Int J Clin Exp Med 2015;8(11):20548-20555
www.ijcem.com /ISSN:1940-5901/IJCEM0015283

Original Article

DYNA CT arteriographic evaluation of hepatocellular carcinoma for treatment by trans-catheter arterial chemoembolization

Caoye Wang[1,2], Qi Wang[2], Wenhua Chen[2], Zhongming He[2], Yuanquan Huang[2], Yifeng Lu[2], Yi Miao[1]

[1]*Department of General Surgery, First Affiliated Hospital of Nanjing Medical University, Nanjing 210029, Jiangsu Province, China;* [2]*Department of Intervention Radiology, First People's Hospital of Changzhou, Third Affiliated Hospital of Soochow University, Changzhou 213003, Jiangsu Province, China*

Received August 30, 2015; Accepted October 27, 2015; Epub November 15, 2015; Published November 30, 2015

Abstract: Purpose: The aim of our study was to determine whether using C-arm CT (DYNA CT) during hepatic arteriography imaging assists in TACE treatment. Materials and methods: 138 patients with HCC, 69 patients (Group A) underwent DYNA CT and routine digital subtraction angiography (DSA), while another 69 patients (Group B) underwent only DSA, were prospectively studied at a single facility between May 2011 and September 2012. Liver vessels and tumors were displayed by DYNA CT. The superior mesenteric artery (SMA) and the celiac artery shape and branch anatomy were visualized. The number of tumors and arteries which feed these was compared. Results: In Group A, DYNA CT showed that the hepatic artery originated from the celiac artery in 60 patients, while the right hepatic artery originated from the SMA and the left hepatic artery originated from the common hepatic artery in 9 patients. In 10 patients, the phrenic artery provided blood to the tumor. DYNA CT detected 258 lesions, while routine DSA found 178 lesions ($P<0.05$). Conclusion: DYNA CT has substantial advantages over routine DSA in demonstrating the shape and branches of the target hepatic vessels and the number of tumors. DYNA CT provides important guidance for TACE which simplifies selective catheterization and improves the treatment and quality of TACE.

Keywords: Hepatocellular carcinoma, DYNA CT, angiography, trans-catheter arterial chemoembolization

Introduction

Hepatocellular carcinoma (HCC) is one of the most common types of malignant liver tumor, and the third leading cause of cancer mortality worldwide [1]. It is responsible for more than 250,000 deaths worldwide each year [2, 3]. Studies have demonstrated that countries in Asia, particularly China, have a high incidence rate of HCC, due to endemic hepatitis B and C [4]. Trans-catheter arterial embolization with chemotherapy (TACE) or without chemotherapy (TAE) has become one of the most popular and effective palliative methods for intermediate stage HCC patients who are ineligible for surgery or percutaneous ablation [3, 5-7].

A successful TACE procedure depends on an accurate anatomical understanding of target vessels, the anatomical structures of the vessel line, and appropriate chemoembolization. This type of information is extremely difficult to obtain promptly and with a clear image during TACE using conventional angiography (which includes Computed Tomography (CT), Magnetic Resonance Imaging (MRI) scan and Digital Subtraction Angiography (DSA)). This is especially true when the patient is on the operating table receiving interventional surgery [8]. DYNA CT (also called flat-detector C-arm computed tomography (C-arm CT)) can provide imaging information during TACE. Liver vessels and tumors are displayed by the volume rendering technique (VRT) and the maximum intensity projection (MIP) technique of DYNA CT. Modern C-arm CT systems are becoming rapidly accepted because they offer improved image quality, versatility and dedicated applications for planning, guiding, monitoring and assessing interventional procedures [9]. However, TACE guided by DYNA CT reconstruction imaging has been rarely reported. There have been some studies using C-arm CT. For example, Meyer et al. found that the C-arm CT technique was limited in terms of visualizing the liver [10]. Because the results of some of these studies were contradictory, the aim of the current study was to evaluate whether C-arm CT can be used as guidance for suitable arteries for TACE. The aim of this prospective study was to report on the feasibility of this technology to provide images resembling CT slices on the operating table during TACE.

