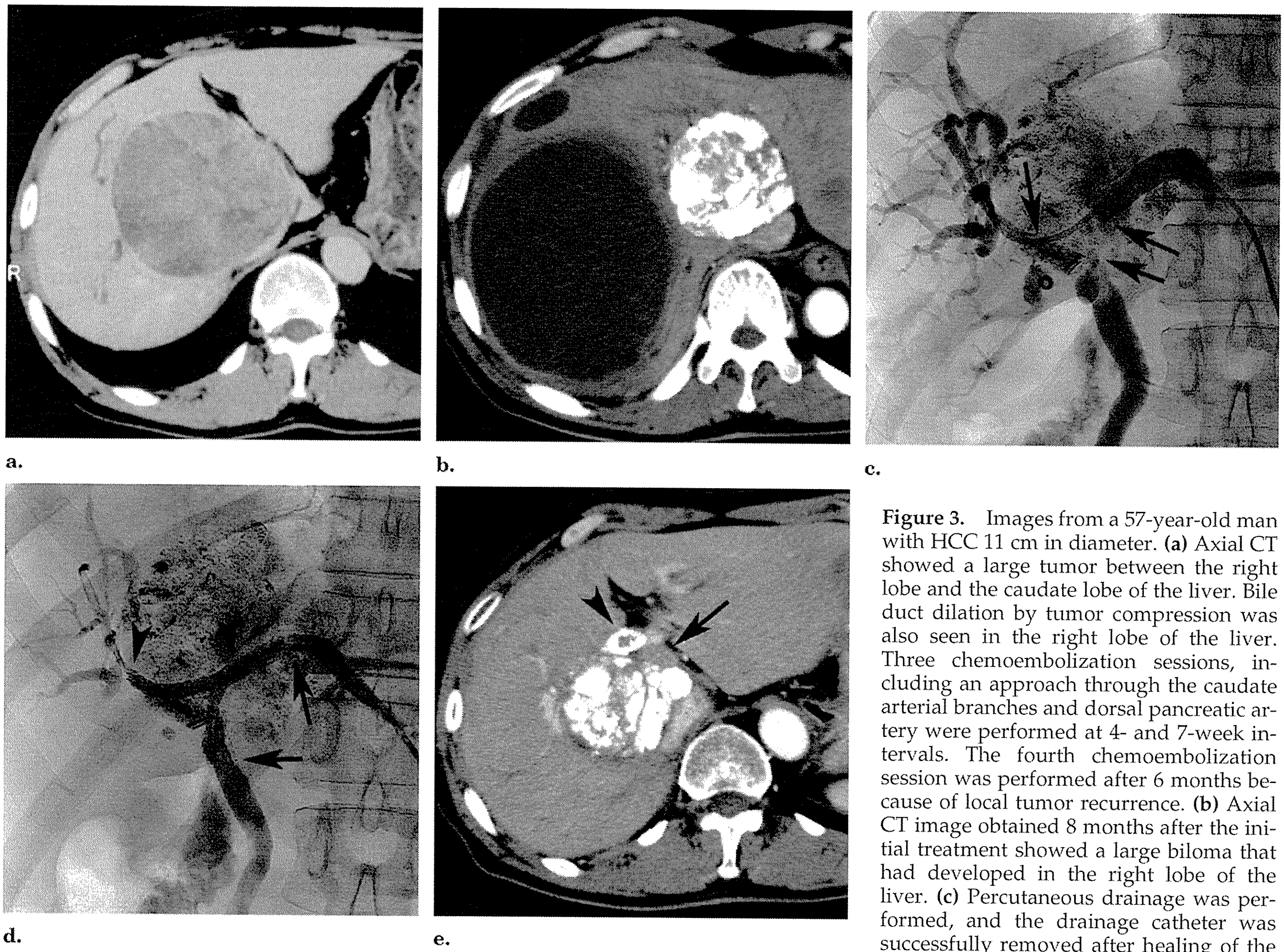

Figure 3. Images from a 57-year-old man with HCC 11 cm in diameter. **(a)** Axial CT showed a large tumor between the right lobe and the caudate lobe of the liver. Bile duct dilation by tumor compression was also seen in the right lobe of the liver. Three chemoembolization sessions, including an approach through the caudate arterial branches and dorsal pancreatic artery were performed at 4- and 7-week intervals. The fourth chemoembolization session was performed after 6 months because of local tumor recurrence. **(b)** Axial CT image obtained 8 months after the initial treatment showed a large biloma that had developed in the right lobe of the liver. **(c)** Percutaneous drainage was performed, and the drainage catheter was successfully removed after healing of the biloma (not shown). Obstructive jaundice developed 10 months after the initial treatment. Percutaneous transhepatic biliary drainage demonstrated a bile duct stricture at the hepatic hilus (arrows). **(d)** The bile duct stricture was successfully treated by placement of two metallic stents: one stent extended from the left hepatic duct to the common bile duct (arrows) and the other from the left hepatic duct to the right hepatic duct through the stented lumen (arrowheads). **(e)** The tumor recurred 11 months after the initial treatment, and a fifth chemoembolization procedure was performed. However, axial CT obtained 15 months after the initial treatment shows a small viable tumor (arrow) despite tumor reduction. The arrowhead indicates the metallic stent.

bolization of large HCCs have been reported (16,25–30). Acute tumor lysis syndrome is one of the most catastrophic complications (25). After treatment, tumor cells are lysed, thereby releasing a significant amount of intracellular potassium and phosphate into the extracellular circulation. As a result, severe hyperuricemia, hyperphosphatemia, hyperkalemia, hypocalcemia, and acute renal failure occur. Pulmonary oil embolism has also been reported and mainly develops in patients who receive more than 20 mL of iodized oil during the chemoembolization procedure (26,27). In the present study, stepwise chemoembolization was attempted to prevent severe complications in cases of tumors with a mean diameter of 10 cm. In addition, the total amount of iodized oil in the single session was limited to less than 10 mL. We consider stepwise chemoembolization key to the safe treatment of large tumors. Acute tumor lysis syndrome and pulmonary oil embolization did not occur in any patient in the present series.

Development of abscess and biloma after chemoembolization is another well-known major complication (16,27–29). The incidence of abscess formation or bile duct injury in patients with larger HCCs may be higher than that in patients with small HCCs. Song et al (28) reported that biliary invasion or extrinsic compression of the bile duct by tumor plus a decrease in portal venous inflow might be risk factors for abscess formation. As a large tumor is more likely to invade or compress the bile duct and portal vein, the risk of abscess formation may increase. In fact, all three of our patients who presented with infectious complications had bile duct dilation or tumor invasion to the gallbladder before chemoembolization. Bile duct necrosis also causes biloma or bile duct stenosis (29,30). This is likely to develop when small particles ($< 250\ \mu m$) are used (30).

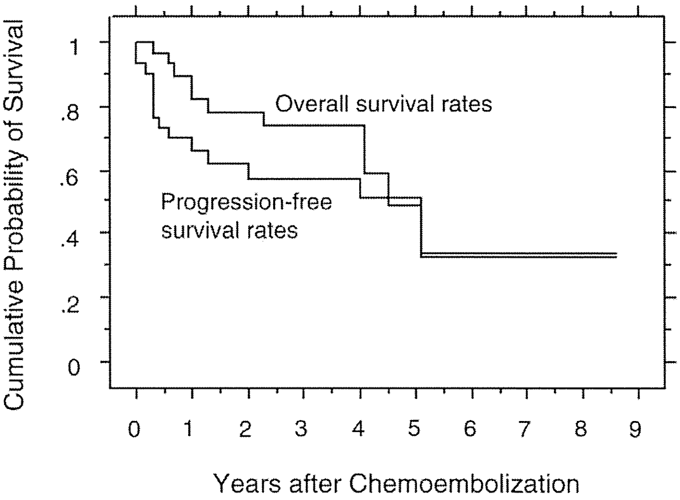

Figure 4. Survival rates of patients who received chemoembolization. Overall survival rates calculated by the Kaplan-Meier method at 1, 2, 3, 4, 5, and 6 years were 82.3%, 78.5%, 73.9%, 73.9%, 49.3%, and 32.9%, respectively. The progression-free survival rates at 1, 2, 3, 4, 5, and 6 years were 66.0% (95% CI, 48.8%–83.3%), 57.6% (95% CI, 39.0%–76.2%), 57.6% (95% CI, 39.0%–76.2%), 51.2% (95% CI, 30.8%–71.6%), 51.2% (95% CI, 30.8%–71.6%), and 34.2% (95% CI, 3.6%–64.8%), respectively.

However, in our case, it developed with the use of particles approximately 1 mm in diameter. We speculate that chemoembolization of the caudate arterial branch carries the potential risk of bile duct stricture at the hepatic hilus (31).

Large HCCs generally have multiple feeding vessels, not only through hepatic branches but also through extrahepatic collateral vessels (10–13). Chung et al (10) reported that right IPA parasitization was retrospectively suspected at the initial chemoembolization in 37 of 50 medium and large tumors (> 3 cm but < 5 cm, *n* = 18; > 5 cm, *n* = 32), with blood supply to tumors from the right IPA demonstrated on follow-up angiography. They also reported that the prevalence of extrahepatic blood supply at the initial chemoembolization session in a tumor smaller than 4 cm in diameter was less than 3%; this increased to 63% when the tumor was larger than 6 cm in diameter (11). In the present study, extrahepatic collateral supply was demonstrated in 70% of patients during the subsequent course of treatment, mainly through the right IPA. In addition, it was demonstrated in 47% of patients at the initial treatment. We consider successful embolization through extrahepatic collateral vessels to be another key to the control of large tumors. Physicians should develop sufficient knowledge of the spectrum of extrahepatic collateral vessels that supply HCC, and should be familiar with procedures for chemoembolization through these vessels.

