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REVIEW

Percutaneous microwave ablation *vs* radiofrequency ablation in the treatment of hepatocellular carcinoma

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Abstract

Hepatocellular cancer ranks fifth among cancers and is related to chronic viral hepatitis, alcohol abuse, steatohepatitis and liver autoimmunity. Surgical resection and orthotopic liver transplantation have curative potential, but fewer than 20% of patients are suitable candidates. Interventional treatments are offered to the vast majority of patients. Radiofrequency (RFA) and microwave ablation (MWA) are among the therapeutic modalities, with similar indications which include the presence of up to three lesions, smaller than 3 cm in size, and the absence of extrahepatic disease. The therapeutic effect of both methods relies on thermal injury, but MWA uses an electromagnetic field as opposed to electrical current used in RFA. Unlike MWA, the effect of RFA is partially limited by the heat-sink effect and increased impedance of the ablated tissue. Compared with RFA, MWA attains a more predictable ablation zone, permits simultaneous treatment of multiple lesions, and achieves larger coagulation volumes in a shorter procedural time. Major complications of both methods are comparable and infrequent (approximately 2%-3%), and they include haemorrhage, infection/abscess, visceral organ injury, liver failure, and pneumothorax. RFA may incur the additional complication of skin burns. Nevertheless, there is no compelling evidence for differences in clinical outcomes, including local recurrence rates and survival.

Key words: Microwave; Radiofrequency; Ablation; Hepatocellular carcinoma; Percutaneous

Core tip: Hepatocellular carcinoma (HCC) is a common neoplasia with high morbidity and mortality. Nowadays, technologic progress has led to several diagnostic and therapeutic challenges regarding HCC, including the optimal use of percutaneous ablation methods, defining their indications and assessing the survival impact. Both radiofrequency and microwave ablation are widely used with their respective advantages and may both offer palliation or cure in the context of a multifaceted treatment approach.

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EPIDEMIOLOGY OF HEPATOCELLULAR CARCINOMA

Hepatocellular carcinoma (HCC) is the most common primary liver neoplasia and a protean disease with a poor prognosis. Its incidence is estimated to range from 500000 to 1000000 cases annually, ranking it fifth across cancers worldwide[1] and third as cause of death from neoplasia[2]. HCC is more prevalent in Asia due to hepatitis B virus (HBV) infection endemicity and among males aged between 30 and 50 years[3]. According to National Comprehensive Cancer Network, patients at risk for HCC are those with cirrhosis related to HBV, HCV, alcohol abuse, hereditary haemochromatosis, non-alcoholic fatty liver disease, stage 4 primary biliary cirrhosis, alpha 1 antitrypsin deficiency, or exposure to aflatoxins. The incidence of HCC has increased in the United States from 1.6 to 4.9 cases per 100000[4], and this increase is expected to continue. Plausible reasons include the effects of the HCV epidemic as well as the rise in Non-Alcoholic Steatohepatitis-associated HCC cases[4].

DIAGNOSIS AND SURVEILLANCE

Imaging is important at all stages of diagnosis, therapy and follow-up of patients with HCC. The diagnostic modalities used in the diagnosis, treatment planning, management and follow-up of HCC are ultrasonography (US), computed tomography (CT) scanning and magnetic resonance imaging (MRI)[5]. The European Association for the Study of the Liver (EASL) and the American Association for the Study of Liver Disease suggest US as the preferred modality for bi-annual surveillance of patients at high risk of HCC[6].

The most characteristic imaging findings of HCC on contrast-enhanced CT and MRI studies are arterial enhancement, contrast washout and pseudocapsule bright enhancement on portal, venous and delayed phase[7]. Heterogeneity, central necrosis and abnormal internal vessels are characteristic findings of large HCCs[8].

The prognosis and treatment decisions of solid tumours are generally related to tumour stage. However, prognosis for HCC patients also depends on the underlying liver function. Currently, the Barcelona Clinic Liver Cancer (BCLC) staging system[9] is widely used in clinical practice and in clinical trials. It is a staging system that also assigns treatment based on tumour stage, liver function, performance status, and treatment intent[10].

