Abdominal Radiology (2019) 44:2276–2282
https://doi.org/10.1007/s00261-019-01950-3

TECHNICAL

Identification of the feeding arteries of hepatocellular carcinomas by performing dual arterial phase CT during pre-transarterial chemoembolization angiography

Kengo Ohta[1] · Masashi Shimohira[1] · Takuya Hashizume[1] · Kazushi Suzuki[1] · Yusuke Sawada[1] · Yuta Shibamoto[1]

Published online: 20 February 2019

Abstract

Purpose This study evaluated the usefulness of performing dual arterial phase computed tomography (CT) during pre-transarterial chemoembolization (TACE) angiography for identifying the feeding arteries of hepatocellular carcinomas (HCC).

Materials and methods Dual arterial phase CT was performed during pre-TACE angiography in 73 patients with 139 HCC. Ten HCC underwent this procedure twice, so the total number of examined HCC was 149. Early and late arterial phase images were obtained 6 seconds after injection of an iodinated contrast material serially during a single breath-hold. The feeding artery was defined as the branch of the hepatic artery that was connected to the enhanced areas of the tumor. For HCC that could not be visualized on the early arterial phase images, fusion images superimposing the early and late arterial phase images were constructed. Furthermore, technical success defined as successful catheterization of the subsegmental or more distal feeding artery was evaluated.

Results The feeding artery was correctly identified on dual arterial phase CT in 146 of the 149 tumors (98.0%). In two HCC, the feeding arteries could not be identified due to severe motion artifacts, and in one, due to the presence of anastomosis between the right and left hepatic arteries. Catheterization of the subsegmental feeding artery was successful in all TACE procedures (technical success rate: 100%).

Conclusion Performing dual arterial phase CT during angiography appears to be useful for identifying the feeding arteries of HCC.

Keywords Feeding artery identification · Hepatocellular carcinoma · CT during angiography · TACE

Introduction

Recently, primary liver cancer, the most common histological type of which is hepatocellular carcinoma (HCC), was estimated to be the second-leading cause of cancer death worldwide [1]. According to the Barcelona Clinic Liver Cancer algorithm, transarterial chemoembolization (TACE) is considered to be the standard treatment for intermediate-stage HCC, which is defined as extensive multifocal disease without vascular invasion in patients with preserved liver function who do not exhibit cancer-related symptoms [2, 3]. In 2007, performing ultraselective TACE in the most distal portion of the subsegmental hepatic artery was reported to improve local control [4]. It is essential that the feeding artery of a HCC is identified before ultraselective TACE is carried out [5]. However, it is quite difficult to identify feeding arteries on digital subtraction arteriography (DSA), because DSA does not produce three-dimensional images.

Performing computed tomography (CT) during angiography of the aorta with an angio-CT system (angiography and CT systems in the same room) was reported to be useful for identifying the feeding arteries of HCC [6, 7]. In practice, however, it is sometimes difficult to identify feeding arteries, even by performing CT during angiography, because contrast-enhanced areas of the tumor may not be easily visualized due to the dual blood supply from the portal vein and hepatic artery in early HCC [8]. Thus, it can be difficult to identify the feeding arteries of HCC, despite good visualization of the hepatic artery. To solve this problem, we employed dual arterial phase CT during pre-TACE

✉ Masashi Shimohira
mshimohira@gmail.com

[1] Department of Radiology, Nagoya City University Graduate School of Medical Sciences, Nagoya 467-8601, Japan

angiography. We assumed that the early arterial phase would be useful for visualizing the hepatic artery, and the late arterial phase would be useful for visualizing tumor enhancement. The aim of our study was to evaluate the usefulness of performing dual arterial phase CT during pre-TACE angiography for identifying the feeding arteries of HCC.

