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Percutaneous radiofrequency ablation of hepatocellular carcinoma abutting the diaphragm and gastrointestinal tracts with the use of artificial ascites: safety and technical efficacy in 143 patients

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Abstract The purpose of this study was to assess the feasibility, safety and efficacy of radiofrequency ablation (RFA) with the use of artificial ascites for hepatocellular carcinoma (HCC) adjacent to the diaphragm and gastrointestinal tract. One hundred forty-three patients with 181 HCCs who underwent US-guided percutaneous RFA with the use of artificial ascites were retrospectively reviewed. Among the 181 HCCs, 148 HCCs were defined as problematic nodules for two major reasons: poor sonic window or possible thermal injury. We artificially induced ascites before performing RFA by dripping 5% dextrose in a water solution. We assessed the technical success of introducing artificial ascites, technical feasibility of the use of artificial ascites and complications. The technical success rate, as well as the primary and secondary technique

success rate, was assessed by regular follow-up CT examinations. RFA with artificial ascites was successfully achieved in 130 of 143 patients. The primary technique effectiveness was 85.3%. During follow-up (mean, 20.4 months), remote intrahepatic recurrence occurred in 49 patients and local tumor progression occurred in 15 patients. Three (2.1%) of the 143 patients experienced major complications (hemoperitoneum, lobar infarction and biloma) related to the RFA procedure. The use of artificial ascites is a simple and useful technique to minimize collateral thermal injury and to improve the sonic window.

Keywords Radiofrequency ablation · Artificial ascites · Hepatocellular carcinoma · Image guided tumor ablation · RFA

Introduction

Hepatocellular carcinoma (HCC) is an aggressive tumor that frequently occurs in the setting of chronic liver disease and cirrhosis [1]. Although the mainstay of therapy for HCC is surgical resection, it is usually limited as a majority of patients have associated severe liver dysfunction [2–4].

A number of image-guided tumor ablation techniques, including chemical or thermal ablation, have been

introduced as treatments for an unresectable HCC [5]. Among the various ablative therapies, radiofrequency ablation (RFA) has been demonstrated as an effective therapy for treating small HCCs [6–9]. However, local ablative therapy for the tumors located close to major structures such as the diaphragm and gastrointestinal tract is technically challenging due to poor visibility of the tumor and collateral thermal injury to the adjacent organs [10–14].

Separating adjacent organs from the index tumor can be achieved with the use of various techniques including the introduction of artificial fluid into the peritoneal or pleural space [15–25], or the use of balloon catheter interposition between the ablation zone and abutting organs [26]. Although there have been many reports about thermal ablation using artificial ascites or pleural effusion, large series studies have been very limited [19, 23–25, 27, 28]. The purpose of this study was to assess the feasibility, safety and efficacy of RFA with the use of artificial ascites in 143 patients with an HCC adjacent to the diaphragm and gastrointestinal tract.

Materials and methods

Patients

From June 2005 to August 2007, percutaneous ultrasound-guided RFA was performed in 878 patients with HCCs in our institution. The inclusion criteria for patients were the following: a single nodular HCC <5 cm in the maximum diameter, multinodular (up to three in number) HCCs <3 cm each in the maximum diameter, the absence of portal venous thrombosis, Child-Pugh class A or B liver cirrhosis, prothrombin time ratio >50% (prothrombin time with an international normalized ratio <1.7) and a platelet count >50,000 cells/mm³ (50 cells × 10⁹/l). Among the 878 patients, 143 patients with 148 problematic tumors who were treated with RFA with the introduction of artificial ascites were retrospectively reviewed. A problematic tumor was defined as belonging to one of two categories. The first category was for a lesion that was either invisible or partially visible on planning sonography due to overlapping lungs or ribs (poor sonic window). The second category was for a lesion clearly visible on planning sonography but located less than 5 mm from adjacent organs, including the diaphragm or gastrointestinal tract (possible thermal injury).

Characteristics of the patients are summarized in Table 1. Among the 143 patients, 31 had other, non-problematic lesions (33 tumors) in addition to the problematic nodules and underwent RF ablation. The diagnosis of HCC was confirmed after a percutaneous needle biopsy in 25 tumors of 23 patients. The remaining 156 tumors in 120 patients were considered as HCCs based on characteristic imaging findings and the presence of an elevated level of a serum tumor marker (α -fetoprotein level >400 mg/l) (n = 27) or satisfaction of at least two coincident radiological findings that were compatible with the presence of an HCC among CT, MRI, sonography and angiography findings (n = 129) [29]. The institutional review board approved the study. Informed consent was obtained from all the patients by one interventional radiologist who performed the procedure.

