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## Microwave Tumor Ablation

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<b>Related Policies (if applicable)</b>
None

### Disclaimer

#### **Carefully check state regulations and/or the member contract.**

Each benefit plan, summary plan description or contract defines which services are covered, which services are excluded, and which services are subject to dollar caps or other limitations, conditions or exclusions. Members and their providers have the responsibility for consulting the member's benefit plan, summary plan description or contract to determine if there are any exclusions or other benefit limitations applicable to this service or supply. **If there is a discrepancy between a Medical Policy and a member's benefit plan, summary plan description or contract, the benefit plan, summary plan description or contract will govern.**

### Coverage

Microwave ablation of primary or metastatic hepatic tumors **may be considered medically necessary** under the following conditions:

- The tumor is unresectable due to location of lesion[s] and/or comorbid conditions;
- A single tumor of  $\leq 5$  cm or up to 3 nodules  $\leq 3$  cm each.

Microwave ablation of primary or metastatic lung tumors **may be considered medically necessary** under the following conditions:

- The tumor is unresectable due to location of lesion and/or comorbid conditions;
- The size of each tumor(s) to be ablated is  $\leq 3$  cm.

Microwave ablation of primary or metastatic tumors other than liver or lung **is considered experimental, investigational, and/or unproven.**

### Policy Guidelines

None.

## Description

Microwave ablation (MWA) is a technique to destroy tumors and soft tissue using microwave energy to create thermal coagulation and localized tissue necrosis. Microwave ablation is used to treat tumors not amenable to resection and to treat individuals ineligible for surgery due to age, comorbidities, or poor general health. Microwave ablation may be performed as an open procedure, laparoscopically, percutaneously, or thoracoscopically under image guidance (e.g., ultrasound, computed tomography, magnetic resonance imaging) with sedation, or local or general anesthesia. This technique is also referred to as microwave coagulation therapy.

### **Microwave Ablation**

Microwave ablation uses microwave energy to induce an ultra-high-speed, 915 MHz or 2 450 MHz (2.45 GHz), alternating electric field, which causes water molecule rotation and creates heat. This results in thermal coagulation and localized tissue necrosis. In MWA, a single microwave antenna or multiple antennas connected to a generator are inserted directly into the tumor or tissue to be ablated; energy from the antennas generates friction and heat. The local heat coagulates the tissue adjacent to the probe, resulting in a small, 2 to 3 cm elliptical area of tissue ablation. In tumors greater than 2 cm in diameter, 2 to 3 antennas may be used simultaneously to increase the targeted area of MWA and shorten the operative time. Multiple antennas may also be used simultaneously to ablate multiple tumors. Tissue ablation occurs quickly, within 1 minute after a pulse of energy, and multiple pulses may be delivered within a treatment session, depending on tumor size. The cells killed by MWA are typically not removed but are gradually replaced by fibrosis and scar tissue. If there is a local recurrence, it occurs at the margins. Treatment may be repeated as needed. Microwave ablation may be used for the following purposes: 1) to control local tumor growth and prevent recurrence; 2) to palliate symptoms; and 3) to prolong survival.

Microwave ablation is similar to radiofrequency (RFA) and cryosurgical ablation. However, MWA has potential advantages over RFA and cryosurgical ablation. In MWA, the heating process is active, which produces higher temperatures than the passive heating of RFA and should allow for more complete thermal ablation in less time. The higher temperatures reached with MWA ( $>100^{\circ}\text{C}$ ) can overcome the “heat sink” effect in which tissue cooling occurs from nearby blood flow in large vessels, potentially resulting in incomplete tumor ablation.

Microwave ablation does not rely on the conduction of electricity for heating and, therefore, does not flow electrical current through patients and does not require grounding pads, because there is no risk of skin burns. Additionally, MWA does not produce electric noise, which allows ultrasound guidance during the procedure without interference, unlike RFA. Finally, MWA can take 20% to 30% less time than RFA, because multiple antennas can be used simultaneously for multiple ablations. There is no comparable RFA system with the capacity to drive multiple electrically dependent electrodes.

### Adverse Events

Complications from MWA may include pain and fever. Other complications associated with MWA include those caused by heat damage to normal tissue adjacent to the tumor (e.g., intestinal damage during MWA of the kidney or liver), structural damage along the probe track (e.g., pneumothorax as a consequence of procedures on the lung), liver enzyme elevation, liver abscess, ascites, pleural effusion, diaphragm injury, or secondary tumors if cells seed during probe removal. Microwave ablation should be avoided in pregnant women because potential risks to the patient and/or fetus have not been established, and in patients with implanted electronic devices (e.g., implantable pacemakers) that may be adversely affected by microwave power output.

### Applications

Microwave ablation was first used percutaneously in 1986 as an adjunct to liver biopsy. Since then, MWA has been used to ablate tumors and tissue to treat many conditions including hepatocellular carcinoma, breast cancer, colorectal cancer metastatic to the liver, renal cell carcinoma, renal hamartoma, adrenal malignant carcinoma, non-small-cell lung cancer, intrahepatic primary cholangiocarcinoma, secondary splenomegaly and hypersplenism, abdominal tumors, and other tumors not amenable to resection. Well-established local or systemic treatment alternatives are available for each of these malignancies. The potential advantages of MWA for these cancers include improved local control and other advantages common to any minimally invasive procedure (e.g., preserving normal organ tissue, decreasing morbidity, shortening length of hospitalization). Microwave ablation also has been investigated as a treatment for unresectable hepatic tumors, as both primary and palliative treatment, and as a bridge to a liver transplant. In the latter setting, MWA is being assessed to determine whether it can reduce the incidence of tumor progression while awaiting transplantation and thus maintain a patient's candidacy while awaiting a liver transplant.

### **Regulatory Status**

Multiple MWA devices have been cleared for marketing by the U.S. Food and Drug Administration (FDA) through the 510(k) process. These devices are indicated for soft tissue ablation, including partial or complete ablation of nonresectable liver tumors. Some devices are specifically cleared for use in open surgical ablation, percutaneous ablation, or laparoscopic procedures. Table 1 is a summary of selected MWA devices cleared by the FDA.

The FDA used determinations of substantial equivalence to existing radiofrequency and MWA devices to clear these devices. FDA product code: NEY.

This medical policy does not address MWA for the treatment of splenomegaly or ulcers, for cardiac applications, or as a surgical coagulation tool.

**Table 1. Selected Microwave Ablation Devices Cleared by the FDA**

Device	Indication	Manufacturer	Date Cleared	510(k) Number
MedWaves Microwave Coagulation/	General surgery use in open procedures for the	MedWaves Incorporated	12/2007	K070356

Ablation System	coagulation and ablation of soft tissues.			
Acculis Accu2i pMTA Microwave Tissue Ablation Applicator	Intraoperative coagulation of soft tissue.	Microsoulis Holdings, Ltd.	08/2010	K094021
Acculis Accu2i pMTA Applicator and SulisV pMTA Generator	Software addition		11/2012	K122762
MicroThermX Microwave Ablation System	Coagulation (ablation) of soft tissue. May be used in open surgical as well as percutaneous ablation procedures.	BSD Medical Corporation	08/2010	K100786
Emprint™ Ablation System	Percutaneous, laparoscopic, and intraoperative coagulation (ablation) of soft tissue, including partial or complete ablation of non-resectable liver tumors.	Medtronic	04/2014	K133821
Emprint™ Ablation System	Same with design modification of device antenna for percutaneous use.		12/2016	K163105
Emprint™ SX Ablation Platform with Thermosphere™ Technology	3-D navigation feature assists in the placement of antenna using real-time image guidance during intraoperative and laparoscopic ablation procedures.		09/2017	K171358
Emprint™ Ablation Platform with Thermosphere™ Technology and Emprint™ SX Ablation Platform with Thermosphere™ Technology	Antenna modification and update to instructions for use.		02/2020	K193232

Certus 140 2.45 GHz Ablation System and Accessories	Ablation (coagulation) of soft tissue.	Johnson & Johnson	10/2010	K100744
Certus 140™ 2.45 GHz Ablation System and Accessories	Ablation (coagulation) of soft tissue in percutaneous, open surgical and in conjunction with laparoscopic surgical settings.		01/2012	K113237
CertuSurg <sup>GT</sup> Surgical Tool	Surgical coagulation (including Planar Coagulation) in open surgical settings.		07/2013	K130399
Certus 140™ 2.45 GHz Ablation System and Accessories	Same indication with probe redesign.		05/2016	K160936
Certus 140 2.45GHz Ablation System	Ablation (coagulation) of soft tissue in percutaneous, open surgical and in conjunction with laparoscopic surgical settings, including the partial or complete ablation of non-resectable liver tumors.		10/2018	K173756
NEUWAVE Flex Microwave Ablation System (FLEX)	Ablation (coagulation) of soft tissue; design evolution of Certus 140 2.45GHz Ablation System (K160936).	Johnson & Johnson	03/2017	K163118
Solero Microwave Tissue Ablation (MTA) System and Accessories	Ablation of soft tissue during open procedures.	Angiodynamics, Inc.	05/2017	K162449
Microwave Ablation System	Coagulation (ablation) of soft tissue.	Surgnova Healthcare Technologies (Zhejiang) Co., Ltd.	07/2019	K183153
NEUWAVE Microwave Ablation System and Accessories	Ablation (coagulation) of soft tissue in percutaneous, open surgical and in conjunction with laparoscopic surgical settings, including the partial or complete ablation of non-	Johnson & Johnson	11/2020	K200081

	resectable liver tumors; not intended for use in cardiac procedures.			
IntelliBlate Microwave Ablation System	Coagulation (ablation) of soft tissue.	Varian Medical Systems, Inc.	07/2024	K240480

FDA: U.S. Food and Drug Administration.

## Rationale

Medical policies assess the clinical evidence to determine whether the use of technology improves the net health outcome. Broadly defined, health outcomes are the length of life, quality of life (QOL), and ability to function including benefits and harms. Every clinical condition has specific outcomes that are important to patients and to managing the course of that condition. Validated outcome measures are necessary to ascertain whether a condition improves or worsens; and whether the magnitude of that change is clinically significant. The net health outcome is a balance of benefits and harms.

To assess whether the evidence is sufficient to draw conclusions about the net health outcome of a technology, 2 domains are examined: the relevance and the quality and credibility. To be relevant, studies must represent 1 or more intended clinical use of the technology in the intended population and compare an effective and appropriate alternative at a comparable intensity. For some conditions, the alternative will be supportive care or surveillance. The quality and credibility of the evidence depend on study design and conduct, minimizing bias and confounding that can generate incorrect findings. The randomized controlled trial (RCT) is preferred to assess efficacy; however, in some circumstances, nonrandomized studies may be adequate. Randomized controlled trials are rarely large enough or long enough to capture less common adverse events and long-term effects. Other types of studies can be used for these purposes and to assess generalizability to broader clinical populations and settings of clinical practice.

### Unresectable Primary or Metastatic Solid Organ Tumors

#### Clinical Context and Therapy Purpose

The purpose of microwave ablation (MWA) in individuals who have unresectable primary or metastatic solid organ tumors is to provide a treatment option that is an alternative to or an improvement on existing therapies.

The following PICO was used to select literature to inform this policy.

#### *Populations*

The relevant population of interest is those with unresectable primary or metastatic hepatic, lung, renal, and solid tumors other than hepatic, lung, or renal. In patients with disseminated disease or in cases where age or comorbidity precludes a surgical approach, volume reduction,

symptom relief, and palliation may be appropriate. In select patients with small tumors, ablation techniques may provide a minimally invasive alternative to surgery.

### *Interventions*

The therapy being considered is MWA.

### *Comparators*

The following therapies are currently being used to manage unresectable primary or metastatic hepatic, lung, or renal tumors: radiofrequency ablation (RFA).

Transcatheter arterial chemoembolization (TACE) may be used in the management of unresectable primary or metastatic hepatic tumors. Cryoablation may be used in the management of unresectable primary or metastatic renal and lung tumors.

The following therapies are currently being used to manage other unresectable primary or metastatic solid tumors: standard of care, which may include systemic therapy, radiotherapy, and/or select local ablation therapies.

### *Outcomes*

The general outcomes of interest are overall survival (OS), disease-specific survival, symptoms, QOL, and treatment-related mortality and morbidity.

Treatment-related morbidities may vary by tumor type. For example, treatment for lung cancer may lead to pneumothorax. Follow-up for treatment-related morbidity is months post procedure. Follow-up to monitor for OS and recurrence rates may be measured in years of follow-up.

### Study Selection Criteria

Methodologically credible studies were selected using the following principles:

- To assess efficacy outcomes, comparative controlled prospective trials were sought, with a preference for RCTs and systematic reviews of these studies;
- In the absence of such trials, comparative observational studies were sought, with a preference for prospective studies;
- To assess long-term outcomes and adverse events, single-arm studies that capture longer periods of follow-up and/or larger populations were sought;
- Studies with duplicative or overlapping populations were excluded.

