Artificial ascites-assisted microwave ablation for liver cancer adjacent to the diaphragm and perioperative nursing care

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Abstract. Liver cancer near the deep diaphragm can be difficult to visualize due to the effects of lung gas, which presents a challenge for microwave ablation (MWA). The present study aimed to investigate the feasibility and efficacy of artificial ascites-assisted MWA for treating liver cancer near the deep diaphragm, as well as the significance of perioperative nursing. A retrospective analysis was conducted on patients who underwent artificial ascites-assisted MWA for liver cancer located near the deep diaphragm between January 2016 and December 2022. Normal saline was utilized as artificial ascites to safeguard the deep diaphragm during MWA. The study recorded the procedural success rate, incidence of major complications, technical efficacy of ablation and local tumor progression (LTP). A total of 62 lesions in 54 patients were included, with 44 men and 10 women, and a mean (± SD) age of 55.64±10.33 years. The ultrasound image quality scores for liver cancer before and after ascites were 3.57±0.79 and 4.89±0.33, respectively, showing a statistically significant difference between the two groups ($t=16.324$; $P<0.05$). No diaphragm injury, skin burns at the puncture site or abdominal hemorrhage occurred during the procedure. A single patient developed right-sided pleural effusion, which did not require drainage. The complete ablation rate was 94.4% (51/54) at 1 month post-ablation, with 3 patients experiencing recurrence and receiving additional MWA treatment. The median follow-up time for the patients in this study was 21 months (range, 12-45 months), with a LTP rate of 5.6% (3/54). In conclusion, MWA assisted by artificial ascites is a safe and effective treatment for liver cancer near the deep diaphragm. Furthermore, perioperative treatment and rehabilitation of the patients with high-quality nursing is beneficial.

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Introduction

Liver cancer is the fourth leading cause of death worldwide, with approximately one-half of the cases occurring in China. Approximately 466,000 new cases of hepatocellular carcinoma are reported annually in China, constituting 55.4% of the global incidence. Concurrently, ~422,000 associated deaths are recorded per annum, representing 53.9% of worldwide mortality from this disease (1,2). Abdominal surgery, liver transplantation and local thermal ablation are commonly used methods for treating liver cancer (3,4). Thermal ablation utilizes energy such as radiofrequency, microwave or laser energy to generate high temperatures and destroy tumor tissues for therapeutic purposes (5). Compared to radiofrequency and laser ablation, microwave ablation (MWA) can heat tissue more rapidly, reaching higher temperatures, and thus more quickly destroy tumor cells. MWA has a smaller thermal deposition effect on blood vessels and bile ducts, which means it is safer when treating tumors close to these structures, reducing damage to surrounding tissues. Additionally, microwaves can penetrate tissues more effectively and deliver energy to greater depths, making it more effective in treating deeper-seated tumors (6,7).

However, adjacent to the deep diaphragm muscle, some lesions may be difficult to visualize due to the influence of gas in the lungs, posing challenges for ablation (8). Furthermore, the heat generated during ablation can affect the diaphragm muscle and potentially cause damage (9). Therefore, when performing MWA for liver cancer adjacent to the deep diaphragm muscle under ultrasound guidance, issues such as the quality of the ultrasound images and diaphragm muscle protection need to be addressed.

To protect the diaphragm muscle from thermal injury, artificial ascites injected into the perihepatic peritoneal space can be utilized as a heat barrier to separate the ablation zone from the diaphragm (10,11). The present study aimed to retrospectively analyze the safety and effectiveness of artificial ascites-assisted MWA for liver cancer adjacent to the deep diaphragm muscle, as well as perioperative nursing measures to ensure the safety of the procedure and reduce complications.

Materials and methods

Study design. The study has been approved by the Ethics Committee of Hangzhou Xixi Hospital (Hangzhou, China) and strictly adheres to the ethical guidelines outlined in the Helsinki Declaration. Patients with liver cancer who underwent artificial ascites-assisted MWA treatment near the diaphragm at Hangzhou Xixi Hospital between January 2016 and December 2022 were included as the study subjects, with all patients or their guardians providing signed informed consent forms.