There are several limitations to the present study. First, we selected patients with three or fewer tumors. Large HCCs generally produce intrahepatic metastases and/or portal vein tumor thrombus. Therefore, we evaluated the efficacy of chemoembolization in only a minority of patients with large HCCs. In addition, the number of patients who were treated in the present study was small and 83% of patients had a solitary tumor. Second, we investigated several extrahepatic vessels to evaluate tumor feeding. However, in elderly patients with atherosclerosis, screening of small branches directly arising from the aorta, such as the middle adrenal artery or right renal capsular artery, may have been incomplete (13). For these reasons, there is a possibility that some small tumor-feeding vessels might have been missed. Third, arterial infusion chemotherapy or irradiation was performed in a few patients in addition to chemoembolization. However, clinically, these treatments were ineffective and did not improve patient prognosis. Therefore, it is thought that our results might directly reflect the efficacy of chemoembolization for large HCCs.

In conclusion, chemoembolization was an effective treatment for large HCCs, as well as surgical resection or combination therapy with chemoembolization and RF ablation. However, there is also a risk of severe complications after chemoembolization for large HCCs, and prompt treatment is necessary to manage such complications.

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CLINICAL INVESTIGATION

The March of Extrahepatic Collaterals: Analysis of Blood Supply to Hepatocellular Carcinoma Located in the Bare Area of the Liver After Chemoembolization

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Abstract The purpose of this study was to evaluate changes in vascular supply to hepatocellular carcinoma (HCC) located in the bare area of the liver in patients who were mainly treated with chemoembolization. Twenty-six patients with HCC showing a mean diameter of 3.1 ± 1.4 cm (mean ± standard deviation) were mainly treated with chemoembolization. All patients underwent 2.7 ± 2.3 chemoembolization sessions over 40.1 ± 25.2 months. Tumor feeding branches demonstrated in each chemoembolization session were retrospectively evaluated. Initially, 18 tumors (59.2%) were supplied by the hepatic artery (H) and 8 (30.8%) by both the hepatic and the extrahepatic arteries (H + C). Fourteen tumors (53.8%) recurred at the posterior aspect of the tumor and were supplied by H ($n = 4$), H + C ($n = 5$), and extrahepatic collaterals (C) ($n = 5$). Several tumors recurred despite repeated chemoembolization, and these were supplied by H ($n = 1$), H + C ($n = 7$), and C ($n = 2$) at the second recurrence, by H ($n = 1$), H + C ($n = 2$), and C ($n = 3$) at the third, by H + C ($n = 2$) and C ($n = 2$) at the fourth, by H + C ($n = 2$) and C ($n = 2$) at the fifth, and by H ($n = 1$) and C ($n = 1$) at the sixth. One tumor was supplied by H at the seventh and by H + C at the eighth recurrence. As the number of local recurrences increased, the feeding vessel shifted from H to C. Especially, the right inferior phrenic artery (IPA) and renal capsular artery (RCA) supplied the tumor early, while the small right RCAs, adrenal arteries, and intercostal and lumbar artery supplied late recurrences in turns. In conclusion, HCCs located in the bare area are frequently supplied by extrahepatic vessels initially, while recurrence after chemoembolization is mainly due to extrahepatic blood supply. The right IPA and RCA are common feeding vessels demonstrated early, while other extrahepatic collateral supply from the retroperitoneal circulation occurs in turns during the later course.

Keywords Hepatocellular carcinoma · Chemoembolization · Bare area of the liver · Extrahepatic blood supply

Introduction

Hepatocellular carcinoma (HCC) frequently recurs after chemoembolization and development of extrahepatic collateral pathways is one of the causes of local tumor recurrence. Several extrahepatic collateral pathways supplying HCC have been reported [1–14].

At the level of the bare area of the liver, branches of the inferior phrenic arteries (IPAs) are in direct contact with the liver [3, 4]. In the event of hepatic artery damage, or even with a patent hepatic artery, these branches contribute substantially to the hepatic tumor vascular supply. In addition, IPAs usually anastomose with several arteries, such as the internal mammary artery and intercostal arteries [5, 6, 15]. Therefore, a tumor located in the bare area of the liver has the potential to receive collateral blood flow through several individual sources. Extrahepatic collateral supplies can inhibit the effectiveness of chemoembolization. For transcatheter management of HCC to be effective, these collaterals should be adequately embolized [1–14].

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Therefore, interventional radiologists should have sufficient knowledge of extrahepatic blood supply to HCCs.

In this report, we retrospectively analyzed changes in vascular supply to HCCs located in the bare area of the liver during the subsequent clinical course of patients who were mainly treated by chemoembolization.

Materials and Methods

Patients

In the present study, we define "the bare area of the liver" as the posterior surface of Segment 7 demarcated by the right hepatic vein. Although we are well aware that "the bare area of the liver" also includes a part of lateral surface of Segment 8, the right-side margin is not anatomically outlined clearly. Between August 1999 and August 2008, we treated 26 consecutive HCC lesions in the bare area of the liver by chemoembolization. The patient profiles are summarized in Table 1. There were 14 men and 12 women and the mean patient age was 68.9 ± 7.5 years (mean ± standard deviation; range, 51 to 81 years). All patients had liver cirrhosis, which was associated with hepatitis C in 19 patients and hepatitis B in 6 patients, while in the remaining patient, the etiology was unknown. All patients had a single HCC lesion at the bare area, including 6 patients with 1 other HCC in addition to the tumor in the bare area and 2 patients with multiple HCCs but fewer than 5 lesions at other sites. The mean diameter of tumors in the bare area was 3.1 ± 1.4 cm (range, 1–6 cm). Diagnosis was established by imaging findings on computed tomography (CT) and/or magnetic resonance (MR) imaging, characteristic nodular enhancement during the arterial phase, and washout during the delayed phase images in all patients.

Initially, 22 tumors were treated by chemoembolization alone and 4 were treated by a combination of chemoembolization and radiofrequency ablation (RFA).

Table 1 Patent profiles

Patient characteristic	
Gender	
Male	14
Female	12
Mean age (yr)	68.9 ± 7.5
Liver cirrhosis	26 (100%)
HCV related	19 (73.1%)
HB related	6 (23.1%)
Etiology unknown	1 (3.8%)
Tumor size in the bare area (cm)	3.1 ± 1.4
Intrahepatic multiplicity	
Single	18 (69.2%)
Two	6 (23.1%)
Three-5 lesions	2 (7.7%)
Treatment	
Chemoembolization alone	22 (84.6%)
Combination of chemoembolization & RFA	4 (15.4%)

RFA radiofrequency ablation

Chemoembolization Procedure

Written informed consent was obtained from each patient before the chemoembolization and RFA procedures. Institutional review board approval was not required at our institution for this retrospective study.

A 2-Fr tip (Progreat α; Terumo, Tokyo, Japan) was mainly used for all chemoembolization procedures. To navigate the microcatheter, a 0.016-in. guidewire (GT-wire; Terumo) was used. After the microcatheter was inserted into the feeding branch, 0.5 ml of 2% lidocaine (Xylocaine; Fujisawa, Osaka, Japan) was intra-arterially injected to prevent pain and vasospasm. First, a mixture of iodized oil (Lipiodol; Andre Guerbet, Aulnaysous-Bois, France) and anticancer drugs (epirubicin [Farmorbicin], Kyowa Hakko, Tokyo, Japan; mitomycin C [Mitomycin], Kyowa Hakko) was injected, and injection of gelatin sponge particles followed. Until December 2006, gelatin sponge particles (Gelfoam; Upjohn, Kalamazoo, MI, USA) cut into approximately 1-mm cubes were used. Since January 2007, 1-mm-diameter commercially available gelatin sponge particles (Gelpart; Nippon Kayaku, Tokyo, Japan) were used.

The embolized branches of the hepatic artery were minimized as selectively as possible in each patient. Extrahepatic collaterals were searched for with the use of a 4-Fr shepherd-hook catheter (Terumo) or cobra-shaped catheter (Hanako Medical, Kobe, Japan). When tumor stain was demonstrated through the extrahepatic vessel on angiography, the tumor-feeding branch was selected by the microcatheter. In total, 1–6 ml of iodized oil, 10–30 mg of epirubicin, and 2–6 mg of mitomycin C were used in a single chemoembolization session, depending on the size of each tumor.

RFA Procedure

RFA was performed 1–2 weeks after chemoembolization in the first 4 consecutive tumors (2.5–5 cm in diameter; mean, 3.3 ± 1.4 cm) in 4 patients. The procedure was performed using an expandable electrode (LeVeen; Radiotherapeutics, Sunnyvale, CA, USA) under ultrasonographic (US) guidance without injection of saline into the pleural cavity. However, RFA was not performed after the fifth patient because we were able to obtain a complete ablative margin in only 1 of the previous 4 tumors.

Follow-Up

Unenhanced CT was obtained 1 week after chemoembolization in all patients to check for iodized oil accumulation within the target tumor. In addition, dynamic CT was also performed the day after RFA. All patients were followed with dynamic CT and/or MR imaging obtained every 2–3 months after treatment to screen for any tumor recurrence. When tumor recurrence and/or newly developed tumors at other sites were detected, additional chemoembolization was performed, if possible.

Definition of Extrahepatic Collateral Supply to HCC

Several extrahepatic collaterals were searched when extrahepatic blood supply to the tumor was suspected. Initial extrahepatic blood supply to HCC was defined as follows: (i) an obvious tumor stain was demonstrated on arteriogram of the extrahepatic vessel during the initial chemoembolization; and (ii) arteriogram of the extrahepatic vessel during additional chemoembolization showed a stain corresponding to the tumor area that had not shown accumulation of iodized oil on CT obtained 1 week after the initial chemoembolization despite the lack of an obvious extrahepatic supply to HCC during the initial procedure (including cases that did not undergo arteriogram of extrahepatic vessels). Extrahepatic blood supply to recurrent HCC was confirmed when tumor stain was demonstrated on arteriogram of extrahepatic collaterals.

Definition of Tumor Recurrence

The tumor portion where iodized oil was not accumulated after the initial chemoembolization was defined as a "residual portion," not a "recurrent portion." Tumor recurrence was defined as the development of a viable tumor portion after the entire tumor was embolized by the initial or additional chemoembolization. The interval between the initial chemoembolization and the demonstration of recurrence on CT or MR imaging was defined as the period of tumor control.