Materials and methods

Patients and assessment

This retrospective study was approved by our institutional review board. Between September 2014 and October 2015, dual arterial phase CT was performed during pre-TACE angiography in 73 patients with 139 HCCs. All tumors were pathologically or clinically diagnosed as HCC and were considered to be indicated for TACE. Ten HCCs underwent this procedure twice, so the total number of examined HCCs was 149. There were 46 males and 27 females, with a median age of 73 years (range, 30–92). There were 59, 14, and 0 patients with Child-Pugh A, B, and C liver function, respectively. In 51 patients, the anatomy of the hepatic artery was orthotopic, while the following replaced hepatic arteries were found in 21 patients: the right hepatic artery (RHA) arose from the superior mesenteric artery (SMA) in 10 patients, the left hepatic artery (LHA) branched off from the left gastric artery (LGA) in 8 patients, the RHA arose from the celiac artery in 2 patients, the RHA branched off from the SMA and the LHA arose from the LGA in 1 patient, and the right posterior artery branched off from the SMA and the LHA arose from the LGA in 1 patient. Ten patients underwent TACE twice, and 4 patients underwent TACE three times, and thus, the total number of TACE procedures was 91. The details of the patients and their HCC are summarized in Table 1. The median size of the HCC was 15 mm (range, 5–120 mm). We evaluated whether the feeding arteries of HCC could be identified by performing dual arterial phase CT during angiography. The feeding artery was defined as the branch of the hepatic artery that was connected to the enhanced areas of the tumor. All images were evaluated by 2 radiologists with 13 and 7 years of experience, respectively, in diagnostic and interventional radiology. Any discrepancies were resolved by consensus. When tumor enhancement was difficult to visualize in the early arterial phase but was clearly visible in the late arterial phase, fusion images superimposing the early and late arterial phase images were constructed on a computer workstation (Excellent-Viewer, PSP Corporation, Tokyo, Japan). Furthermore, we evaluated the total procedure time, any TACE-related complications based on the dual arterial phase CT images obtained during angiography, and technical success defined as successful catheterization of the subsegmental or more distal feeding artery according to the dual arterial phase CT during angiography.

Table 1 Details of the patients and HCC

Patients (*n* = 73)	
Male/female	46/27
Age[a]	73 (30–92)
Liver function: child pugh A/B/C	59/14/0
Anatomy: orthotopic/replaced hepatic artery	52/21
Tumors (*n* = 149)	
Size (mm)[a]	15 (5–120)
Location: S1/2/3/4/5/6/7/8	7/16/15/18/19/17/19/38
TACE (*n* = 91)	
Initial/repeated	73/18
Dual phase CT during angiography (*n* = 99)	
Position of catheter: CA/CHA/PHA/RHA/LHA/replaced RHA/replaced RPHA/replaced LHA	12/46/20/3/4/12/1/1

S1 Caudate lobe, *S2* dorsolateral segment of the left hepatic lobe, *S3* ventrolateral segment of the left hepatic lobe, *S4* medial segment of the left hepatic lobe, *S5* anteroinferior segment of the right hepatic lobe, *S6* posteroinferior segment of the right hepatic lobe, *S7* posterosuperior segment of the right hepatic lobe, *S8* anterosuperior segment of the right hepatic lobe, *CA* celiac artery, *CHA* common hepatic artery, *PHA* proper hepatic artery, *RHA* right hepatic artery, *LHA* left hepatic artery, *RPHA* right posterior hepatic artery

[a]Median (range)

