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Complications Associated with Image-Guided Percutaneous Thermal Ablation of Liver Tumors

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Abstract

Image-guided thermal ablation of liver cancer is a well-established treatment for patients with primary or secondary liver tumors. While the safety profile for liver ablations is high, several procedure-related complications can occur. An awareness of the potential complications, their recognition, and management are essential for the interventionist who performs liver ablation. This review will describe some of the most frequently encountered complications associated with image-guided thermal ablation of hepatic malignancies.

Keywords
- hepatocellular carcinoma
- colorectal metastasis
- complications

Image-guided thermal ablations, including radiofrequency ablation (RFA), microwave ablation (MWA), and cryoablation, are well-established locoregional treatment options for selected patients with primary or metastatic liver cancer.[1–5] While the mortality rates are low,[6] the complication rates for image-guided thermal ablation can range from approximately 2 to 8%.[6–8] Therefore, awareness of potential complications related to thermal ablation is important and critical for the interventionalist to anticipate, recognize, and manage complications when they occur. This review will highlight some of the most frequent complications related to thermal ablation of liver tumors and discuss methods of management.

Brief Review of Thermal Ablative Techniques

Radiofrequency Ablation

RFA relies on heat generated through ionic agitation within tissues to ablate tumors. Ionic agitation is accomplished by placing a patient into a closed-loop circuit that includes the radiofrequency generator, an electrode applicator, and dispersive electrodes (grounding pads). Electric current delivered to the electrode applicator results in an alternating current of 450 to 500 Hz within the closed-loop circuit. The rapidly alternating electrical field leads to ionic agitation in the tissues surrounding the tip of the electrode. The friction generated by the rapidly oscillating ions results in the generation of heat, which then destroys tissues. The goal of RFA is to generate temperatures within tumors between 50 and 100 °C for greater than 5 minutes to achieve cellular necrosis, manifested as irreversible destruction of intracellular organelles, including mitochondria, cytoplasmic membranes, ribosomes, and cellular membranes.[9]

Microwave Ablation

With MWA, tissue heating occurs when an alternating electromagnetic field forces water within the tissue to fluctuate out of phase with the applied electrical field. Most microwave devices operate at frequencies of either 915 MHz or 2.45 GHz. The absorbed energy through the oscillation of water molecules is absorbed as heat, leading to tissue destruction.[10] In contrast to RFA, MWA does not require that the patient be part of a closed-loop circuit; thus, the use of grounding pads is not required.

Cryoablation

Cryoablation destroys tissue through freezing. The mechanism of action of cryoablation is via the Joule-Thompson effect, which describes cooling that occurs with the rapid expansion of gases.[11,12] Most cryoablation devices use argon gas that is forced through the cryoprobe. As argon is forced through a narrow opening (throttle) in the distal end of the cryoprobe, the gas rapidly expands which leads to a drop in temperature.

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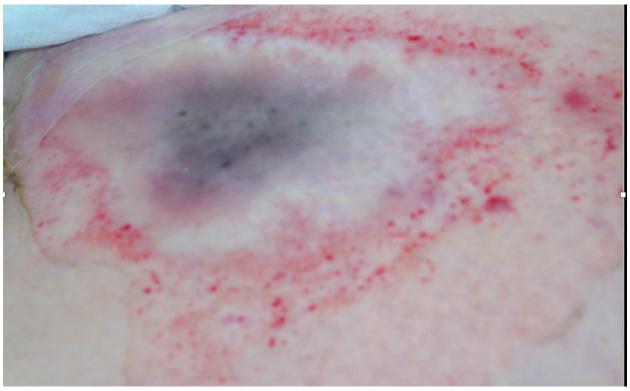

Fig. 1 Photograph demonstrating skin injury at the site of ground pad used during radiofrequency ablation.

The drop in temperature is then transmitted through the walls of the cryoprobe, resulting in freezing of adjacent tissues.[12] A typical cryoablation treatment includes periods of active freezing, followed by a short interval of partial thawing, followed by repeat freezing. Formation of intracellular ice during freezing results in breakdown of cellular membranes with pore formation. During the thaw phase, melted intracellular ice leads to cellular swelling and rupture as well as endothelial damage of the blood vessels in tissues. Following completion of the freeze–thaw–freeze cryoablation cycle, ongoing cellular death through apoptosis.