Materials and methods

Patients

For this prospective study from May 2011 to September 2012, a total of 138 patients with HCC were referred to our department for TACE, which included 104 men and 34 women with a mean age of 58.5 years (range: 40 to 82 years). Fifty-six were diagnosed by surgical pathology, 30 were confirmed by CT-guided biopsy and the remaining 52 cases were verified by pre-operative CT and with high levels of plasma alpha-fetoprotein (AFP). Patients classified as grade A or grade B, according to Child-Pugh score, were included. Patients classified as grade C or grade D or patients with portal vein thrombosis and distant metastasis, allergies to contrast agent and renal function insufficiency were excluded. All patients underwent advanced CT scan before TACE. From the imaging findings, all patients were diagnosed as having at least one tumor within liver. These patients were randomly divided into two groups, groups A and B. In group A, 69 patients had DYNA CT (radiation exposure to the patient was 311 mGy per scan) and conventional DSA conducted during TACE, while in group B, 69 patients took only conventional DSA. Two qualified radiologists (>10 years experience each) interpreted the results of DSA imaging, while another two qualified radiologists (>10 years experience each) interpreted the results of DYNA CT imaging. In group A, each pair reviewed the pre-operative advanced CT scan, and was blinded to the results of the other technique and the clinical data. We recorded the operation time of each patient, and the two year survival rate for each group. The study was approved by the Institutional Review Board and Ethics Committee of the local Hospital. All patients provided written informed consent prior to participation.

DYNA CT

DYNA CT was performed on each patient according to a standard protocol during routine clinical examination using a femoral arterial approach with a 5F sheath (by the Seldinger technique) [11]. A 5F pigtail catheter was placed in the upper abdominal aorta. According to this angiography result, an appropriate catheter was then placed in the celiac artery and/or the superior mesenteric artery (SMA). Imaging was performed using a Siemens_Artis_zeego_Syngo_DYNA CT_360 digital angiography system (Siemens Medical Solutions, Forchheim, Germany), DYNA CT software, non-ionic iodinated contrast agent (omnipaque® = iohexol, GE Healthcare Company, UK), and a high-pressure syringe (Mark V Provis, MERAD.INC, USA). Rates and volumes of contrast agent for DYNA CT were as follows: omnipaque (300 mg/ml, upper abdominal aorta: 10 ml/s, 70 ml, and celiac artery/SMA: 2.5 ml/s, 20 ml). The DYNA CT scan was conducted 4 s after the start of injection of the contrast agent with: acquisition frame rate, 60 frames/s; collection matrix, 1024*1024; rotation speed, 30°/s; acquisition time, 7 s. Rotational angiographic data were acquired after the scan. Images were automatically corrected for gain of the image intensifier during the acquisition. 3D representation was then generated by using the 3D angiography software (DYNA CT Arterial 2005), and transferred to a computer workstation (Siemens X-LEONARDO image process workstation) for vascular imaging processing with the VRT and the MIP. Because the time for the whole procedure was only 7 seconds, only a short breath hold was required, resulting in few artifacts.

Conventional DSA

In group A, according to the results of DYNA CT angiographic data, an appropriate catheter was inserted into the celiac artery or the SMA to observe the presentation of the tumor, and the vascular architecture. Using contrast agent omnipaque® = iohexol (300 mg/ml, celiac artery/SMA: 4 ml/s, 12 ml), a DSA scan was conducted 2 s after the start of the contrast agent injection, with an acquisition frame rate of 4 frames/s; the collection matrix was 1024*1024 with acquisition time of 3 seconds. In group B, the operators performed a conventional DSA procedure according to the usual protocol.

Table 1. Location and number of tumors detected by both methods

Tumor Site	DYNA CT	DSA	*P* value
Right lobe of the liver	150	107	
Left lobe of the liver	83	60	
Caudate lobe	25	11	
Total	258	178	<0.05

DSA: Digital subtraction angiography.

Statistical analysis

Statistical analysis was performed using Student's t-test for continuous variables. Values of $P<0.05$ were considered statistically significant using SPSS 11.0 statistical analysis software package.

