

Variations in feeding arteries of hepatocellular carcinoma located in the left hepatic lobe

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Abstract The left hepatic lobe is divided into three subsegments according to anatomical landmarks; however, there are several variations in the vascular territories of the left hepatic arterial branches. Hepatocellular carcinoma (HCC) located near the umbilical fissure or at the left side of the umbilical portion of the left portal vein has frequent crossover blood supply. HCC located in the caudal aspect of the lateral segment has a variety of feeding arteries, and is infrequently supplied by the caudate artery or the medial subsegmental artery (A4), and by the lateral left hepatic arteries. HCC located in the posterior aspect of segment 4 is frequently supplied by the caudate artery or a small A4 branch arising from the caudate artery. In addition, the left inferior phrenic, right and left internal mammary, right and left gastric, cystic, and omental arteries are well known extrahepatic collateral pathways supplying HCC in the left hepatic lobe, especially when the hepatic artery is attenuated by previous transcatheter arterial chemoembolization (TACE). Interventional radiologists should have sufficient knowledge of vascular territories in the left hepatic arterial branches and extrahepatic collaterals to perform effective TACE for HCC located in the left hepatic lobe.

Keywords Left hepatic lobe · Vascular territory · Hepatocellular carcinoma · Transcatheter arterial chemoembolization

Introduction

Transcatheter arterial chemoembolization (TACE) is one of the most effective treatments for inoperable hepatocellular carcinoma (HCC) and is performed worldwide [1–4]. Superselective catheterization into the tumor-feeding branches using a microcatheter is fundamental to effective TACE [2–4].

The left hepatic lobe is divided into three subsegments according to anatomical landmarks, for example the gallbladder fossa, the middle and left hepatic veins, the umbilical portion of the left portal vein, the falciform ligament, and the fissure for the ligamentum venosum and ligamentum teres. However, there are several variations in the vascular territories of the left hepatic arterial branches. Furthermore, several extrahepatic collateral pathways reach the left hepatic lobe and supply HCC lesions. It is very important to be familiar with such vascular variations in the left hepatic lobe to perform effective TACE for HCC.

In this article, we describe several variations in the tumor-feeding arteries of initially developed or recurrent HCCs after TACE located in the left hepatic lobe.

HCC located near the umbilical fissure

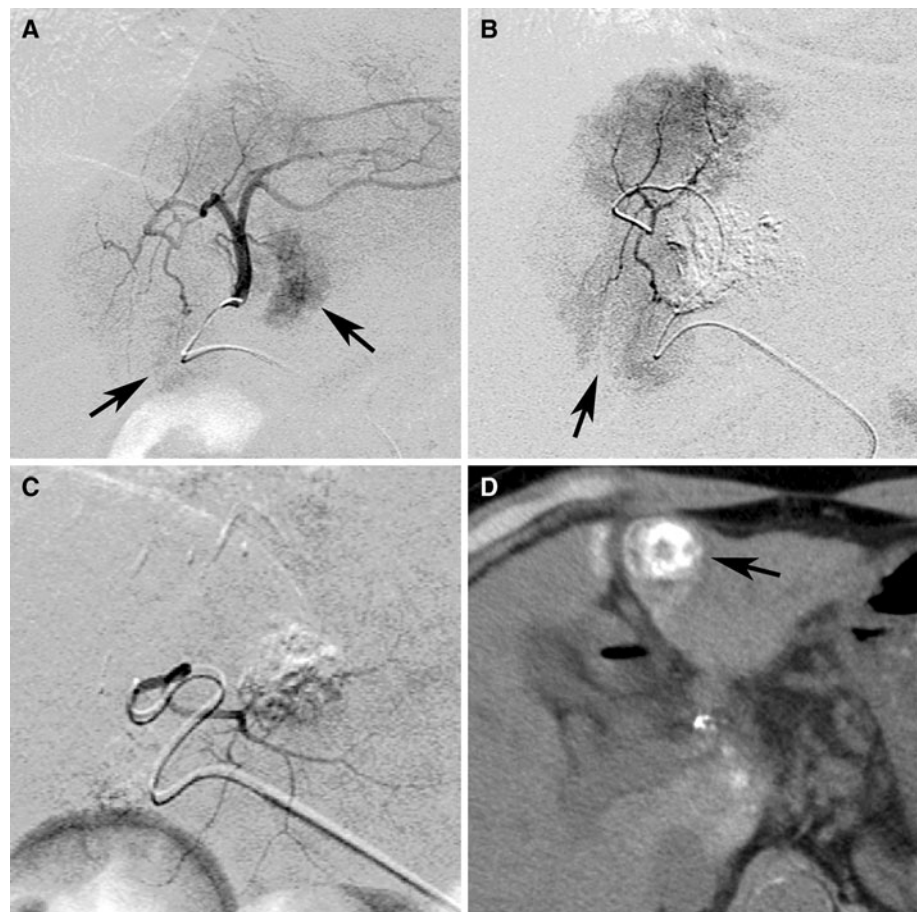
The umbilical fissure, consisting of the parietal surface of the attachment of the falciform ligament and the visceral surface of the fissure for the ligamentum venosum and

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Fig. 1 HCC located at the left side of the umbilical fissure.