Grounding Pad Burns

Grounding pad burns are a relative rare complication specific to RFAs that was reported during the early experience with this technique.[13,14] In a total of 312 patients with primary or metastatic liver cancer treated with RFA, de Baère et al reported 5 (1.4%) skin burns encountered in 350 ablation sessions.[15]

To minimize the risk of skin thermal injury, it is important to place multiple large-surface area dispersive at a distance greater than 25 cm from the electrode. Orientation is also important; the pads should be placed on the skin such that the longest surface area is facing the electrode.[16] When skin burns do occur, management is largely dependent on the severity of the injury (►**Fig. 1**). First-degree burns can be treated with topical antibiotic ointment or skin care products. Second-degree burns are treated similarly but maybe required physician-prescribed creams or ointments. Third-degree and fourth-degree burns require more complicated care, such as intravenous antibiotic, fluid replacement, and surgical debridement and skin grafting.

Biliary Obstruction and Bilomas

The reported incidence of biliary injury following RFA of hepatic tumors is 1.8%.[17] Biliary obstruction can develop because of heat-induced stenosis or obstruction of bile ducts near ablated tumors. Stenosis of central ducts can result in chronic atrophy of the affected segment(s) (►**Fig. 2**). Decompression of central obstruction of central ducts may be indicated in the setting of cholangitis. In the absence of cholangitis, it is probably better to not intervene, since crossing the ampulla with catheters will likely result in chronically infected bile ducts from the introduction of enteric bacteria. Upstream biliary obstruction of peripheral tumors is usually of little consequence and can be managed conservatively[18] (►**Fig. 3**).

Intrahepatic bilomas are rarely encountered following thermal ablation of hepatic tumors, and like peripheral biliary obstruction can usually be managed conservatively for asymptomatic patients (►**Fig. 4**) or percutaneous drainage if clinical suspicion for infection is high. Risk factors that may be associated with biloma formation include previous treatment with chemoembolization and tumors closely associated with bile ducts.[19]

Biliary Fistula

Biliary fistulas to adjacent organs are rare and most of the literatures regarding these types of complications are case reports, reflecting the rarity of biliary type complications.[20–25] Biliary pleural fistulas have been described with RFA[22] and MWA of hepatic lesions[25,26] and usually present as bilious effusions (►**Fig. 5**). A report of a fatal bile pulmonary embolism was reported by Schmidt-Mutter et al in a 74-year-old patient who underwent multiple RFA treatments for HCC.[27] Interestingly, the cases reported in the literature document thermal ablation of centrally located lesions, with subsequent stenosis of the bile ducts that eventually erode through the liver, across the diaphragm, and into the pleural space.[25,26] Postablation fistulas between the biliary