Results

Group A: DYNA CT and DSA imaging of lesions

The size, number and distribution of intrahepatic tumors were observed by DYNA CT and DSA imaging was recorded. There were 42 cases of massive HCC, 16 cases of nodular form of HCC, and 11 cases of small HCC. The maximum diameter of the tumors detected by DYNA CT and DSA was 12.8 cm and 13 cm, respectively while the minimum diameter of the tumors was 0.3 cm and 0.5 cm, respectively. The site and number of tumors detected by both methods are shown in **Table 1**. DYNA CT imaging detected 258 lesions and DSA imaging with 178 lesions found in 69 cases, and a total of 110 lesions found in both tests. The imaging with DYNA CT was significantly better than conventional DSA in lesion presentation ($P<0.05$) (**Figure 1A-C**).

DYNA CT presentation of the celiac artery/SMA and the HCC feeding arteries

DYNA CT was carried out and images were processed by VRT and MIP angiography techniques. The common hepatic artery was found to issue from the celiac artery in 60 cases. Replaced hepatic arteries were found in 9 cases (right hepatic artery originated from the SMA and the left hepatic artery originated from the common hepatic artery). DYNA CT imaging clearly demonstrated the anatomy, spatial location, and the walk-line of the celiac artery, the SMA and their branches (**Figures 2**, **3A**). In ten cases, the phrenic artery was the tumor-supplying artery in the right lower lobe of the liver (**Figure 2**). DYNA CT imaging clearly showed the supplying artery of the tumor (**Figures 2**, **3A**, **4A-C**). In cross-sectional scans, the angle between the celiac artery/trunk and the sagittal plane was skewed to the left by a maximum of 36°, and skewed to the right by a maximum of 70° with an average right skew of 7.8°. The angle between the SMA and the sagittal plane was a maximum left deviation of 52°, maximum right deviation of 24° and an average left deviation of 5.7° (**Figure 3B**). In sagittal scans, the angle between the celiac artery and the abdominal aorta underneath ranged from 28° to 153°, with an average of 70.1°. The angle between the SMA trunk and the abdominal aorta underneath ranged from 12° to 54°, with an average of 25.2° (**Figure 3C**). The angle between the celiac artery trunk and the abdominal aorta underneath was found to be more than 90° in 10 patients. The length between the celiac artery trunk opening and the hepatic-splenic artery bifurcation ranged from 0.8 to 3.5 cm, with an average 1.8 cm. The length of the celiac artery trunk was longer than 3 cm in 8 cases. The length of the SMA was longer than 6 cm in 6 cases. DYNA CT information was used as guidance for intubation. 5F vertebral artery catheters with micro-catheters were used in 10 cases whose celiac artery trunk and the abdominal aorta underneath were at an angle of more than 90° in sagittal angiography. Cobra catheters with micro-catheter were used in 14 patients whose celiac artery trunks were longer than 3 cm (8 patients) or SMA was longer than 6 cm (6 patients). All of these patients had successful procedures. The mean operation time was 43.6 min ± 15.8 min. The two year overall survival rate was 69.5%.

Group B: conventional DSA

The size, number and distribution of intrahepatic tumors were observed only by DSA imaging. There were 34 cases of massive HCC, 21 cases of nodular form of HCC, and 14 cases of small HCC. The maximum diameter of the tumors detected by DSA was 10.3 cm and the minimum diameter of the tumors was 0.5 cm. All of these patients had successful procedures. The mean operation time was 55.3 ± 20.9 min, significantly longer than that in group A ($P<0.05$). The two year overall survival rate was 53.6%, significantly shorter than that in group A ($P<0.05$).

