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Diagn Interv Radiol 2023; DOI: 10.5152/dir.2022.21809

INTERVENTIONAL RADIOLOGY

PICTORIAL ESSAY

Vascular complications related to image-guided percutaneous thermal ablation of hepatic tumors

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ABSTRACT

Percutaneous thermal ablation of hepatic tumors is accepted as a safe, reliable, and cost-effective therapeutic option for treating hepatocellular carcinoma and hepatic metastases. However, operators should be familiar with the myriad of vascular and non-vascular complications that can occur post-ablation and that are described in the literature. This review will focus on the various vascular complications related to percutaneous thermal ablation of hepatic tumors and discuss strategies to avoid and manage these complications.

KEYWORDS

Ablation, complications, hepatic tumors, microwave ablation, radiofrequency ablation

Minimally invasive therapies like image-guided percutaneous thermal ablation have gained widespread acceptance as a method for treating focal primary and secondary hepatic malignancies. This review will focus only on radiofrequency ablation (RFA) and microwave ablation (MWA). These are the most frequently used modalities for thermal ablation of hepatic malignancies. The other less common modalities are laser thermal ablation, cryoablation, and irreversible electroporation.

Several studies, trials, and meta-analyses comparing thermal ablation with surgical resection of small hepatic tumors have shown that thermal ablation is less expensive and invasive. It also has a lower complication rate but a comparable survival rate.[1] Additionally, RFA and MWA are the most cost-effective treatment modalities for patients with very early and early-stage hepatocellular carcinoma (HCC).[2] According to the Barcelona Clinic Liver Cancer (BCLC) staging system, these patients are classified as BCLC-0 (very early-stage HCC) and BCLC-A (early-stage HCC). Thermal ablation is currently the standard of care for patients with oligo-metastases or those with BCLC-0 and BCLC-A HCC who are not well suited for surgical resection.[3] It is also used as a "bridging therapy" to prevent patient dropout from the liver transplantation waiting list.[3]

Vascular complications are usually due to vessel damage caused by either direct mechanical insertion of the ablation needle or by indirect thermal injury.[4] The complications encountered are needle tract bleeding, hepatic artery damage, venous thrombosis, hepatic infarction, hemobilia, arterioportal fistula (APF) formation, and cardiac tamponade. Vascular complications of MWA and RFA are similar since both modalities require insertion of needles and can result in heat-based damage.

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Received 29 July 2021; revision requested 31 October 2021; last revision received 22 December 2021; accepted 16 January 2022.

Ebup: 13.03.2023

Publication date: 29.03.2023

DOI: 10.5152/dir.2022.21809

You may cite this article as: Tashi S, Gogna A, Leong S, Venkatanarasimha N, Chandramohan S. Vascular complications related to image-guided percutaneous thermal ablation of hepatic tumors. *Diagn Interv Radiol.* 2023;29(2):318-325.

Complications

Needle tract bleeding

Significant needle tract bleeding is a major complication (Common Terminology Criteria for Adverse Events grade 3 or higher) of percutaneous thermal ablation of hepatic tumors, as it can be immediately life-threatening and may lead to prolonged hospitalization.[5] It is also one of the more frequent major complications of thermal ablation, with a prevalence ranging from 0.37% to 2.0%.[4-6] A greater risk of bleeding has been reported in patients with liver cirrhosis, given the higher degree of clinical or subclinical coagulation disorders in these patients. There is also greater vascularity when comparing HCC with metastases.[7]

Needle tract bleeding is also the most common vascular complication related to percutaneous thermal ablation of hepatic tumors. It often results from direct mechanical injury to the vasculature caused by the insertion of the needle rather than because of thermal damage to the vessels.[4]

Most bleeding during thermal ablation is minor and self-limited; it is usually of little clinical significance and can be managed expectantly.[7] The bleeding can result in the formation of regional hematomas (intrahepatic, subcapsular, or perihepatic) along the ablation needle pathway (Figure 1) or extend into the adjacent body cavities, such as the hemoperitoneum or hemothorax.

Venous bleeding is usually self-limited and is mainly treated conservatively with occasional blood transfusions (Figure 2).[4] However, if arterial bleeding is suspected, this would require vigilant clinical evaluation and monitoring along with a low threshold to intervene if active bleeding is established.

Multiphasic contrast-enhanced computed tomography (CT) should be routinely performed as it helps recognize immediate post-ablation bleeding and can determine whether the ablation procedure was effective. Close and vigilant monitoring of the patient's symptoms and vital signs are also indispensable for the early detection and proper management of such a potentially life-threatening complication. Prompt transcatheter arterial embolization should be performed if there is clinical or imaging evidence of continued arterial bleeding.

