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ORIGINAL ARTICLE

Change in hepatic hemodynamics assessed by hepatic arterial blood pressure and computed tomography during hepatic angiography with the double balloon technique

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Abstract

Purpose To assess the change in hepatic arterial blood pressure (HABP) and computed tomography during hepatic arteriography (CTHA) using the double balloon technique.

Materials and methods Nine patients with hepatocellular carcinoma (HCC) were enrolled. We inserted a 5.2-Fr balloon catheter into the common or proper hepatic artery and a 1.8-Fr microballoon catheter into the lobar or segmental artery feeding the HCC. HABPs were measured with the 1.8-Fr microballoon catheter (usual-HABP), with the 1.8-Fr balloon inflated (B-HABP), and with both the 5.2-Fr and 1.8-Fr balloons inflated (BB-HABP). CTHAs were performed via a 1.8-Fr microcatheter (usual-CTHA), with the 1.8-Fr balloon inflated (B-CTHA selective), with both the 5.2-Fr and 1.8-Fr balloons inflated (BB-CTHA selective), and via the 5.2-Fr catheter with the 1.8-Fr balloon inflated (B-CTHA whole) and with both the 5.2-Fr and 1.8-Fr balloons inflated (BB-CTHA whole).

Results In all cases, B-HABP was lower than usual-HABP. There was a decrease in BB-HABP in comparison with B-HABP in cases with occlusion of the proper hepatic artery. The contrast effect of B-CTHA selective increased in four cases. The contrast effect on B-CTHA whole remained in all cases.

Conclusion This technique can be useful in decreasing HABP and collateral blood flow from the adjacent hepatic segment.

Keywords Balloon-occluded transarterial chemoembolization · Computed tomography during hepatic arteriography · Double balloon technique · Hepatic arterial blood pressure · Hepatocellular carcinoma

Introduction

Although cancer death rates have declined by 25% over the past two decades, incidence rates for hepatocellular carcinoma (HCC) have increased by approximately 3–4% per year and death rates have risen by almost 3% per year [1]. Transarterial chemoembolization (TACE) has been the established therapy for HCC and is selected in cases that are not indicated for surgical resection or local treatment such as percutaneous ethanol injection, microwave coagulation therapy, and radiofrequency ablation [2, 3]. In these cases, balloon-occluded TACE (B-TACE), a novel interventional technique for the treatment of HCC, increased lipiodol uptake in HCC compared with conventional TACE (C-TACE) [4, 5], and unenhanced computed tomography (CT) values immediately after B-TACE were predictive of local recurrence [6]. Local control of HCC was higher in B-TACE than C-TACE [7, 8]. Furthermore, B-TACE improved overall survival in patients with one or two HCCs [8]. According to an article by Irie et al. [4], B-TACE induced dense accumulation of lipiodol when balloon-occluded arterial stump pressure (BOASP) was decreased to ≤ 64 mm Hg. Hepatic hemodynamics were assessed by measuring BOASP [9] and CTHA findings during occlusion of the intrahepatic feeding artery [10–12]. However, no article has reported on the hepatic hemodynamics of extrahepatic artery occlusion such as in the common or proper hepatic artery (CHA/PHA). Double balloon occlusion of both the intrahepatic and extrahepatic arteries is expected

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to lower BOASP and highly concentrated lipiodol accumulation resulting in favorable local control in B-TACE. Therefore, the aim of this study is to assess hepatic hemodynamics under balloon occlusion of the hepatic artery by measuring hepatic arterial blood pressure (HABP) and evaluating CT hepatic arteriography (CTHA) using double balloon catheters including a 1.8-Fr microballoon catheter to occlude the intrahepatic feeding artery and a 5.2-Fr balloon catheter to occlude the PHA/CHA.

Material and methods

Patients

This prospective study was approved by our institutional review board, and all patients provided written informed consent for their participation. Patients scheduled to undergo TACE for HCCs were considered for this study. Patients who refused to participate in this study, patients who underwent past treatment for HCCs, or patients with vascular anomalies, such as replaced and accessory hepatic arteries, were excluded. Finally, we enrolled nine patients (seven males, two females; mean age, 69.4 years) with untreated HCC for this study.