Since most HCCs develop in the setting of chronic liver disease, the risk of death involves tumour and non-tumour related factors. An HCC diagnosed as symptomatic disease has a disappointing 5-year survival of 0% to 10%[11], as opposed to early detection of small HCCs by surveillance which may be amenable to cure. The best case scenario is for a malignant nodule to be found before reaching 2 cm in size. It is crucial to diagnose HCC at an early stage, given that major advances are unlikely to emerge from treating late stage disease.

STANDARD TREATMENT

HCC treatment has a short time window before end-organ liver dysfunction leads to increased complications rate and mortality. In past years, diagnosis of HCC was made at advanced stage, with symptomatic disease and various extent of liver function compromise. As a consequence, no treatment (whether surgical resection or systemic chemotherapy) provided significant curative potential or the substantial capacity to prolong survival and the associated morbidity. Owing to the surveillance guidelines currently in place, early detection is now common, liver function is adequately preserved, symptoms are absent and several treatment options are feasible[12].

The standard treatment options of HCC consist of surgical resection, orthotopic liver transplantation, ablation, transarterial therapies (chemoembolization or radiotherapy) and chemotherapy and notably targeted molecular therapies.

Therapies with curative potential include hepatectomy, liver transplantation and percutaneous thermal ablation. The remaining options are mostly palliative, with a non-curative intent but with a positive impact on survival. For patients with solitary HCC or early multifocal disease and decompensated cirrhosis, the optimal choice is liver transplantation[13,14]. The Milan criteria applied in liver transplantation require a solitary lesion < 5 cm or up to three lesions < 3 cm[15].

Surgical resection may be warranted for patients that either do not have cirrhosis or have cirrhosis with residual liver function, normal bilirubin and hepatic vein pressure gradient < 10 mmHg. Five-year disease-free survival estimates exceeding 50% have been described for resection and liver transplantation[16,17].

Systemic chemotherapy has limited activity and is outweighed by frequent toxicity and lack of significant survival benefit[18]. Molecular targeted approaches include sorafenib, a multikinase inhibitor which has prolonged overall survival rates over placebo in a recent study[1]. Expert opinion is mandatory for the selection of candidates and their assignment to different treatments.

INTERVENTIONAL TREATMENTS

Few patients (less than 20%) are amenable to

resection and transplantation due to difficulties related to size, location and number of tumours, vascular and extrahepatic involvement and functional hepatic reserve due to cirrhosis. The ultimate treatment choice for the remaining 80% is interventional therapies. In patients with early- or intermediate-stage disease, interventional therapies could control disease progression until definitive therapy or increase the patient's eligibility for a curative treatment. In advanced disease, the main aim of treatment is to control symptoms, prolong survival, and improve quality of life[19]. Available interventional therapies include direct ablation, transarterial embolization or chemoembolization (TACE), drug-eluting beads and transarterial radioembolization.

Ablation involves the use of chemicals or thermal energy delivered directly to the tumour to achieve necrosis. The types of thermal ablation available are hyperthermic [radiofrequency ablation (RFA), microwave ablation (MWA), and laser ablation] and hypothermic (cryoablation).

Percutaneous thermal ablation, either RFA or MWA, is considered the optimal locoregional treatment choice for focal unresectable HCC of early stage, but its use has been proposed for several other clinical scenarios such as the reduction of the tumour burden and as a bridge to transplantation[20,21].