In addition to multiphasic CT, interrogation of the needle track with either color Doppler study or contrast-enhanced ultrasound can be performed in cases where intravenous CT contrast media is contraindicated. This can be helpful in the early detection of arterial bleeding along the needle track immediately after removal of the ablation needle.[4,8] In such cases, a repeat cauterization can be performed by immediately reintroducing the needle to the entry point at the liver's surface, and this can be done under real-time ultrasound guidance (Figure 3).[9]

Hepatic artery damage

Hepatic artery damage has an incidence of 0.2%.[10] As mentioned previously, damage to the hepatic artery is usually by direct mechanical injury during the placement of the ablation needle, and this typically manifests as acute bleeding.[4] However, the formation and subsequent rupture of a hepatic artery pseudoaneurysm can also manifest as delayed hemorrhage and be potentially catastrophic (Figure 4).[10,11] Hepatic artery thrombosis is also very rare. Preclinical studies suggest that hepatic arteries are less likely to thrombose due to their high flow state.[12]

Venous thrombosis

The reported incidence of venous thrombosis is 0.1% to 1.08%.[10,13] Portal and hepat-

Main points

- There should be stringent criteria for patient selection and meticulous preprocedural planning and evaluation. Coagulopathy should be corrected before ablation is performed.
- Choose the most optimal imaging modality for ensuring a safe needle trajectory. To approach centrally located tumors more cautiously, avoid tumors abutting large major blood vessels and biliary ducts.
- Ensure patient cooperation and comfort during ablation. Thermal ablation should preferably be performed under general anesthesia or intravenous sedation.
- There should be vigilant postprocedural monitoring. Watch out for abdominal pain with increasing intensity, sustained tachycardia (>100 beats/min), and/or hypotension (systolic blood pressure <90 mmHg or drop in the systolic blood pressure by >40 mmHg).
- Well-timed follow-up imaging should be used for early detection of vascular complications.

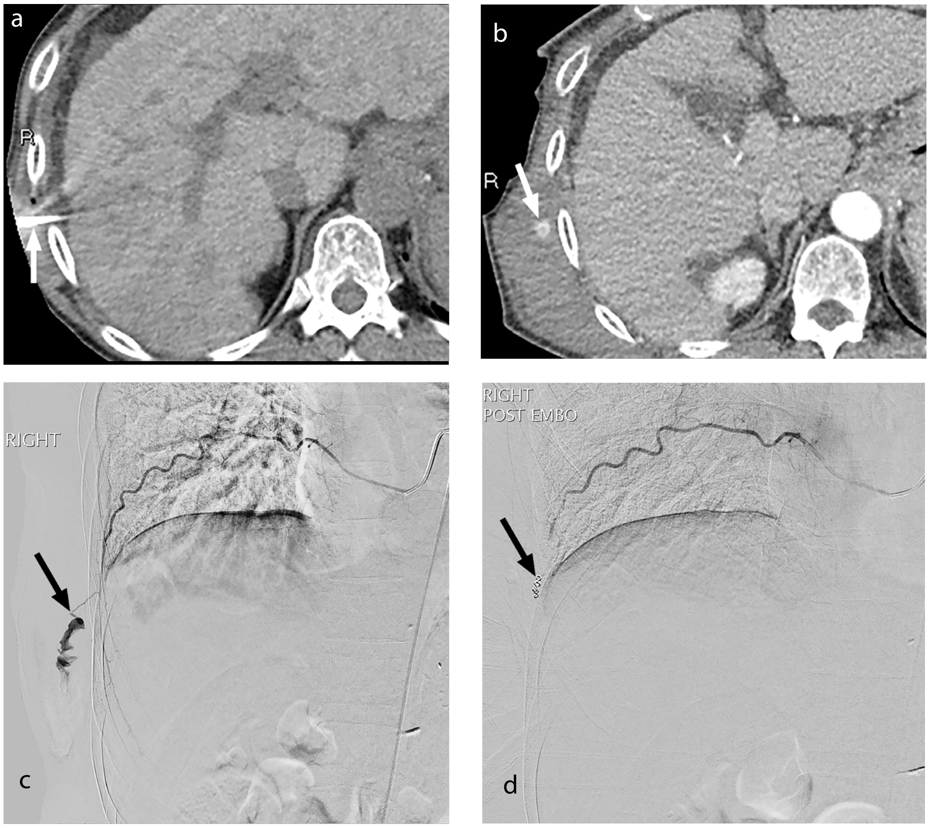

Figure 1. (a-d) Chest wall hematoma due to active bleeding from the intercostal artery after radiofrequency ablation (RFA) of a segment 8/5 hepatocellular carcinoma. Plain axial computed tomography image **(a)** at the entry point level of the RFA needle (arrow). Axial contrast-enhanced computed tomography image **(b)** in the arterial phase demonstrates a right chest wall hematoma with active contrast extravasation (arrow). Selective angiogram **(c)** of the right 8th intercostal artery shows active contrast extravasation (arrow). Post-embolization angiogram **(d)** shows complete cessation of the active contrast extravasation after embolization with 2 mm coils (arrow).