a Left lateral hepatic arteriogram shows two tumor stains (*arrows*) supplied by the caudate artery and the medial subsegmental artery (A4). **b** The branch derived from the A4 was selected and transcatheter arterial chemoembolization (TACE) was performed after TACE of the caudate artery. The *arrow* shows the umbilical fissure. **c** Arteriogram of the inferior lateral subsegmental artery (A3) that arises separately from the proper hepatic artery shows no tumor staining. **d** CT performed 1 week after TACE shows dense accumulation of iodized oil in the tumor located at the left side of the umbilical fissure in segment 3 (*arrow*). Iodized oil is also distributed at the right side of the umbilical fissure



ligamentum teres, anatomically divides the left hepatic lobe into the medial and lateral segments. Therefore, the right side of the umbilical fissure is included in segment 4 and the left side is included in segment 3. In a cadaver study by Gupta et al. [5], small branches of the medial segmental duct and blood vessels crossed to the left of the umbilical fissure in 4.7 % of cases and the lateral segmental duct and blood vessels crossed to the right of the umbilical fissure in 2.4 %. In an angiographic study, more frequent crossover blood supply through the umbilical fissure was reported [6]. The tumor-feeding branch of HCC located near the umbilical fissure frequently arises from the opposite subsegmental artery (Fig. 1) or both subsegmental arteries (Fig. 2). In addition, a separate small branch infrequently supplies tumors located there [6].

HCC located at the left side of the umbilical portion of the left portal vein

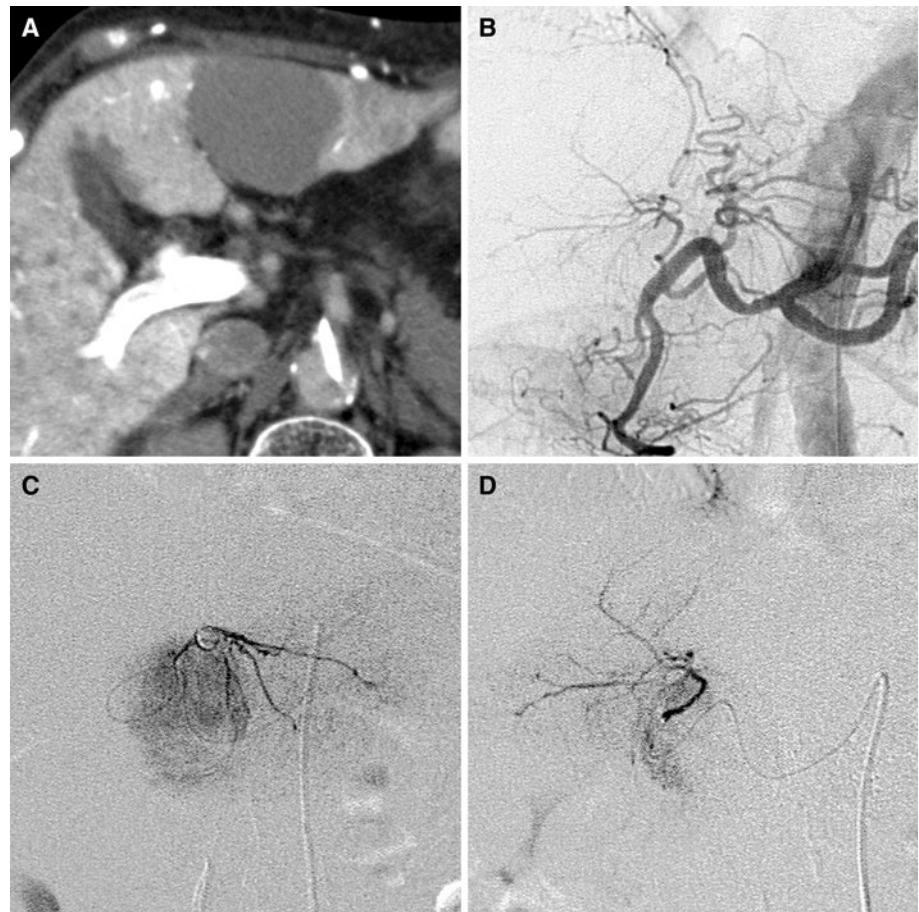
The intersegmental plane along the left hepatic vein divides the lateral segment into segments 2 and 3. Typically, the dorsal part of the left side of the umbilical portion of the left portal vein is included in segment 2,

and the ventral part is included in segment 3. However, the vascular territories do not always correspond to the anatomical condition. The branch of the lateral inferior subsegmental artery of the left hepatic artery (A3) infrequently supplies HCC in the dorsal portion of the lateral segment, which is anatomically thought of as segment 2 (Fig. 3). In addition, a small branch directly arising between the lateral superior segmental artery of the left hepatic artery (A2) and A3 supplies any tumors located there (Fig. 4).

HCC located in the caudal aspect of the lateral segment

The caudal aspect of the lateral segment beneath the left diaphragm is mainly included in segment 2 [7]. However, this area has complex vascular anatomy because the vascular territories of each branch of the left hepatic artery, including not only A2, but also the medial subsegmental artery (A4) and the caudate artery, differ in individual cases. The caudate artery arising from the left hepatic artery infrequently supplies the dorsal part of the caudal aspect of the lateral segment (Fig. 5) and the branch of A4 also supplies the ventral part (Fig. 6).

Fig. 2 HCC located at the left side of the umbilical fissure. **a** CT during arteriportography (CTAP) shows a tumor (*arrow*) at the left side of the umbilical fissure. **b** Celiac angiogram shows that the left and middle hepatic arteries arise from the common hepatic artery. The right hepatic artery arises from the superior mesenteric artery (not shown). **c** Angiogram of A3 shows tumor staining. **d** Angiogram of the middle hepatic artery also shows staining at the right side of the tumor



HCC located in the gallbladder bed of segment 4

It is well known that the intersegmental plane based on the vascular territory is not flat and that crossover blood supply is present at the boundary between the right and left hepatic lobes [8], in addition to both sides near the umbilical fissure [6], as described above. Renz et al. [9] reported that a significant (>1 mm) arterial branch(s) derived from the right hepatic artery which crossed Cantlie's line to supply the left lobe was identified in 15 % of 60 specimens. In our experience, a small branch of the anterior inferior subsegmental artery of the right hepatic artery (A5) infrequently supplies tumors in the gallbladder bed of segment 4 (Fig. 7).

