TRANSCATHETER CT ARTERIAL PORTOGRAPHY (CTAP) AND CT HEPATIC ARTERIOGRAPHY (CTHA) TO ENABLE OR IMPROVE LIVER TUMOR VISUALIZATION DURING PERCUTANEOUS ABLATION

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ABSTRACT

**Purpose:** To evaluate the feasibility of combining transcatheter computed tomography (CT) arterial portography or transcatheter CT hepatic arteriography with percutaneous liver ablation for optimized and repeated tumor exposure.

**Materials and Methods:** Study participants were 20 patients (13 men and 7 women; mean age, 59.4 y; range, 40–76 y) with unresectable liver-only malignancies; 14 with colorectal liver metastases (29 lesions), 5 with hepatocellular carcinoma (7 lesions), and 1 with intrahepatic cholangiocarcinoma (2 lesions), that were obscure on nonenhanced CT. A catheter was placed within the superior mesenteric artery (CT arterial portography) or in the hepatic artery (CT hepatic arteriography). CT arterial portography or CT hepatic arteriography was repeatedly performed after injecting 30–60 mL1:2 diluted contrast material to plan, guide, and evaluate ablation. The operator confidence levels and the liver-to-lesion attenuation differences were assessed as well as needle-to-target mismatch distance, technical success, and technique effectiveness after 3 months.

**Results:** Technical success rate was 100%; there were no major complications. Compared to conventional unenhanced CT, operator confidence increased significantly for CTAP/CTHA cases (p < 0.001). The liver-to-lesion attenuation-differences between unenhanced CT, contrast-enhanced CT and CT arterial portography or CT hepatic arteriography were statistically significant (mean attenuation-difference 5HU vs. 28HU vs. 70HU; p < 0.001). Mean needle-to-target mismatch-distance was 2.4±1.2 mm (range 0-12.0mm). Primary technique effectiveness at 3 months was 87% (33/38 lesions).

**Conclusions:** In patients with technically unresectable liver-only malignancies, single-session CTAP/CTHA guided percutaneous tumor ablation enables repeated contrast-enhanced imaging and real-time contrast-enhanced CT fluoroscopy and hereby improves lesion conspicuity.
INTRODUCTION

An important prerequisite for all ablation techniques is the coverage of all tumor cells, with tumor size representing the most important limiting factor. Although the results of established thermal ablation techniques, such as radiofrequency (RF) ablation and microwave (MW) ablation, are approaching the results of surgical resection \(^1\)\(^-\)\(^3\), the frequency of local site recurrence, especially for percutaneous procedures, is still considered relatively high (5%–10% for lesions <3 cm and >10% for lesions >3 cm in diameter) \(^4\)\(^-\)\(^7\).

Apart from careful planning before the procedure and detailed evaluation after the procedure, accurate intraprocedural targeting, monitoring, and control of ablation play a critical role in the success of percutaneous ablation \(^8\). At the present time, computed tomography (CT) is one of the most widely used imaging modalities for percutaneous ablation because it enables acquisition of three-dimensional images of the tumor in relation to the surrounding structures, the needle electrodes, and the ablation zone. CT fluoroscopy enables two-dimensional dynamic and real-time image-guided probe placement. However, in many cases, tumor tissue and ablation zones are barely visible on nonenhanced CT. During CT-guided thermal ablation, the delineation of tumor tissue and the induced coagulation zone is often limited to a time window after the application of intravenous contrast material. Consequently, having reached the maximum dose of intravenous contrast material after one or two injections, repetitive monitoring during the intervention is restricted and in most centers limited to injection before the procedure (treatment planning). This limited monitoring is a major drawback because dynamic and real-time tumor delineation during probe advancement and repositioning is key to precise probe placement. The purpose of this study was to evaluate the feasibility of combining transcatheter CT arterial portography or transcatheter CT hepatic arteriography with liver tumor ablation.

