

Cone Beam Computed Tomography for Vascular Interventional Radiology Procedures: Early Experience

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Abstract

Introduction: Cone beam computed tomography (CBCT) is a relatively new technological innovation that utilises flat-panel detector technology to obtain CT-like images. The key strength of a CBCT system is that cross-sectional imaging can be obtained using the angiographic flat panel unit without having to move the patient, allowing the radiologist to obtain soft tissue imaging during the procedure. This allows treatment planning, guidance, and assessment of outcome to be performed in one interventional suite. **Materials and Methods:** From December 2008 to June 2009, 24 CBCT scans were performed during vascular interventional procedures on our department's newly installed multi-axis flat panel angiographic unit. **Results:** Ten cases were performed for hepatic trans-arterial chemoembolisation, 9 cases for hepatic arterial Yttrium-90 infusion, while 5 cases were for other indications. CBCT was found to be useful in 20 of the 24 cases. **Conclusion:** Our early experience showed that CBCT was useful in impacting decisions during selected vascular interventional procedures. As CBCT technology improves, we can foresee wider applications of this technology.

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Introduction

Cone beam computed tomography (CBCT) is a relatively new technological innovation which utilises flat-panel detector technology to obtain CT-like axial images. The radiation source beam and flat panel detector are coupled together by a C-arm. In a single 180-degree rotation of the C-arm (Fig. 1), a typical CBCT unit is able to acquire a volumetric dataset of approximately 25 cm (diameter) x 18 cm (thickness),¹ the exact volume of which varies depending on the machine. Both the radiation source and the detector are part of the angiographic unit that is used for acquiring fluoroscopic and digital subtraction angiography (DSA) images during an interventional radiology procedure.

The fundamental difference between CBCT and multi-detector CT (MDCT) is that information is acquired using a 2-dimensional detector in a CBCT unit, whereas multiple 1-dimensional detectors are used in an MDCT scanner.¹ The exact details of CBCT image acquisition are not within the

scope of this paper, and the reader is referred to an excellent primer on the concept of CBCT.¹

The spatial resolution of a typical CBCT-acquired image is high and generally better than an MDCT-acquired image.² Contrast resolution, image acquisition time and image processing times, on the other hand, are better in MDCT systems.^{1,2}

The key strength of a CBCT system in an interventional suite is that cross-sectional imaging can be obtained using the existing angiographic unit, without having to move the patient to a traditional MDCT scanner.^{1,3,4} Prior to the introduction of CBCT systems, when axial images were desired during an interventional procedure, the patient had to be moved out of the angiography suite to a dedicated MDCT scanner. This resulted in precious time wasted, and more importantly, increased the risk of catheter dislodgement due to movement of the patient.

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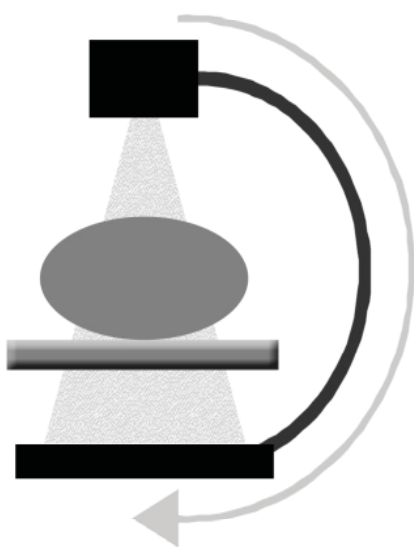


Fig. 1. Volumetric data acquisition by a CBCT system.

