive seeds implantation, follow-up less than 6 months, incomplete data, and the presence of pneumothorax before MWA.
Technique	MWA: An MTC-3C MWA system (Vison Medicine) or an ECO-100A1 MWA system (ECO Medical Instrument) was used, with a microwave emission frequency of 2450±50 MHz and an adjustable continuous wave output power of 20 to 80 W.
Follow-up	Mean 27.2 months (SD 11.8)
Conflict of interest/source of funding	Funding: This work was funded by the Central Healthcare Research Fund (No. 2020YB10) and the Clinical and Translational Medical Research Fund, Chinese Academy of Medical Sciences (No. 2020-I2M-C&T-A-021). Conflict of interest: none.

Analysis

Follow-up issues: Patients were followed up at 1 to 5 days, 3 to 4 weeks and then every 1 to 4 months after MWA.

Study design issues: This retrospective study explored the outcomes of MWA in patients with NSCLC and ALI and to compare the outcomes of patients with ALI-NSCLC and patients with non-ALI NSCLC after MWA.

The pre-MWA CT images were examined for the detection of ALI by 2 radiologists with more than 5 years of experience in diagnostic radiology.

Study population issues: At baseline, there were statistically significant differences in tumour diameter (ALI group, 4.7±2.2 cm; non-ALI group, 3.5±2.2 cm; p=0.003), and the number of pleural punctures (ALI group, 1.7±0.7; non-ALI group, 1.4±0.6; p=0.004). The ALI group included 8 (23.5%) patients with right lung horizontal interlobar fissure invasion, 11 (32.4%) patients with right lung oblique fissure invasion, and 15 (44.1%) patients with left lung oblique fissure invasion. A synchronous coaxial-cannula biopsy was done for 108 (33.9%) patients, which consist of 16 (47.1%, 16/34) in the ALI group and 92 (32.3%, 92/285) in the non-ALI group.

Patients from this study might also be included in Xu (2021a).

Other issues: There were several limitations. First, it was a retrospective study, and patient selection bias might therefore exist. Second, the sample size was limited for patients with ALI-NSCLC. Third, the mean follow-up of this study was 27.2±11.8 months, and a longer follow-up and comparisons were needed. Fourth, the incomplete data of immediate contrast-enhanced CT scans after MWA prevented a comparison of the complete ablation rate between the 2 groups.

Key efficacy findings

Number of patients analysed: 319

Post-MWA treatments and ablation factors

Variables	Overall (n=319)	ALI group (n=34)	Non-ALI group (n=285)	P value
Post-MWA treatments				
Post chemotherapy	19.7% (n=63)	23.5% (n=8)	19.3% (n=55)	0.558
Post radiotherapy	11.9% (n=38)	20.6% (n=7)	10.9% (n=31)	0.170
Post tyrosine kinase inhibitors	37.6% (n=120)	41.2% (n=14)	37.2% (n=106)	0.650
Post immunotherapy	8.8% (n=28)	8.8% (n=3)	8.8% (n=25)	1
Ablation factors				
Maximum power (W)	55.5±11.1	57.4±13.3	55.2±10.8	0.290
Total ablation time (minutes)	10.4±5.8	12.1±4.8	10.2±5.9	0.072
Diameter of instruments				0.112
15G	42.3% (n=135)	29.4% (n=10)	43.9% (n=125)	
16G	15.7% (n=50)	11.8% (n=4)	16.1% (n=46)	
17G	42.0% (n=134)	58.8% (n=20)	40.0% (n=114)	

Clinical outcomes of ALI and non-ALI groups who had MWA

Variables	Overall (n=319)	ALI group (n=34)	Non-ALI group (n=285)	P value
Local recurrence	21.6% (n=69)	29.4% (n=10)	20.7% (n=59)	0.244
Status				0.172
Survival	58.0% (n=185)	47.1% (n=16)	59.3% (n=169)	
Mortality	42.0% (n=134)	52.9% (n=18)	40.7% (n=116)	
Median PSF (months)	13.0±10.5	12.0±10.2	13.0±10.6	0.329
Median OS (months)	17.0±10.9	15.5±9.5	17.0±11.1	0.394

Of the patients who experienced a local recurrence, 18 (5.6%) NSCLC patients had secondary MWA.

New pulmonary metastases were found in 5 (14.7%) ALI-NSCLC patients and 21 (7.4%) non-ALI NSCLC patients. Of these, 7 (2.2%) NSCLC patients had secondary MWA.

Key safety findings

Main complications of ALI and non-ALI groups who had MWA

Variables	Overall (n=319)	ALI group (n=34)	Non-ALI group (n=285)	P value
Pneumothorax	29.8% (n=95)	52.9% (n=18)	27.0% (n=77)	0.002
Pleural effusion	2.2% (n=7)	5.9% (n=2)	1.8% (n=5)	0.350
Haemoptysis	2.8% (n=9)	5.9% (n=2)	2.5% (n=7)	0.247

The risk of pneumothorax increased when the NSCLC patients presented with ALI (HR 2.867, 95% CI 1.256 to 6.548, p=0.012) and emphysema (HR 9.891, 95% CI 5.538 to 17.665, p<0.001).

No MWA-associated mortality and severe complications were found within 30 days after MWA.

Study 13 Ramos-Bossini AJL (2021)

Study details

Study type	Case report
Country	Spain
Recruitment period	Not reported
Study population and number	n=1 patient with lung adenocarcinoma
Age and sex	74 years; male
Patient selection criteria	Not reported
Technique	CT-guided MWA was done.
Follow-up	Not reported
Conflict of interest/source of funding	None

Analysis

Study population issues: The patient who had lung adenocarcinoma (pT1aN0M0) in the right upper lobe, had segmental resection and post-surgical radiation therapy. Local tumour recurrence was found during follow-up.

Key efficacy findings

Number of patients analysed: 1

MWA procedure went smoothly, and the patient was discharged.

Key safety findings

Bronchial fistula and bronchocutaneous fistula from the post-MTA cavity: n=1

At 1 week after discharge, a chest X-ray revealed marked subcutaneous emphysema, with no signs of pneumothorax. Chest CT showed pulmonary cavitation at the MWA site communicating with a bronchus leading to the right upper lobe and with a large gas-filled space in the chest wall, along with extensive pneumomediastinum and subcutaneous emphysema, findings consistent with bronchial fistula and bronchocutaneous fistula from the post-MWA cavity. The patient was hospitalised and kept under observation and the emphysema was drained. Progress was favourable.

Validity and generalisability of the studies

- When reported, studies were conducted in China, France and Spain. All studies were retrospective.
- There was likely to be some patient overlap between studies (Nelson 2019; Sun 2018; Yuan 2019; Xu 2021a, 2021b).
- When reported, the mean age ranged from 56 to 83 years and more than 50% of patients were male.
- There was variation in patient populations (in terms of tumour sizes, histologies, and number of treated nodules per patient), operators' technical experiences and MWA techniques.
- Of the included 13 studies, 6 had a longest follow up of 3 to 5 years.
- There were several devices used for MWA.

Existing assessments of this procedure

The guideline from ECIO (European Conference on Interventional Oncology) and ESOI (European Society of Oncology Imaging) on follow-up after radiological intervention in oncology was published in 2020. One recommendation for follow-up after thermal ablation of lung tumours was 'after 6 months, the treated lesion may remain stable or slightly decreased in size after RAF or MWA. Shrinkage after cryoablation is usually more profound.' Evidence on thermal ablation (RFA and MWA) in NSCLC included 21 articles and modalities covered CT, MRI and FDG-PET (fluorodeoxyglucose positron emission tomography, -CT).

Related NICE guidance

Below is a list of NICE guidance related to this procedure.

Interventional procedures

- Irreversible electroporation for treating primary lung cancer and metastases in the lung. NICE interventional procedure guidance 441 (2013). Available from https://www.nice.org.uk/guidance/IPG441

- Percutaneous radiofrequency ablation for primary or secondary lung cancers. NICE interventional procedure guidance 372 (2010). Available from https://www.nice.org.uk/guidance/IPG372

NICE guidelines

- Lung cancer: diagnosis and management. NICE guideline 122 (2019). Available from https://www.nice.org.uk/guidance/ng122

Additional information considered by IPAC

Professional experts' opinions

Expert advice was sought from consultants who have been nominated or ratified by their professional Society or Royal College. The advice received is their individual opinion and is not intended to represent the view of the society. The advice provided by professional experts, in the form of the completed questionnaires, is normally published in full on the NICE website during public consultation, except in circumstances but not limited to, where comments are considered voluminous, or publication would be unlawful or inappropriate. No professional expert questionnaires for Microwave ablation for primary or metastatic cancer in the lung were submitted.

Patient commentators' opinions

NICE's Public Involvement Programme was unable to gather patient commentary for this procedure.

Company engagement

A structured information request was sent to 3 companies who manufacture a potentially relevant device for use in this procedure. NICE received 3 completed submissions. These were considered by the IP team and any relevant points have been taken into consideration when preparing this overview.

References

1. Yuan ZH, Wang Y, Zhang J et al. (2019) A meta-analysis of clinical outcomes after radiofrequency ablation and microwave ablation for lung cancer and pulmonary metastases. Journal of the American College of Radiology: JACR 16(3): 302-14
2. Sun YD, Zhang H, Liu JZ et al. (2019) Efficacy of radiofrequency ablation and microwave ablation in the treatment of thoracic cancer: A systematic review and meta-analysis. Thoracic cancer 10(3): 543-50
3. Nelson DB, Tam AL, Mitchell KG et al. (2019) Local Recurrence After Microwave Ablation of Lung Malignancies: A Systematic Review. The Annals of thoracic surgery 107(6): 1876-83
4. Aufranc V, Farouil G, Abdel-Rehim M et al. (2019) Percutaneous thermal ablation of primary and secondary lung tumours: Comparison between microwave and radiofrequency ablation. Diagnostic and Interventional Imaging 100(12): 781-91
5. Das SK, Huang YY, Li B et al. (2020) Comparing cryoablation and microwave ablation for the treatment of patients with stage IIIB/IV non-small cell lung cancer. Oncology Letters 19(1): 1031-41
6. Yao W, Lu MJ, Fan WZ et al. (2018) Comparison between microwave ablation and lobectomy for stage I non-small cell lung cancer: a propensity score analysis. International journal of hyperthermia: the official journal of European Society for Hyperthermic Oncology, North American Hyperthermia Group 34(8): 1329-36
7. Hu H, Zhai B, Liu R et al. (2021) Microwave ablation versus wedge resection for stage I non-small cell lung cancer adjacent to the pericardium: propensity score analyses of long-term outcomes. CardioVascular and Interventional Radiology 44(2): 237-46
8. Li B, Wang ZW, Zhou K et al. (2016) Safety and feasibility within 24 h of discharge in patents with inoperable malignant lung nodules after percutaneous microwave ablation. Journal of cancer research and therapeutics 12(supplement): c171-5
9. Huang GH, Ye X, Yang X et al. (2018) Invasive pulmonary aspergillosis secondary to microwave ablation: a multicenter retrospective study. International journal of hyperthermia: the official journal of European Society for Hyperthermic Oncology, North American Hyperthermia Group 35(1): 71-8
10. Harvey J, Windsor MN and Steinke K (2015) Delayed complications following microwave ablation of lung tumours. Journal of Medical Imaging and Radiation Oncology 63(6): 770-8

11. Xu S, Bie, ZX, Li, YM, et al. (2021a) A Comparative Study of Cavitary and Noncavitary Non-small Cell Lung Cancer Patients Treated with CT-Guided Microwave Ablation. Journal of Vascular and Interventional Radiology 32(8): 1170-1178
12. Xu S, Bie ZX, Li YM et al. (2021b) Computed tomography-guided microwave ablation for the treatment of non-small cell lung cancer patients with and without adjacent lobe invasion: a comparative study. Thorac Cancer 12: 2780-8
13. Lainez Ramos-Bossini AJ, Ruiz Carazo E and Lopez Milena G (2021) Double fistula after cavitation of lung adenocarcinoma treated by microwave thermal ablation. An exceedingly rare complication. Archivos de bronconeumologia
14. Maas M, Beets-Tan R, Gaubert JY et al. (2020) Follow-up after radiological intervention in oncology: ECIO-ESOI evidence and consensus-based recommendations for clinical practice. Insights into Imaging 11(1): 83

Literature search strategy

Databases	Date searched	Version/files
Cochrane Database of Systematic Reviews – CDSR (Cochrane Library)	07/09/2021	Issue 9 of 12, September 2021
Cochrane Central Database of Controlled Trials – CENTRAL (Cochrane Library)	07/09/2021	Issue 9 of 12, September 2021
International HTA database (INAHTA)	06/09/2021	1946 to September 03, 2021
MEDLINE (Ovid)	06/09/2021	September 03, 2021
MEDLINE In-Process (Ovid)	06/09/2021	September 03, 2021
MEDLINE Epubs ahead of print (Ovid)	06/09/2021	1974 to 2021 September 03
EMBASE (Ovid)	06/09/2021	1974 to 2021 September 03

The following search strategy was used to identify papers in MEDLINE. A similar strategy was used to identify papers in other databases.

