

Security and efficiency of percutaneous microwave ablation by combining computer tomography- with ultrasound-guided in patients with BCLC-A1-3 hepatocellular carcinoma

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Research

Keywords: Microwave ablation, hepatocellular carcinoma, CT, ultrasound, BCLC-A

Posted Date: March 5th, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-16176/v1>

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Abstract

Background : To evaluate prospectively security and efficiency of percutaneous microwave ablation (MWA) by combining computer tomography (CT)- with ultrasound (US)-guided of in patients with BCLC-A1-3 hepatocellular carcinoma (HCC).

Methods : We studied 88 consecutive patients with single HCC who were treated with transcatheter hepatic arterial chemoembolization (TACE), patients were divided into 3 groups at random by using draw lots 1 week after TACE, combination group (34 cases) received MWA under the guidance of CT and US, while single group (CT group 30 cases, US group 24 cases) received MWA under the guidance of CT or US alone. 1 month, 3 months, 6 months and 12 months after the procedure, contrast-enhanced MRI scan were performed in all cases. Study endpoints included treatment time, puncture time, local recurrence rate and adverse events.

Results : A total of 88 lesions were radically treated with MWA after TACE. The median diameter of the lesion was 3.1 (1.5-4.2) cm. The mean treatment time, puncture time were 38.6 (30-45) min, 36.7 (30-47) min, and 1.2 (1-2), 1.1 (1-2) in the combination group and US group, which were significantly inferior to CT group (45.8 minutes and 4.2); Local recurrence rate was 5.9% in the combination group, which was significantly inferior to US group (16.7%). Grade C complication rates occurred in the combination group was 5.9%, while it was 13.3% and 8.3% in CT group and US group, there was statistically significant between combination group and CT group ($P < 0.05$).

Conclusions : Using CT- and US-guided microwave ablation in patients with BCLC-A1-3 hepatocellular carcinoma appeared to be much better in security and efficiency than that under the guidance of CT or US alone.

Background

Percutaneous microwave ablation (MWA) is widely applied for the treatment of hepatocellular carcinoma (HCC), MWA has a 1–5 year overall survival, low local recurrence rate and slight adverse events [1, 2]. In majority of cases, percutaneous MWA is performed under image guidance, such as computed tomography (CT) or ultrasound (US). However, each approach of image guidance has its own advantages and disadvantages. US has the advantages of real-time monitoring, easy operation, radiationless, low cost, and clear display of blood vessels and bile duct; But there are a few disadvantages, such as low resolution of image, low location accuracy, be susceptible to nearby organs (for instance, rib, lung and gastrointestinal tract) and hard to evaluate ablation range [3, 4]. In contrast, CT can avoid such disadvantages greatly [5, 6]. However, the disadvantage of CT is that it lacks real time and dynamic tracking, has radiation hazards, is relatively expensive and not evident on vasculature. The disadvantage of each imaging guidance and monitoring will bring enormous incommodity for MWA and be bound to influence safety and effectiveness of MWA.

The previous research mainly focuses on single Image-guided MWA for the treatment of HCC, such as CT or US. As neither of two imaging guidance is not effective enough to solve the problem, we attempt to work with a combination of the two. In this study, from a perspective of technology success, we try to combine US with CT to explore if we can maximumly overcome shortcomings and improve the inadequacy of the guidance of CT or US alone, and get a better result.

Methods

Patients

The study protocol was approved by the ethical committee of the Beijing Ditan Hospital. All patients signed an informed consent before procedure. From November 1,2017 to February 28, 2019, a total of 88 patients with single BCLC-A HCC who were candidates for MWA and admitted to Beijing Ditan Hospital, Capital Medical University, were enrolled in this study. Diagnostic criteria of HCC were performed according to the guidelines for the diagnosis and treatment of primary liver cancer in BCLC Staging Classification [7].

The eligibility criteria were: (1) patients aged 18–80 years; (2) tumor clinical stage is BCLC-A1-3: diameter ≤ 5 cm,liver function Child-Pugh class A or B; no vascular cancer embolus, vascular and intrahepatic bile duct invasion and distant metastasis; (3) patients who did not receive any anti-cancer treatment, such as surgery, radiotherapy, chemotherapy, ablation, and targeted drugs; (4) the performance status score of patients is less than 2, no serious organ dysfunction syndrome, such as heart, brain, liver, and kidney problems.

The exclusive criteria were as follows: (1) severe liver malfunction(Child–Pugh score > 9 , serum total bilirubin level > 3 mg/dl and prothrombin time-international normalized ratio > 1.5); (2) severe hepatic atrophy, expected ablated area would be larger than one-third of liver volume; (3) esophageal and gastric variceal bleeding patients in the last six months; (4) active infection or intra-hepatic bile duct dilation; (5) uncorrectable coagulopathy($PLT \geq 30 \times 10^9/L$, $PT \geq 30$ s, $PTA \geq 40\%$); and (7) obstinate massive ascites and hepatic encephalopathy.

