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Review Article

Ablation for Benign Liver Tumors: Current Concepts and Limitations

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Abstract

Percutaneous ablation under imaging guidance is a curative treatment that can induce complete tumor necrosis with advantages of minimal invasiveness and a low risk of complications. Thermal ablation, which includes radiofrequency ablation and microwave ablation, is a representative technique that has sufficient antitumor effects in cases of hepatocellular carcinoma with ≤3 lesions measuring ≤3 cm and preserved liver function. The short- and long-term outcomes of patients are comparable with those achieved with surgical resection. Despite their nonmalignant nature, some benign liver tumors require treatment for symptoms caused by the presence of the tumor and/or continuous enlargement. Ablation may be the treatment of choice because it has lower burden on patients than surgical treatment. This review describes the recent concepts, progress, and limitations of ablation-based treatment for benign liver tumors.

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Introduction

Percutaneous ablation under imaging guidance is a curative treatment with the advantages of minimal invasiveness and a low risk of complications.[1] It includes energy-based ablation techniques, such as radiofrequency ablation (RFA), microwave ablation (MWA), cryoablation, irreversible electroporation, laser ablation, and chemical-based ablation techniques, such as percutaneous ethanol injection.[2] Patients with hepatocellular carcinoma (HCC), ≤3 lesions measuring ≤3 cm and Child-Pugh class A or B are good candidates for thermal ablation by RFA or MWA, which save more of the surrounding nontumor liver tissues than surgical treatment.[3–5] In fact, recent studies have shown comparable results between ablation and surgical treatment for HCC (Table 1).[6–8] The data strongly suggest that surgical treatment has no therapeutic or survival advantages over ablation in the study cohort.

Development of various imaging tools have made it possible to identify benign liver tumors that are incidentally found as focal hepatic lesions.[9] In 1994, the World Congress of Gastroenterology reported a heterogeneous group of lesions with different cellular origins, including hemangioma, focal nodular hyperplasia (FNH), and hepatocellular adenoma (HCA).[10] Despite their nonmalignant nature, some benign liver tumors require treatment for symptoms caused by the presence of the tumor and/or continuous enlargement. Ablation may be the treatment of choice because it is less invasive than surgery. Moreover, there is a quite difference in the cost burden, which is approximately $10,000 for hepatic resection and approximately $5,000 for ablation in Japan, being much more economical for the patients in the latter.

Against that background, this review describes recent trends, progress, and limitations of ablation-based treatment for benign liver tumors. The aim was to recognize and understand the current concepts, to extract problems, and to discuss future directions in relevant fields.

Methods

Literature search and study selection

We searched PubMed and the Web of Science core collection databases using the terms "ablation" AND "liver" OR "hepatic" OR "hepatic lesion" OR "hepatic nodule" AND "benign".

Eligibility criteria and data extraction

Full-text articles published in English were included, except for reviews. To widen the scope of our research, we did not exclude case reports or studies that included pediatric populations (Fig. 1). Two independent hepatologists extracted bibliographic information, including the first author's name, country, journal name, and demographic information, including the sample size, age, and characteristics and size of

Keywords: Liver tumor; Radiofrequency ablation; Microwave ablation; Benign.
Abbreviations: CT, computed tomography; FNH, focal nodular hyperplasia; HCA, hepatocellular adenoma; HCC, hepatocellular carcinoma; HEHE, hepatic epithelioid hemangioendothelioma; MRI, magnetic resonance imaging; MWA, microwave ablation; RFA, radiofrequency ablation; TAE, transcatheter arterial embolization.
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Table 1. Comparison of outcomes between ablation and surgical treatment for HCC

RFS/PFS/DFS		*p*-value		OS	*p*-value	Reference
RFA	Surgery		RFA	Surgery		6
54.7%/5y*	50.5%/5y*	0.498	70.4%/5y*	74.6%/5y*	0.828	
MWA	Surgery		MWA	Surgery		7
38.7%/5y#	35.7%/5y#	0.801	71.9%/5y#	67.6%/5y#	0.879	
MWA	Laparoscopic		MWA	Laparoscopic		8
49.7%/5y§	55.6%/5y§	0.071	66.8%/5y§	66.2%/5y§	0.46	

RFA, radiofrequency ablation; MWA, microwave ablation; RFS, recurrence free survival (duration from the date of enrollment to the date of the diagnosis of recurrence); PFS, progression free survival (interval from date of operation to the date of the onset of progression, death, or last follow-up visit); DFS, disease free survival (interval between first treatment and recurrence or death, whichever occurred earlier). *RFS; #PFS after propensity score matching; §DFS from 2014–2019, after propensity score matching.

hepatic lesions; symptoms, reasons for ablation, and ablation details, methods, guidance, results, and complications.