### Unresectable Primary or Metastatic Hepatic Tumors

#### *Systematic Reviews*

Several systematic reviews have evaluated MWA for patients with liver tumors. (1-5) Recent meta-analyses, published in 2016, (1) 2019, (4) 2020, (5) and 2022 (6) are summarized in Tables 2 through 4. Two of these reviews compared MWA to RFA, (6, 1) 1 compared MWA to resection, (4) and 1 compared MWA to a variety of therapies, including RFA and resection. (5) As part of a large meta-analysis comparing all locoregional therapies for hepatocellular

carcinoma, Patel et al. (2024) did not identify any new trials comparing MWA to other therapies. (7)

**Table 2. Microwave Ablation for Hepatic Tumors: Comparison of Trials/Studies Included in SR & MA**

Study	Chinnaratha et al. (2016) (1)	Glassberg et al. (2019) (4)	Cui et al. (2020) (5)	Dou et al. (2022) (6)
Seki et al. (1999) (8)			●	
Shibata et al. (2002) (9)	●		●	●
Xu et al. (2004) (10)	●			●
Lu et al. (2005) (11)	●		●	●
Tanaka et al. (2006) (12)		●		
Wang et al. (2008) (13)		●		
Ohmoto et al. (2009) (14)	●		●	●
Yin et al. (2009) (15)	●			●
Kuang et al. (2011) (16)	●			●
Imura et al. (2012) (17)		●		
Qian et al. (2012) (18)	●			●
Chinnaratha et al. (2013) (19)	●			
Ding et al. (2013) (20)	●		●	●
Stattner et al. (2013) (21)		●		
Takami et al. (2013) (22)		●		
Zhang et al. (2013) (23)	●		●	●
Abdelaziz et al. (2014) (24)			●	●
Shi et al. (2014) (25)		●	●	
Tan et al. (2014) (26)		●		
Zhang et al. (2014) (27)			●	
Abdelaziz et al. (2015) (28)			●	

Vogl et al. (2015) (29)			●	●
Xu et al. (2015) (30)		●		
Potretzke et al. (2016) (31)			●	●
Zhang et al. (2016) (32)		●	●	
Li et al. (2017) (33)		●		
Philips et al. (2017) (34)		●		
Ryu et al. (2017) (35)		●		
Song et al. (2017) (36)		●		
Xu et al. (2017) (37)			●	●
Yu et al. (2017) (38)			●	●
Zhang et al. (2017) (39)		●		
Chen et al. (2018) (40)		●		
Chong et al. (2018) (41)		●		
Chinnaratha et al. (2015) (42)				●
Cillo et al. (2014) (43)				●
Correa et al. (2014) (44)				●
Di Vece et al. (2014) (45)				●
Hompes et al. (2010) (46)				●
Kamal et al. (2019) (47)				●
Lee et al. (2017) (48)				●
Liu et al. (2013) (49)				●
Liu et al. (2018) (50)				●
Sakaguchi et al. (2009) (51)				●
Santambrogio et al. (2017) (52)				●
Sever et al. (2018) (53)				●
Shady et al. (2017) (54)				●

Simo et al. (2011) (55)				●
Sparchez et al. (2019) (56)				●
Tian et al. (2014) (57)				●
van Tilborg et al. (2016) (58)				●
Vietti et al. (2018) (59)				●
Yang et al. (2017) (60)				●

MA: meta-analysis; SR: systematic review.

**Table 3. Microwave Ablation for Hepatic Tumors: SR and MA Characteristics**

Study	Chinnaratha et al. (2016) (1)	Glassberg et al. (2019) (4)	Cui et al. (2020) (5)	Dou et al. (2022) (6)
<b>Dates</b>	1980-2014	2006-2018	1994-2017	2002-2018
<b>Trials</b>	10	16	15	33
<b>Participants</b>	Adults with either very early stage, early-stage (single tumor or up to 3 nodules with each measuring $\leq 3$ cm), or multifocal/large HCC outside Milan criteria	Adult patients with confirmed HCC or liver cancer	Adults with HCC without extrahepatic malignant manifestations, vascular invasions, or contraindications for MWA	Adult patients with confirmed HCC or liver cancer
<b>Comparison</b>	MWA vs. RFA	MWA vs. Resection	MWA vs. RFA MWA vs. Resection	MWA vs. RFA
<b>N (Range)</b>	1066 (42 to 198)	965 MWA; 755 resections (22 to 424)	2458 (53 to 460)	4589 (19 to 562)
<b>Design</b>	1 RCT, 9 observational (1 prospective, 8 retrospective)	1 RCT, 15 observational (2 prospective, 13 retrospective)	4 RCT, 11 nonrandomized clinical trials	7 RCT, 26 observational (2 prospective, 24 retrospective)
<b>Duration</b>	5 to 45 months	15 months to 5 years	15 to 53 months	5 to 62 months

HCC: hepatocellular carcinoma; MA: meta-analysis; MWA: microwave ablation; RCT: randomized controlled trial; RFA: radiofrequency ablation; SR: systematic reviews.

**Table 4. Microwave Ablation for Hepatic Tumors: SR and MA Results**

Study	Local Tumor Recurrence/Progression	Overall Survival	Disease-free Survival	Adverse Events
<b>Chinnaratha et al. (2016) (1)</b>	<i>MWA vs RFA</i>	<i>MWA vs RFA</i>		<i>MWA vs RFA</i>
Total N	1298	538	NR	<i>Major Complications 1043</i>
Pooled odds ratio (95% CI), p value	1.01 (0.67 to 1.50); p=0.98	1 year: 1.18 (0.46–3.03), p=0.73  3 year: 0.76 (0.44–1.32), p=0.33	NR	0.63 (0.29–1.38), p=0.25
$I^2$ , p value	$I^2<23%$ , p=0.23	1 year: $I^2=32%$ , p=0.2  3 year: $I^2=53%$ , p=0.09	NR	$I^2=0%$ , p=0.8
<b>Glassberg et al. (2019) (4)</b>	<i>MWA vs resection</i>	<i>MWA vs resection</i>	<i>MWA vs resection</i>	<i>MWA vs resection</i>
Risk ratio (95% CI), p value	2.49 (1.19–5.22), p=0.016	1 year: 1.01 (0.99–1.03), p=0.409  3 year: 0.94 (0.88–0.99), p=0.03  5 year: 0.88 (0.80–	1 year: 0.95 (0.90–1.01), p=0.085  3 years: 0.78 (0.65–0.94), p=0.009  5 years: 0.83 (0.58–1.17), p=0.284	<i>Overall complications</i> 0.31 (0.19–0.51)  <i>Major complications</i> 0.24 (0.10–0.61) p=.002

		0.97), p=0.01		
<b>Cui et al. (2020) (5)</b>	<i>MWA vs RFA</i>	<i>MWA vs RFA</i>	<i>MWA vs RFA</i>	<i>MWA vs RFA</i>
Pooled odds ratio (95% CI), p value	<i>Local tumor progression at 1 year</i> 1.28 (0.52–3.18) p=0.59  <i>Progression-free survival at 3 years</i> 1.05 (0.77–1.43), p=0.74	3 year: 0.94 (0.66– 1.34), p=0.74  5 year: 0.83 (0.58– 1.18), p=0.29	NR	<i>Major complications</i> 1.04 (0.56–1.93) p=0.90
$I^2$ , p value	<i>Local tumor progression at 1 year</i> $I^2=8\%$ , p=0.34  <i>Progression-free survival at 3 years</i> $I^2=35\%$ , p=0.19	3 year: $I^2=40\%$ , p=0.12  5 year: $I^2=23\%$ , p=0.27	NR	<i>Major complications</i> $I^2=0\%$ , p=0.47
<b>Cui et al. (2020) (5)</b>	<i>MWA vs resection</i>	<i>MWA vs resection</i>	<i>MWA vs resection</i>	<i>MWA vs resection</i>
Pooled odds ratio (95% CI), p value	NR	3 year: 0.89 (0.59– 1.35), p=0.59	NR	NR
$I^2$ , p value	NR	3 year: $I^2=0\%$ , p=0.91	NR	NR
<b>Dou et al. (2022) (6)</b>	<i>MWA vs. RFA</i>	<i>MWA vs. RFA</i>	<i>MWA vs. RFA</i>	<i>MWA vs. RFA</i>
Pooled odds ratio (95% CI), p value	0.78 (0.64 to 0.96); p=.02	RCTs  1 year: 1.86 (0.91 to 3.80), p=.09  3 year: 1.16 (0.77	RCTs  1 year: 1.04 (0.48 to 2.24), p=.92	NR

		to 1.74), p=.49  5 year: 0.79 (0.51 to 1.21), p=.27  Cohort Studies  1 year: 0.97 (0.69 to 1.36), p=.85  3 year: 0.92 (0.75 to 1.13), p=.64  5 year: 1.12 (0.93 to 1.36), p=.22	3 year: 3.00 (0.91 to 9.87), p=.07  Cohort Studies  1 year: 1.20 (0.96 to 1.51), p=.11  3 year: 1.15 (0.93 to 1.41), p=.20  5 year: 0.84 (0.67 to 1.05), p=.13	
$I^2$ , p value	5 RCTs ( $I^2=32\%$ ); 28 cohort studies ( $I^2=39\%$ )	5 RCTs, 1 year ( $I^2=52\%$ ); 28 cohort studies, 3 year ( $I^2=64\%$ )	No significant heterogeneity found	NR

CI: confidence interval; MA: meta-analysis; MWA: microwave ablation; N: sample size; NR: not reported; RFA: radiofrequency ablation; SR: systematic review.

Chinnaratha et al. (2016) published a systematic review of RCTs and observational studies that compared the effectiveness and safety of RFA with MWA in patients who had primary hepatocellular carcinoma (HCC). (1) PubMed, EMBASE, and Cochrane Central databases were searched between 1980 and 2014 for human studies comparing the 2 technologies. The primary outcome was the risk of local tumor progression; secondary outcomes were complete ablation, OS, and major adverse events. Odds ratios were combined across studies using a random-effects model. Ten studies (1 RCT [9], 1 prospective cohort, 8 retrospective) were

included. One study was conducted in Australia and the others in China or Japan. Using the modified Newcastle-Ottawa quality assessment scale, the reviewers rated 5 of 10 studies high quality. The overall local tumor progression rate was 14% (176/1298). There was no difference in local tumor progression rates between RFA and MWA (odds ratio [OR], 1.01; 95% confidence interval [CI], 0.67 to 1.50;  $p=.98$ ). The complete ablation rate, 1- and 3- year OS, and major adverse events were similar between the 2 modalities ( $p>.05$  for all). Subgroup analysis showed local tumor progression rates were lower with MWA for treatment of larger tumors (OR, 1.88; 95% CI, 1.10 to 3.23;  $p=.02$ ). No significant publication bias was detected nor was interstudy heterogeneity ( $I^2<50\%$ ,  $p>.1$ ) observed for any measured outcomes. The reviewers concluded that both MWA and RFA are effective and safe.

Glassberg et al. (2019) conducted a systematic review of MWA compared to resection in patients with HCC or metastatic liver cancer. (4) One RCT (Xu et al. [2015] [30]) was included; the other studies ( $n=15$ ) were observational (2 prospective, 13 retrospective). Patients who received MWA had a significantly higher risk of local tumor progression compared to those who received resection (relative risk [RR], 3.04;  $p<.001$ ). At 1 year, OS did not differ between MWA and resection but 3- and 5-year OS was significantly higher in patients who had received resection. Overall and major complications were lower with MWA compared to resection. Additionally, operative time, intraoperative blood loss, and hospital length of stay were significantly lower with MWA. Some studies included patients that were nonresectable in the MWA treatment arm, but due to limited reporting and patient preference affecting which treatment was performed, the reviewers were not able to calculate the number of patients who were nonresectable or to conduct subgroup analyses by resectable versus unresectable tumors. Microwave ablation was typically selected for patients with smaller and/or deeper tumors, more comorbidities, and a preference for a less invasive procedure. The reviewers concluded that MWA can be an effective and safe alternative to hepatic resection in patients or tumors that are not amenable to resection, but more studies are needed to determine the target population that would benefit most from MWA.

Cui et al. (2020) conducted a systematic review and meta-analysis of MWA compared to various treatment modalities. The analysis included 4 RCTs, with 3 comparing MWA to RFA (38, 9, 24) and 1 comparing MWA to TACE. (28) The remaining 11 studies were nonrandomized trials comparing MWA to RFA ( $n=8$  studies), resection ( $n=2$  studies), or ethanol ablation ( $n=1$  study). Meta-analyses were not performed for MWA versus TACE or ethanol ablation, because these comparisons were only examined in 1 study each. Meta-analyses of studies comparing MWA to RFA found no difference in 3-year OS, 5-year OS, local tumor progression at 1 year, progression-free survival at 3 years, or major complications. A meta-analysis of 2 nonrandomized studies comparing MWA to resection found no difference in 3-year OS between treatments; however, this comparison is limited by the small number of studies and lack of RCTs included. The reviewers concluded that MWA showed similar safety and efficacy compared with RFA, but higher quality clinical studies are needed to validate the superiority of MWA.

Dou et al. (2022) conducted a systematic review and meta-analysis that compared the safety and efficacy of MWA compared to RFA in patients with HCC. (6) The analysis included 28 cohort

studies and 5 RCTs. Overall, there was no significant difference in disease-free survival, OS, or major complications between the 2 groups. In the cohort studies, MWA had a lower local tumor progression rate than RFA (OR, 0.78; 95% CI, 0.64 to 0.96;  $p=.02$ ). The reviewers concluded that there were various differences in the included studies (e.g., equipment used, operator experience) and that more high-quality RCTs are needed to draw a definitive conclusion on the pros versus cons of MWA and RFA in this patient population.