Literature search strategy

Number	Search term
1	exp Lung Neoplasms/
2	((lung* or pulmon* or thora*) adj4 (neoplasm* or cancer* or carcinoma* or adenocarcinom* or tumour* or tumor* or malignan* or metasta* or angiosarcoma* or chrondosarcoma* or sarcoma* or teratoma* or lymphoma* or blastoma* or microcytic* or carcinogenes* or nodule*)).tw.
3	(NSCLC or NSCL or SCLC).tw.
4	or/1-3
5	Microwaves/
6	(microwave* or micro-wave*).tw.
7	(MCT or PMCT or MWA or MW or MWTA).tw.
8	or/5-7
9	4 and 8
10	(Acculis or Microsulis or sulis or NeuWave or solero or Amica or Emprint or cool?tip).tw.
11	9 or 10
12	animals/ not humans/

13	11 not 12

Appendix

The following table outlines the studies that are considered potentially relevant to the IP overview but were not included in the summary of the key evidence. It is by no means an exhaustive list of potentially relevant studies.

Additional papers identified

Article	Number of patients/follow-up	Direction of conclusions	Reasons for non-inclusion in summary of key evidence section
Abbas G, Danish A and Krasna MJ (2016) Stereotactic body radiotherapy and ablative therapies for lung cancer. Surgical oncology clinics of North America 25(3): 553-66	Review	Microwave ablation is a promising novel ablative modality that in the near future would be available for transbronchial ablation of small lung tumours, especially more central tumours	Review article
Acksteiner C and Steinke K (2015) Percutaneous microwave ablation for early-stage non-small cell lung cancer (NSCLC) in the elderly: a promising outlook. Journal of medical imaging and radiation oncology 59(1): 82-90	Case series n=10 (11 lesions)	MWA therapy is a promising option of treating early-stage NSCLC in the elderly with good treatment outcome and negligible morbidity. Determining successful treatment outcome may be challenging at times as local tissue increase and PET-CT positivity do not seem to necessarily correlate with recurrence of malignancy.	Studies with a larger sample or a better design are included in the key evidence summary.

Al-Hakim RA, Abtin FG, Genshaft SJ et al. (2016) Defining new metrics in microwave ablation of pulmonary tumours: ablation work and ablation resistance score. Journal of vascular and interventional radiology 27(9): 1380-6	Non-randomised comparative study n=71 (98 tumours)	Pulmonary microwave ablation zone is significantly smaller in regions with higher ablation resistance score. Ablation work correlates to ablation zone with a nonlinear involution pattern in the first year and may be useful for planning before the procedure.	This study investigated pulmonary microwave ablation metrics including ablation work, ablation resistance score, and involution.
Backlund M and Freedman J (2017) Microwave ablation and immune activation in the treatment of recurrent colorectal lung metastases: a case report. Case Reports in Oncology 10(1): 383-7	Case report n=1	The presented case demonstrates the possibilities of using stereotactically navigated ablation antennas for microwave ablation of multiple lung metastases.	Single case report
Baisi A, de Simone M, Raveglia F et al. (2013) Thermal ablation in the treatment of lung cancer: present and future. European journal of cardio-thoracic surgery: official journal of the European Association for Cardio-thoracic Surgery 43(4): 683-6	Review	Local efficacy is directly correlated to tumour target size: for MWA, according to the largest available study, 95% of initial ablations are reported to be successful for tumours smaller than 5 cm. Very few series provide survival data beyond 3 years.	Review article
Belfiore G, Ronza F, Belfiore MP et al. (2013) Patients' survival in lung malignancies treated by microwave ablation: our experience on 56 patients. European	Case series n=56 (69 unresectable malignancies)	MW ablation seems to represent a potential safe and effective percutaneous technique in the treatment of lung malignancies. MW	This study was included in the previous overview.

journal of radiology 82(1): 177-81		ablation may improve survival in patients not suitable to surgery.	
Best L, Seddon B, Woldman S et al. (2014) Microwave ablation of pulmonary metastases associated with perioperative takotsubo cardiomyopathy. Journal of vascular and interventional radiology 25(7): 1139-41	Case report n=1	Although Takotsubo cardiomyopathy associated with microwave lung ablation has not previously been reported, there have been reports describing TCM related to adrenal gland metastasis ablation and endovascular procedures. Radiologists performing pulmonary ablation should be aware of this entity should a “perioperative myocardial infarction” occur.	Single case report
Bin Traiki TA, Fisher OM, Valle SJ et al. (2017) Percutaneous lung ablation of pulmonary recurrence may improve survival in selected patients undergoing cytoreductive surgery for colorectal cancer with peritoneal carcinomatosis. European journal of surgical oncology: the journal of the European Society of Surgical Oncology and the British Association of Surgical Oncology 43(10): 1939-48	Case series n=21 (7 MWA, 13 RFA and 1 combined MWA and RFA)	Pulmonary metastases develop in approximately a fourth of patients undergoing CRS/IPC for colorectal cancer. Of these, about 1/3 may be eligible for percutaneous lung ablative therapy (PLAT). PLAT is a valuable treatment option providing good local control and potentially prolongation of overall survival.	Small sample and outcomes (efficacy and safety) were not reported separately.

Bonichon F, de Baere T, Berdelou A et al. (2021) Percutaneous thermal ablation of lung metastases from thyroid carcinomas. A retrospective multicenter study of 107 nodules. On behalf of the TUTHYREF network. Endocrine 72(3): 798-808	Case series n=47 (106 nodules)	TA is a useful, safe and effective option for local treatment of lung metastases from thyroid carcinoma. Prolonged OS was obtained, especially for lung metastases from follicular, oncocytic, or papillary follicular variant carcinomas. Achieving disease control with TA delays the need for systemic treatment.	Studies with a larger sample are included in the key evidence. outcomes for MWA were not reported separately from RFA and cryoablation.
Bui JT, Gaba RC, Knuttinen MG et al. (2011) Microwave lung ablation complicated by bronchocutaneous fistula: case report and literature review. Seminars in interventional radiology 28(2): 152-5	Case report and literature review n=1	This case shows a microwave lung ablation complicated by bronchocutaneous fistula and its treatment. BCF treatment options include close monitoring, surgical closure, percutaneous sealant injection, and endoscopic plug or sealant in those who are not surgical candidates.	Single case report
Carrafiello G, Mangini M, Fontana F et al. (2012) Complications of microwave and radiofrequency lung ablation: personal experience and review of the literature. La Radiologia medica 117: 201-13	Non-randomised comparative study n=45 (MWA, n=16; RFA, n=29)	Pneumothorax is the most common complication of both techniques. MWA and RFA are both excellent choices in terms of safety and tolerance.	This study was included in the previous overview.
Carrafiello G, Mangini M, Fontana F et al. (2014) Microwave ablation of	Case series	Technical success was 100 %. No major complications	Studies with a larger sample or a better

lung tumours: single-centre preliminary experience. La Radiologia medica 119(1): 75-82	n=24 (26 lesions)	were recorded. Asymptomatic grade-1 pneumothorax was recorded in 9 patients (37.5%). One case of asymptomatic pleural effusion and one of haemoptysis, not requiring transfusion, were observed. No patients were diagnosed with a post-ablation syndrome. Complete necrosis was observed in 16 of 26 lesions (62%). Partial necrosis was obtained in 31 % (8/26 lesions); in one case (3.8%) a progression of the disease was recorded and, in another case, (3.8%) a stability was observed.	design are included in the key evidence summary.
Chaddha U, Kyle Hogarth, D and Murgu S. (2019) Bronchoscopic ablative therapies for malignant central airway obstruction and peripheral lung tumours. Annals of the American Thoracic Society 16(10): 1220-9	Review	Pneumothorax has been reported in 30% to 60% of the patients. Other complications include skin burns (up to 9%), alveolar haemorrhage (0 to45%), haemoptysis (up to 30%), pleural effusion (0 to 34%), infection (0 to 18%), and bronchopleural fistula (0 to 2%).	Review article
Chan JWY, Lau RWH, Ngai, JCL et al. (2021)	Case series	Bronchoscopic transbronchial MWA	Studies with a larger sample

Transbronchial microwave ablation of lung nodules with electromagnetic navigation bronchoscopy guidance-a novel technique and initial experience with 30 cases. Translational Lung Cancer Research 10(4): 1608-22	n=25 (30 nodules)	is safe and feasible for treatment of malignant lung nodules. Prospective study on clinical application of this novel technique is warranted.	are included in the key evidence.
Chan MV, Huo YR, Cao C et al. (2021) Survival outcomes for surgical resection versus CT-guided percutaneous ablation for stage I non-small cell lung cancer (NSCLC): a systematic review and meta-analysis. European Radiology	Systematic review and meta-analysis n=8 studies (MWA in 2 studies)	Surgical resection of stage 1 NSCLC remains the optimal choice. However, for non-surgical patients with stage 1A, ablation offers promising DFS, CSS, and OS. Future prospective randomised controlled trials are warranted.	Limited outcomes for MWA were reported.
Chan G, Kwan J, Samol J et al. (2019) Remote right main pulmonary bronchus bronchopleural fistula formation after microwave ablation of lung tumour. Journal of vascular and interventional radiology 30(10): 1656-8	Case report n=1	Central airway bronchus bronchopleural fistula can occur away from the microwave ablation zone and could be treated using endoscopic application of fibrin glue.	Single case report
Chen B, Li W, Liu Y et al. (2020) The efficacy and complications of computed tomography guided microwave ablation in lung cancer. Annals of palliative medicine 9(5): 2760-5	Case series n=45	CT-guided microwave ablation is an effective method in the treatment of lung cancer, with a low incidence of complications. It is a safe and effective method for the treatment of lung cancer.	Studies with a larger sample or a better design are included in the key evidence summary.