Interventional procedure

Following local anesthesia, 4-Fr and 5-Fr introducer sheaths (Super Sheath, length: 25 cm; Medikit, Tokyo, Japan) were inserted into the right femoral artery using the Seldinger technique. Next, we inserted a 4-Fr J-shaped catheter through the introducer sheath into the celiac trunk and performed angiography (Infinix Celeve-i, INFX-8000V; Canon Medical Systems, Tochigi, Japan) to identify the vascular anatomy and feeding artery of the tumor. We inserted a 5.2-Fr balloon catheter (Selecon MP catheter II, balloon diameter: 9 mm, length: 70 mm; Terumo clinical supply, Tokyo, Japan) via an introducer sheath into the PHA or CHA (PHA whenever possible), and a 1.8-Fr microballoon catheter (LOGOS, balloon diameter: 4 mm, length 105 cm; Piolax Medical Devices, Inc., Yokohama, Japan) was inserted into the segmental or subsegmental hepatic artery connected to the feeding artery via a 4-Fr catheter with a 0.014-inch guidewire (Labyrinth, length: 165 cm; Piolax Medical Devices, Inc.). B-TACE was performed using miriplatin (Miripla, Dainippon Sumitomo Pharma Co., Ltd, Osaka., Japan) using two inflated balloons if BB-HABP was ≤ 64 mmHg and using inflated microballoon occlusion if B-HABP was lower than usual-HABP after ensuring the enhancement of HCCs on BB-CTHA selective and B-CTHA selective, respectively. The feeding artery was embolized by a 1-mm gelatin sponge particle (Gelpart, Nippon Kayaku Co., Ltd., Tokyo, Japan) after administration of miriplatin.

Hepatic arterial blood pressure measurement

We measured HABP at the tip of a 1.8-Fr microballoon catheter with a pressure transducer (LifeScope i BSM-2301; Nihon Kohden, Tokyo, Japan). In addition, we measured the three types of HABP as follows: (1) usual-HABP was measured using a deflated balloon and a deflated microballoon; (2) B-HABP was measured with a deflated balloon and an inflated microballoon; and (3) BB-HABP was measured with an inflated balloon and an inflated microballoon.

Computed tomography during hepatic angiography

Five types of CTHA studies were performed on a 320-row detector CT scanner (Aquilion ONE; Canon Medical Systems, Tochigi, Japan) following the administration of twice-diluted iodine contrast medium (ICM) made of iohexol (Omnipaque 300; Daiichi Sankyo, Tokyo, Japan) and saline as follows: (1) usual-CTHA selective: CTHA was measured at 10 s following ICM administration via 1.8-Fr microballoon catheter with deflated balloon and deflated microballoon; (2) B-CTHA selective: CTHA was measured at 10 s after ICM administration via 1.8-Fr microballoon catheter with deflated balloon and inflated microballoon; (3) BB-CTHA selective: CTHA was measured at 10 s after ICM administration via 1.8-Fr microballoon catheter with inflated balloon and inflated microballoon; (4) B-CTHA whole: CTHA was measured at 5 s following ICM administration via 5.2-Fr balloon catheter with deflated balloon and inflated microballoon; and (5) BB-CTHA whole: CTHA was measured at 5 s after ICM administration via 5.2-Fr balloon catheter with inflated balloon and inflated microballoon (Fig. 1). In usual-CTHA, B-CTHA, and BB-CTHA selective, we administered either 3 mL or 6 mL ICM at a rate of 0.5 mL/s or 1.0 mL/s from the subsegmental or segmental artery, respectively. In B-CTHA and BB-CTHA whole, a total of 8 mL ICM was administered at a rate of 2 mL/s. B-CTHA and BB-CTHA whole were not performed in case 2.

Imaging analysis

Two interventional radiologists (A.I. and S.O.) with 11 and 23 years, respectively, of experience reading abdominal images evaluated the angiogram and CTHA images at both phases by consensus. We documented the tumor location and diameter on contrast-enhanced CT and performed angiography via the celiac artery to determine the feeding artery of the tumor.