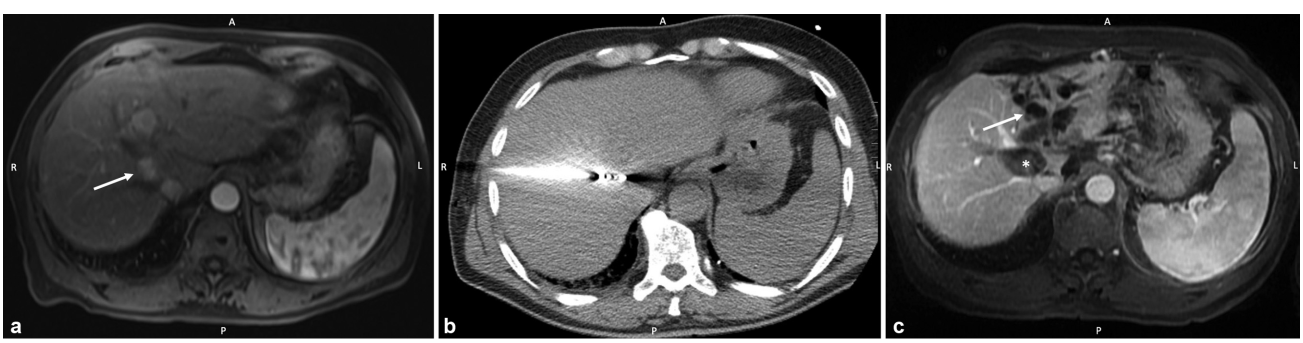

Fig. 2 (**a**) Axial contrast-enhanced MRI of the liver which demonstrated hepatocellular carcinoma (HCC) in the right hepatic lobe (white arrow). (**b**) Axial image at the time of RFA of the HCC. (**c**) Axial contrast-enhanced MRI 3 months after ablation which demonstrated biliary obstruction of the left hepatic lobe bile ducts (white arrow). Asterisk indicates the ablated tumor.

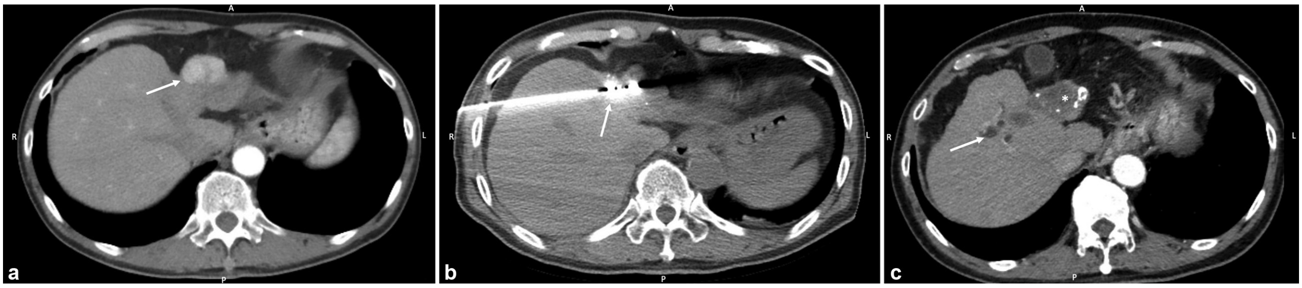

Fig. 3 (**a**) Axial contrast-enhanced CT scan demonstrating segment II hepatocellular carcinoma (HCC) (white arrow). (**b**) Axial CT scan demonstrating MWA ablation of the HCC (white arrow). (**c**) Axial contrast-enhanced CT scan 1 month after MWA demonstrates dilated bile ducts at the periphery of the liver (white arrow), adjacent to the zone of ablation (asterisk).

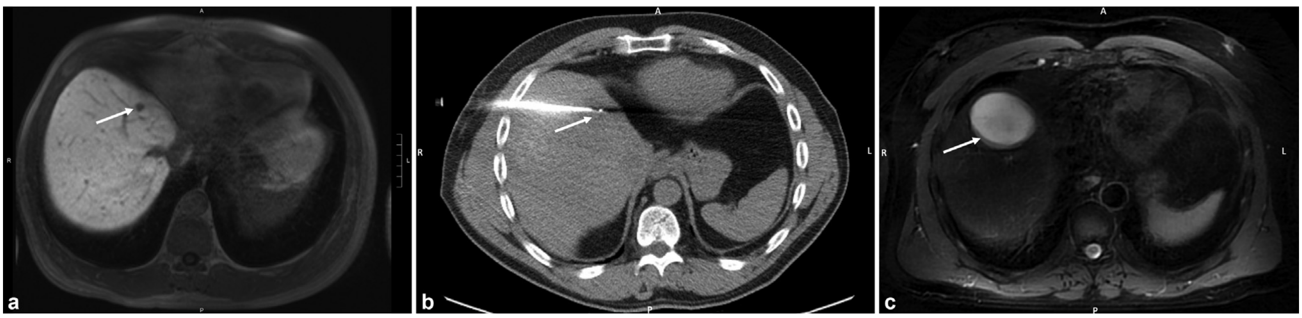

Fig. 4 (**a**) Axial T1-weighted image of the liver demonstrating a colorectal metastasis (white arrow). (**b**) Axial CT scan demonstrating MWA of the colorectal metastasis. (**c**) Axial T2-weighted image 6 months post-MWA which demonstrates a biloma (white arrow). Patient was asymptomatic.