Cheng M, Fay M and Steinke K (2016) Percutaneous CT-guided thermal ablation as salvage therapy for recurrent non-small cell lung cancer after external beam radiotherapy: A retrospective study. International journal of hyperthermia: the official journal of European Society for Hyperthermic Oncology, North American Hyperthermia Group 32(3): 316-23	Case series n=12 (RFA for 4 lesions and MWA for 13)	Both RFA and MWA ablation prolonged local tumour control with minimal morbidity in this study group of recurrent NSCLC after radiotherapy.	This study was included in Sun et al. (2018).
Cheng G, Shi LR, Qiang WG et al. (2018) The safety and efficacy of microwave ablation for the treatment of CRC pulmonary metastases. International journal of hyperthermia: the official journal of European Society for Hyperthermic Oncology, North American Hyperthermia Group 34(4): 486-91	Case series n=32 (48 lesions)	CT-guided percutaneous microwave ablation is a safe and effective minimally invasive method for treating colorectal cancer pulmonary metastases.	Studies with a larger sample or a better design are included in the key evidence summary.
Chi JC, Ding M, Shi YP et al. (2018) Comparison study of computed tomography-guided radiofrequency and microwave ablation for pulmonary tumours: A retrospective, case-controlled observational study. Thoracic cancer 9(10): 1241-8	Non-randomised comparative study n=238 (MWA, n=139; RFA, n=99)	Both RFA and MWA are safe and effective treatments with a survival benefit for selected patients with primary and metastatic lung tumours.	This study was included in Sun et al. (2018).
Danaher LA and Steinke K (2013) Hot tips on hot tips: technical problems with percutaneous insertion of a microwave antenna through rigid	Case report n=1	This case shows an instance of microwave antenna breakage upon insertion through rigid costal cartilage	This study was included in the previous overview.

tissue. Journal of medical imaging and radiation oncology 57: 57-60		and tip dislodgement during withdrawal of the antenna. It also highlights antenna incompatibility with certain coaxial needles.	
de Baere T and Deschamps F (2014) New tumor ablation techniques for cancer treatment (microwave, electroporation). Diagnostic and Interventional Imaging 95(78): 677-82	Review	Microwave ablation is a rapidly developing thermal ablation technique similar to RFA but with numerous differences. Electroporation, a non-thermal ablation technique with other possibilities, is in earlier stages of clinical development.	Review article
de Baere T, Tselikas L, Catena V et al. (2016) Percutaneous thermal ablation of primary lung cancer. Diagnostic and interventional imaging 97(10): 1019-24	Review	Alternative ablation techniques to radiofrequency, such as microwave and cryoablation, may help to overcome the limitations of RFA in the future, particularly for large tumours or tumours close to large vessels.	Review article
de Baere T, Tselikas L, Gravel G et al. (2017) Lung ablation: Best practice/results/response assessment/role alongside other ablative therapies. Clinical radiology 72(8): 657-64	Review	It has been shown that MWA as a local therapy for oligometastatic NSCLC should be considered in patients with acquired resistance to epidermal growth factor receptor tyrosine kinase inhibitor drugs.	Review article

Dupuy DE and Shulman M (2010) Current status of thermal ablation treatments for lung malignancies. Seminars in interventional radiology 27(3): 268-75	Review	Recent studies with microwave ablation and cryoablation have shown some advantages over RFA	Review article
Egashira Y, Singh S, Bandula S et al. (2016) Percutaneous high-energy microwave ablation for the treatment of pulmonary tumours: a retrospective single-centre experience. Journal of vascular and interventional radiology 27(4): 474-9	Case series n=44 (87 tumours)	High-energy microwave ablation is safe and effective for the destruction of lung tumours.	Studies with a larger sample or a better design are included in the key evidence summary.
Ferguson CD, Luis CR and Steinke K (2017) Safety and efficacy of microwave ablation for medically inoperable colorectal pulmonary metastases: Single-centre experience. Journal of medical imaging and radiation oncology 61(2): 243-9	Case series n=14 (20 lesions)	Microwave ablation is safe and efficacious in the local control of colorectal pulmonary metastases. The frequent systemic disease progression despite local control would favour a minimally invasive treatment option over invasive surgery in the setting of oligometastatic disease.	Studies with a larger sample or a better design are included in the key evidence summary.
Freedman J and Harbut P (2016) Navigated percutaneous lung ablation under high-frequency jet ventilation of a metastasis from a Wilms' tumour: A Paediatric Case Report. Case Reports in Oncology 9(2): 400-4	Case report n=1	A paediatric patient with an inoperable lung metastasis from a Wilms' tumour was successfully treated with percutaneous navigated microwave ablation under high-frequency jet	Single case report

		ventilation. The case shows the clinical applicability of new generation targeting technologies, energy sources and a new application of an old ventilation technique.	
Frodsham AE and Reddy CB (2017) Case report of parabronchial lung metastasis treated by percutaneous microwave ablation in combination with bronchoscopic endobronchial saline solution cooling to minimize injury to a bronchus. Journal of vascular and interventional radiology 28(8): 1205-7	Case report n=1	Combined bronchoscopic visualisation and cooling during microwave ablation was effective in protecting the bronchial endothelium from thermal injury and perforation. This also served as a safety measure for possible intraprocedural bronchoscopic placement of an endobronchial valve in the event of a bronchopleural fistula.	Single case report
Ghaye B (2013) Percutaneous ablation of malignant thoracic tumours. JBR-BTR 96(3): 142-54	Review	The ideal lesion for thermal ablation is less than 2 or 3 cm in diameter. Success of percutaneous thermal ablation appears to be close to those of surgery for localised lung cancer.	Review article
Guo R, Li YM, Bie ZX et al. (2020) Pneumothorax triggered by EGFR-tyrosine kinase inhibitors in three microwave	Case series n=3	Microwave ablation candidates treated with epidermal growth factor receptor tyrosine	Studies with a larger sample or a better design are included in the

ablation candidates: A review of the literature. Thoracic cancer 11(7): 2031-5		kinase inhibitors are more likely to suffer pneumothorax. The risk of delayed pneumothorax or even bronchopleural fistula in patients pretreated with tyrosine kinase inhibitors should be taken into consideration when selecting patients and performing microwave ablations.	key evidence summary.
Han X, Yang X, Huang G et al. (2019) Safety and clinical outcomes of computed tomography-guided percutaneous microwave ablation in patients aged 80 years and older with early-stage non-small cell lung cancer: A multicenter retrospective study. Thoracic Cancer 10(12): 2236-42	Case series n=63	CT-guided percutaneous MWA is a safe and effective modality for treating patients aged 80 years and older with early-stage peripheral NSCLC.	Studies with a larger sample or a better design are included in the key evidence summary.
Han X, Yang X, Ye X et al. (2015) Computed tomography-guided percutaneous microwave ablation of patients 75 years of age and older with early-stage nonsmall cell lung cancer. Indian journal of cancer 52suppl2: e56-60	Case series n=28	CT-guided percutaneous MWA is safe and effective for the treatment of patients 75 years of age and older with medically inoperable early-stage peripheral NSCLC.	Studies with a larger sample or a better design are included in the key evidence summary.
Harrison OJ, Sarvananthan S, Tamburrini A et al. (2021) Image-guided combined ablation and resection in thoracic surgery for the treatment of multiple pulmonary	Case series n=4	The hybrid approach provides a minimally invasive and comprehensive personalised therapy for patients with multiple	Studies with a larger sample are included in the key evidence.

metastases: A preliminary case series. JTCVS Techniques		pulmonary metastases under a single general anaesthetic. It provides histology-based diagnosis whilst minimising lung tissue loss and eliminating the need for transfer from radiology to operating theatre. Emergence of ablation as a treatment for stage 1 NSCLC and the expansion of lung cancer screening may widen the application of the image-guided combined ablation and resection in thoracic surgery in the future.	
Hartley-Blossom ZJ and Healey TT (2019) Percutaneous thermal ablation for lung cancer: an update. Surgical technology international 34: 359-364	Review	Percutaneous thermal ablation has been shown to be a safe and effective treatment for patients with early-stage NSCLC who are not candidates for surgery, as well as a potential treatment for local small cell lung cancers. As the field of oncology, and specifically the treatment of lung cancer, continues to evolve, PTA will represent a useful tool in the arsenal.	Review article
He W, Hu X, Wu D et al. (2006) Ultrasonography-	Case series	Ultrasonography-guided PMA, a	This study was included

guided percutaneous microwave ablation of peripheral lung cancer. Clinical Imaging 30:234-41	n=12	mildly invasive procedure, is an effective, safe, and feasible method for treating peripheral lung tumours. Percutaneous MWA provides an alternative therapy for patients with inoperable peripheral lung cancer as well as for patients who refuse radiation or chemotherapy.	in the previous overview.
Healey TT, March BT, Baird G et al. (2017) Microwave ablation for lung neoplasms: a retrospective analysis of long-term results. Journal of vascular and interventional radiology 28(2): 206-11	Case series n=108	This study supports the safe and effective use of MW ablation for the treatment of lung tumours	This study was included in Yuan et al. (2019)
Hernandez JI, Cepeda MFJ, Valdes F et al. (2015) Microwave ablation: State-of-the-art review. OncoTargets and Therapy 8: 1627-32	Review	MWA is a technique that has proved to be promising and likely to be used increasingly in the ablation of cancerous tumours. However, MWA needs to be used more widely to establish itself as a common tool in the treatment of inoperable tumours.	Review article
Hinshaw JL, Lubner MG, Ziemlewicz TJ et al. (2014) Percutaneous tumour ablation tools: microwave, radiofrequency, or cryoablation--what should you use and	Review	Authors favour the use of high-powered microwave ablation for treatment of tumours in the liver, periphery of the kidney, and lung. The use of any	Review article

why?. Radiographics : a review publication of the Radiological Society of North America, Inc 34(5): 1344-62		heat-based ablation modality in the lung can be associated with prolonged air leaks or bronchopleural fistulas, and, thus, the operator must avoid both tract cautery and direct puncture of peripheral tumours.	
Hou XW, Zhuang Xg, Zhang HW et al. (2017) Artificial pneumothorax: a safe and simple method to relieve pain during microwave ablation of subpleural lung malignancy. Minimally invasive therapy & allied technologies: MITAT : official journal of the Society for Minimally Invasive Therapy 26(4): 220-6	Case series n=9 (10 tumours)	The tumours of the 9 patients were eliminated successfully using microwave ablation with artificial pneumothorax under local anaesthesia. The artificial pneumothorax is a reliable therapy to improve the curative effect of microwave ablation by relieving the pain.	Studies with a larger sample or a better design are included in the key evidence summary.
Hsia DW and Musani AI (2018) Bronchoscopic therapies for peripheral lung malignancies. Clinics in Chest Medicine 39(1): 245-59	Review	A variety of therapeutic ablation methods are in use for bronchoscopic treatment of central airway malignancies and percutaneous CT-guided interventions for peripheral lung cancer. These modalities are being adapted for use with guided bronchoscopy. Early studies of guided bronchoscopy ablation of early-stage lung cancers	Review article

		are promising but still investigational.	
Ierardi AM, Coppola A, Lucchina N et al. (2017) Treatment of lung tumours with high-energy microwave ablation: a single-centre experience. Medical oncology 34(1): 5	Case series n=19 (31 tumours)	Overall survival was 93.8%. Percutaneous high-energy MWA is a safe, effective and confident technique to treat lung tumours not suitable for surgery.	Studies with a larger sample or a better design are included in the key evidence summary.
Leppelmann KS, Levesque VM, Bunck AC et al. (2021) Outcomes following percutaneous microwave and cryoablation of lung metastases from adenoid cystic carcinoma of the head and neck: a bi-institutional retrospective cohort study. Annals of Surgical Oncology	Non-randomised comparative study n=10 (60 tumours)	Percutaneous computed tomography-guided microwave and cryoablation can treat lung metastases from adenoid cystic carcinoma of the head and neck. Complications are common but manageable, with full recovery expected.	Studies with a larger sample or a better design are included in the key evidence summary.
Lezzi R, Cioni R, Basile D et al. (2021) Standardising percutaneous microwave ablation in the treatment of lung tumours: a prospective multicentre trial (MALT study). European Radiology 31: 2173-82	Non-randomised comparative study n=54 (69 tumours)	Percutaneous CT-guided MWA is a reproducible, safe, and effective treatment for malignant lung tumours up to 4cm in size.	Studies with a larger sample or a better design are included in the key evidence summary.
Jahangeer S, Forde P, Soden D et al. (2013) Review of current thermal ablation treatment for lung cancer and the potential of electrochemotherapy as a means for treatment of lung tumours. Cancer	Review	The theoretical advantages that MWA offers over RFA have yet to be demonstrated clinically; current literature review shows no evidence of MWA being a superior form of thermal ablation. To	Review article