Results

Findings at the Initial Chemoembolization

All tumors were partially or completely supplied by the hepatic arterial branches at the initial chemoembolization. The embolized hepatic artery was the superior posterior subsegmental artery (A7) ($n = 12$), posterior segmental artery ($n = 7$), superior anterior subsegmental artery (A8) and A7 ($n = 5$), inferior posterior subsegmental artery (A6) ($n = 1$), and A7 and the caudate artery ($n = 1$).

Arteriograms of extrahepatic collateral vessels were obtained in 18 patients (69.2%) during the initial chemoembolization procedure. Arteriogram of the right IPA was obtained in 12 patients, right IPA and right renal capsular artery (RCA) in 5, and right RCA and right middle adrenal artery in 1. In 2 patients, the right IPA was reconstructed through the dorsal pancreatic artery arising from the superior mesenteric artery ($n = 1$) or left gastric artery ($n = 1$) (Fig. 1). One right IPA could not be detected during the initial chemoembolization procedure because a vessel that arose from the left renal polar artery was demonstrated at the second chemoembolization when it was shown to supply the tumor (Fig. 2). Extrahepatic blood supply to the tumor at the initial procedure was observed in 8 tumors (30.8%), with a mean tumor diameter of 3.4 ± 1.4 cm (range, 1.6–6 cm), through the right IPA ($n = 5$), right IPA and right RCA ($n = 2$), and right RCA ($n = 1$). In 5 tumors, the extrahepatic collateral supply was demonstrated during the initial procedure and chemoembolization through these feeding branches was subsequently performed. In the remaining 3 tumors supplied by the right IPA ($n = 2$) and right RCA ($n = 1$), arteriograms of these vessels were not obtained during the initial procedure. Based on CT findings obtained 1 week after the procedure that showed a tumor area without iodized oil accumulation, additional chemoembolization was performed through these vessels 2–3 months after the initial chemoembolization.

Tumor Recurrence After Treatment

All patients were followed for a mean of 40.1 ± 25.2 months (range, 8–116 months). In all 26 tumors, including 3 tumors that were treated with additional chemoembolization sessions, iodized oil was accumulated in the entire tumor. In 3 of 4 tumors treated with RFA after chemoembolization, the ablative area did not cover the entire tumor on CT and these tumors recurred at 14.3 ± 5.5 months (range, 9–20 months). In total, 14 tumors (53.8%), 11 of 22 tumors treated by chemoembolization alone and 3 of 4 tumors treated by a combination of chemoembolization and RFA, recurred 13.2 ± 9.0 months (range, 4–40 months) after the initial treatment. All 14 tumors recurred at the posterior aspect of the tumor arising in the bare area. Second recurrence was observed in 10 tumors 6.5 ± 3.1 months (range, 2–12 months) after treatment. Despite repeated chemoembolization, third recurrence was observed in 7 tumors after 5.7 ± 2.6 months (range, 3–11 months), fourth recurrence was observed in 6 tumors after 5.3 ± 2.2 months (range, 4–8 months), fifth recurrence was observed in 4 tumors after 9.8 ± 6.4 months (range, 5–19 months), and sixth recurrence was observed in 3 tumors after 4.7 ± 3.8 months (range, 2–9 months). Moreover, 1 tumor recurred at 10, 23, and 5 months after each additional

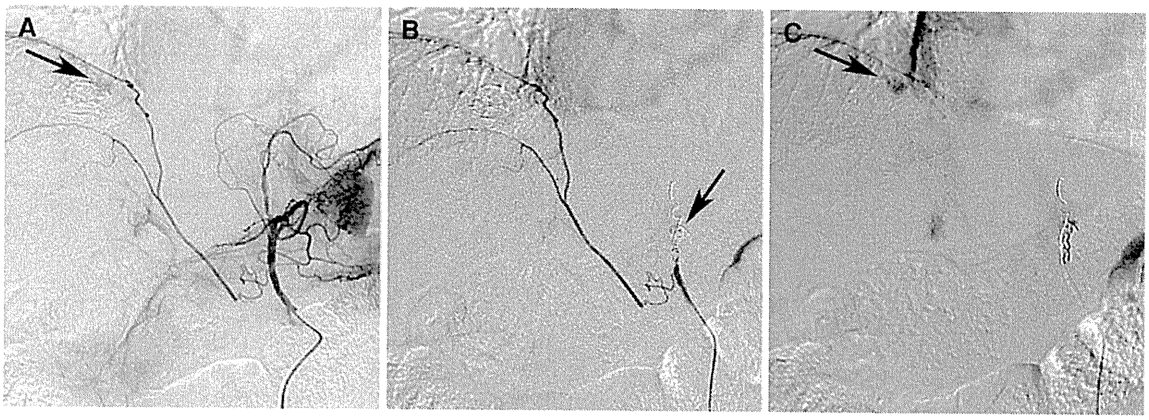


Fig. 1 A 76-year-old man with a recurrent HCC located in the bare area of the liver after chemoembolization through the hepatic arterial branch. **A** Arteriogram of the left gastric artery shows the reconstructed right IPA and tumor stain (*arrow*). **B** The anasotomosis branch could not be selected, therefore embolization of the left gastric artery at the distal end from the anastomosis branch was performed, using metallic coils (*arrow*). **C** The tumor stain (*arrow*) is clearly depicted, without gastric wall staining after coil embolization. Chemoembolization was successfully performed, without any complications, through the left gastric artery

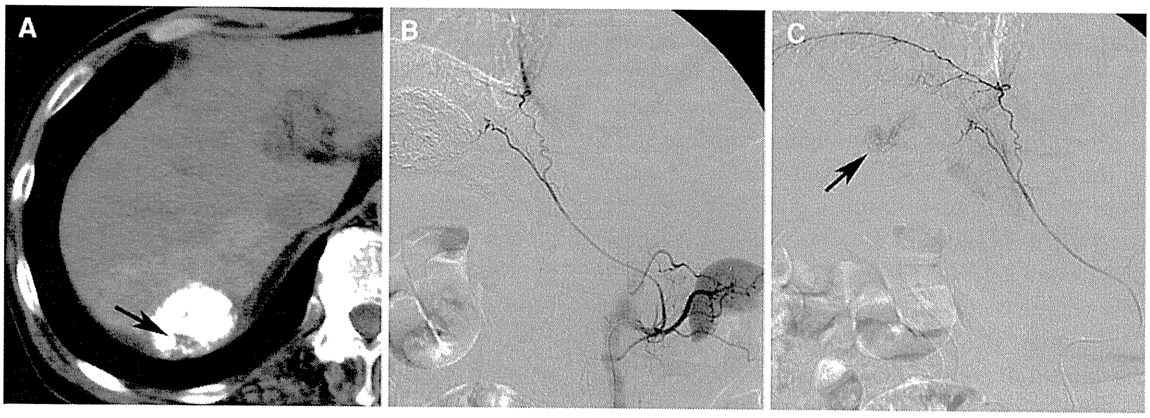


Fig. 2 A 68-year-old man with an HCC located in the bare area of the liver. **A** CT obtained 1 week after chemoembolization through the hepatic arterial branch shows a defect of iodized oil accumulation at the posterior aspect of the tumor (*arrow*). **B** The right IPA is derived from the left upper renal polar branch. **C** Selective arteriogram of the right IPA shows a tumor stain corresponding to the defect of iodized oil (*arrow*)

chemoembolization session and the tumor was finally treated by irradiation. In total, 19 tumors (73.1%) could be controlled but 7 (26.9%) could not, despite repeated chemoembolization. Nine patients died after 42.9 ± 15.1 months (range, 18–69 months), including 3 who died of liver-unrelated causes (pneumonia [$n = 1$], traffic accident [$n = 1$], and pancreatic cancer [$n = 1$]). To date, 17 patients have survived 37.5 ± 29.0 months (range, 8–116 months) after the initial treatment, including 1 patient with a recurrent tumor in the bare area and 2 patients with a viable tumor at another site.

Extrahepatic Collateral Supply to Recurrent Tumors

All patients underwent 1–10 chemoembolization sessions (mean, 2.7 ± 2.3 sessions) for HCC in the bare area. During the subsequent treatment course, arteriogram of the right IPA was obtained for all but 1 patient (96.2%) whose tumor did not recur after the initial chemoembolization procedure. Arteriogram of the right RCA was obtained in 21 patients (80.8%), except for 4 patients without tumor recurrence after the initial chemoembolization and 1 patient whose recurrent tumor after the initial chemoembolization was controlled by chemoembolization through the right IPA. Arteriogram of the right intercostal and/or lumbar artery was obtained in 9 patients (34.6%), and arteriogram of the adrenal arteries directly arising from the aorta was obtained in 7 patients (26.9%). In 1 patient (3.8%), arteriogram of the right gonadal artery directly arising from the aorta was also obtained.

During follow-up, extrahepatic collateral supply to the tumor was observed in 18 patients (69.2%), including 8 (30.8%) in whom findings were observed at the initial treatment (Table 2). The tumor-feeding extrahepatic

Table 2 Incidence of blood supply to HCCs from extrahepatic collaterals

	During follow-up ($n = 18$; 69.3%)	At initial treatment ($n = 8$; 30.8%)
RIPA	13	7
RRCA	7	3
RMAA	4	
RIAA	4	
RLA	4	
RICA	2	
DPA	1	
BDA	1	

RIPA right inferior phrenic artery, *RRCA* right renal capsular artery, *RMAA* right middle adrenal artery, *RIAA* right inferior adrenal artery, *RICA* right posterior intercostal artery, *RLA* right lumbar artery, *DPA* dorsal pancreatic artery, *BDA* bile duct artery

collateral was the right IPA ($n = 13$), right RCA ($n = 7$), right middle adrenal artery ($n = 4$), right lumbar artery ($n = 4$), right inferior adrenal artery ($n = 4$), right intercostal artery ($n = 2$), bile duct artery ($n = 1$), and dorsal pancreatic artery ($n = 1$). All tumor-feeding branches were embolized during each procedure. One feeding branch derived from the left gastric artery connected with the reconstructed right IPA could not be directly selected because of its small caliber and acute angulation. The left gastric artery was embolized using metallic coils (Tornado; Cook, Bloomington, IN, USA) at the distal level of the anastomosis branch to prevent nontarget embolization, and chemoembolization was successfully performed through the microcatheter placed in the left gastric artery proximal to the anastomosis branch (Fig. 1).