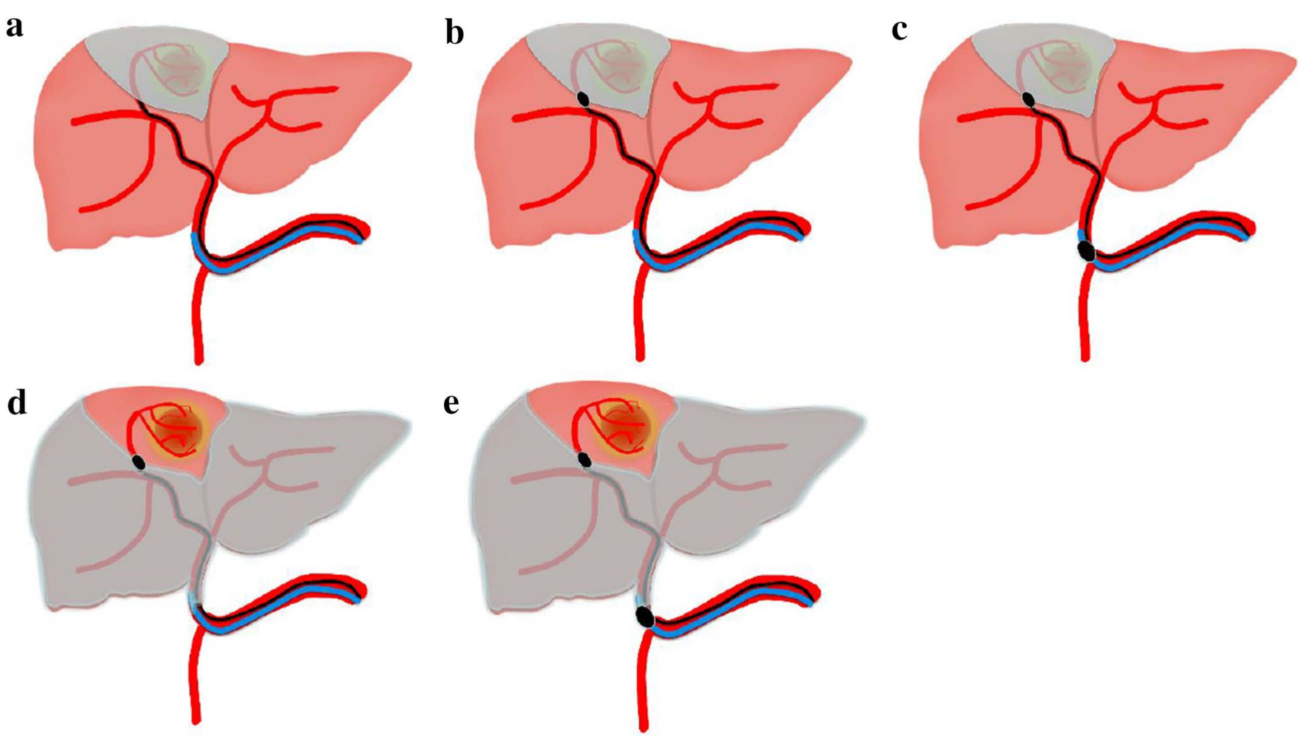

Fig. 1 CTHA after ICM administration via a 1.8-Fr microballoon catheter with deflated balloon and deflated microballoon in usual-CTHA selective (**a**), with deflated balloon and inflated microballoon in B-CTHA selective (**b**), and with inflated balloon and inflated microballoon in BB-CTHA selective (**c**). CTHA after ICM administration via a 5.2-Fr balloon catheter with deflated balloon and inflated microballoon in B-CTHA whole (**d**) and with inflated balloon and inflated microballoon in BB-CTHA whole (**e**)

We compared both B-CTHA and BB-CTHA selective with usual-CTHA selective to determine the influence of the microballoon versus the double balloon. We visually classified the changes in contrast effect on B-CTHA and BB-CTHA selective compared with those on usual-CTHA selective on a 5-point scale (extremely decreasing, decreasing, unchanged, increasing, and extremely increasing). Next, we evaluated B-CTHA and BB-CTHA whole to determine the influence of the intrahepatic collateral artery using a microballoon versus a double balloon catheter. Presence or absence of tumor enhancement was evaluated on B-CTHA whole, and subsequently BB-CTHA whole versus B-CTHA whole was visually classified using a 3-point score (unchanged, decreasing, and increasing).

CT values of the tumor and embolized liver parenchyma were measured on non-enhanced CT immediately after B-TACE. The ratio of the lipiodol emulsion concentration in the tumor to that in the embolized liver parenchyma (*T*/*L* ratio) was calculated as following equation:

$$T/L \text{ ratio } = \text{ CT value}_{\text{tumor}} \text{ (HU)}/\text{CT value}_{\text{embolized liver parenchyma}} \text{ (HU)}.$$

Results

Location of the balloon catheter

The 5.2-Fr balloon catheter was advanced into the common hepatic artery in five of the nine cases and the proper hepatic artery in four, and a 1.8-Fr microballoon catheter was inserted into the lobar artery in six and the segmental artery in three (Table 1).

Measurement of hepatic arterial blood pressure

In all cases, B-HABP was lower than usual-HABP. Furthermore, BB-HABP decreased compared with B-HABP in six of nine cases, particularly in four cases in which the balloon catheter occluded the proper hepatic artery (Table 1).