Table 1 Baseline characteristics of study population

Age (years)	
Mean	58.4
Range	43–72
Sex ratio	
Male	113
Female	30
Etiology of liver disease	
Hepatitis B virus	109
Hepatitis C virus	28
Other	6
Underlying liver disease	
Liver cirrhosis	133
Child-Pugh class A	117
Child-Pugh class B	16
Chronic hepatitis	10
Prothrombin time*	57–193 [77]
Platelet counts (× 10 ³ /μl)*	50–276 [107]
Total ablated tumors (N = 181)	
Size (cm)*	0.8–3.8 [2.2]
Number*	1–3 [1.3]
Location	
Segment 1	0
Segment 2–3	24
Segment 4	17
Segment 5–6	46
Segment 7–8	94
Problematic tumors (N= 148)	
Poor sonic window	98
Possible thermal injury	
Adjacent to the colon	24
Adjacent to the diaphragm	13
Adjacent to the stomach	9
Adjacent to the peritoneum	4

*Mean value in brackets

Induction of artificial ascites

We selected the peritoneal space under sonographic guidance with either a 5- or 6-French angio-sheath (Radifocus Introducer; Terumo, Tokyo, Japan) using the Seldinger technique (n = 84), an 18-G spinal needle (n = 55) or an 18-G sheathed needle (n = 4). All procedures for the induction of artificial ascites were performed by one interventional radiologist with 15 years of experience in sonographically guided intervention. In cases where an angio-sheath was used, we selected the right 7–8th intercostal space along the anterior axillary line for a

tumor in the right lobe and segment IV right to the falciform ligament, and the epigastric area for a tumor in segments II and III. The detailed method to select the peritoneal space using the angio-sheath was the same as described in a previous study [25] (Fig. 1). After placement of the angio-sheath into the peritoneal space, we opened a three-way stopcock at the side arm of the angio-sheath. This stopcock was connected to 1 l of 5% dextrose in water solution at room temperature. When the sonic window was improved and the distance from the adjacent organ was more than 1 cm, we stopped the infusion of artificial ascites. If the distance decreased as the artificial ascites was shifted away during the ablation, we added fluid just by opening the three-way stopcock.

In cases where the 18-G spinal needle or 18-G sheathed needle were used, we used previously described methods as reported in the literature [23]. We selected the right subhepatic space for a tumor in the right lobe and segment IV right to the falciform ligament, and the left subhepatic space for a tumor in segments II and III.

We did not try to perform any position change of the patient to collect infused fluid at the desired portion. If the entire boundary of the index tumor could be visualized and if a safe RF electrode path could be achieved by downward displacement of the liver or separation of the index tumor from an adjacent organ could be achieved with sonographic monitoring, we considered the induction of artificial ascites technically

successful. We then performed a conventional RFA ablation procedure.

Radiofrequency ablation

Descriptions of the RF ablation procedure in this study follow proposed standardization of terminology and reporting criteria [30]. All RFA procedures were also performed on an inpatient basis by the same interventional radiologist with 15 years of experience in the performed of RFA. All procedures were performed with the patient under conscious sedation using 50 mg pethidine hydrochloride administered via the intravenous route (Samsung Pharmaceuticals, Seoul, Korea). Vital signs were continuously monitored during the procedure.

We used an internally cooled electrode system (Cool-tip, Valleylab; Boulder, CO). This system includes an electrode with a tip internally cooled by chilled saline. The device was equipped with a 200-W generator. It uses either a single 17-gauge straight electrode or a cluster electrode consisting of three electrodes mounted on a common handle in a triangular fashion.

The therapeutic strategy of RFA was to include a peripheral margin of at least 5 mm of the normal hepatic parenchyma surrounding the tumor and the entire tumor itself. For 181 HCCs (148 problematic HCCs) in 143 patients, a total of 147 sessions (one or two sessions per patient; mean, 1.03) with

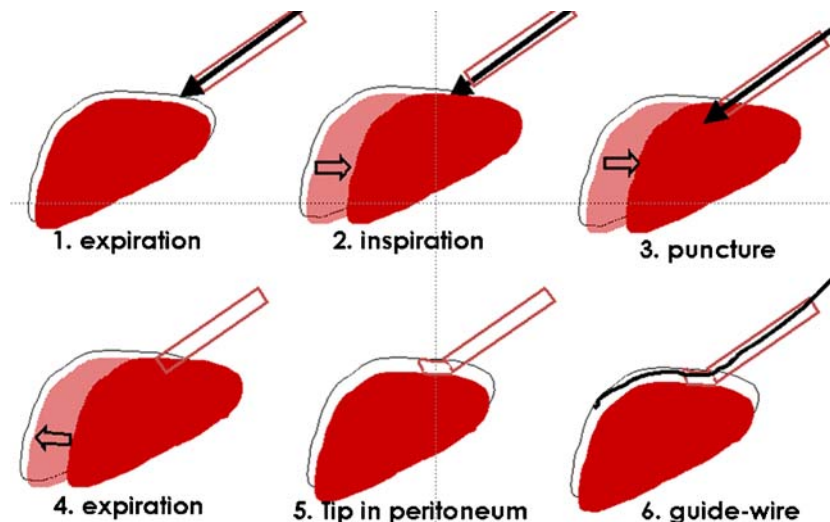


Fig. 1 After administering local anesthetic to the skin at the puncture site using 2% lidocaine, we inserted an 18-gauge sheathed needle just to the peritoneum. To effectively select the peritoneal space, we instructed the patient to slightly inhale downward to displace the level of the liver parenchyma and to breath-hold. Then we advanced the sheath needle into the subcapsular portion of the liver parenchyma. After removal of the inner stylet of the sheath needle, we instructed the patient to fully exhale and breath-hold again. At this moment, the tip of the sheath usually remained in the peritoneal space because of its retraction from upward-displaced