RFA *VS* MWA: PRINCIPLES AND APPLICATION

In RFA, an electrical current in the radiofrequency range is delivered through a needle electrode under imaging or surgical guidance, producing heat-based thermal cytotoxicity[22]. A complete electrical circuit is created and completed through grounding pads attached to the thighs or back. Temperatures range between 60 ℃ to 100 ℃ and result in almost instant coagulation necrosis[23]. These temperatures are observed near the electrode resulting in a small area of necrosis, with the larger portion of the final ablation zone being attributed to thermal conduction into more peripheral areas around the electrode[24]. Tissue boiling and charring act as electrical insulators and limit the effect of RFA through increased impedance; hence, the important tissue properties for RFA are electrical and thermal conductivity[24]. Radiofrequency ablation is also moderated by the heat-sink effect, a phenomenon that occurs when thermal energy is dispersed from the target lesion due to blood flow in the vessels adjacent to it[25]. Consequently, the shape and size of the ablation zone may be unpredictable and the efficacy of RFA may be restricted as multiple sessions are necessary for complete tumour eradication[26]. In order to attain larger necrosis volumes, numerous innovative electrode modifications are applied, such as expandable electrodes or internally cooled electrodes as well as multiple electrodes. The result is ablation zones of lesions up to 2-5 cm. A margin of 0.5-1.0 cm of healthy liver tissue is mandatory to be ablated in order to secure treatment of the peripheral tumour, including any microscopic extension beyond the radiographically visible margins[27].

RFA is more effective in HCC than in liver metastases due to the so-called "oven effect". Owing to cirrhosis and its pseudocapsule, the surrounding fibrotic liver of HCC functions as an oven, and higher peak temperatures with prolongation of the duration of cytotoxic temperatures are achieved within the tumour[28].

MWA uses electromagnetic energy (up to 2 cm surrounding the antenna); in the absence of current flow, the electromagnetic field creates a rapid and homogeneous heating of tissue and subsequently coagulation necrosis. The best heating effect is achieved in tissues with a high content of water and the worst is observed in fat[24]. Another mechanism of MWA function is ionic polarization with conversion of kinetic energy into heat. A more homogeneous, larger ablation zone that is easily predicted is feasible and the heat-sink effect is attenuated[29,30]. One reason for the reduced heat-sink effect may be the faster heating and higher temperatures provided by microwave energy. Notably, the ablation heat beyond the microwave field is conducted in a similar way as in RFA with the heat-sink effect still present[31]. Another consequence of the different production of heat seen with MWA is that the time needed for ablation is less in MWA than that required in RFA.

MWA equipment consists of a generator and a monopolar electrode connected to the generator that is introduced to the lesion through an access needle, applying a coaxial technique[32]. The devices use frequencies higher than 900 MHz (in the United State 915 MHz and 2.54 GHz). Microwaves of 915 MHz can penetrate more deeply than 2450 MHz microwaves[33]; thus, the low frequency MWA may theoretically result in larger ablation zones. To prevent skin burns at the insertion site, internal circulation of fluid or carbon dioxide through the needle shaft is applied achieving continuous cooling[34]. As opposed to RFA, MWA permits the simultaneous treatment of multiple lesions with multiple electrodes that can produce larger ablation volumes. Each microwave application can produce a discrete focus of approximately 1.6 cm of necrosis for 120 s at 60 W[32]. In contrast to RFA, grounding pads are not needed because the completion of an electrical circuit is not required. Therefore, the presence of metallic materials like surgical clips or a pacemaker does not constitute a contraindication.

These advantages of MWA are also its flaws. The higher thermal efficiency of MWA can easily injure the adjacent critical tissues because the tissue surrounding the antenna may be ablated rapidly. Simultaneous deployment of multiple probes of microwave antennae can significantly increase the diameter of the ablation zone, whereas recession of the coagulation zone for the inter-antenna distance may not entirely cover the

Table 1 Comparison of radiofrequency over microwave ablation methods

RFA	MWA
Electric current	Electromagnetic energy
Grounding pads (risk of burns due to ground pads)	No grounding pads (no risk of burns)
Tissue charring and boiling cause increase of impedance that reduce electrical and thermal conductivity	Rapid and homogeneous heating + ionic polarization
Lower intratumoral temperatures	Higher intratumoral temperatures
More peri-procedural pain	Less peri-procedural pain
Unpredictable ablation zone	More predictable ablation zone
Heat-sink effect	Less susceptible to heat-sink effect
Single lesion can be treated	Simultaneous treatment of multiple lesions
More procedural time	Shorter procedural time
Less ablation volume	Larger ablation volume
Similar complications and complication rate	
Surgical clips or pacemaker are contraindications	Surgical clips or a pacemaker not a contraindication

RFA: Radiofrequency; MWA: Microwave ablation.

large tumour and result in incomplete ablation[35]. The summary comparison of the two methods is seen in Table 1.