#### *Randomized Controlled Trials*

Six RCTs have compared MWA to RFA in patients with primary hepatic tumors (59, 9, 38, 24, 61, 62) and 1 RCT has compared MWA to resection; (30) the majority of these trials were included in the systematic reviews and meta-analyses described above and are not discussed in further detail here. Tables 5 and 6 summarize the characteristics and results of trials comparing MWA to RFA that have not been included in the above systematic reviews or meta-analyses. Tables 9 and 10 summarize the relevance, design, and conduct limitations of these trials.

Chong et al. (2020) conducted a RCT comparing MWA to RFA in 93 patients with HCC (up to 3 lesions of 5 cm or smaller). (61) Mean tumor size was 3.1 cm in the MWA group and 2.8 cm in the RFA group. The primary outcome of this study was the rate of complete ablation at 1 month, which did not differ significantly for MWA (95.7%) versus RFA (97.8%;  $p>.99$ ). Rates of OS up to 5 years and rates of disease-free survival up to 3 years were similar between groups. However, the sample size calculations were based on rates of complete ablation at 1 month, so the study may not have been adequately powered to detect differences in OS or disease-free survival.

Vogl et al. (2024) compared MWA and RFA for the treatment of small and medium-sized hepatocellular carcinomas. (62) Patients (N=50) were randomized to receive MWA or RFA treatment. Both treatments demonstrated a 100% technique efficacy rate and a technical success rate ( $p =1.00$ ), and there were no significant differences in local tumor progression or OS between treatment groups.

**Table 5. MWA versus RFA in Patients with Hepatic Tumors: Summary of Key RCT Characteristics**

Study; Trial	Countries	Sites	Dates	Participants	Interventions	
					MWA	RFA
Vogl et al. (2024) (62)	Germany	1	NR	Patients age 19 or older, HCC diagnosed by histological and/or radiological exam, 1 planned thermal ablation treatment with MWA or RFA, single lesion < 5 cm, up to 3 lesions (<3 cm), and no extrahepatic manifestation or vascular invasion	25	25

Chong et al. (2020) (61)	China	1	2011-2017	Patients age 18 or older, unresectable HCC or resectable HCC but patient opts for ablation, HCC lesion measuring 5 cm or smaller with up to 3 nodules, Child-Pugh score A or B, absence of extrahepatic metastases, absence of radiologic evidence of major vascular or bile duct invasion.	47	46
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HCC: hepatocellular carcinoma; MWA: microwave ablation; NR: not reported; RCT: randomized controlled trial; RFA: radiofrequency ablation.

**Table 6. MWA vs RFA in Patients with Hepatic Tumors: Summary of Key RCT Results**

Study	Local Tumor Progression	Overall Survival		Disease-free Survival	Complications
		MWA vs RFA	MWA vs RFA		
<b>Vogl et al. (2024) (62)</b>					
Percentage/ or months, p value	2 year: 4% vs. 16%, p=.056	1 year: 100% vs. 72% 2 year: 80% vs. 64% 3 year: 72% vs. 60% p≥.14	24.5 months vs. 13.4 months, p=.02		No moderate or severe AEs were documented
<b>Chong et al. (2020) (61)</b>					
Percentage, p value	NR	1 year: 97.9% vs 93.5% 3 year: 67.1% vs. 72.7% 5 year: 42.8% vs. 56.7% p=0.899	1 year: 51.5% vs 58.7% 3 year: 24.1% vs. 22.7% p=0.912		<i>Postoperative complications</i> 2.1% vs. 2.2%, p>0.999

AE: adverse event; CI: confidence interval; MWA: microwave ablation; NR: not reported; RCT: randomized controlled trial; RFA: radiofrequency ablation.

Zaitoun et al, (2021) compared the safety and efficacy of combination therapy with TACE and MWA (n=89) compared to TACE (n=84) or MWA (n=92) only in patients with solitary HCC lesions measuring between 3 to 5 cm. (63) TACE was performed first, followed by MWA after 15 days. Mean tumor size was 3.6 cm, 3.9 cm, and 3.7 cm in the TACE, MWA, and combination groups, respectively (p=.053). Complete response at 1 month was achieved by 86.5% of patients who received combination therapy compared with 54.8% of patients treated with TACE and 56.5% of patients treated with MWA. Patients treated with combination therapy had a significantly lower recurrence rate at 12 months (p=.0001) and a significantly higher OS rate at 3 years (69.6%; p=.02). Post-procedural minor adverse events (e.g., nausea, vomiting,

abdominal pain, and low-grade fever) were reported in 24.7%, 47.6%, and 38% of patients in the combined, TACE, and MWA groups, respectively. Severe hepatic dysfunction was observed in 1 patient in the combined group and 3 patients in the TACE group. Tumor seeding was reported in 2 patients in the MWA group. A decrease in alpha-fetoprotein (AFP) concentration was observed in 75%, 63%, and 48% of patients who underwent combined therapy, MWA, or TACE, respectively. Study characteristics and results are summarized in Tables 7 and 8. Study relevance, design, and conduct limitations are summarized in Tables 9 and 10.

**Table 7. MWA versus TACE in Patients with Hepatic Tumors: Summary of Key RCT Characteristics**

Study; Trial	Countries	Sites	Dates	Participants	Interventions		
					MWA	TACE	MWA + TACE
Zaitoun et al. (2021) (63)	Egypt	1	2017-2020	Patients with solitary HCC lesion >3 to <5 cm; absence of extrahepatic metastases; absence of a history of encephalopathy or refractory ascites; Child-Pugh score A or B; absence of severe coagulation disorders; lack of portal vein thrombosis; absence of renal impairment; no prior local ablation therapy of HCC.	89 to 95 with follow-up	84 of 90 with follow-up	89 of 93 with follow-up

HCC: hepatocellular carcinoma; MWA: microwave ablation; RCT: randomized controlled trial; TACE: transarterial chemoembolization.

**Table 8. MWA versus TACE in Patients with Hepatic Tumors: Summary of Key RCT Results**

Study; Trial	Treatment Response, n (%) <sup>a</sup>	Recurrence Rate, n (%)	Overall Survival, n (%) <sup>a</sup> ; median duration	Mean Progression-Free Survival	Adverse Events, n (%)
Zaitoun et al. (2020) (63)	1 month	12 months	3 years		
MWA	CR: 52 (56.5) PR: 25 (27.2)	47 (5.1)	50 (54.3); 21 months	16.7 months	Nausea, vomiting: 7

	SD: 6 (6.5) PD: 9 (9.8)				(7.6) Abdominal pain: 20 (21.7) Low-grade fever: 8 (8.7) Tumor seeding: 2 (2.2)
TACE	CR: 46 (54.8) PR: 27 (32.1) SD: 5 (6) PD: 6 (7.1)	51 (60.7)	46 (54.8); 19 months	15.4 months	Nausea, vomiting: 5 (6) Abdominal pain: 24 (28.6) Low-grade fever: 11 (13.1) Severe hepatic dysfunction: 3 (3.6)
MWA + TACE	CR: 77 (86.5) PR: 3 (3.3) SD: 5 (5.6) PD: 4 (4.55)	20 (22.47)	62 (69.6); 24 months	22.3 months	Nausea, vomiting: 4 (4.5) Abdominal pain: 15 (16.9) Low-grade fever: 3 (3.4) Severe hepatic dysfunction: 1 (1.1)
p value	.0002	.0001	.02	<.001	

CR: complete response; MWA: microwave ablation; PD: progressive disease; PR: partial response; RCT: randomized controlled trial; SD: stable disease; TACE: transarterial chemoembolization.

<sup>a</sup> Treatment response based on mRECIST criteria.

**Table 9. Study Relevance Limitations**

Study	Population <sup>a</sup>	Intervention <sup>b</sup>	Comparator <sup>c</sup>	Outcomes <sup>d</sup>	Follow-up <sup>e</sup>
Zaitoun et al. (2021) (63)	2. Unclear if patients presented			1. Primary outcome was rate of	

	with resectable disease			complete response at 1 month	
Chong et al. (2020) (61)	3. Included some patients with resectable disease			1. Primary outcome was rate of complete ablation at 1 month	
Vogl et al. (2024) (62)	2. Unclear if patients presented with resectable disease  4. Conducted in a single country				

The study limitations stated in this table are those notable in the current review; this is not a comprehensive gaps assessment.

<sup>a</sup> Population key: 1. Intended use population unclear; 2. Study population is unclear; 3. Study population not representative of intended use; 4. Enrolled populations do not reflect relevant diversity; 5. Other.

<sup>b</sup> Intervention key: 1. Not clearly defined; 2. Version used unclear; 3. Delivery not similar intensity as comparator; 4. Not the intervention of interest (e.g., proposed as an adjunct but not tested as such); 5. Other.

<sup>c</sup> Comparator key: 1. Not clearly defined; 2. Not standard or optimal; 3. Delivery not similar intensity as intervention; 4. Not delivered effectively; 5. Other.

<sup>d</sup> Outcomes key: 1. Key health outcomes not addressed; 2. Physiologic measures, not validated surrogates; 3. Incomplete reporting of harms; 4. Not establish and validated measurements; 5. Clinically significant difference not prespecified; 6. Clinically significant difference not supported; 7. Other.

<sup>e</sup> Follow-Up key: 1. Not sufficient duration for benefit; 2. Not sufficient duration for harms; 3. Other.

**Table 10. Study Design and Conduct Limitations**

Study	Allocation <sup>a</sup>	Blinding <sup>b</sup>	Selective Reporting <sup>c</sup>	Data Completeness <sup>d</sup>	Power <sup>e</sup>	Statistical <sup>f</sup>
Zaitoun et al. (2021) (63)	3. Allocation concealment unclear	1-3. Blinding not described		6. Analysis not intention-to-treat		
Chong et al. (2020) (61)						

Vogl et al. (2024) (62)		1-3. Blinding not described			1. Power calculations not reported	
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The study limitations stated in this table are those notable in the current review; this is not a comprehensive gaps assessment.

<sup>a</sup> Allocation key: 1. Participants not randomly allocated; 2. Allocation not concealed; 3. Allocation concealment unclear; 4. Inadequate control for selection bias; 5. Other.

<sup>b</sup> Blinding key: 1. Participants or study staff not blinded; 2. Outcome assessors not blinded; 3. Outcome assessed by treating physician; 4. Other.

<sup>c</sup> Selective Reporting key: 1. Not registered; 2. Evidence of selective reporting; 3. Evidence of selective publication; 4. Other.

<sup>d</sup> Data Completeness key: 1. High loss to follow-up or missing data; 2. Inadequate handling of missing data; 3. High number of crossovers; 4. Inadequate handling of crossovers; 5. Inappropriate exclusions; 6. Not intent to treat analysis (per protocol for noninferiority trials); 7. Other

<sup>e</sup> Power key: 1. Power calculations not reported; 2. Power not calculated for primary outcome; 3. Power not based on clinically important difference; 4. Other.

<sup>f</sup> Statistical key: 1. Analysis is not appropriate for outcome type: a) continuous; b) binary; c) time to event; 2. Analysis is not appropriate for multiple observations per patient; 3. Confidence intervals and/or p values not reported; 4. Comparative treatment effects not calculated; 5. Other.

### Hepatic Metastases From Primary Cancers From Other Sites

#### *Systematic Reviews*

A Health Technology Assessment by Loveman et al. (2014) (64) and a Cochrane review by Bala et al. (2013) (65) reported on ablation for liver metastasis. Reviewers found insufficient evidence to determine any benefits of MWA for liver metastasis over surgical resection.

Pathak et al. (2011) conducted a systematic review of ablation techniques for colorectal liver metastases, which included 13 studies on MWA (N=406) with a minimum of 1-year follow-up. (66) Mean survival rates were 73%, 30%, and 16% and ranged from 40% to 91.4%, 0% to 57%, and 14% to 32% at the 1-, 3-, and 5-year follow-ups, respectively. Minor and major complication rates were considered acceptable and ranged from 6.7% to 90.5% and 0% to 19%, respectively. Local recurrence rates ranged from 2% to 14%.

Mimmo et al. (2022) conducted a systematic review of MWA for colorectal liver metastases. (67) Twelve studies (N=741) were included, and 395 patients were treated with MWA versus conventional surgical procedure (n=346). The mean follow-up duration was 20.5 months. Pooled data analysis showed mean recurrence free rates for MWA at 1, 3, and 5 years were 65.1%, 44.6%, and 34.3%, respectively. Mean OS rates for MWA at 1, 3, and 5 years were 86.7%, 59.6%, and 44.8%, respectively. Mean local recurrence rates for MWA at 3, 6, and 12 months were 96.3%, 89.6%, and 83.7%, respectively.

#### Section Summary: Hepatic Tumors

For individuals who have an unresectable primary or metastatic hepatic tumor who receive MWA, the evidence includes RCTs, comparative observational studies, and systematic reviews

comparing MWA to RFA or TACE and to surgical resection. The body of evidence indicates that MWA is an effective option in patients for whom resection is not an option. Although studies had methodological limitations, they consistently showed that MWA and RFA had similar survival outcomes with up to 5 years of follow-up in patients with a single tumor  $\leq 5$  cm or up to 3 nodules  $\leq 3$  cm each. In a meta-analysis of observational studies, patients receiving MWA had higher local recurrence rates and lower survival than those who received resection but the patient populations were not limited to those who had unresectable tumors. Microwave ablation was associated with lower complications, intraoperative blood loss, and hospital length of stay. A single RCT showed that patients with solitary lesions  $>3$  and  $<5$  cm treated with combination MWA plus TACE achieved higher overall and progression-free survival compared to MWA or TACE only. However, it is unclear whether patients in this study were classified with unresectable disease.