Change of the Feeding Vessel in Each Recurrence

At the initial chemoembolization, 18 tumors (69.2%) were supplied by the hepatic artery alone and 8 (30.8%) were supplied by both the hepatic and the extrahepatic arteries. Of 14 tumors showing first recurrence, 4 tumors were supplied by the hepatic artery, 5 were supplied by both the hepatic and the extrahepatic arteries, and 5 were supplied by extrahepatic collaterals alone. Of 10 tumors showing second recurrence, 1 tumor was supplied by the hepatic artery alone, 7 were supplied by both the hepatic and the extrahepatic arteries, and 2 were supplied by extrahepatic collaterals alone. In 6 of 7 tumors showing third recurrence, 1 tumor was supplied by the hepatic artery alone, 2 were supplied by both the hepatic and the extrahepatic arteries, and 3 were supplied by extrahepatic collaterals alone. Angiography was not performed for the remaining tumor because of poor hepatic function. In 4 of 6 tumors showing fourth recurrence, 2 tumors were supplied by both the hepatic and the extrahepatic arteries and 2 were supplied by extrahepatic collaterals alone. Angiography was not performed for the remaining 2 tumors because of poor hepatic function or dementia. In 3 of 4 tumors showing fifth recurrence, all tumors were supplied by extrahepatic collaterals alone. Angiography was not performed for the remaining tumor because of diffuse metastases. In 2 of 3 tumors showing sixth recurrence, 1 was supplied by both the hepatic and the extrahepatic arteries and 1 was supplied by extrahepatic collaterals alone. Angiography was not performed for 1 tumor because of diffuse metastases. At the seventh recurrence, the tumor was again supplied by the restored hepatic artery, and it was supplied by both the hepatic and the extrahepatic arteries at the eighth recurrence. As the number of tumor recurrences increased, the tumor-feeding vessels shifted from the hepatic artery to extrahepatic collaterals (Fig. 3). Table 3 shows the tumor-feeding branches at each recurrence in patients who underwent 3 or more chemoembolization procedures. In particular, other or small right RCAs, right adrenal arteries, and right lumbar and intercostal arteries fed the tumor in turns after the right IPA or right RCA had already been embolized (Figs. 4, 5, 6).

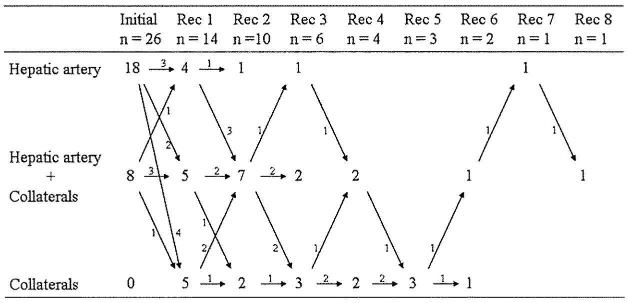


Fig. 3 Changes in blood supply to recurrent tumors. As the number of tumor recurrences increases, the tumor-feeding vessels shift from the hepatic artery to the extrahepatic collaterals

Discussion

Extrahepatic collateral pathways to the liver and HCC are established under various conditions. These pathways mainly develop after interruption of the hepatic artery by surgical ligation, arterial injury induced by repeated chemoembolization procedures, or placement of a catheter. Adhesion between the liver and the other organ exaggerates the degree of extrahepatic collaterals [7]. An extrahepatic blood supply to HCC also develops in the anatomical location of a tumor, although the hepatic arterial supply remains intact [3, 14]. In particular, it is thought that extrahepatic collateral supplies develop early in the bare area of the liver [14].

Table 3 Changes in tumor-feeding vessels of HCCs located in the bare area of the liver in patients who underwent three or more chemoembolization sessions

Patient no./age/gender	Initial	Rec 1	Rec 2	Rec 3	Rec 4	Rec 5	Rec 6	Rec 7	Rec 8	Duration
1/68/M	RIPA RRCA	A7 RIPA RMAA	A7 RICA	Post Br						1 years 3 months
2/73/M	A7	A7	A7 RIPA	A7 RRCA [1]	RIPA RIAA	RRCA [2] RIAA	RLA	A7	A7 RRCA [3]	9 years 2 months
3/68/F	A7 RRCA [1]	A7	A7 RIAA [1, 2]	Post Br RRCA [2–4] RLA						2 years 5 months
4/63/F	A7	RIPA	A7 RIPA	Post Br RIPA RRCA [1] RICA	RIPA RRCA [2]	RIPA RRCA [3, 4] RIAA RICA RLA				4 years 1 months
5/76/M	A7	RIPA	RIPA RMAA							1 years 2 months
6/76/F	Post Br	Post Br	A7							1 years 8 months
7/71/F	Post Br	PIPA	A7 RIPA	RLA						2 years 2 months
8/73/F	Post Br	RIPA	A7 RIPA							4 months
9/77/F	A7	Post Br	Post Br	Post Br RIPA						2 years 2 months
10/59/M	Post Br	Post Br A1 RIPA	RIPA RRCA	RIPA	RMAA	RIAA [1] DPA	Post Br A1 BDA RIAA [2]			3 years 2 months
11/76/M	A7	A7 A8 RIPA	A7 A8 RIPA							9 months

Rec recurrence, *Post Br* posterior segmental artery of the right hepatic artery, *RIPA* right inferior phrenic artery, *RRCA* right renal capsular artery, *RMAA* right middle adrenal artery, *RICA* right posterior intercostal artery, *RIAA* right inferior adrenal artery, *RLA* right lumbar artery, *DPA* dorsal pancreatic artery, *BDA* bile duct artery

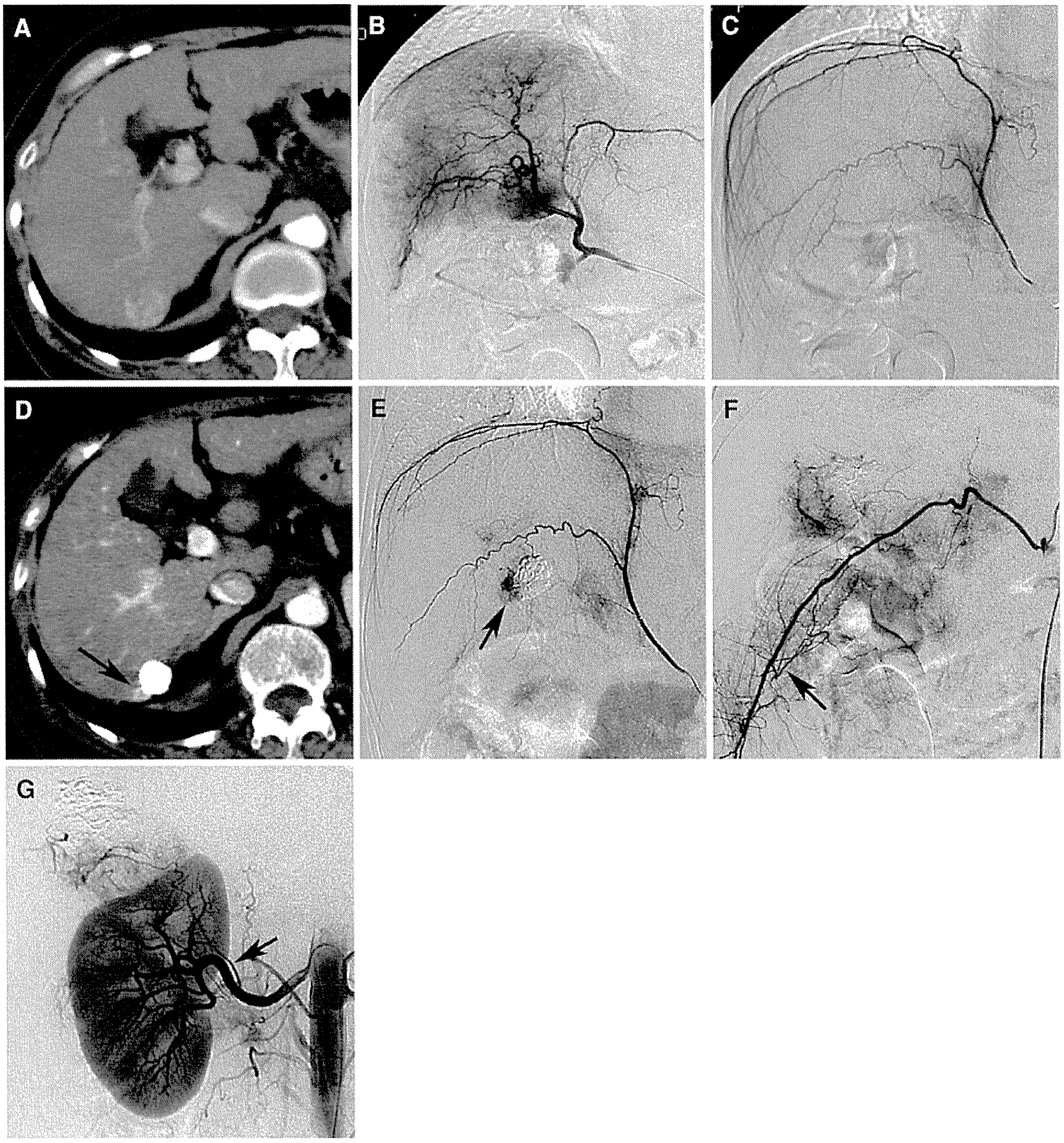


Fig. 4 A 63-year-old woman with an HCC located in the bare area of the liver. **A** Arterial phase CT shows an enhancing tumor in the bare area of the liver. **B** Arteriogram of the proper hepatic artery shows tumor stain supplied by the posterior superior subsegmental artery of the liver. The branch was selected and chemoembolization was performed. **C** Arteriogram of the right IPA obtained simultaneously during the initial chemoembolization does not show any tumor stains. In this patient, RFA was added after chemoembolization. **D** CT obtained 20 months after the initial treatment shows a recurrent tumor (*arrow*). **E** Arteriogram of the right IPA shows a tumor stain in turn (*arrow*). Chemoembolization was performed; however, the tumor recurred again after treatment. **F** At the third recurrence (2 years 11 months after the initial treatment), the tumor is supplied by the right 11th intercostal artery. The tumor-feeding branch (*arrow*) was selected and chemoembolization was performed. The posterior branch of the right hepatic artery, right IPA, and right RCA were simultaneously embolized (not shown). **G** At the fourth recurrence (3 years 4 months after the initial treatment), the tumor is supplied by another right RCA (*arrow*), in addition to the right IPA supply