EVOLUTION OF ELECTRODES

Since the most important disadvantage of RFA is that the temperature falls quickly as the distance from the electrode tip increases due to increased tissue impedance. Research has focused to the development of new electrodes that would overcome this limitation[36]. The evolution in RFA ablation devices and technologies has improved the results of RFA in terms of achieving a larger necrotic burden. Expandable and multitined electrodes were initially introduced which are now widely used and are adequately studied with satisfactory results. Attempts to increase ablated lesion sizes have involved the use of perfused electrodes[37], expandable-wet electrodes[38], cooled-wet electrodes[39,40] and saline-enhanced bipolar single electrodes[41].

Another technological progress in electrodes is the use of bipolar and multipolar electrodes rather than the monopolar type. In monopolar mode, the current travels outward toward a dispersive pad and the heat is diverted from the ablation site in all directions. A bipolar electrode does not require a grounding pad since both electrodes are located inside one probe and the alternative current circuit is concentrated between the probes within the target lesion only[42,43]. Additionally, one electrode is thermally shielded by the opposing electrode, an effect that results in active heating of the tissue in its proximity[44]. The heating effect is trapped between the two electrodes, producing higher temperatures and larger ablation lesions**.** Haemmerich *et al*[45] demonstrated that bipolar modes showed an improved electric potential profile and temperature distribution as compared with the monopolar mode. Multipolar mode is based on simultaneous insertion of multiple, internally cooled bipolar probes[46]. In bipolar mode, the two parallel probes should be inserted and the lesion must be between them; this is sometimes technically difficult and can cause probe insertion-related complications. Moreover, there is no way of controlling the heat generated in the vicinity of the probes. Of note, in terms of technical effectiveness, Seror *et al*[47] showed that multipolar ablation of small HCC lesions improves the rate of complete necrosis during pathologic examination compared with monopolar techniques.

The introduction of MRI-compatible devices providing real-time control of tissue temperature proved a useful tool and signalled an evolution in ablation techniques[48]. MRI is the only imaging modality that can provide quantitative and high spatial resolution real-time monitoring of rate-of-change temperature (and hence thermal dose) in the heated area, determining the cut-off point (or endpoint) for the application of power.

Microwave ablation is a highly effective modality, with its most important limitation being the heating of antenna shaft that results in reduced power delivery[49-52]. Some manufacturers have introduced internal or external water-cooling systems of the antenna, at the expense of increased shaft diameter and complexity[53,54]. A microwave ablation system has recently been introduced that can provide high power (140 W). It uses a small diameter antenna (17 gauge) as it incorporates a novel gas-cooling mechanism[55].

CLINICAL STUDIES OF RFA IN HCC

RFA is indicated in patients with early HCC, as staged by BCLC, who are not eligible for surgical treatment due to comorbidities, and in patients who refuse resection or when there is a need to preserve liver function[56]. The ablation success rate for lesions smaller than 2 cm reaches 90% with a local recurrence rate of 1%[57]. For this reason, RFA is considered effective for tumours < 3 cm; combined locoregional treatment should be considered for lesions > 3 cm[58]. RFA combined with TACE is recommended for tumours larger than 3 cm in diameter, but RFA may also be used for four or more nodules where applicable[59].

The main contraindications of RFA are severe

bleeding diathesis (platelet count less than 50000/μL), haemostatic compromise, decompensated ascites, jaundice and presence of metallic devices such as pacemakers. Relative contraindications are lesions near the gastrointestinal tract, biliary system and heart. RFA should also be avoided for tumours within 1 cm proximity to the hepatic portal tract. Major complications include liver failure, bleeding, infection, abscesses, intercostal nerve injury, organ injury, tumour lysis syndrome and pneumothorax[60]. In a multicentre study of RFA for malignant liver tumours in 2320 patients, the rate of major complications reached 2.2%[61].