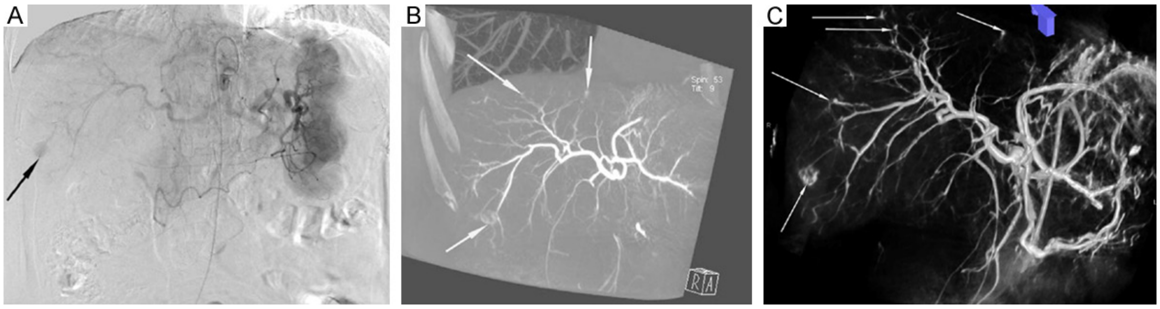

Figure 1. A 76 year old man with hepatocellular carcinoma. A. Celiac artery angiography (DSA-AP image). A small tumor stain can be seen in the right lobe of the liver (arrow). B. Maximum intensity projection of 3D rotational angiography with contrast agent injected into the common hepatic artery. Multiple tumor stains (arrows) can be seen in both lobes of the liver. The branching features of the hepatic artery and feeding arteries can be clearly visualized in the 3D image. C. Volume rendering technique reconstructions of 3D rotational angiography with contrast agent injected into the common hepatic artery. Multiple tumor stains (arrows) can be seen in both lobes of the liver. The branching features of the hepatic artery and feeding arteries can be clearly visualized in the 3D image.

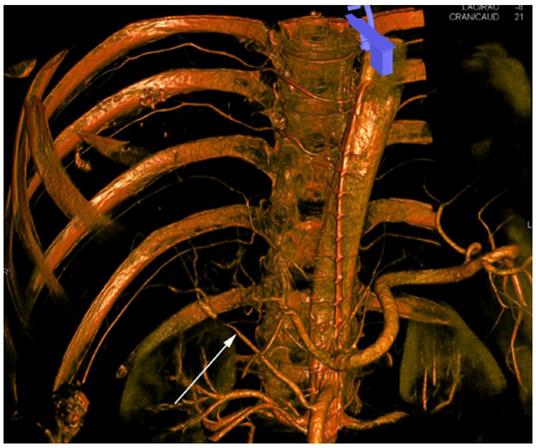

Figure 2. A 54 year old man with hepatocellular carcinoma, in whom the right hepatic artery (arrow) originated from the superior mesenteric artery (SMA). DYNA CT reconstruction imaging shows the spatial location of the abdominal aorta, celiac artery and SMA.

Discussion

This study was undertaken to evaluate whether DYNA CT is useful for visualization of tumors and supplying arteries during hepatic angiography in the treatment of HCC by TACE. Compared with pre-operative CT, we found that more tumors were identified in DYNA CT than DSA, and that DYNA CT clearly showed the celiac artery and SMA as well as the HCC supplying arteries. This shows that DYNA CT is a useful imaging technique and can be used in conjunction with TACE, which corroborates other studies. However, Iwazawa et al. found that C-arm CT was better than digital subtraction angiography and multiple detector CT for identifying feeding arteries and small tumors [12-14]. Higashihara et al. [15] and Tognolini et al. [16] also found benefits of C-arm CT in some patients. However, Meyer et al. found that flat-detector C-arm CT had sensitivity issues in some patients because the liver could not be visualized completely [10]. The DYNA CT system used in this study showed that none of the limitations were observed by Iwazawa et al. and that the technique proved superior to DSA [12-15]. Tognolini et al. suggested that C-arm CT should be used in conjunction with DSA rather than considered as a method in isolation. They stated that C-arm CT added beneficial information in 25% of the patients they studied, including identifying additional tumors and incomplete treatment of patients [16]. We suggest the following details will assist in its successful use.