Dual arterial phase CT and TACE techniques

All procedures were performed via the femoral artery with a 4-Fr. sheath (Supersheath; Medikit, Tokyo, Japan). A 4-Fr. catheter (Shepherd hook; Terumo, Tokyo, Japan) was placed into the celiac artery or SMA. A 2.7-Fr. catheter (Sniper2 highflow; Terumo) was advanced into the target artery through the 4-Fr. catheter. Then, dual arterial phase CT was performed during angiography with an angio-CT system consisting of a 16-detector row helical CT (ECLOS; Hitachi Healthcare, Tokyo, Japan) and a single C-arm angiography unit (Allura Xper; Philips Medical Systems, Best, The Netherlands). The early arterial phase image was obtained 6 seconds after injection of an iodinated contrast material (Oypalomin® 300; Fuji pharma, Tokyo, Japan) at a rate of 2–3 ml/second for 10 seconds through the 2.7-Fr. catheter Sniper2 highflow. The late arterial phase image was obtained 20–25 s after the injection. Both phase images were obtained serially during a single breath-hold. In 7 patients (8 TACE procedures) with replaced hepatic arteries, the dual arterial phase CT was carried out twice because tumors were present in both the right and left hepatic lobes. Thus, the total number of dual arterial phase CT scans conducted during angiography was 99. The contrast material was injected into the common hepatic artery in 46 patients, the proper hepatic artery in 20 patients, a RHA arising from the SMA in 12 patients, the celiac artery in 12 patients, the LHA in 4 patients, the RHA in 3 patients, a right posterior hepatic artery branching off from the SMA in 1 patient, and a LHA arising from the LGA in 1 patient. The site of the injection was determined according to the vascular anatomy. When the RHA and/or LHA arose from the celiac artery directly, the contrast material was injected from the celiac artery. When the contrast material was injected from the celiac or common hepatic artery, the portal vein could be visualized in late arterial phase images. After the dual arterial phase CT, a 1.6-Fr. microcatheter (MARVEL-S; Tokai Medical, Kasugai, Japan) was introduced through the 2.7-Fr. catheter, and TACE was attempted using epirubicin mixed with iodized oil (Lipiodol; Guerbet Japan, Tokyo, Japan) and gelatin sponge (Gelpart; Nippon Kayaku, Tokyo, Japan) while referring to the dual arterial phase CT images obtained during angiography. Immediately after the TACE, the lipiodol accumulation was confirmed with CT.

Results

In 146 of the 149 HCCs (98.0%), the feeding arteries were successfully identified on dual arterial phase CT. In two HCCs, the feeding arteries could not be identified due to severe motion artifacts, and in one, due to the presence of anastomosis between the RHA and LHA. In 116 HCCs (78%), tumor enhancement was visualized during the early arterial phase scan (Fig. 1). In the remaining 31 HCCs (21%), tumor enhancement was not visualized during the early arterial phase, so fusion images of these HCCs were produced (Fig. 2). Eighteen tumors had 2 feeding arteries, and 2 tumors had 3 feeding arteries. Therefore, the total number of feeding arteries was 169. The locations of the feeding arteries were as follows: branches of the LHA in 62 HCCs (the dorsolateral segmental artery in 19 HCCs, the ventrolateral segmental artery in 14 HCCs, and the medial segmental artery in 29 HCCs); branches of the RHA in 101 HCCs (the anteroinferior segmental artery in 20 HCCs, the posteroinferior segmental artery in 20 HCCs, the posterosuperior segmental artery in 16 HCCs, and the anterosuperior