Inclusion criteria. The inclusion criteria were as follows: i) A clinical diagnosis of liver cancer that met the Milan criteria (6) or histopathological confirmation through preoperative puncture biopsy. Milan criteria specific contents include: For a solitary tumor, the diameter should not exceed 5 cm. For multiple tumors, the total number of tumors should be ≤3, and the maximum diameter of each individual tumor should not exceed 3 cm. There should be no evidence of macrovascular invasion, lymph node metastasis or extrahepatic metastasis; ii) a tumor located within 1 cm of the diaphragm, with a single lesion diameter not exceeding 5 cm, or multiple lesions (≤3) with each individual lesion diameter not exceeding 3 cm; and iii) Child-Pugh class A or B (6). Child-Pugh class A indicates relatively preserved liver function, characterized by low total bilirubin levels, high serum albumin levels, mild prolongation of prothrombin time, minimal or no ascites, and only mild symptoms of hepatic encephalopathy. By contrast, patients with Child-Pugh class B, representing moderate to severe impairment of liver function, exhibit worsening in one or more of these parameters, including elevated bilirubin levels, decreased albumin level and significantly prolonged prothrombin time. They may also present with moderate ascites or some degree of hepatic encephalopathy.

Exclusion criteria. The exclusion criteria were as follows: i) The presence of major vascular invasion and/or distant metastasis; and ii) a lack of regular follow-up after surgery or patients who were lost to follow-up.

Artificial ascites technique. The tumor location was initially assessed and visualized clearly using ultrasound. Subsequently, a single cavity central venous catheter set was utilized to draw 5 ml of 0.9% sodium chloride solution and pre-place the guide wire into the empty needle tube. With ultrasound guidance, the needle tip was carefully inserted parallel to the liver surface, targeting the puncture point near the gall bladder at the lower margin of the right anterior lobe of the liver. Upon encountering a sudden decrease in resistance, the 0.9% sodium chloride solution was injected, and if no resistance was encountered, the wire was advanced further. In the absence of resistance, the wire was expeditiously introduced into the abdominal cavity, followed by the withdrawal of the needle and placement of the drainage tube along the guide wire. Throughout the procedure, the patient maintained a Trendelenburg position and continuous instillation of 0.9% sodium chloride solution at 40˚C into the abdominal cavity was performed until the separation distance between the liver and the diaphragm reached a minimum of 0.5 cm.

Ablation procedure. MyLab™ X90 (Esaote SPA) color doppler ultrasound machine was used, equipped with contrast-enhanced ultrasound function and abdominal convex array probes CA431 and CA541, with a frequency range from 1 to 8 MHz. MWA was performed using a KY-2000 MWA instrument (Nanjing Kangyou Co., Ltd.). After the establishment of artificial ascites, ultrasound-guided MWA was performed. All patients underwent general anesthesia and the procedure was performed according to the ablation plan determined preoperatively: The ablation power was set at 60 W, the size of the ablation area was ~3.5x2.5 cm and the ablation time at each point was 6 min. The microwave ablation needle has a temperature sensor that displays the internal temperature in real time. Tumors with a diameter of <2 cm were ablated with a single needle and a single point, while tumors with a diameter of 2-5 cm were ablated with a single needle and multiple points, or double needles and multiple points overlapping. Ablation was required to extend 0.5 cm beyond the tumor margin to ensure a safe margin. Immediately after ablation, contrast-enhanced ultrasound assessment was performed to determine whether the ablation zone reached the safe boundary. If the safe boundary was reached, the ablation was terminated; otherwise, additional ablation was performed immediately until the safe boundary was reached.

Tumor image quality score. The study evaluated the visualization of liver cancer through the assessment of ultrasound images before and after the introduction of artificial ascites. The images were scored by three experienced radiologists independently, with each image receiving a score that was then averaged to determine the final score. The scoring criteria were as follows: 1 point, the lesion was affected by gas in the lung and could not be visualized; 2 points, the visualized region represented <1/3 of the lesion; 3 points, the visualized region represented between 1/3 and 2/3 of the lesion; 4 points, the visualized lesion represented >2/3 of the lesion; and 5 points, complete and clear visualization of the lesion. This scoring system can help physicians evaluate the quality and visualization of ultrasound images of liver cancer to guide subsequent treatment and decision-making.

Perioperative nursing. Preoperative nursing involved the nurses explaining the purpose, methods, advantages, surgical process, precautions and possible complications of MWA to the patients and their families in detail, so as to eliminate the anxiety and tension of patients. These patients received Situation, Background, Assessment and Recommendations communication mode of care, in addition to the routine preoperative care provided (12).