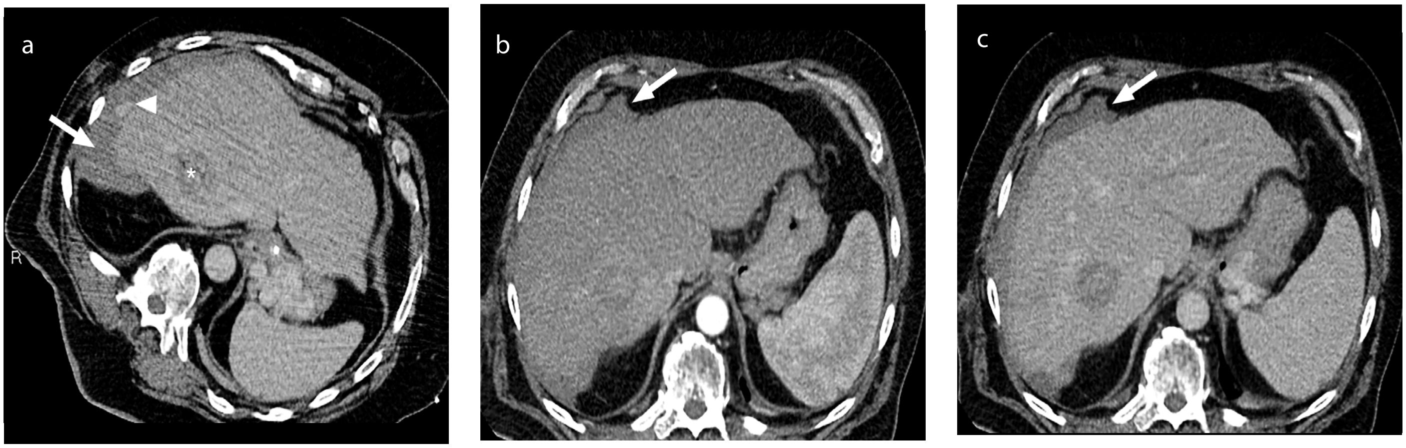

Figure 2. (a-c) Perihepatic hematoma after microwave ablation of a segment 7/8 hepatocellular carcinoma. Axial contrast-enhanced computed tomography (CECT) image **(a)** showing a perihepatic hematoma (arrow) with a focus on extracapsular contrast extravasation (arrowhead) seen only in the venous phase due to bleeding. Site of ablation (asterisk). The patient's hemodynamic status remained stable and unchanged during close monitoring. Repeat axial CECT images in the arterial **(b)** and venous **(c)** phases two hours post-procedure demonstrate a stable perihepatic hematoma (arrow) with the disappearance of the contrast extravasation.