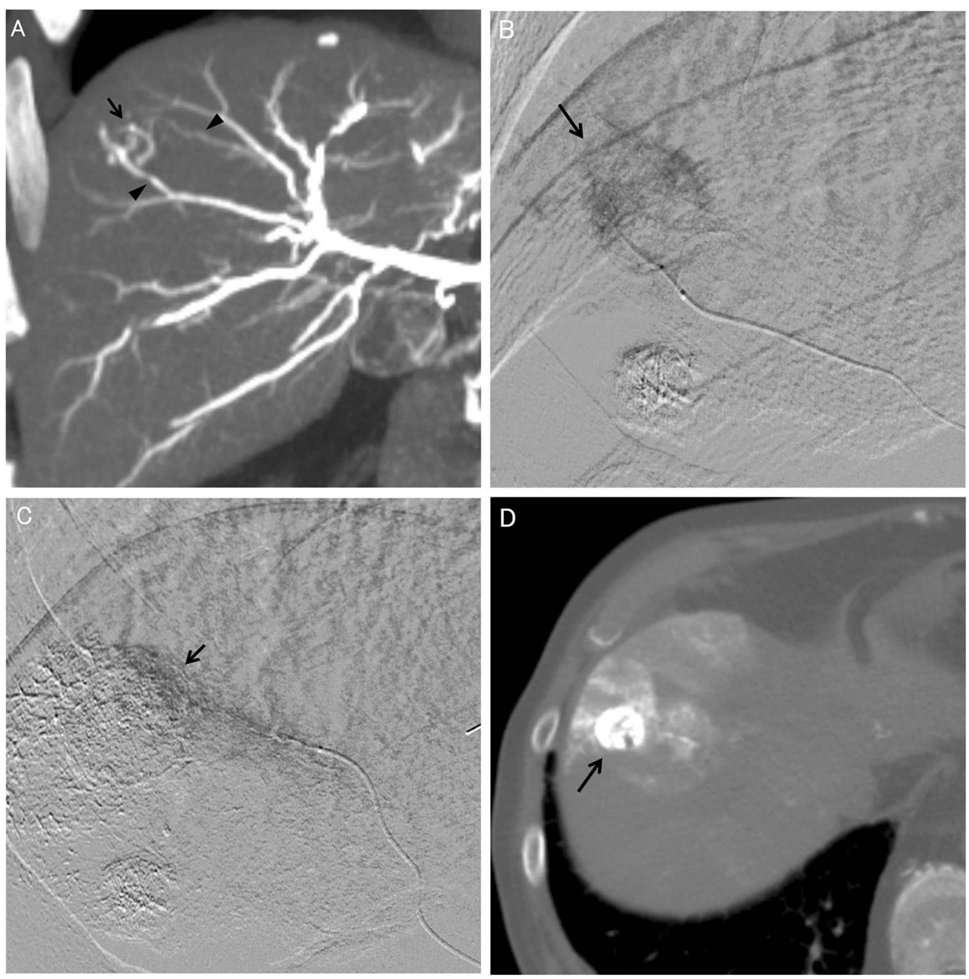

Fig. 1 An 86-year-old male with a HCC in the superior anterior segment. **a** Early arterial phase coronal images obtained by performing CT during angiography of the proper hepatic artery showed enhancement of the HCC (arrow) and two feeding arteries (arrowheads). **b** Angiography of one of the feeding arteries was carried out. It showed tumor enhancement (arrow) and so TACE was performed. The inferior lipiodol accumulation was the **c** Then, angiography of another feeding artery was performed, and it showed a part of the enhanced region of the tumor (arrow). Thereafter, TACE was performed. **d** Postoperative CT showed good accumulation of iodized oil in the HCC (arrow)