Equipment

We used a KV2100 Microwave tumor treatment device (Nanjing Kangyou Microwave Energy Sources Institute, China; frequency,2450 MHz; needle type, internal water-cooling; electrode diameter, 15G; electrode length, 150 or 180 mm; power, 0–100 W; distance from the aperture of the MW emission to the needle tip, 11 mm); ultrasound machine was LOGIQ P6 (GE, USA), using broadband convex array probe(frequency,1–5 MHz);CT devices was produced by Germany's Siemens AG (tube voltage,120 kV; tube current, 200mAs; the slice thickness, 5 mm; pitch,1).

Treatment

All patients were initially treated with TACE. The purpose of TACE was to interdict tumor target artery and make tumor easier to recognize on CT images, and it could enhance the efficiency and the effect of MWA. The treatment process was as follows: Hepatic artery angiography was performed using the Seldinger technique. Femoral arterial catheterization was conducted through the common hepatic artery or proper hepatic artery, and the location, number, size, and blood supply of the lesions were evaluated. Subsequently, a microcatheter was super-selectively inserted into the hepatic lobe or hepatic segmental artery branch, and mixed suspensions of iodized oil (5–10 ml) and Loplatin injection (40 mg) were infused into the artery through the catheter. Finally, blank microsphere (100–300 μm) were infused to embolize the artery until the arterial blood flow supplying the tumor was completely blocked.

MWA was initiated 1 week after TACE. Patients were divided into 3 groups at random by using draw lots: CT group, US group and combination group. The procedure was performed under local anesthesia, and the vital signs were monitored under ECG monitor. The patient was given pethidine hydrochloride injection and diazepam injection 30 minutes before the treatment. The microwave therapy instrument was in good working condition. Procedures were performed by one of two doctors with 10 years of experience in HCC ablation.

The CT group, most patients took the supine position, a few patients took lateral decubitus position or prone position according to the point and direction of embedded microwave electrode. CT scan provided clinically useful information such as the size, shape and position of lesion and the relationship between lesion and adjacent structure, measure the distance from lesion to skin, confirm the puncture path and site. The skin around the puncture site was disinfected routinely, local anesthesia with lidocaine, inserting prepared guide pin (21G) in advance and dynamically adjusting the position of guide pin according to CT scanning image, enabling it to reach to lesion edge. Subsequently, microwave electrode was inserted precisely into lesions in the direction of guide pin, pulling out the guide pin and adjusting slightly microwave electrode to the best position according to CT scanning image. Microwave electrode placement was performed based on the expected ablation zone size described by the manufacturer, considering a sufficient (> 5 mm) safety margin around the tumor. The microwave power was set at 50–60 W. The ablation time for each lesion was 5–8 minutes, and the ablation area covering the lesion and its surrounding area measured 5 mm or more. If a single treatment did not produce satisfactory results, adjusted microwave electrode according to CT scanning image, a second MWA treatment was conducted immediately, until the ablation area covering the lesion. Routine ablation needle track was performed to prevent implantation metastasis, pressure dressing was performed to prevent hemorrhage immediately after the procedure, a postoperative CT scan was performed to confirm whether it had some complications (for example, pneumothorax, pleural effusion, subcapsular hemorrhage, etc) to manage further. After treatment, liver protection, anti-inflammatory and sedation therapies were prescribed. A follow-up study by repeat contrast-enhanced magnetic resonance imaging (MRI) was conducted. As shown in Fig. 1.

The US group, all patients took the supine position or left lateral decubitus position and must follow the principle that the lesions were more apparent in ultrasonic imaging. If necessary, artificial pleural effusion

and ascites were applied to treat US-invisible HCC in the hepatic dome or adjacent gastrointestinal tract before procedure. Microwave electrodes were inserted precisely into lesions under US guidance. The ablation power was 50–60 W, ablation time was 5–8 minutes. During course of treatment, internal echoes change of lesion and manifestations of intrahepatic and perihepatic tissue were observed by US in real time. When hyperechoic completely cover targeted lesions, the therapy was stopped. It would be the same as CT group, the same needle track ablation and pressure dressing were made after the procedure. Whether there were any complications, such as pleural effusion and subcapsular hemorrhage, were evaluated by US after treatment. Regular follow-up examinations would continue for greater than 12 months. As shown in Fig. 2.

