Percutaneous ultrasound-guided thermal ablation for liver tumor with artificial pleural effusion or ascites

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[Abstract] Background and Objective: Percutaneous ultrasound-guided thermal ablation is one of the major treatment methods for liver cancer. Tumor location close to the diaphragm or gastrointestinal tract was regarded as the treatment contraindication before due to poor visibility of the tumor or increased risk of thermal injury to the adjacent organs. This study used artificial pleural effusion or ascites to extend the indications of thermal ablation for liver cancer. Methods: Artificial pleural effusion (20 cases) or ascites (36 cases) was performed in 56 difficult cases of percutaneous thermal ablation for liver tumors. The technical success rates, the rate of approaching the procedure goal, complications, and local treatment response were assessed. Results: The technical success rates were 95% (19/20) for artificial pleural effusion and 100% (36/36) for artificial ascites, the achieve purpose rates were 100% (19/19) and 91.7% (33/36), the complete ablation rates were 84.2% (16/19) and 93.9% (31/33), respectively. Coughing, transient hematuria, and subcutaneous effusion were observed in 3 patients after the procedure of artificial pleural effusion, and hydrothorax in the right chest occurred in 1 patient during the artificial ascites process. Conclusions: Thermal ablation with the use of artificial pleural effusion or ascites is a safe and effective treatment for liver tumors, and the technique can widen the indications of thermal ablation for liver tumors.

Key words: Artificial pleural effusion, artificial ascites, thermal ablation, liver neoplasms
importantly, because conventional thermal ablation is associated with an increased risk of intestinal perforation, the lesion adjacent to the gastrointestinal track is listed as a contraindication of ablation. Even if thermal ablation is performed on tumor in such locations, the ablation time is shortened to avoid injury on the gastrointestinal track, leaving incomplete ablation in the margin of the tumors. In addition, no safe puncture path can be identified for conventional thermal ablation in some tumors close to major intrahepatic vessels or due to interference from the lungs or ribs. How to provide opportunities of thermal ablation procedures as well as complete thermal ablation for these difficult cases is significant in expanding the indications of thermal ablation in liver tumors, increasing complete ablation rate, and improving long-term survival in these patients. Herein, we report our preliminary experience in using artificial pleural effusion or ascites in the treatment of such difficult cases, and evaluate its feasibility, complications, and clinical value.

Materials and Methods

Clinical data

Between December 2000 and January 2010, among the patients with liver tumors who were to receive ultrasonography-guided percutaneous thermal ablation at the Department of Ultrasonography of the First Affiliated Hospital of Sun Yat-sen University, 56 were defined as difficult cases due to unclearly visualized lesions as a result of gas interference, or the lack of puncture path for thermal ablation, or high risk of injury on adjacent organs and tissues during thermal ablation of the lesion. Of the 56 patients, 46 were men and 10 were women; they aged between 24 and 80 years with a median of 59.5 years. Before the ablation procedures, artificial pleural effusion was induced in 20 and artificial ascites in 36 patients.

Criteria for inducing artificial pleural effusion were as follows: lesions were not clearly revealed by conventional ultrasonography due to its location in the hepatic dome (in 2 patients); lesions were close to the gastrointestinal track (in 34 patients). HCC was seen in 28 patients; all of them were HBsAg-positive; hepatic function was rated as Child grade A in 21 and grade B in 7 patients. Metastatic hepatic cancer was found in 7 patients (from colorectal cancer in 5, pancreatic cancer in 1, and cholangiocarcinoma in 1 patient). One patient had intrahepatic cholangiocellular carcinoma. Target lesions were 1.0–6.7 cm in diameter, averagely (3.1 ± 1.4) cm. The tumor was located in the right lobe in 29 patients and in the left lobe in 7 patients.

The trial was conducted in accordance with medical ethical principles and informed consent was signed by all patients before the procedures.

Instruments and agents

FORSEA MTC-3 microwave ablation therapeutic system (by Qinghai Microwave Electronics Institute, Nanjing, China) and Radionics radiofrequency therapeutic system (by Valleylab, US) were used to perform microwave and radiofrequency ablation, respectively. Acuson Sequoia 512 (by Siemens Medical Solutions, Mountain View, CA, USA; with 4V1 probe at the frequency of 1.0–4.0 MHz) and SSA-250A (by Toshiba, Japan; with 3.75 MHz linear array puncture probe) ultrasonography systems were used for ultrasonic guidance. In addition, 5% glucose saline or normal saline, 18G-PTC needle (by Hakko Corporation, Japan) and veress needle (by Olympus Corporation, Japan) were used during the procedures.

