The value of Dyna CT in the hepatocellular carcinoma treated by transcatheter arterial chemoembolisation

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Aims and objectives

Hepatocellular carcinoma (HCC) is one of the most common types of malignant liver tumor, and the third leading cause of cancer mortality worldwide\textsuperscript{[1]}. It is responsible for more than 250,000 deaths worldwide each year\textsuperscript{[2,3]}. Studies have demonstrated that countries in Asia, particularly China, have a high incidence of HCC, due to endemic hepatitis B and C \textsuperscript{[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\textsuperscript{[2,5-7]}.

It is very important to comprehensively understand HCC and know its imaging information during the TACE process, because this can improve its tumor detection rate and directly affect HCC embolization efficacy. A successful TACE procedure depends on accurate anatomical understanding of a target vessel, the anatomical structures of the vessel line and appropriate chemoembolization. During TACE with conventional angiography (Computed Tomography (CT), Magnetic Resonance Imaging (MRI) scan and Digital Subtraction Angiography (DSA)), this type of information is extremely difficult to obtain in a timely manner and with a clear image, especially when the patient is on the operating table for interventional surgery\textsuperscript{[8]}. Dyna CT (also called Flat-detector computed tomography (FD-CT)) can also be used to provide imaging information during TACE. Liver vessels and tumors are displayed by the volume rendering technique and the maximum intensity projection technique of Dyna CT. This technique has become widely accepted for interventional and intra-operative imaging using C-arm systems. It provides a very efficient way of combining two-dimensional (2D) radiographic or fluoroscopic information with 3D CT imaging offering distinct practical advantages, above all the availability of immediate CT imaging in the interventional suite or the operating room\textsuperscript{[9,10]}.

Dyna CT can be considered to be synonymous with cone-beam CT, which requires complicated image reconstruction. The standard convolution-back projection approaches only work with high image qualities when a perfect planar or fan-beam geometry is given\textsuperscript{[11]}. For wider cone angles and for circular scan trajectories the situation is more complicated. Its performance varies slightly with the type of implementation; reconstruction times are typically 2-10 min for an image volume of 512\textsuperscript{3} resolution. In principle, high image quality can only be guaranteed for the central plane. Image quality degrades for areas outside the central plane, and the degradation increases as a function of the distance from it\textsuperscript{[12]}. Three-dimensional angiography using rotational digital subtraction (3D-DSA) allows volumetric data acquisition in a single rotation of source and detector\textsuperscript{[13]}. Original image data from digital radiography collected by rotation are sent to the image processing workstation and corrected by Dyna CT to make a tomographic
reconstruction using MIP and VRT. A 3D image of the vascular anatomy filled with contrast agent can then be visualized. However, metallic foreign bodies or movement can easily produce artifacts\cite{14}.

Modern C-arm CT systems are currently becoming rapidly accepted because they offer improved image quality, versatility and dedicated applications for planning, guiding, monitoring and assessing interventional procedures\cite{15}. However, TACE guided by Dyna CT reconstruction imaging is rarely reported; some studies have investigated C-arm CT. Meyer et al found the C-arm CT technique limited in terms of visualizing the liver\cite{16}, but Iwazawa et al had more success, they found it was better at identifying feeding arteries and small tumors than digital subtraction angiography and multiple detector CT\cite{17,18,19} Higashihara et al also found benefits in using this technique\cite{20} and Tognolini et al found benefits in some patients\cite{21}. As some of these studies are contradictory, we therefore consider it important to add more evidence to the published data on Dyna CT. This will give us more information on whether Dyna CT can find more tumors, display the course of the celiac artery and its relationship with adjacent vessels and clearly show the tumor feeding arteries. We shall therefore evaluate whether it can be used as guidance for suitable arteries for TACE. In order to do this we designed a prospective study to report on the feasibility of this technology to provide images resembling CT slices on the operating table during TACE. To assess its practical applicability, 34 patients underwent TACE with both Dyna CT and conventional DSA and the performance of these methods were compared and analyzed.
MATERIALS AND METHODS