Guidance for intubation using the DYNA CT image system

3D-DSA combines the anatomic resolution of DSA with 3D visualization previously only offered using CT or MR angiography. 3D-DSA provides more detailed information than routine DSA methods [17]. DYNA CT digital rotational subtraction angiography improves the visibility of the vascular anatomy, allows a better knowledge of the hepatic artery branches, and improves angiographic investigation of the patient by providing correct spatial assessment [18]. It provides a very efficient way of combining two-dimensional (2D) radiographic or fluoroscopic information with 3D CT imaging and

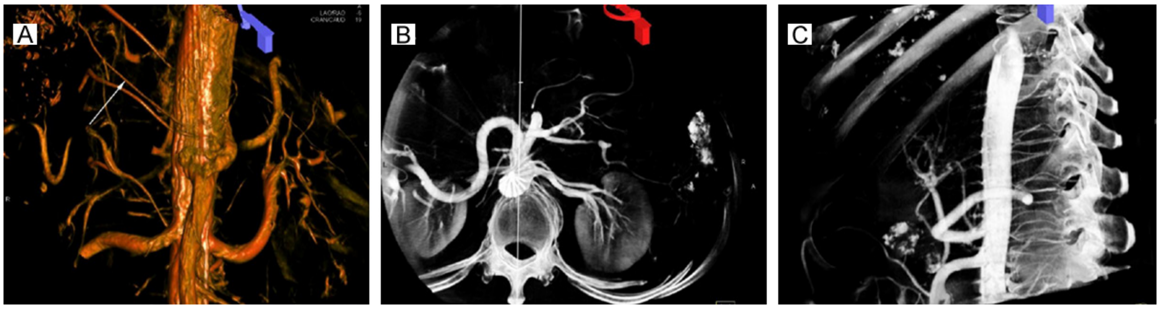

Figure 3. A 50 year old man with hepatocellular carcinoma. A. The phrenic artery (arrow) provided blood to the tumor in the right lower lobe of the liver. B. DYNA CT reconstruction imaging in cross-section showed the angle between celiac artery trunk/SMA and the sagittal plane. C. DYNA CT reconstruction imaging in the sagittal plane showed the angle between the abdominal aorta and the celiac artery trunk/SMA.

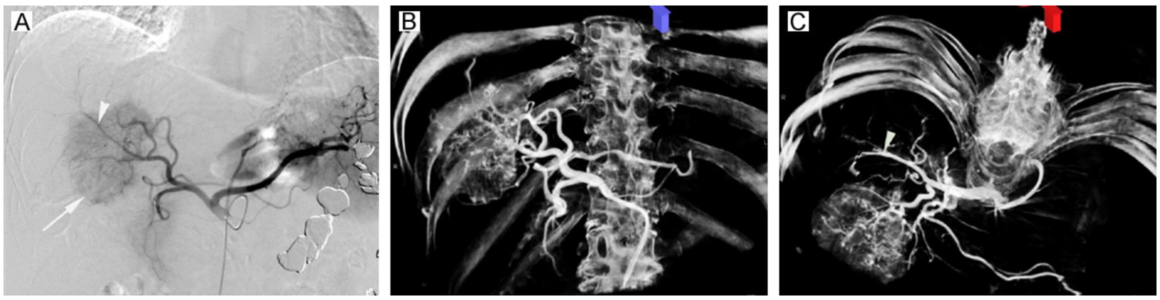

Figure 4. A 59 year old woman with hepatocellular carcinoma. A. Celiac artery angiography (digital subtraction angiography anterior-posterior images (DSA-AP images)). The image of the tumor stain (arrow) is visible. We presume that the right hepatic artery is (arrow head) the feeding artery. B. Anterior-posterior view of volume rendering technique construction of 3D rotational angiography with contrast media injected into the celiac artery. C. Adjustment of the angle of picture allowed visualization of the anterior-posterior relationship of the left and right hepatic arteries, and the feeding artery. An overlapping right hepatic artery (arrow head) was seen in the AP view, and determined not to be the supply artery. These images are useful for identifying tumor supply arteries and super-selecting trans-arterial chemoembolization of the hepatic tumor.