MATERIALS AND METHODS

Between May 2011 and March 2013, 20 patients (13 men and 7 women; mean age, 59.4 y; range, 40–76 y) with liver malignancies that were occult or at least difficult to delineate on both abdominal ultrasonography and unenhanced CT but otherwise considered suitable for percutaneous ablation by our multidisciplinary liver tumor board were prospectively evaluated. The following patients were excluded: (a) patients with significant atherosclerotic plaques, stenosis, or occlusions of the path from the access site to the splanchnic arteries; (b) patients with any bleeding disorder; or (c) patients with documented allergy to contrast medium. The participants had histologically proven
or fluorodeoxyglucose positron emission tomography–avid colorectal liver metastases (CRLM) (n = 14), histologically proven or double-modality imaging–proven early-stage hepatocellular carcinoma (HCC) (n = 5), or histologically proven intrahepatic cholangiocarcinoma) (n = 1). The study was approved by the local review board, and written informed consent was obtained from all participants.

**Catheter Placement**

Based on contrast-enhanced CT performed before the procedure, the relevant arterial anatomy and patency of the splanchnic arteries was assessed. Hyperattenuating lesions were considered suitable for CT hepatic arteriography (typically primary tumors, such as HCC), and hypoattenuating lesions were considered suitable for CT arterial portography (typically liver metastases). In the angiography suite, a 5-F sheath was introduced in the right common femoral artery for both CT arterial portography and CT hepatic arteriography. For CT hepatic arteriography, a 4-F Cobra (Cordis Corporation, Bridgewater, New Jersey) or 5-F Cobra (Cook, Bloomington, Indiana), Shepherd Hook (Boston Scientific, Natick, Massachusetts), SOS Omni (Boston Scientific), or Sim catheter (Cook) was advanced within the common, proper, left, or right hepatic artery. For CT arterial portography, the catheter tip was placed in the proximal superior mesenteric artery. A minimal amount of contrast material (Xenetix 300; Guerbet SA, Villepinte, France) was administered to ensure a correct and stable catheter position. Patients were transported to the CT room with a continuous saline drip infusion through the catheter.

**CT Hepatic Arteriography or CT Arterial Portography Procedure**

All ablative procedures were performed under general anesthesia. CT scans were obtained during breath hold with a four-slice multidetector CT (Volume Zoom; Siemens AG, Erlangen, Germany). Imaging parameters were 120 kV, 165 mAs, 4 mm 2.5 mm collimation, pitch 6 mm, and reconstructed slice width 3 mm with a reconstruction increment of 2 mm. The CT arterial portography and CT hepatic arteriography protocol parameters are shown in Table 1. For CT hepatic arteriography, a 1:2 mixed bolus of contrast material (Xenetix 300) with saline was injected (injection rate, 4 mL/s; scan delay, 6 s) (Fig 1a–f). The amount of contrast material and saline was defined depending on the location of the tip of the catheter. For CT arterial portography, a 1:2 mixed bolus of 20 mL contrast material with 40 mL saline was injected (injection rate, 4 mL/s; scan delay, 18 s) (Fig 2a–f).
Table 1  CTAP/CTHA Protocol Parameters

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<tr>
<th>Technique and Catheter Position</th>
<th>Contrast Material (ml)</th>
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<th>Total (ml)</th>
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</table>

CTAP = CT arterial portography; CTHA = CT hepatic arteriography

Figure 1. CT hepatic arteriography–guided MW ablation for a solitary HCC, which is invisible on unenhanced CT (a) and clearly visible as a hyperattenuating lesion on both planning CT hepatic arteriography (b) and contrast-enhanced CT fluoroscopy with the needle tip resting against the liver capsule (c) and during advancement of the single antenna (d). Verifying CT hepatic arteriography (e) confirms an optimal position of the antenna, and control CT hepatic arteriography performed after MW ablation shows a nonenhancing hypoattenuating ablation zone including the tumor and a tumor-free margin with a remarkable hyperattenuating rim surrounding the ablated area (f).
A CT arterial portography or CT hepatic arteriography scan of the liver was performed first for treatment planning. The optimal location for needle introduction was determined, and the probes were inserted with the tip resting against the liver capsule. A second dose of contrast material was administered, and CT fluoroscopy (120 kV, 40 mAs, 4-mm slice thickness) was performed to advance the needle into the desired position. Subsequently, a series of CT arterial portography or CT hepatic arteriography scans was acquired to verify electrode or antenna position before ablation. Whenever necessary (eg, for needle repositioning), CT arterial portography or CT hepatic arteriography scans were repeated. To establish technical success, a final series of scans was obtained after ablation.