HCC located in the posterior aspect of segment 4

The posterior aspect of segment 4 is a peculiar area and has great variety in form and numerous vascular and biliary variations [10]. Arterial blood supply to the posterior aspect of segment 4 is not clearly understood [11, 12]. On the basis of embryologic development, this area has a close

relationship with the caudate lobe of the liver [10]. HCCs located there are frequently supplied by the caudate artery or by a small A4 branch arising from the caudate artery (Fig. 8). It may be necessary to perform TACE of the caudate arterial branch, in addition to TACE of A4, to control tumors originating in the posterior aspect of segment 4.

Extrahepatic collateral pathways supplying HCC in the left hepatic lobe

Several extrahepatic collateral pathways enter the liver, especially when the hepatic arterial circulation is attenuated by a TACE procedure [13]. Infrequently, HCCs at the liver surface are initially supplied by extrahepatic collateral pathways (Figs. 9, 10). The left inferior phrenic, right and left internal mammary, right and left gastric, cystic, and omental arteries are well known extrahepatic collateral pathways supplying HCC in the left hepatic lobe [13]. The left intercostal artery also supplies tumors in the lateral segment, in particular when the tumor is large and protrudes from the liver surface (Fig. 10).

Fig. 3 HCC located at the left side of the umbilical portion of the left portal vein. **a** CT shows a tumor at the left side of the umbilical portion of the left portal vein (*arrow*). **b** Angiogram of the left hepatic artery shows faint tumor staining (*arrow*). **c** Angiogram of A3 shows tumor staining (*arrow*). TACE was performed at this point. **d** CT performed 1 week after TACE shows dense accumulation of iodized oil in the tumor

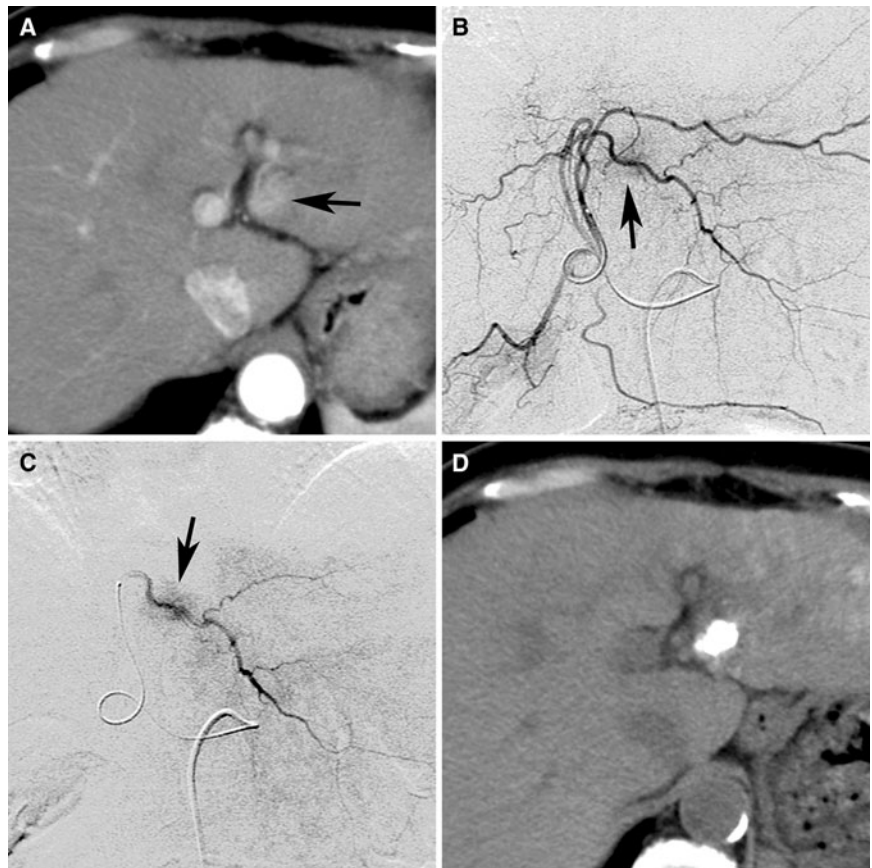


Fig. 4 HCC located at the left side of the umbilical portion of the left portal vein. **a** CT shows two tumors at the left side of the umbilical portion of the left portal vein (*arrows*). A small branch directly arising from the left hepatic artery is also seen (*arrowhead*). **b** Common hepatic angiogram shows tumor staining (*arrow*) supplied by a small branch arising between A2 and A3 (*arrowhead*). **c** Selective angiogram of this branch shows faint tumor staining (*arrow*). TACE was performed at this point. **d** CT performed 1 week after TACE shows dense accumulation of iodized oil in the tumors and a small area at the left side of the umbilical portion of the left portal vein