treatment reviews 39(8): 862-71		date, there has not been any clinical study comparing the efficacy of these 2 forms of ablations in treating lung tumours.	
Jia H, Tian J, Liu B et al. (2019) Efficacy and safety of artificial pneumothorax with position adjustment for CT-guided percutaneous transthoracic microwave ablation of small subpleural lung tumours. Thoracic Cancer 10(8): 1710-6	Non-randomised comparative study n=56 (MWA with the support of artificial pneumothorax, n=24; MWA without the support of artificial pneumothorax, n=32)	Artificial pneumothorax with position adjustment for CT-guided MWA is effective and may be safely applied to small subpleural lung tumours. Artificial pneumothorax is a reliable therapy for pain relief.	Studies with a larger sample or a better design are included in the key evidence summary.
Jones GC, Kehrer JD Kahn J et al. (2015) Primary treatment options for high-risk/medically inoperable early stage NSCLC patients. Clinical lung cancer 16(6): 413-30	Review	Limited outcomes data is available to support the use of MWA in the treatment of early-stage NSCLC. As with RFA, MWA can be considered in the treatment of recurrent disease or in combination with other techniques to provide palliation of progressive pulmonary lesions. Future studies will hopefully clarify the role of MWA in the treatment of high-risk NSCLC.	Review article
Kashiwabara K, Fujii S, Tsumura S et al. (2021) Efficacy and safety of transbronchial microwave ablation therapy under moderate sedation in malignant central airway	Non-randomised comparative study n=38 (10 with respiratory failure and 28 without respiratory failure)	Transbronchial microwave ablation therapy under moderate sedation was well tolerated and effective in patients with malignant central	Studies with a larger sample or a better design are included in the key evidence summary.

obstruction patients with respiratory failure: a single-institution retrospective study. Journal of Cancer Research and Clinical Oncology		airway obstruction, including those with respiratory failure.	
Kiani A, Taghavi K, Rokni-Yazdi H et al. (2017) Application of microwave ablation for treating pulmonary adenocarcinoma: A case report. Tanaffos 16(4): 304-8	Case report n=1	Microwave ablation is a safe treatment modality for pulmonary malignancies and that it improves survival of patients unsuitable for surgery.	Single case report
Kim EY, Kim YS and Kim JH (2017) Thermal ablation for the treatment of primary and secondary pulmonary malignancies. Journal of Thoracic Disease 9(10): 3641-4	Review	Thermal ablation has been shown to be safe and effective for the treatment of primary and secondary lung malignancies in nonsurgical candidates, although there has been no large, randomised study comparing ablation to surgery or SBRT.	Review article
Ko WC, Lee YF, Chen YC et al. (2016) CT-guided percutaneous microwave ablation of pulmonary malignant tumours. Journal of Thoracic Disease 8 (supplement9): s659-65	Case series n=15 (32 tumours)	After appropriate patient selection, MWA with a dynamic frequency range (902 to 928 MHz) and power (10 to 32 W) is an effective and safe procedure for local tumour control of recurrent and metastatic lung tumours.	This study was included in the key evidence summary (Yuan, 2019).
Kurilova I, Gonzalez-Aguirre A, Beets-Tan RG et al. (2018) Microwave Ablation in the	Case series n=50 (90 tumours)	MWA with minimal ablation margin of 5 mm or more is essential for local	Studies with a larger sample or a better design are

Management of Colorectal Cancer Pulmonary Metastases. Cardiovascular and interventional radiology 41(10): 1530-44		control of colorectal cancer pulmonary metastases. Pleural-based metastases and larger tumour size were associated with higher risk of local tumour progression. Carcinoembryonic antigen level and pre-MWA chemotherapy impacted cancer-specific survival.	included in the key evidence summary.
Lee KS and Pua BB (2013) Alternative to surgery in early stage NSCLC-interventional radiologic approaches. Translational lung cancer research 2(5): 340-53	Review	Microwave ablation may potentially provide superior local control due to its larger zone of active heating and its ability to achieve higher intratumoral temperatures. There is still limited safety and efficacy data on the use of microwave ablation in early-stage NSCLC although its use is growing.	Review article
Lee KS and Erinjeri JP (2017) Decision Making in Interventional Oncology: Ablative Options in the Lung. Seminars in Interventional Radiology 34(2): 176-181	Review	Image-guided ablation is a minimally invasive, safe, repeatable, effective treatment option for patients with primary or metastatic pulmonary tumours.	Review article
Leppelmann KS, Mooradian MJ, Ganguli S et al. (2021) Thermal ablation, embolization, and selective internal radiation therapy	Non-randomised comparative study n=65 (78 therapies; 5 MWA)	No unmanageable or unanticipated toxicities occurred within 90 days after interventional oncology therapies	Studies with a larger sample or a better design are included in the

combined with checkpoint inhibitor cancer immunotherapy: safety analysis. Journal of Vascular and Interventional Radiology 32(2): 187-95		combined with immune checkpoint inhibitors.	key evidence summary.
Li C, Wang J, Shao JB et al. (2019) Microwave ablation combined with chemotherapy improved progression free survival of IV stage lung adenocarcinoma patients compared with chemotherapy alone. Thoracic Cancer 10(7): 1628-35	Non-randomised comparative study n=49 (21 MWA combined with chemotherapy compared with 28 chemotherapy)	MWA, as a topical treatment method, when combined with chemotherapy improved the PFS and TTLP of patients with stage IV lung adenocarcinoma.	MWA alone was not assessed and studies with a larger sample are included in the key evidence summary.
Li L, Wu K, Lai H et al. (2017) Clinical application of CT-guided percutaneous microwave ablation for the treatment of lung metastasis from colorectal cancer. Gastroenterology Research and Practice 2017: 9621585	Case series n=22 (36 lesions)	The results show that CT-guided percutaneous MWA appears to be an effective, reliable, and minimally invasive method for the treatment of lung metastasis from colorectal cancer.	Studies with a larger sample or a better design are included in the key evidence summary.
Lin M, Eiken P and Blackmon S (2020) Image guided thermal ablation in lung cancer treatment. Journal of Thoracic Disease 12(11): 7039-47	Review	Imaged guided thermal ablation has a good safety profile, with pneumothorax as the most common morbidity.	Review article
Little MW, Chung D, Boardman P et al. (2013) Microwave ablation of pulmonary malignancies using a novel high-energy antenna system. Cardiovascular and interventional radiology 36(2): 460-5	Case series n=23 (29 tumours)	MWA using a high-power antenna of pulmonary malignancies is safe, technically achievable, and enables fast ablation times.	Studies with a larger sample or a better design are included in the key evidence summary.

Liu H and Steinke K (2013) High-powered percutaneous microwave ablation of stage I medically inoperable non-small cell lung cancer: A preliminary study. Journal of Medical Imaging and Radiation Oncology 57; 466-74	Case series n=15	Percutaneous MWA in early-stage non-small cell lung cancer is well tolerated and has promising midterm outcomes.	Studies with a larger sample or a better design are included in the key evidence summary.
Liu B, Wang Y, Tian S et al. (2020) Salvage treatment of NSCLC recurrence after first-line chemotherapy failure: Iodine-125 seed brachytherapy or microwave ablation?. Thoracic Cancer 11(3): 697-703	Non-randomised comparative study n=82 (51 MWA compared with 32 brachytherapy)	MWA and brachytherapy are effective and safe options for the treatment of NSCLC recurrence after first-line chemotherapy. Which modality should be considered is dependent upon tumour location, tumour size and experience of specialists.	Studies with a larger sample or a better design are included in the key evidence summary.
Liu JJ, Huang W, Wu ZY et al. (2019) The application of computed tomography-guided percutaneous coaxial biopsy combined with microwave ablation for pulmonary tumours. Journal of cancer research and therapeutics 15(4): 760-5	Case series n=23 (27 tumours)	CT-guided percutaneous coaxial biopsy combined with MWA can improve the quality of life of patients, prolong survival, and improve the survival rate. It is currently 1 of the most promising interventional treatments.	Studies with a larger sample or a better design are included in the key evidence summary.
Liu NL, Yang B, Chen TM et al. (2020) The application of magnetic resonance imaging-guided microwave ablation for lung cancer. Journal of cancer	Case series n=43 (44 lesions)	As a minimally invasive method for treating lung tumours, MRI-guided MWA requires fewer localization scans, a	Studies with a larger sample or a better design are included in the key evidence summary.

research and therapeutics 16(5): 1014-9		shorter MWA duration, no radiation, real-time observation of the curative effect, and it prevents overtreatment.	
Lubnar MG, Brace CL, Hinshaw L et al. (2010) Microwave tumor ablation: mechanism of action, clinical results and devices. J Vasc Interv Radiol	Review	Microwave tumour ablation is an exciting technique with many theoretical advantages over currently existing ablation systems including generation of larger ablation zones in shorter times with very high temperatures, and less susceptibility to heat sink effects. In addition, microwaves have an advantage in high impedance tissues such as lung and bone that have been problematic for other ablation modalities. Preclinical and early clinical studies have begun to confirm these advantages; but further study and continued development of more robust clinical systems is still needed.	Review article
Macchi M, Belfiore MP, Floridi C et al. (2017) Radiofrequency versus microwave ablation for treatment of the lung tumours: LUMIRA (lung	Randomised controlled trial n=25 (MWA, n=24; RFA, n=28)	This trial confirms MWA and RFA are both excellent choices in terms of efficacy and safety in lung tumour	This study (follow-up, 12 months) was included in Sun et al. (2018).

microwave radiofrequency) randomized trial. Medical oncology 34(5): 96		treatments. However, when compared to RFA therapy, MWA produced a less intraprocedural pain and a significant reduction in tumour mass.	
Maxwell AWP, Healey TT and Dupuy DE (2017) Microwave ablation of lung tumours near the heart: a retrospective review of short-term procedural safety in ten patients. Cardiovascular and interventional radiology 40(9): 1401-7	Case series n=10 (10 tumours)	Microwave ablation of lung tumours located 10 mm or less from the heart appears to have low associated short-term morbidity and may be appropriate in selected patients.	Studies with a larger sample or a better design are included in the key evidence summary.
Maxwell AWP, Healey TT and Dupuy DE (2016) Percutaneous thermal ablation for small-cell lung cancer: initial experience with ten tumours in nine patients. Journal of vascular and interventional radiology 27(12): 1815-1821	Non-randomised comparative studies n=9 (10 tumours)	This preliminary analysis suggests favourable outcomes in selected patients with local small-cell lung cancer who had percutaneous thermal ablation without adjuvant therapy.	This study was included in Sun et al. (2018).
Mendogni P, Daffre E, Rosso L et al. (2020) Percutaneous lung microwave ablation versus lung resection in high-risk patients. A monocentric experience. Acta bio-medica: Atenei Parmensis 91(10s): e2020002	Non-randomised comparative study n=67 (MWA, n=32; lobectomy, n=35)	This study showed a high percentage of local relapse in the MWA group but a comparable overall survival. Although lung lobectomy remains the gold standard treatment for stage I NSCLC, MWA can be considered as valid alternative local treatment in high-risk patients for stage I NSCLC.	Studies with a larger sample or a better design are included in the key evidence summary.