Computed tomography during hepatic angiography

The contrast effect of whole tumor was confirmed with usual-CTHA selective in all cases. The change in contrast effect was extremely increased in one case (Fig. 2), increased in three, unchanged in one, decreased in three, and extremely decreased in one case (Fig. 3) on B-CTHA selective versus usual-CTHA. The change in contrast effect was extremely

Table 1 Results for diameter (mm) and location of hepatocellular carcinoma, location of balloon and microballoon catheters, and hepatic arterial blood pressures (mm Hg) and computed tomography during hepatic arteriography

Case	Age	Sex	Diameter	HCC	BC	MBC	Usual-HABP	B-HABP	BB-HABP	B-CTHAs	BB-CTHAs	B-CTHAw	BB-CTHAw
1	58	M	81	S4/8	CHA	LHA	97	71	50	−−	−	Existence	↑
2	73	M	22	S4/5	CHA	A4	135	109	76	−	−	Existence	→
3	73	M	15	S8	CHA	RHA	120	73	125	±	±	NA	NA
4	71	M	20	S7	CHA	A7	125	120	125	+	++	Existence	→
5	69	M	10	S4	CHA	LHA	93	88	91	−	−	Existence	→
6	63	F	15	S5	PHA	RHA	88	65	52	+	+	Existence	↑
7	77	M	12	S5	PHA	RHA	119	45	29	−	±	Existence	→
8	66	M	11	S2	PHA	LHA	95	60	55	+	+	Existence	→
9	75	F	24	S3	PHA	A3	112	108	85	++	+	Existence	↑

The unit of diameter is mm. B-CTHA selective and BB-CTHA selective were compared to usual-CTHA selective using a 5-point score. Contrast enhancement on B-CTHA whole was evaluated using a 2-point score, and BB-CTHA whole was compared to B-CTHA whole using a 3-point score

HCC, location of hepatocellular carcinoma; BC, location of a 5.2-Fr balloon catheter; MBC, location of a 1.8-Fr microballoon catheter; HABP, hepatic arterial blood pressure; CTHA, computed tomography during hepatic arteriography; CTHAs, CTHA selective; CTHAw, CTHA whole; −−, extremely decreasing; −, decreasing; ±, unchanged; +, increasing; ++, extremely increasing; ↑, increasing; →, unchanged

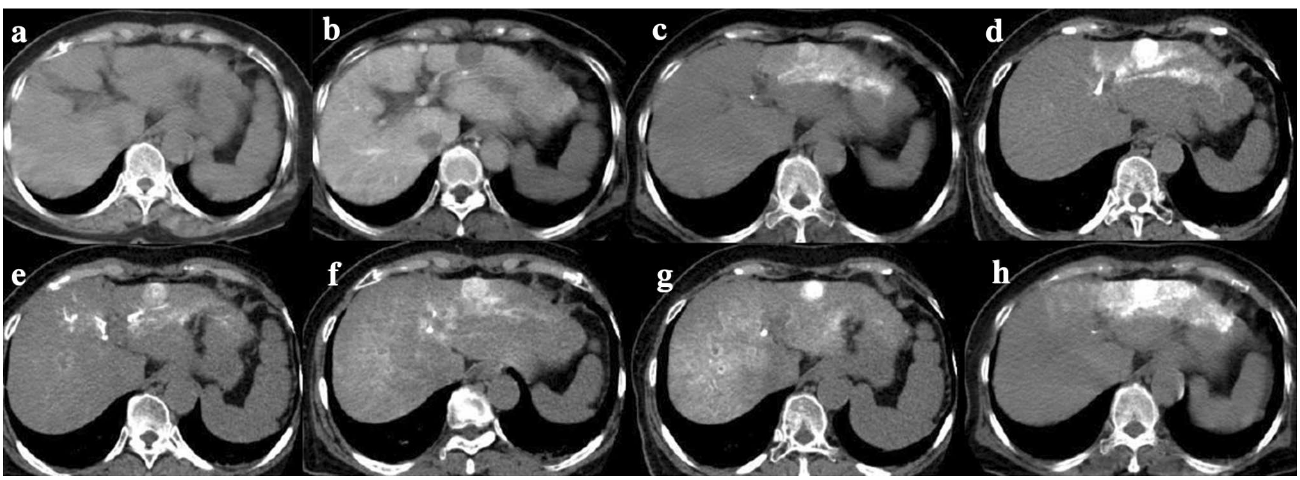

Fig. 2 A 75-year-old female with hepatocellular carcinoma (HCC) in S3 (case 9). Compared with non-contrast CT (**a**), HCC in S3 is revealed as a low-dense mass on computed tomography during portography (CTAP) (**b**) and high-dense mass on usual-CTHA via A3 (**c**). The contrast effect of HCC was extremely increased on B-CTHA selective (**d**) and BB-CTHA selective (**e**) compared with usual-CTHA (**c**). The contrast effect of HCC exists on B-CTHA whole (**f**) and increased on BB-CTHA (**g**). B-TACE was performed with a deflated balloon and inflated microballoon. Non-contrast CT following B-TACE show strong lipiodol accumulation (**h**)

increased in one case, increased in three (Fig. 2), unchanged in two, and decreased in three cases (Fig. 3) on BB-CTHA selective compared with usual-CTHA.