The combination group, at first, all patients underwent CT examination in a supine position. Designing the best puncture path and site according to CT image, avoiding nearby larger blood vessels and bile duct, pulmonary tissue and pleural cavity. Subsequently, microwave electrode was inserted precisely into lesions avoiding nearby larger blood vessels and bile duct under real-time US guidance. Then, repeat CT was performed to further precisely targeted the position of microwave electrode and the relationship between microwave electrode and around structure of the lesion, when necessary, to adjust slightly. Ablation power was 50–60 W, ablation time was 5–8 minutes. Internal echoes change of lesion was observed by real-time US, timely CT examination was performed. The therapy was stopped, when the ablation area completely covered targeted lesions and had not some complications according to CT image. Routine needle track ablation and pressure dressing were made after the procedure. Regular follow-up examinations would continue for greater than 12 months. As shown in Fig. 3.

Efficacy and safety

All patients were on preoperative contrast-enhanced MRI, after 1 month, 3 months, 6 months and 12 months of treatment. Treatment time, puncture time, local recurrence rate were used to evaluate the efficacy of the three groups. Follow-up period, if we found local recurrence and we will treat them by a second MWA; if we found intrahepatic metastasis and distant metastasis and we will treat them by other treatment methods, such as targeted drugs.

At the same time, liver and kidney functions, AFP were recorded. The MWA-related complications including bile duct injury, GI bleeding and hydrothorax, sepsis, liver failure, renal dysfunction, peritoneal hemorrhage, and skin burn were assessed.

Statistical analysis

Parameters were tested for normality using the Shapiro Wilk test. The means and standard deviations (SD) of continuous, normally distributed parameters were determined and compared using one-way analysis of variance or the independent-samples t test. Patient age, lesion size, treatment time, complete ablation rate, local recurrence rate, number of puncture and adverse events were compared between the three groups. Differences with p values < 0.05 were considered significant, and p values were not adjusted

for multiple comparisons. Statistical analyses were performed by an SPSS19.0 software (SPSS, IBM Company, USA).

Results

Patients and procedures

All the procedures were performed according to the pre-operative planning. A total of 88 lesions in 88 patients who were treated with transcatheter hepatic arterial chemoembolization (TACE) were radically treated with MWA. These patients comprised 60 males and 28 females, with a mean age of 52 ± 11.2 (36–72) years. 56 cases had elevated levels of serum alpha-fetoprotein (AFP). Combination group (34 cases) received MWA under the guidance of CT and US, while single group (CT group: 30 cases; US group: 24 cases) received MWA under the guidance of CT or US alone.

Baseline characteristics of patients were shown in Table 1, there were no significant differences between three groups. The median diameter of the lesion was 3.1(1.5–4.2) cm. The average treatment time and the mean puncture number were 38.6 (30–45) minutes and 1.2 (1–2) in the combination group, which were 45.8 (35–56) minutes and 4.2 (3–7) in CT group and 36.7 (30–47) minutes and 1.1 (1–2) in US group. The average treatment time and the mean puncture number in the combination group and US group were significantly better than CT group. Details were shown in Table 2.

Table 1
Baseline characteristics of patients with HCC

Variables	Combination group(n = 34)	CT group (n = 30)	US group (n = 24)	Total
Age (years)	53 ± 10.8 (40–71)	50 ± 11.6 (36–70)	54 ± 11.4 (44–72)	52 ± 11.2 (36–72)
Sex (male/female)	24/11	20/9	16/8	60/28
Tumor size (mean ± SD, cm)	3.4 (1.8–4.4)	3.0 (1.3–3.9)	3.2 (1.7–4.0)	3.1 (1.5–4.2)
Tumor location (left/right, n)	12/22	11/19	9/15	32/56
AFP (ng/ml)	46.6 (6.8–158.4)	40.8 (7.9–110.2)	43.8 (5.2–160.1)	42.7 (7.1–140.2)
Viral hepatitis (HBV/HCV)	32/2	29/1	23/1	84/4
Cirrhosis (%)	88.2	83.3	87.5	86.4
Hb (g/L)	121.2 (93.8–148.7)	131.0 (102.5–152.1)	120 (100.6–154.3)	124 (108.8–144.6)
PLT (× 10 ⁹)	103.2 (58.2–180.7)	118.2 (56.8–171.5)	110.2 (62.4–163.2)	106.2 (64.8–146.5)
WBC (× 10 ⁹)	4.2 (2.7–6.8)	5.1 (2.2–7.3)	4.7 (2.4–7.0)	4.6 (2.5–6.4)
ALB (g/L)	42.6 (32.3–46.8)	44.5 (33.7–48.2)	41.5 (34.4–45.9)	43.3 (34.1–45.8)
ALT (U/L)	43.3 (20.5–65.8)	39.6 (26.8–55.6)	45.4 (30.8–64.2)	40.9 (29.6–60.8)
TBIL (umol/L)	19.1 (10.2–28.8)	17.2 (8.2–30.3)	20.5 (12.4–33.5)	19.6 (10.5–27.4)
PT (s)	13.0 (10.4–14.1)	12.1 (10.1–13.8)	12.7 (10.6–14.0)	12.6 (10.5–13.7)
There was no significant difference in all variables among the 3 groups.				