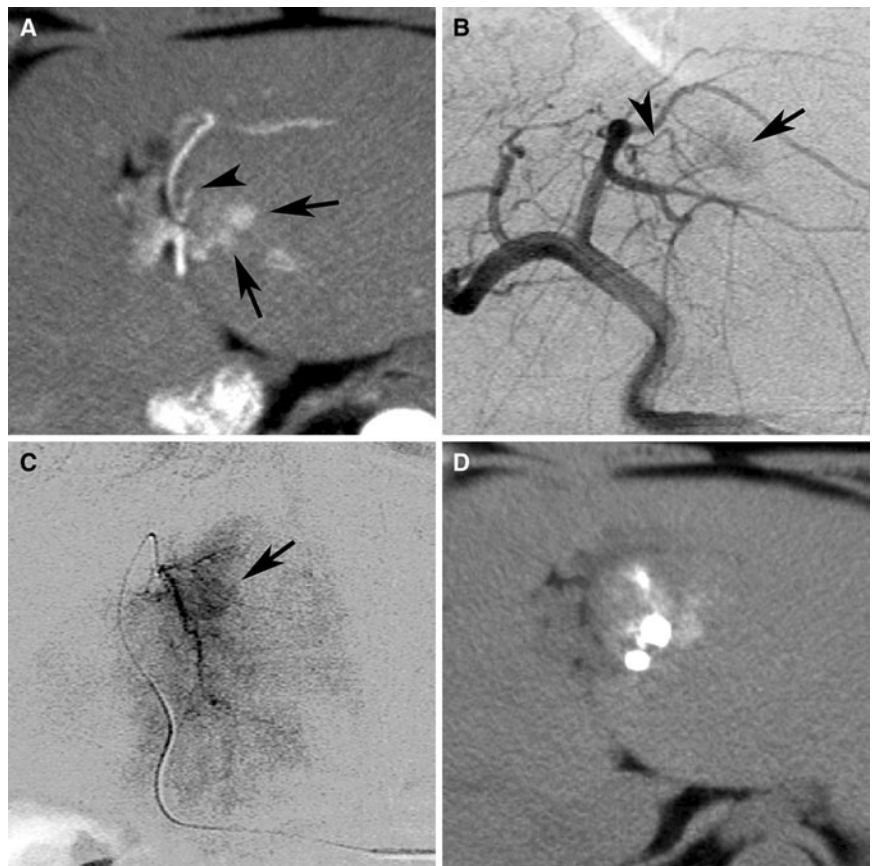


Fig. 5 HCC located in the caudal aspect of the lateral segment. **a** Left hepatic angiogram shows faint tumor staining (*arrow*). The communicating arcade derived from the caudate artery is also seen (*arrowhead*). **b** Selective angiogram of a branch of the caudate artery shows partial tumor staining (*arrow*). TACE was performed at the more distal level of this branch (not shown). **c** Selective angiogram of a proximal branch of A2 also shows tumor staining (*arrow*). TACE was performed at the more distal level of this branch (not shown). **d** CT performed 1 week after TACE shows dense accumulation of iodized oil in the tumor

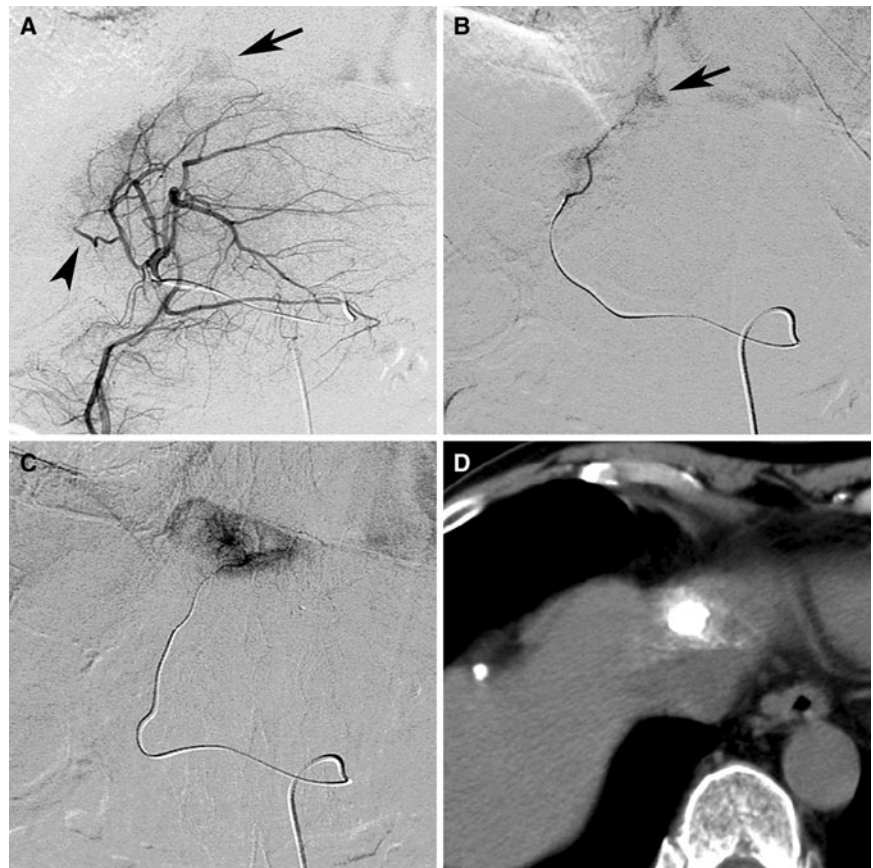


Fig. 6 HCC located in the caudal aspect of the lateral segment. **a** Left hepatic angiogram shows faint tumor staining (*arrow*) through a branch of A4 (*arrowhead*). **b** Selective angiogram of the branch shows tumor staining. TACE was performed at the more distal level of this branch (not shown). **c** CT performed 1 week after TACE shows dense accumulation of iodized oil in the tumor