### Unresectable Primary or Metastatic Lung Tumors

#### *Systematic Reviews*

Three systematic reviews have compared MWA to RFA for lung cancer (Tables 11 to 13). (68-70)

Nelson et al. (2019) included 12 retrospective observational studies of MWA in patients with primary or metastatic lung tumors. (70) The reviewers did not pool results due to clinical and methodological heterogeneity across the studies. The studies varied with regard to patient characteristics (tumor size, histology, number of treated nodules), outcome measures, and technical experience of surgeons performing the procedures. The primary outcome was local recurrence, and survival outcomes were not assessed. Overall, local recurrence rates ranged from 9% to 37% across the studies. Newer reports and those that targeted smaller tumors showed more favorable efficacy rates. Results in patients with multiple tumors were not reported separately. Four studies reported results by tumor size; the local recurrence rates for large tumors ( $>3$  or 4 cm depending on the study) were 50%, 75%, 36%, and 26%. In the same 4 studies, for small tumors ( $<3$  or 3.5 cm depending on the study), local recurrence rates were 19%, 18%, 18%, and 5%, respectively. The most frequent adverse event with MWA was a pneumothorax requiring a chest tube. The reviewers concluded that MWA may be a useful tool in selected patients who are not ideal surgical candidates.

In a meta-analysis of observational studies, Yuan et al. (2019) found higher OS for patients who received RFA compared to those who received MWA. (68) However, these estimates were not directly comparable because they came from different sets of studies, and the reviewers concluded that percutaneous RFA and MWA were both effective with a high safety profile. The studies used different patient eligibility criteria (e.g., tumor size, lesion number, age, follow-up). Subgroup analyses by tumor size or tumor number were not possible from the data reported.

Jiang et al. (2018) conducted a network meta-analysis to determine the effectiveness of different ablation techniques in patients with lung tumors. (69) Tumor size, stage of the disease, and primary versus metastatic disease were not accounted for in the analysis. For MWA, weighted average OS rates were 82.5%, 54.6%, 35.7%, 29.6%, and 16.6% at 1, 2, 3, 4, and 5 years, respectively.

**Table 11. Comparison of Trials/Studies Included in SR & MA of MWA in Lung Cancer**

Study	Nelson et al. (2019) (70)	Yuan et al. (2019) <sup>a</sup> (68)	Jiang et al. (2018) <sup>a</sup> (69)
He et al. (2006) (71)			●
Wolf et al. (2008) (72)	●		
Vogl et al. (2011) (73)	●	●	
Lu et al. (2012) (74)	●	●	
Carrafiello et al. (2013) (75)		●	
Liu et al. (2013) (76)			●
Vogl et al. (2013) (77)	●	●	
Wei et al. (2014) (78)	●		
Yang et al. (2014) (79)		●	
Zheng et al. (2014) (80)	●		
Acksteiner et al. (2015) (81)			●
Wei et al. (2015) (82)		●	
Egashira et al. (2016) (83)	●		
Ko et al. (2016) (84)	●	●	
Li et al. (2016) (85)			●
Macchi et al. (2017) (86)			●
Maxwell et al. (2016) (87)			●
Vogl et al. (2016) (88)	●	●	●
Zheng et al. (2016) (89)	●	●	●
Healey et al. (2017) (90)		●	
Nour-Eldin et al. (2017) (91)		●	
Wei et al. (2017) (92)		●	●
Yang et al. (2017) (93)	●		
Zhong et al. (2017) (94)	●		

MA: meta-analysis; MWA: microwave ablation; SR: systematic reviews.

<sup>a</sup>Studies of MWA only**Table 12. Characteristics of Systematic Reviews of MWA in Lung Cancer**

Study	Dates	Trials	Participants	N (Range)	Designs	Duration
Nelson et al.	Up to October 3, 2017	12	Primary or secondary lung malignancies	985 (15-184)	12 retrospective observational;	9-47 months

(2019) (70)					excluded case series with <30 lesions	
Yuan et al. (2019) (68)	2010-2017	12	Primary or secondary lung malignancies	800 (15-183)	12 retrospective, observational	Median 10-35 months (range 3-75 months), NR in 3 studies
Jiang et al. (2018) (69)	Up to December 31, 2017	9	Primary lung cancer or pulmonary metastases from other primary tumors	438 (5-183)	1 RCT, 8 retrospective observational; excluded studies that used other treatments combined with thermal ablation	Median 12-35 months (range 3-108 months)

MWA: microwave ablation; N: sample size; NR: not reported; RCT: randomized controlled trial.

**Table 13. Results of Systematic Reviews of MWA in Lung Cancer**

Study	Overall Survival	Progression-free Survival	Local Recurrence Rate	Adverse Events
<b>Nelson et al. (2019) (70)</b>				
Range of effect sizes	NR (primary analysis was local recurrence)	NR	9%-37% 25% or greater (n=4 studies); less than 25% (n=7 studies); less than 15% (n=2 studies) 7 studies found a significantly higher likelihood of local recurrence with larger tumors (>3 cm)	<i>Pneumothorax</i> 1%-15%  <i>Skin burns</i> 1.5%-6%  <i>Periprocedural mortality</i> 1 patient (0.5%) from ventricular tachycardia
			<i>Local tumor progression-free</i>	

<b>Yuan et al. (2019) (68)</b>				
Pooled estimate (95% CI)	1 year: 79.3% (73.7%-85.0%) 2 year: 51.9% (46.2%-57.5%) 3 year: 34.6% (26.8%-42.5%)	1 year: 64.8% (37.1%-92.4%) 2 year: 43.1% (1.5%-84.7%) 3 year: 56.0% (41.1%-70.9%)	1 year: 84.6% (72.9%-96.3%) 2 year: 68.5% (51.8%-85.1%) 3 year: 72.2% (64.5% to 79.9%) 4 year: 74.1% (67.0%-81.2%) 5 year: 48.0% (23.8%-72.2%)	<i>Pneumothorax</i> 33.9% (23.8%- 44.8%) <i>Pneumothorax</i> <i>needing</i> <i>intervention</i> 11.0% (4.5%- 19.7%) <i>Pleural effusion</i> 9.6% (1.5%- 22.4%) <i>Pleural effusion</i> <i>needing</i> <i>intervention</i> 0.3% (0%-1.4%)
$I^2$ , p	1 year: $I^2=37.7\%$ , $p=0.155$ 2 year: $I^2=0\%$ , $p=0.691$ 3 year: $I^2=7.6\%$ , $p=0.458$	1 year: $I^2=88.4\%$ , $p=0.003$ 2 year: $I^2=94.3\%$ , $p<0.001$ 3 year: NA	1 year: $I^2=87.9\%$ , $p<0.001$ 2 year: $I^2=81.9\%$ , $p=0.019$ 3 year: $I^2=15.1\%$ , $p=0.278$ 4 year: NA 5 year: NA	NA
<b>Jiang et al. (2018) (69)</b>				
Weighted average	1 year: 82.5% 2 year: 54.6% 3 year: 35.7% 4 year: 29.6% 5 year: 16.6%	NR	10.9%	<i>Major</i> <i>complications</i> 22.5%

CI: confidence interval; MWA: microwave ablation; N: sample size; NR: not reported.

#### *Randomized Controlled Trials*

There is a single RCT of MWA compared to RFA for lung tumors, conducted by Macchi et al. (2017) (Tables 14 and 15). (86) Patients were eligible for the study if they had a single tumor up to 5 cm, and up to 5 metastases up to 5 cm. However, at baseline, the mean tumor size was 2.21 cm (standard deviation [SD], 0.89) in the MWA group and 1.64 cm (SD, 0.80) in the RFA group. Mortality rates at 6 and 12 months did not differ between groups, and complications were significantly lower in the MWA group. Limitations of this study are summarized in Tables 16 and 17 and include its small sample size, lack of reporting on blinding, and relatively short follow-up period (12 months). Results were not reported by tumor size or the number of metastases.

**Table 14. Summary of Key RCT Characteristics: MWA versus RFA in Patients with Lung Tumors**

Study; Trial	Countries	Sites	Dates	Participants	Interventions	
					MWA	RFA
Macchi et al. (2017) (86)	Italy	Multisite, NR	NR	Age 18 years or older; with tumors considered surgically inoperable, or patients that did not respond to standard chemotherapy or radiotherapy, or patients affected by conditions with high morbidity rates that are contraindicative to surgery; maximum diameter of the primary lesion $\leq$ 5 cm; percutaneous accessibility of the lesion; for those with pulmonary metastases, number of metastases <5 each with maximum diameter of 5 cm	24	28

MWA: microwave ablation; NR: not reported; RCT: randomized controlled trial; RFA: radiofrequency ablation.

**Table 15. Summary of Key RCT Results: MWA versus RFA in Patients with Lung Tumors**

Study	Local Tumor Recurrence	Survival time	Mortality at 6 months	Mortality at 12 months	Complications
<b>Macchi et al. (2017) (86)</b>					
MWA	NR	(graph only)	4/24 (16.7%)	4/20 (20.0%)	8/24 (33.3%)
RFA			3/28 (10.7%)	5/25 (20.0%)	16/28 (57.1%)
p-value		0.883	0.35	<0.0001	0.05

MWA: microwave ablation; NR: not reported; RCT: randomized controlled trial; RFA: radiofrequency ablation.

**Table 16. Study Relevance Limitations**

Study	Population <sup>a</sup>	Intervention <sup>b</sup>	Comparator <sup>c</sup>	Outcomes <sup>d</sup>	Follow-Up <sup>e</sup>
Macchi et al. (2017) (86)	1. Did not report results by tumor size, histology, or number of tumors 5. Combined patients with primary and metastatic tumors in analyses			1. Local recurrence not reported	1. 12 months only

The study limitations stated in this table are those notable in the current review; this is not a comprehensive gaps assessment.

<sup>a</sup> Population key: 1. Intended use population unclear; 2. Study population is unclear; 3. Study population not representative of intended use; 4. Enrolled populations do not reflect relevant diversity; 5. Other.

<sup>b</sup> Intervention key: 1. Not clearly defined; 2. Version used unclear; 3. Delivery not similar intensity as comparator; 4. Not the intervention of interest (e.g., proposed as an adjunct but not tested as such); 5: Other.

<sup>c</sup> Comparator key: 1. Not clearly defined; 2. Not standard or optimal; 3. Delivery not similar intensity as intervention; 4. Not delivered effectively; 5. Other.

<sup>d</sup> Outcomes key: 1. Key health outcomes not addressed; 2. Physiologic measures, not validated surrogates; 3. Incomplete reporting of harms; 4. Not establish and validated measurements; 5. Clinically significant difference not prespecified; 6. Clinically significant difference not supported; 7. Other.

<sup>e</sup> Follow-Up key: 1. Not sufficient duration for benefit; 2. Not sufficient duration for harms; 3. Other.

**Table 17. Study Design and Conduct Limitations**

Study	Allocation <sup>a</sup>	Blinding <sup>b</sup>	Selective Reporting <sup>c</sup>	Data Completeness <sup>d</sup>	Power <sup>e</sup>	Statistical <sup>f</sup>
Macchi et al. (2017 (86)		4. Not reported			1. Power calculation not reported	

The study limitations stated in this table are those notable in the current review; this is not a comprehensive gaps assessment.

<sup>a</sup> Allocation key: 1. Participants not randomly allocated; 2. Allocation not concealed; 3. Allocation concealment unclear; 4. Inadequate control for selection bias; 5. Other.

<sup>b</sup> Blinding key: 1. Participants or study staff not blinded; 2. Outcome assessors not blinded; 3. Outcome assessed by treating physician; 4. Other.

<sup>c</sup> Selective Reporting key: 1. Not registered; 2. Evidence of selective reporting; 3. Evidence of selective publication; 4. Other.

<sup>d</sup> Data Completeness key: 1. High loss to follow-up or missing data; 2. Inadequate handling of missing data; 3. High number of crossovers; 4. Inadequate handling of crossovers; 5. Inappropriate exclusions; 6. Not intent to treat analysis (per protocol for noninferiority trials); 7. Other.

<sup>e</sup> Power key: 1. Power calculations not reported; 2. Power not calculated for primary outcome; 3. Power not based on clinically important difference; 4. Other.

<sup>f</sup> Statistical key: 1. Analysis is not appropriate for outcome type: a) continuous; b) binary; c) time to event; 2. Analysis is not appropriate for multiple observations per patient; 3. Confidence intervals and/or p values not reported; 4. Comparative treatment effects not calculated; 5. Other.