**RF Ablation, MW Ablation, and Irreversible Electroporation Procedures**

Patients were positioned supine or in left side-lying position. The needles were carefully placed using CT hepatic arteriography–guided or CT arterial portography–guided CT fluoroscopy aiming at a tumor-free ablation zone of at least 10 mm. Primary endpoints for a technically successful ablation were as follows: (a) for RF ablation (LeVeen Needle Electrodes and RF 3000 Radiofrequency Generator; Boston Scientific, Natick, Massachusetts), at least two increases in tissue impedance with an interablation delay...
of 30 seconds; (b) for MW ablation (Evident MW Ablation System percutaneous 3.7 cm antenna and generator; Covidien, Dublin, Ireland), at least a 10-minute ablation at 45W; and (c) for irreversible electroporation (IRE) (NanoKnife; AngioDynamics, Latham, New York), successful administration of 90 pulses (70 ms per pulse; 1,200–1,500 V/cm; 20–50 A; electrode distance, 1.5–2.0 cm; active working length, 2.0 cm) between all electrode pairs. When considered necessary, additional overlapping ablations were performed after electrode repositioning. When the procedure was successfully completed, the probes were retracted using tract ablation, and the arterial catheter and sheath were removed. To achieve hemostasis, an extravascular closure device was placed (Mynx; AccessClosure, Inc, Mountain View, California). Secondary endpoints for a technically successful ablation were defined as a nonenhancing hypointense ablation zone including tumor and a tumor-free margin of at least 5 mm on CT for RF ablation and MW ablation and a hypointense ablation zone with a hyperintense ring of edema surrounding the lesion on magnetic resonance (MR) imaging diffusion-weighted imaging (b800) 24 hours after the procedure for IRE.

Radiologic and Clinical Effectiveness

The total injected volume of contrast material was carefully noted. Radiation exposure was calculated by estimating the effective dose on reference humans using the Monte Carlo IV method (expressed according to the International Commission on Radiological Protection publication 103) recommendations, with a commercially available software program (ImPACT version 1.0.4; Medical Physics Department, St. George’s Healthcare Trust, London, United Kingdom) and by documenting the actual dose-length product (DLP) values for all procedures.

For qualitative analysis, hard copies of three image sets were reviewed by two experienced radiologists (J.H.v.W. and M.R.M. with 11 years and 6 years of experience, respectively, after board certification) in consensus: (a) diagnostic conventional unenhanced and (b) contrast-enhanced CT performed a maximum of 4 weeks before the procedure and (c) CT arterial portography or CT hepatic arteriography planning CT. Operator confidence for lesion demarcation, expressed as lesion conspicuity, was rated according to a previously described 5-point scale: nonvisualized lesions (grade 1), poorly visualized lesions (grade 2), adequately visualized lesions with poor margin delineation (grade 3), good delineation of almost the entire margin (grade 4), and lesions with clear demarcation of the entire margin (grade 5). Examples for each grade are shown in Figure E1a–e.
Figure E1. (a–e) Examples of the 5-point scale to assess operator confidence for lesion demarcation. A nonvisualized lesion on unenhanced CT (arrow; grade 1) (a), adequately visualized lesion with poor margin delineation on contrast-enhanced CT (arrow; grade 3) (c), and clear demarcation of the entire margin on CT arterial portography (arrow; grade 5, e) for the same lesion in one patient. A poorly visualized lesion on unenhanced CT (arrows; grade 2) (b) with good delineation of almost the entire margin on contrast-enhanced CT (arrow; grade 4) (d) in one lesion of another patient.

The absolute liver-tolesion attenuation difference was measured using a region-of-interest analysis for nonenhanced CT, conventional contrast-enhanced CT (arterial phase for CT hepatic arteriography cases and portal venous phase for CT arterial portography cases), and CT arterial portography or CT hepatic arteriography image set.