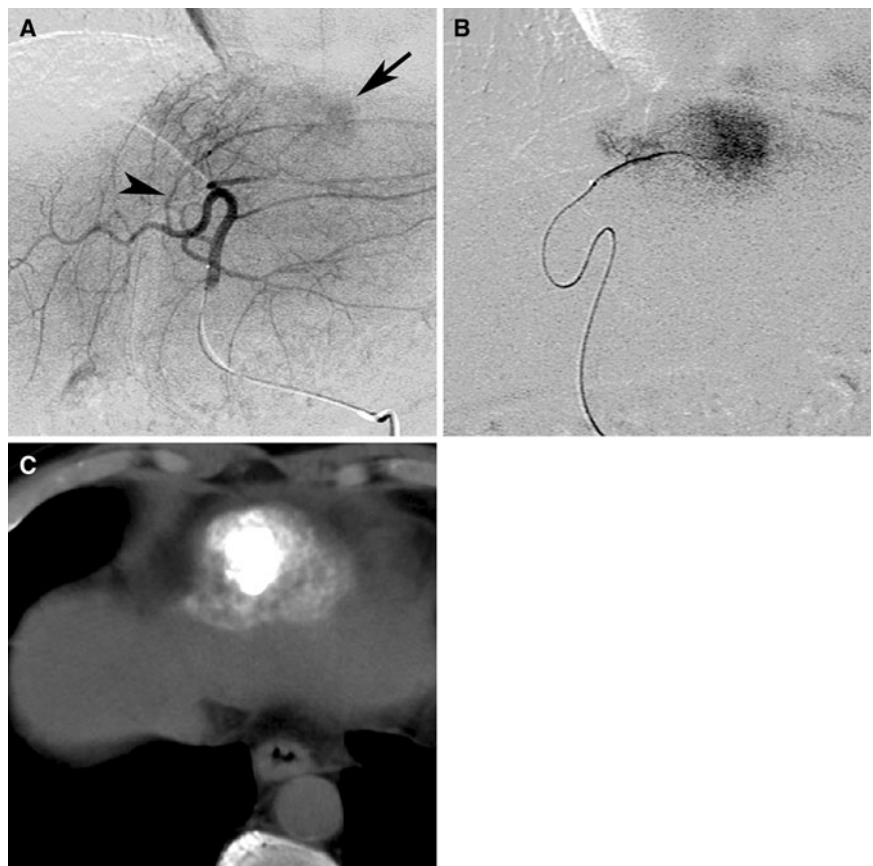


Fig. 7 HCC located in the gallbladder bed in segment 4. **a** Angiogram of the right hepatic artery shows two tumor stains (*arrows*). **b** Selective arteriogram of a branch of the anterior inferior subsegmental artery of the right hepatic artery (A5) shows tumor staining. TACE was performed at this point. **c** CT performed 1 week after TACE reveals that the tumor supplied by A5 is located in the gallbladder bed of segment 4 (*arrow*)

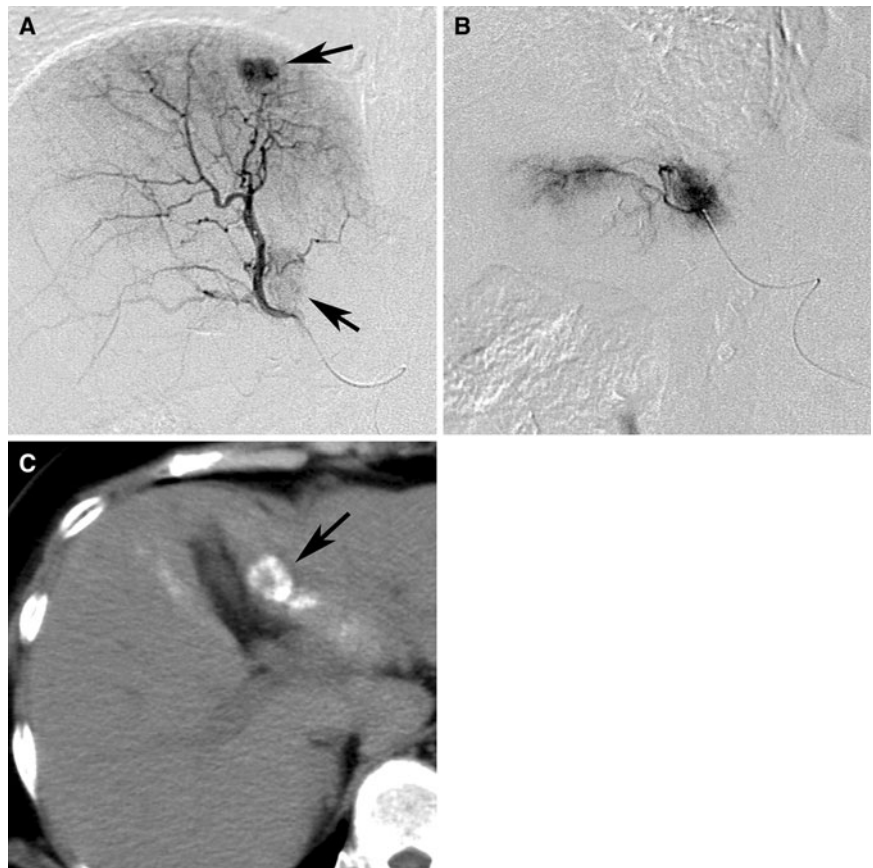


Fig. 8 HCC located in the posterior aspect of segment 4. **a** Celiac angiogram shows multiple tumor staining. TACE was performed at the left hepatic artery (not shown). The *arrow* indicates the caudate artery. **b** CT performed 1 week after TACE shows dense accumulation of iodized oil in the anterior part of the tumor in segment 4. Iodized oil is not distributed in the posterior part of the tumor (*arrow*). **c** Additional TACE was performed 3 weeks later. Angiogram of the caudate artery shows that a small A4 branch arising from the caudate artery (*arrow*) supplies the residual tumor. **d** CT performed 1 week after additional TACE shows dense accumulation of iodized oil in the posterior tumor part in segment 4