### Section Summary: Lung Tumors

For individuals who have an unresectable primary or metastatic lung tumor who receive MWA, the evidence includes a single RCT, retrospective observational studies, and systematic reviews of these studies. The body of evidence indicates that MWA is an effective option in patients for whom resection is not an option. In the RCT, direct comparison of MWA and RFA in patients with primary or metastatic lung cancer (mean tumor size, 1.90 cm [ $\pm$  0.89] at baseline) found similar mortality rates up to 12 months of follow-up. In the first of 3 systematic reviews that

included 12 retrospective observational studies, local recurrence rates were similar for MWA and RFA at a range of 9 to 47 months of follow-up. In the second systematic review with a meta-analysis, there was lower OS with MWA compared to RFA, but studies were not directly comparable due to clinical and methodological heterogeneity. However, the authors concluded that percutaneous RFA and MWA were both effective with a high safety profile. In the third systematic review using a network meta-analysis, the weighted average OS rates for MWA were 82.5%, 54.6%, 35.7%, 29.6%, and 16.6% at 1, 2, 3, 4, and 5 years, respectively. Limitations of the body of evidence included a lack of controlled studies and heterogeneity across studies. The RCT did not report results by tumor size or the number of metastases. The observational studies included in the systematic reviews did not report sufficient information to assess the effectiveness or safety of MWA in subgroups based on the presence of multiple tumors or total tumor burden. Therefore, conclusions about the evidence sufficiency can only be made about patients with single tumors.

### Unresectable Primary or Metastatic Renal Tumors

#### *Systematic Reviews*

Uhlig et al. (2019) published a systematic review with meta-analyses to compare partial nephrectomy, RFA, cryoablation, and MWA and the effect on oncologic, perioperative, and functional outcomes in studies published from 2005 to 2017. (95) Microwave ablation was a treatment in 344 of 24,077 patients and represented in 6 of 47 studies. The review included the single RCT (Guan 2012 [96]), which is the only study with results for all 3 outcomes of interest. No new data were included, but the review utilized a network meta-analyses technique. Microwave ablation when compared to partial nephrectomy, the comparator of interest, was reported to have a lower procedural complication rate but higher local recurrence and cancer-specific mortality rates. (95)

In a systematic review and meta-analysis, Katsanos et al. (2014) compared thermal ablation (MWA and RFA) with surgical nephrectomy for small renal tumors (mean size, 2.5 cm). (97) The analysis included 1 randomized study on MWA (96) (described below) and 5 cohort studies on RFA (N=587 patients). In the ablation group, complication rates and renal function declines were significantly higher than in the nephrectomy group ( $p=.04$  and  $p=.03$ , respectively). The local recurrence rate was 3.6% in both groups (RR, 0.92; 95% CI, 0.4 to 2.14;  $p=.79$ ) and disease-free survival up to 5 years did not differ significantly between groups (hazard ratio [HR], 1.04; 95% CI, 0.48 to 2.24;  $p=.92$ ).

Martin et al. (2013) conducted a meta-analysis comparing MWA with cryoablation for small renal tumors. (98) The analysis included 7 MWA studies (n=164 patients) and 44 cryoablation studies (n=2989 patients). Selected studies were prospective or retrospective, nonrandomized, and noncomparative. Mean follow-up duration was shorter for MWA (17.86 months) than for cryoablation (30.22 months;  $p=.07$ ). Mean tumor size was significantly larger in the MWA studies than in the cryoablation studies (2.58 cm vs. 3.13 cm, respectively,  $p=.04$ ). Local tumor progression (4.07% vs. 2.53%, respectively;  $p=.46$ ) and progression to metastatic disease (0.8% vs. 0%, respectively;  $p=.12$ ) did not differ significantly. In another meta-analysis comparing MWA with cryoablation, McClure et al. (2023) identified 99 observational studies with 62

cryoablation arms and 41 MWA arms. (99) Local tumor recurrence at 1 year was lower with MWA than cryoablation (OR, 0.33; 95% CI, 0.10 to 0.93; p=.04). No significant differences were found for OS or disease-free survival. The data is limited by the comparison of single-arm studies which were observational and primarily retrospective.

#### *Randomized Controlled Trial*

Guan et al. (2012) reported on a prospective randomized study that compared the use of MWA with partial nephrectomy (the criterion standard of nephron-sparing surgical resection) for solitary renal tumors less than 4 cm. (96) Forty-eight patients received MWA and 54 had partial nephrectomy. Patients in the MWA group (6 [23.5%]) had significantly fewer postoperative complications than in the partial nephrectomy group (18 [33.3%]; p=.019). Microwave ablation patients also had significantly less postoperative renal function declines (p<.009) and estimated perioperative blood loss (p<.001) than partial nephrectomy patients. At last follow-up, estimated glomerular filtration rate declines in both groups were similar (p=1.00). Disease-specific deaths did not occur, and overall local recurrence-free survival by Kaplan-Meier estimates at 3 years was 91.3% for MWA and 96.0% for partial nephrectomy (p=.541).

#### *Case Series and Retrospective Reviews*

Two recent retrospective reviews were not included in meta-analyses. Guo et al. (2020) reported a retrospective review of 106 patients with 119 T1a renal cell carcinoma tumors treated with MWA. (100) Complete response was achieved in 95.3% of patients (mean tumor diameter, 2.4 cm; range, 1 to 4 cm). Local tumor progression was observed in 6 patients at a mean of 20 months post-procedure. Local progression-free survival rates were 100%, 92.8%, and 90.6% at 1, 2, and 3 years, respectively. Overall survival rates were 99%, 97.7%, and 94.6% at 1, 2, and 3 years, respectively. Complications were reported in 6 patients (5.7%) within 30 days of the procedure, but none of these required intervention. Aarts et al. (2020) conducted another retrospective review of 100 patients with 108 T1 renal cell carcinomas treated with MWA. (101) The median tumor size in this study was 3.2 cm (interquartile range, 2.4 to 4 cm). Primary efficacy was achieved for 81% (88/108) of lesions overall, but primary efficacy rates were lower among patients with T1b tumors (52%) versus T1a tumors (89%; p<.001). Secondary efficacy was achieved for 97% (101/103). Over a median follow-up time of 19 months, local tumor recurrence was observed for 4 (4%) tumors.

#### Section Summary: Renal Tumors

For individuals who have an unresectable primary or metastatic renal tumor who receive MWA, the evidence includes a single RCT that compared MWA to partial nephrectomy, systematic reviews, retrospective reviews, and case series. In the RCT, overall local recurrence-free survival at 3 years was 91.3% for MWA and 96.0% for partial nephrectomy (p=.54). However, there is a lack of controlled studies comparing MWA to other ablation techniques in patients with renal tumors.

#### Unresectable Primary or Metastatic Solid Tumors Other than Hepatic, Lung, or Renal

#### *Unresectable Primary or Metastatic Breast Tumors - Systematic Reviews*

A systematic review by Zhao and Wu (2010) assessing ablation techniques for breast cancer found that only 0% to 8% of breast cancer tumors were completely ablated with MWA. (102) The studies identified by reviewers were mostly feasibility and pilot studies conducted in research settings.

#### *Unresectable Primary or Metastatic Breast Tumors - Case Series*

Zhou et al. (2012) reported on 41 patients treated with MWA directly followed by mastectomy for single breast tumors with a mean volume of 5.26 cm (range, 0.09 to 14.14 cm).

(103) Complete tumor ablation was found by microscopic evaluation in 37 (90%) of the 41 tumors ablated (95% CI, 76.9% to 97.3%). Reversible thermal injuries to the skin and pectoralis major muscle occurred in 3 patients.

#### Other Unresectable Primary or Metastatic Solid Tumors

##### *Systematic Reviews*

A systematic review of ablation therapies, including MWA, for locally advanced pancreatic cancer was published by Keane et al. (2014). (104) Reviewers found limited evidence on the use of MWA for pancreatic cancer. Cui et al. (2019) conducted a non-comparative systematic review and meta-analysis of 5 retrospective studies and 2 prospective studies in patients with benign thyroid nodules or papillary thyroid microcarcinoma and found that MWA improved nodule volume and symptom scores in these patients. (105) Wu et al. (2022) conducted a systematic review and meta-analysis comparing MWA versus conventional surgery for the treatment of papillary thyroid microcarcinoma. (106) There were 13 included studies which were all non-randomized. There were no differences between the 2 groups in recurrence rate or lymph node metastasis; however, the MWA group did have a shorter operation time, less intra-operative blood loss, shorter postoperative hospital stay, and few complications.

##### *Randomized Controlled Trials*

Chen et al. (2024) published one small RCT (N=152) conducted at 5 institutions comparing MWA and RFA for benign thyroid nodules. (107) Six-month and 2-year volume reduction rates were noninferior with MWA compared to RFA (mean difference, -5.6% and -2.4%, respectively). The study is limited by the small sample size, limited number of sites (N=5), open-label design, and its application to only benign nodules. Further RCTs in patients with thyroid nodules are needed.

##### *Case Series*

Case studies and retrospective reviews on the use of MWA for adrenal carcinoma, (108) metastatic bone tumors, (109) intrahepatic primary cholangiocarcinoma, (110) pancreatic neuroendocrine tumors, (111) and other nononcologic conditions (i.e., bleeding peptic ulcers, esophageal varices, secondary hypersplenism) were identified.

#### Section Summary: Other Solid Tumors

For individuals who have unresectable primary or metastatic solid tumors other than hepatic, lung, or renal. who receive MWA, the evidence includes systematic reviews and case series. No RCTs on the use of MWA for other tumors or conditions were identified.

## **Summary of Evidence**

For individuals who have an unresectable primary or metastatic hepatic tumor who receive microwave ablation (MWA), the evidence includes randomized controlled trials (RCTs), comparative observational studies, and systematic reviews comparing MWA to radiofrequency ablation (RFA) and to surgical resection. Relevant outcomes are overall survival (OS), disease-specific survival, symptoms, quality of life (QOL), and treatment-related mortality and morbidity. The body of evidence indicates that MWA is an effective option in patients for whom resection is not an option. Although studies had methodological limitations, results consistently showed that MWA and RFA had similar survival outcomes with up to 5 years of follow-up in patients with a single tumor  $\leq 5$  cm or up to 3 nodules  $\leq 3$  cm each. In a meta-analysis of observational studies, patients receiving MWA had higher local recurrence rates and lower survival than those who received resection, but the patient populations were not limited to those who had unresectable tumors. Microwave ablation was associated with lower complications, intraoperative blood loss, and hospital length of stay. The evidence is sufficient to determine that the technology results in an improvement in the net health outcome.

For individuals who have an unresectable primary or metastatic lung tumor who receive MWA, the evidence includes a single RCT, retrospective observational studies, and systematic reviews of these studies. Relevant outcomes are OS, disease-specific survival, symptoms, QOL, and treatment-related mortality and morbidity. The body of evidence indicates that MWA is an effective option in patients for whom resection is not an option. In the RCT, direct comparison of MWA and RFA in patients with primary or metastatic lung cancer (mean tumor size, 1.90 cm [ $\pm 0.89$ ] at baseline) found similar mortality rates up to 12 months of follow-up. In the first of 3 systematic reviews that included 12 retrospective observational studies, local recurrence rates were similar for MWA and RFA at a range of 9 to 47 months of follow-up. In the second systematic review with a meta-analysis, there was lower OS with MWA compared to RFA, but studies were not directly comparable due to clinical and methodological heterogeneity. However, the authors concluded that percutaneous RFA and MWA were both effective with a high safety profile. In the third systematic review using a network meta-analysis, the weighted average OS rates for MWA were 82.5%, 54.6%, 35.7%, 29.6%, and 16.6% at 1, 2, 3, 4, and 5 years, respectively. Limitations of the body of evidence included a lack of controlled studies and heterogeneity across studies. The RCT did not report results by tumor size or the number of metastases. The observational studies included in the systematic reviews did not report sufficient information to assess the effectiveness or safety of MWA in subgroups based on the presence of multiple tumors or total tumor burden. Therefore, conclusions about the evidence sufficiency can only be made about patients with single tumors. For this population, the evidence is sufficient to determine that the technology results in an improvement in the net health outcome.

For individuals who have an unresectable primary or metastatic renal tumor who receive MWA, the evidence includes a single RCT that compared MWA to partial nephrectomy, retrospective reviews, systematic reviews, and meta-analyses of the retrospective reviews (with or without the single RCT) and case series. Relevant outcomes are OS, disease-specific survival, symptoms,

QOL, and treatment-related mortality and morbidity. In the RCT, overall local recurrence-free survival at 3 years was 91.3% for MWA and 96.0% for partial nephrectomy ( $p=.54$ ). This positive outcome should be replicated in additional RCTs. There are also no controlled studies comparing MWA to other ablation techniques in patients with renal tumors. The evidence is insufficient to determine that the technology results in an improvement in the net health outcome.

For individuals who have unresectable primary or metastatic solid tumors other than hepatic, lung, or renal who receive MWA, the evidence includes systematic reviews and case series. No RCTs on the use of MWA for other malignant tumors or conditions were identified. Relevant outcomes are OS, disease-specific survival, symptoms, QOL, and treatment-related mortality and morbidity. One RCT in benign thyroid tumors found MWA to be noninferior to RFA, but the study is limited by the small number of sites and lack of blinding. The evidence is insufficient to determine that the technology results in an improvement in the net health outcome.

### **Practice Guidelines and Position Statements**

#### American College of Chest Physicians

The American College of Chest Physicians (2025) evidence-based guidelines on the treatment of early-stage non-small cell lung cancer (NSCLC) combined ablative procedures as a single group rather than individual types. (112) Ablation is considered an option for inoperable patients; however, stereotactic body radiotherapy (SBRT) has been shown to improve overall survival compared with ablation and is preferred for most patients. Ablation is considered a reasonable approach if SBRT is deemed to have a high-risk of complications or limited effectiveness.