The right IPA is the major source of diaphragmatic pathways and is the most frequent extrahepatic collateral vessel of HCCs [12–14]. There is close contact between the posterior portion of the liver and the diaphragm in the bare area, and branches of the IPA are in direct contact with the liver [3, 4]. Takeuchi et al. [16] clearly demonstrated blood supply to the liver from the right IPA immediately after balloon occlusion of the proper hepatic artery using a unified CT and angiography system. Chung et al. [3] also reported that right IPA parasitization was retrospectively

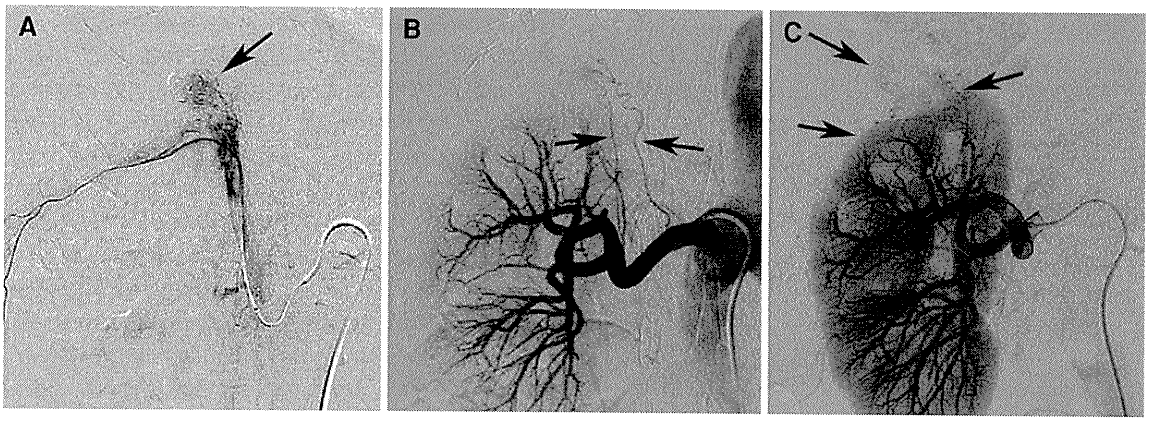


Fig. 5 A 68-year-old woman with an HCC located in the bare area. **A** At the initial treatment, the residual tumor after chemoembolization of the hepatic arterial branch (*arrow*) is fed by the right RCA. **B** The recurrent tumor 1 year after the procedure is supplied by the hepatic arterial branch (not shown). At the second recurrence (1 year 8 months after the initial treatment), the tumor is fed by two right inferior adrenal arteries (*arrows*). Chemoembolization was performed through these vessels. **C** At the third recurrence (2 years 5 months after the initial treatment), the tumor is fed by 3 small RCAs (*arrows*)

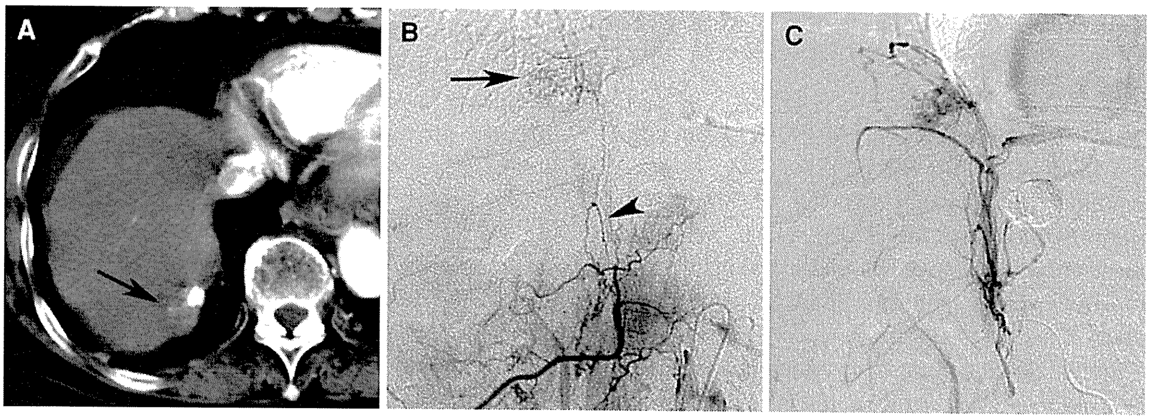


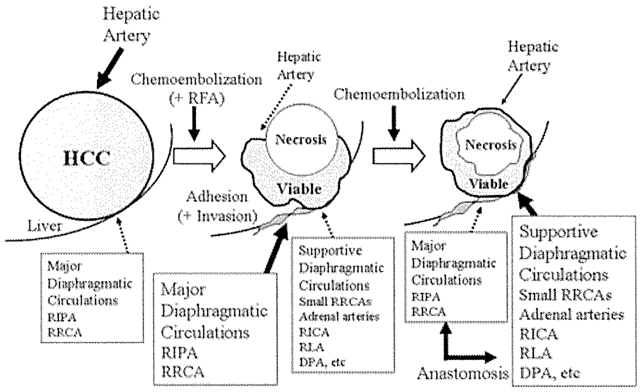
Fig. 6 A 71-year-old woman with an HCC located in the bare area. **A** Arterial phase CT at the third recurrence 4 years 2 months after the initial treatment shows a tumor protruding to the bare area (*arrow*). **B** The tumor was initially supplied by the hepatic arterial branch and was supplied by the right IPA at the first and second recurrences (not shown). At the third recurrence, the tumor (*arrow*) is supplied by a small branch arising from the right first lumbar artery (*arrowhead*). **C** The tumor-feeding branch was selected and chemoembolization was successfully performed

suspected at the initial chemoembolization in 80% of their patients, with blood supply to tumors from the right IPA demonstrated on follow-up angiography.

The RCA system distributes to the renal capsule and perirenal space, and it is composed of three basic pathways: superior, medial, and inferior RCAs. These vessels usually arise from or together with the adrenal arteries. The system may also originate from the main renal artery or from the gonadal artery. In addition, perforating capsular arteries (small RCAs) arise from the arcuate and interlobular arteries, which are branches of the renal artery [17]. The perirenal space is anatomically connected with the bare area on the right side [18], therefore, the right RCA also distributes into the bare area.

The intercostal artery and internal mammary artery usually connect with the right IPA and support the diaphragmatic pathways [5]. There are also fine retroperitoneal networks between the right IPA, right RCA, dorsal pancreatic artery, adrenal artery, left gastric artery, and right lumbar artery [6]. Therefore, these vessels also infrequently act as a supportive diaphragmatic pathway [5, 19]. Because of such overlapping vascular territories, a tumor located in the bare area may potentially be fed by several separate extrahepatic collateral vessels, in addition to the hepatic arterial branch. When one vessel is attenuated by chemoembolization, other vessels may in turn replace the blood supply to the recurrent tumor at the next chemoembolization session. We named this sequence "the march of extrahepatic collaterals" (Fig. 7).

As the tumor size increases, the prevalence of an extrahepatic supply increases [13]. Chung et al. [14] reported that prevalence of extrahepatic blood supply at the initial chemoembolization session in a tumor <4 cm in



RIPA right inferior phrenic artery, *RRCA* right renal capsular artery, *RICA* right intercostal artery, *RLA* right lumbar artery, *DPA* dorsal pancreatic artery

Fig. 7 Schematic representation of "the march of extrahepatic collaterals." At the beginning of the treatment, the tumor located in the bare area of the liver is mainly supplied by the hepatic arterial branch and partially supplied by major extrahepatic collaterals, such as the right IPA and right RCA. After damage to these vessels by repeated chemoembolization, minor extrahepatic collateral vessels of retroperitoneal circulation, such as the small right RCAs, adrenal arteries, posterior intercostal artery, and lumbar artery, feed the recurrent tumor in turns

diameter was <3%; this increased to 63% when the tumor was >6 cm in diameter. In the present study, however, 30.8% of tumors with a mean diameter of 3.4 cm were receiving an extrahepatic blood supply at the initial chemoembolization. This suggests that extrahepatic parasitization easily develops even for a small tumor located in the bare area.

At the beginning of treatment, a tumor located in the bare area of the liver was mainly supplied by the hepatic arterial branch and partially supplied by major extrahepatic collaterals, such as the right IPA and right RCA. After damage to these vessels by repeated chemoembolization, minor extrahepatic collateral vessels of the retroperitoneal circulation, such as small right RCAs, adrenal arteries, posterior intercostal artery, and lumbar artery, fed the recurrent tumor in turns. Adhesion between the liver and the diaphragm after repeated chemoembolization and RFA may also exaggerate the development of such minor extrahepatic collaterals. These small vessels may make it more difficult to control the tumor by chemoembolization after the tumor has recurred several times.

RFA is one of the most effective techniques for local treatment of inoperable HCCs. It is also useful to treat a tumor located in the bare area, however, several thoracic complications, such as diaphragmatic perforation (intrathoracic hernia, abscess extending to the thorax, and bronchobiliary fistula), right shoulder pain, and pleural effusion, have been reported [20–22]. In a report by Kang et al. [22], RFA of a tumor abutting the diaphragm was less effective with regard to technical success and local tumor control because of the difficulty in targeting the tumor by US. In addition, the operator's concern regarding thermal injury of the adjacent diaphragm may lead to incomplete ablation because it is very difficult to monitor the ablative zone and the diaphragm in the subphrenic area with a poor sonic window and ill-defined hyperechoic zone during ablation. Conversely, Takaki et al. [23] reported that there was no significant difference in tumor progression rates between tumors adjacent to the diaphragm and tumors apart from the diaphragm after CT-guided RFA combined with chemoembolization. In our small number of patients treated with a combination of chemoembolization and US-guided RFA, however, the ablative margin did not cover the entire tumor in 3 of 4 cases, and these 3 tumors subsequently recurred. CT guidance may allow the operator to easily target tumor abutting the diaphragm by the RF electrode, although the risk of thermal injury to the diaphragm remains [21].