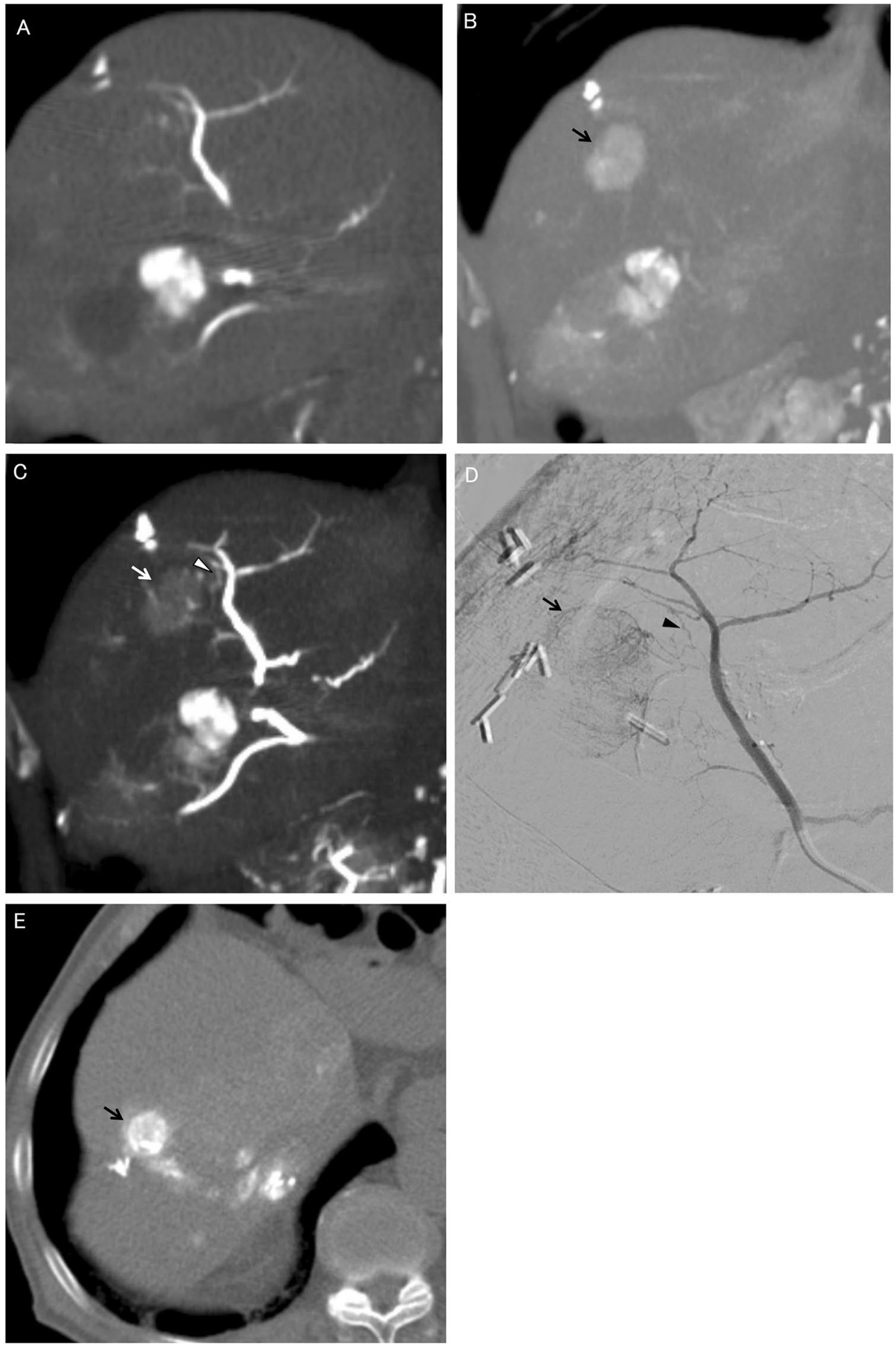

Fig. 2 A 78-year-old male with a HCC in the superior anterior segment. **a** Early arterial phase coronal images obtained by performing CT during angiography of the common hepatic artery showed the hepatic artery, but did not produce any tumor enhancement. **b** Late arterial phase coronal images acquired by performing CT during angiography showed clear tumor enhancement (arrow). **c** Fusion coronal images constructed from early and late arterial phase images showed both the feeding artery (arrowhead) and tumor enhancement (arrow). **d** Angiography of the feeding artery showed both the feeding artery (arrowhead) and tumor enhancement (arrow), and so TACE was performed. **e** Postoperative CT showed good accumulation of iodized oil in the HCC (arrow)

segmental artery in 45 HCCs); the arteries of the caudate lobe in 3 HCCs; and the inferior phrenic artery, cholecystic artery, and right gastric artery in 1 HCC each.

In the HCC with the anastomosis between the RHA and LHA, the feeding arteries could not be identified (Fig. 3). In this case, the RHA arose from the SMA, so dual arterial phase CT was performed during angiography to visualize both the replaced RHA and the orthotopic LHA. However, it did not identify the branch of the hepatic artery that was connected to the enhanced part of the tumor. Angiography from both the replaced RHA and the orthotopic LHA could not visualize the tumor enhancement, but the angiography of the common hepatic artery showed the presence of anastomosis between the RHA and LHA. After selective catheterization