#### American Urological Association

The American Urological Association (2021) updated its guidelines on renal mass and localized renal cancer, which note that both RFA and cryoablation may be offered as options for patients who elect thermal ablation (Conditional Recommendation; Evidence Level: Grade C. (113) Thermal ablation can be considered as an alternate approach in the management of T1a solid renal masses  $<3$  cm. In these patients, a percutaneous technique is preferred (Moderate Recommendation; Evidence Level: Grade C). The guidelines do not specifically address MWA.

#### National Comprehensive Cancer Network

The National Comprehensive Cancer Network (NCCN) guidelines on hepatocellular carcinoma (HCC) (v.2.2025) list MWA as a locoregional therapy option (along with other ablation forms, arterially directed therapies, and radiotherapy. (114) Ablation should only be considered when tumors are accessible by percutaneous, laparoscopic, or open approaches. The guidelines indicate "Ablation alone may be curative in treating tumors less than or equal to 3 cm [...] Lesions 3 to 5 cm may be treated to prolong survival using arterially directed therapies, or with combination of an arterially directed therapy and ablation as long as tumor location is accessible for ablation."

The guidelines on NSCLC (v.1.2026) state that image-guided thermal ablation therapies such as cryotherapy, microwave, or radiofrequency may be an option for select medically inoperable

patients not receiving stereotactic ablative radiotherapy or definitive radiotherapy. (115) Image-guided thermal ablation therapy is considered an option for the management of NSCLC lesions <3 cm. Ablation for NSCLC lesions >3 cm has been associated with higher rates of local recurrence and complications.

Guidelines on small-cell lung cancer (v.2.2026) state that stereotactic ablative radiotherapy is an option for certain patients with medically inoperable stage I to IIA small-cell lung cancer. (116) There is no mention of MWA specifically.

The Network guidelines on neuroendocrine tumors (v.3.2025) state that "percutaneous thermal ablation, often using microwave energy (radiofrequency and cryoablation are also acceptable), can be considered for oligometastatic liver disease, generally up to four lesions each <3 cm." (117)

The guidelines on kidney cancer (v.1.2026) state that percutaneous ablation techniques (MWA, RFA and cryotherapy) may be an option for T1 renal lesions, particularly for masses  $\leq 3$  cm. (118) "Percutaneous ablation is an option for clinical T1b masses in select patients not eligible for surgery."

The guidelines on breast cancer (v.5.2025) do not address thermal ablation techniques such as MWA. (119)

Thyroid cancer guidelines from NCCN (v.1.2025) recommend ablation techniques such as cryoablation or RFA as an option for metastatic disease in select patients. (120) There is not specific mention of MWA.

#### National Institute for Health and Care Excellence

The National Institute for Health and Care Excellence (2016) updated its guidance on MWA for treatment of metastases in the liver. (121) The revised guidance states:

- Current evidence on MWA for treating liver metastases raises no major safety concerns and the evidence on efficacy is adequate in terms of tumor ablation. Therefore this procedure may be used provided that standard arrangements are in place for clinical governance, consent, and audit.
- Patient selection should be carried out by a hepatobiliary cancer multidisciplinary team.
- Further research would be useful for guiding the selection of patients for this procedure. This should document the site and type of the primary tumor being treated, the intention of treatment (palliative or curative), imaging techniques used to assess the efficacy of the procedure, long-term outcomes, and survival.

The Institute (2007) also published guidance on MWA for HCC. (122) This guidance indicated:

"Current evidence on the safety and efficacy of MWA of hepatocellular carcinoma appears adequate to support the use of this procedure...." The guidance also stated there are no major

concerns about the efficacy of MWA, but noted that limited, long-term survival data are available.

The Institute (2022) has published guidance on MWA for lung tumors as well. (123) This guidance indicated that, "Evidence on the safety of microwave ablation for treating primary lung cancer and metastases in the lung is adequate but shows it can cause infrequent serious complications. Evidence on its efficacy shows it reduces tumour size. But the evidence on improvement in survival, long-term outcomes and quality of life is limited in quantity and quality. Therefore, this procedure should only be used with special arrangements for clinical governance, consent, and audit or research." The guidance encourages further research.

#### Society of American Gastrointestinal and Endoscopic Surgeons

In 2023, the Society of American Gastrointestinal and Endoscopic Surgeons (SAGES) and the Americas Hepato-Pancreato-Biliary Association (AHPBA) published guidelines for the use of MWA and RFA for the treatment of HCC. (124) The panel recommended that MWA or RFA can be utilized in patients with HCC and colorectal liver metastases. However, they did note that available evidence was poor quality and treatment decisions should be individualized.

#### **Ongoing and Unpublished Clinical Trials**

Some currently ongoing and unpublished trials that might influence this review are listed in Table 18.

**Table 18. Summary of Key Trials**

NCT Number	Trial Name	Planned Enrollment	Completion Date
NCT04081168	COLLISION XL: Unresectable Colorectal Liver Metastases (3-5cm): Stereotactic Body Radiotherapy vs. Microwave Ablation (COLLISION-XL)	68	Jan 2025
NCT03775980 <sup>a</sup>	CIRSE Emprint Microwave Ablation Registry (CIEMAR)	500	Jan 2026
NCT04365751	To Compare the Efficacy of Microwave Ablation and Laparoscopic Hepatectomy for Hepatocellular Carcinoma	1134	Dec 2026
NCT04107766 <sup>a</sup>	NeuWave Observational Liver Ablation Registry (NOLA)	1255	Jun 2025

NCT: national clinical trial.

<sup>a</sup> Denotes industry-sponsored or cosponsored trial.

#### **Coding**

Procedure codes on Medical Policy documents are included **only** as a general reference tool for each policy. **They may not be all-inclusive.**

The presence or absence of procedure, service, supply, or device codes in a Medical Policy document has no relevance for determination of benefit coverage for members or reimbursement for providers. **Only the written coverage position in a Medical Policy should be used for such determinations.**

Benefit coverage determinations based on written Medical Policy coverage positions must include review of the member's benefit contract or Summary Plan Description (SPD) for defined coverage vs. non-coverage, benefit exclusions, and benefit limitations such as dollar or duration caps.

<b>CPT Codes</b>	32998, 47382, 50592, 76940
<b>HCPCS Codes</b>	C9751

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## References

1. Chinnaratha MA, Chuang MY, Fraser RJ, et al. Percutaneous thermal ablation for primary hepatocellular carcinoma: A systematic review and meta-analysis. *J Gastroenterol Hepatol.* Feb 2016; 31(2):294-301. PMID 26114968
2. Bertot LC, Sato M, Tateishi R, et al. Mortality and complication rates of percutaneous ablative techniques for the treatment of liver tumors: A systematic review. *Eur Radiol.* Dec 2011; 21(12):2584-2596. PMID 21858539
3. Ong SL, Gravante G, Metcalfe MS, et al. Efficacy and safety of microwave ablation for primary and secondary liver malignancies: A systematic review. *Eur J Gastroenterol Hepatol.* Jun 2009; 21(6):599-605. PMID 19282763
4. Glassberg MB, Ghosh S, Clymer JW, et al. Microwave ablation compared with hepatic resection for the treatment of hepatocellular carcinoma and liver metastases: A systematic review and meta-analysis. *World J Surg Oncol.* Jun 12 2019; 17(1):98. PMID 31182102
5. Cui R, Yu J, Kuang M, et al. Microwave ablation versus other interventions for hepatocellular carcinoma: A systematic review and meta-analysis. *J Cancer Res Ther.* 2020; 16(2):379-386. PMID 32474527
6. Dou Z, Lu F, Ren L, et al. Efficacy and safety of microwave ablation and radiofrequency ablation in the treatment of hepatocellular carcinoma: A systematic review and meta-analysis. *Medicine (Baltimore).* Jul 29 2022; 101(30):e29321. PMID 35905207
7. Patel KR, Menon H, Patel RR, et al. Locoregional Therapies for Hepatocellular Carcinoma: A Systematic Review and Meta-Analysis. *JAMA Netw Open.* Nov 04 2024; 7(11):e2447995. PMID 39602117
8. Seki T, Wakabayashi M, Nakagawa T, et al. Percutaneous microwave coagulation therapy for patients with small hepatocellular carcinoma: comparison with percutaneous ethanol injection therapy. *Cancer.* Apr 15 1999; 85(8):1694-1702. PMID 10223562
9. Shibata T, Iimuro Y, Yamamoto Y, et al. Small hepatocellular carcinoma: comparison of radio-frequency ablation and percutaneous microwave coagulation therapy. *Radiology.* May 2002; 223(2):331-337. PMID 11997534
10. Xu HX, Xie XY, Lu MD, et al. Ultrasound-guided percutaneous thermal ablation of hepatocellular carcinoma using microwave and radiofrequency ablation. *Clin Radiol.* Jan 2004; 59(1):53-61. PMID 14697375

11. Lu MD, Xu HX, Xie XY, et al. Percutaneous microwave and radiofrequency ablation for hepatocellular carcinoma: a retrospective comparative study. *J Gastroenterol*. Nov 2005; 40(11):1054-1060. PMID 16322950
12. Tanaka K, Shimada H, Nagano Y, et al. Outcome after hepatic resection versus combined resection and microwave ablation for multiple bilobar colorectal metastases to the liver. *Surgery*. Feb 2006; 139(2):263-273. PMID 16455336
13. Wang ZL, Liang P, Dong BW, et al. Prognostic factors and recurrence of small hepatocellular carcinoma after hepatic resection or microwave ablation: a retrospective study. *J Gastrointest Surg*. Feb 2008; 12(2):327-337. PMID 17943391
14. Ohmoto K, Yoshioka N, Tomiyama Y, et al. Comparison of therapeutic effects between radiofrequency ablation and percutaneous microwave coagulation therapy for small hepatocellular carcinomas. *J Gastroenterol Hepatol*. Feb 2009; 24(2):223-227. PMID 18823439
15. Yin XY, Xie XY, Lu MD, et al. Percutaneous thermal ablation of medium and large hepatocellular carcinoma: long-term outcome and prognostic factors. *Cancer*. May 01 2009; 115(9):1914-1923. PMID 19241423
16. Kuang M, Xie XY, Huang C, et al. Long-term outcome of percutaneous ablation in very early-stage hepatocellular carcinoma. *J Gastrointest Surg*. Dec 2011; 15(12):2165-2171. PMID 21972056
17. Imura S, Shimada M, Utsunomiya T, et al. Ultrasound-guided microwave coagulation assists anatomical hepatic resection. *Surg Today*. Jan 2012; 42(1):35-40. PMID 22075665
18. Qian GJ, Wang N, Shen Q, et al. Efficacy of microwave versus radiofrequency ablation for treatment of small hepatocellular carcinoma: experimental and clinical studies. *Eur Radiol*. Sep 2012; 22(9):1983-1990. PMID 22544225
19. Chinnaratha MA, Sathananthan D, Pateria P, et al. Predictors of hepatocellular carcinoma recurrence post thermal ablation. *J Gastroenterol Hepatol*. 2013; 28(Suppl 2):66-67. PMID 25563141
20. Ding J, Jing X, Liu J, et al. Comparison of two different thermal techniques for the treatment of hepatocellular carcinoma. *Eur J Radiol*. Sep 2013; 82(9):1379-1384. PMID 23726122
21. Stättner S, Jones RP, Yip VS, et al. Microwave ablation with or without resection for colorectal liver metastases. *Eur J Surg Oncol*. Aug 2013; 39(8):844-849. PMID 23769976
22. Takami Y, Ryu T, Wada Y, et al. Evaluation of intraoperative microwave coagulo-necrotic therapy (MCN) for hepatocellular carcinoma: A single center experience of 719 consecutive cases. *J Hepatobiliary Pancreat Sci*. Mar 2013; 20(3):332-341. PMID 22710886
23. Zhang L, Wang N, Shen Q, et al. Therapeutic efficacy of percutaneous radiofrequency ablation versus microwave ablation for hepatocellular carcinoma. *PLoS One*. 2013; 8(10):e76119. PMID 24146824
24. Abdelaziz A, Elbaz T, Shousha HI, et al. Efficacy and survival analysis of percutaneous radiofrequency versus microwave ablation for hepatocellular carcinoma: An Egyptian multidisciplinary clinic experience. *Surg Endosc*. Dec 2014; 28(12):3429-3434. PMID 24935203
25. Shi J, Sun Q, Wang Y, et al. Comparison of microwave ablation and surgical resection for treatment of hepatocellular carcinomas conforming to Milan criteria. *J Gastroenterol Hepatol*. 2014; 29(7):1500-1507. PMID 24628534