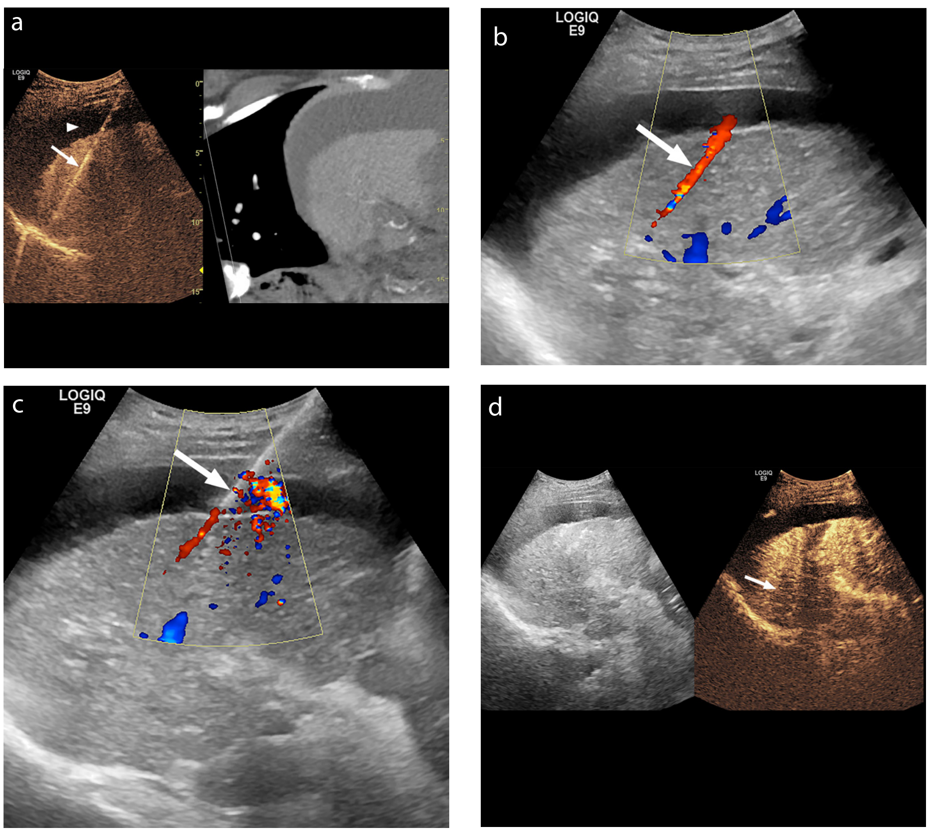

Figure 3. (a-d) Repeat cauterization of the needle tract bleeding after microwave ablation (MWA) of a recurrent segment 7 hepatocellular carcinoma. Fusion contrast-enhanced ultrasound (CEUS) with computed tomography **(a)** was performed to guide the MWA needle (arrow). Concomitant ascites (arrowhead). After removing the ablation needle, Doppler interrogation of the needle track **(b)** demonstrates a linear color Doppler flow (arrow) along the needle tract, indicating active bleeding. **(c)** The ablation needle (arrow) was immediately reintroduced under real-time ultrasound guidance to the needle entry point at the liver's surface, and repeat cauterization was performed. Post-ablation CEUS **(d)** demonstrates complete ablation of the lesion (arrow) with no evidence of active bleeding from the needle tract.

ic vein thrombosis is mainly caused by heat damage to the endothelium of these veins near the ablation zone.[13]

In vivo studies have shown that smaller vessels (with a diameter of <3 mm) encompassed by the ablation zone are more prone to thrombosis from thermal injury. This is due to the absence of vascular perfusion-mediated heat sink effect, which is mainly dependent on the vessel size.[14]

After ablation, thrombosis of larger vessels (with a diameter of >3 mm) is uncommon when the blood flow is normal;[15] however, thermal damage may cause thrombosis if the flow is compromised. Hence, other factors besides portal hypertension that can potentially decrease the blood flow in the portal venous system should be considered before ablation. Some factors include pre-existing thrombosis and compression of the vein by the tumor.[16]

Most patients with portal and hepatic vein thromboses are asymptomatic even when larger segmental vessels are thrombosed, and they require no specific therapy (Figure 5). However, extensive portal vein thrombosis can result in potentially fatal complications, such as hepatic failure or the worsening of portal hypertension, especially in patients with insufficient hepatic reserves.[13,15,16] Systemic anticoagulation or local thrombolysis may be necessary if the liver function is affected.[14,16]

Moreover, the presence of post-ablation portal and hepatic vein thrombosis warrants further investigation and follow-up imaging to rule out tumor progression within the venous system.[13]

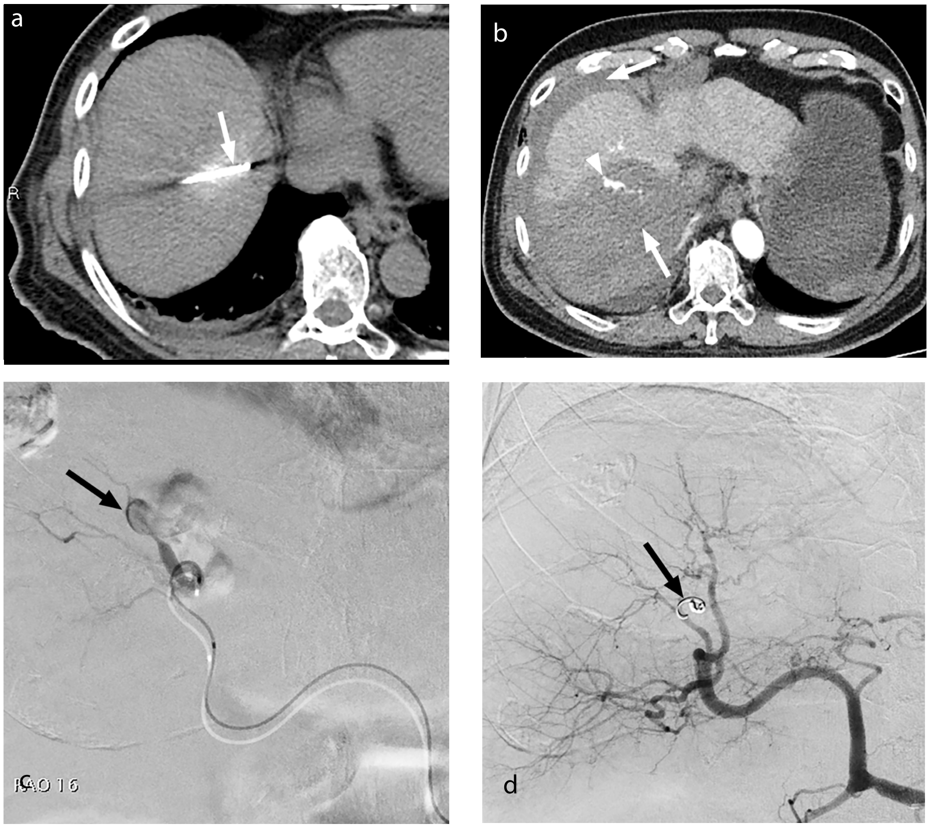

Figure 4. (a-d) Ruptured hepatic artery pseudoaneurysm with delayed presentation after radiofrequency ablation (RFA) of a segment 7 hepatocellular carcinoma. Axial plain computed tomography image **(a)** shows the final position of the RFA needle (arrow) before ablation. Axial contrast-enhanced computed tomography (six days post ablation) image **(b)** in the arterial phase demonstrates large intrahepatic and perihepatic hematomas (arrows) with a focus on active contrast extravasation (arrowhead). Selective angiogram **(c)** of the offending branch of the right hepatic artery shows a ruptured pseudoaneurysm (arrow) with active contrast extravasation. Post-embolization angiogram **(d)** shows successful embolization with 3 mm coils (arrow).