Patients

For this prospective study from May 2012 to September 2012, a total of 34 patients with HCC were referred to our department (Intervention Radiology Department, The First People's Hospital of Changzhou, China) for TACE, which included 26 men and 8 women with a mean age of 58.5 years (range: 40 to 82 years). 13 were diagnosed by surgical pathology, 7 were confirmed by CT-guided biopsy, and the remaining 14 cases were verified by preoperative B-scan ultrasound (B-US) and/or CT and/or MRI with a high level of plasma alpha-feroprotein (AFP). Patients classified as grade A or grade B, according to Child-Pugh score, were included. From the imaging findings, all patients were suspected of having at least one liver tumor. All patients had Dyna CT and conventional DSA conducted during TACE. The study was approved by the Institutional Review Board and Ethics Committee of the First People's Hospital of Changzhou (China). All patients provided written informed consent for participation.

Dyna CT

Dyna CT was performed on each patient according to a standard protocol during routine clinical examination. We used the trans-right femoral arterial approach with a 5F sheath (by the Seldinger technique). A 5F pigtail catheter was placed in the upper abdominal aorta. An appropriate catheter was also placed in the celiac artery and/or the superior mesenteric artery (SMA). Siemens_Artis_zeego_Synco_Dyna_CT_360 digital angiography system (Siemens Medical Solutions, Forchheim, Germany), Dyna CT software, nonionic iodinated contrast agent (omnipaque, GE Healthcare Company, UK) and a high-pressure syringe (Mark V Provis, MERAD.INC, USA) were used during detection. Rates and volumes of contrast agent for Dyna CT in our department were as follows: omnipaque (300mgI/ml, upper abdominal aorta: 10ml/s, 70ml, celiac artery/ SMA: 2.5ml/s, 20ml), the Dyna CT scan was conducted 1s after the start of injection of the contrast agent, acquisition frame rate: 60 frames/s, collection matrix: 512*512, rotation speed: 30°/s, acquisition time: 7s. 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 volume rendering technique (VRT) and the maximum intensity projection (MIP) technique.

Conventional DSA
According to the result 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 walk-line. Contrast agent: omnipaque (300mgI/ml, celiac artery/SMA: 4ml/s, 12ml), DSA scan was conducted the same time as the start of the contrast agent injection, acquisition frame rate: 4 frames/s, collection matrix: 512*512, acquisition time: 3s.
Results

Patient characteristics

The patient characteristics are shown in table 1. Of the 34 studied 26 were male and 8 were female. Their age range was 40-82 years. According to Child-Pugh score 20 were classed as A and 14 as B. 13 were diagnosed by surgical pathology, 7 by CT-guided biopsy and 14 by ultrasound/CT/MRI imaging and a high AFP level.

Dyna CT and DSA Imaging of HCC

The size, number and distribution of intra-hepatic tumors were observed by Dyna CT and DSA imaging. 20 cases had massive HCC, 12 cases had a nodular form of HCC and 2 cases had small HCC. The maximum diameter of the tumors detected by Dyna CT and DSA was 12.8cm and 13cm while the minimum diameter of the tumors was 0.3cm and 0.5cm, respectively. The site and number of tumors detected by both methods are shown in table 2.

126 lesions were found by Dyna CT imaging and 98 lesions were found by DSA imaging. 30 cases with a total of 110 lesions were found in both tests. The imaging with Dyna CT was clearer than conventional DSA in lesion presentation with a significant difference (Fig 3).

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

Dyna CT was carried out and images were processed by the VRT and MIP angiography techniques. The hepatic artery issued from the celiac artery in 32 cases, the right hepatic artery originated from the SMA and the left hepatic artery originated from the common hepatic artery in 2 cases. Dyna CT imaging could clearly present the anatomy, spatial location and the walk-line of the celiac artery, the SMA and their branches (Fig 1A). 4 cases had the phrenic artery providing blood to the tumor in the right lower lobe of the liver (Fig 1B). Dyna CT imaging could clearly show the feeding artery of the tumor (Fig 1B/2C).