hepatic parenchyma with full expiration. At this moment, we quickly inserted a 0.035-inch guidewire through the sheath and checked by sonography whether the wire was located in the peritoneal space. Finally, we placed a 6-French angiosheath over the guidewire. After placement of the angiointroducer sheath into the peritoneal space, we opened a three-way stopcock at the side arm of the angio-introducer sheath. This stopcock was connected to 1,000 ml of 5% dextrose in water (D/W) solution at room temperature

single or multiple overlapping ablations (1–4 overlapping ablations; mean, 1.8) were performed. We cauterized the electrode path during retraction of the electrode to minimize bleeding after the ablation. We did not aspirate or drain the infused artificial ascites after the ablation procedure. After RF ablation, all patients remained in the hospital overnight, and vital signs were monitored. If the patient was regarded as well (based on a clinical examination, laboratory findings and immediate follow-up CT scans), the patient was discharged in the afternoon.

Follow-up after ablation

For an early evaluation of the completeness of the ablation, we performed contrast-enhanced CT imaging within 4 h after the RF ablation. One of three types of helical CT systems (HiSpeed or LightSpeed QX/i, GE Medical Systems, Milwaukee, WI; Brilliance 40, Philips Medical Systems, Best, The Netherlands) was used. A total of 120 ml of nonionic contrast material containing 300 mg of iodine per milliliter (Ultravist 300; Schering, Berlin, Germany) was administered intravenously at a rate of 3 ml/s with an automatic power injector. Images were obtained at 30, 60 to 70 and 180 s after IV contrast material injection to obtain hepatic arterial, portal venous and equilibrium phase images, respectively. CT data acquisition was performed in the craniocaudal direction and during a single patient breath-hold, with a collimation of 5 mm, table speed of 5 mm/s and total scanning time of 25–30 s, depending on the liver size. Coronal and sagittal reformatted images were also obtained. The radiologist who performed the RFA procedure also evaluated the therapeutic response and any immediate complications including hemoperitoneum and thermal injury. When the tumor was not ablated completely (when enhancement in part of the index tumor was still observed on CT images), RFA was repeated, as described, approximately 1 day later.

All of the patients underwent a follow-up four-phase CT examination 1 month after RFA. In cases of complete ablation of the tumor with no appearance of a new tumor in other sites of the liver as seen on 1-month follow-up CT images, each patient underwent follow-up every 3 months with subsequent blood tests for liver function and tumor markers. In addition, either abdominal ultrasound or contrast-enhanced CT examinations were part of the follow-up protocol.

Assessment of technical feasibility and safety of artificial ascites

The primary study end-point was the assessment of feasibility of percutaneous RFA with artificial ascites for the treatment of an HCC abutting a adjacent organ or showing a poor sonic window. Feasibility of the use of

percutaneous RFA with artificial ascites was assessed by the ability to improve the visibility of the index tumor or the RF electrode path with the creation of sufficient space between the liver surface and diaphragm or the gastrointestinal tract. We also recorded the time for successful induction of artificial ascites and the total amount of artificial ascites infused.

To assess the safety related to the use of artificial ascites, we evaluated if the artificial ascites were shifted into the pleural space and if the use of artificial ascites may have a role in the development of hemoperitoneum after RFA. Complications were assigned to major and minor categories. Minor complications were defined as temporary and self-limiting symptoms requiring no therapy or normal therapy without any clinical sequelae, and major complications were defined as symptoms that required further intervention and/or hospitalization or symptoms producing permanent sequelae [29].

Assessment of therapeutic efficacy

To assess the therapeutic efficacy of ablation, we evaluated the primary (technique) effectiveness in terms of the presence of residual tumor with 1-month follow-up CT imaging. When follow-up contrast-enhanced CT images showed reappearance of an enhancing area within the ablation zone or less than 2.0 cm from its borders, this finding was designated as local tumor progression. Distant intrahepatic recurrence referred to a new tumor that appeared in other segments or more than 2.0 cm from the ablation zone [31].

Statistical analysis

Categorical variables were compared using the Pearson's chi-squared test (or Fisher's exact test where appropriate). We estimated the rates of overall survival and event-free survival by use of the Kaplan-Meier method. Data analyses were performed with the use of commercially available software (SPSS for Windows, version 6.0; SPSS, Chicago, IL). P values were set at 0.05.

Results

Technical feasibility and safety of the use of artificial ascites

Induction of artificial ascites was achieved successfully in 130 of 143 patients (90.9%). In these successful cases, artificial ascites induced with 436 ± 273 ml of 5% dextrose in water solution created a space between the liver surface and diaphragm or the gastrointestinal tract. The time required for successful induction of artificial ascites in 130 patients ranged from 1 min to 19 min (mean time, 4.3 min).