Table 2

A comparison of operation data among the 3 groups.

Variables	Combination group(n = 34)	CT group (n = 30)	US group (n = 24)
Treatment time (min)	38.6 ■ (30–45)	45.8 ■□ (35–56)	36.7 □ (30–47)
Puncture time (n)	1.2 (1–2) ▲	4.2 (3–7) ▲△	1.1 (1–2) △
■p = 0.036; □p = 0.028; ▲p = 0.016; △p = 0.015			

Therapeutic outcomes and complications

The average follow-up period was 14 (12–20) months. During follow-up time, 8 patients (Combination group: 2 cases; CT group: 2 cases; US group: 4 cases) experienced local recurrence and received repeated MWA, local recurrence rate was 5.9%, 6.7% and 16.7% in combination group, CT group and US group respectively, there was significant difference between combination group and US group in local recurrence rate, and was statistically indistinguishable between patients with CT- and US-guided MWA. 4 patients (Combination group: 1 case; CT group: 2 cases; US group: 1 case) were found intrahepatic and distant metastases after MWA, no significant difference was found between three groups. There was no death during the follow-up period. Details were shown in Table 3. There was significant reduction in the level of AFP among three groups after treatment; but, the rate of decline was not statistically significant between the three groups (Table 4).

Table 3

The local recurrence rate and complication rates for patients following MWA procedures.

Variables	Combination group(n = 34)	CT group (n = 30)	US group (n = 24)
Local recurrence rate (n/%)	2/5.9 [▲]	2/6.7	4/16.7 [▲]
1 month post-MWA (n/%)	0/0	0/0	1/4.2
3 month post-MWA (n/%)	1/2.9	1/3.3	2/8.3
6 month post-MWA (n/%)	1/2.9	1/3.3	1/4.2
12 month post-MWA (n/%)	0/0	0/0	0/0
Grade C complication (n/%)	2/5.9 [△]	4/13.3 [△]	2/8.3
Hyperpyrexia (n/%)	1/2.9	1/3.3	1/4.2
Hyperemesis (n/%)	1/2.9	0/0	0/0
Biloma (n/%)	0/0	1/3.3	0/0
Subcapsular hemorrhage (n/%)	0/0	1/3.3	0/0
Hydrothorax (n/%)	0/0	1/3.3	1/4.2
▲p = 0.038; △p = 0.042			

Table 4
The variety of AFP in patients before and after treatment

Variables	Baseline	1 month post-MWA	3 month post-MWA	6 month post-MWA	12 month post-MWA
Combination group (ng/ml)	46.6 ^{▲▲■□} (6.8-158.4)	11.7 [▲] (4.6-16.6)	10.6 [△] (3.2-15.4)	11.5 [■] (4.0-14.3)	10.8 [□] (4.2-13.3)
CT group (ng/ml)	40.8 ^{▼▽□□} (7.9-110.2)	9.9 [▼] (3.6-18.2)	11.5 [▽] (3.8-16.6)	10.4 [□] (3.4-15.7)	11.7 [□] (3.9-15.3)
US group (ng/ml)	43.8 ^{●●□□} (5.2-160.1)	12.8 [●] (4.4-17.4)	11.8 [●] (3.9-16.6)	10.9 [□] (4.1-15.8)	11.9 [□] (4.2-15.2)
▲p = 0.009, △p = 0.008 □■p = 0.009 □□p = 0.007 ▼p = 0.006 ▽p = 0.008 □□p = 0.007					
□p = 0.01, ●p = 0.012 □●p = 0.009, □p = 0.006 □□p = 0.008					

Complications were evaluated according to unified standardized Society of Interventional Radiology (SIR) grading system [8]. The common adverse effects during treatment and after treatment were low-grade fever, right epigastric mild pain, mild nausea and vomiting, these commonly occurred 1–3 days after treatment, the most majority of which belonged to grade A or B according to the SIR grading system and resolved spontaneously without any other treatment. Patients with grade C complication needed to be treated in hospital.