All cases showed contrast effects on B-CTHA whole (Figs. 2, 3). The contrast effect on BB-CTHA whole increased in three cases (Fig. 2) and was unchanged in six cases.

Interventional procedure and lipiodol accumulation

TACE procedures were performed using an inflated microballoon in five cases and inflated both balloons in three cases (Table 2). In case 1, the TACE procedure was performed with both balloons deflated, because B-CTHA selective showed no contrast enhancement although B-HABP was lower than usual-HABP and BB-HABP was ≤ 64 mmHg.

The *T*/*L* ratio in TACE with both balloons inflated was more than 2.5 and relatively higher than that in TACE with both balloons deflated and an inflated microballoon (Table 2).

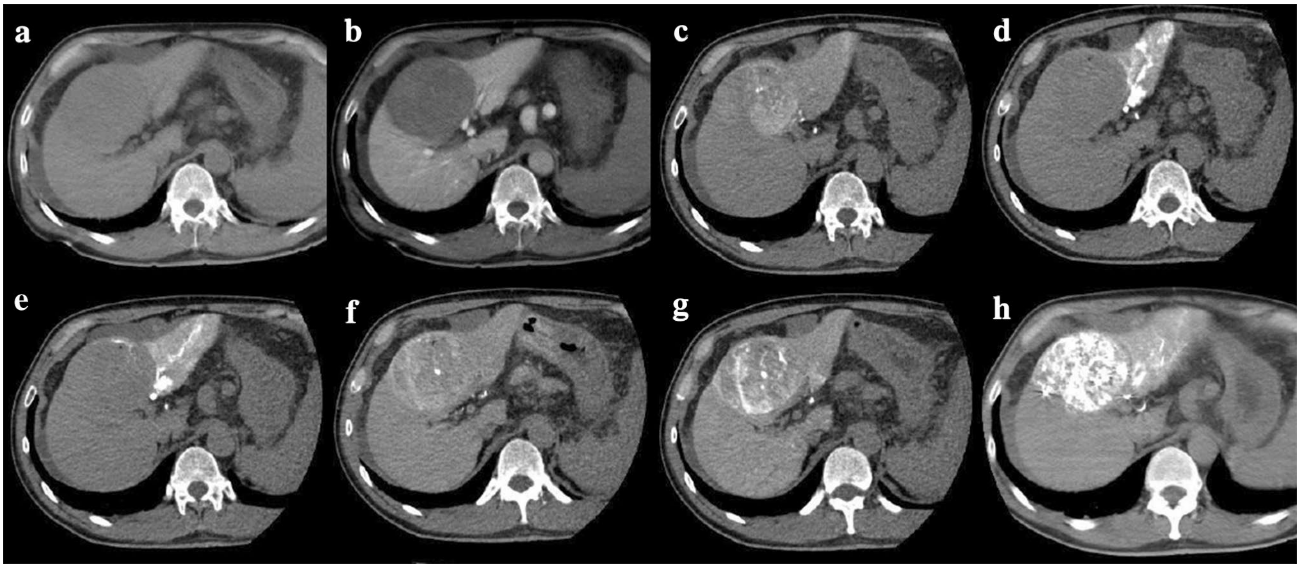

Fig. 3 A 58-year-old male with hepatocellular carcinoma (HCC) in S4/8 (case 1). The HCC in S4/8 is revealed as a low-dense mass on computed tomography during portography (CTAP) (**b**) and a high-dense mass on usual-CTHA via the left hepatic artery (**c**). The contrast effect of the HCC was extremely decreased on B-CTHA selective (**d**) and decreased on BB-CTHA selective (**e**). The contrast effect of the HCC exists on B-CTHA whole (**f**) and increased on BB-CTHA whole (**g**). TACE was performed via A4 and A8 without balloon occlusion. Non-contrast CT after B-TACE shows strong lipiodol accumulation (**h**)

Table 2 CT values in the tumor and liver parenchyma immediately after TACE, the ratio of lipiodol emulsion concentration in the tumor to that in the embolized liver parenchyma (*T*/*L* ratio), and balloon status during TACE