In 13 patients with 13 problematic tumors (3 tumors in segment III, 3 tumors in segment IV, 1 tumor in segment VI, 1 tumor in segment VII and 5 tumors in segment VIII), 4 patients had a history of undergoing only a surgical resection. Two patients had a history of undergoing transarterial chemoembolization (TACE) only and two patients had a history of undergoing both surgical resection and TACE before RFA with artificial ascites.

Although the sample size was particularly small, the relationship between successful induction of artificial ascites and a history of hepatic resection is shown in Table 2. The rate of successful induction of artificial ascites was significantly lower in patients with a history of previous hepatic resection (22/28, 78.6%) than in patients without a history of previous hepatic resection (108/115, 93.9%) ($P = 0.021$, Fisher's exact test). There was no significant difference among the puncture methods used (5–6-F angio-sheath in 84 of 143 patients, 18-gauge spinal needle or sheathed needle in 59 of 143 patients) and the successful induction of artificial ascites ($P = 0.560$, Fisher's exact test).

There were no perioperative deaths. Three (2.1%) of the 143 patients experienced major complications related to the RFA procedure (Table 3). These complications were treated as follows. Peritoneal bleeding was treated with blood transfusions and transarterial embolization, lobar infarction was treated with close observation and the administration of antibiotics, and biloma, which was found on 4-month follow-up CT images, was treated with antibiotics and percutaneous drainage.

The artificial ascites were partially shifted into the right pleural space in 8 of 143 patients as depicted on immediate follow-up CT images. All patients showed complete absorption of artificial ascites and the shifted pleural effusion as seen on 1-month follow-up CT images. No patient showed delayed bleeding or peritonitis as a potential complication of the use of artificial ascites.

Therapeutic efficacy

Of the 148 problematic nodules, 135 nodules (91.2%) showed complete radiological necrosis as seen on immediate (within 4 h after the RF ablations) follow-up contrast-

enhanced CT images (Figs. 2 and 3). Eight of the 148 problematic nodules showed residual viable foci as seen on immediate follow-up CT images. Among the eight incompletely ablated nodules, five tumors were treated with a second session of RFA on the next day. The remaining three nodules were regarded as treatment failure and were treated with supplementary TACE as successful targeting with repeated RFA was expected to be very difficult due to a poor sonic window.

Five of 148 problematic nodules showed intact enhancing portions that were not enclosed by an ablative zone as seen on immediate follow-up CT images. We assumed that unsuccessful induction of artificial ascites resulted in poor visualization of the index tumor ($n = 3$), and even though artificial ascites were achieved successfully, we failed to distinguish the index tumor ($n = 2$) from other regenerating or dysplastic nodules. These tumors were regarded as a technical failure and were treated with TACE or radiation therapy. The relationship between complete radiological necrosis as depicted on immediate follow-up CT images and the successful induction of artificial ascites is shown in Table 4. The rate of unsuccessful ablation including incomplete ablation and technical failure was significantly higher in patients without successful induction of artificial ascites (8/13, 61.5%) than in patients with successful induction of artificial ascites (5/135, 3.7%) ($P < 0.001$, Fisher's exact test).

The primary technique effectiveness was 85.3% (122 of the 143 patients), with one (117 cases, 95.9%) or two (five cases, 4.1%) sessions of RFA as evaluated on 1-month follow-up CT images. Tumor recurrence was evaluated in 122 patients with complete ablation. During follow-up (mean, 20.4 months; range, 1–36 months), remote intrahepatic recurrence occurred in 49 patients (40%) and local tumor progression in 15 patients (12%). Three patients (2.5%) died during the follow-up period. The cause of death was tumor progression in one patient and hepatic failure in two patients. No neoplastic needle track seeding was found during follow-up.

The cumulative survival rates estimated by use of the Kaplan-Meier method for all patients were 97.2% at 1 year and 97.2% at 2 years, respectively. The cumulative event-free survival rates estimated at 12, 24 and 34 months were 60.8%, 42.7% and 35.3%, respectively (Fig. 4). Cumulative

Table 2 Relationship between successful induction of artificial ascites and history of hepatic resection

	Successful artificial ascites induction		Total (patients)
	Yes	No	
History of hepatic resection			
Yes	22	6	28
No	108	7	115
Total (patients)	130	13	143

$P = 0.021$, Fisher's exact test

Table 3 Major complications related to the radiofrequency ablation with artificial ascites

Complications	Sex/ HCC age size (mm)	Segment	Reason for artificial ascites	No. of punctures	Puncture methods	Puncture site	Time 1 ^a (min:s)	Time 2 ^b (min:s)	Amount of infused artificial ascites (mm ³)	Technical success of infused artificial ascites	Treatment
Hemoperitoneum	1 26	VII	Poor sonic window	1	18-Gauge spinal needle	Intercostal space	01:00	20:00	750	No	Transarterial embolization of segmental hepatic artery
Lobar infarction	1 30	VIII	Poor sonic window	2	6-F angio-sheathed needle	Intercostal space	05:35	11:40	200	Yes	Close observation with antibiotic therapy
Biloma	1 17	VI	Possible thermal injury (colon)	3	18-Gauge spinal needle	Intercostal space	15:00	25:00	800	Yes	Percutaneous drainage with antibiotic therapy

^aTime from peritoneal space selection until placement of angiosheath into peritoneal space^bTime for successful induction of artificial ascites

probabilities of distant intrahepatic recurrence at 12, 24 and 34 months were 29.8%, 50.8% and 75.5%, respectively. Cumulative probabilities of local tumor recurrence at 1 and 2 years were 13.9 and 18.7, respectively. The median disease-free survival period was 16.1 months.