Mouli SK, Kurilova I, Sofocleous CT et al. (2017) The role of percutaneous image-guided thermal ablation for the treatment of pulmonary malignancies. AJR. American journal of roentgenology 209(4): 740-51	Review	Although no large, randomised studies exist comparing ablation to surgery or radiotherapy, numerous studies have reported safety and efficacy for the treatment of both primary and metastatic disease in select patients. Future studies will refine patient selection, procedural technique, and assessment for local recurrence and will evaluate long-term survival.	Review article
Moussa AM, Ziv E, Solomon SB et al. (2019) Microwave ablation in primary lung malignancies. Seminars in Interventional Radiology 36(4): 326-33	Review	MWA is a proven safe and effective tool in the management of medically inoperable patients with early-stage NSCLC. Prospective trials comparing it to anatomical resection and SBRT with long-term follow-up are needed to accurately assess its location in the treatment algorithm provided to medically operable patients with early-stage NSCLC.	Review article
Nance M, Khazi Z, Kaifi J et al. (2021) Computerized tomography-guided microwave ablation of	Case series n=21	MWA provides a safe and effective alternative to stereotactic brachytherapy	Studies with a larger sample are included in the key evidence.

patients with stage I non-small cell lung cancers: A single-institution retrospective study. Journal of Clinical Imaging Science 11(1): 7		resulting in promising OS and PFS in patients with stage I peripheral NSCLC. Larger sample sizes are needed to further define the effects of underlying comorbidities and tumour biology.	
Narsule CK, Sridhar P, Nair D et al. (2017) Percutaneous thermal ablation for stage IA non-small cell lung cancer: Long-term follow-up. Journal of Thoracic Disease 9(10): 4039-45	Non-randomised comparative study n=25 (21 RFA and 4 MWA)	Thermal ablation effectively treated or controlled stage IA NSCLC in medically inoperable patients. Three-year OS exceeded 50%, and LP did not affect OS. Therefore, thermal ablation is a viable option for medically inoperable patients with early-stage NSCLC.	Studies with a larger sample or a better design are included in the key evidence summary.
Ni X, Han JQ, Ye X et al. (2015) Percutaneous CT-guided microwave ablation as maintenance after first-line treatment for patients with advanced NSCLC. OncoTargets and Therapy 8: 3227-35	Case series n=35 (39 tumours)	This study concluded two points, including: 1) patients benefited from MWA as maintenance both in local control and survival; 2) as maintenance MWA was superior to conventional maintenance therapy with improved survival and well-tolerated complications. Therefore, MWA was a safe and effective maintenance after first-line treatment in	Studies with a larger sample or a better design are included in the key evidence summary.

		patients with advanced NSCLC.	
Ni Y, Peng J, Yang X et al. (2021) Multicentre study of microwave ablation for pulmonary oligorecurrence after radical resection of non-small-cell lung cancer. British Journal of Cancer 125(5): 672-8	Case series n=103 (135 pulmonary oliorecurrences)	MWA should be considered to be an effective and safe treatment option for selected patients with pulmonary oligorecurrence after NSCLC radical surgical resection.	Studies with a larger sample or better design are included in the key evidence.
Ni Y, Xu H and Ye X (2020) Image-guided percutaneous microwave ablation of early-stage non-small cell lung cancer. Asia-Pacific journal of clinical oncology 16(6): 320-5	Review	For lung tumours treatment, minimally invasive therapy is one of the treatment directions in the future, especially for image-guided percutaneous thermal ablation technology. Currently, there are still some limitations of MWA technology for early-stage NSCLCs.	Review article
Ni Y, Bi JW, Ye X et al. (2016) Local microwave ablation with continued EGFR tyrosine kinase inhibitor as a treatment strategy in advanced non-small cell lung cancers that developed extra-central nervous system oligoprogressive disease during EGFR tyrosine kinase inhibitor treatment: A pilot study. Medicine 95(25): e3998	Non-randomised comparative study n=54 (28 MWA compared with 26 chemotherapy)	MWA with continued EGFR inhibition might be associated with favourable progression-free survival and overall survival in patients with extra- central nervous system oligometastatic disease. MWA as a local therapy for extra-CNS oligometastatic disease should be considered for NSCLC with acquired resistance to EGFR-TKIs	Studies with a larger sample or a better design are included in the key evidence summary.
Ni Y, Ye X, Yang X. et al. (2020) Microwave	Case series	MWA may serve as an alternative	Studies with a larger sample

ablation for non-small cell lung cancer with synchronous solitary extracranial metastasis. Journal of Cancer Research and Clinical Oncology 146(5): 1361-7	n=29	treatment for NSCLCs with synchronous solitary extracranial metastases.	or a better design are included in the key evidence summary.
Ni Y, Ye X, Yang X et al. (2020) Microwave ablation as local consolidative therapy for patients with extracranial oligometastatic EGFR-mutant non-small cell lung cancer without progression after first-line EGFR-TKIs treatment. Journal of cancer research and clinical oncology 146(1): 197-203	Non-randomised comparative study n=86 (consolidation group, n=34; monotherapy group, n=52)	The findings suggest that MWA as local consolidative therapy after first-line EGFR-TKIs treatment leads to better disease control and survival than TKIs monotherapy in EGFR-mutant advanced NSCLC patients with extracranial oligometastasis. MWA as a novel option of LCT might be considered for clinical management of these patients.	Studies with a larger sample or a better design are included in the key evidence summary.
Nour-Eldin NEA, Exner S, Al-Subhi M et al. (2017) Ablation therapy of non-colorectal cancer lung metastases: retrospective analysis of tumour response post-laser-induced interstitial thermotherapy (LITT), radiofrequency ablation (RFA) and microwave ablation (MWA). International journal of hyperthermia: the official journal of European Society for Hyperthermic Oncology, North American Hyperthermia Group 33(7): 820-9	Non-randomised comparative study n=109 (17 had LITT, 29 RFA and 63 MWA)	LITT, RFA and MWA may provide an effective therapeutic option for non-colorectal cancer lung metastases with an advantage for MWA regarding local tumour control and progression-free survival rate.	This study was included in Yuan et al. (2019).

Paez-Carpio A, Isus Olive G, Sanchez M et al. (2021) Image-guided percutaneous ablation for the treatment of lung malignancies: current state of the art. Insights into Imaging 12(1): 57	Review	Image-guided percutaneous lung ablation has proven to be a safe and effective treatment modality in patients with early-stage NSCLC or oligometastatic lung disease. As there are no specific protocols established in handling these patients, there must be a careful patient selection to avoid unnecessary treatments and undesired results. When choosing among the available ablative modalities, the available scientific evidence indicates that their efficacy and safety are comparable. Therefore, selection depends on the specific characteristics of the tumour and the patient. Finally, prospective, comparative, and randomised studies between these techniques, stereotactic radiotherapy (SBRT), and surgery are pending to define and improve patient selection.	Review article
Padda S, Kothary N, Donington J et al. (2008)	Case series	Ablation procedures can result in	This study was included

Complications of ablative therapies in lung cancer. Clinical Lung Cancer 9:122-6	n=2	complications, including residual disease and cavitary lesions susceptible to infection. This study highlights the caution that should still be observed when recommending lung ablation strategies and the importance of selecting appropriate patients.	in the previous overview.
Palussiere J, Cazayus M, Catena V et al. (2021) Is there a role for percutaneous ablation for early stage lung cancer? What is the evidence?. Current Oncology Reports 23(7): 81	Review	Thermal ablation (TA) has shown interesting results for safety, benefits in overall survival, and acceptable local control. Local progression rates after thermal ablation are highly dependent on tumour size; thermal ablation is adapted to T1 tumours, but it should be stratified by T-score since tumour size is of critical importance on outcomes. Prospective studies have demonstrated major advantages after TA in the fragile patient population: the low complication profile, the absence of mid- and long-term toxicities, and no deleterious effects on lung function. Many recent reviews and database analyses	Review article

		show that outcomes after TA (mainly RFA and MWA) are comparable to SBRT in terms of survival rates. Nevertheless, the evidence for TA is weaker than for SBRT and there is no direct comparison with the techniques. More prospective studies with larger sample sizes are warranted, as well as randomized studies to clarify indications, even though the hope for these last studies is rather bleak given the difficulties building these kinds of trials and recruiting sufficient patients to reach statistical significance.	
Palussiere J, Catena V, Lagarde P et al. (2019) Primary tumours of the lung: should we consider thermal ablation as a valid therapeutic option? International Journal of Hyperthermia 36(2): 46-52	Review	Among the various thermal ablation techniques covered here, RFA remains the most robust with the highest level of evidence of efficacy. In the future, thermal ablation should be compared with stereotaxic body radiation therapy, which also showed high local control rate.	Review article
Palussiere J, Catena V and Buy X (2017) Percutaneous thermal	Review	Local efficacy of RFA, MWA or cryoablation applied	Review article

ablation of lung tumours - Radiofrequency, microwave and cryotherapy: Where are we going? Diagnostic and interventional imaging 98(9): 619-25		to lung tumours, appears comparable even though no randomised studies have been conducted to demonstrate this point. Faster ablations could be achieved with MWA and, with the latest generation of devices, reproducibility of the ablation is better.	
Palussiere J, Lagarde P, Auperin A et al. (2015) Percutaneous lung thermal ablation of non-surgical clinical N0 non-small cell lung cancer: results of eight years' experience in 87 patients from two centres. Cardiovascular and interventional radiology 38(1): 160-6	Case series n=87 (97 tumours; 82 RFA and 5 MWA)	Oversized and overlapping ablation of N0 NSCLC was well tolerated, effective, with few local tumour progressions, even over long-term follow-up. Increasing tumour size was the main prognostic factor linked to OS, DFS, and local tumour progression.	Studies with a larger sample or a better design are included in the key evidence summary.
Peng J, Bie Z, Li Y et al. (2021) Microwave ablation of lung malignancies with coexisting severe emphysema: a retrospective analysis of safety and efficacy in 26 patients. International Journal of Hyperthermia 38(1): 136-43	Case series n=26	MWA appears to be a safe and effective therapeutic option for treating lung malignancies in patients with severe emphysema.	Studies with a larger sample or a better design are included in the key evidence summary.
Petre EN, Sofocleous CT and Solomon SB (2015) Ablative and catheter-directed therapies for colorectal liver and lung	Review	The safety and efficacy of lung MWA have been prospectively evaluated in nonsurgical	Review article

metastases. Hematology/oncology clinics of North America 29(1): 117-33		candidates with pulmonary metastases. The study included 80 patients with various lung metastases, half of which were of colorectal cancer origin. One- and 2-year survival rates were 91.3% and 75%, respectively, with no significant difference by histopathologic type.	
Prasanna T, Briggs G, Jain S et al. (2018) Massive fatal pulmonary haemorrhage during bevacizumab treatment following microwave ablation therapy for oligometastatic lung metastasis from rectal cancer. Interactive cardiovascular and thoracic surgery 26(3): 514-5	Case report n=1	Antiangiogenetic properties of bevacizumab are associated with delayed wound healing, which might have been a crucial factor in the development of arteriopulmonary fistula and haemorrhage. Extra caution is warranted with advanced interventional procedures in relation to new anticancer therapies, and it would appear prudent to leave a gap of 6 to 8 weeks between an ablative procedure and angiogenesis inhibitors.	Single case report
Prud'homme C, Deschamps F, Moulin B et al. (2019) Image-guided lung metastasis ablation: a literature	Review	Percutaneous ablation of lung metastases, whatever technic is used, is feasible,	Review article