During the operation, other nursing duties were required. Firstly, venous access is established to replenish and rescue fluid circulation. The position is then assisted in choosing the supine or lateral position according to the location of the lesion. The operation of all equipment was tested, checking

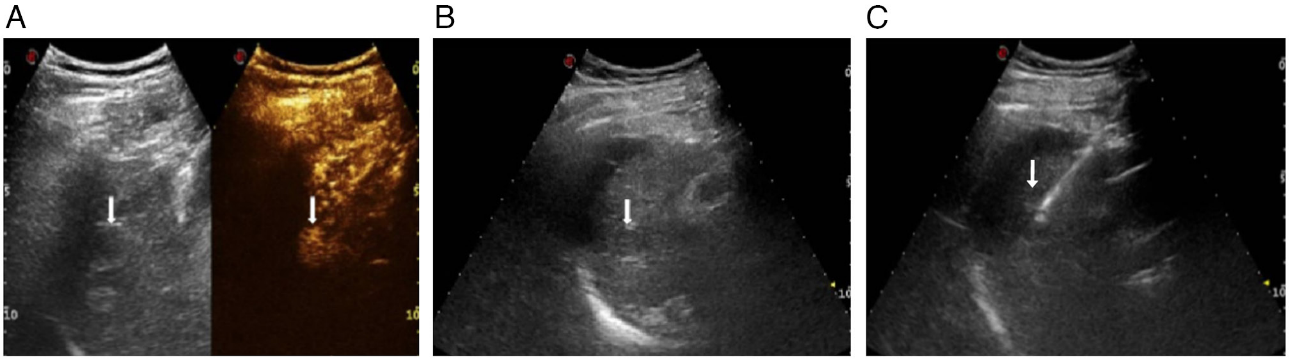

Figure 1. Representative case of microwave ablation of liver cancer performed after artificial ascites in a 67-year-old man: An ultrasound image of liver cancer in the right liver adjacent to the dome of the diaphragm. (A) Before artificial ascites, the liver cancer could not be clearly displayed by conventional ultrasound, and the lesion could not be completely visualized by contrast enhanced ultrasound (location of the tumor indicated by arrows). (B) Artificial ascites was established during microwave ablation, and the outline of the lesion was clearly visible (hypoechoic nodules indicated by arrows). (C) Ultrasound-guided microwave ablation was performed, with precise needle placement during the operation to complete the microwave ablation treatment (hypoechoic nodules indicated by arrows).

whether the connecting instrument pipeline was smooth. The doctor was then assisted to operate the MWA instrument, closely observing the ECG monitor, and watching for bleeding, changes in heart rate, dyspnea and other reactions.

Postoperative nursing care included monitoring the vital signs and clinical symptoms of the patients for the first 72 h after ablation to detect any early complications such as fever, swelling, pain and bleeding. In particular, severe complications, which may result in significant morbidity and disability, would require an increased level of care, hospitalization or a significantly prolonged hospital stay.

The aforementioned nursing measures for MWA before, during and after operation were designed to ensure the smooth operation and promote the recovery of patients. Nurses aimed to closely observe any changes to the condition of the patients during the whole process and communicate with doctors in time to ensure the safety and comfort of the patients.

Complications. Pain and fever are common mild complications after ablation, and even pleural effusion may occur. Burns and perforations of the diaphragm, gastrointestinal injuries, severe bleeding and stress ulcers require further treatment. In particular, severe complications that may lead to significant morbidity and disability require increased levels of care, hospitalization or significantly prolonged hospital stays.

Follow-up. Patients with complications were managed according to the complication, while those without serious complications were discharged 3-7 days after surgery. Contrast-enhanced magnetic resonance imaging (MRI) or contrast-enhanced computed tomography (CT) was performed at 1 month after ablation to evaluate the short-term efficacy of MWA. Complete ablation was defined as ablation completely covering the lesion without abnormal enhancement. The ablation was defined as incomplete ablation if it did not completely cover the lesion and there was neoplastic enhancement. If residual lesions were present, repeat thermal ablation or surgical resection may be required. Subsequently, contrast-enhanced MRI or contrast-enhanced CT was performed every 3-6 months to assess local tumor progression (LTP) in comparison with the previous images, and technical efficacy and LTP were recorded.

Statistical analysis. Data analysis and mapping were performed using the R software (version 3.5.3; R Core Team). Patient age, tumor size and sonographic quality score were used as measurement data and expressed as mean ± SD. The paired t-test was used for comparison of image score before and after the induction of artificial ascites. To evaluate different radiologists in ultrasonic image visual grading consistency, Cohen's κ coefficient predominate analysis method was applied. The number of cases of adverse reactions and complications, the number of cases of tumor complete ablation and the number of cases of LTP were included as the count data and expressed as n (%). $P<0.05$ was considered to indicate a statistically significant difference.