Results

Hepatic hemangioma

Hepatic hemangioma is the most common primary benign liver tumor, with a prevalence of 2.5–3.3%.[11–13] Hemangiomas are usually small (<4 cm) and solitary, but clinicians occasionally encounter patients with hemangiomas measuring 10–20 cm in diameter, with most patients being asymptomatic.[14] The following indications are usually applied to choose the treatment of hemangioma: (1) presence of persistent symptoms such as abdominal pain/discomfort and dyspepsia because of disturbance of bowel movements by mass effects related to hemangioma that are difficult to manage with medical treatments or (2) progressive enlargement of 1–2 cm per year even in asymptomatic patients.

Before treatment, the location of hemangiomas needs to be carefully examined to determine whether they are eligible for approach with an ablation needle (RFA electrode or MWA antenna) with an adequate sonographic window. A laparoscopic approach may be preferred in cases in which the percutaneous approach is difficult. Ultrasound (US) is the most frequently used tool for guiding ablation needles. Computed tomography (CT) guidance is used when US guidance is insufficient to support needle visualization and advancement. According to recent studies, either the laparoscopic/surgical or percutaneous approach is predominantly used with US guidance (Tables 2 and 3).[15–29] Complete ablation was reported in >86% of patients with RFA and >84.6% with MWA. The resolution of clinical symptoms was achieved by most patients, complete resolution of clinical symptoms in 50–90.9% by RFA, and 50–100% by MWA.[15–24] There are some possible complications of ablation for hemangioma, most of which are classified as Clavien-Dindo grade 1, with hemoglobinuria, fever, and pain being common events (Tables 4 and 5).[15–23,25–29] According to Wu *et al*.,[25] the rates of achieving complete ablation and procedure-related complications were similar in 253 patients with hemangiomas of 5–9.9 cm and 38 patients with hemangiomas of ≥10 cm.[25] However, the rates of hemolysis-related and systemic inflammatory response syndrome-related complications were higher in patients with hemangiomas of ≥10 cm than in those with hemangiomas of 5–9.9 cm. In addition, the postoperative stay was longer in the former than in the latter (9.04 vs. 5.73 days, $p<0.001$). The data suggest that care should be taken when performing ablation for hemangiomas of ≥10 cm in terms of safety risk and patient burden.

Regarding technical aspects, Qu *et al*.[26] recommended the use of three-step RFA for hepatic hemangiomas of 5–12.8 cm, briefly defined by the ablation of the target lesion following ablation of the feeding artery and aspiration of blood from the tumor. The technique appears to increase the efficiency of RFA, with a shorter ablation time, fewer punctures, improved effectiveness and safety, better complete ablation rate, better maximum postoperative pain score, better symptomatic relief, and lower rate of severe complication. In addition, as they reported a shorter hospital stay, three-step RFA may benefit patients by reducing the burden, but there was no description of the financial aspect.

According to the study comparing MWA (n=82, 6.9±1.8 cm) and transcatheter arterial embolization (TAE; n=53, 7.1±1.5 cm) for the treatment of large hepatic hemangiomas,[27] the MWA group had a significantly higher rate of complete radiological response defined as no obvious enhancement of lesions on contrast-enhanced CT/magnetic resonance imaging (MRI; 89.0% vs. 37.7%, $p<0.001$) and complete clinical response defined as disappearance of hemangioma-related symptoms (88.6% vs. 69.2%, $p=0.046$). MWA was associated with fewer minor complications, defined as events without substantial morbidity or disability that increased the level of care (43.9% vs. 66.0%, $p=0.019$), shorter time of analgesic use ($p<0.001$), and shorter hospital stay ($p=0.003$) than the TAE group. The