Discussion

RFA, which is associated with minimal morbidity and excellent local tumor control rates, is widely performed for patients with hepatocellular carcinoma due to its safety and efficacy [6–9]. However, when a tumor is located close to major structures, such as the gastrointestinal tract and diaphragm, RFA is difficult to perform due to a risk of thermal injury of the adjacent organ or incomplete treatment of the tumor resulting from poor visibility on sonography [10–14]. Separating the RF ablation zone from an adjacent organ during ablation to prevent thermal injury and to improve tumor visibility or the electrode path has been achieved with various techniques, such as the introduction of artificial fluid into the peritoneal or pleural space [15–25, 32], or the use of balloon catheter interposition between the RFA zone and abutting organs [26]. The use of artificial ascites is a well known technique for tumors in local thermal ablation. However, clinical results with a large series of patients have been very limited.

Recently, we reported our initial experience with the use of percutaneous US-guided RFA with artificial ascites on 25 patients with an HCC located in the hepatic dome [25]. We have demonstrated that percutaneous induction of artificial ascites is technically feasible and effective in RFA for an HCC at the hepatic dome. In this study, we demonstrated that the introduction of artificial ascites for RFA of an HCC adjacent to the diaphragm and gastrointestinal tract can be induced easily and safely. However, satisfactory separation of the RF ablation zone from an adjacent organs failed in 13 (9%) of 143 patients.

Kondo et al. [23] have reported the safety and effectiveness of the use of artificial ascites in RFA of liver tumors adjacent to the gastrointestinal tract. The study reported a successful artificial ascites induction rate of 78% and postoperative adhesion of abdominal organs as a major restricting factor to separate the organs from the tumor.

The most common cause of technical failure for successful induction of artificial ascites was perihepatic adhesion due to a prior history of hepatic resection or TACE in our series. In addition, a prominent omentum surrounding the hepatic capsule was a limiting factor for technical success. Despite a large amount of artificial ascites, the omentum floating in the ascites did not shift away from the index tumor, which resulted in technical difficulty to target the index tumor. Finally, the location of tumor at the narrow peritoneal space close to a bare area (the peritoneal reflecting area) can be a negative factor for successful induction of artificial ascites. Therefore, an