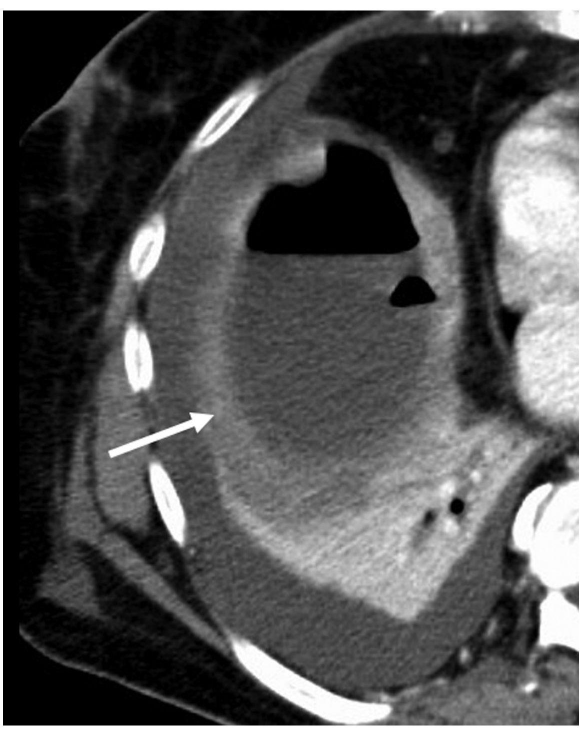

Fig. 5 Axial CT scan obtained 3 weeks after RFA of a colorectal metastasis which demonstrates a biliopleural fistula (white arrow).

tree and duodenum, stomach, and colon have also been reported following RFA of liver lesions.[20,23] For cases of biliary/hepatic to enteric fistulas, some authors have postulated that potential adhesions between the liver and bowel that may have developed after previous enteric surgery can act as a pathway of electrical current between the liver and bowel, thus leading to non-target organ injury.[28] Fortunately, most of these complications were reported within 5 to 10 years of adoption of thermal ablation to treat liver tumors and the overall complications of biliary rare.

Peritoneal and Diaphragmatic Complications

The peritoneum and diaphragm are at risk of thermal injury after thermal ablation of liver tumors, especially for the treatment of lesions that are subcapsular along the anterior surfaces of segments II, IV, V, VI, VII, and VIII.

Diaphragmatic Injury

Diaphragmatic injuries following thermal ablation of liver tumors is a rare but potentially fatal complication[29] (►**Fig. 6**). In many of the reported cases, diaphragmatic injury presents as a delayed complication that occurs several months after treatment.[29–31] In many instances, patients present with new onset of shortness of breath and right shoulder pain.[32] A secondary complication of diaphragmatic injury can be herniation of bowel loops across the diaphragmatic defect.[33,34] Treatment requires surgical repair whenever feasible.[34,35]

Peritoneal Injury

Much of the peritoneum of the right upper quadrant and epigastrium is in direct contact with the liver. While the visceral peritoneum is not innervated, sub-mesothelial