Accuracy of needle placement was assessed by (a) evaluating the number of unforeseen needle repositionings and (b) measuring needle-to-target mismatch distances. Mismatch distances were expressed as the needle-to-target mismatch, the depth mismatch (mismatch distance along the axis of the needle [z axis]), and the transversal mismatch (perpendicular to the z axis) in a plane defined by the needle axis and the lesion center (Figs 3, 4a–e), using three-dimensional multiplanar reformatting with a commercially available software program (Syngo; Siemens AG). To measure these distances, the tip for the RF ablation needle electrodes, the active feeding point (hy-
poattenuating marker) for the MW ablation needle antennas, and the midpoint of the noninsulated (adjustable) active part for the IRE needle electrodes were used.

**Figure 3.** Mismatch distances were expressed as the needle-to-target mismatch, the depth mismatch (mismatch distance along the axis of the needle [z axis]), and the transversal mismatch (perpendicular to the z axis) in a plane defined by the needle axis and the lesion center.
Figure 4. CT hepatic arteriography–guided RF ablation in a patient with a right liver lobe HCC, which is invisible on unenhanced CT (a) and clearly visible on the preradiofrequency ablation (before RF ablation) scan as a hyperattenuating lesion after injection of contrast material in the right hepatic artery (b). CT hepatic arteriography performed after the RF ablation procedure shows a complete ablation of the tumor, including a tumor-free margin surrounding the lesion (c). Mismatch distances were calculated using a multiplanar reformatted plane defined by the needle axis and the lesion center (d, e).

Procedure-related complications were evaluated using the Common Terminology Criteria of Adverse Events (version 3.0)\textsuperscript{12}. Initial technical success and primary technique effectiveness at 3 months were reported according to the standardization of terminology and reporting criteria as described by the International Working Group on Image-guided Tumor Ablation\textsuperscript{13}.

Serum creatinine was measured before and 24–72 hours after the procedure. Contrast-induced nephropathy was defined as either an increase of serum creatinine > 25% or an absolute increase in serum creatinine of 0.5 mg/dL after the procedure.
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<th>Technique</th>
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<th>Lesion conspicuity (qualitative analysis)</th>
<th>Lesion conspicuity (liver to lesion contrast (HU))</th>
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Table 2: Overview of patients treated with CTAP/CTHA guided RFA/MWA: patient and lesion characteristics.
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*treated lesion is local site recurrence after previous thermal ablation; CTAP = CT arterial portography; CTHA = CT hepatic arteriography; NE-CT = non-enhanced CT; CE-CT = contrast-enhanced CT; LSR = local site recurrence; RFA = radiofrequency ablation; MWA = microwave ablation; IRE = irreversible electroporation; HCC = hepatocellular carcinoma; ICC = intrahepatic cholangiocarcinoma.
Statistics
To compare operator confidence levels and liver-to-lesion attenuation differences for the three different scan techniques (unenhanced CT, contrast-enhanced CT, and CT arterial portography or CT hepatic arteriography), we used the Friedman test for nonparametric paired samples. When significant, a post hoc analysis, with a Wilcoxon signed rank test and Bonferroni correction, was conducted, resulting in a significance level set at $P < .017$.

RESULTS
Patient and lesion characteristics, results of the qualitative and quantitative analysis, and outcomes are presented in Table 2.

There were 38 lesions (29 CRLM, 7 HCC, and 2 intrahepatic cholangiocarcinoma) treated. For six patients (nine lesions) with CRLM, the targeted lesion was a local site recurrence of a previous thermal ablation (all performed during open laparotomy). In all patients with CRLM and in one patient with intrahepatic cholangiocarcinoma (31 lesions), CT arterial portography–guided ablation was performed; all patients with HCC (7 lesions) underwent CT hepatic arteriography–guided ablation.