The technical effectiveness of RFA is evaluated with the use of contrast-enhanced CT or MRI. A tumour is considered successfully ablated by the lack of any enhanced regions during the arterial phase and the presence of at least a 0.5 cm margin of apparently normal surrounding hepatic tissue during the portal phase. An incomplete safety margin is shown to be an independent risk factor for local tumour progression on multivariate analysis. Nodular peripheral enhancement is suggestive of tumour viability[59].

Local recurrence rates of small HCCs after RFA were reported within the range of 1.3%-12% at 1 year, 1.7%-24% at 2 years, and 3.2% at both 5 and 10 years. Factors correlated with local recurrence included larger tumour size (diameter > 2 cm or > 3 cm), tumour without encapsulation, poorly-differentiated HCC, subcapsular location, an ablative margin of less than 1 cm and a nearby vessel that could induce a heat-sink effect. This increase in local recurrence is presumably due to unexplored peri-tumoral satellite nodules, insufficient safety margin, or incomplete ablation. Owing to underlying advanced liver disease in the presence of HCC, additional new recurrence is very common in patients with HCC[62].

Complete tumour necrosis in early stage HCC is reported to be 80%-95% and 5%-year survival 33%-57%[63]. According to some series, percutaneous RFA show 5-year survival rates of 48%-55% in early stage HCC, and 51%-64% in Child-Pugh class A cirrhosis[64]. Patients with resectable tumours may have prolonged survival over those with non-resectable tumours; this is likely a reflection of the better physiologic state of patients deemed eligible for surgery[65].

HCC appears most commonly in patients with cirrhosis. Since these patients are not usually considered ideal candidates for surgery, it is difficult to conduct a study comparing RFA against surgery in such patients. Most reports of percutaneous RFA for HCC are single-centre retrospective studies conducted among patients not eligible for resection. Resection remains the gold standard therapy in early stage HCC. The few published studies that compared RFA to resection showed no benefit in survival rates (overall or disease-free): 4-year overall survival of 67.9% for ablation *vs* 64% for surgery[66]. Huang *et al*[67] applied the Milan criteria (no more than one HCC of 5 cm or smaller, or up to 3 HCCs measuring 3 cm or smaller) and patients were randomized to receive RFA or surgery. Significant differences were reported: 4-year and 5-year survival rates of 66% and 55% respectively for ablation *vs* 83% and 76% for surgery. Overall, recurrence was more frequent in the group of patients that were ablated. The limitations of this study lay in more patients being lost in follow-up in the surgery group[23].

CLINICAL STUDIES OF MWA IN HCC

Indications and contraindications for MWA are the same as those for RFA, apart from the size of a lesion that can be ablated; according to most studies, MWA can treat 5-8 cm tumours[68]. Furthermore, MWA allows simultaneous ablation of multiple tumours or even combined resection and ablation. In a multicentre effort that gathered data for patients treated with MWA for tumours of any origin, the advantages included the short total time of microwave application for each lesion (median: 4 min/lesion) and the fewer microwave applications for each ablated lesion (> 50% had one application and > 75% two applications). Of the 140 patients analysed, 114 (81.4%) patients received microwave alone, and 26 (18.6%) were treated with microwave combined with resection. Forty per cent of patients were treated with microwave for multiple tumours[31].

Major complications include bile duct stenosis, bleeding, haemothorax or intrahepatic haematoma, peritoneal haemorrhage, liver abscess, colon perforation and tumour seeding[68]. In another multicentre study, 736 patients with hepatic lesions underwent MWA; the reported rate of major complications was 2.9%. MWA was not proven to increase the risk of damage of vascular structures and/or bleeding. Minor complications included pain, post-ablation syndrome, and asymptomatic pleural effusions, which are usually self-limiting and do not require any further treatment. With the peri-procedural mortality rate being reported to be as low as < 0.01%, the safety of MWA was established[69].

MWA shares a high rate of local recurrence in HCC with all other ablation modalities. Lee *et al*[70] studied surgical MWA in tumours of 2-6 cm in diameter. All early postoperative CT imaging showed no residual lesions; however, on follow-up, 42% of patients experienced local tumour progression. As Lee *et al*[70] noted, high local tumour progression is a drawback of MWA and can be attributed to the use of a large applicator (5 mm in diameter), which increases the risk of tumour puncture and subsequent tumour seeding.