offers distinct practical advantages. Above all, the availability of immediate CT imaging in the interventional operating room cannot be overstated [19, 20]. The image intensifier component which can improve image quality during interventional procedure is the key part in DYNA CT; it determines its versatility and high-performance. As conventional angiography images are generally 2D, with patients usually having overlapping vessels or complicated vascular structures, it is important to be able to assess the 3D-anatomy of the vasculature and perform selective catheterization in patients with overlapping tumors on DSA anterior-posterior (DSA-AP) images, or with complex vascular anatomy [21, 22]. With single coronal images, physicians often find it difficult to judge the original supplying arteries in some cases, which may lead to misjudgment, cause an error intubation, prolong the operation time and increase the possibility of vasospasm or damage. Multiple images are needed in multi-facet, multi-angle observation of the feeding vessels. This has been confirmed in the current study. In conventional DSA, if the angle and spatial location of the celiac artery are to be observed, along with the SMA, the abdominal aorta, and the origin of the feeding artery, anterior-posterior and lateral projections are required. Two intubations and multi-angle oblique projections are also required. This prolongs operative time, and requires a variety of catheters to be used. DYNA CT reconstruction imaging with one scan can show vessels from different angles using MIP and VRT. It can clearly display a 3D image and spatial location of the celiac artery, the SMA and their branches. It can help in the selection of the type and shape of the catheter in advance. In the current study using DYNA CT images, we smoothly intubated and achieved the desired result in all cases.

Images of liver tumors and their supplying arteries are displayed by DYNA CT

DYNA CT image-guided tumor therapy is one of the fastest growing applications in radiology. It can be applied to all regions of the body and is used for tumor embolization [19]. 3D-DSA imaging with a single rotation can obtain liver volume data which can increase the visibility of the vascular anatomy and provide a better understanding of the hepatic artery branch and the overall vasculature. It can also allow spatial estimates of liver lesions [18]. DYNA CT images can clearly show the size and number of tumors, the supply artery to the tumor, and the degree and distribution of contrast agent, which has an important value. In the current study, in group A, DYNA CT imaging found more tumor lesions than conventional DSA compared with pre-operative CT. In conventional DSA imaging, the smaller lesions often overlapped and were easily overshadowed by other large lesions or intra-hepatic iodized oil deposition after TACE, which resulted in misdiagnosis and delayed treatment.

X-ray acquisition delay time is also a critical factor for 3D reconstruction. If acquisition is conducted prematurely, the intravascular contrast agent concentration is too high to produce a clear picture. In contrast, if acquisition is conducted too late, the concentration of contrast agent in the hepatic artery is too low, and images of arteries and veins are displayed at the same time. Therefore, it is important to set the best acquisition time, and judge the right time point for the contrast agent needed to reach the target vessel and perfuse the whole liver. The key step for DYNA CT imaging and 3D image reconstruction success is the synchronization of the peak liver contrast agent concentration with the acquisition time.

DYNA CT images not only enhance the visualization of vessels, but also increase the imaging of soft liver tissue [19]. DYNA CT can reconstruct the vascular system and soft tissue of the liver to give a comprehensive and accurate assessment of lesions, provide timely guidance and help selection of appropriate surgical options. This can significantly improve the success rates of selective intubation of the supply arteries to the tumors. 3D rotational angiographic images are superior for 3D visualization of pathologic vascular structures. They are especially useful for identifying 3D structures of tumors and supply arteries in patients whose DSA-AP images show overlapping tumors, or complex vascular anatomy. HCC metastasizes easily, often with micro-metastases outside the original lesion [23]. Some irregular small tumor foci are more easily displayed with multi-angle, multi-level and multi-facet images of liver nodule staining, the supply arteries and the surrounding soft tissues. DYNA CT images after 3D reconstruction are superior to conventional DSA in terms of displaying the small lesions. It greatly improves the detection rate, and reduces the rate of misdiagnosis and mistreatment. The Siemens_Artis_Zeego_Syngo_DYNA CT_360 can perform a complete rotation in only 8 s. Requiring the patient to hold their breath for a short time minimizes breathing artefacts. This is especially important for those patients with advanced forms of the disease.