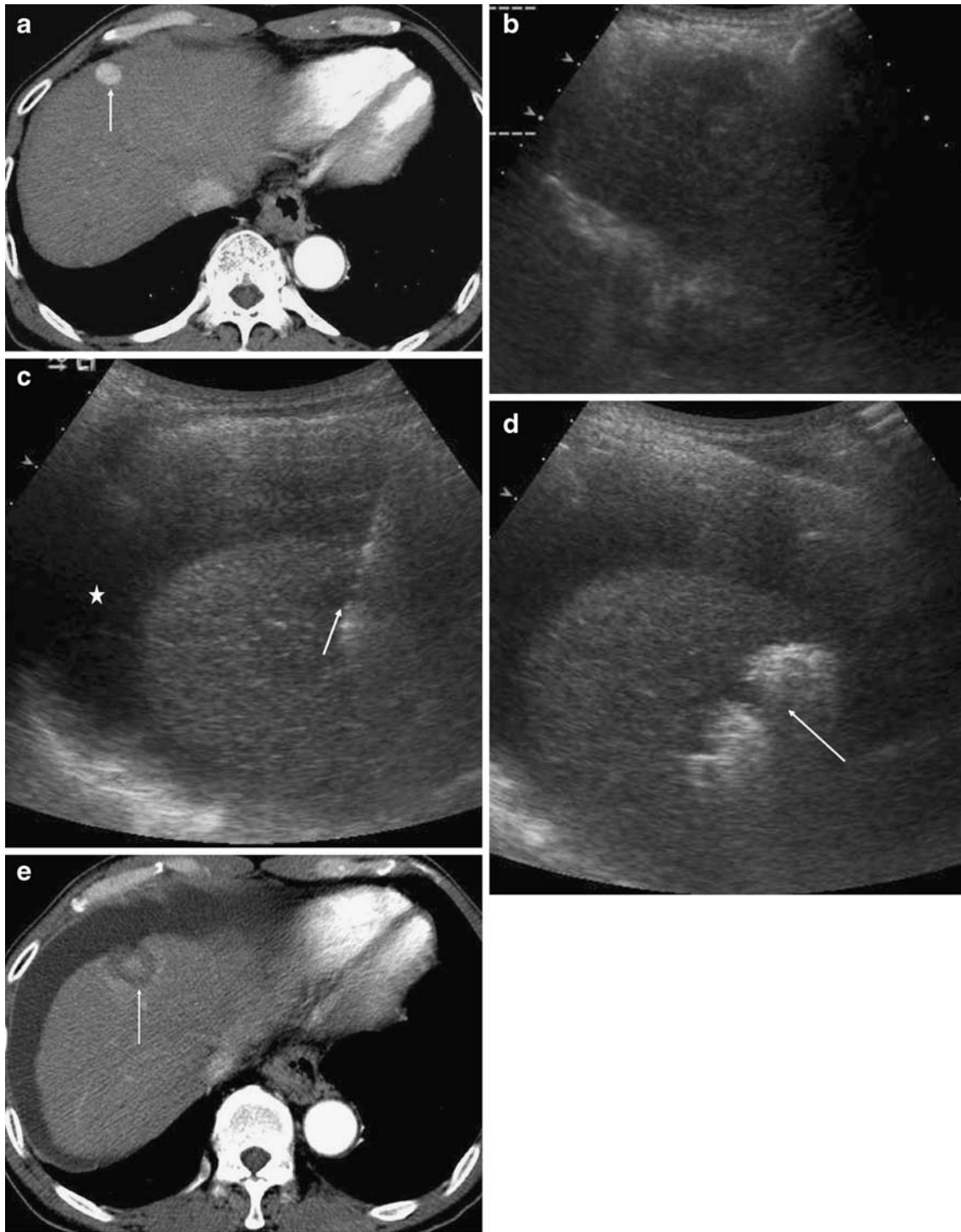


Fig. 2 A 59-year-old man with hepatocellular carcinoma in the right hepatic dome (S8). (a) Transverse contrast-enhanced CT scan before RF ablation shows a hyperattenuating, 1.5-cm nodule in liver segment VIII (arrow). (b) The index tumor is barely seen, but there is no adequate RF electrode path due to overlying costochondral junction. (c) Sonogram shows perihepatic artificial ascites (*) and targeting phase of procedure. Note radiofrequency electrode in

index tumor (arrow). (d) Sonogram shows monitoring phase of procedure. Note hyperechoic radiofrequency ablation zone during ablation (arrow). (e) Transverse contrast-enhanced CT scan obtained immediately after radiofrequency ablation shows nonenhancing radiofrequency ablation zone encompassing tumor (arrow). There is no evidence of collateral thermal damage to the diaphragm