Grade C complication rates occurred in the combination group (hyperpyrexia:1 case, hyperemesis: 1 case) was 5.9%, while it was 13.3% and 8.3% in CT group (hyperpyrexia:1case,biloma:1case,subcapsular hemorrhage: 1 case, hydrothorax:1case) and US group (hyperpyrexia: 1 case, hydrothorax:1case), there was statistically significant between combination group and CT group ($P < 0.05$), and the difference was insignificant between CT group and US group. all above-mentioned adverse effects were relieved by applying anti-inflammatory agent, analgesics, external drainage, hemostasia and antiemetic drug. Details were shown in Table 3.

The transient elevation of ALT and TBil occurred, approaching the peak level on 3rd day and back to the normal on 7th day. Renal function was no obvious change postoperative compare to preoperative.

Discussion

MWA could lead to complete necrosis of the HCC, however, the cooling effect of blood flow had the greatest impact on ablation zone, the induced area of necrosis was small [9]. TACE had the advantage of reducing blood perfusion of tumor after hepatic arterial blockage. Therefore, it could decrease the cooling

effect of blood flow on the heating action of MWA, and enhance the coagulation action of MWA [10]. Combined therapy with TACE and MWA was safe and effective, and had become a recommended treatment protocol in patients with HCC [11–13].

Although the limited literature on comparing the thermal ablation of HCC under the guidance of CT and US showed they both had made excellent outcomes [14]. It was worth noticing that the postprocedural complications rates of thermal ablation varied a lot, from 2.2–53.2% [14, 15], we could not say that this was not influenced by image guide method. Either image guidance had its own disadvantages, to surmounted this handicap, various methods have been proposed by the researchers to achieve this goal, such as CT/MRI-CEUS and US-CEUS fusion imaging techniques, multimodality imaging-compatible insertion robot [16–19]. All these measures could aid operator to perform technically challenging procedures, with the potential to reduce procedure time and radiation dose. However, the calibration error caused by organ deformation, displacement and respiratory movement was not avoided, the process was very complicated and time consuming and needed specific hardware and software requirements and trained professionals, further studies were needed to clarify these problems [17–19].

In our analysis, we prospectively compared the effectiveness and safety of US-, CT- and combination guided percutaneous MWA in treating patients with HCC. The local recurrence and grade C complication rate were no significant differences between patients with CT- and US-guided MWA, which was consistent with the findings of the previous related study [14, 21]. US had the advantages of real-time monitoring, short operation time and clear display of blood vessels and bile duct, CT had a high accuracy of puncture and a high resolution of image [3, 4]. Therefore, in combination group, the operator could significantly shorten treatment time, increased the success rate of puncture and reduce blood vessel and bile duct damage resulting from repeated puncture. Maybe this could explain why treatment time, puncture time and grade C complication rates in combination group were inferior to CT group. Theoretically, CT guidance for mass targeting led to a certain degree of radiation exposure to patients. So, reductions in treatment time and puncture time could dramatically reduce radiation dose which harmed patient's health [20]. One disadvantage of US guidance was limited capability to visualize tumor boundary and monitor thermal effects due to air bubbles produced by vaporization; CT guidance had a high accuracy and won't be interrupted by the air bubbles, particularly in the patients with HCC who underwent TACE, which contributed to distinguish adequate safety margin (measured as the distance from the initial tumor boundaries to the border of the post-treatment ablation zone) [21, 22]. These could, therefore, partly explain why local recurrence rates of combination group was lower than that of US group in our study.

After treatment, AFP among three groups had a continued momentum of decline, the liver and renal function were no non-reversible damage comparing to preoperative, these results were consistent with past experiments[23], demonstrated the validity and security of MWA.

Limitations of this study were mainly in the following aspects: Firstly, the large sample size, multicenter random controlled trial and long-term outcomes were not investigated. However, preliminary results showed combination guidance had advantage over single image. This supported further validation

studies with long-term data. Secondly, some clinical variables that could potentially affect the health outcomes, such as tumor number, location and size, comorbidity, we were unable to delve into these analyses to the desired detail. Therefore, more specific studies were needed in the future to compare MWA under different image guidance. Thirdly, we included lesions less than 5 cm in size to assess the effects of microwave ablation under different image guidance. It, so that, is not comprehensive.

Conclusions

In conclusion, the combined imaging guidance could overcome some disadvantages of CT and US, as single modality of imaging guidance. CT- combined US-guided microwave ablation in patients with BCLC-A1-3 HCC appeared to be much better in security and efficiency than that under the guidance of CT or US alone.

Declarations

Ethics approval and consent to participate

The study protocol was approved by the ethical committee of Beijing Ditan Hospital, Capital Medical University, the institute consent to participate.

Consent for publication

We confirm that all individual person in the study have consent to publish their data;The manuscript has been read and approved by all named authors and the order of authors listed in the manuscript has been approved by all of us. All authors have approved to submit to your journal for publication.