In the case of a CBCT system, with the source beam and detector as part of the angiographic unit, the radiologist can obtain axial soft tissue imaging during the procedure itself.^{5,6} As a result, treatment planning, guidance, and assessment of outcome can be performed in one interventional suite, at the same time doing away with the problems associated with moving the patient during the procedure.⁷

CBCT has been used in vascular⁴⁻¹² and non-vascular interventional procedures,¹³⁻¹⁵ as well as during surgery.¹⁶⁻¹⁸ In particular, relevant to this study, the results of several groups have suggested the benefits of CBCT in various vascular interventional procedures, including hepatic trans-

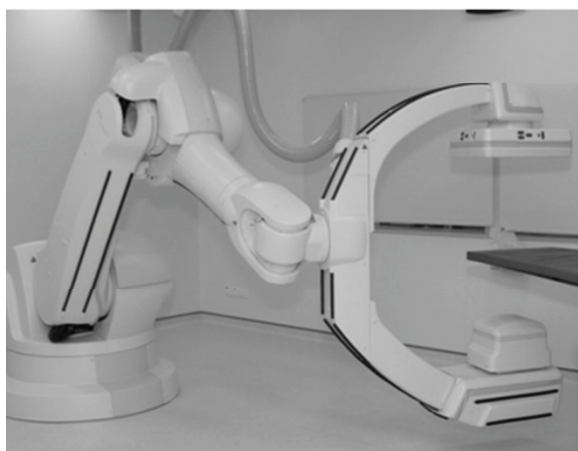


Fig. 2. Artis zeego (Siemens, Erlangen, Germany).

arterial chemoembolisation (TACE)^{4,9,10} and assessment of extra-hepatic shunting before radioembolisation.¹¹

Several CBCT systems are currently available in the market. The CBCT system installed in our centre is the Artis zeego (Siemens, Erlangen, Germany) (Fig. 2). The acquisition time for this system is 8 seconds, with an image reconstruction time of 30 seconds. One unique feature of the Artis zeego compared to other CBCT systems available in the market is that its C-arm is mounted on a multi-axis system. A greater range of gantry movement is thus possible, allowing a larger volume to be imaged. Using the large volume imaging protocol, a volumetric dataset of 47 cm (diameter) x 18 cm (thickness) is obtained, allowing the entire liver to be visualised in almost all cases.

Materials and Methods

A retrospective study was conducted to review all the vascular interventional cases performed on the Artis zeego from December 2008 to June 2009 during which CBCT images were acquired, with the aim of evaluating whether the images acquired using CBCT were useful in impacting decision-making during the interventional procedures. As it was a retrospective study (the results of which would not have directly affected outcome), patient consent was not obtained. Approval to proceed with the study was however obtained from our hospital's institutional review board.

CBCT images were acquired for 24 cases performed on the Artis zeego. Depending on the case, the CBCT images were acquired using the standard and/or large volume protocol (Fig. 3). These cases included hepatic TACE (n = 10), hepatic arterial Yttrium-90 infusion (n = 9), and other cases (n = 5).

For each of these cases, DSA images were initially acquired and reviewed by the radiologist. This was followed by the acquisition of CBCT images. A variety of contrast medium infusion protocols were used, depending on the vessel of interest (Table 1).

For this study, the images were retrospectively reviewed by the respective consultant radiologist to determine if the CBCT-acquired images were useful in the decision-making process, when compared to the DSA images alone.

Results

Hepatic Trans-Arterial Chemoembolisation

Table 2 provides a summary of the results. In all the TACE procedures (n = 10), the CBCT-acquired images were found to be useful. Pre-TACE, the images were primarily useful in demonstrating more detailed vascular anatomical information that was not shown on the traditional DSA images (Fig. 4). Post-TACE, the images were able to more



Standard (acquisition time 8s, reconstruction time 30s) CBCT of the liver.



Large volume (acquisition time 16s, reconstruction time 54s) CBCT of the lower chest.