By referring to DYNA CT 3D images, a microcatheter can be inserted as close to the target lesion as possible, allowing injection of the appropriate amount of chemotherapy drugs mixed with iodized oil, a rough estimate of the amount of iodized oil required, and successful blockage of the vessel with gelatin sponge powder causing the maximum amount of tumor necrosis while protecting surrounding normal liver tissues. This can improve the TACE treatment efficacy, which was supported by a statistically significant superior 2 year overall survival rate for group A, compared with group B.

This study has some limitations. First, the sample size is small. A larger study would provide more evidence for the utility of DYNA CT. Second, the follow-up time of each patient was only two years so longer follow up is planned. Third, the method may also have some disadvantages in that there is a need for more X-ray exposure and more contrast agent than standard CT. Patients with insufficient renal function are not suitable for having DYNA CT. The use of Visipaque instead of Omnipaque is recommended for the conventional DSA procedure. Prior dialysis treatment may be advisable. Other disadvantages include equipment expense and high demand. These facts may make this technique difficult to become widely adopted in spite of the apparent advantages. Further studies into various uses of DYNA CT may help overcome these problems. More studies are required to determine impacts on survival outcomes in metastatic hepatic carcinomas, and whether this technique could improve those outcomes.

Conclusions

DYNA CT can create high-quality 3D images which may be helpful in formulating a program for HCC interventional therapy. Advantages include the ability to use it during TACE procedures, and the provision of a precise vascular roadmap for determining the supply arteries of HCC during TACE. DYNA CT 3D imaging had a higher rate of correct target vessel identification, higher speed of target vessel access, and higher quality of treatment.

Acknowledgements

This work was partially supported by the National Natural Science Foundation of China (81272239, 81170336); Public Welfare Industry of Health, 201202007.

Disclosure of conflict of interest

None.

Address correspondence to: Yi Miao, Department of General Surgery, First Affiliated Hospital of Nanjing Medical University, Nanjing 210029, Jiangsu Province, China. Tel: +86-15861174247; E-mail: 13327883530@189.cn

References

[1] He J, Gu D, Wu X, Reynolds K, Duan X, Yao C, Wang J, Chen CS, Chen J, Wildman RP, Klag MJ, Whelton PK. Major causes of death among men and women in China. N Engl J Med 2005; 353: 1124-34.

[2] Bruix J, Sherman M; American Association for the Study of Liver Diseases. Management of hepatocellular carcinoma: an update. Hepatology 2011; 53: 1020-2.

[3] McGlynn KA, London WT. Epidemiology and natural history of hepatocellular carcinoma. Best Pract Res Clin Gastroenterol 2005; 19: 3-23.

[4] Taura N, Hamasaki K, Nakao K, Ichikawa T, Nishimura D, Goto T, Fukuta M, Kawashimo H, Miyaaki H, Fujimoto M, Kusumoto K, Motoyoshi Y, Shibata H, Inokuchi K, Eguchi K. Aging of patients with hepatitis C virus-associated hepatocellular carcinoma: long-term trends in Japan. Oncol Rep 2006; 16: 837-43.

[5] Kawano Y, Sasaki A, Kai S, Endo Y, Iwaki K, Uchida H, Shibata K, Ohta M, Kitano S. Short- and long-term outcomes after hepatic resection for hepatocellular carcinoma with concomitant esophageal varices in patients with cirrhosis. Ann Surg Oncol 2008; 15: 1670-6.

[6] Saab S, Yeganeh M, Nguyen K, Durazo F, Han S, Yersiz H, Farmer DG, Goldstein LI, Tong MJ, Busuttil RW. Recurrence of hepatocellular carcinoma and hepatitis B reinfection in hepatitis B surface antigen-positive patients after liver transplantation. Liver Transpl 2009; 15: 1525-34.

[7] Xiao EH, Hu GD, Li JQ, Huang JF. [Transcatheter arterial chemoembolization in the treatment of hepatocellular carcinoma]. Zhonghua Zhong Liu Za Zhi 2005; 27: 478-82.