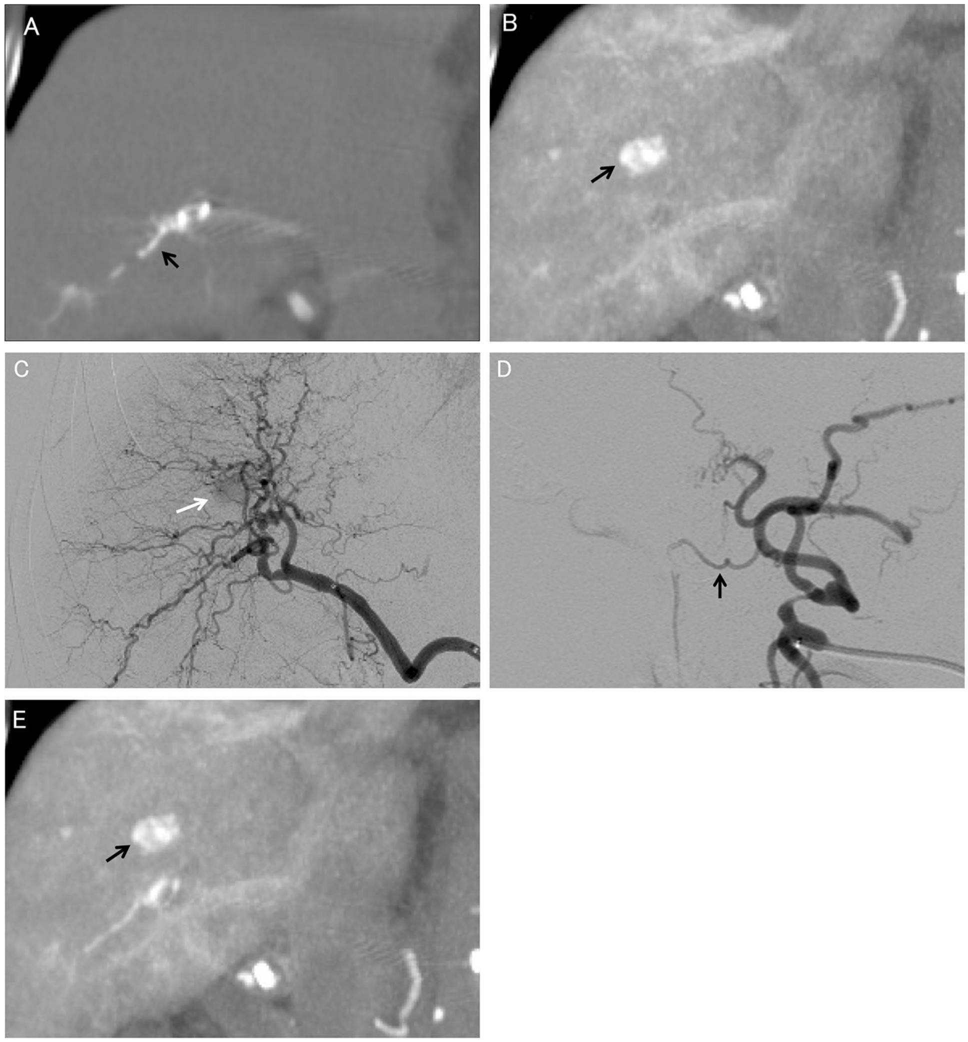

Fig. 3 A 77-year-old female with a HCC in the superior posterior segment. **a** Early arterial phase coronal images obtained by performing CT during angiography of the RHA, which arose from the SMA, did not show the posterosuperior segmental artery, which was suspected to be the feeding artery. It only showed the posteroinferior segmental artery (arrow). **b** Late arterial phase coronal images obtained by performing CT during angiography only showed tumor enhancement (arrow). **c** Angiography of the replaced RHA resulted in tumor enhancement (arrow). **d** Angiography of the common hepatic artery showed an anastomosis from the LHA (arrow). According to preoperative CT findings, the anastomosis may be the artery of the caudate lobe, and we think the blood flow from the anastomosis without a contrast material makes it difficult to visualize the feeding artery, i.e., posterosuperior segmental artery. **e** Fusion coronal images constructed from the early and late arterial phase images only showed tumor enhancement (arrow). It was difficult to identify the feeding artery

to the posterosuperior segmental artery, angiography could show the tumor enhancement, and then TACE was successfully performed.

Catheterization of the subsegmental feeding artery was successfully performed in all TACE procedures. Therefore, the technical success rate was 100%. The mean TACE procedure time was 121 minutes (range 45–216). In all patients, slight fever and/or abdominal pain (postembolization syndrome) occurred, but they were controllable using analgesics. There were no major complications that required an advanced level of care.