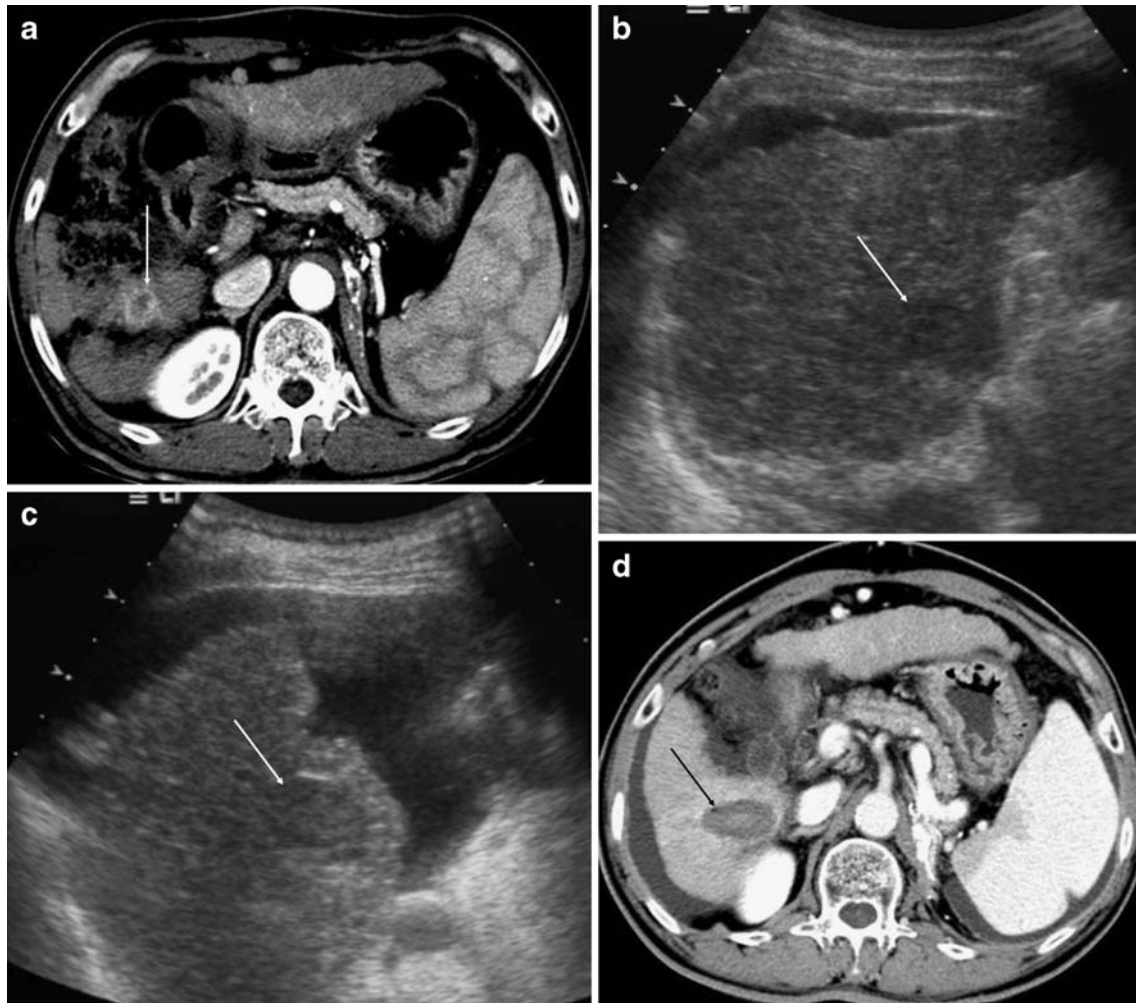


Fig. 3 A 62-year-old man with hepatocellular carcinoma abutting hepatic flexure. (a) Transverse contrast-enhanced CT scan before RF ablation shows a hyperattenuating, 2.0-cm HCC in segment VI (arrow). (b) Oblique subcostal sonograms of right hepatic lobe show index tumor (arrow) abutting hepatic flexure. (c) After artificial ascites induction of 5% dextrose, the nodule is separated by ascites

and thus can be ablated without risk of thermal injury to the colon. (d) Transverse contrast-enhanced CT scan obtained immediately after radiofrequency ablation shows nonenhancing radiofrequency ablation zone encompassing tumor (arrow). There is no evidence of collateral thermal damage to the colon

operator should keep in mind that these three factors can be a cause of technical failure for the induction of artificial ascites.

The introduction of artificial ascites can be achieved by various techniques with the use of different equipment [23, 25]. We used one of three devices (5–6-F angio-sheath, 18-G spinal needle and 18-G sheathed needle). Although the induction of artificial ascites using a 5–6-F angio-sheath showed no significant decrease in terms of the time required for successful induction compared to the other techniques using an 18-gauge spinal needle or sheathed needle ($P = 0.113$), the successful induction rate among the use of these techniques was not significantly different ($P = 0.560$, Fisher's exact test). However, we prefer the technique using the angiosheath as it does not require the need to monitor the tip of the needle during the ablation.

There were no cardiopulmonary complications due to volume overload, and the performance of RFA with artificial ascites was associated with no mortality in our study. The rate of major complications was 2.1% in this study, which is comparable with the 2.2% rate reported in large studies of patients with liver tumors treated with conventional percutaneous RFA [33], and all complicated cases were successfully controlled by additional treatment during hospitalization. There was no collateral thermal injury such as perforation of the gastrointestinal wall, which has been reported to occur in 0.7% of patients in a previous study [33] in patients with problematic tumors close to the diaphragm and gastrointestinal tract. We regard the use of artificial ascites as the most simple and effective technique to avoid collateral thermal complications in percutaneous thermal ablation therapy.

Table 4 Relationship between complete ablation (complete radiologic necrosis on immediate follow-up CT) and successful induction of artificial ascites

	Complete ablation		
	Yes	No	Total (nodules)
Successful induction of artificial ascites			
Yes	130	5	135
No	5	8	13
Total (nodules)	135	13	148

$P < 0.001$, Fisher's exact test

Potential complications related to the use of artificial ascites itself are bleeding, peritonitis and tumor seeding. Among the three patients that showed major complications in our series, bleeding in one patient could be considered as a complication related to the procedure of inducing artificial ascites. The risk of seeding might be increased by the use of artificial ascites, as the cooling effect and presence of free space could facilitate the dissemination of viable tumor cells. However, no instances of neoplastic seeding after RFA were observed during follow-up in our series, which was lower than the reported rate in the previous studies without the use of ascites (0.61% for RFA without a biopsy, 0.95% for RFA with a biopsy) [34].

Traditionally, the presence of ascites was considered to increase the risk of sustained intraperitoneal hemorrhage from the hepatic surface by washing away thrombogenic material at the puncture site and decreasing the "tamponade effect" from the opposing parietal peritoneum against the liver [35]. However, the rate of bleeding complications was 0.7% in this study, which was equivalent to the 0.7% rate reported in a large study [33]. Indeed, in the single case of hemoperitoneum in our study, the cause of bleeding was thought to be due to injury from the spinal needle tip used for induction of fluid. A mildly prolonged serum prothrombin time (ratio 53%; international normalized ratio, 1.63) and decreased platelet count (119,000/ μ l) before ablation might worsen the result. Thus, the needle used for the introduction of artificial ascites should be removed after achieving placement of the artificial ascites at the time of RF electrode insertion as it is difficult to monitor both the spinal needle and RF electrode simultaneously [36]. We have no data to demonstrate the true impact of artificial ascites on accelerating potential complications for the current study. Further investigation with multi-center study may be warranted to prove this effect.