Local recurrence rates of HCCs located in the bare area treated with chemoembolization were higher than those of HCCs treated with RFA in a report by Kang et al. [22]. We speculate that differences in local recurrence rates in each study may involve a different tumor location rather than different therapeutic modalities. In the present study, all tumors were located in the bare area. However, in their report, not only tumors abutting the diaphragm but also tumors located within a 5-mm-wide area near the diaphragm were included in the "abutting group." In addition, the hepatic segment of the tumor location was not provided. We speculate that tumors originating in the bare area may be more difficult to treat by a combination of chemoembolization and RFA than tumors in other segments abutting the diaphragm.

There are some limitations to the present study. We excluded equivocal staining on angiograms of extrahepatic collaterals. In addition, in elderly patients with atherosclerosis, screening of small branches arising directly from the aorta, such as the middle adrenal artery, may be incomplete. For these reasons, the incidence of blood supply from extrahepatic collaterals to the tumor may have been underestimated in this study. In addition, "tumor recurrence" in the present study may include small residual tumor tissue following the initial or additional chemoembolization. Therefore, the prevalence of extrahepatic blood supply to HCC at the initial chemoembolization may also have been underestimated.

In conclusion, HCCs located in the bare area are frequently supplied by extrahepatic vessels in addition to the hepatic artery even at the initial treatment. Recurrence of such tumors after chemoembolization is mainly due to the extrahepatic blood supply. The right IPA and RCA are common feeding vessels demonstrated early, while other extrahepatic collateral supply from the retroperitoneal circulation, such as the small right RCAs, adrenal arteries, and intercostal and lumbar artery, occurs in turns during the later course. Interventional radiologists should be familiar with the clinical features of HCCs located in the bare area and the complex vascular sequence supplying such tumors.

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CLINICAL INVESTIGATION

Hepatocellular Carcinoma Supplied by the Right Lumbar Artery

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Abstract This study evaluated the clinical features of hepatocellular carcinoma (HCC) supplied by the right lumbar artery. Eleven patients with HCC supplied by the right lumbar artery were treated with chemoembolization. The patients' medical records were retrospectively analyzed. All patients underwent 6.7 ± 3.7 (mean ± SD) chemoembolization sessions, and the hepatic arterial branches were noted as being attenuated. The right inferior phrenic artery (IPA) was also embolized in 10 patients. The interval between initial chemoembolization and chemoembolization of the lumbar artery supply was 53.2 ± 26.9 months. Mean tumor diameter was 3.1 ± 2.4 cm and was located at the surface of S7 and S6. The feeding-branch arose proximal to the bifurcation of the dorsal ramus and muscular branches ($n = 8$) or from the muscular branches ($n = 3$) of the right first ($n = 10$) or second lumbar artery ($n = 1$). The anterior spinal artery originated from the tumor-feeding lumbar artery in one patient. All feeders were selected, and embolization was performed after injection of iodized oil and anticancer drugs ($n = 10$) or gelatin sponge alone in a patient with anterior spinal artery branching ($n = 1$). Eight patients died from tumor progression 10.1 ± 4.6 months later, and two patients survived 2 and 26 months, respectively. The remaining patient died of bone metastases after 32 months despite liver transplantation 10 months after chemoembolization. The right lumbar artery supplies HCC located in the bare area of the liver, especially in patients who undergo repeated chemoembolization, including chemoembolization by way of the right IPA. Chemoembolization by way of the right lumbar artery may be safe when the feeder is well selected.

Keywords Hepatocellular carcinoma · Chemoembolization · Lumbar artery supply

Introduction

Extrahepatic collateral pathways to the liver and hepatocellular carcinoma (HCC) can develop under various conditions, e.g., after interruption of the hepatic artery by surgical ligation, arterial injury induced by repeated chemoembolization procedures, or placement of a catheter [1, 2]. Adhesion between the liver and other organs exaggerates the degree of extrahepatic collaterals [3]. An extrahepatic blood supply to HCC also develops in the anatomic location of HCC, although the hepatic arterial supply remains intact [4]. Extrahepatic collateral supplies can inhibit the effectiveness of chemoembolization treatment. To ensure effective transcatheter management of HCC, these collaterals should be adequately embolized [3–12]. The right lumbar artery infrequently supplies HCC located in the bare area of the liver [5, 6]. In this report, we describe the clinical features of HCC supplied by the lumbar artery.

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Materials and Methods

Patients

Between October 2002 and January 2009, 11 patients with HCC supplied by the right lumbar artery were treated with chemoembolization. During the same period, 489 patients were treated by chemoembolization; therefore, the prevalence of right lumbar artery supply to the HCC was 2.2%. There were eight men and three women, and mean patient age was 69.4 ± 8.3 years (mean ± SD) (range, 53–82). Patient characteristics are listed in Table 1. All patients had liver cirrhosis. This was related to hepatitis C in eight patients and to hepatitis B in one patient; one patient had both hepatitis B and C; HCC etiology in the remaining patient was unknown. The original tumor treated by initial chemoembolization was single nodular ($n = 5$) or multinodular ($n = 6$) and located in segment 8 ($n = 2$), segment 5 ($n = 2$), segment 7 ($n = 2$), segments 8 and 7 ($n = 2$), segments 7 and 1 ($n = 1$), segments 6 and 3 ($n = 1$), and segments 8, 7, and 6 ($n = 1$). The treatment records were retrospectively analyzed.

Classification of Hepatic Arterial Damage

Angiographic findings demonstrating the right lumbar artery supply were retrospectively analyzed. Damage to the hepatic arterial branch was divided into four grades: (1) severe, i.e., occlusion of the right or left hepatic artery; (2) moderate, i.e., occlusion of the segmental artery of the liver; (3) slight, i.e., occlusion of the subsegmental artery of the liver; and (4) none, i.e., no obvious damage to the hepatic arterial branches.

Chemoembolization Methods and Follow-Up

Written informed consent was obtained from each patient before chemoembolization was performed. Institutional Review Board approval was not required at our institution for this retrospective study. Arteriograms of the right lower intercostal arteries (T10 and T11), the subcostal artery, and the right upper lumbar arteries (L1 and L2) were routinely obtained in all patients to determine where the anterior spinal artery originated. After confirmation of the tumor-feeding branch, selective catheterization into the tumor-feeding branch using a 2F tip microcatheter (Progreat α; Terumo, Tokyo, Japan) was attempted. The embolization procedure was performed according to the following therapeutic strategies:

(1) When the tumor-feeding branch could be selected and the anterior spinal artery was not derived from the parent artery or adjacent arteries, chemoembolization was performed using gelatin sponge particles (Gelfoam; Upjohn, Kalamazoo, MI, or Gelpart; Nihon Kayaku, Tokyo, Japan) after injection of a mixture of 1 to 2 ml iodized oil (Lipiodol; Andre Guerbet, Aulnaysous-Bois, France) and anticancer drugs (10 mg epirubicin [Farmorbicin; Kyowa Hakko, Tokyo, Japan] and 2 mg mitomycin C [Mitomycin; Kyowa Hakko]).
(2) When the tumor-feeding branch could be selected and the anterior spinal artery was derived from the parent artery or adjacent arteries, the feeding branch was embolized by gelatin sponge particles alone.
(3) When the tumor-feeding branch could not be selected, the procedure was ended without embolization.

Chemoembolization was simultaneously performed not only by way of the hepatic arterial branches but also other extrahepatic collaterals if necessary.

Computed axial tomography (CAT) was performed 1 week after the procedure in all patients to determine the distribution of iodized oil. All patients but one were followed up, and tumor recurrence was judged by CAT or magnetic resonance imaging obtained every 2–3 months after chemoembolization. The remaining patient underwent follow-up CAT 1 week later only because chemoembolization had been performed 2 months previously, and further follow-up imaging was not performed.

Results

Pretreatment Findings

All patients underwent 3 to 15 chemoembolization sessions (mean 6.7 ± 3.7) before discovery of blood supply from the right lumbar artery to the HCC. The interval between initial chemoembolization and discovery of the right lumbar artery supply was 53.2 ± 26.9 months (range, 6–86). In addition, seven patients had undergone previous percutaneous local therapy (percutaneous ethanol injection [$n = 3$], microwave coagulation therapy [$n = 1$], or radiofrequency ablation [RFA] [$n = 5$]) combined with chemoembolization to the tumor fed by the right lumbar artery ($n = 2$) or other tumors ($n = 5$). One patient had undergone previous radiation therapy to the tumor fed by the right lumbar artery in addition to RFA. Another patient had a history of hepatic resection for HCC. All patients had undergone previous chemoembolization of extrahepatic collateral vessels supplying the HCC. The right inferior phrenic artery (IPA) was embolized in 10 patients. In addition, the right renal capsular artery ($n = 5$), left IPA ($n = 2$), right intercostal arteries ($n = 4$), right middle adrenal artery ($n = 2$), omental arteries ($n = 2$), cystic