Although MWA is a new method and the cumulative reported experience is limited, there is growing interest in this modality as a treatment choice of HCC that can yield promising survival results[71,72]. The reported 1-year and 5-year survival estimates were 92.7% and 56.7%, respectively[73]. A recent multicentre study from China documented that 1007 patients with primary liver cancer treated by MWA achieved 1-year and 5-year

Table 2 Comparison of clinical outcomes across published series of hepatocellular carcinoma patients for microwave ablation over radiofrequency

Ref.	Method	Guidance	Patients	Lesions	Mean age	Time	Size in cm	Complete ablation (%)	Local recurrence (%)	Overall survival					
										1 yr (%)	2 yr (%)	3 yr (%)	4 yr (%)	5 yr (%)	Median (mo)
Shibata *et al*[50]	MWA	Percutaneous	36	46	62.5	-	< 4	89	17.4	-	-	-	-	-	-
	RFA	Percutaneous	36	48	63.6	-	< 4	96	8.3	-	-	-	-	-	-
Xu *et al*[84]	MWA	Percutaneous	54	112	53.4	-	2.5 ± 1.1	94.6	7.1	-	-	-	-	-	-
	RFA	Percutaneous	43	78	53.4	-	2.6 ± 1.4	89.7	12.8	-	-	-	-	-	-
Simo *et al*[85]	MWA	Laparoscopic, US	13	15	59	8-10 min	2.31	-	-	-	-	-	-	-	7
	RFA	Laparoscopic, US	22	27	59	10-12 min	2.53	-	-	-	-	-	-	-	19
Lu *et al*[78]	MWA	Percutaneous, US	49	98	50.1	5 min	3 (25/49)	94.9	11.8	81.6	61.2	50.5	36.8	-	32.5
	RFA	Percutaneous, US	53	72	54.5	10 min	3 (32/53)	93.1	20.9	71.7	47.2	37.6	24.2		27.1
Qian *et al*[63]	MWA	Percutaneous, US	22	22	52	-	4.8	95.5	18	-	-	-	-	-	-
	RFA	Percutaneous, US	20	20	56	-	3.5	95	15	-	-	-	-	-	-
Zhang *et al*[86]	MWA	Percutaneous, US	77	105	54	8 min	< 3 (36), 3.1 to 5 (41)	86.7	10.5	92.2	-	51.7	-	38.5	-
	RFA	Percutaneous, US	78	97	54	6-20 min	< 3 (47), 3.1 to 5 (31)	83.4	11.8	91	-	64.1	-	41.3	-
Abdelaziz *et al*[79]	MWA	Percutaneous	66	-	53.5	-	2.9 ± 0.97	96.1	3.9	96.4	62	-	-	-	-
	RFA	Percutaneous	45	-	56.8	-	2.95 ± 1.03	94.2	13.5	67.6	47.4	-	-	-	-
Ding *et al*[81]	MWA	Percutaneous	85	98	59	10	< 3	98.5	10.9	98.7	92.3	82.7	77.8	-	45.34
	RFA	Percutaneous	113	131	58.6	12	< 3	99	5.2	98	90.7	77.6	77.6	-	52.99
Ohmoto *et al*[80]	MWA	Percutaneous	49	56	64		< 2		19	89	70	49	39	-	-
	RFA	Percutaneous	34	37	67		< 2		9	100	83	70	70	-	-

MWA: Microwave ablation; RFA: Radiofrequency; US: Ultrasonography.

survival rates of 91.2%, and 59.8%, respectively[72,74]. For larger tumours, (> 5 cm) the reported 5-year survival rates ranged from 29% to 68.6%.