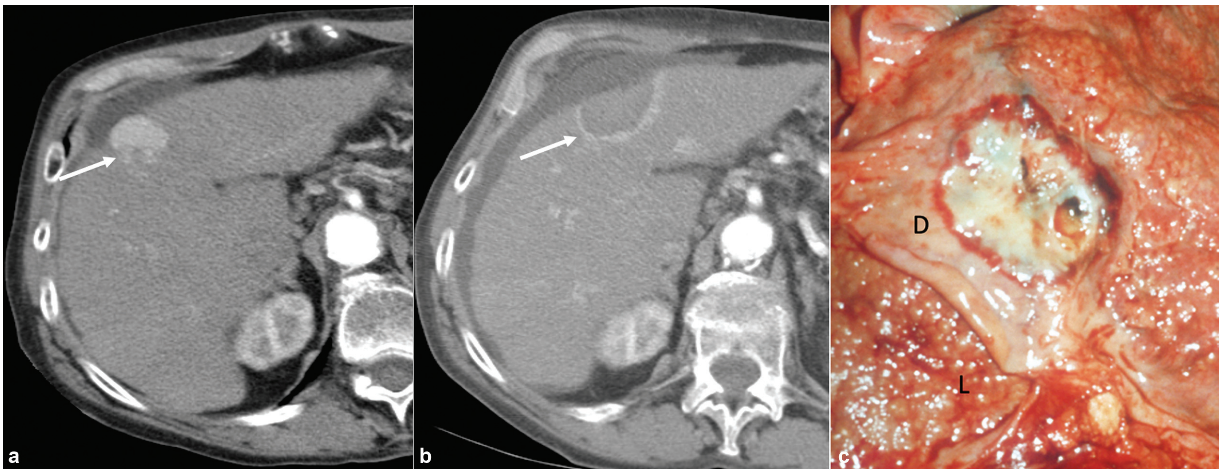

Fig. 6 (**a**) Axial contrast-enhanced CT scan which demonstrates a hepatocellular carcinoma (HCC) at the periphery of segment VIII. (**B**) Axial contrast-enhanced CT scan obtained 24 hours post-RFA of the HCC. (**c**) Photograph of an anatomic specimen that demonstrated diaphragmatic burn (**d**) that resulted from a liver ablation. L, liver.

tissue innervation is via the autonomic nervous system.[36] Thus, the visceral peritoneum reacts to pressure and tugging. In contrast, the parietal peritoneum is innervated by visceral and somatic afferent nerves and is sensitive to friction, pressure, cutting, and temperature.[36] This explains why thermal ablation of subcapsular tumors, which are often immediately adjacent to the parietal peritoneum, are often associated with intra- and postprocedure pain.[37] Thermal injury–related pain to the peritoneum can persist for several days postprocedure and often required narcotic analgesics for pain control.[38] The best way to manage thermal injury to the parietal peritoneum is to try to prevent it from happening. To help prevent the incidence of or alleviate parietal peritoneal pain related to thermal injury, some authors advocate the use of artificial ascites to create a liquid barrier between the liver capsule and peritoneum.[38,39] With the creation of artificial ascites, a needle or catheter is placed within the peritoneal cavity using imaging guidance, followed by instillation of 0.9% normal saline or 5% dextrose in water into the peritoneum.[38,40,41] By physically separating the liver capsule from the parietal peritoneum, the operator can treat subcapsular lesions with little risk of thermal injury to the peritoneum.[39] When applied for the treatment of subcapsular dome lesions, this technique further helps minimize the risk of procedure-related pneumothorax by displacing the liver away from the diaphragm.[42–45]

Gastrointestinal Complications

Gastrointestinal injury following radiofrequency or MWA of liver tumors has a reported incidence of 0.11%.[46] Thermal injury to esophagus, stomach, and bowel has been described.[47–51] Most incidences of thermal ablation–related bowel injury occur from treatment of subcapsular tumors.[49] As mentioned earlier, some authors have postulated that presumed enterohepatic adhesions may act as a conduit to transfer heat from the liver to bowel in patients who have undergone previous bowel surgery.[28] To help mitigate the risk of thermal injury to the gastrointestinal tract, several adjunctive maneuvers have been described, including balloon interposition between liver and gastrointestinal tract and use of artificial ascites.[52–54] Management of gastrointestinal perforations in most cases requires surgical repair.

Infection

Patients with prior bilioenteric reconstructive surgery or sphincterotomy as well as patients previously treated with chemoembolization are at a higher risk of developing ablation-related abscesses.[55,56] Therefore, patients with a history of pancreatic adenocarcinoma and Whipple procedure undergoing thermal ablation for liver metastases at a minimum should be treated with intraprocedural antibiotics. Some authors advocate a pre- and posttreatment antibiotic regimen.[57,58] Liver abscesses can be managed with percutaneous drainage and/or long-term intravenous antibiotics until resolution.