review. International Journal of Hyperthermia 36(2): 37-45		with high local control rate, and acceptable complication rate. Although indications seem clear enough, validation through controlled trials is mandatory.	
Pusceddu C, Melis L, Sotgia B et al. (2019) Usefulness of percutaneous microwave ablation for large non-small cell lung cancer: A preliminary report. Oncology Letters 18(1): 659-66	Case series n=53 (65 tumours)	CT-guided MWA may represent a useful tool in the multimodality treatment of patients with large, advanced NSCLC.	Studies with a larger sample or a better design are included in the key evidence summary.
Qi H, Wan C, Li X et al. (2015) Computed tomography-guided percutaneous microwave ablation treatment for lung metastases from nasopharyngeal carcinoma. Indian journal of cancer 52suppl2: e91-5	Case series n=17 (29 lesions)	CT-guided MWA is a promising treatment alternative for local tumour control in selected patients with lung metastases from NPC.	Studies with a larger sample or a better design are included in the key evidence summary.
Quirk MT, Lee S, Murali N et al. (2020) Alternatives to surgery for early-stage non-small cell lung cancer: Thermal Ablation. Clinics in Chest Medicine 41(2): 197-210	Review	Thermal ablation does not cause a decline in pulmonary function tests and may therefore be used to treat multiple synchronous or metachronous lung tumours. Advances in ablation technology, including microwave and cryoablation, now allow safe and effective treatment of nearly all small tumours regardless	Review article

		of location within the lung.	
Quirk MT, Pomykala KL, Suh RD (2014) Current readings: Percutaneous ablation for pulmonary metastatic disease. Seminars in thoracic and cardiovascular surgery 26(3): 239-48	Review	Percutaneous image-guided ablation is a technique for maintaining local control of metastatic lung lesions that may, in selected patients, confer a survival benefit over no treatment or systemic therapy alone. Clinical trials are needed to directly compare therapeutic options and further define the role of percutaneous image-guided ablation in the treatment of pulmonary metastatic disease.	Review article
Ridouani F and Srimathveeravalli G (2019) Percutaneous image-guided ablation: From techniques to treatments. Presse Medicale 48(78p2): e219-31	Review	A growing body of clinical evidence supports the use of image guided ablation to treat primary and metastatic tumours in the liver, lung, kidney and musculoskeletal tissue of patients. Prospective and comparative trials indicate that for select patients, ablation can provide treatment outcomes equivalent to surgical resection with lower treatment	Review article

		related morbidity and greater preservation of residual organ function. The complication profile following ablation can be conservatively managed, even in an outpatient setting.	
Robert Sheu Y and Hong K (2013) Percutaneous lung tumour ablation. Techniques in vascular and interventional radiology 16(4): 239-52	Review	Percutaneous ablation offers patients who are not surgical candidates a chance at potential cure and improved survival. Even with the development of stereotactic whole-body radiation, percutaneous ablation remains a viable alternative and adjunct treatment option.	Review article
Roberton BJ, Liu D, Power M et al. (2014) Pulmonary ablation: a primer. Canadian Association of Radiologists journal 65(2): 177-85	Review	RFA is the most-established technique, but new thermal ablation technologies, such as MW and cryoablation, offer some potential advantages over RFA. Thermal ablation has been to proven to be safe and efficacious in achieving local control and improving outcomes in the treatment of both early stage NSCL and	Review article

		metastatic disease. There are some data to suggest that combining thermal ablation and radiation may improve outcome over thermal ablation alone.	
Ryu SW and Pua U (2019) Update in percutaneous lung ablation. Current Radiology Reports 7(10): 30	Review	Percutaneous lung ablations are best suited for medically inoperable patients with small primary lesions or favourably located metastases.	Review article
Sandler KA, Abtin F, Suh R et al. (2018) A prospective phase 2 study evaluating safety and efficacy of combining stereotactic body radiation therapy with heat-based ablation for centrally located lung tumours. International Journal of Radiation Oncology Biology Physics 101(3): 564-73	Case series n=16 (17 tumours)	Combining SBRT and heat-based ablation (HBA) for centrally located lung tumours offers reasonable local control and toxicity despite the anatomic challenges of this location. HBA may be a reasonable supplement to SBRT when trachea and bronchus, large vessel, or oesophageal constraints cannot be met with full-dose SBRT and a biologically effective dose less than 100 Gy is delivered because of an ultra-central location or large tumour size.	Studies with a larger sample or a better design are included in the key evidence summary.
Schneider T, Heussel CP, Herth FJF et al. (2013) Thermal ablation of malignant lung	Review	Image-guided thermoablation cannot now be considered an	Review article

tumours. Dtsch Arztebl Int 110(22): 394-400		alternative to surgery for the treatment of malignant lung tumours with curative intent. It does, however, widen the spectrum of therapeutic options for patients who are medically unable to undergo a surgical procedure.	
Shan YQ, Yin XY, Lin FX et al. (2021) Chemotherapy combined with intermittent microwave ablation in the treatment of oligometastatic non-small cell lung cancer. Journal of B.U.ON. 26(2): 320-7	Non-randomised comparative study n=67 (chemotherapy combined with MWA, n=34; chemotherapy alone, n=33)	Chemotherapy combined with intermittent microwave ablation is superior to chemotherapy alone in improving the disease control rate and the quality of life of patients, as well as prolonging the PFS of patients.	MWA alone was not assessed and studies with a larger sample are included in the key evidence.
Shao CC, Yang MH, Pan YY et al. (2021) Case report: abscopal effect of microwave ablation in a patient with advanced squamous NSCLC and resistance to immunotherapy. Frontiers in Immunology 12: 696749	Case report n=1	This case showed a durable abscopal effect of MWA in squamous NSCLC after acquired resistance of immunotherapy. Local ablation eliminated the primary lesion and exerted an abscopal effect on the distant lesions by boosting the immune system; local ablation might provide a novel strategy for patients who developed acquired resistance to immunotherapy. NSCLC patients with multiple	Single case report

		metastases might also benefit from local ablation therapy due to the appearance of abscopal effect. Therefore, the application of local ablative therapies showed a superior potency in the area of immunotherapy than targeted therapy.	
Shen XK, Chen TM, Yang B et al. (2021) Magnetic resonance imaging-guided microwave ablation for lung tumor: A case report. Quantitative Imaging in Medicine and Surgery 11(6): 2780-4	Case report n=1	MRI-guided percutaneous MWA may be a suitable adjunctive therapeutic option for patients with advanced lung cancer. Comprehensive treatment plans combining MWA with other treatment strategies can achieve good therapeutic results for patients.	Single case report
Shi F, Li G, Zhou Z et al. (2017) Microwave ablation versus radiofrequency ablation for the treatment of pulmonary tumours. Oncotarget 8(65): 109791-8	Non-randomised comparative study n=75 (MWA, n=32; RFA, n=43)	This study shows that no significant differences exist in efficacy and safety between MWA and RFA for the treatment of pulmonary tumours, which indicates that MWA could be a substitute therapy for RFA in terms of effectiveness and safety for treating pulmonary tumours.	Studies with a larger sample or a better design are included in the key evidence summary.
Sidoff L and Dupuy DE (2017) Clinical	Review	The main benefits of MWA in comparison	Review article

experiences with microwave thermal ablation of lung malignancies. International journal of hyperthermia : the official journal of European Society for Hyperthermic Oncology, North American Hyperthermia Group 33(1): 25-33		to RF lung tumour ablation include larger ablation zones, quicker heating times, higher intralesional temperatures, less procedural pain, and less susceptibility to both insulating effects intrinsic to lung tissue and those associated with tissue charring. However, given the higher temperatures associated with microwave ablation, planning for optimal antenna trajectory is critical to avoid potential risks of persistent air leak and bronchopleural fistula.	
Singh S, Bandula S, Brown J et al. (2016) Aspergillosis complicating a microwave ablation cavity. BMJ case reports 2016	Case report n=1	This case shows that persisting lung cavities after MWA are a potential site for semi-invasive aspergillosis and has implications for the timing of chemotherapy in patient with metastatic lung disease.	Single case report
Song PY, Sun W, Pang M et al. (2021) Efficacy comparison between microwave ablation combined with radiation therapy and radiation therapy alone for locally advanced nonsmall-cell lung cancer. Journal of Cancer Research and	Non-randomised comparative study n=76 (MWA, n=34; IMRT, n=42)	MWA combined with intensity-modulated radiation therapy (IMRT) in the treatment of locally advanced peripheral NSCLC was not inferior to the clinical effect of radiation therapy alone, and	Studies with a larger sample are included in the key evidence.

Therapeutics 17(3): 715-9		radiation lung injury incidence was also lower.	
Splatt AM and Steinke K (2015) Major complications of high-energy microwave ablation for percutaneous CT-guided treatment of lung malignancies: Single-centre experience after 4 years. Journal of medical imaging and radiation oncology 59(5): 609-16	Case series n=51	MWA of pulmonary tumours carries moderate risk; nevertheless, the usually manageable complications should not deter from undertaking a potentially curative therapy for poor surgical candidates.	Studies with a larger sample or a better design are included in the key evidence summary.
Smith S and Jennings P (2019) Thoracic intervention and surgery to cure lung cancer: image-guided thermal ablation in primary lung cancer. Journal of the Royal Society of Medicine 112(6): 218-25	Review	Microwave ablation does offer some theoretical advantages to radiofrequency ablation, including a shorter treatment time, higher end temperature and less ’heat sink effect’.	Review article
Sroufe R and Kong FMS (2015) Triaging early-stage lung cancer patients into non-surgical pathways: who, when, and what? Translational lung cancer research 4(4): 438-47	Review	Cryotherapy and photodynamic therapy (and to a lesser extent RFA and MWA) can also be considered for central tumours when stereotactic body radiation therapy is contraindicated but need further study.	Review article
Stone J, Hartley-Blossom Z. and Healey T (2020) The emerging role of percutaneous thermal ablation in the treatment of thoracic malignancies: A review.	Review	Recent data suggest percutaneous thermal ablation (PTA) may be useful in more aggressive malignancies, such as advanced NSCLC and small	Review article

Surgical Technology International 36: 1-8		cell lung cancer. Looking forward, PTA remains well positioned to be a valuable therapeutic option in the treatment of patients with lung cancer.	
Sun YH, Song PY, Guo Y et al. (2015) Computed tomography-guided percutaneous microwave ablation therapy for lung cancer. Genetics and molecular research : GMR 14(2): 4858-64	Case series n=29 (39 lesions)	CT-guided percutaneous microwave ablation therapy is a minimally invasive, safe, and effective treatment for lung cancer. It can improve quality of life, prolong survival, and improve the survival rate.	Studies with a larger sample or a better design are included in the key evidence summary.
Sun YH, Song PY, Guo, Y et al. (2015) Effects of microwave ablation or its combination with whole-body chemotherapy on serum vascular endothelial growth factor levels in patients with stage IIIB/IV NSCLC. Genetics and molecular research: GMR 14(3): 10015-25	Non-randomised comparative study n=40 (22 had MWA and chemotherapy and 18 had MWA alone)	MWA combined with whole-body chemotherapy appears to be an effective method to increase the disease control rate, reduce the probability of metastasis and recurrence, and thus improve long-term survival.	Studies with a larger sample or a better design are included in the key evidence summary.
Swietlik JF, Longo KC, Knott EA et al. (2019) Percutaneous microwave tumour ablation is safe in patients with cardiovascular implantable electronic devices: a single-institutional retrospective review. Journal of Vascular and Interventional Radiology 30(3): 396-400	Case series n=13 (28 tumours)	No device-based cardiovascular complications or class C or higher complications per Society of Interventional Radiology criteria were identified. MW ablation appears to be safe in select patients with cardiac implantable electronic devices.	Studies with a larger sample or a better design are included in the key evidence summary.