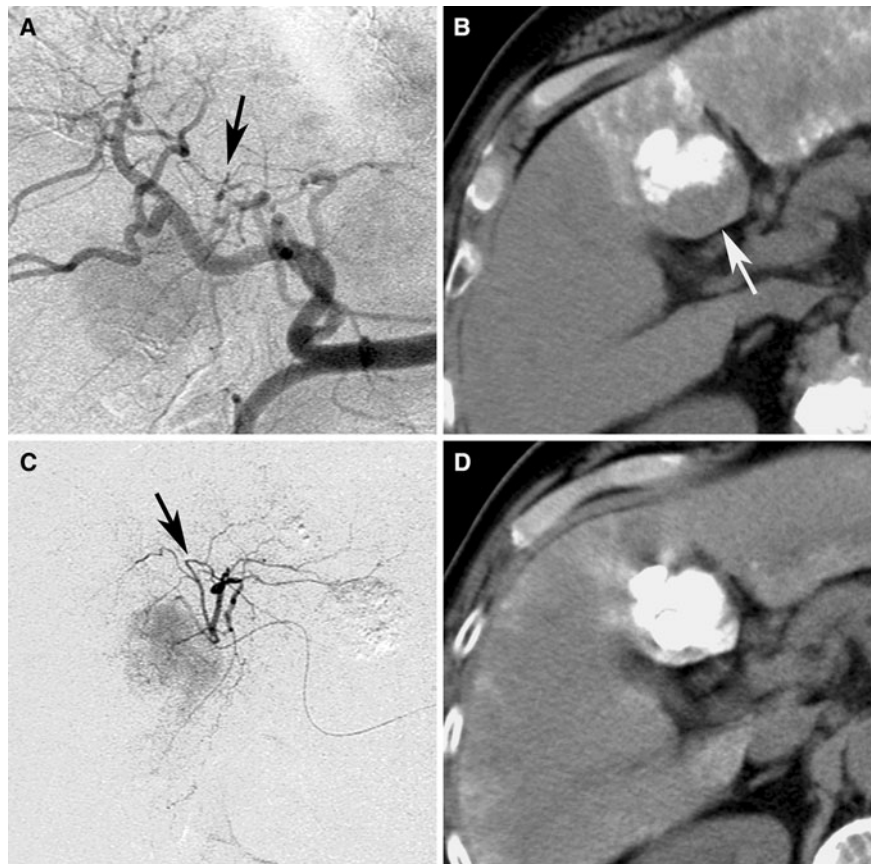


Fig. 9 HCC initially supplied by the right internal mammary artery. **a** CT shows a tumor protruding from the left hepatic lobe. **b** Angiogram of the phrenic branch of the right internal mammary artery obtained immediately after TACE of the left hepatic artery shows partial tumor staining (*arrow*)

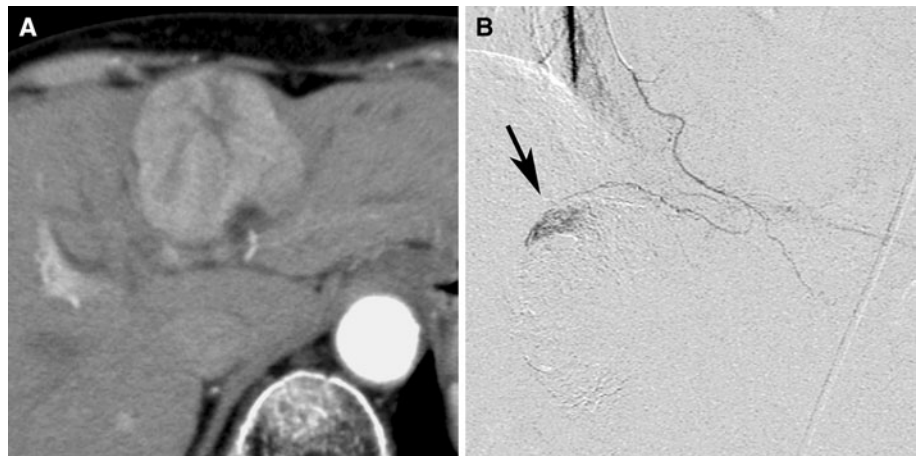


Fig. 10 HCC initially supplied by the left intercostal artery. **a** CT shows a large tumor protruding from the lateral segment of the left lobe of the liver. **b** Angiogram of the left 11th intercostal artery obtained immediately after TACE of the left hepatic artery shows tumor staining (*arrow*)

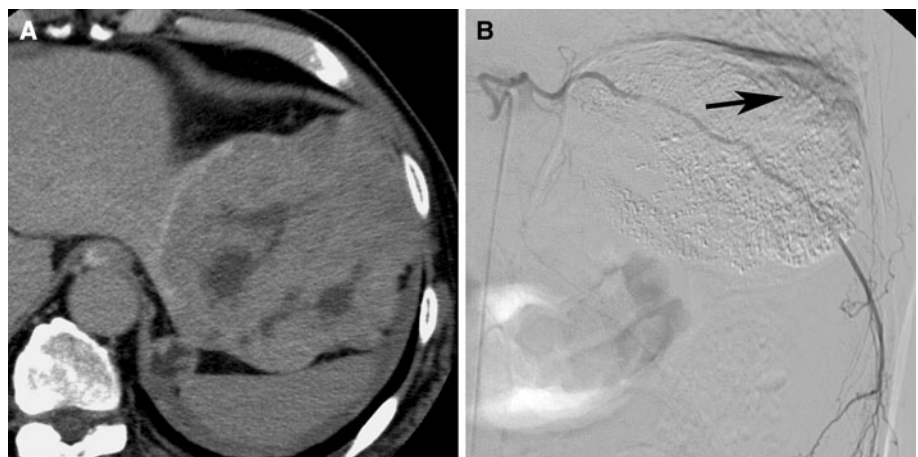
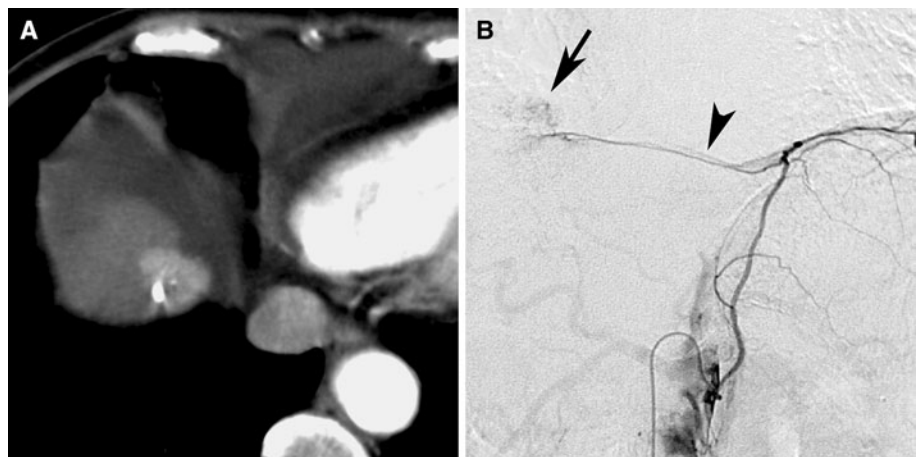