Vascular Complications

Thermal ablation–related vascular complications include hemorrhage, pseudoaneurysm, and thrombosis. Life-threatening hemorrhage is rare with a reported incidence of less than 1%.[7,59] Pseudoaneurysms can present as acute or delayed complications and when ruptured and present clinically with new-onset abdominal pain and drop in hemoglobin and imaging findings of hemoperitoneum (►**Fig. 7**). Intraparenchymal hematomas (►**Fig. 8**) may or may not require intervention and their management is driven by patient hemodynamics and changes in hemoglobin count. Coagulopathies, a frequent finding in cirrhotic patients, should be corrected whenever possible to minimize the risk of hemorrhage. General guidelines suggest that platelet counts between 30 and 50×10^9 should be corrected. Similarly, a recommended target range for international normalize ratio should be less than 1.5 to 1.9; values above this range should be corrected with fresh frozen plasma.

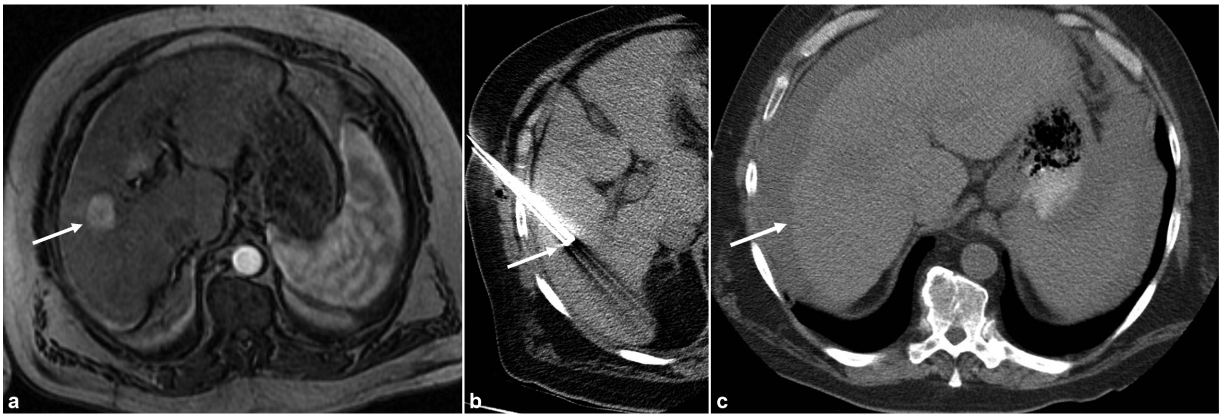

Fig. 7 (**a**) Axial gadolinium-enhanced T1-weighted image of the liver which demonstrated a segment V hepatocellular carcinoma (HCC) (white arrow). (**b**) Axial CT image at the time of RFA which demonstrates electrode within the HCC (white arrow). (**c**) Axial unenhanced image of the liver taken 2 days after RFA when patient presented with acute onset of abdominal pain. White arrow indicates new large volume hemoperitoneum.

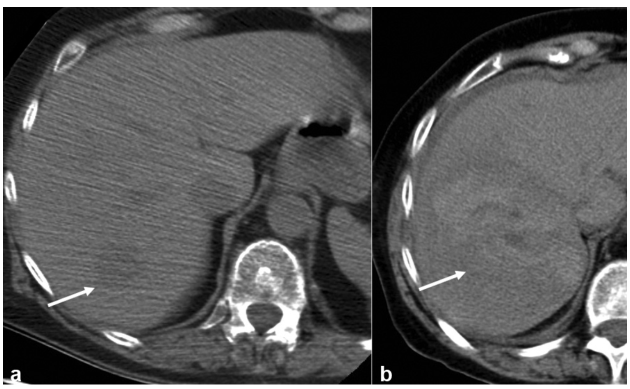

Fig. 8 (**a**) Axial unenhanced preliminary CT scan of the liver obtained at the time of RFA which demonstrates a colorectal metastasis (white arrow). (**b**) Axial unenhanced CT scan obtained immediately after RFA which demonstrates an intraparenchymal hematoma.

Conclusion

Overall, the safety profile of image-guided thermal ablation is high. Nevertheless, an awareness of the potential complications that can occur with ablation is essential to properly plan and anticipate an untoward outcome. In most cases, ablation-related complications can be managed conservatively or with minimal escalation of care to achieve resolution.

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Conflict of Interest
None declared.

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