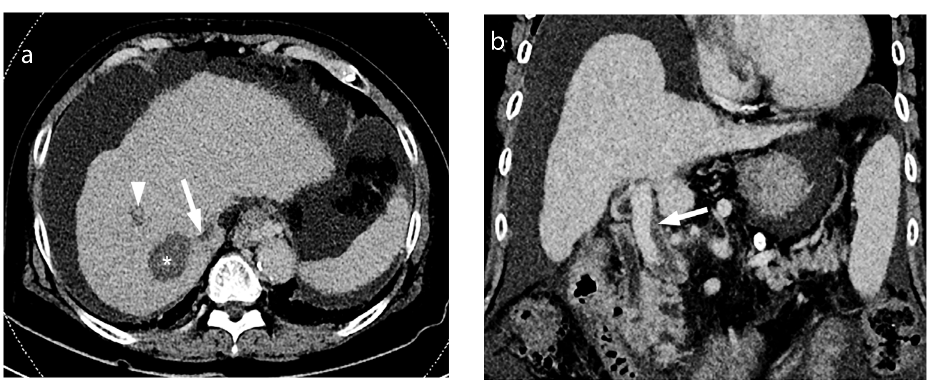

Figure 5. (a, b) Portal vein and hepatic vein thrombosis after microwave ablation of a segment 7 hepatocellular carcinoma. Axial contrast-enhanced computed tomography (CECT) (one month follow up) image **(a)** in the venous phase shows adequate ablation of the lesion (asterisk) with the formation of partial thrombus within the adjacent right hepatic vein (arrow) and portal vein (arrowhead). Coronal CECT image **(b)** in the venous phase demonstrates the extension of the partial thrombus into the main portal vein (arrow).

Hepatic infarction

Hepatic infarction is an uncommon complication with an incidence of up to 0.07%.[17] It is uncommon because of the dual blood supply to the liver and the organ's ability to develop extensive collateral pathways. Nevertheless, hepatic infarction can occur from insult to both the hepatic arterial and portal venous systems.[17,18]

Most of these patients can be managed conservatively and may be treated with prophylactic antibiotics until the infarcted tissue heals (Figure 6). However, there can be accompanied complications, such as biloma or abscess formation, portal vein thrombosis, and rarely death from hepatic failure due to lobar infarction.[16]

Hemobilia

Another hemorrhagic complication is hemobilia, with an incidence of 0.1% to 0.5%.[6,10] It usually occurs from a concomitant puncture of the biliary tract and blood vessel with the ablation needle. The presenting symptoms are typically upper abdominal pain, hematemesis, and melena.[6] Additional laboratory tests may show elevated levels of bilirubin and biliary enzymes. Clots may be visualized within the gallbladder or biliary tree on imaging.

No treatment is necessary for asymptomatic patients, but endoscopic or percutaneous drainage may be required for those with symptoms and biochemical evidence of biliary obstruction (total bilirubin concentration exceeding 4 mg/dL). Drainage may be necessary since there is a risk of liver failure or potentially fatal acute obstructive suppurative cholangitis caused by biliary obstruction from blood clots (Figure 7).[6]

Hence, careful selection of an appropriate needle pathway with real-time visualization of the needle trajectory is paramount to avoid puncturing biliary radicles, especially those that may be locally dilated because of tumor compression. Since the hepatic artery, portal vein, and intrahepatic bile duct run together, it is crucial to avoid these structures during needle insertion.[6] If a large arterio-biliary fistula is present, transcatheter arterial embolization may be performed to arrest any bleeding.[7]

Arterioportal fistula

In a multicenter study of RFA complications, the incidence of APF formation was reported to be about 0.4%.[18] However, the actual incidence could have been higher since most patients are asymptomatic and APF formation is discovered on follow-up CT imaging (Figure 8).[19] The majority of small APFs heal spontaneously post ablation.[10]

However, APFs can potentially exacerbate portal hypertension symptoms and lead to the rupture of gastroesophageal varices, the worsening of ascites, and the deterioration of liver function (Figure 9). In such cases, a comprehensive evaluation of the APF should be performed, and it should be treated with transcatheter embolization.[20]

Cardiac tamponade

Hemorrhagic cardiac tamponade is an extremely rare but potentially fatal complication that can be successfully treated if detected promptly. To date, about six cases have been reported in the literature.[21] Tumors located in the liver's left lobe near the pericardium (namely in segments II and IVa) are considered pertinent risk factors for this complication (Figure 10).[21] Emergency pericardiocentesis (with the placement of a drainage catheter into the pericardial space) should be performed if the post-procedure hemodynamic parameters and imaging favor a pericardial effusion.