Many studies have reported on ways to improve the sonic window using artificial pleural effusion in RFA of an HCC for liver tumors in the hepatic dome [19, 32, 37]. These studies reported a complete necrosis rate of 88–96% and a local recurrence rate of up to 4.5% during a mean follow-up period of 10.6 months with the assistance of the use of artificial pleural effusion. Recently, Kondo et al. [32] have reported safety and efficacy of ultrasonographically

guided percutaneous RFA for liver tumors in the hepatic dome with intrapleural infusion. Complete ablation was achieved in most cases, and intrapleural infusion was not associated with a lower overall survival. There were no complications associated specifically with the intrapleural fluid infusion procedure, such as pneumothorax or hemothorax. Although the use of artificial pleural effusion is safe and independent of the history of a previous hepatectomy, the use of artificial ascites may be more effective in preventing thermal injury to the diaphragm when the target tumor is located close to the liver capsule. Moreover, artificial ascites can be also used in patients with an HCC abutting the gastrointestinal tract to prevent gastrointestinal tract perforation.

The intent of our study was not to determine the long-term survival or mortality in patients treated by RFA with artificial ascites as several patients had been previously treated for other HCCs by the use of RFA or with other treatments. The main objective of this study was to determine the safety and the local control efficacy of percutaneous RFA with artificial ascites. In our institution, when residual enhancing foci are noted on 1-month follow-up CT scans, planning US is performed to confirm whether additional RFA is feasible. If additional RFA is not feasible, other treatments such as TACE or radiation therapy are recommended. Actually, in our study, seven patients with incomplete ablation that was assessed by CT imaging performed 1 month after RF ablation underwent TACE, except for one patient, and these patients were excluded from further analysis. This finding might explain the relatively lower primary effective rate of 85.3% in the current study as compared to the primary effective rate of previous reports for subcapsular HCC [19, 20, 23–25, 27, 37, 38]. We assumed that a possible heat sink effect of artificial ascites on a subcapsular mass and difficult

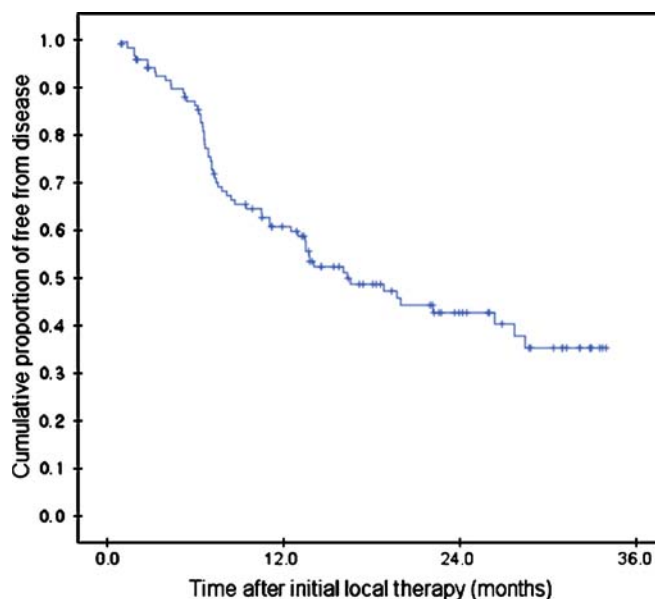


Fig. 4 Estimated 1-year and 2-year disease-free survival rates (122 patients)

placement of the electrode in the small hepatic nodule in the cirrhotic liver floating in the ascites might affect results at the same time.

This study has several inherent limitations. First, we could not evaluate the true benefit of the use of artificial ascites to allow successful percutaneous ablation and to minimize thermal injury of the diaphragm, as we could not perform a randomized controlled study. Second, in terms of a poor sonic window, the first category tumors (98 tumors) might have the possibility of thermal injury, and we didn't have objective criteria to assess tumor conspicuity or adequacy of the needle path in this study. We should assess the possibility of thermal injury in a poor sonic window group and design a scoring system for conspicuity and adequacy of the needle path. However, it would be difficult to achieve interobserver agreement due to the intrinsic limitation of ultrasonography.

The use of more subjective criteria will be necessary when controlled trials are performed.

In summary, we have performed percutaneous RFA with the use of artificial ascites for an HCC abutting diaphragm and gastrointestinal tract in 143 patients. This procedure has been considered difficult to perform percutaneously due to a poor sonic window or radiofrequency electrode path or possible thermal injury. We have demonstrated that the use of artificial ascites can improve the radiofrequency electrode path by downward displacement of the hepatic parenchyma and can separate the RFA zone from the diaphragm and gastrointestinal tract in most patients. In conclusion, US-guided percutaneous RFA with the use of artificial ascites is a safe and effective technique for the treatment of an HCC abutting the diaphragm or gastrointestinal tract.

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