26. Tan K, DU X, Yin J, et al. Microwave tissue coagulation technique in anatomical liver resection. *Biomed Rep.* Mar 2014; 2(2):177-182. PMID 24649092
27. Zhang NN, Cheng XJ, Liu JY. Comparison of high-powered MWA and RFA in treating larger hepatocellular carcinoma. *J Pract Oncol.* 2014; 29:349-356.
28. Abdelaziz AO, Nabeel MM, Elbaz TM, et al. Microwave ablation versus transarterial chemoembolization in large hepatocellular carcinoma: prospective analysis. *Scand J Gastroenterol.* Apr 2015; 50(4):479-484. PMID 25592058
29. Vogl TJ, Farshid P, Naguib NN, et al. Ablation therapy of hepatocellular carcinoma: a comparative study between radiofrequency and microwave ablation. *Abdom Imaging.* Aug 2015; 40(6):1829-1837. PMID 25601438
30. Xu J, Zhao Y. Comparison of percutaneous microwave ablation and laparoscopic resection in the prognosis of liver cancer. *Int J Clin Exp Pathol.* Dec 2015; 8(9):11665-11669. PMID 26617907
31. Potretzke TA, Ziemlewicz TJ, Hinshaw JL, et al. Microwave versus radiofrequency ablation treatment for hepatocellular carcinoma: A comparison of efficacy at a single center. *J Vasc Interv Radiol.* May 2016; 27(5):631-638. PMID 27017124
32. Zhang EL, Yang F, Wu ZB, et al. Therapeutic efficacy of percutaneous microwave coagulation versus liver resection for single hepatocellular carcinoma 3 cm with Child-Pugh A cirrhosis. *Eur J Surg Oncol.* May 2016; 42(5):690-697. PMID 26995115
33. Li W, Zhou X, Huang Z, et al. Short-term and long-term outcomes of laparoscopic hepatectomy, microwave ablation, and open hepatectomy for small hepatocellular carcinoma: a 5-year experience in a single center. *Hepatol Res.* Jun 2017; 47(7):650-657. PMID 27487979
34. Philips P, Scoggins CR, Rostas JK, et al. Safety and advantages of combined resection and microwave ablation in patients with bilobar hepatic malignancies. *Int J Hyperthermia.* Feb 2017; 33(1):43-50. PMID 27405728
35. Ryu T, Takami Y, Wada Y, et al. Oncological outcomes after hepatic resection and/or surgical microwave ablation for liver metastasis from gastric cancer. *Asian J Surg.* Jan 2019; 42(1):100-105. PMID 29254868
36. Song P, Sheng L, Sun Y, et al. The clinical utility and outcomes of microwave ablation for colorectal cancer liver metastases. *Oncotarget.* Aug 01 2017; 8(31):51792-51799. PMID 28881688
37. Xu Y, Shen Q, Wang N, et al. Microwave ablation is as effective as radiofrequency ablation for very-early-stage hepatocellular carcinoma. *Chin J Cancer.* Jan 19 2017; 36(1):14. PMID 28103953
38. Yu J, Yu XL, Han ZY et al. Percutaneous cooled-probe microwave versus radiofrequency ablation in early-stage hepatocellular carcinoma: a phase III randomised controlled trial. *Gut.* Jun 2017; 66(6):1172-1173. PMID 27884919
39. Zhang QB, Zhang XG, Jiang RD, et al. Microwave ablation versus hepatic resection for the treatment of hepatocellular carcinoma and oesophageal variceal bleeding in cirrhotic patients. *Int J Hyperthermia.* May 2017; 33(3):255-262. PMID 27817240
40. Chen ZB, Qin F, Ye Z, et al. Microwave-assisted liver resection vs. clamp crushing liver resection in cirrhosis patients with hepatocellular carcinoma. *Int J Hyperthermia.* Dec 2018; 34(8):1359-1366. PMID 29353503

41. Chong CCN, Lee KF, Chu CM, et al. Microwave ablation provides better survival than liver resection for hepatocellular carcinoma in patients with borderline liver function: application of ALBI score to patient selection. *HPB (Oxford)*. Jun 2018; 20(6):546-554. PMID 29352659
42. Chinnaratha MA, Sathananthan D, Pateria P, et al. High local recurrence of early-stage hepatocellular carcinoma after percutaneous thermal ablation in routine clinical practice. *Eur J Gastroenterol Hepatol*. Mar 2015; 27(3):349-354. PMID 25563141
43. Cillo U, Noaro G, Vitale A, et al. Laparoscopic microwave ablation in patients with hepatocellular carcinoma: A prospective cohort study. *HPB (Oxford)*. Nov 2014; 16(11):979-986. PMID 24750429
44. Correa-Gallego C, Fong Y, Gonan M, et al. A retrospective comparison of microwave ablation vs. radiofrequency ablation for colorectal cancer hepatic metastases. *Ann Surg Oncol*. Dec 2014; 21(13):4278-4283. PMID 24889486
45. Di Vece F, Tombesi P, Ermili F, et al. Coagulation areas produced by cool-tip radiofrequency ablation and microwave ablation using a device to decrease back-heating effects: A prospective pilot study. *Cardiovasc Intervent Radiol*. Jun 2014; 37(3):723-729. PMID 24196263
46. Hompes R, Fieuws S, Aerts R, et al. Results of single-probe microwave ablation of metastatic liver cancer. *Eur J Surg Oncol*. Aug 2010; 36(8):725-730. PMID 20605397
47. Kamal A, Elmoety AAA, Rostom YAM, et al. Percutaneous radiofrequency versus microwave ablation for management of hepatocellular carcinoma: A randomized controlled trial. *J Gastrointest Oncol*. Jun 2019; 10(3):562-571. PMID 31183208
48. Lee KF, Wong J, Hui JW, et al. Long-term outcomes of microwave versus radiofrequency ablation for hepatocellular carcinoma by surgical approach: A retrospective comparative study. *Asian J Surg*. Jul 2017; 40(4):301-308. PMID 26922631
49. Liu Y, Li S, Wan X, et al. Efficacy and safety of thermal ablation in patients with liver metastases. *Eur J Gastroenterol Hepatol*. Apr 2013; 25(4):442-446. PMID 23470267
50. Liu W, Zheng Y, He W, et al. Microwave vs radiofrequency ablation for hepatocellular carcinoma within the Milan criteria: A propensity score analysis. *Aliment Pharmacol Ther*. Sep 2018; 48(6):671-681. PMID 30063081
51. Sakaguchi H, Seki S, Tsuji K, et al. Endoscopic thermal ablation therapies for hepatocellular carcinoma: A multi-center study. *Hepatol Res*. Jan 2009; 39(1):47-52. PMID 18761680
52. Santambrogio R, Chiang J, Barabino M, et al. Comparison of laparoscopic microwave to radiofrequency ablation of small hepatocellular carcinoma ( $\leq 3$  cm). *Ann Surg Oncol*. Jan 2017; 24(1):257-263. PMID 27581608
53. Sever I H, Sucu M, Biyikli E. Radiofrequency and microwave ablation in the treatment of hepatocellular carcinoma. *Iran J Radiol*. 2018;15(3):e62396.
54. Shady W, Petre EN, Do KG, et al. Percutaneous microwave versus radiofrequency ablation of colorectal liver metastases: Ablation with clear margins (A0) provides the best local tumor control. *J Vasc Interv Radiol*. Feb 2018; 29(2):268-275.e1. PMID 29203394
55. Simo KA, Sereika SE, Newton KN, et al. Laparoscopic-assisted microwave ablation for hepatocellular carcinoma: Safety and efficacy in comparison with radiofrequency ablation. *J Surg Oncol*. Dec 2011; 104(7):822-829. PMID 21520094

56. Sparchez Z, Mocan T, Hajjar NA, et al. Percutaneous ultrasound guided radiofrequency and microwave ablation in the treatment of hepatic metastases. A monocentric initial experience. *Med Ultrason.* Aug 31 2019; 21(3):217-224. PMID 31476199

57. Tian W, Kuang M, Lv M, et al. A randomised comparative trial on liver tumors treated with ultrasound-guided percutaneous radiofrequency versus microwave ablation. *Chin J Hepatobiliary Surg* 2014; 20:11922.

58. van Tilborg AA, Scheffer HJ, de Jong MC, et al. MWA versus RFA for perivascular and peribiliary CRLM: A retrospective patient- and lesion-based analysis of two historical cohorts. *Cardiovasc Intervent Radiol.* Oct 2016; 39(10):1438-1446. PMID 27387188

59. Vietti Violi N, Duran R, Guiu B, et al. Efficacy of microwave ablation versus radiofrequency ablation for the treatment of hepatocellular carcinoma in patients with chronic liver disease: a randomised controlled phase 2 trial. *Lancet Gastroenterol Hepatol.* Mar 6 2018; 3(5):317-325. PMID 29503247

60. Yang B, Li Y. A comparative study of laparoscopic microwave ablation with laparoscopic radiofrequency ablation for colorectal liver metastasis. *J BUON.* May-Jun 2017; 22(3):667-672. PMID 28730772

61. Chong CCN, Lee KF, Cheung SYS, et al. Prospective double-blinded randomized controlled trial of Microwave versus RadioFrequency Ablation for hepatocellular carcinoma (McRFA trial). *HPB (Oxford).* Aug 2020; 22(8):1121-1127. PMID 32044268

62. Vogl TJ, Martin SS, Gruber-Rouh T, et al. Comparison of microwave and radiofrequency ablation for the treatment of small- and medium-sized hepatocellular carcinomas in a prospective randomized trial. *Rofo.* May 2024; 196(5):482-490. PMID 38065541

63. Zaitoun MMA, Elsayed SB, Zaitoun NA, et al. Combined therapy with conventional trans-arterial chemoembolization (cTACE) and microwave ablation (MWA) for hepatocellular carcinoma 3-5 cm. *Int J Hyperthermia.* 2021; 38(1):248-256. PMID 33615957

64. Loveman E, Jones J, Clegg AJ, et al. The clinical effectiveness and cost-effectiveness of ablative therapies in the management of liver metastases: systematic review and economic evaluation. *Health Technol Assess.* Jan 2014; 18(7):vii-viii, 1-283. PMID 24484609

65. Bala MM, Riemsma RP, Wolff R, et al. Microwave coagulation for liver metastases. *Cochrane Database Syst Rev.* Oct 13 2013; 10(10):CD010163. PMID 24122576

66. Pathak S, Jones R, Tang JM, et al. Ablative therapies for colorectal liver metastases: a systematic review. *Colorectal Dis.* Sep 2011; 13(9):e252-265. PMID 21689362

67. Mimmo A, Pegoraro F, Rhaiem R, et al. Microwave ablation for colorectal liver metastases: A systematic review and pooled oncological analyses. *Cancers (Basel).* Mar 03 2022; 14(5):1305. PMID 35267612

68. Yuan Z, Wang Y, Zhang J, et al. A meta-analysis of clinical outcomes after radiofrequency ablation and microwave ablation for lung cancer and pulmonary metastases. *J Am Coll Radiol.* Jan 16 2019; 16(3):302-314. PMID 30642784

69. Jiang B, McClure MA, Chen T, et al. Efficacy and safety of thermal ablation of lung malignancies: A Network meta-analysis. *Ann Thorac Med.* Nov 13 2018; 13(4):243-250. PMID 30416597

70. Nelson DB, Tam AL, Mitchell KG, et al. Local recurrence after microwave ablation of lung malignancies: A systematic review. *Ann Thorac Surg.* Dec 7 2018; 107(6):1876-1883. PMID 30508527

71. He W, Hu XD, Wu DF, et al. Ultrasonography-guided percutaneous microwave ablation of peripheral lung cancer. *Clin Imaging*. Jul-Aug 2006; 30(4):234-241. PMID 16814137
72. Wolf FJ, Grand DJ, Machan JT, et al. Microwave ablation of lung malignancies: effectiveness, CT findings, and safety in 50 patients. *Radiology*. Jun 2008; 247(3):871-879. PMID 18372457
73. Vogl TJ, Naguib NN, Gruber-Rouh T, et al. Microwave ablation therapy: clinical utility in treatment of pulmonary metastases. *Radiology*. Nov 2011; 261(2):643-651. PMID 22012906
74. Lu Q, Cao W, Huang L, et al. CT-guided percutaneous microwave ablation of pulmonary malignancies: Results in 69 cases. *World J Surg Oncol*. May 07 2012; 10:80. PMID 22564777
75. Carrafiello G, Mangini M, Fontana F, et al. Microwave ablation of lung tumours: Single-centre preliminary experience. *Radiol Med*. Jan 2014; 119(1):75-82. PMID 24234180
76. Liu H, Steinke K. High-powered percutaneous microwave ablation of stage I medically inoperable non-small cell lung cancer: a preliminary study. *J Med Imaging Radiat Oncol*. Aug 2013; 57(4):466-474. PMID 23870347
77. Vogl TJ, Worst TS, Naguib NN, et al. Factors influencing local tumor control in patients with neoplastic pulmonary nodules treated with microwave ablation: a risk-factor analysis. *AJR Am J Roentgenol*. Mar 2013; 200(3):665-672. PMID 23436860
78. Wei Z, Ye X, Yang X, et al. Microwave ablation in combination with chemotherapy for the treatment of advanced non-small cell lung cancer. *Cardiovasc Intervent Radiol*. Feb 2015; 38(1):135-142. PMID 24809754
79. Yang X, Ye X, Zheng A, et al. Percutaneous microwave ablation of stage I medically inoperable non-small cell lung cancer: clinical evaluation of 47 cases. *J Surg Oncol*. Nov 2014; 110(6):758-763. PMID 24965604
80. Zheng A, Wang X, Yang X, et al. Major complications after lung microwave ablation: a single-center experience on 204 sessions. *Ann Thorac Surg*. Jul 2014; 98(1):243-248. PMID 24793688
81. Acksteiner C, Steinke K. Percutaneous microwave ablation for early-stage non-small cell lung cancer (NSCLC) in the elderly: a promising outlook. *J Med Imaging Radiat Oncol*. Feb 2015; 59(1):82-90. PMID 25335916
82. Wei Z, Ye X, Yang X, et al. Microwave ablation plus chemotherapy improved progression-free survival of advanced non-small cell lung cancer compared to chemotherapy alone. *Med Oncol*. Feb 2015; 32(2):464. PMID 25572816
83. Egashira Y, Singh S, Bandula S, et al. Percutaneous high-energy microwave ablation for the treatment of pulmonary tumors: A retrospective single-center experience. *J Vasc Interv Radiol*. Apr 2016; 27(4):474-479. PMID 26944360
84. Ko WC, Lee YF, Chen YC, et al. CT-guided percutaneous microwave ablation of pulmonary malignant tumors. *J Thorac Dis*. Oct 2016; 8(Suppl 9):S659-S665. PMID 28066666
85. Li B, Wang Z, Zhou K, et al. Safety and feasibility within 24 h of discharge in patients with inoperable malignant lung nodules after percutaneous microwave ablation. *J Cancer Res Ther*. Dec 2016; 12(Supplement):C171-C175. PMID 28230012
86. Macchi M, Belfiore MP, Floridi C, et al. Radiofrequency versus microwave ablation for treatment of the lung tumours: LUMIRA (lung microwave radiofrequency) randomized trial. *Med Oncol*. Apr 19 2017; 34(5):96. PMID 28417355