[8] Lim HS, Jeong YY, Kang HK, Kim JK, Park JG. Imaging features of hepatocellular carcinoma after transcatheter arterial chemoembolization and radiofrequency ablation. AJR Am J Roentgenol 2006; 187: W341-9.

[9] Fahrig R, Dixon R, Payne T, Morin RL, Ganguly A, Strobel N. Dose and image quality for a cone-beam C-arm CT system. Med Phys 2006; 33: 4541-50.

[10] Meyer BC, Frericks BB, Voges M, Borchert M, Martus P, Justiz J, Wolf KJ, Wacker FK. Visualization of hypervascular liver lesions During TACE: comparison of angiographic C-arm CT and MDCT. AJR Am J Roentgenol 2008; 190: W263-9.

[11] Guan YS, He Q, Wang MQ. Transcatheter arterial chemoembolization: history for more than 30 years. ISRN Gastroenterol 2012; 2012: 480650.

[12] Iwazawa J, Ohue S, Hashimoto N, Abe H, Hamuro M, Mitani T. Detection of hepatocellular carcinoma: comparison of angiographic C-arm CT and MDCT. AJR Am J Roentgenol 2010; 195: 882-7.

[13] Iwazawa J, Ohue S, Kitayama T, Sassa S, Mitani T. C-arm CT for assessing initial failure of iodized oil accumulation in chemoembolization of hepatocellular carcinoma. AJR Am J Roentgenol 2011; 197: W337-42.

[14] Iwazawa J, Ohue S, Mitani T, Abe H, Hashimoto N, Hamuro M, Nakamura K. Identifying feeding arteries during TACE of hepatic tumors: comparison of C-arm CT and digital subtraction angiography. AJR Am J Roentgenol 2009; 192: 1057-63.

[15] Higashihara H, Osuga K, Onishi H, Nakamoto A, Tsuboyama T, Maeda N, Hori M, Kim T, Tomiyama N. Diagnostic accuracy of C-arm CT during selective transcatheter angiography for hepatocellular carcinoma: comparison with intravenous contrast-enhanced, biphasic, dynamic MDCT. Eur Radiol 2012; 22: 872-9.

[16] Tognolini A, Louie JD, Hwang GL, Hofmann LV, Sze DY, Kothary N. Utility of C-arm CT in pa-

tients with hepatocellular carcinoma undergoing transhepatic arterial chemoembolization. J Vasc Interv Radiol 2010; 21: 339-47.
[17] Gailloud P, Oishi S, Carpenter J, Murphy KJ. Three-dimensional digital angiography: new tool for simultaneous three-dimensional rendering of vascular and osseous information during rotational angiography. AJNR Am J Neuroradiol 2004; 25: 571-3.
[18] Gattoni F, Dova S, Tonolini M, Uslenghi CM. [Study of the liver and the portal venous system with digital rotational angiography]. Radiol Med 2001; 101: 118-24.
[19] Kalender WA, Kyriakou Y. Flat-detector computed tomography (FD-CT). Eur Radiol 2007; 17: 2767-79.
[20] Racadio JM, Babic D, Homan R, Rampton JW, Patel MN, Racadio JM, Johnson ND. Live 3D guidance in the interventional radiology suite. AJR Am J Roentgenol 2007; 189: W357-64.
[21] Lanzavecchia S, Bellon PL, Radermacher M. Fast and accurate three-dimensional reconstruction from projections with random orientations via radon transforms. J Struct Biol 1999; 128: 152-64.
[22] Tanigawa N, Komemushi A, Kojima H, Kariya S, Sawada S. Three-dimensional angiography using rotational digital subtraction angiography: usefulness in transarterial embolization of hepatic tumors. Acta Radiol 2004; 45: 602-7.
[23] Van den Eynden GG, Majeed AW, Illemann M, Vermeulen PB, Bird NC, Hoyer-Hansen G, Eefsen RL, Reynolds AR, Brodt P. The multifaceted role of the microenvironment in liver metastasis: biology and clinical implications. Cancer Res 2013; 73: 2031-43.