Availability of data and material

Please contact author for data requests

Competing interests

All authors declare that they have no any competing interest.

Funding

The subject is funded by the Scientific Research Foundation of Beijing Ditan Hospital (Grant No.DTYM201605)

Authors' contributions

Changqing Li, raised study concepts adn participated in study design. Wenpeng Zhao together with Jiang Guo performed the study.

Wenpeng Zhao drafted the manuscript.

Honglu Li, Liang Cai, Youjia Duan, Xiaopu Hou and Zhenying Diaocollected the clinical data and participated in statistical analysis.

Xihong Shao, Hongliu Du and Wei Li participated in quality control of data and algorithms.

Acknowledgements

The subject is supported by the Scientific Research Foundation of Beijing Ditan Hospital

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Figures

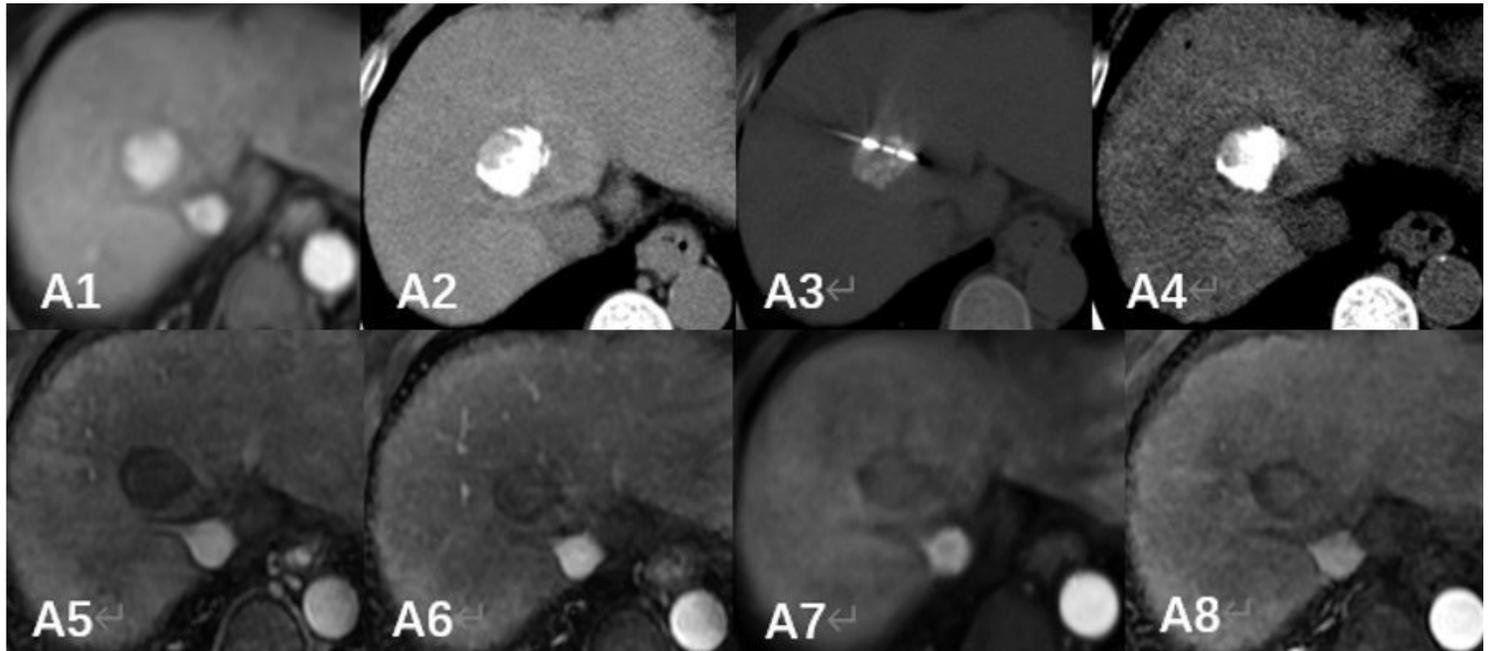


Figure 1

A 58-year-old female. A1: Contrast-enhanced MRI indicated a liver lesion located in segment 8, with a size of 2.8cm×3.2cm; Arterial enhancement was observed. A2: After TACE, the accumulation of iodized oil in the lesion was satisfactory. A3, A4: MWA was applied under the guidance of CT; Around the lesion was low density ring after MWA on CT images. A5-A8: Subsequent contrast-enhanced MRI within 12 months confirmed that the lesion had been completely ablated (A5, 1 month post-MWA; A6, 3 months post-MWA; A7, 6 months post-MWA; A8, 12 months post-MWA).