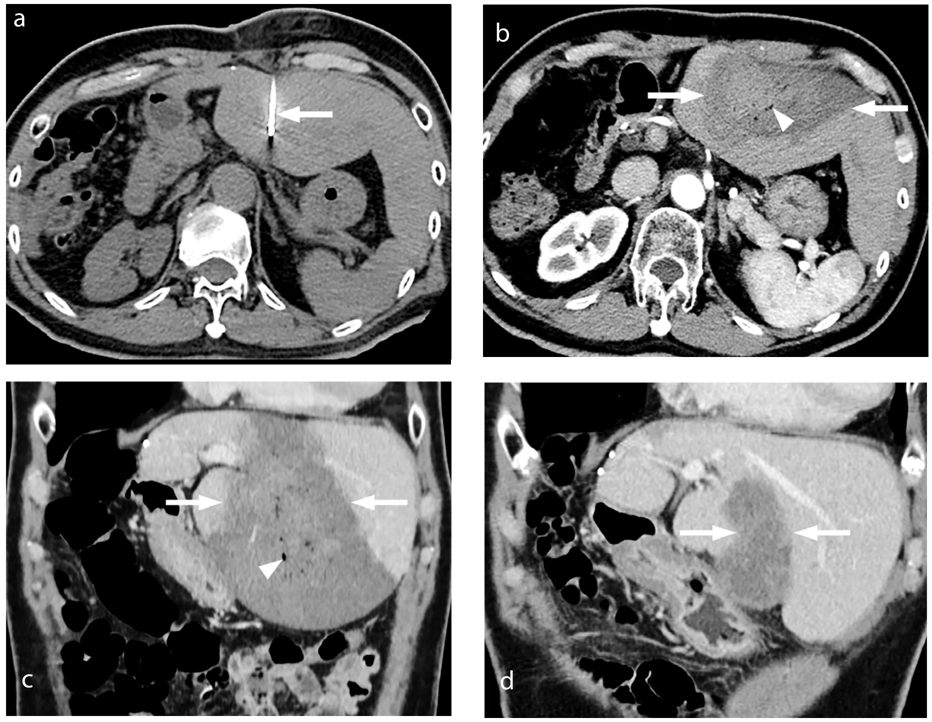

Figure 6. (a-d) Hepatic infarction after radiofrequency ablation (RFA) of a segment 3 metastasis from rectal carcinoma. Prior right hepatectomy was performed for hepatic metastases. Axial plain computed tomography (CT) image **(a)** shows the final position of the RFA needle (arrow) pre-ablation. Axial contrast-enhanced computed tomography (CECT) (two days post ablation) image in the arterial phase **(b)** and coronal CT image in the venous phase **(c)** demonstrate a large, well-defined hypodense area in the liver's left lobe, in keeping with hepatic infarction (arrows). Small, scattered pockets of gas (arrowhead) within this infarcted area suggest a concurrent infection. The patient was treated conservatively with antibiotics. Coronal CECT (six months follow up) image **(d)** in the venous phase demonstrates retraction and reduction in size (arrows).