Case	Age	Sex	Diameter	HCC	BC	MBC	CT value of tumor (HU)	CT value of liver parenchyma (HU)	*T*/*L* ratio	Balloon
1	58	M	81	S4/8	CHA	LHA	218.0	121.0	1.80	Usual
2	73	M	22	S4/5	CHA	A4	342.6	205.8	1.66	B
3	73	M	15	S8	CHA	RHA	265.2	138.9	1.91	B
4	71	M	20	S7	CHA	A7	397.6	139.2	2.86	B
5	69	M	10	S4	CHA	LHA	342.2	149.1	2.30	B
6	63	F	15	S5	PHA	RHA	352.3	138.9	2.54	BB
7	77	M	12	S5	PHA	RHA	351.1	122.4	2.87	BB
8	66	M	11	S2	PHA	LHA	399.5	121.3	3.29	BB
9	75	F	24	S3	PHA	A3	623.9	221.8	2.81	B

HCC, location of hepatocellular carcinoma; BC, location of a 5.2-Fr balloon catheter; MBC, location of a 1.8-Fr microballoon catheter; *T*/*L* ratio, the ratio of lipiodol emulsion concentration in the tumor to that in the embolized liver parenchyma; B, inflated microballoon; BB, inflated both balloon and microballoon

Discussion

The peribiliary plexus, interlobar communicating arcade, and isolated artery are three types of hepatic arteries that work as anastomotic arteries under balloon occlusion. Previous studies on balloon-occluded CTHA for HCC using only a microballoon catheter [11, 12] could not determine the influence of the extrahepatic anastomotic arteries including the gastroduodenal artery, bilateral gastric arteries, bilateral inferior phrenic arteries, and the other extrahepatic arteries.

In all cases, B-HABP was lower than usual-HABP. An animal experiment revealed that reducing blood pressure downstream by balloon occlusion helps increase the delivery of embolic agents to the target lesion relative to the other components, because blood flows into the target lesion from neighboring hepatic arteries [13]. Irie et al. [4] reported that dense accumulation of lipiodol in HCC during B-TACE, and B-HABP in their study was ≤ 64 mm Hg. Lower HABP is preferred for delivering a higher concentration of lipiodol to HCC. Occlusion of the CHA lowered HABPs in two cases, and occlusion of the PHA lowered HABPs in all four cases. Furthermore, B-HABP and BB-HABP ≤ 64 mm Hg was observed in two and four cases, respectively. Thus, in cases, where BB-HABP was ≤ 64 mm Hg, the use of TACE with both balloons inflated at the proper hepatic artery achieved high lipiodol accumulation. The double balloon technique can be used successfully to lower HABP and increase lipiodol concentration in B-TACE if a balloon catheter is inserted into the proper hepatic artery. Intrahepatic anastomosis remains during microballoon occlusion of the segmental or subsegmental artery (Fig. 4a) [12]. Occlusion of the common hepatic artery could not block the extrahepatic arterial blood supply via the gastroduodenal artery, which causes an increase in HABP by the arterial blood supply from the adjacent segment, and occlusion of the common hepatic artery leads to compensatory flow of the arterial blood supply via the gastroduodenal artery instead of the common hepatic artery (Fig. 4b). Conversely, occlusion of the proper hepatic artery could block them (Fig. 4c). Therefore, occlusion of the common hepatic artery appeared to be insufficient for decreasing HABP, and a 5.2-Fr balloon catheter should be inserted into the proper hepatic artery to sufficiently decrease HABP. The other extrahepatic arteries, including the inferior phrenic artery and internal thoracic artery, are known as extrahepatic feeders of HCCs; however, their influences are limited in HCCs without an extrahepatic feeder. The absence of extrahepatic feeder was confirmed by tumoral enhancement on usual-CTHA selective.