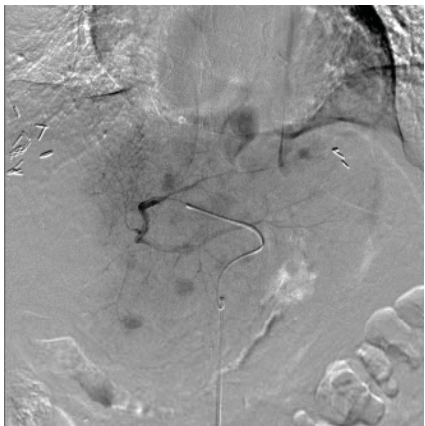
Fig. 3. Comparison between standard and large volume imaging protocols.

Table 1. Contrast Infusion Protocols

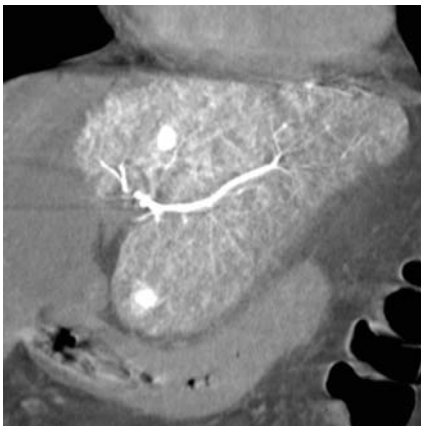
CBCT Angiogram	Protocol Details			
	Volume (mL)	Rate (mL/s)	Concentration (%)	Delay Before Imaging (s)
Right Hepatic Artery	14	1.3	50	5
Left Hepatic Artery	14	1.3	50	5
Common Hepatic Artery	24	2.0	50	6
Superior Mesenteric Artery	28	2.0	50	8

Table 2. Summary of Results

Procedure	CBCT-acquired images useful?		
	Yes	No	Total
TACE	10	0	10
Y-90 infusion	7	2	9
Others	3	2	5



Selective left hepatic angiogram demonstrates hypervascular tumours in the left lobe.



Coronal CBCT angiogram shows the tumours more elegantly.

Fig. 4. A 67-year-old female with multifocal hepatocellular carcinoma.

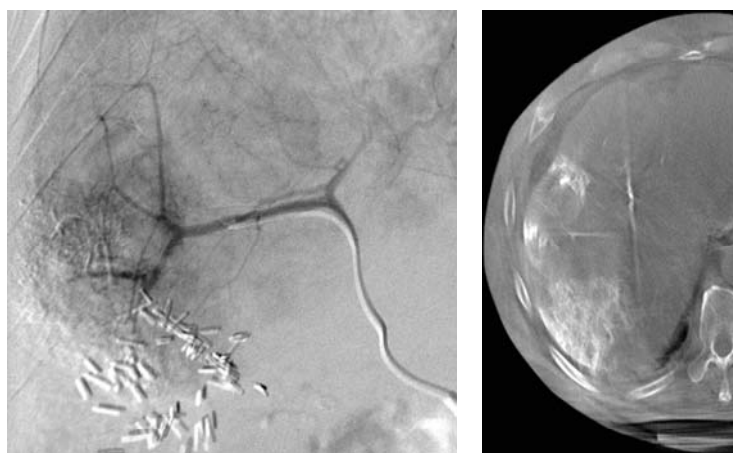


Fig. 5. Comparison of post-TACE images acquired using DSA (left) and CBCT (right).