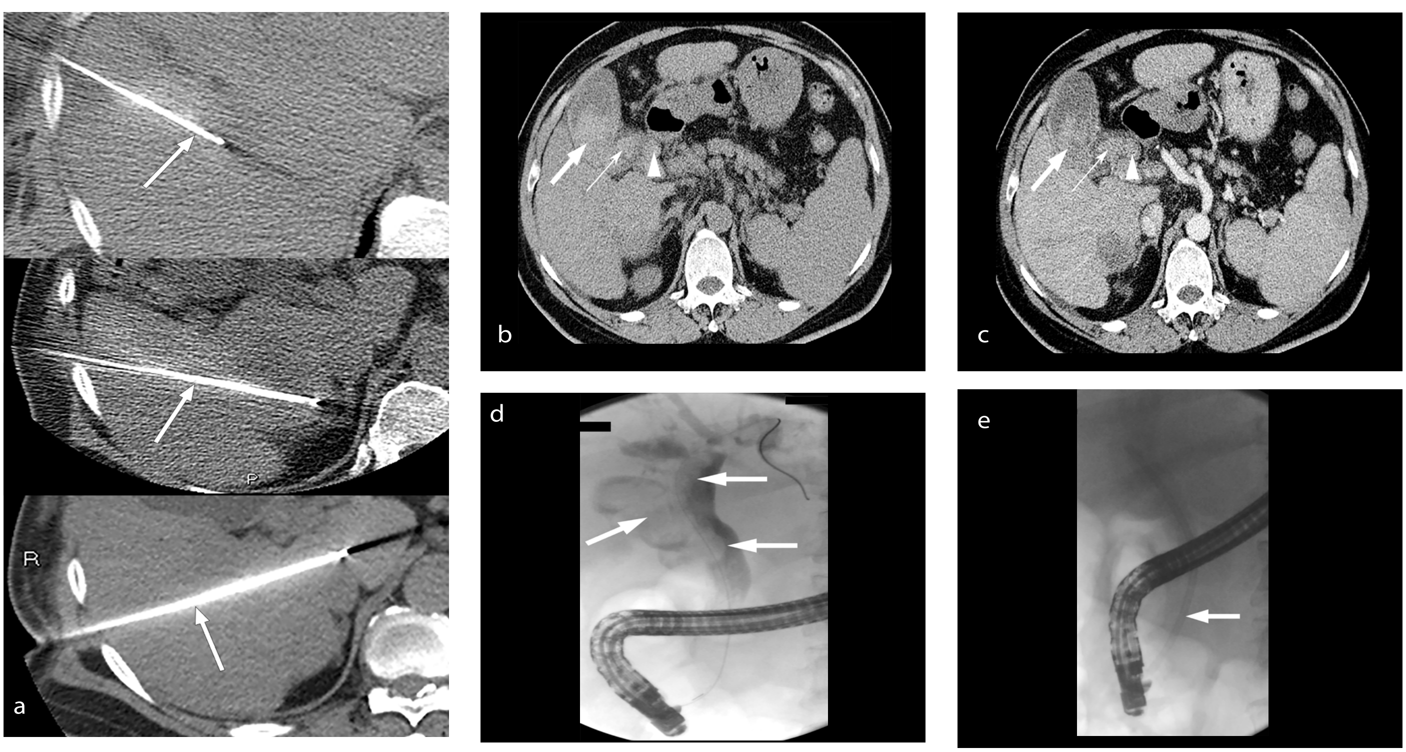

Figure 7. (**a-e**) Hemobilia presenting as melena with hemoglobin drop. The patient underwent sequential radiofrequency ablation (RFA) of three hepatocellular carcinomas in the same setting. Axial plain computed tomography (CT) images **(a)** show the RFA needle's position (arrows) in the segments 5/8, 5, and the caudate lobe. Axial CT (one week post ablation) images in the plain **(b)** and arterial **(c)** phases demonstrate hyperdense material within the gallbladder (thick arrow), cystic duct (thin arrow), and common bile duct (arrowhead), likely representing blood clots. No active contrast extravasation was noted on the CT scan. An endoscopic retrograde cholangiography (ERCP) was performed since the serum bilirubin level was markedly elevated. Fluoroscopic spot image from the ERCP **(d)** shows filling defects (arrows) within the opacified common bile duct, cystic duct, and gallbladder, likely caused by blood clots. **(e)** A plastic biliary stent (arrow) was deployed endoscopically for drainage of the biliary system.

Figure 8. Arterioportal fistula (APF) formation after microwave ablation of a segment 8 hepatocellular carcinoma. Coronal maximum intensity projection contrast-enhanced computed tomography image in the arterial phase displays the APF (arrowhead) with early opacification of the adjacent segmental portal vein (arrow). Note the ablation zone (asterisk).