Table 1 Summary of 11 patients with HCC fed by the right lumbar artery

Patient no./age/sex	No. of previous chemoembolizations	Other therapy	Tumor type/location at initial chemoembolization	Interval between initial chemoembolization and lumbar artery supply (mo)	Angiographic findings of tumor fed by lumbar artery					
					Tumor size (cm)/location	Hepatic artery damage	Feeding artery	Feeding branches	Anterior spinal artery	Outcomes
1/53/M	9	None	Multinodular/S5	82	1.5/S7	Severe	L2	Proximal[a]	–	Dead at 32 mo[b]
2/82/M	15	PEI, MCT	Multinodular/S8	86	2/S7	Severe	L1	Proximal	–	Dead at 5 mo
3/74/F	3	None	Multinodular/S7 and S1	38	1.8/S7	Moderate	L1	Proximal	–	Dead at 16 mo
4/73/M	10	PEI, RFA	Single nodular/S5	48	1.8/S7	Severe	L1	Proximal	–	Dead at 10 mo
5/79/M	6	RFA	Single nodular/S7	76	2/S7	Slight	L1	Proximal	–	Alive at 26 mo
6/68/M	6	RFA	Multinodular/S6 and S3	34	3/S6	Severe	L1	Distal[c]	–	Dead at 7 mo
7/58/M	4	None	Single nodular/S8 and S7	6	9.8/S7	Moderate	L1	Proximal	–	Dead at 13 mo
8/69/M	4	PEI	Multinodular/S8, S7, and S6	20	2.3/S7	Moderate	L1	Proximal	–	Dead at 15 mo
9/69/M	9	RFA	Single nodular/S8	78	2.8/S7	Severe	L1	Distal	–	Dead at 5 mo
10/67/F	5	RFA, RT	Single nodular/S7	49	4.3/S7	Moderate	L1	Distal	–	Dead at 7 mo
11/71/F	3	Resection	Multinodular/S8 and S7	68	3/S7	Moderate	L1	Proximal	+	Alive at 2 mo

PEI percutaneous ethanol injection, *MCT* microwave coagulation therapy, *RFA* radiofrequency ablation, *RT* radiotherapy

[a] The feeding-branch arose proximal to the bifurcation of the dorsal ramus and muscular branches

[b] This patient underwent liver transplantation 10 months after chemoembolization by way of the right lumbar artery

[c] The feeding-branch arose from the muscular branches

Fig. 1 A 79-year-old man with HCC supplied by the right lumbar artery (patient no. 5). (**A**) CAT during arterial portography image shows a hypoattenuating area adjacent to a defect of iodized oil accumulation at the posterior aspect of the tumor, suggesting local recurrence (*arrow*). (**B**) Arteriogram of the right first lumbar artery shows a small tumor-feeding branch arising at the proximal portion (*arrow*) and tumor stain (*arrowhead*). (**C**) The tumor-feeding branch was selected, and chemoembolization was performed. (**D**) CAT obtained 1 week after the procedure shows dense iodized oil accumulation in the recurrent tumor portion

artery ($n = 1$), middle colic artery ($n = 1$), right internal mammary artery ($n = 1$), branches of left ($n = 1$) or right gastric artery ($n = 1$), and bile duct artery ($n = 1$) were also embolized.

All patients had a single HCC that was partially ($n = 6$) or completely ($n = 5$) fed by the right lumbar artery. Ten tumors were local recurrences after chemoembolization. Six tumors were original tumors with local recurrence despite several chemoembolization procedures. Four were sequentially developed tumors at other sites with local recurrence after additional chemoembolization. The remaining tumor was a newly developed tumor at another site without any treatment. Nine patients had multiple viable tumors in addition to the tumor fed by the right lumbar artery. Two patients had a solitary tumor fed by the right lumbar artery that was the original tumor with local recurrence.

Hepatic arterial damage was found in all patients. The grades of damage were classified as severe ($n = 5$), moderate ($n = 5$), and slight ($n = 1$). None of the tumors supplied by the lumbar artery had invaded the abdominal wall, and the mean tumor diameter was 3.1 ± 2.4 cm (range 1.5 to 9.8). All except one of the tumors supplied by the right lumbar artery were located in the bare area of segment 7. The remaining tumor was located on the liver surface of segment 6 near the right renal fossa.

Chemoembolization

In 10 patients, the HCC was supplied by the right first lumbar artery (Figs. 1 through 4). In the remaining patient, the right second lumbar artery supplied the tumor because the first lumbar artery was hypoplastic. In one patient, the anterior spinal artery was derived from the tumor-feeding right first lumbar artery (Fig. 4). In the other 10 patients, the anterior spinal artery did not originate from the right lower intercostal, subcostal, or upper lumbar arteries.

A small branch arising proximal to the bifurcation of the dorsal ramus and muscular branches supplied the HCC in eight patients (Figs. 1, 3, 4). In three patients, the feeding branch was derived from the proximate portion of the muscular branches (Fig. 2). In two patients, the right IPA, which was previously embolized, was demonstrated by way of the retroperitoneal anastomosis (Fig. 3).

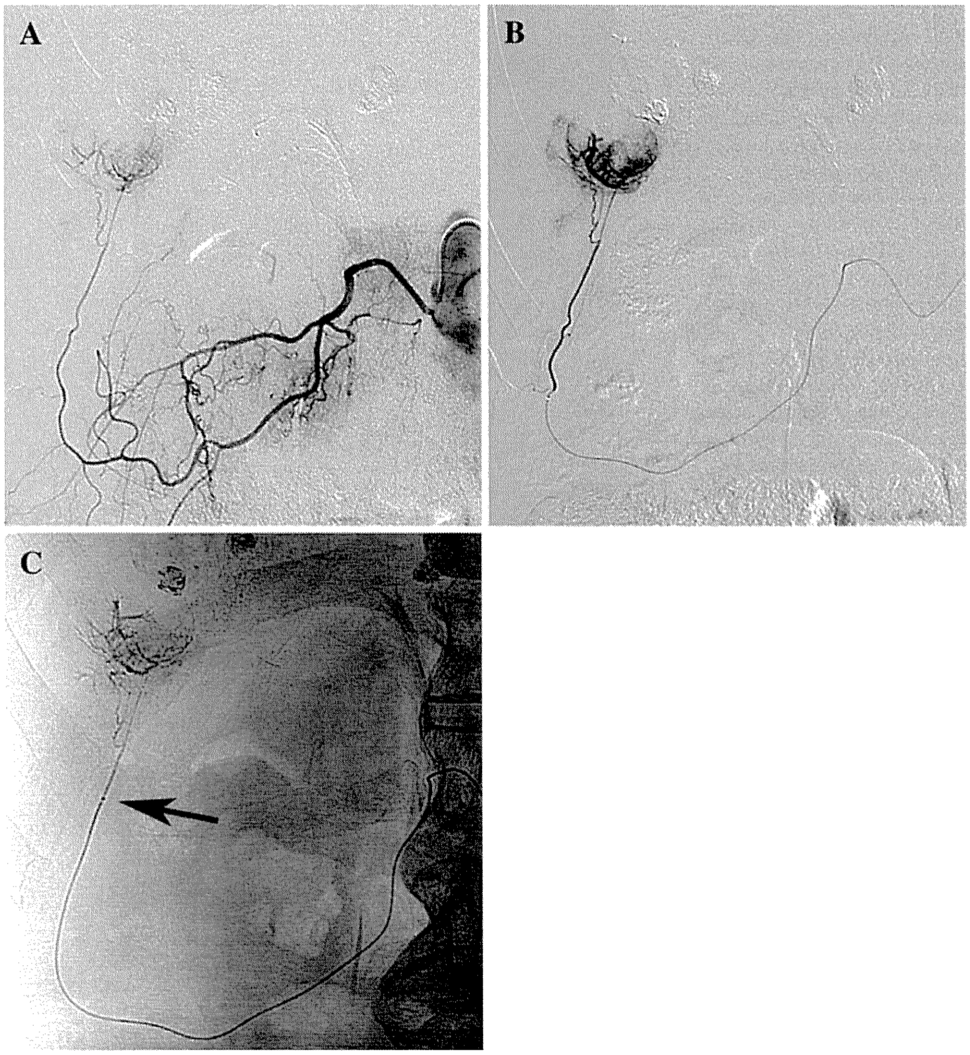

Fig. 2 A 68-year-old man with HCC supplied by the right lumbar artery (patient no. 6). (**A**) Arteriogram of the right first lumbar artery shows a tumor-feeding branch arising from the muscular branches as well as tumor stain. (**B**) The tumor-feeding branch was successfully selected. (**C**) Chemoembolization was performed at a more distal level. The catheter tip can be seen (*arrow*)

All tumor-feeding branches could be selected by the microcatheter (Figs. 1 through 4). In 10 patients, chemoembolization was performed without complications (Figs. 1 through 3). In the remaining patient whose anterior spinal artery originated from the right first lumbar artery, bland embolization was performed without complications (Fig. 4). Other extrahepatic collateral vessels were simultaneously embolized in eight patients as follows: the left gastric artery branch ($n = 1$), right intercostal arteries ($n = 3$), right IPA ($n = 1$), middle colic artery ($n = 1$), right renal capsular artery ($n = 1$), right middle adrenal artery ($n = 1$), bile duct artery ($n = 1$), and omental artery ($n = 1$). In addition, the hepatic arterial branches were embolized in 10 patients.

Outcomes

The tumor that was supplied by the right lumbar artery recurred in 9 of 10 patients at 4–9 months (4.0 ± 2.5) after chemoembolization. Four of 10 patients underwent additional chemoembolization, and the recurrent tumor was fed by the hepatic arterial branch ($n = 1$), attenuated right IPA ($n = 2$), and intercostal arteries ($n = 1$). Additional angiography was not performed in 6 patients, including one patient who underwent liver transplantation, because of diffuse tumor progression. In the remaining patient, the tumor supplied by the right lumbar artery did not recur despite progression of other tumors during the course of 4 months.

Eight patients died from tumor progression at 5–15 months (10.1 ± 4.6) after chemoembolization of the right lumbar artery. Two patients are currently alive after the procedure. One patient survived for 26 months despite two additional chemoembolization procedures for recurrent tumor. One patient survived for 2 months; however, follow-up CAT was not performed. The remaining patient, who underwent liver transplantation 10 months later, died of diffuse bone metastases 32 months after chemoembolization of the right lumbar artery.