Fig. 11 Recurrent HCC after TACE in the right liver dome. **a** CT shows a recurrent tumor in the right liver dome. **b** Angiogram of the left inferior phrenic artery shows tumor staining (*arrow*) supplied by the anteromedial limb (*arrowhead*)



The left inferior phrenic artery mainly supplies tumors in the left lateral segment; however, the anteromedial limb also supplies tumors in the right liver dome, including segment 4 (Fig. 11) [14]. The internal mammary artery mainly supplies tumors in the subcapsular area of segments 3 and 4 (Figs. 9, 12). The ensiform branch of the internal

mammary artery enters the liver through the falciform ligament and connects with the middle or left hepatic arteries [15]. In addition, the inferior phrenic, internal mammary, and intercostal arteries anastomose each other and form a network [16, 17]. The branch of the cystic artery supplies a tumor located near the gallbladder fossa,

Fig. 12 HCC supplied by the left internal mammary artery. **a** CT during arterial portography (CTAP) shows a tumor in segment 4. **b** The tumor is supplied by the phrenic branch of the left internal mammary artery

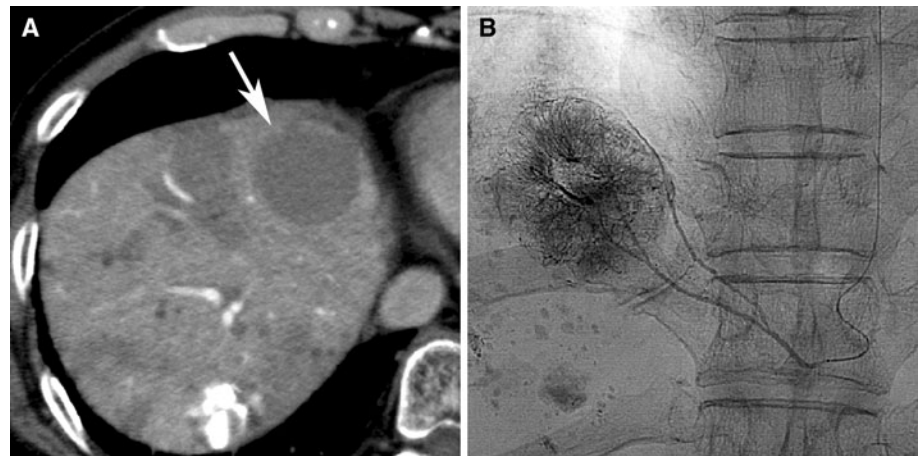
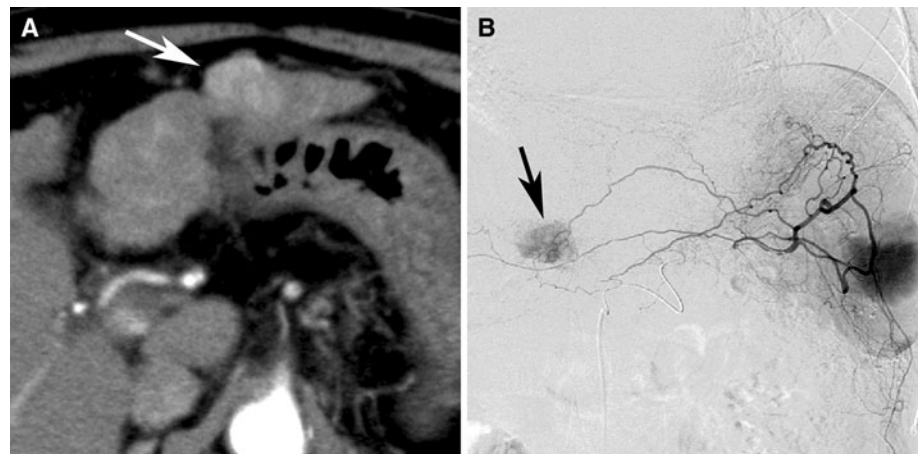


Fig. 13 HCC supplied by the omental artery derived from the left gastroepiploic artery. **a** CT shows a tumor protruding from the lateral segment of the left lobe of the liver (arrow). **b** Angiogram of the left gastroepiploic artery shows a tumor stain. TACE was performed at the more distal level (not shown)



even at initial treatment [18]. In addition, there is an anastomosis between A4 and the cystic artery [16]. The right and left gastric arteries mainly supply tumors located at or near the surface of the left hepatic lobe. In the right gastric artery, a small branch arising from the proximate portion usually supplies the liver. In the left gastric artery, small branches toward the right side usually supply the liver. The omental arteries mainly supply tumors at the ventral or caudal surface of the left hepatic lobe. The omental arteries arising from both right and left gastroepiploic arteries have the potential to supply tumors in the left hepatic lobe (Fig. 13) [13, 19]. It is very important to suspect an extrahepatic blood supply to HCC and to look for it according to tumor location and treatment history.