Tafti BA, Genshaft S, Suh R et al. (2019) Lung ablation: indications and techniques. Seminars in Interventional Radiology 36(3): 163-75	Review	With technological advancements in thermal modalities, particularly microwave ablation and cryoablation, better identification of the cohort of patients who best benefit from ablation, and understanding the role of imaging after ablation, image-guided thermal ablation for primary and secondary pulmonary malignancies is increasingly recognised and accepted as a cogent form of local therapy.	Review article
Tarasevych S, Lauwers P, Vandaele F et al. (2014) Novel treatment options in stage I non-small-cell lung cancer. Expert review of anticancer therapy 14(9): 1007-20	Review	The available evidence of RFA, MWA and cryo-ablation remains uncontrolled. In the absence of randomised trials, their use will be limited to expert centres and selected patient groups.	Review article
Thakore S and Perez Lozada JC (2020) Percutaneous Ablation of Intrathoracic Malignancy. Current Pulmonology Reports 9(4): 171-80	Review	Percutaneous techniques include radiofrequency ablation, microwave ablation, cryoablation, or irreversible electroporation. These modalities can be used with an intent to cure, as	Review article

		well as palliative intent in various clinical scenarios of lung cancer and other thoracic malignancies. Studies have exhibited comparable overall survival with ablative techniques in comparison to SBRT and sublobar resection with different side effect profile.	
Thivolet A, Menassel B, Chatte G et al. (2018) Delayed bronchocutaneous fistula without pneumothorax following a microwave ablation of a recurrent pulmonary metastasis. Cardiovascular and interventional radiology 41(2): 340-3	Case report	Microwave ablation provides higher energies and larger ablation volume than RFA. Due to the rapid and recent development of MWA, occurrences of major complications like BCF have been less reported. Furthermore, pleural lesions induced by repeated treatment, surgery or radiotherapy and ablation margins close to pleura should be considered as potential risk factors for the occurrence of this rare complication.	Single case report
Tsakok MT, Jones D, MacNeill A. et al. (2019) Is microwave ablation more effective than radiofrequency ablation in achieving local control	Review	The recurrence rates for MWA and RFA overlapped, and for the included studies ranged between 16% and	Review article

for primary pulmonary malignancy? Interactive cardiovascular and thoracic surgery		44% for MWA and 9% and 58% for RFA. The current evidence, therefore, does not clearly show a benefit of MWA over RFA in achieving local control in primary lung cancer.	
Tsakok MT, Little MW, Hynes G et al. (2019) Local control, safety, and survival following image-guided percutaneous microwave thermal ablation in primary lung malignancy. Clinical radiology 74(1): 80e19-80e26	Case series n=52 (61 tumours)	MWA for primary lung malignancy is a safe and effective treatment for primary lung tumours with outcomes that may be comparable to stereotactic body radiation therapy.	Studies with a larger sample or a better design are included in the key evidence summary.
Venturini M, Cariati M, Marra P et al. (2020) CIRSE standards of practice on thermal ablation of primary and secondary lung tumours. CardioVascular and Interventional Radiology	Review	Promising preliminary studies have been reported combining immunotherapy with cryotherapy, ablation therapies and MWA. Two mechanisms may favour immunotherapy after ablation therapy: mechanical changes in the tumour micro-environment (i.e. exposure of tumour antigens following cell necrosis) and inflammatory-mediated changes in immune phenotype.	Review article
Vogl TJ, Basten LM, Nour-Eldin NEA et al. (2019) Microwave ablation (MWA) of	Non-randomised comparative study	High frequency spatial-energy-control MWA technology and	Studies with a larger sample or a better design are

pulmonary neoplasms: clinical performance of high-frequency MWA with spatial energy control versus conventional low-frequency MWA. AJR. American journal of roentgenology 213(6): 1388-96	n=115 (high frequency MWA, n=59; low frequency MWA, n=56)	conventional low frequency MWA technology are safe and effective for the treatment of lung malignancies independent of the MWA system used. However, high frequency spatial-energy-control MWA as high frequency and high-energy MWA technique achieves ablation zones that are closer to an ideal sphere and achieves larger ablative margins than low frequency MWA (p<0.0001).	included in the key evidence summary.
Vogl TJ, Eckert R, Naguib NNN et al. (2016) Thermal ablation of colorectal lung metastases: retrospective comparison among laser-induced thermotherapy, radiofrequency ablation, and microwave ablation. AJR. American journal of roentgenology 207(6): 1340-9	Non-randomised comparative study n=109 (MWA, n=47; LITT, n=21; RFA, n=41)	MWA, LITT and RFA can be used as therapeutic options for lung metastases resulting from colorectal cancer. Statistically significant differences in local tumour control revealed a potential advantage in using MWA. No differences in time to tumour progression or survival rates were detected when the three different ablation methods were compared.	This study was included in Sun et al. (2018).
Vogl TJ, Nour-Eldin NEA, Albrecht MH et al. (2017) Thermal ablation of lung tumors: focus on	Review	Despite technical improvements, the current generation of MWA systems	Review article

microwave ablation. RoFo : Fortschritte auf dem Gebiete der Rontgenstrahlen und der Nuklearmedizin 189(9): 828-43		has comparable clinical outcomes to those of RFA.	
Vogl TJ, Roman A, Nour-Eldin NEA et al. (2018) A comparison between 915 MHz and 2450 MHz microwave ablation systems for the treatment of small diameter lung metastases. Diagnostic and interventional radiology (Ankara, Turkey) 24(1): 31-7	Non-randomised comparative study n=66 (low frequency system, n=36; high frequency system, n=30)	High frequency ablations resulted in larger ablation margins with fewer local progression compared with low frequency ablations	Studies with a larger sample or a better design are included in the key evidence summary.
Vroomen LGPH, Petre EN, Cornelis FH et al. (2017) Irreversible electroporation and thermal ablation of tumours in the liver, lung, kidney and bone: What are the differences? Diagnostic and interventional imaging 98(9): 609-17	Review	Ablation with RFA, MWA and cryoablation of primary or oligometastatic lung tumours is safe and effective, especially for patients who are medically unfit to undergo surgery.	Review article
Wang YZ, Liu B, Cao P et al. (2018) Comparison between computed tomography-guided percutaneous microwave ablation and thoracoscopic lobectomy for stage I non-small cell lung cancer. Thoracic cancer 9(11): 1376-82	Non-randomised comparative study n=131 (MWA, n=46; thoracoscopic lobectomy, n=85)	MWA and thoracoscopic lobectomy for stage I NSCLC show similar 1- and 2-year OS and DFS, with no significant differences between the 2 groups. MWA involved a shorter hospital stay and lower cost, thus should be considered a better option for patients with severe cardiopulmonary comorbidity and	Studies with a larger sample or a better design are included in the key evidence summary.

		patients unwilling to undergo surgery.	
Wasser EJ and Dupuy DE (2008) Microwave ablation in the treatment of primary lung tumors. Seminars in respiratory and critical care medicine 29: 384-94	Review	Microwave and other thermoablative treatment approaches to lung cancer hold immense promise for both curative treatment and symptom palliation in patients with lung cancer. Future directions for research include exploring potential synergy of microwave and other thermoablative techniques with radiation treatment, either external beam or brachytherapy.	Review article
Watson RA, Tol I, Gunawardana S et al. (2019) Is microwave ablation an alternative to stereotactic ablative body radiotherapy in patients with inoperable early-stage primary lung cancer? Interactive cardiovascular and thoracic surgery 29(4): 539-43	Review	The evidence base for MWA is less than that for SBRT and is heterogenous in terms of participants and technical design. However, within these limitations, authors conclude that MWA appears comparable with SBRT in terms of local control and survival rates.	Review article
Wei Z, Li Q, Ye X et al. (2019) Microwave ablation or plus monochemotherapy in elderly advanced non-small-cell lung cancer patients. Minimally Invasive Therapy and Allied Technologies	Non-randomised comparative study n=54 (MWA, n=18; MWA plus monochemothrapy, n=36)	MWA was effective in the treatment of elderly patients with advanced NSCLC.	Studies with a larger sample or a better design are included in the key evidence summary.

Wei Z, Wang J, Ye X et al. (2016) Computed tomography-guided percutaneous microwave ablation of early stage non-small cell lung cancer in a pneumonectomy patient. Thoracic Cancer 7(1): 151-3	Case report n=1	A squamous cell lung cancer patient was treated with pneumonectomy. A recurrent lung cancer (adenocarcinoma) was found 45 months later and successfully biopsied and treated with microwave ablation. After 18 months of follow up, no evidence of tumour recurrence was observed.	Single case report
Wei ZG, Wang QX, Ye X et al. (2018) Microwave ablation followed by immediate biopsy in the treatment of non-small cell lung cancer. International journal of hyperthermia: the official journal of European Society for Hyperthermic Oncology, North American Hyperthermia Group 35(1): 262-8	Case series n=68	Immediate biopsy post-MWA can distinguish cancer cells or histology types in most cases of NSCLC. However, pathology changes pre- and post-ablation could not predict the response to MWA and patient survival.	Studies with a larger sample or a better design are included in the key evidence summary.
Wei Z, Yang X, Ye X et al. (2020) Microwave ablation plus chemotherapy versus chemotherapy in advanced non-small cell lung cancer: a multicenter, randomized, controlled, phase III clinical trial. European Radiology	Randomised controlled trial n=293 (MWA plus chemotherapy, n=148; chemotherapy, n=145)	In patients with advanced NSCLC, longer PFS and OS can be achieved with the treatment of combined MWA and chemotherapy than chemotherapy alone.	MWA alone was not assessed and studies with a larger sample are included in the key evidence summary.
Wei ZG, Ye X, Yang X et al. (2017) Advanced non small cell lung cancer: response to microwave ablation and EGFR	Case series n=61	The EGFR status was not related to response to MWA, and response to MWA was a predictor of survival.	Studies with a larger sample or a better design are included in the

Status. European radiology 27(4): 1685-94			key evidence summary.
Wei ZG, Ye X, Yang X et al. (2015) Microwave ablation in combination with chemotherapy for the treatment of advanced non-small cell lung cancer. Cardiovascular and interventional radiology 38(1): 135-42	Case series n=39 (39 tumours)	Patients with advanced NSCLC could benefit from MWA in combination with chemotherapy. Complications associated with MWA were common but tolerable.	Studies with a larger sample or a better design are included in the key evidence summary.
Wei ZG, Ye X, Yang X et al. (2015) Microwave ablation plus chemotherapy improved progression-free survival of advanced non-small cell lung cancer compared to chemotherapy alone. Medical oncology (Northwood, London, England) 32(2): 464	Non-randomised comparative study n=71 (MWA and chemotherapy group, n=43; chemotherapy group, n=28)	MWA/chemotherapy combination improved PFS of advanced NSCLC compared to chemotherapy alone, and the combination did not increase the adverse events of chemotherapy.	This study was included in the key evidence summary (Yuan, 2019).
Wei Z, Ye X, Yang X et al. (2017) Microwave ablation combined with EGFR-TKIs versus only EGFRTKIs in advanced NSCLC patients with EGFR-sensitive mutations. Oncotarget 8(34): 56714-25	Non-randomised comparative study n=58 (MWA plus EGFR-TKIs, n=34; EGFR-TKIs, n=24)	MWA of primary tumour sites plus EGFRTKIs demonstrated no survival advantage compared with EGFR-TKIs alone in advanced NSCLC patients with EGFR sensitive mutations. MWA should not be recommended for unselected patients with EGFR-sensitive mutations.	MWA alone was not assessed and studies with a larger sample are included in the key evidence summary.
Wei ZG, Ye X, Yang X et al. (2019) Efficacy and safety of microwave ablation in the treatment of patients with oligometastatic non-small-cell lung cancer: a retrospective study.	Case series n=79 (103 lesions)	MWA was safe and effective for patients with oligometastatic NSCLC.	Studies with a larger sample or a better design are included in the key evidence summary.