The procedure was considered technically successful in all patients. No complications related to sheath or catheter placement or removal or to selective intra-arterial contrast agent administration were recorded. In one patient, the MW ablation procedure led to an occlusion of the right bile duct and a large hepatic biloma requiring percutaneous drainage and at a later stage endoscopic placement of a biliary endoprosthesis. Because we observed local site residue or recurrence in 5 lesions (5 patients), primary site technique effectiveness was 87% (33 of 38 lesions) and patient technique effectiveness was 75% (5 of 20 patients) at 3 months. The mean size of lesions with local site residue or recurrence was 42 mm (range; 14–61 mm); three lesions were treated with MW ablation, one was treated with RF ablation, and one was treated with IRE; four of five lesions were located perivascularly (abutting a large vessel measuring at least 4 mm). Mean size of nonrecurring lesions was 19 mm (range; 8–53 mm). There were no patients with contrast-induced nephropathy. Average amount of contrast material administered was 10 mL during angiography (range; 4–22 mL) and 120 mL during CT arterial portography or CT hepatic arteriography (range; 90–150 mL). The estimated effective radiation dose for one CT hepatic arteriography or CT arterial portography series was 3.4 mSv (range; 15 cm; CT dose index volume, 11.6 mGy; DLP, 174 mGy · cm) and for CT fluoroscopy was 1.3 mSv (33 mSv/s; CT dose index volume, 3.9 mGy; DLP, 2 mGy · cm), which constitutes an estimated total effective radiation dose of 11.5 mSv for the three series acquired within the protocol plus an estimated fluoroscopy
time of 40 seconds. Because the scan range was often > 15 cm and because fluoroscopy times were longer than expected, the mean actual DLP values were higher (mean, 244 mGy · cm, and range, 172–370 mGy · cm, for the CT arterial portography or CT hepatic arteriography series, and mean, 112 mGy · cm, and range; 36–220 mGy · cm, for CT fluoroscopy) resulting in a mean actual effective radiation dose of 16.1 mSv. There was a statistically significant difference in scoring liver lesions using the three different imaging techniques (χ² = 63.955, P < .001). Compared with cases in which conventional unenhanced CT was used, qualitative lesion conspicuity clearly increased in all cases in which CT arterial portography or CT hepatic arteriography was used (mean, 1.2 vs 4.4; Z = 5.481, P < .001). It was impossible to distinguish marginal local site recurrence (vital tumor tissue) from the nonvital scar lesion induced by previous thermal ablation in all six patients (nine lesions) (Fig 5a–e). There were no statistically significant differences in lesion conspicuity for the conventional diagnostic contrast-enhanced CT versus the CT arterial portography or CT hepatic arteriography image sets (mean, 4.3 vs 4.4; Z = 0.617, P = .537). As expected, the absolute liver-to-lesion attenuation difference increased in all CT arterial portography and CT hepatic arteriography cases after administering contrast material. The difference between unenhanced CT and CT arterial portography or CT hepatic arteriography was statistically significant (mean liver-to-lesion attenuation difference, 5 HU vs 70 HU; Z = 5.331, P < .001) as was the difference between contrast-enhanced CT and CT arterial portography or CT hepatic arteriography (28 HU vs 70 HU; Z = 4.888, P < .001).

Both reviewers noted the presence of perfusion heterogeneities and subsequent pseudolesions on CT arterial portography and CT hepatic arteriography. During the procedure, these pseudolesions were not regarded malignant and were left untreated. For CT arterial portography, a gravity-induced gradient in contrast concentration was observed with the highest concentrations of contrast material and subsequently highest liver-to-lesion contrast in dorsal liver segments for patients in the supine position (Fig 6a, b). This gravity-induced gradient in contrast concentration was not observed for CT hepatic arteriography.

For 38 lesions, 52 needles were used with 8 planned repositionings for overlapping ablations (60 planned needle advancements). The mismatch distance between the needle position and the desired target position was considered too high for a safe and successful ablation in 13 needle advancements (21.7%) requiring either additional unforeseen overlapping ablations to establish a complete ablation (n = 8) or needle repositioning to establish a complete and a safe ablation (n = 5). Mean depth mismatch along the axis of the needle (z axis) was 1.4±0.4mm (range 0-10mm), mean transversal-mismatch was 2.0±1.0 mm (range 0-9.0mm) in the plane perpendicular to the needle (x-and y-axis) and mean needle-tip-to-target distance was 2.4±1.2 mm (range 0-12.0 mm).
Figure 5. Patient with fluorodeoxyglucose positron emission tomography–avid (a) local site recurrence after previous RF ablation (asterisk) of a CRLM (arrows). The recurring lesion is poorly visible on unenhanced CT (b) and hypoattenuating on CT arterial portography (arrows, c) compared with normal liver parenchyma but indistinguishable from the nonvital scar lesion induced by previous thermal ablation (asterisk). After percutaneous MW ablation (d), CT arterial portography clearly shows a hypoattenuating ablation zone, surrounding the local site recurrence (arrows), including the needle tract after tract ablation (arrowheads, e).
Figure 6. Unenhanced CT (a) and CT arterial portography (b) of a patient with a segment VII CRLM (arrow), which is invisible on unenhanced CT and clearly visible on CT arterial portography. The gravity-induced gradient in contrast concentration observed with CT arterial portography is probably caused by the incomplete mixing in the portal vein of densely contrasted (high specific gravity) blood from the superior mesenteric vein and the noncontrast (low specific gravity) blood from the splenic vein.