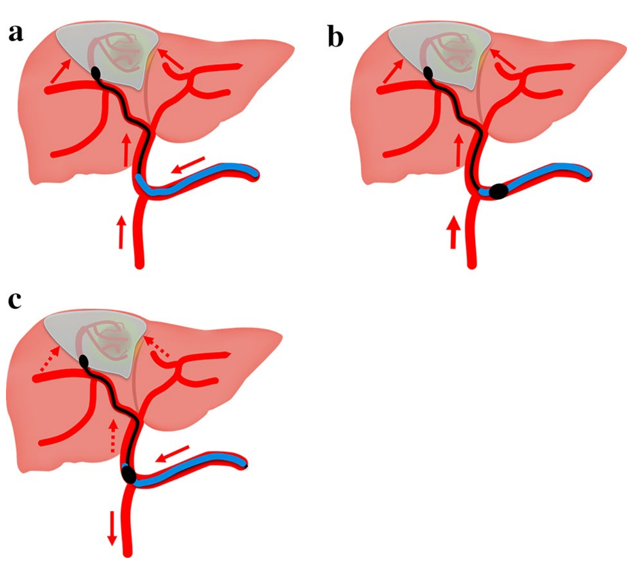

Fig. 4 Intrahepatic arterial blood supply from the adjacent segment remains under inflated microballoon catheter (**a**). Extrahepatic arterial blood supply via the gastroduodenal artery increases instead of the common hepatic artery under occlusion of the common hepatic artery, and there is no significant change in intrahepatic arterial blood supply from the adjacent segment (**b**). The arterial blood supply via the gastroduodenal artery is blocked under occlusion of the proper hepatic artery, which decreases arterial blood supply from the adjacent segment (**c**)

The contrast effect of the lesion, including S4 (cases 1, 2, and 5), decreased on both B-CTHA selective and BB-CTHA selective. CTHA with the balloon status, which provides the lowest HABP before TACE, is necessary to simulate lipiodol accumulation to some extent, although the viscosity varies. Lipiodol accumulation cannot be expected in HCCs without enhancement on CTHA. C-TACE should be performed instead of B-TACE when there is no enhancement on B-CTHA or BB-CTHA selective even if B-HABP and BB-HABP are ≤ 64 mmHg. According to a previous study, the interlobar communicating arcade works as a collateral artery to prevent a decrease in HABP during occlusion of the lobar hepatic artery in B-TACE [14] and is known as anastomosis between the right and left hepatic arteries originating mainly from A4 and the anterior segmental branch of the right hepatic artery. In the current study, the CTHA results demonstrated that arterial blood flow via the communicating arcade to the HCC in the watershed area (S4) was dominant during occlusion of the lobar and segmental arteries feeding the HCC. The T/L ratio in two HCCs in S4 was < 2.0, and the interlobar communicating arcade prevented lipiodol accumulation during occlusion of the lobar and segmental artery including A4. Therefore, B-TACE using the double balloon technique does not help increase lipiodol accumulation in HCC in S4 and in its border. The candidates for this procedure are patients with HCCs in regions other than S4 and its border and between S4 and the other segments.

In all cases, the contrast effect was retained on B-CTHA whole, which means that arterial blood flow via the collateral vessels developed during occlusion of the lobar and segmental arteries feeding the HCC. A previous article reported that non-targeted B-TACE (B-TACE via the lobar artery) should be avoided in order for B-TACE to be effective [14]. In the current study, the result for B-CTHA whole suggested the presence of collateral arterial blood flow from the neighboring segment in occlusion of the lobar artery as well the segmental artery. In some cases, it appears that a microballoon catheter should be inserted into the subsegmental artery.

There were some limitations in this study. First, our study population was small, and local recurrence and overall survival were not evaluated, because our study focused on hemodynamic change during double balloon occlusion.

Second, a 5.2-F balloon catheter, which is more difficult to handle compared to a normal catheter. The double balloon technique is difficult to perform for patients with vascular anomalies of the celiac trunk and its branches, because a 5.2-F balloon catheter cannot be inserted into the proper hepatic artery; therefore, these patients were excluded from this study. When we could not insert a 5.2-F balloon catheter into the celiac artery, we had to insert a normal catheter and then exchange a 5.2-F balloon catheter by detaining the guidewire. It was also difficult to insert a 5.2-Fr catheter into the proper hepatic artery in some cases. The location of the 5.2-Fr balloon was different among the respective cases due to technical difficulty, and hemodynamics depends on the balloon catheter's position. Arterial flow via the gastroduodenal artery is blocked when a 5.2-Fr balloon catheter is inserted at the PHA, while it is not blocked when it is inserted at the CHA. In fact, occlusion of the PHA decreased HABP in all four cases, which expects high lipiodol accumulation. Conversely, HABP decreased in two of five cases and increased in three of five cases due to occlusion of the CHA. That is because the gastroduodenal artery or those arteries working as collateral arteries when the CHA was occluded. Assessment of HABPs during balloon occlusion is required in double balloon B-TACE.

Third, it is unknown whether B-TACE using the double balloon technique is effective in patients who have undergone previous treatment, including surgical resection, radiofrequency ablation (RFA), and TACE, because we enrolled patients with untreated HCC. Surgical procedure and RFA may cause extrahepatic anastomosis due to adhesion, and TACE damages the feeder and leads to anastomosis of the adjacent segmental arteries or extrahepatic collateral arteries. We expect this technique to be effective even in patients who have undergone previous treatment, because it could transport lipiodol into the anastomosis if it decreases HABP, but further examination is needed to prove efficacy in treaded HCC.