87. Maxwell AW, Healey TT, Dupuy DE. Percutaneous thermal ablation for small-cell lung cancer: Initial experience with ten tumors in nine patients. *J Vasc Interv Radiol.* Dec 2016; 27(12):1815-1821. PMID 27776982

88. Vogl TJ, Eckert R, Naguib NN, et al. Thermal ablation of colorectal lung metastases: Retrospective comparison among laser-induced thermotherapy, radiofrequency ablation, and microwave ablation. *AJR Am J Roentgenol.* Dec 2016; 207(6):1340-1349. PMID 27680945

89. Zheng A, Ye X, Yang X, et al. Local efficacy and survival after microwave ablation of lung tumors: A retrospective study in 183 patients. *J Vasc Interv Radiol.* Dec 2016; 27(12):1806-1814. PMID 27789077

90. Healey TT, March BT, Baird G, et al. Microwave ablation for lung neoplasms: A retrospective analysis of long-term results. *J Vasc Interv Radiol.* Feb 2017; 28(2):206-211. PMID 27993505

91. Nour-Eldin NA, Exner S, Al-Subhi M, et al. 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). *Int J Hyperthermia.* Nov 2017; 33(7):820-829. PMID 28540791

92. Wei Z, Ye X, Yang X, et al. Advanced non small cell lung cancer: Response to microwave ablation and EGFR Status. *Eur Radiol.* Apr 2017; 27(4):1685-1694. PMID 27436020

93. Yang X, Ye X, Huang G, et al. Repeated percutaneous microwave ablation for local recurrence of inoperable Stage I nonsmall cell lung cancer. *J Cancer Res Ther.* 2017; 13(4):683-688. PMID 28901314

94. Zhong L, Sun S, Shi J, et al. Clinical analysis on 113 patients with lung cancer treated by percutaneous CT-guided microwave ablation. *J Thorac Dis.* Mar 2017; 9(3):590-597. PMID 28449467

95. Uhlig J, Strauss A, Rucker G, et al. Partial nephrectomy versus ablative techniques for small renal masses: A systematic review and network meta-analysis. *Eur Radiol.* Mar 2019; 29(3):1293-1307. PMID 30255245

96. Guan W, Bai J, Liu J, et al. Microwave ablation versus partial nephrectomy for small renal tumors: Intermediate-term results. *J Surg Oncol.* Sep 1 2012; 106(3):316-321. PMID 22488716

97. Katsanos K, Mailli L, Krokidis M, et al. Systematic review and meta-analysis of thermal ablation versus surgical nephrectomy for small renal tumours. *Cardiovasc Intervent Radiol.* Apr 2014; 37(2):427-437. PMID 24482030

98. Martin J, Athreya S. Meta-analysis of cryoablation versus microwave ablation for small renal masses: Is there a difference in outcome? *Diagn Interv Radiol.* Nov-Dec 2013; 19(6):501-507. PMID 24084196

99. McClure T, Lansing A, Ferko N, et al. A Comparison of Microwave Ablation and Cryoablation for the Treatment of Renal Cell Carcinoma: A Systematic Literature Review and Meta-analysis. *Urology.* Oct 2023; 180:1-8. PMID 37331485

100. Guo J, Arellano RS. Percutaneous microwave ablation of stage T1a renal cell carcinoma: Intermediate results on safety, technical feasibility and clinical outcomes of 119 tumors. *AJR Am J Roentgenol.* Jan 2021; 216(1):117-124. PMID 32603227

101. Aarts BM, Prevoo W, Meier MAJ, et al. Percutaneous microwave ablation of histologically proven T1 renal cell carcinoma. *Cardiovasc Intervent Radiol.* Jul 2020; 43(7):1025-1033. PMID 32052093
102. Zhao Z, Wu F. Minimally-invasive thermal ablation of early-stage breast cancer: a systemic review. *Eur J Surg Oncol.* Dec 2010; 36(12):1149-1155. PMID 20889281
103. Zhou W, Zha X, Liu X, et al. US-guided percutaneous microwave coagulation of small breast cancers: a clinical study. *Radiology.* May 2012; 263(2):364-373. PMID 22438362
104. Keane MG, Bramis K, Pereira SP, et al. Systematic review of novel ablative methods in locally advanced pancreatic cancer. *World J Gastroenterol.* Mar 07 2014; 20(9):2267-2278. PMID 24605026
105. Cui T, Jin C, Jiao D, et al. Safety and efficacy of microwave ablation for benign thyroid nodules and papillary thyroid microcarcinomas: A systematic review and meta-analysis. *Eur J Radiol.* Sep 2019; 118:58-64. PMID 31439259
106. Wu X, Jiang Z, Liu J, et al. The efficacy and safety of microwave ablation versus conventional open surgery for the treatment of papillary thyroid microcarcinoma: a systematic review and meta-analysis. *Gland Surg.* Jun 2022; 11(6):1003-1014. PMID 35800741
107. Chen S, Dou J, Cang Y, et al. Microwave versus Radiofrequency Ablation in Treating Predominantly Solid Benign Thyroid Nodules: A Randomized Controlled Trial. *Radiology.* Oct 2024; 313(1):e232162. PMID 39436295
108. Li X, Fan W, Zhang L, et al. CT-guided percutaneous microwave ablation of adrenal malignant carcinoma: preliminary results. *Cancer.* Nov 15 2011; 117(22):5182-5188. PMID 21523760
109. Pusceddu C, Sotgia B, Fele RM, et al. Treatment of bone metastases with microwave thermal ablation. *J Vasc Interv Radiol.* Feb 2013; 24(2):229-233. PMID 23200605
110. Yu MA, Liang P, Yu XL, et al. Sonography-guided percutaneous microwave ablation of intrahepatic primary cholangiocarcinoma. *Eur J Radiol.* Nov 2011; 80(2):548-552. PMID 21300500
111. Egorov AV, Vasilyev IA, Musayev GH, et al. The role of microwave ablation in management of functioning pancreatic neuroendocrine tumors. *Gland Surg.* Dec 2019; 8(6):66-772. PMID 32042685
112. Howington J, Souter LH, Arenberg D, et al. Management of Patients With Early-Stage Non-Small Cell Lung Cancer: An American College of chest Physicians Clinical Practice Guideline. *Chest.* Sep 2025; 168(3):810-827. PMID 40562304
113. Campbell SC, Clark PE, Chang SS, et al. Renal Mass and Localized Renal Cancer: Evaluation, Management, and Follow-Up: AUA Guideline: Part I. *J Urol.* Aug 2021; 206(2):199-208. PMID 34115547
114. National Comprehensive Cancer Network (NCCN). NCCN Clinical Practice Guidelines in Oncology: Hepatocellular Carcinoma. Version 2.2025. Available at <<https://www.nccn.org>> (accessed November 10, 2025).
115. National Comprehensive Cancer Network (NCCN). NCCN Clinical Practice Guidelines in Oncology: Non-Small Cell Lung Cancer. Version 1.2026. Available at <<https://www.nccn.org>> (accessed November 10, 2025).

116. National Comprehensive Cancer Network (NCCN). NCCN Clinical Practice Guidelines in Oncology: Small Cell Lung Cancer. Version 2.2026. Available at <<https://www.nccn.org>> (accessed November 10, 2025).
117. National Comprehensive Cancer Network (NCCN). NCCN Clinical Practice Guidelines in Oncology Neuroendocrine and Adrenal Tumors. Version 3.2025. Available at <<https://www.nccn.org>> (accessed November 10, 2025).
118. National Comprehensive Cancer Network (NCCN). NCCN Clinical Practice Guidelines in Oncology: Kidney Cancer. Version 1.2026. Available at <<https://www.nccn.org>> (accessed August 31, 2025).
119. National Comprehensive Cancer Network (NCCN). NCCN Clinical Practice Guidelines in Oncology: Breast Cancer. Version 5.2025. Available at <<https://www.nccn.org>> (accessed November 10, 2025).
120. National Comprehensive Cancer Network (NCCN). NCCN Clinical Practice Guidelines in Oncology: Thyroid Carcinoma. Version 1.2025. Available at <<https://www.nccn.org>> (accessed August 27, 2025).
121. National Institute for Health and Care Excellence (NICE). Microwave ablation for treating liver metastases [IPG553]. 2016. Available at <<https://www.nice.org.uk>> (accessed September 1, 2025).
122. National Institute for Health and Care Excellence (NICE). Microwave Ablation of Hepatocellular Carcinoma [IPG214]. 2007. Available at <<https://www.nice.org.uk>> (accessed September 2, 2025).
123. National Institute for Health and Care Excellence (NICE). Microwave ablation for treating primary or metastatic cancer in the lung [IPG716]. 2022. Available at <<https://www.nice.org.uk>> (accessed December 20, 2024).
124. Ceppa EP, Collings AT, Abdalla M, et al. SAGES/AHPBA guidelines for the use of microwave and radiofrequency liver ablation for the surgical treatment of hepatocellular carcinoma or colorectal liver metastases less than 5 cm. *Surg Endosc*. Dec 2023; 37(12):8991-9000. PMID 37957297

## **Centers for Medicare and Medicaid Services (CMS)**

The information contained in this section is for informational purposes only. HCSC makes no representation as to the accuracy of this information. It is not to be used for claims adjudication for HCSC Plans.

The Centers for Medicare and Medicaid Services (CMS) does not have a national Medicare coverage position. Coverage may be subject to local carrier discretion.

A national coverage position for Medicare may have been developed since this medical policy document was written. See Medicare's National Coverage at <<https://www.cms.hhs.gov>>.

## **Policy History/Revision**

Date	Description of Change
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12/15/2025	Document updated. Coverage unchanged. Added references 7, 107, 112, and 124.
02/01/2025	Document updated with literature review. The following change was made in coverage: 1) Existing criteria for microwave ablation of primary or metastatic lung tumors modified to state, "The size of each tumor(s) to be ablated is $\leq 3$ cm". 2) Removed microwave ablation of more than a single primary or metastatic tumor in the lung is considered experimental, investigational, and/or unproven. Added references 61, 98, 118; others updated/removed.
01/01/2024	Reviewed. No changes.
01/01/2023	Document updated with literature review. Coverage unchanged. The following references were added/updated: 6, 41-57, 59, 61, 65, 97, 108, 113-118, and 123.
02/01/2022	Reviewed. No changes.
08/01/2021	Document updated with literature review. The following change was made to Coverage: For the first coverage statement, in the second bullet, changed "A single tumor of $\leq 5$ cm or up to 3 nodules $<3$ cm each" to "A single tumor of $\leq 5$ cm or up to 3 nodules $\leq 3$ cm each". Added/updated the following references: 7-8, 10, 12-29, 31-37, 39-41, 43, 50-64, 66-74, 78-79, 85, 89-94, 97, and 99.
01/15/2021	Reviewed. No changes.
07/15/2020	Document updated with literature review. The following changes were made to Coverage: 1) Added medically necessary coverage for primary or metastatic hepatic tumors under the following conditions: The tumor is unresectable due to location of lesion[s] and/or comorbid conditions; or a single tumor of $\leq 5$ cm or up to 3 nodules $<3$ cm each; 2) Added medically necessary coverage for primary or metastatic lung tumors under the following conditions: The tumor is unresectable due to location of lesion and/or comorbid conditions; or a single tumor of $\leq 3$ cm; and 3) Added "Microwave ablation of more than a single primary or metastatic tumor in the lung is considered experimental, investigational, and/or unproven."; 4) Added "Microwave ablation of primary or metastatic tumors other than liver or lung is considered experimental, investigational, and/or unproven." References 6, 8-10, 15-26, 28, and 32-35 were added; some references removed.
04/15/2018	New medical document. Microwave ablation of primary and metastatic tumors is considered experimental, investigational and/or unproven.