DISCUSSION

Imaging guidance for percutaneous ablation should ensure precise targeting and enable monitoring of induced tissue coagulation\textsuperscript{14,15}. We describe the feasibility and accuracy of CT arterial portography or CT hepatic arteriography as an imaging modality for planning before the procedure and intraprocedural realtime imaging guidance to facilitate percutaneous ablation of liver tumors and to create an endpoint after a technically successful ablation. To enhance contrast, we used CT hepatic arteriography for hyperattenuating lesions and CT arterial portography for hypoattenuating lesions. We performed CT hepatic arteriography for hypervascular tumors such as all HCCs and CT arterial portography for hypovascular lesions such as all CRLMs. The presence of lesions that are invisible on ultrasound and unenhanced CT would imply either a
“blind” percutaneous ablation, where localization of the lesion is estimated based on reference landmarks (eg, the liver contour) that are visible on unenhanced CT, using the conventional contrast-enhanced CT as reference, or a contraindication for percutaneous ablation. Excluding these patients would mean palliative care, with a presumed less favorable outcome for patients with HCC and CRLM. Taking into account a tumor-free margin of at least 10 mm, the mean needle mismatch distance of 1.4–2.4 mm seems acceptable and is comparable to results described in the literature after image-guided percutaneous procedures. The lesion-based primary technique effectiveness of 87% at 3 months also seems to concur with previous reports for similar-sized liver lesions. The remarkable hyperattenuating rim surrounding the ablation zone directly after thermal ablation as visualized on CT hepatic arteriography supports the hypothesis that transarterial chemoembolization can have a synergistic effect to thermal ablation because chemotherapeutics and embolization material preferentially flow into the temporarily and reversibly agitated microenvironment where local site recurrences commonly arise.

Although CT arterial portography or CT hepatic arteriography is considered a useful diagnostic technique with higher detection rate of both primary and secondary hepatic neoplasms compared with contrastenhanced CT, the invasive nature and the lack of changing therapy strategy have prohibited its widespread use as a diagnostic tool. Nontumorous perfusion abnormalities and subsequent formation of pseudolesions are well-known pitfalls. Because both techniques are susceptible to false-positive pseudolesions, the detection of additional lesions on CT hepatic arteriography and CT arterial portography before ablation does not automatically justify treating them within the same session. Because marginal local site recurrence (from CRLM) was indistinguishable from the scar lesion induced by previous thermal ablation on CT arterial portography, this may cause imprecise ablations of locally recurring tumor tissue, and delineation between vital and nonvital tissue needs further improvement. The gravity-induced gradient in contrast concentration observed with CT arterial portography is not observed on routine portal venous phase contrast-enhanced CT and is probably caused by the incomplete mixing in the portal vein of densely contrasted (high specific gravity) blood from the superior mesenteric vein and noncontrasted (low specific gravity) blood from the splenic vein. Although this suboptimal mixing leads to lower lesion conspicuity for tumors located in a higher level along the axis of gravity, all lesions in our series could be detected with CT arterial portography regardless of their position along the axis of gravity.

With an increasing trend toward minimally invasive liver interventions, the role of advanced navigation platforms is expected to gain importance. Imaging modalities are largely chosen based on operator preference and local availability of dedicated equipment. Ultrasound guidance offers real-time multiplanar imaging and enables
Chapter 4.1

fast, three-dimensional applicator placement. However, many lesions are difficult to delineate or detect because of anatomic location, biologic characteristics of both the tumor and the surrounding liver parenchyma, patient characteristics (eg, obesity), or superimposing structures. The limited capability to monitor thermal effects owing to air bubbles produced by vaporization is especially disadvantageous when overlapping ablations are required. Contrast-enhanced ultrasound can show an incomplete ablation shortly after an initial procedure through the continuous dynamic evaluation of tumor microcirculation, which allows for additional overlapping ablations within the same session 27,28.