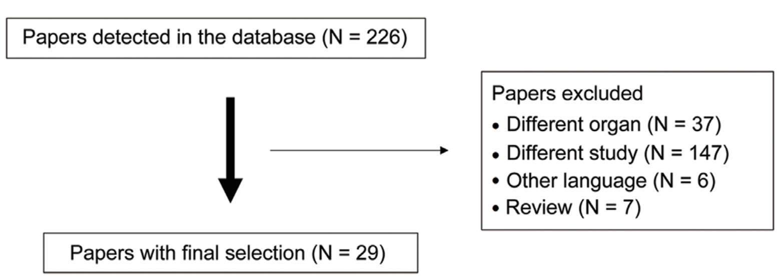

Fig. 1. Flow diagram for literature research.

Table 2. Effectiveness of RFA for hemangioma

N	Size in mm	US/CT	Approach	Effectiveness: Symptom-related	Effectiveness: Tumor reduction-related	Reference
44 (50)	50–100	US	Laparoscopy/Percutaneous	–	86% with complete effect*	16
4	106–145	US	Surgical	50% with complete relief	58–92% volume reduction	17
12 (15)	25–95	US	Percutaneous	58.3% with significant/complete relief	38–79% (mean, 67%) volume reduction	15
291 (304)	50–200	US/CT	Laparoscopy/Percutaneous	–	99% with complete effect*	25
27	28–100	US	Laparoscopy	52% with complete relief	100% with complete effect*	20
24 (25)	40–150	US	Percutaneous	71.4% with complete relief	92% with complete effect*	19
2	15.7–25	US	Laparoscopy	50% with complete relief	56% and 32% reduction	18
106**	5–12.8	US	Percutaneous	90.9%/65%† with complete relief	86.5%/40.7%†† with complete effect	26
66#	40–100	US	Laparoscopy	76.5% with complete relief	94.4% with complete effect*	28
72	≤50, <100	US/CT	Laparoscopy/Percutaneous	–	94.4% with complete effect	29

RFA, radiofrequency ablation; N, number of patients (number of lesions); US (ultrasound)/CT (computed tomography) guidance. *Complete effect, no nodular or irregular enhancement adjacent to the ablated zone, as shown on post-treatment enhanced CT or MRI or US; **52 by three-step RFA and 54 by conventional RFA; †90.95% by three-step RFA and 65% by conventional RFA; ††86.5% by three-step RFA and 40.7% by conventional RFA; #32 patients treated by RFA and 34 treated by open resection.

Table 3. Effectiveness of MWA for hemangioma

N	Size in mm	US/CT	Approach	Effectiveness: Symptom-related	Effectiveness: Tumor reduction-related	Reference
46 (47)	50–96	US	Percutaneous	–	91.5% with complete effect*	21
44	106–145	US	Percutaneous	50% with complete relief	93.2% with complete effect*	22
82	50–100	US	Percutaneous	88.6% with complete relief	89.0% with complete effect*	27
12 (13)	100–145	US	Percutaneous	100% with complete relief	84.6% with complete effect*	23
40 (42)	41–108	US	Percutaneous	95% with clinical effectiveness†	100% with technical effectiveness#	24
72	≤50, <100	US/CT	Laparoscopy/Percutaneous	–	95.8% with complete effect*	29

MWA, microwave ablation; N, number of patients (number of lesions); US (ultrasound)/CT (computed tomography) guidance. *Complete effect, no nodular or irregular enhancement adjacent to the ablated zone, as shown on post-treatment enhanced CT or MRI; †Clinical effectiveness defined as improvement of symptoms notated during follow-up; #technical effectiveness defined as treatment of 90–100% of the volume of the hemangioma based on contrast-enhanced imaging within three days after ablation.