Results

Baseline characteristics. A total of 62 lesions in 54 patients were included in this study, and all patients underwent percutaneous MWA. The cohort consisted of 44 men and 10 women, with ages ranging from 35 to 82 years and a mean age of 55.64±10.33 years. Among the patients, 46 had a single lesion, while 8 had two lesions. A total of 39 patients were receiving treatment for the first time, while 15 had recurrent lesions (7 with prior surgical resection and 8 with prior thermal ablation). The distribution of the tumors was predominantly concentrated in liver segments I (1; 1.6%), IV (6.5%), VII (23; 37.1%) and VIII (34; 54.8%). The size of the tumors ranged from 14 to 49 mm, with a mean size of 31.64±8.37 mm (Table I).

Ultrasonic image evaluation. The κ-value among the three radiologists was 0.878, indicating a high degree of agreement among the three radiologists in the visual evaluation of ultrasound images. The score for ultrasonographic image quality before artificial ascites was 3.57±0.79, while after artificial ascites it increased significantly to 4.89±0.33 (t=16.324; $P<0.05$), indicating a marked improvement in lesion image quality following artificial ascites treatment (Fig. 1).

Amount of artificial ascites. Artificial ascites successfully separated the diaphragm from the liver at a distance of ≥0.5 cm in all 54 patients. The mean dosage of 0.9% sodium chloride solution was 1,021±544 ml (range, 500-2,000 ml) (Table I).

Microwave ablation. Among the 62 lesions, 45 lesions were ablated with single needle and single point, and 17 lesions were ablated with single needle and multiple points or double needle and multiple points overlapping. In 13 cases, the ablation range was insufficient, and additional ablation was performed immediately until the safe boundary was reached.

Complications. There were no treatment-related deaths or cardiopulmonary complications due to fluid overload. No diuretics or punctures were required to manage any of the patients infused with artificial ascites. The ascites was completely absorbed before the patient was discharged. There was no injury to the diaphragm, no burn to the skin at the puncture site and no abdominal hemorrhage. A single patient developed right-sided pleural effusion, which was not drained, and on the seventh postoperative day, the pleural effusion had disappeared on re-examination. The most common minor complications after ablation were pain and fever. A total of 11 patients developed fever after treatment and were treated with antipyretics (Table I). A total of 12 patients required analgesics after treatment.

Efficacy. Enhanced MRI or CT examination was conducted within 1 month of ablation, resulting in a complete ablation rate of 94.4% (51/54). Only 3 patients experienced recurrence and subsequently underwent further ultrasound-guided MWA treatment. The patients were followed up for 12 to 48 months post-surgery, with a median follow-up period of 20 months. According to the enhanced MRI or CT results, the LTP rate was found to be 5.6% (3/54).

Table I. Clinical information of patients (n=54) and characteristics of liver cancer.

Characteristic	Value	P-value
Age, years	55.64±10.33	
Sex, n (%)		
Male	44 (81.5)	
Female	10 (18.5)	
Number of lesions, n (%)		
Single	46 (85.2)	
Multiple	8 (14.8)	
Liver segment distribution, n (%)[a]		
I	1 (1.6)	
IV	4 (6.5)	
VII	23 (37.1)	
VIII	34 (54.8)	
Treatment mode, n (%)		
First	39 (72.2)	
Second or more	15 (27.8)	
Tumor size, mm	31.64±8.37	
Image score		<0.05
Before	3.57±0.79	
After	4.89±0.33	
Artificial ascites dosage, ml		
Minimum	500	
Max	2,000	
Mean ± SD	1,021±544	
Microwave ablation, n (%)[a]		
Single needle and point	45 (72.6)	
Multiple points	17 (27.4)	
Complications, n (%)		
Diaphragmatic injury	0 (0.0)	
Hematoma	0 (0.0)	
Pleural effusion	1 (1.9)	
Fever	11 (20.4)	
Pain	12 (22.2)	
Efficacy, n (%)		
Complete ablation	51 (94.4)	
Recurrence	3 (5.6)	

[a]n=62.

Discussion

MWA has been shown to effectively control and eliminate liver cancer lesions (13); it preserves the patient's normal liver tissue to the greatest extent and reduces the impact on liver function (14). The artificial ascites technique can separate the diaphragm from the liver, improving the image quality of liver cancer ablation near the diaphragm and reducing thermal damage caused by microwave energy. Perioperative high-quality nursing can enhance the safety and therapeutic effect of MWA. Therefore, safe and effective treatment methods, along with systematic nursing measures, are crucial for ensuring rapid patient recovery and surgical success.