Artificial pleural effusion or ascites

As guided by ultrasonography under local anesthesia, the puncture needle was slowly inserted from selected puncture sites: for artificial pleural effusion, the veress needle was punctured at the right mid-axillary line on 7th intercostal space level; for artificial ascites, the 18G-PTC needle was punctured at the right mid-axillary line on lower margin of the liver for the lesion in the right lobe, or at the upper abdomen on the left margin of the liver for the lesion in the left lobe. When the resistance was suddenly reduced, glucose saline or normal saline was instilled through the needle. If saline was instilled without any resistance, it suggested that the needle had achieved the pleural or abdominal cavity. The volume of instilled fluid was determined based on the changes in the ultrasonic images. When inducing artificial pleural effusion, pulmonary tissue should be completely pushed away from the costophrenic angle and the hepatic dome should be completely revealed. With artificial ascites, the target tumor should be separated from the diaphragm or gastrointestinal track, the puncture
path should be revealed. Microwave and radiofrequency ablation were performed under local anesthesia and intravenous analgesia. During microwave ablation, single-needle puncture and single ablation were used for the nodules less than 3 cm in diameter, multiple-needle puncture and multiple-spot ablation for the nodules more than 3 cm in diameter. During radiofrequency ablation, single-needle puncture and single ablation were used for the nodules of less than 2 cm in diameter, multiple-needle puncture and multiple ablation for the nodules of more than 2 cm in diameter.

**Observed parameters**

Time needed to induce artificial pleural effusion and ascites, volume of instilled fluid, and procedure success rate were recorded. Whether the lesion was clearly revealed and completely separated from adjacent tissues, and the revealing of puncture path were observed. Complications caused by the procedures were recorded. Contrast enhanced CT or contrast enhanced ultrasonography were performed 1 month after the ablation to evaluate local efficacy. No enhancement in target lesion was regarded as complete ablation, and images otherwise indicated incomplete ablation. Re-emergence of lesion in initial treatment area was regarded as local recurrence, whereas the emergence of new intrahepatic or extrahepatic lesions regarded as distant metastasis.

**Statistical analyses**

SPSS 13.0 software was used. Measurement data were presented as mean ± standard deviation.

**Results**

**Procedure time and volume of instilled fluid for artificial pleural effusion and ascites**

In general, the procedure took 10–15 min. The volume of instilled fluid was 700–1000 mL in artificial pleural effusion and 150–1000 mL in artificial ascites. If the goals were not achieved after 1000 mL of fluid had been instilled, the procedure would be terminated.

**Procedure success rate**

Among 56 cases of artificial pleural effusion or ascites, 1 failed. The success rate was 98.2% (55/56). The technical success rates were 95% (19/20) for artificial pleural effusion and 100% (36/36) for artificial ascites.

**Achievement of predefined goals**

The induction of artificial pleural effusion was successful in 19 (95.0%) patients. In 15 patients with tumors in the S7.8 of the liver near the hepatic dome, the tumor was partially or completely sheltered by gas-containing pulmonary tissue and could not be revealed or fully revealed before instilling of artificial pleural effusion. After that, all lesions were clearly revealed (Figure 1). In another 4 patients whose tumors were located in S1.3.6 of the liver, these lesions were surrounded by major vessels without safe puncture path. When pleural effusion was instilled, the pulmonary tissue was compressed and lifted, as a result, a safe

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**Figure 1** Artificial pleural effusion performed in a 43-year-old patient with hepatocellular carcinoma located in the segment 8, 2.3 cm in diameter

Before intrapleural fluid infusion, the cranial side of the tumor (arrow) is hardly visible because of the interference of the air in the lung (arrowhead) (A). After giving local anesthesia, the veress needle was carefully inserted through an intercostals space (usually the seventh intercostals between the right anterior and the right posterior axillary lines) until the tip reaches the pleural cavity, the needle was considered to be correctly inserted into the pleural cavity when no resistance was noted during the test injection. After infusing 500 mL of 5% glucose solution, the entire tumor (arrow) is clearly visible (arrowhead indicates the artificial pleural effusion) (B).
puncture path via the pleural cavity was identified.

The induction of artificial ascites was successful in all the 36 (100%) patients. Among the 34 patients whose tumors were close to the gastrointestinal tract with a distance < 5 mm, 31 had the liver separated from the intestines after induction of artificial ascites, increasing the safety of thermal ablation (Figure 2). The liver was not separated from intestine in 3 patients after induction of artificial ascites, and artificial ascites procedure was then terminated. In another 2 patients whose tumors were adjacent to the diaphragm, the lesions could not be completely revealed due to interfering air in the lung. When ascites was successfully instilled, the tumor was clearly revealed and the diaphragm separated from the liver by the fluid, avoiding the injury on the diaphragm during thermal ablation. Therefore, the procedures had achieved predefined goals in 52 (92.9%) patients.