COMPARISON OF MWA *VS* RFA IN HCC

Obvious advantages of MWA over RFA include the capacity to heat charred tissues without increasing impedance and lower intratumoral temperature, as well as the lack of grounding pads that can cause skin burns. In addition, microwaves in animal studies seem to achieve larger ablation zones and faster ablation times[34], thereby allowing tumours to be treated with fewer applicator insertions compared to RFA[70]. The effect of MWA on perivascular tumours is also better because of the attenuated heat-sink effect[75]; consequently, microwave ablation should be preferred for tumours near the hepatic veins and inferior vena cava.

RFA appears to be effective for lesions up to 3 cm distant from the vessels due to the heat-sink effect (efficacy: 97% and 5-year survival: 68%)[76], while MWA seems to overcome size limitation of RFA treating lesions up to 7 cm, showing a faster ablation procedure, a reduced heat-sink effect and improved convection profile; however, MWA emerges as more appropriate for superficial lesions[77].

The results concerning local disease control rate of MWA *vs* RFA are controversial. Early reports show similar rates for local tumour control for MWA and RFA. In a retrospective comparative study of 102 patients, a complete ablation rate of 95% was reported for MWA and 93% for RFA[78]. On the other hand, Shibata *et al*[50] performed a randomized trial in 72 patients and reported local control rates of 89% for MWA and 96% for RFA. Overall, the published studies support the comparability of the two methods in terms of overall survival, local recurrence and complication rates (Table 2), with some notable exceptions.

One study[79] showed MWA to be superior in terms of local recurrence (3.9% *vs* 13.5% in the RFA group). On the contrary, Ohmoto *et al*[80] and Ding *et al*[81] describe fewer recurrences in the RFA group over MWA (9% *vs* 19% and 5.2% *vs* 10.9%, respectively). In the latter study, authors ascribe this difference to the fact that larger lesions were ablated (26.7% were > 3 cm in the MWA group as opposed to 15.3% in the RFA group). The size of the tumour lesion is a well-known factor associated with

local recurrence; it seems to have played a role in different results among studies.

Across studies, the survival rates were generally comparable for MWA over RFA groups, having being reported within the range of 68%-100% at 1st year and 24%-78% at 4th year.

EVALUATION OF RESPONSE

As locoregional therapies can increase tumour dimensions due to necrosis or haemorrhage, the role of tumour size quantification in assessing tumour response in this setting is limited[15]. The modified RECIST and EASL criteria are applied to HCC. The EASL criteria were developed in 2000 for evaluating the HCC response to locoregional therapies. Residual viable tumour tissue is defined as the arterially enhancing tissue within the treated HCC and is measured to assess treatment response. The EASL criteria use bi-dimensional measurements and categorize response in a similar way to the World Health Organization guidelines. On the other hand, modified RECIST were proposed in 2010 which quantified the longest diameter of the enhancing part of HCC, assessed in the arterial phase of CT or MRI and measured to avoid any major areas of intervening necrosis[82]. However, different liver tumours in the same patient may be treated at different points, and the lack of provision for that fact poses a significant limitation of all current criteria for quantifying liver tumour response to locoregional therapies. More specifically, the same patient may have both treated and untreated tumours. Nevertheless, knowledge of these criteria is necessary as they are part of a common language between radiologists and oncologists.

Evolving imaging biomarkers involve volumetric quantification, diffusion-weighted imaging of lesions and apparent diffusion coefficient values, lesion perfusion, MR spectroscopy and US and MR elastography[83]. The use of positron emission tomography in the evaluation of treatment response is also increasing.

CONCLUSION

The great progress of oncology over the last few years now permits the treatment of more patients with advanced disease who were previously considered unfit for surgery or indeed any kind of palliative treatment. Locoregional treatments such as RFA and MWA constitute the backbone of interventional treatment in HCC, a malignancy that affects up to a million people per year worldwide. The two methods differ in their mechanism of action (RFA uses current as opposed to MWA that uses electromagnetic energy), with MWA having a more advantageous profile in terms of ablation volume, procedural time and simultaneous treatment of multiple lesions. However, with respect to clinical end-points, there is no solid proof as yet to support the advantage of one over the other. The evolution of devices and instruments coupled with the progress of multidisciplinary patient management may allow a better stratification that would maximize treatment benefit.

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