International journal of hyperthermia: the official journal of European Society for Hyperthermic Oncology, North American Hyperthermia Group 36(1): 827-34			
Wolf FJ, Grand DJ, Machan JT et al. (2008) Microwave ablation of lung malignancies: effectiveness, CT findings, and safety in 50 patients. Radiology 247:871-9	Case series n=50	Microwave ablation is effective and may be safely applied to lung tumors.	This study was included in the previous overview.
Xiong L and Dupuy DE (2016) Lung ablation: whats new? Journal of thoracic imaging 31(4): 228-37	Review	MWA has emerged as a potentially superior treatment option to RFA due to a much broader energy deposition capable of producing a larger zone of active heating.	Review article
Xu F, Song J, Lu YY et al. (2021) Clinical efficacy of systemic chemotherapy combined with radiofrequency ablation and microwave ablation for lung cancer: a comparative study. International journal of hyperthermia: the official journal of European Society for Hyperthermic Oncology, North American Hyperthermia Group 38(1): 900-6	Non-randomised comparative study n=124 (systemic chemotherapy combined with MWA, n=56; systemic chemotherapy combined with RFA, n=68)	MWA was superior to RFA over local tumour control rate and PFS and showed great potential in lung cancer ablation treatment.	MWA alone was not assessed and studies with a larger sample are included in the key evidence.
Xu H, Sun W, Kong Y. et al. (2020) Immune abscopal effect of microwave ablation for lung metastases of endometrial carcinoma. Journal of Cancer	Case report n=1	This case presents a rare abscopal effect in a patient in whom MWA of one lesion was followed by a marked regression of the	Single case report

Research and Therapeutics 16(7): 1718-21		lesion at other sites. Further studies are crucial to validate whether this systemic response occurs as a result of the activation of the antitumor immune response induced by MWA	
Xu S, Qi J, Li B et al. (2021) Risk prediction of pleural effusion in lung malignancy patients treated with CT-guided percutaneous microwave ablation: a nomogram and artificial neural network model. International Journal of Hyperthermia 38(1): 220-8	Non-randomised comparative study n=496 (357 in the training cohort compared with 139 in the validation cohort)	Maximum power, number of pleural punctures and minimum distance from needle to pleura were predictors of pleural effusion after MWA in LM patients. The nomogram and ANN model could effectively predict the risk of pleural effusion after MWA. Patients showing a high risk (>0.16) on the nomogram should be monitored for pleural effusion.	Limited efficacy and safety data were reported.
Xu S, Qi J, Li B et al. (2021) Survival prediction for non-small cell lung cancer patients treated with CT-guided microwave ablation: development of a prognostic nomogram. International journal of hyperthermia: the official journal of European Society for Hyperthermic Oncology, North American Hyperthermia Group 38(1): 640-9	Non-randomised comparative study n=234 (training group, n=176; validation group, n=58)	The nomogram was effective in predicting the OS in NSCLC patients treated with MWA and could be applied to identify patients who may benefit most from MWA and be helpful for clinical decision making.	Studies with a larger sample are included in the key evidence.
Xu XL, Ye X, Liu G et al. (2015) Targeted percutaneous microwave	Randomised controlled trial	Percutaneous microwave ablation followed by	MWA alone was not assessed and

ablation at the pulmonary lesion combined with mediastinal radiotherapy with or without concurrent chemotherapy in locally advanced non-small cell lung cancer evaluation in a randomized comparison study. Medical oncology 32(9): 227	n=98 (MWA combined with mediastinal radiotherapy concurrent chemotherapy, n=51; radiotherapy concurrent chemotherapy, n=47)	radiotherapy for inoperable stage III NSCLCs may result in a lower rate of radiation pneumonia and better local control than radical radiotherapy treatments.	studies with a larger sample are included in the key evidence summary.
Yan P, Tong AN, Nie XL et al. (2021) Assessment of safety margin after microwave ablation of stage I NSCLC with three-dimensional reconstruction technique using CT imaging. BMC medical imaging 21(1): 96	Case series n=36	The minimal ablative margin is an independent factor of NSCLC relapse after MWA, and the fusion of 3D reconstruction technique can feasibly assess the minimal ablative margin.	Studies with a larger sample are included in the key evidence.
Yang X, Ye X, Huang GH et al. (2017) Repeated percutaneous microwave ablation for local recurrence of inoperable Stage I nonsmall cell lung cancer. Journal of cancer research and therapeutics 13(4): 683-8	Case series n=104	The local recurrence (LR) was higher in tumours >3.5 cm than that of in tumours ≤3.5 cm. For patients with LR, it was feasible and effective to use MWA repeatedly to achieve the similar OS and PFS as patients without LR. No additional complications were reported in the repeat MWA compared to the original MWA.	Studies with a larger sample or a better design are included in the key evidence summary.
Yang X, Ye X, Zheng A et al. (2014) Percutaneous microwave ablation of stage I medically	Case series n=47	MWA is safe and effective for the treatment of medically inoperable	This study was included in the key evidence

inoperable non-small cell lung cancer: clinical evaluation of 47 cases. Journal of surgical oncology 110(6): 758-63		stage I peripheral NSCLC.	summary (Yuan, 2019).
Yang X, Zhang K, Ye X et al. (2015) Artificial pneumothorax for pain relief during microwave ablation of subpleural lung tumours. Indian journal of cancer 52suppl2: e80-3	Non-randomised comparative study n=36 (17 MWA with artificial pneumothorax compared with 19 MWA without artificial pneumothorax)	Creation of an artificial pneumothorax is a safe and effective method for pain relief during MWA of subpleural lung tumours.	Studies with a larger sample or a better design are included in the key evidence summary.
Yang X, Ye X, Zhang LC et al. (2018) Microwave ablation for lung cancer patients with a single lung: Clinical evaluation of 11 cases. Thoracic cancer 9(5): 548-54	Case series n=11	CT-guided percutaneous MWA is safe and effective for the treatment of peripheral NSCLC in patients with a single lung after prior pneumonectomy.	Studies with a larger sample or a better design are included in the key evidence summary.
Yu PSY, Chu CM, Lau RWH et al. (2021) Hybrid theatre facilitates lung-preserving multimodal treatment for multiple pulmonary metastases. The Annals of thoracic surgery 111(2): e89-e92	Case report n=1	Microwave ablation under the guidance of electromagnetic navigation bronchoscopy in the hybrid theater is a novel contribution to the multimodal operative management of multiple pulmonary neoplasms. It is a unique choice for patients with multilobar, subcentimeter metastases, and with concerns about lung function preservation.	Single case report

Yuan Z, Liu B, Hu C. et al. (2020) Clinical outcomes of percutaneous thermal ablation for pulmonary metastases from hepatocellular carcinoma: a retrospective study. International Journal of Hyperthermia 37(1): 651-9	Case series n=39	Percutaneous thermal ablation is a safe and effective treatment for pulmonary metastases from hepatocellular Carcinoma.	Studies with a larger sample or a better design are included in the key evidence summary.
Zhang Y, Feng Y, Wu Y. et al. (2020) Comparative clinical study on microwave ablation combined with gemcitabine and cisplatin or combined with pemetrexed and cisplatin in treatment of advanced NSCLC. Clinical Respiratory Journal 14(9): 864-70	Randomised controlled trial n=100 (50 MGC compared with 50 MPC)	The 2 therapeutic regimens have similar efficacy in treatment of advanced NSCLC, but MPC causes slighter myelosuppression and can be the first-line therapy for advanced NSCLC.	MWA alone was not assessed and studies with a larger sample are included in the key evidence summary.
Zhang YQ, Wu YL, Feng Y et al. (2020) A clinical study on microwave ablation in combination with chemotherapy in treating peripheral IIIB-IV non-small cell lung cancer. Cancer biotherapy & radiopharmaceuticals	Randomised controlled trial n=100 (microwave ablation, radiotherapy and chemotherapy, n=52; pemetrexed disodium or gemcitabine hydrochloride, cisplatin chemotherapy, and conventional radiotherapy, n=48)	Microwave ablation is safe and effective. Combination chemotherapy is superior to chemotherapy in treating peripheral IIIB-IV NSCLC in terms of effectiveness rate, disease control rate, and extended patient survival time.	MWA alone was not assessed and studies with a larger sample are included in the key evidence summary.
Zhao H and Steinke K (2020) Long-term outcome following microwave ablation of early-stage non-small cell lung cancer. Journal of Medical Imaging and	Case series n=30 (34 tumours)	MWA is safe and effective at achieving local control of early-stage NSCLC and may prolong patient	Studies with a larger sample or a better design are included in the

Radiation Oncology 64(6): 787-93		survival. Nodal or distant metastases were the dominant manifestations of disease progression at long-term follow-up.	key evidence summary.
Zhao ZR, Lau RWH and Ng CSH. (2018) Catheter-based alternative treatment for early-stage lung cancer with a high-risk for morbidity. Journal of Thoracic Disease 10 (supplement16): s1864-70	Review	Patients with early-stage NSCLC deemed high-risk, medically inoperable or otherwise unsuitable for SBRT have the treatment options described above. Emerging evidence shows that catheter-based therapies are feasible and safe, with manageable morbidities and toxicities.	Review article
Zhao ZL, Su ZM, Zhang WF et al. (2016) A randomised study comparing the effectiveness of microwave ablation radioimmunotherapy and postoperative adjuvant chemoradiation in the treatment of non-small cell lung cancer. Journal of BUON: official journal of the Balkan Union of Oncology 21(2): 326-32	Randomised controlled trial n=96 (chemotherapy with docetaxel and cisplatin and 3-dimensional conformal radiotherapy 3 to 4 weeks after surgery, n=49; ^{131}I-chTNT and PMCT sequentially, with follow-up chemotherapy, n=47)	^{131}I-chTNT radioimmunotherapy with PMCT has a complementary effect in NSCLC, which can effectively improve therapeutic ratio and survival of patients effectively and has the same effect as that of post-operative adjuvant chemoradiation.	MWA alone was not assessed and studies with a larger sample are included in the key evidence summary.
Zhao Q, Tian G, Chen F et al. (2017) CT-guided percutaneous laser ablation of metastatic lung cancer: three cases report and literature	Case series (n=3) and literature review	Percutaneous CT-guided PLA could be a safe and promising minimally invasive treatment for patients with	Studies with a larger sample or a better design are included in the

review. Oncotarge 8(2): 2187-96.		primary lung cancer or unresectable pulmonary metastases, especially multineedle PLA in large tumours, which still needs more large-scale prospective studies to convince this method in the future.	key evidence summary.
Zheng AM, Wang XW, Yang X et al. (2014) Major complications after lung microwave ablation: a single-center experience on 204 sessions. The Annals of thoracic surgery 98(1): 243-8	Case series n=184 (253 lesions)	As a relatively practical and safe modality, lung tumour MWA can induce serious complications. Enough attention should be paid to patients with emphysema, subpleural, or large target tumour, but the indications for lung MWA need not be limited as most major complications were easily managed.	This study was included in Nelson et al. (2019)
Zheng A, Yang X, Ye X et al. (2015) Bronchopleural fistula after lung ablation: Experience in two cases and literature review. Indian journal of cancer 52suppl2: e41-6	Case series n=2	Bronchopleural fistula is a rare but severe complication of lung ablation, and the management needs a multidisciplinary and individualized treatment strategy.	Studies with a larger sample or a better design are included in the key evidence summary.
Zheng A, Ye X, Yang X et al. (2016) Local Efficacy and Survival after Microwave Ablation of Lung Tumours: A Retrospective Study in 183 Patients. Journal of	Case series n=183	MW ablation is effective for lung tumours, especially small lesions of early-stage primary lung cancer and	This study was included in Yuan (2019).

vascular and interventional radiology 27(12): 1806-14		solitary lung metastasis.	
Zhong L, Sun S, Shi J et al. (2017) Clinical analysis on 113 patients with lung cancer treated by percutaneous CT-guided microwave ablation. Journal of Thoracic Disease 9(3): 590-7	Case series n=113	MWA is an effective, safe and minimally invasive treatment for the patients with lung cancer who cannot be tolerated by surgical resection	This study was included in Nelson et al. (2019).