![Figure 2](image)

**Figure 2** Artificial ascites performed in a 57-year-old patient with hepatocellular carcinoma located in the segment 6, 4.3 cm in diameter

Before artificial ascites, ultrasound shows index tumor (arrow) abutting the colon (A). After administering local anesthetic to the skin, we inserted an 18-gauge PTC needle along the edge of the liver. The needle was considered to be correctly inserted into the abdominal cavity when no resistance was noted during the test injection. After artificial ascites infusion of 5% glucose with a volume of 500 mL, the nodule and the adjacent colon is separated by ascites (arrowhead) and thus can be ablated without risk of thermal injury to the colon (B).

### Complications of artificial pleural effusion and ascites

Among the 55 patients who had successful induction of artificial pleural effusion and ascites, 4 had developed mild complications: 1 had cough after instilling of pleural effusion, 1 subcutaneous effusion, 1 transient hematuria, and 1 pleural effusion of the right pleural cavity. The subcutaneous effusion and the pleural effusion of the right pleural cavity were cured after puncture and aspiration, while cough and transient hematuria were cured after conservative treatment. No procedure-related death occurred. In the follow-up ultrasonography two weeks after the procedures in 19 patients with artificial pleural effusion and 36 with artificial ascites showed that the effusion or ascites had been completely absorbed.

### Local efficacy after thermal ablation on target lesions

Predefined goals of artificial pleural effusion and ascites were achieved in 52 patients, with a complete ablation rate of 90.4% (47/52) after thermal ablation, and 96.2% (50/52) after a supplementary second ablation. Local recurrence rate was 5.8% (3/52). Among the 23 patients with a lesion of <3 cm in diameter, the complete ablation rate was 95.7% (22/23); for the 29 patients with a lesion of ≥3 cm in diameter, the complete ablation rate was 86.2% (25/29). No treatment-related death occurred.

### Discussion

Ultrasonography-guided percutaneous thermal ablation is one of the main treatments of early stages hepatic cancer, and plays an important role in the treatment of recurrent hepatic cancer. However, in clinical practice, some lesions are inappropriate for thermal ablation because the lesions are partially or completely sheltered by gas-containing pulmonary tissue and are thus not revealed by ultrasonography, or due to the lack of safe puncture path as a result of adjacent major vessels, or because the lesions were close to the gastrointestinal track. Strategies for these difficult cases include thoracoscopic or laparoscopic thermal ablation, artificial pleural effusion,
artificial ascites, balloon placement between target tumor and adjacent organs, and so on. In this study, we used artificial pleural effusion and ascites to create treatment opportunities for these difficult cases and thus to expand the indications of ablation in liver tumors. Laeseke et al. suggested that 5% glucose saline was more proper than normal saline and sterilized water as a material for artificial pleural effusion and ascites. In our study, 5% glucose saline was used for non-diabetic patients and normal saline for diabetic patients.

The use of artificial pleural effusion in percutaneous thermal ablation was first reported by Shimada et al. The rationale behind it is that when artificial pleural effusion is instilled, pulmonary tissue will be compressed and lifted, so that the lesions can be devoid of interference from gas-containing pulmonary tissue. Meanwhile, the costophrenic angle is filled with fluid, creating a good acoustic window to clearly reveal lesions in the hepatic dome by ultrasonography, which is helpful for subsequent local treatment. Second, for some tumors, the puncture path has to go through important structures, such as the porta hepatis and gallbladder, or through the costophrenic angle. With artificial pleural effusion, pulmonary tissue will be pushed upward, so the puncture needle can start via the pleural cavity, and travel through a safer path. Kondo et al. had used adjuvant artificial pleural effusion to avoid damage to the important structure in the radiofrequency ablation of 587 patients with liver tumors, and found that this procedure had no effect on overall survival. Koda et al. induced artificial pleural effusion in 25 patients with lesions in the hepatic dome and then performed ultrasonography-guided radiofrequency ablation. After instilling pleural effusion, 22 (88%) lesions were revealed, and safer and more feasible puncture path was identified for 14 (56%) lesions. The complete tumor ablation rate was 88% (22/25). In our study, artificial pleural effusion was successfully induced in 19 patients, 15 tumors in the hepatic dome were clearly revealed, and safe puncture path was identified for 4 tumors where no puncture path was initially found due to adjacent major vessels; the complete ablation rate was 84.2% (16/19). Artificial pleural effusion-induced adverse reactions include cough and dyspnea. In our study, 1 patient experienced cough during the procedure after instilling of artificial pleural effusion, but the cough disappeared on the second day. After the thermal ablation, 1 patient developed hematuria, which was improved by fluid replacement therapy. Another patient had subcutaneous effusion due to movement of the thoracic puncture needle, and the effusion was removed by puncture and aspiration. No hemothorax, pneumothorax, and empyema occurred.