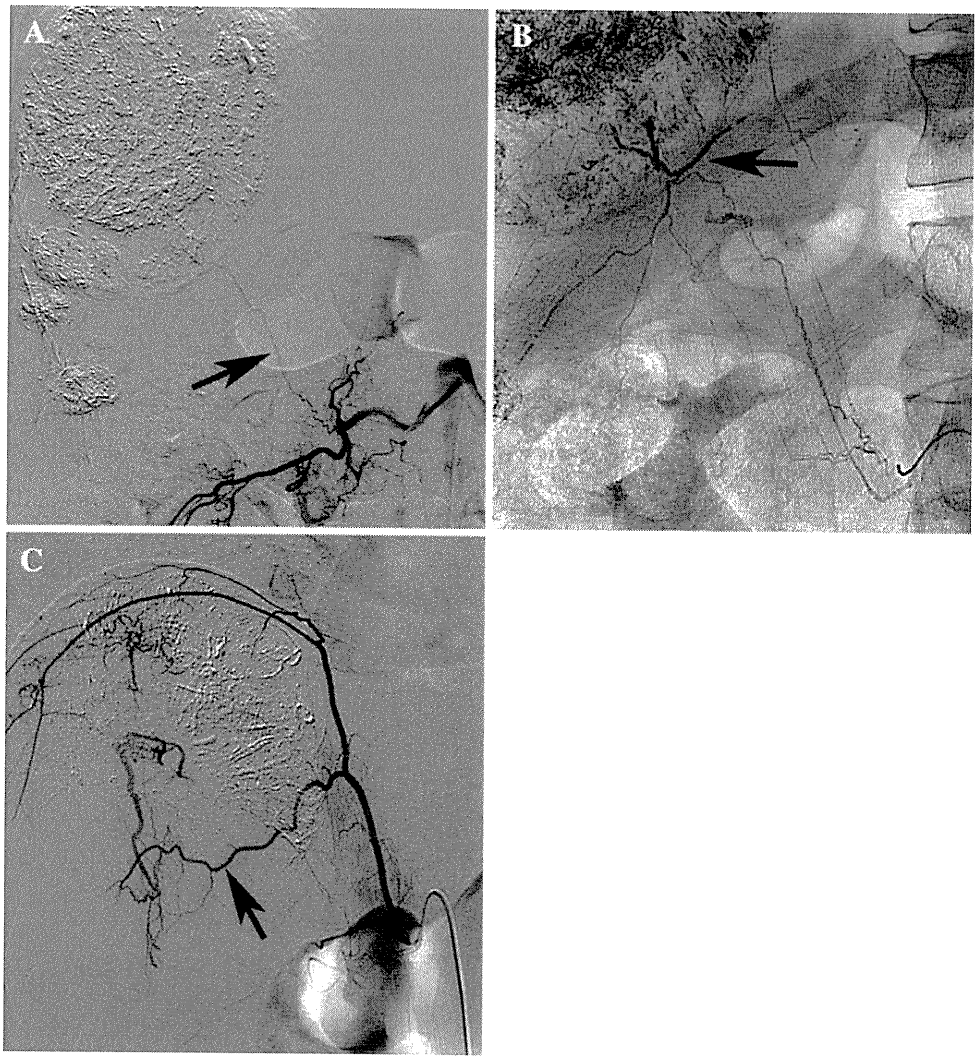

Fig. 3 A 58-year-old man with HCC supplied by the right lumbar artery (patient no. 7). (**A**) Arteriogram of the right first lumbar artery shows a tumor-feeding branch arising at the proximal portion (*arrow*). (**B**) The tumor-feeding branch was selected, and chemoembolization was performed. During the procedure, a vessel that was not seen on (**B**) was demonstrated (*arrow*). (**C**) Arteriogram obtained before right IPA chemoembolization 6 months earlier shows that the vessel is a branch of the right IPA (*arrow*)

Discussion

Various extrahepatic collaterals to HCC can develop during a subsequent course of treatment but infrequently at the initial treatment [1–12]. The right IPA is the most frequent extrahepatic collateral vessel of HCC [4–6]. The cystic artery, omental artery, internal mammary artery, intercostal artery, right renal capsular artery, left IPA, adrenal arteries, colic artery, bile duct artery, and gonadal artery are also known to develop other extrahepatic collaterals [3–12].

There are usually four lumbar arteries on each side arising from the posterior aspect of the abdominal aorta. These arteries anastomose with one another and with the lower posterior intercostal, subcostal, iliolumbar, deep circumflex iliac, and inferior epigastric arteries [13]. Three major branches derive from the lumbar artery: the dorsal ramus, spinal, and muscular branches. In the present study, a small branch arising proximal to the bifurcation of the dorsal ramus and muscular branches fed the HCC in eight patients, and small branches arising from the muscular branches fed the tumor in three patients.

In all patients, the right IPA was also embolized either previously or simultaneously. The right IPA is the major source of the diaphragmatic pathways, and the intercostal and internal mammary arteries support these pathways [9]. There are fine retroperitoneal networks between the right IPA, dorsal pancreatic artery, adrenal artery, and left gastric artery. In addition, the right lumbar artery infrequently also acts as a supportive diaphragmatic pathway [14]. Lumbar artery collateral supply occurs late, after both the hepatic and diaphragmatic circulations are severely attenuated by repeated chemoembolization. In contrast, a large tumor invading the abdominal wall may receive the blood supply from the lumbar artery without damaging the hepatic arteries and IPA [5]. Therefore, the prevalence of a lumbar artery supply may be influenced by tumor size. In our series, none of the tumors had invaded the abdominal wall, and all tumors except one were relatively small.

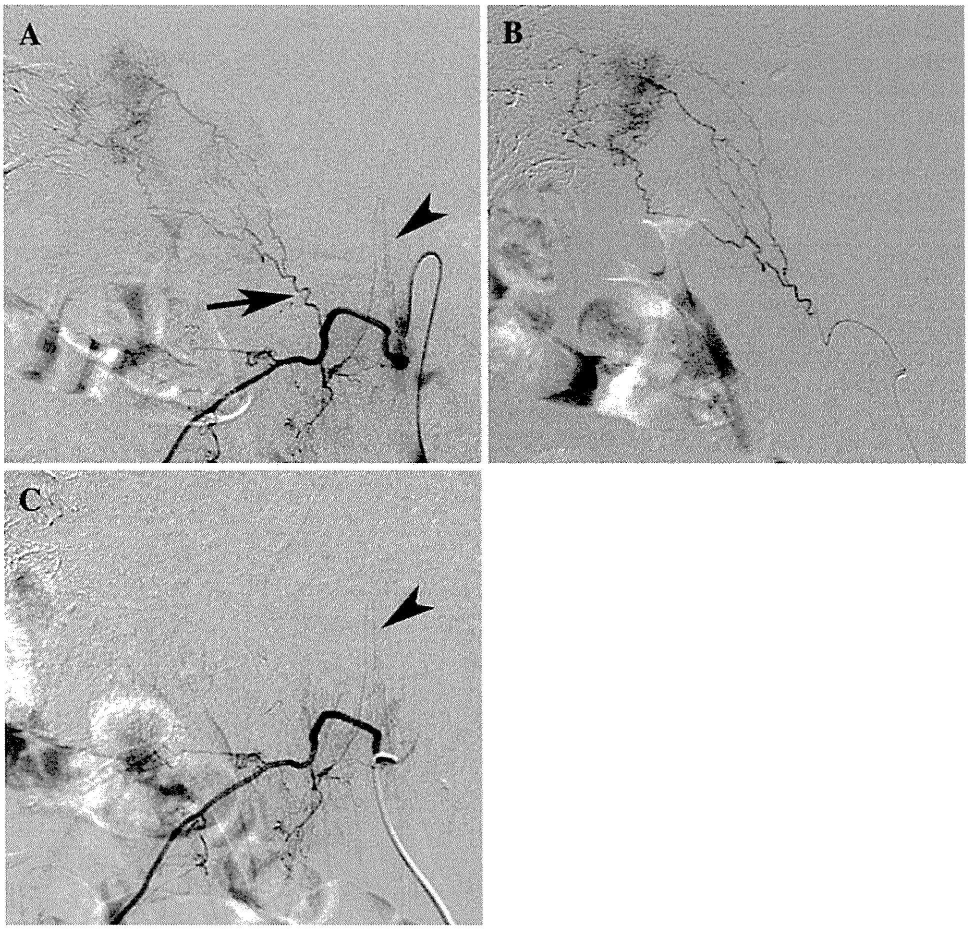

Fig. 4 A 71-year-old woman with HCC supplied by the right lumbar artery (patient no. 11). (**A**) Arteriogram of the right first lumbar artery shows a tumor-feeding branch arising from the proximal portion (*arrow*) as well as tumor stain. The anterior spinal artery is also seen (*arrowhead*). (**B**) The tumor-feeding branch was selected, and bland embolization was performed without complication. (**C**) Arteriogram obtained immediately after embolization shows that the tumor-feeding branch is embolized and the anterior spinal artery is patent (*arrowhead*)

Therefore, repeated chemoembolization procedures and tumor location at the bare area of the liver may have exaggerated the lumbar artery supply.

Inadvertent chemoembolization of the spinal or skin-feeding branches may cause spinal cord injury or skin necrosis [6, 15, 16]. Superselective catheterization into the tumor-feeding branch is necessary to safely perform chemoembolization of collateral vessels. All tumor-feeding branches were small; however, they could be selected using a 2F tip microcatheter in our series. Because the lumbar arteries anastomose with arteries from above and from below [13, 17], embolic materials may pass through these anastomoses 18]. Therefore, arteriography of the right lower intercostal, subcostal, and upper lumbar arteries should be performed before chemoembolization to confirm where the anterior spinal artery originates. Bland embolization by way of the tumor-feeding branch using gelatin sponge particles may be safe when the anterior spinal artery derives from the tumor-supplying lumbar artery or from neighboring arteries.

Efficacy of chemoembolization by way of the right lumbar artery is uncertain because the majority of our patients died within a relatively short period after chemoembolization by way of the right lumbar artery. However, one patient survived for 26 months after chemoembolization by way of the right lumbar artery despite two local recurrences. Therefore, we believe that chemoembolization by way of the right lumbar artery may prolong patient survival.

In conclusion, the right lumbar artery supplies HCC located at the bare area of the liver, especially in patients with attenuation of hepatic arterial branches by repeated chemoembolization, including by way of the right IPA. The tumor-feeding branch arises proximal to the bifurcation of the dorsal ramus and muscular branches in most cases; however, it infrequently arises from the muscular branches. Chemoembolization by way of the right lumbar artery may be safe when the tumor-feeding branch is successfully selected.

References

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