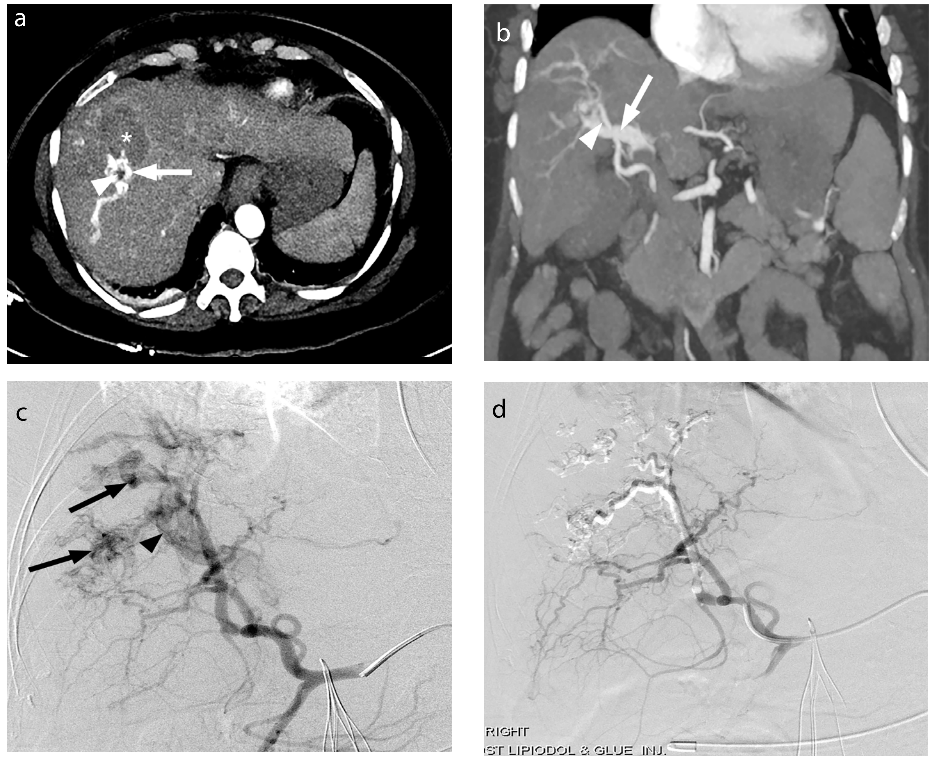

Figure 9. (a-d) Arterioportal fistula (APF) with exacerbation of portal hypertension. Massive hematemesis due to esophageal variceal bleed after microwave ablation of a segment 8 hepatocellular carcinoma. Axial **(a)** and coronal **(b)** maximum intensity projection contrast-enhanced computed tomography in the arterial phase demonstrates opacification of the right portal vein (arrow) adjacent to the ablation site (asterisk) due to APF. A non-occlusive thrombus in the opacified right portal vein is evident (arrowhead). The variceal bleeding was controlled with endoscopic band ligation. Angiogram **(c)** of the right hepatic artery demonstrates APF formation (arrows) with immediate opacification of the right portal vein (arrowhead). The APF was embolized with a mixture of histoacryl (n-butyl-2-cyanoacrylate) and lipiodol in a 1:2 ratio. Post-embolization angiogram **(d)** shows complete occlusion of the feeding artery with no evidence of APF.

Figure 10. (a-c) Cardiac tamponade. Coronal fat-suppressed post-contrast T1-weighted image **(a)** shows a hepatocellular carcinoma (arrow) with washout in segment 2 of the liver near the pericardium. The patient became hypotensive after insertion of the radiofrequency ablation (RFA) needle and developed increased central venous pressure suggestive of cardiac tamponade. Sagittal plain computed tomography image **(b)** demonstrates the RFA needle's tip (arrowhead) abutting the pericardium with adjacent pericardial effusion (arrow). An 8-French pigtail catheter was immediately inserted into the pericardial space via the subcostal route. Fluoroscopic spot image **(c)** shows the position of the pigtail drainage catheter (arrow).

Discussion

Meticulous preprocedural planning and evaluation are indispensable. A detailed assessment of the coagulation profile, tumor location, and hepatic reserve is essential.[4]

The risk factors for increased risk of bleeding include:

- coagulopathy,
- the size of the ablation needle,
- the tumor size,
- multiple punctures or electrodes,
- tumor location (tumors behind major blood vessels[6,16] or located superficially are at greater risk of bleeding).

Various periprocedural strategies can be taken to minimize the risk of bleeding. Preprocedural correction of underlying coagulopathy should be carried out. This can be done by administering the appropriate blood products, such as fresh frozen plasma, cryoprecipitate, and platelet concentrate, along with the appropriate withholding of antiplatelet or anticoagulant drugs.[6,8] Ablation should be judiciously deferred until all parameters are corrected in patients with coagulopathy.[4]

Careful selection of the needle path during the procedure is also paramount. It is crucial to select a path that traverses sufficient normal liver parenchyma and avoids transgressing any major vessels or biliary ducts near the index tumors.[6,8] Sufficient cauterization of the needle tract during withdrawal is also an effective method to prevent or reduce the risk of bleeding.[8,10] Finally, ablation should be avoided in patients with poor hepatic reserve.[7]

Some tumors are better visualized by a specific imaging modality; hence, to reduce the risk of damage to adjacent structures, the operator should choose the best modality for optimal visualization of the target tumor.[4]

Sometimes patients exhibit uncooperative breath-holding due to pain and anxiety, and this can result in difficulty targeting the lesion and misplacement of the ablation needle. Therefore, performing these procedures under intravenous sedation or general anesthesia is recommended, depending on the operator or institutional preference[3] for patient cooperation and comfort.

Besides performing routine postprocedural imaging, closely monitoring the patient's hemodynamic parameters during and after the procedure is highly recommended. Cirrhotic patients are often already in a hyperdynamic circulatory state, and the appearance of tachycardia due to hypovolemia may be delayed.[6] Any post-procedural clinical symptoms that suggest a vascular complication should be immediately brought to the clinician's attention. Among patients with hemoperitoneum, the most common symptom after ablation is abdominal pain with increasing intensity.[6] If this occurs along with tachycardia (>100 beats/min) and/or hypotension (systolic blood pressure <90 mmHg or reduction in the systolic blood pressure by >40 mmHg), the clinician should be notified. Additionally, hemorrhagic complications may manifest >8 hours after the procedure; therefore, it is highly recommended that all ablation procedures are performed in an inpatient setting.[6]

Conclusion

Although percutaneous thermal ablation of hepatic tumors is a safe procedure with a low incidence of significant complications, a spectrum of vascular complications can occur. As with any procedure, a better outcome can be achieved when patients are selected carefully, and the operator is knowledgeable about the array of complications encountered after the procedure. This is important for the early detection and appropriate management of any complications.

Conflict of interest disclosure

The authors declared no conflicts of interest.

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