Table 4. Complications related to RFA for hemangioma

N	Size in mm	Complications		Reference
44	50–100	Clavien-Dindo Grade 1*		16
		Hemoglobinuria	18.2%	
		Hemolytic jaundice anemia	11.3%	
		Elevated serum transaminase	11.3%	
		Fever	9.1%	
		Skin burns	9.1%	
		Transient renal damage	6.9%	
		Hydrothorax	6.9%	
		Clavien-Dindo Grade 3a*		
		Pneumothorax	2.3%	
		Liver abscess	2.3%	
4	106–145	Self-limiting postprocedural pain lasting for 6 days	25%	17
		Macroscopic hematuria lasting for 24 h	25%	
12	25–95	NONE		15
291	50–200	Clavien-Dindo Grade 1		25
		Hemoglobinuria	81.9%	
		Anemia	13.2%	
		Lung injury	1.6%	
		SIRS	39.1%	
		Postprocedural pain	7.2%	
		Transient hepatic injury	16.1%	
		Asymptomatic pleural effusion	5.9%	
		Skin burn	1%	
		Clavien-Dindo Grade 2		
		Esophageal injury	0.3%	
		Myocardial dysfunction	0.3%	
		Clavien-Dindo Grade 2–3		
		Diaphragmatic injury	1.3%	
		AKI	1%	
		Clavien-Dindo Grade 3		
		Symptomatic pleural effusion	0.3%	
		Bleeding at the electrode entry site	1.3%	
		Rupture of hepatic hemangioma	1%	
		Clavien-Dindo Grade 4		
		ARDS	0.3%	
27	28–100	Postoperative low-grade fever	48.1%**	20
		Elevated serum transaminase	48.1%**	
24	40–150	Abdominal pain	16.7%***	19
		Fever	8.3%***	
		Anemia	8.3%***	
		Jaundice	12.5%***	
		Ascites	4.2%***	
2	15.7–25	AKI, anemia	100%	18

(continued)

Table 4. *(continued)*

N	Size in mm	Complications		Reference
106	5–12.8	Clavien-Dindo Grade 1		26
		Pleural effusion	7.5%	
		Clavien-Dindo Grade 2		
		Fever	8.5%	
		Hemoglobinuria	2.8%	
		Moderate anemia	1.9%	
		Acute renal insufficiency	2.8%	
		Jaundice	16%	
		Clavien-Dindo Grade 3		
		Abdominal Hemorrhage	0.9%	
66[#]	40–100	Fever	18.8%	28
		Hemoglobinuria	3.1%	
		Transient renal damage	3.1%	
		Jaundice	3.1%	
144[##]		Clavien-Dindo Grade 1		29
		Hemoglobinuria	76.4%	
		SIRS	30.6%	
		Hemolytic jaundice	8.3%	
		Anemia	6.9%	
		Postprocedural pain	8.3%	
		Transient hepatic injury	12.5%	
		Asymptomatic pleural effusion	2.8%	

AKI, acute kidney injury; ARDS, acute respiratory distress syndrome; N, number of patients; RFA, radiofrequency ablation; SIRS, systemic inflammatory response syndrome. [*]All complications were resolved by conservative treatment. [**]spontaneously resolved within 7 days after RFA; [***]All complications were resolved within 7 days; [#]32 patients treated by RFA, and 34 treated by open resection; [##]72 patients treated by RFA, and 72 treated by microwave ablation.

study suggests that TAE has limited effectiveness for volume reduction of hemangioma. Meanwhile, Wang *et al*.[30] reported the outcome of TAE followed by percutaneous US-guided MWA for hemangioma (95 × 97 × 117 mm), with an 80% reduction with no complications, which might have potential as an option for the treatment of large hemangioma. A recent prospective study compared the clinical results of laparoscopic RFA (6.4 cm, 4.0–9.3) and open resection (6.5 cm, 4.0–9.8) for the treatment of symptomatic-enlarging hepatic hemangiomas.[28] Although radiological and clinical responses were comparable between the groups, the laparoscopic RFA group had a significantly shorter operative time and less blood loss than the open resection group. In addition, patients who underwent laparoscopic RFA experienced significantly less pain, required less analgesia, had a significantly shorter length of hospital stay, and had lower hospital costs compared with those who underwent open resection. Another study retrospectively compared the effectiveness of percutaneous MWA and surgical resection (open 62 and laparoscopic 6) for hemangiomas (6.3±1.4 cm, 5.0–9.6); the MWA group had a significantly shorter operative time, less blood loss, and a lower rate of prophylactic abdominal drainage than the surgical resection group.[22] In addition, postoperative recovery was significantly better and duration of hospital stay was significantly shorter in the MWA group than in the surgical resection group. However, there was no significant difference in effectiveness between the groups. Taken together, despite the limited number of studies comparing ablation and surgical treatment, ablation appears to provide an sufficient therapeutic effect compared with open surgery, with the advantages of safety and less burden for patients. However, difference of clinical effectiveness between RFA and MWA for hemangioma has not been fully described, as limited studies have compared the two methods. In a recent study, MWA had a shorter ablation time, fewer hemolysis-related complications, and a shorter hospital stay.[29] Additional studies may be required to compare RFA and MWA, and long-term outcomes of ablation for hemangioma with cost effectiveness.