Discussion

In the present study, the feeding artery identification rate was high (98.0%) with dual arterial phase CT during angiography. We think it is an advantage of performing TACE successfully. Compared with single arterial phase CT during angiography, we believe this method can achieve a high identification rate of the feeding artery, because in the present study we had to construct fusion images in 31 tumors (21%, 31/147) from both early and delay arterial phases due to poor tumor visualization in the early arterial phase. In a previous study, dynamic CT resulted in a feeding artery identification rate of 77.8% [9], and Miyayama et al. [10] reported that cone beam CT produced a manual feeding artery identification rate of 81%, whereas the use of an automatic feeding artery detection software led to a feeding artery identification rate of 88%. So, we think cone beam CT should also be useful, but another advantage of our procedure is considered to be the high resolution of angio-CT compared with cone beam CT. Meanwhile, in our study, the technical success rare, defined as successful catheterization of the subsegmental or more distal feeding artery, was 100%, and there were no severe complications. Thus, performing dual arterial phase CT during angiography is considered to be a useful tool for guiding TACE.

In one case in which the feeding artery was not identified due to the presence of anastomosis between the RHA and LHA, CT during angiography was performed at the RHA and LHA separately because the RHA arose from the SMA. Then, in this case, an anastomosis was confirmed between the RHA and LHA. Judging from the findings of pre-operative CT, the anastomosis may be the artery of the caudate lobe. So, we think the blood flow from the anastomosis without a contrast material makes it difficult to visualize the feeding artery of the tumor. However, in selective angiography of the posterosuperior segmental artery, tumor stain was visualized. We think it is because selective angiography may not be influenced by the flow from the anastomosis. The anastomosis can be between the RHA and LHA potentially [11]. Furthermore, TACE can damage the hepatic artery [12, 13], and as a result an anastomosis might form. So, when a HCC cannot be visualized on dual arterial phase CT during angiography we need to consider the possibility that an anastomosis might be present, and angiography should be carried out at a high injection rate exceeding the normal blood flow rate to visualize anastomosis.

In our study, the median procedure time was 121 min. The use of a combination of feeding artery identification software and cone beam CT was reported to shorten the procedure time [14]. So, we consider that performing dual arterial phase CT during angiography could also shorten the procedure time. Extra-hepatic arteries, such as the inferior phrenic artery, sometimes feed HCC [15, 16]. Thus, obtaining a CT scan during angiography of the aorta should be effective [6]. However, a large amount of contrast material is required to sufficiently enhance small arteries that branch off from the aorta. So, in our procedure the CT was initially performed during angiography of the hepatic artery. When the enhanced region of the tumor is unclear, an extra-hepatic artery such as the inferior phrenic artery can be considered to be the feeding artery. Then, angiography of the extra-hepatic artery should be performed according to the findings of pre-operative dynamic contrast-enhanced CT scan.

This study had several limitations. First, the retrospective design was a key limitation. Second, the local control and overall survival rates could not be evaluated. However, we consider that successful identification of the feeding artery can facilitate selective catheterization in TACE, and selective TACE was reported to result in improved local control and overall survival rates [17, 18]. Third, the radiation dose could not be evaluated, even though no radiation-related complications occurred during the TACE. Therefore, we consider that further studies will be required.

In conclusion, performing dual arterial phase CT during angiography appears to be useful for identifying the feeding arteries of HCC before TACE.