Artificial ascites improves visualization of adjacent deep diaphragmatic muscle lesions by increasing the distance between the lesion and lung, thereby reducing interference from gas in the lung and enhancing sonographic image quality (15,16). Quality scores of tumor ultrasonographic images before and after artificial ascites were established in the present study. The results showed a significant improvement in ultrasonographic image quality after artificial ascites, leading to improved visualization and integrity of tumors adjacent to the top of the diaphragm. This ultimately enhances puncture accuracy, ablation effectiveness and operator confidence. The thermal barrier formed by artificial ascites reduces thermal damage to the diaphragm during ablation (17), as evidenced by no instances of diaphragmatic injury among patients in the present study. Huang *et al* (15) conducted a study on patients with previous history of abdominal surgery to evaluate the feasibility and effectiveness of artificial ascites-assisted thermal ablation in the treatment of liver cancer near the gastrointestinal tract. Artificial ascites was successfully utilized in 38 out of 40 operations, resulting in a success rate of 95%, and effectively protecting the surrounding organs.

However, the use of artificial ascites may be limited by abdominal adhesions, which can hinder the separation of fluid from the patient's gastrointestinal tissue, particularly in patients with a history of previous abdominal surgery. However, in the present study, none of the cases exhibited any radiographic evidence of diaphragmatic injury during postoperative review, and no abnormalities such as perforation were detected during follow-up, indicating that artificial ascites played a protective isolating role.

In the present study, only 1 patient developed a small pleural effusion that was not treated with drainage. In this patient, the lesion was large and tightly connected to the diaphragm, along with a history of surgery and the presence of visceral adhesions. Injecting too much ascites may lead to the occurrence of pleural effusion, and may also be related to indirect stimulation of the diaphragm and lung after heating of the ascites (18). During ablation, it is important to closely monitor bubble coverage resulting from thermal ablation and adjust the power emission of the ablation needle to effectively prevent burns.

Mild adverse effects, such as a low fever and epigastric pain, are commonly observed after liver cancer ablation. These symptoms generally do not require special treatment and will resolve on their own (19). In fact, artificial ascites infusion can even reduce the pain during subcapsular radiofrequency ablation of hepatocellular carcinoma (20). In the present study, no stress response were triggered by the infusion of artificial ascites. The management of a perioperative stress response is very difficult, and it will even affect the operation and the evaluation of the curative effect (21). Although the present study did not observe any cases of stress response, it does not rule out its occurrence in future cases, and adequate monitoring during the perioperative period is necessary.

Studies have indicated that failure to achieve a safe boundary during liver cancer ablation is a significant factor in postoperative LTP (22). In the present study, contrast-enhanced ultrasonography was utilized during the ablation process to assess immediate efficacy. For patients with inadequate ablation, additional procedures were performed until a safe margin was reached. At 1 month post-operation, the complete ablation rate was 94.4% (51/54), which aligns with a previous report on thermal ablation for liver cancer adjacent to the diaphragm (16).

Perioperative nursing primarily involves comprehensive care of the psychological, physiological and social well-being of the patients throughout the entire operation process to ensure they receive satisfactory treatment outcomes (23). Strengthening preoperative education can alleviate patient anxiety and improve surgical compliance. Nursing staff should be knowledgeable about and proficient in the treatment procedures related to ablation technology, while also developing relevant nursing process plans. Postoperative care is equally important for ensuring rehabilitation and timely management of unexpected events. Close observation of the patient's condition after surgery is essential, along with implementing relevant treatment measures in collaboration with physicians to ensure smooth progress across all aspects of the operation (24). Safe and effective treatment methods alongside systematic nursing measures are crucial for promoting rapid patient recovery and increasing surgical success rates (25).

The present study has several limitations. Firstly, it is retrospective with a small sample size; therefore, prospective large-sample studies are necessary to validate the safety and efficacy of artificial ascites in liver cancer ablation. Additionally, the tumor sonographic quality score used in this study was subjective and dependent on operator experience.

In conclusion, artificial ascites not only enhances lesion sonography visualization but also helps prevent thermal ablation-induced diaphragm burns to reduce complications. Perioperative treatment and rehabilitation of the patients with high quality nursing is beneficial.

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Availability of data and materials

The data generated in the present study may be requested from the corresponding author.

Authors' contributions

QA, YP and DL contributed to the data curation, analysis, investigation and writing of the manuscript. FL, ZK and DL performed and analyzed the ultrasonography examinations and operation of the patients. XZ designed and supervised the project, acquired funding and revised the manuscript. QA reviewed and edited the writing, and validated the whole analysis process with regard to study design and expectations. All authors read and approved the final manuscript. QA and DL confirm the authenticity of all the raw data.

Ethics approval and consent to participate

This study was conducted according to the Declaration of Helsinki. Ethics approval was obtained from the Medical Ethics Committee of Hangzhou Xixi Hospital (Hangzhou, China; approval no. 2021KY937) and written informed consent was obtained from all patients or their guardians.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no conflict of interest.

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