Hepatocellular adenoma (HCA)

HCA is a benign liver tumor that most often develops in young women taking oral contraceptives, with an incidence of approximately 3 per 100,000 women.[31] Complications such as hemorrhage (15–20%) or malignant transformation (5%) appear to increase with increase in tumor size. Therefore, surgical treatment is recommended for HCAs of >5 cm.[32]

There are limited reports regarding the ablative effects of HCA (Table 6).[33–37] Rocourt *et al*.[33] reported a 13-year-old patient in whom a liver tumor measuring 35 mm was incidentally detected and was histologically diagnosed as adenoma by percutaneous biopsy.[33] Because of the relatively small lesion, RFA was selected as the treatment of choice. US-guided percutaneous RFA was performed under general anesthesia with three sequential overlapping ablations of 12

Table 5. Complications related to MWA for hemangioma

N	Size in mm	Complications			Reference
46 (47)	50–96	Minor complications (fever, mild pain and transient hepatic dysfunction)*	78.3%		21
		Major complications (2 with acute renal dysfunction** , 2 with symptomatic pleural effusion**, and 1 with Hyperbilirubinemia)	10.9%		
44	106–145	Clavien-Dindo Grade 1			22
		Pain	22.7%		
		Excessive wound exudate	6.8%		
		Low-grade fever	4.5%		
		Coprostasis	13.6%		
		Stomach discomfort	4.5%		
		AKI	6.8%		
		Clavien-Dindo Grade 3			
		Diaphragmatic hernia	2.3%		
82	50–100	Major complications	9.8%	SIR#	27
		Diaphragmatic hernia	1.2%	D	
		Symptomatic pleural effusion	2.4%	C	
		Jaundice	2.4%	C	
		Acute renal dysfunction	3.7%	C	
		Minor complications	43.9%		
		Fever	6.1%	B	
		Abdominal pain	22%	B	
		Both fever and pain	6.1%	B	
		Other discomfort	9.8%	A	
12 (13)	100–145	Fever (≧38)	15.4%		23
		Constipation	30.8%		
		Slight wound pain	30.8%		
		Stomach discomfort	7.7%		
		High bilirubin (total bilirubin >34.2 mmol/L)	53.8%		
		Anemia (hemoglobin <100 g/L)	30.8%		
		Elevated serum transaminase (>80 U/L)	100%		
		Elevated serum creatinine	15.4%		
40 (42)	41–108	Fever (37.2–8.5 Celsius degrees lasting 1–2 days)	15%		
		Pleura effusion without drainage	5%		
		Hemoglobinuria at the first urination after ablation	37.5%		
		AKI caused by massive heat-induced intravascular hemolysis##	2.5%		
144§		Clavien-Dindo Grade 1			29
		Hemoglobinuria	48.6%		
		SIRS	15.3%		
		Hemolytic jaundice	2.8%		
		Anemia	4.2%		
		Postprocedural pain	4.2%		
		Transient hepatic injury	4.2%		
		Asymptomatic pleural effusion	1.4%		

AKI, acute kidney injury; SIRS, systemic inflammatory response syndrome; N, number of patients (number of lesions); MWA, microwave ablation. *All patients recovered within 3–9 days after hepatoprotection and symptomatic treatment; **Recovered with medical intervention; #Society of Interventional Radiology classification; ##After 12 hemodialysis sessions, 32 days later, renal function gradually recovered, dialysis was stopped, and the patient was discharged 34 days after the procedure. §72 patients treated by RFA, and 72 treated by microwave ablation