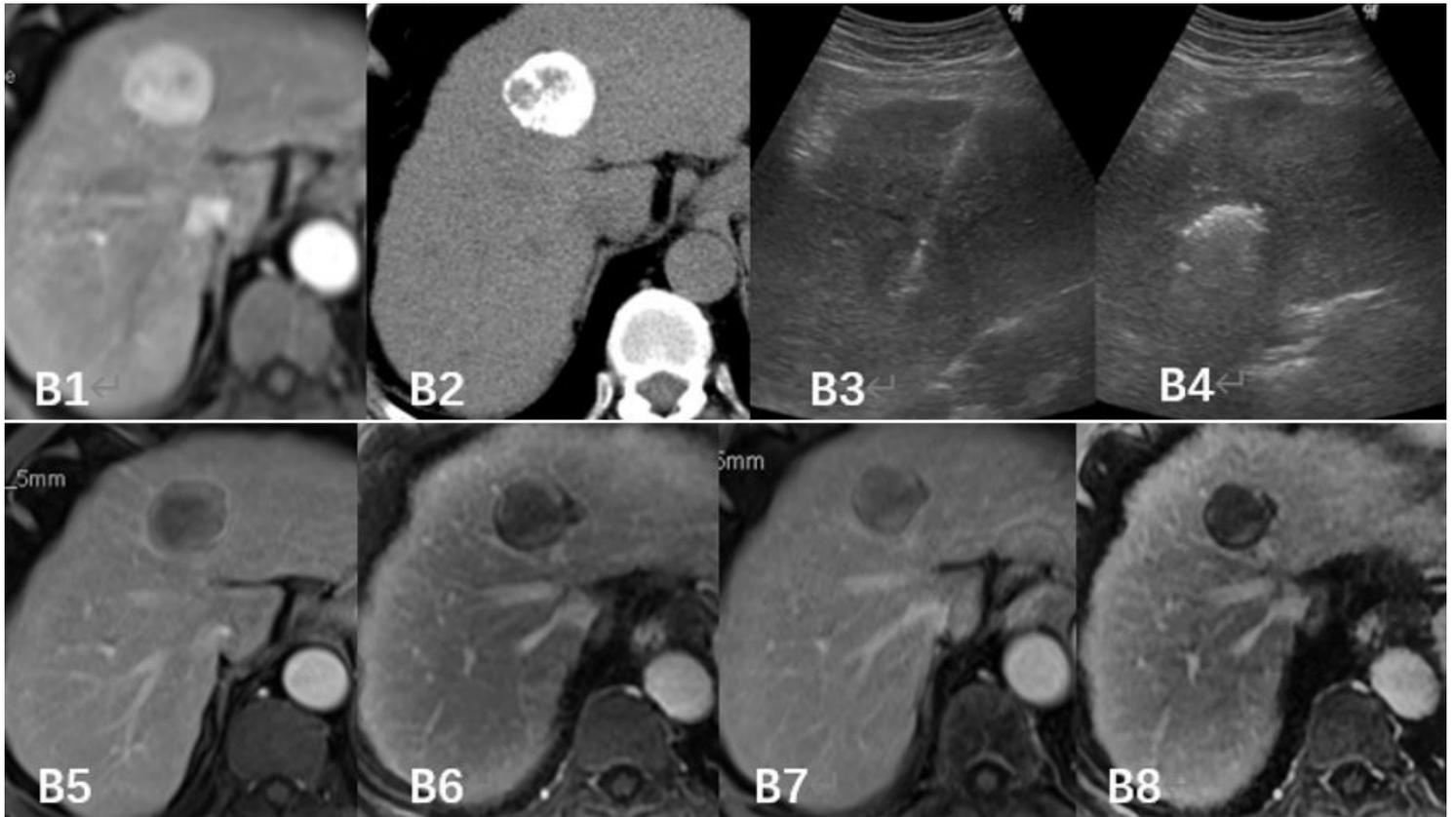


Figure 2

A 64-year-old male. B1: Contrast-enhanced MRI indicated a liver lesion located in segment 4, with a size of 3.6cm×3.8cm; Arterial enhancement was observed. B2: After TACE, the accumulation of iodized oil in the lesion was satisfactory. B3, B4: A hypoechoic lesion in US, MWA was applied under the guidance and monitoring of real-time US; liver lesion was completely covered by diffusely increased echogenicity after MWA. B5-B8: Subsequent contrast-enhanced MRI within 12 months confirmed that the lesion had been completely ablated(B5, 1 month post-MWA; B6, 3 months post-MWA; B7, 6 months post-MWA; B8, 12 months post-MWA).