The use of artificial ascites in percutaneous thermal ablation was first reported by Ohmoto et al. The rationale behind it is that when artificial ascites is instilled, the fluid will be distributed between the diaphragm and the liver, so that tumors in the hepatic dome will be clearly revealed, avoiding intense pain caused by injury on diaphragm during thermal ablation. For the lesions adjacent to the hepatic dome, Rhim et al. had used adjuvant artificial ascites before performing thermal ablation in 25 patients with such tumors, with a procedure success rate of 88%, and 93.4% (15/16) of lesions that were initially unclearly revealed could be clearly seen; safer puncture path was identified in 77.8% (7/9) of the tumors. But they also pointed out that for the tumor in the upper segment of the right posterior lobe, it was difficult for the fluid to be distributed into the post-hepatic space due to the adherence and fixation effects of the triangular ligament of the liver, and thus the diaphragm was not well separated. In our study, 2 tumors in the hepatic dome were well separated from the diaphragm. In addition, artificial ascites was distributed between the liver and intestines, avoiding heat transmission to adjacent intestinal wall and subsequent intestinal perforation during thermal ablation; meanwhile, artificial ascites was also helpful in reducing the temperature around the liver and thus protected organs around the liver. Previously, Livraghi et al. reported that the incidence of intestinal perforation, a serious complication caused by thermal ablation for liver tumors, was as high as 0.7%, therefore patients with tumors adjacent to the intestine had to give up on this treatment. Further, Kim et al. found that artificial ascites would not increase the heat-sink effect induced during thermal ablation. Kondo et al. had achieved separation of the liver from the intestine in 43 (78%) out of 55 radiofrequency ablation procedures using adjuvant artificial ascites. The separation rate was 91.2% (31/34) in our study. The biggest hindrance when trying to achieve separation with artificial ascites is patients’ previous abdominal surgery. The adhesion of intra-abdominal organs occurs in almost all patients who have previous abdominal surgery, particularly adhesion between the liver and the intestines. Livraghi et al. revealed that 6 out of 7 patients with thermal ablation-induced intestinal perforation had a history of radical resection of colorectal cancer. In our study, the goals of artificial ascites were not achieved in 3 patients, of whom 2 had a history of partial liver resection and 1 had a history of radical resection of colon cancer. Two of them quited thermal ablation and switched to other treatments. In one patient who had a history of upper abdominal surgery and had not achieved separation with conventional artificial ascites procedure, 18G-PTC needle was used to puncture through normal hepatic tissue and then reached beyond the liver capsule at the adhesion between the liver and intestines around the lesion, and thereby artificial ascites was instilled via the needle at the adhesion site, leading to separation of the liver and the intestine.
Potential risks associated with artificial ascites procedure include intra-abdominal hemorrhage, peritonitis, and needle track implantation\(^\text{[9]}\). Traditionally, it is considered that instilling of artificial ascites will increase the chance for hemorrhage by reducing coagulative substances in the puncture site of the liver capsule and by decreasing the compression of lateral abdominal wall on the liver \(^\text{[9]}\). However, no intra-abdominal hemorrhage occurred after thermal ablation in our study, with an incidence lower than 0.7% as reported in literature\(^\text{[10]}\). It is presumed that thermal ablation with adjuvant artificial ascites is more prone to needle track implantation\(^\text{[9]}\), but no needle track implantation was seen after thermal ablation in our study, with an incidence lower than 0.61% as reported in literature\(^\text{[9]}\).

The use of artificial pleural effusion and ascites results in clearly visualized tumors located in the hepatic dome that are previously inappropriate for thermal ablation due to their location in the blind area of ultrasonography. This procedure also increases the safety of treatment for liver tumors adjacent to the gastrointestinal tract and provides safe puncture path for some patients. Therefore, it expands the indications of thermal ablation and offers treatment opportunities for some difficult cases. Artificial pleural effusion and ascites are safe and feasible, and should be spread and used in larger clinical population.

References