Table 6. Ablation for hepatocellular adenoma

N	Size in mm	Method	Guidance	Approach	Effect	Reference
1	55	RFA	US	Laparoscopy	No residual tumor, 19 months	35
1	35	RFA	US	Percutaneous	No recurrence, 2 years	33
3 (*)	20–50	RFA	US	Surgical	1 residual tumor**	34
16 (26)	11–48	RFA	US/CT	Percutaneous	1/26 (4%) with residual tumor**	36
1	50	IRE	CT	Percutaneous	Rapid tumor shrinkage	37

N, number of patients (number of lesions); RFA, radiofrequency ablation; US, ultrasound; CT, computed tomography; IRE, irreversible electroporation. *Multiple lesions; **Re-ablated by RFA.

min each. No evidence of recurrence was seen on MRI 2 years after treatment. A study of three cases of multiple HCAs (2–5 cm) treated with hepatic resection combined with RFA (intraoperative approach with no complications) was reported in the USA in the same year.[34] An RFA study by McDaniel *et al*.[35] used four cool-tip 15 cm long electrodes (Radionics, Burlington, MA, USA) and a 3 cm ablative zone, under laparoscopic US guidance with a four-way laparoscopic 8666-RF intraoperative transducer (BK Medical, Peabody, MA, USA) to treat HCA (segment 7; 5.5 cm) adjacent to the right hemidiaphragm in an 11-year-old patient with chronic liver disease secondary to alpha-1-antitrypsin deficiency. The patient did well after treatment and was discharged on the third postoperative day. The follow-up MRI performed 19 months after the first RFA procedure showed a further decrease in the ablation zone size, with no residual tumor. Costa *et al*.[36] treated 16 patients with 26 HCAs between 11 and 48 mm with US/CT-guided RFA using coaxial 14–18 gauge RFA needles and 3–4 cm cool-tip needle systems.[36] The treatment was uneventful and technically successful in all cases. Only one patient (4%) had residual lesions that increased in size over time, but showed no further enlargement in or around the ablated area after re-ablation. The mean follow-up was 27 (range: 2–84) months. The authors also found that fat in the ablation zone of HCAs was a common finding on MRI, which, in isolation, does not indicate residual tumors. Thus, RFA seems to have beneficial effects in the treatment of HCAs, meanwhile, there is a case report that demonstrated the effect of percutaneous CT-guided irreversible electroporation, a nonthermal ablation of a 5 cm HCA in a 28-year-old woman who wanted to get pregnant.[37] It was effective, with rapid and impressive tumor shrinkage without any complications. However, it should be noted that HCAs are benign tumors, and treatment is limited to preventing bleeding or malignant transformation. Radical treatment needs to be selected according to the subtype, as described in recently published guidelines endorsing the use of personalized clinical care.[38] Following the guidelines, the indications for treatment are any HCA in men regardless of size and subtype and HCAs of >5 cm or much rarer smaller HCAs with worrisome features such as β-catenin activation or rapid growth in women.[38] Appropriate selection of surgical or nonsurgical treatment including various ablation techniques, should be further investigated in studies with large patient populations.

Hepatic epithelioid hemangioendothelioma

Hepatic epithelioid hemangioendothelioma (HEHE) is a rare vascular tumor that consists of epithelioid and histiocytoid vascular endothelial cells in a myxoid or fibrotic stroma. HEHE has a variable clinical course. It is generally considered less aggressive than angiosarcoma, but is not completely benign.[39] There is no standard/consensus therapeutic strategy, and there are several treatment options, including liver transplantation, liver resection, chemotherapy, and locoregional/radiation therapy. Cao *et al*.[40] evaluated the medical records of 12 patients with histologically proven HEHE who were followed up for a mean of 39.6±20.1 (range: 15–82) months.[40] Three patients, including one with three lesions of a maximum 3.5 cm, one with >5 lesions, and one with 4 lesions, who underwent RFA were without recurrence for a median 36 (range: 28–63) months of follow-up. Although the sample size was small, RFA showed favorable results for HEHE.