In cross sectional observation, the angle between the celiac artery/trunk and the sagittal plane was skewed to the left by a maximum of 36°, 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° (Fig 1C). In sagittal observation, the angle between the celiac artery and the abdominal aorta beneath was from 28° to 153°, with an average of 70.1°; the angle between the SMA trunk and the abdominal aorta beneath was from 12° to 54°, with an average of 25.2° (Fig 1D). The angle between the celiac artery trunk and the abdominal aorta beneath was found to be more than 90° in 5 patients. The length between the celiac artery trunk opening and the hepatic-splenic artery bifurcation was from 0.8 to 3.5cm,
with an average 1.8cm. The length of the celiac artery trunk was longer than 3cm in 4 cases. The length of the SMA was longer than 6cm in 1 case.

Dyna CT information was then used as guidance for intubation. Dyna CT showed 4 patients with long celiac arteries and 4 patients with tumor-feeding arteries originating from the SMA. In 3 patients a Cobra catheter was used with micro-catheter technology and in 6 patients a Simmons catheter was used with micro-catheter technology. All of them had successful surgery. We used a 5F vertebral artery catheter with micro-catheter technology in 5 cases whose celiac artery and the abdominal aorta beneath were at an angle of more than 90° in sagittal angiography.

High-pressure syringe parameters

X-ray acquisition delay time is the most critical factor for 3D reconstruction. If acquisition is conducted prematurely, the intravascular contrast agent concentration is too high to produce a clear picture. On the contrary, 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 contrast agent addition needed to reach the target vessel and perfuse the whole liver. The key step for Dyna CT tomographic imaging and 3D image reconstruction success is the synchronization of the peak of liver contrast agent concentration with the acquisition time. Although there are different positions for the catheter, the tumor vessels and individual conditions, our experience with these 34 cases has shown that Dyna CT and 3D reconstruction images can meet the requirements of diagnosis and treatment when we select the appropriate acquisition parameter. Generally, the choice of contrast agent injection rate is 10ml/s and 2.5ml/s. The total amount of contrast agent is 70ml and 20ml respectively. X-ray delay is 1s for Dyna CT and 0s for conventional DSA.
Fig. 1: A 54-year-old man with hepatocellular carcinoma (HCC), 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.

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Fig. 2: A 50-year-old man with HCC, the phrenic artery (arrow) provided blood to the tumor in the right lower lobe of the liver

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**Fig. 3:** Dyna CT reconstruction imaging in cross-section showed the angle between celiac artery trunk/SMA and the sagittal plane

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Fig. 4: Dyna CT reconstruction imaging in the sagittal plane showed the angle between the abdominal aorta and the celiac artery trunk/SMA

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Fig. 5: A 59-year-old woman with hepatocellular carcinoma (HCC) A: Celiac artery angiography (DSA-AP image). The image of the tumor stain (arrow) is visible. We presume that the right hepatic artery is (arrow head) the feeding artery.

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**Fig. 6:** Anterior posterior (AP) view of volume rendering technique (VRT) construction of 3D rotational angiography with contrast media injected into the celiac artery.

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**Fig. 7:** When we adjust the angle of picture, the anterior-posterior relationship of the left and right hepatic arteries can be seen and the feeding artery can be clearly identified. We can discover that the overlapping right hepatic artery (arrow head) seen in the AP view is not the feeding artery. These images are useful for identifying tumor feeding arteries and super-selecting trans-arterial chemoembolization of the hepatic tumor.

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**Fig. 8:** A 76 year-old-man with hepatocellular carcinoma (HCC) A: Celiac artery angiography (DSA-AP image). A small tumor stain can be seen in the right lobe of the liver (arrow).

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Fig. 9: Maximum intensity projection (MIP) and volume rendering technique (VRT) 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.

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Fig. 10: Maximum intensity projection (MIP) and volume rendering technique (VRT) 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.

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Conclusion

Dyna CT can create a high-quality 3D image, which has great significance in terms of formulating a program for HCC interventional therapy, reducing the frequency of CT & MRI monitoring, providing a precise vascular roadmap for determining the feeding arteries of HCC during TACE and accurately selecting the amount and type of embolic agents. With the help of Dyna CT3D images, we can have better guidance for treatment of HCC and improve the quality of care.
Personal information

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