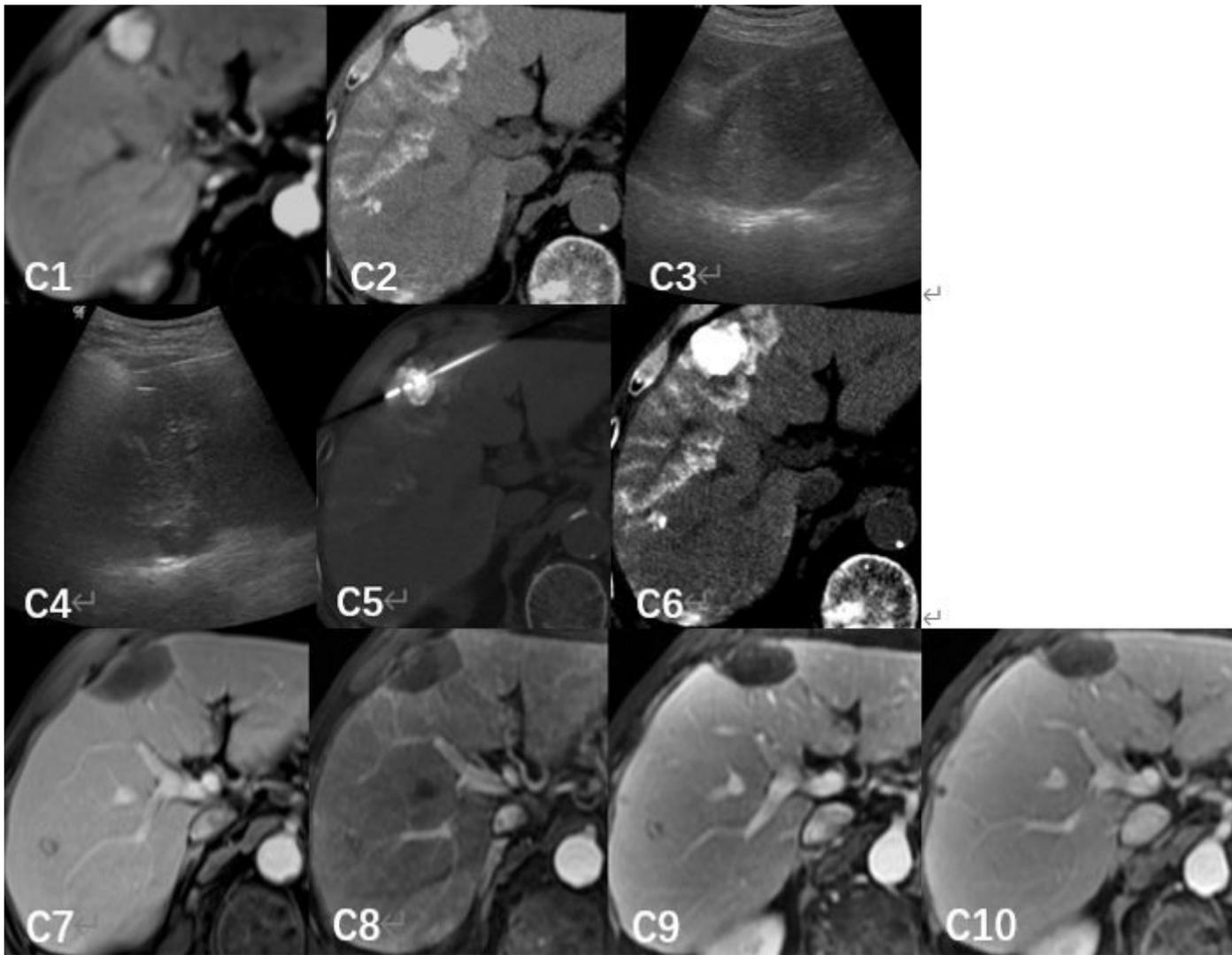


Figure 3

A 70-year-old male. C1: Contrast-enhanced MRI indicated a liver lesion located in segment 4, with a size of 2.6cm×3.0cm; Arterial enhancement was observed. C2: After TACE, the accumulation of iodized oil in the lesion was satisfactory. C3, C4: Iso-hypoechoic lesion in US, MWA was applied under the guidance and monitoring of real-time US; Liver lesion was completely covered by diffusely increased echogenicity after MWA. C5, C6: Using CT scan further checked the position of Microwave electrode and evaluated whether the lesion had been completely ablated after MWA. C7-C10: Subsequent contrast-enhanced MRI within 12 months confirmed that the lesion had been completely ablated (C7, 1 month post-MWA; C8, 3 months post-MWA; C9, 6 months post-MWA; C10, 12 months post-MWA).