Compliance with ethical standards

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

References

1. Torre LA, Siegel RL, Ward EM, Jemal A (2016) Global cancer incidence and mortality rates and trends - an update. Cancer Epidemiol Biomarkers Prev 25:16-27.
2. Han K, Kim JH (2015) Transarterial chemoembolization in hepatocellular carcinoma treatment: Barcelona clinic liver cancer staging system. World J Gastroenterol 21:10327-10335.
3. European Association for the Study of the Liver; European Organisation for Research and Treatment of Cancer (2012) EASL-EORTC clinical practice guidelines: management of hepatocellular carcinoma. J Hepatol 56:908-943.
4. Miyayama S, Matsui O, Yamashiro M, Ryu Y, Takata H, Takeda T et al (2007) Iodized oil accumulation in the hypovascular tumor portion of early-stage hepatocellular carcinoma after ultraselective transcatheter arterial chemoembolization. Hepatol Int 1:451-459.
5. Bouvier A, Ozenne V, Aubé C, Boursier J, Vullierme MP, Thouveny F et al (2011) Transarterial chemoembolisation: effect of selectivity on tolerance, tumour response and survival. Eur Radiol 21:1719-1726.
6. Minamiguchi H, Kawai N, Sato M, Ikoma A, Sanda, H, Nakata K et al (2013) Hepatoma feeding arteriogram created by CT during aortography using IVR 64-multidetector-row CT for catheterization in transcatheter arterial chemoembolization for hepatocellular carcinoma. Jpn J Radiol 31:428-436.
7. Tsurusaki M, Sugimoto K, Fujii M, Fukuda T, Matsumoto S, Sugimura K (2007) Combination of CT during arterial portography and double-phase CT hepatic arteriography with multi-detector row helical CT for evaluation of hypervascular hepatocellular carcinoma. Clin Radiol 62:1189-1197.
8. Honda H, Tajima T, Kajiyama K, Kuroiwa T, Yoshimitsu K, Irie H et al (1999) Vascular changes in hepatocellular carcinoma: correlation of radiologic and pathologic findings. Am J Roentgenol 173:1213-1217.
9. Kim I, Kim DJ, Kim KAm Yoon SW, Lee JT (2014) Feasibility of MDCT angiography for determination of tumor-feeding vessels in chemoembolization of hepatocellular carcinoma. J Comput Assist Tomogr 38:742-746.
10. Miyayama S, Yamashiro M, Hashimoto M, Hashimoto M, Ikuno M, Okumura K et al (2013) Identification of small hepatocellular carcinoma and tumor-feeding branches with cone-beam CT guidance technology during transcatheter arterial chemoembolization. J Vasc Interv Radiol 24:501-508.
11. Yamagami T, Yoshimatsu R, Matsumoto T, Nishimura T (2008) Redistribution of multiple hepatic arteries into a single hepatic artery to perform repeated hepatic arterial infusion chemotherapy. Acta Radiol 49:513-520.
12. Lee S, Kim KM, Lee SJ, Lee KH, Lee DY, Kim MD et al (2017) Hepatic arterial damage after transarterial chemoembolization for the treatment of hepatocellular carcinoma: comparison of drug-eluting bead and conventional chemoembolization in a retrospective controlled study. Acta Radiol 58:131-139.
13. Onizuka H, Sueyoshi E, Ishimaru H, Sakamoto I, Uetani M (2017) Arterial injury during transcatheter arterial chemoembolization for hepatocellular carcinoma: predictors of risk and outcome. Abdom Radiol 42:2544-2550.
14. Iwasawa J, Ohue S, Hashimoto N, Mitani T (2013) Comparison of the number of image acquisitions and procedural time required for

transarterial chemoembolization of hepatocellular carcinoma with and without tumor-feeder detection software. Radiol Res Pract 2013:580839.
15. Takada K, Ito T, Kumada T, Toyoda H, Tada T, Sone Y et al (2016) Extra-hepatic feeding arteries of hepatocellular carcinoma: An investigation based on intra-arterial CT aortography images using an angio-MDCT system Eur J Radiol. 85:1400-1406.
16. Kim HC, Chung JW, An S, Seong NJ, Son KR, Jae HJ et al (2011) Transarterial chemoembolization of a colic branch of the superior mesenteric artery in patients with unresectable hepatocellular carcinoma. J Vasc Interv Radiol 22:47-54.
17. Shimohira M, Ogino H, Kawai T, Sakurai K, Nakagawa M, Shibamoto Y (2012) Clinical usefulness of the triaxial system in super-selective transcatheter arterial chemoembolization for hepatocellular carcinoma. Acta Radiol 53:857-861.
18. Yamakado K, Miyayama S, Hirota S, Mizunuma K, Nakamura K, Inaba Y et al (2012) Hepatic arterial embolization for unresectable hepatocellular carcinomas: do technical factors affect prognosis? Jpn J Radiol 30:560-566.