Conclusion

There are several variations in the vascular territories of the left hepatic arterial branches, and several extrahepatic collateral vessels also supply tumors in the left hepatic lobe, especially when the hepatic arterial circulation is interrupted by previous TACE. Interventional radiologists

should be familiar with these variations to perform effective TACE for HCC.

References

1. Yamada R, Sato M, Kawabata M, Nakatsuka H, Nakamura K, Takashima S. Hepatic artery embolization in 120 patients with unresectable hepatoma. *Radiology*. 1983;148:397–401.
2. Uchida H, Ohishi H, Matsuo N, Nishimine K, Ohue S, Nishimura Y, et al. Transcatheter hepatic segmental arterial embolization using lipiodol mixed with an anticancer drug and Gelfoam particles for hepatocellular carcinoma. *Cardiovasc Intervent Radiol*. 1990; 13:140–5.
3. Matsui O, Kadoya M, Yoshikawa J, Gabata T, Arai K, Demachi H, et al. Small hepatocellular carcinoma: treatment with subsegmental transcatheter arterial embolization. *Radiology*. 1993; 188:79–83.
4. Miyayama S, Matsui O, Yamashiro M, Ryu Y, Kaito K, Ozaki K, et al. Ultrasensitive transcatheter arterial chemoembolization with a 2-F tip microcatheter for small hepatocellular carcinomas: relationship between local tumor recurrence and visualization of the portal vein with iodized oil. *J Vasc Interv Radiol*. 2007;18: 365–76.
5. Gupta SC, Gupta CD, Arora AK. Subsegmentation of the human liver. *J Anat*. 1977;124:413–23.

6. Miyayama S, Yamashiro M, Shibata Y, Hashimoto M, Yoshida M, Tsuji K, et al. Origins of feeding arteries of hepatocellular carcinoma located near the umbilical fissure of the left hepatic lobe: angiographic evaluation. *Cardiovasc Intervent Radiol*. 2011 (in press).
7. Lee HY, Chung JW, Lee JM, Yoon CJ, Lee W, Jae HJ, et al. A new and simple practical plane dividing hepatic segment 2 and 3 of the liver: evaluation of its validity. *Korean J Radiol*. 2007;8:302–10.
8. Chen RC, Chou CT, Chen WT, Chen T, Lii JM, Chu D. Delineation of the watershed between right and left hepatic arterial territories with carbon dioxide-enhanced ultrasonography. *J Vasc Interv Radiol*. 2011;22:667–72.
9. Renz JF, Reichert PR, Emond JC. Hepatic arterial anatomy as applied to living-donor and split-liver transplantation. *Liver Transpl*. 2000;6:367–9.
10. Couinaud C. Surgical anatomy of the liver revisited. Paris: Couinaud; 1989. p. 96–124.
11. Miyayama S, Matsui O, Taki K, Minami T, Ryu Y, Ito C, et al. Arterial blood supply to the posterior aspect of segment IV of the liver from the caudate branch: demonstration at CT after iodized oil injection. *Radiology*. 2005;237:1110–4.
12. Kobayashi K, Matsui O, Yoshikawa J, Kadoya M, Kawamori Y, Takashima T. Right hepatic arterial supply to the posterior aspect of segment IV of the liver: analysis by CT during hepatic arteriography. *Abdom Imaging*. 1999;24:591–3.
13. Miyayama S, Matsui O, Taki K, Minami T, Ryu Y, Ito C, et al. Extrahepatic blood supply to hepatocellular carcinoma: angiographic demonstration and transcatheter arterial chemo-embolization. *Cardiovasc Intervent Radiol*. 2006;29:39–48.
14. Kim HC, Chung JW, An S, Seong NJ, Jae HJ, Cho BH, et al. Left inferior phrenic artery feeding hepatocellular carcinoma: angiographic anatomy using C-arm CT. *AJR Am J Roentogenol*. 2009;193:W288–94.
15. Kim HC, Chung JW, Choi SH, Jae HJ, Lee W, Park JH. Internal mammary arteries supplying hepatocellular carcinoma: vascular anatomy at digital subtraction angiography in 97 patients. *Radiology*. 2007;242:925–32.
16. Duprat G, Charnsangavej S, Wallace S, Carrasco H. Inferior phrenic artery embolization in the treatment of hepatic neoplasms. *Acta Radiol*. 1988;29:427–9.
17. Miyayama S, Yamashiro M, Okuda M, Aburano H, Shigenari N, Morinaga K, et al. Anastomosis between the hepatic artery and the extrahepatic collateral or between extrahepatic collaterals: observation on angiography. *J Med Imaging Radiat Oncol*. 2009;53:271–82.
18. Hirota S, Matsumoto S, Fukuda T, Yoshikawa T, Motohara T, Ichikawa S. Solitary hepatocellular carcinoma fed by the cystic artery: limitation of transcatheter arterial embolization. *Cardiovasc Intervent Radiol*. 1999;22:206–9.
19. Miyayama S, Matsui O, Akakura Y, Yamamoto T, Nishida H, Yoneda K, et al. Hepatocellular carcinoma with blood supply from omental branches: treatment with transcatheter arterial embolization. *J Vasc Interv Radiol*. 2001;12:1285–90.