CT techniques are not altered by air bubbles produced during RF ablation; with CT fluoroscopy, the time required for needle positioning during ablation is short 29. On nonenhanced CT images, tumor tissue and ablation zones are hardly visible in many cases. During ablation, the delineation of tumor tissue and induced coagulation is often limited to a time window after contrast agent administration. Because of the risk of contrast nephropathy, sequential intravenous administration of contrast material for repetitive monitoring of the lesions before, during, and after the procedure is not favorable; this impairs accurate needle placement, especially when overlapping ablations are required.

MR imaging offers a high soft tissue contrast and repeatable delineation of tumor tissue and the hepatic anatomy without administration of contrast material. Important disadvantages of MR imaging guidance are the limited availability of MR-compatible RF probes and large-bore or open-bore MR imaging systems for interventional use, the required sophisticated technology, and more time-consuming imaging 30.

Two other techniques used to address problems with tumor localization for poorly visible HCCs include ethiodized oil–guided ablation and percutaneous coil placement before ablation 31–33. Although presumed synergistic for larger tumors, the use of embolization materials before ablation remains controversial because complications directly attributable to ethiodized oil injection, such as a postembolization syndrome, tumor rupture, persistent fever, or nontarget embolization, can occur.

Image fusion, the process of aligning and superimposing images obtained using two different imaging modalities, is a rapidly evolving field of interest. Preliminary reports demonstrate that real-time registration of CT volume images obtained before the procedure with intraoperative ultrasound is feasible and accurate in vitro, although physiologic motion and the nonrigid nature of the organs remain problematic, and clinical experience and availability are limited 8,15,16,34,35. Another technique for image-guided tumor ablation is cone-beam CT, using a C-arm angiography system. This technology enables assessment before treatment for planning and three-dimensional fluoroscopic guidance for the insertion of needles into hepatic tumors 36. Cone-beam CT/positron emission tomography fusion– guided interventions for image-guided ablation are also
under investigation, although more research is needed to document accuracy compared with other techniques 37. Because of misregistration pitfalls, the currently available fusion techniques may prove inferior to a technique that enables repeated and real-time liver tumor visualization before, during, and after placement of the probes as suggested in this study.

In the present study, the average administered dose of iodinated contrast material was 120 mL. Although slightly greater than the average dose for a conventional contrast-enhanced CT scan, this dose is unlikely to lead to contrast-induced nephropathy in patients with normal renal function 38. Patients with suboptimal glomerular filtration rates (<60 mL/min/1.73 m2) and one or more risk factors such as peripheral arterial occlusive disease, chronic heart failure, age >75 years, anemia, hypertension, and the use of diuretic or nephrotoxic drugs may benefit from hydration regimens before and after the procedure 39.

One limitation of this study is the absence of a control group treated with “blind” percutaneous ablation to compare the mismatch distances and technique effectiveness. Although the heterogeneity of included patients and the heterogeneity of ablation methods are relative limitations, our study indicates that the technique can be applied to primary and secondary liver malignancies regardless of the needle electrode or antenna type and the applied energy form. Because a validated scoring system for lesion conspicuity on CT is lacking, we used a previously published subjective numeric scale analysis 11 to express operator confidence levels alongside quantitative liver-to-lesion attenuation differences. The consensus approach for lesion conspicuity impairs determination of any variation between observers.

In conclusion, use of CT arterial portography or CT hepatic arteriography to guide percutaneous tumor ablation enables repeated contrast-enhanced imaging and real-time contrast-enhanced CT fluoroscopy and improves lesion conspicuity; these advantages come with a cost of a higher radiation dose and possible complications related to catheter placement. Although primary technique effectiveness seems promising, a longer follow up and a larger patient group are needed to gather evidence before these techniques can be used as standard of care for a specific group of patients.
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