An additional occlusion balloon catheter placed in the PHA as well as a microballoon provided decreasing HABP, which achieved highly dense accumulation of lipiodol. Occlusion of the PHA using the double balloon technique is worth attempting when HABP is > 64 mm Hg by microballoon occlusion prior to B-TACE. CTHA using a double balloon catheter could assess hemodynamic changes via collateral arterial blood flow by balloon occlusion of the intrahepatic and extrahepatic arteries. Arterial blood flow via the collateral vessels in HCC developed immediately during occlusion of the lobar and segmental arteries.

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Compliance with ethical standards

Conflict of interest All authors have no conflict interest of interest to disclose with respect to this article.

Ethical statement This prospective study was approved by our institutional review board; prior informed consent for participation was obtained from all patients.

References

1. Siegel R. Cáncer statistics. CA Cáncer J. 2017;67(1):7–30.
2. Yamada R, Sato M, Kawabata M, Nakatsuka H, Nakamura K, Takashima S. Hepatic artery embolization in 120 patients with unresectable hepatoma. Radiology. 1983;148(2):397–401.
3. Matsui O, Kadoya M, Yoshikawa J, et al. Small hepatocellular carcinoma: treatment with subsegmental transcatheter arterial embolization. Radiology [Internet]. 1993;188(1):79–83.
4. Irie T, Kuramochi M, Takahashi N. Dense accumulation of lipiodol emulsion in hepatocellular carcinoma nodule during selective balloon-occluded transarterial chemoembolization: Measurement of balloon-occluded arterial stump pressure. Cardiovasc Intervent Radiol. 2013;36(3):706–13.
5. Maruyama M, Yoshizako T, Nakamura T, Nakamura M, Yoshida R, Kitagaki H. Initial experience with balloon-occluded transcatheter arterial chemoembolization (B-TACE) for hepatocellular carcinoma. Cardiovasc Intervent Radiol. 2016;39(3):359–66.
6. Ishikawa T, Abe S, Inoue R, et al. Predictive factor of local recurrence after balloon-occluded TACE with miriplatin (MPT) in hepatocellular carcinoma. PLoS ONE. 2014;9(7):7–12.
7. Ogawa M, Takayasu K, Hirayama M, et al. Efficacy of a microballoon catheter in transarterial chemoembolization of hepatocellular carcinoma using miriplatin, a lipophilic anticancer drug: short-term results. Hepatol Res. 2016;46(3):E60–E6969.
8. Irie T, Kuramochi M, Kamoshida T, Takahashi N. Selective balloon-occluded transarterial chemoembolization for patients with one or two hepatocellular carcinoma nodules: retrospective comparison with conventional super-selective TACE. Hepatol Res. 2016;46(2):209–14.
9. Matsumoto T, Endo J, Hashida K, et al. Balloon-occluded transarterial chemoembolization using a 1.8-French tip coaxial microballoon catheter for hepatocellular carcinoma: technical and safety considerations. Minim Invasive Ther Allied Technol 2015; 24(2): 94–100.
10. Ishikawa T, Imai M, Owaki T, et al. Hemodynamic changes on cone-beam computed tomography during balloon-occluded transcatheter arterial chemoembolization using miriplatin for hepatocellular carcinoma: a preliminary study. Dig Dis. 2017;35(6):598–601.
11. Yoshimatsu R, Yamagami T, Ishikawa M, et al. Change in imaging findings on angiography-assisted CT during balloon-occluded transcatheter arterial chemoembolization for hepatocellular carcinoma. Cardiovasc Intervent Radiol. 2016;39(6):865–74.
12. Asayama Y, Nishie A, Ishigami K, et al. Hemodynamic changes under balloon occlusion of hepatic artery: predictor of the short-term therapeutic effect of balloon-occluded transcatheter arterial chemolipiodolization using miriplatin for hepatocellular carcinoma. Springerplus. 2016;5:157.
13. Rose SC, Halstead GD, Narsinh KH. Pressure-directed embolization of hepatic arteries in a porcine model using a temporary occlusion balloon microcatheter: proof of concept. Cardiovasc Intervent Radiol. 2017;40(11):1769–76.
14. Matsumoto T, Endo J, Hashida K, Mizukami H, Nagata J, Ichikawa H. Balloon-occluded arterial stump pressure before balloon-occluded transarterial chemoembolization. Minim Invasive Ther Allied Technol. 2016;25(1):22–8.