FNH

There were two reports of cases with FNH treated by ablation and having favorable outcomes. One was treated by CT-guided percutaneous cool-tip RFA that unfortunately resulted in incomplete ablation of a 22 mm FNH, but provided disappearance of right upper quadrant pain with no complications and required only a 2 day hospital stay.[41] The second was a US-guided percutaneous MWA that resulted in complete ablation of a 29 mm FNH with no complications and a 6 day hospital stay.[42] However, it should be noted that Cheng *et al*.[43] reported regrowth of residual FNH after treatment with US-guided percutaneous MWA, which was finally treated by TAE. Although it is difficult to draw a conclusion because of the small number of studies, indication of treatment and methodology of ablation need to be further evaluated for FNH. In addition, selection of post-treatment monitoring should be discussed because of the possibility of enlargement of residual lesion.

Cysts

Kim *et al*.[44] described the treatment of 14 hepatic cysts with a mean diameter of 7.8 (range: 3.7–12.7) cm and mean initial cyst volume of 243.7 (range: 25.1–1,057.2) mL in 14 patients by US-guided percutaneous cool-tip RFA performed after aspiration of the cyst contents until the diameter was ≤3 cm in diameter. Eight of nine cysts ≤8.5 cm in diameter significantly decreased in volume. The mean reduction was 93.6% (range: 76.8–100), and one cyst was surgically removed because of regrowth. Four cysts 8.5–12.0 cm in diameter were reduced by 61.7% (range: 26.0–98.8). There were no major complications. The data suggest that RFA has a role as an option alternative to conventional sclerotherapy or surgery, and volume reduction rate showed relation with pre-treatment size and presence of septum.

Summary, recent progress, limitations, and future planning

A recent advance in ablation-based treatment is the introduction and spread of MWA which has become a representative therapy for the treatment of benign and malignant tumors. Another advance is the development of imaging techniques having improved time and spatial resolution in support of the ablation procedure. As already shown, thermal ablation appears to be an effective treatment method for hepatic hemangiomas and HCAs. The burden on patients undergoing MWA may be smaller than in patients undergoing surgical treatment in terms of operative time, complications, and duration of hospital stay. However, for patients undergoing RFA, because limited studies have been conducted, it may be difficult to draw a definite conclusion. Moreover, there are a few reports of ablation of angiomyolipoma with malignant potential,[45] or FNH,[46,47] the effectiveness of ablation for such tumors should be investigated in future studies.

At this time, there are some limitations in this field. First, histological diagnosis of hepatic lesions is usually made by needle biopsy in cases treated by ablation. There is a risk that malignant potential or combined malignancy cannot completely be excluded by the limited sample, and distinguishing HCA and FNH or HCA and well-differentiated HCC can still be challenging, even for an expert pathologist.[31] In such a situation, we need to be mindful of the risk of incomplete ablation and residual lesions, the possible need of subsequent surgery, increased medical expense, and patient discomfort. Second, a definitive indication for ablation for benign liver tumors has not been determined, and the selection of treatment is generally performed based on clinicians' judgment. In that regard, establishment of international guidelines may be needed. Third, there is a risk of complications, particularly in cases with large hemangiomas, and hemolysis-related complications such as acute kidney injury that may cause serious condition. Therefore, future studies should be conducted to determine how to prevent or reduce the risk of complications. In addition, ablation techniques to treat benign liver tumors other than thermal-based methods should be studied. Against these background, it is strongly recommended to plan future studies of (1) risk stratification of benign hepatic lesions based on resected specimens, (2) ablative techniques other than thermal-based methods for various benign hepatic lesions including the occurrence of complications, and (3) large, prospective studies to provide international guidelines.

Conclusion

Although there are many positive results of the effectiveness of the ablative treatment for benign hepatic tumors, more studies with larger patient populations are required to confirm their benefits, including cost effectiveness and to provide specific measures against possible complications. Further, organization of medical care, including those for pre-ablation, ablation, and post-ablation may help the improvement of the quality in the practical management of benign hepatic tumors.

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Conflict of interest

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Author contributions

Conception and design (HM), administrative support (SS), provision of study materials or patients (TY), collection and assembly of data (MT, HN), data analysis and interpretation (HM, SS), manuscript writing and final approval of manuscript (all authors).

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