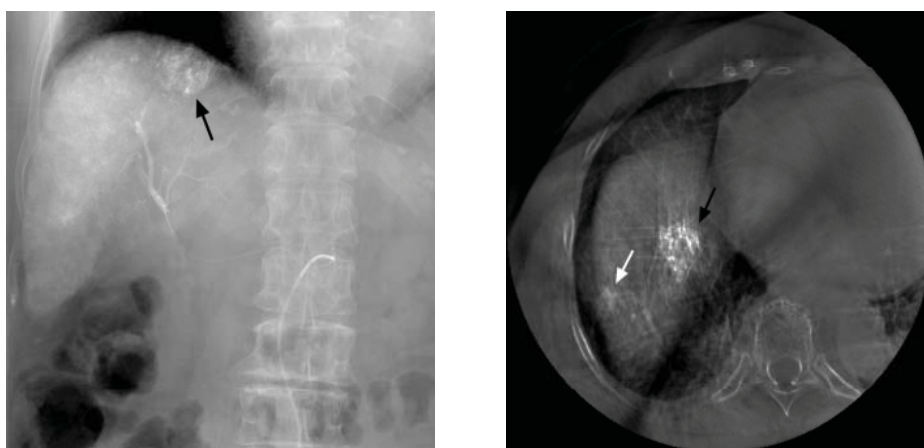


Fig. 6. Post-TACE Lipiodol uptake by a right lobe segment VIII tumour (black arrows), demonstrated on both the radiograph (left) and CBCT-acquired image (right). However, the CBCT-acquired image demonstrates Lipiodol uptake by a smaller segment VII tumour as well (white arrow).

clearly demonstrate the distribution of Lipiodol, and thus the retention of chemotherapeutic agent, within the tumour (Figs. 5 and 6).

Hepatic Arterial Yttrium-90 Infusion

CBCT-acquired images were deemed useful in 7 out of the 9 of the hepatic arterial Yttrium-90 infusion procedures.

In 3 patients, gastric supply from the left hepatic artery was demonstrated on the CBCT-acquired images. This was not clearly demonstrated on the initial DSA images (Fig. 7). This information is critical as the small branches supplying the stomach had to be embolised prior to delivery of Yttrium-90 via the left hepatic artery. Otherwise, these patients would have been at risk of developing radiation-induced ulcers in the stomach.^{19,20} In 2 patients, initial DSA

images raised the possibility of gastric supply from the left hepatic artery; the CBCT-acquired images were useful as they helped to definitively exclude this possibility. In another 2 cases, the CBCT-acquired images demonstrated tumour arterial supply more clearly than the initial DSA images, allowing the radiologist to determine the appropriate amount of Yttrium-90 to be administered via each of the supplying arterial branches.

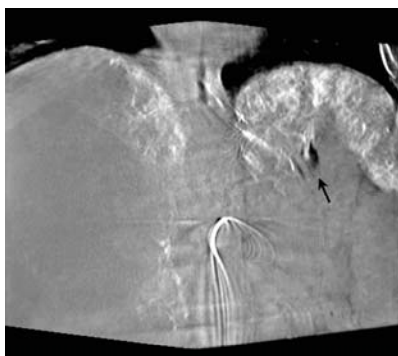
In the 2 cases that the CBCT-acquired images were deemed not useful, the common reason was that the initial DSA images had already provided adequate information for the intervention to be performed optimally.

Other Cases

Other cases performed (n=5) included internal iliac artery



Selective left hepatic angiogram demonstrates multiple hypervascular tumours in the left lobe. It is difficult to ascertain the presence of gastric supply.



Coronal and axial CBCT images of left hepatic angiogram clearly demonstrate gastric supply (arrows) by the left hepatic artery.

Fig. 7. A 57-year-old male with multifocal hepatocellular carcinoma.



Fig. 8. CBCT renal arteriogram confirms lack of hypervascularity of a lower pole renal angiomyolipoma (left), in keeping with DSA (right).

embolisation, central venogram, planned embolisation of a renal mass ($n = 1$ each) as well as 2 cases of portal vein embolisation. In 3 out of these 5 cases, the CBCT-acquired images were felt to be useful as they provided additional information that the traditional DSA images were unable to provide.

In the case of a renal arteriogram (performed with a view of subsequently embolising a possible renal angiomyolipoma), the CBCT-acquired images confirmed that the mass demonstrated a lack of hypervascularity, thus obviating the need for embolisation (Fig. 8).

In 2 of the cases, it was felt that the CBCT-acquired images did not provide additional information as the initial DSA images had already provided adequate information for the intervention to be performed satisfactorily.

Discussion

The cross-sectional imaging ability of CBCT introduces an additional dimension in imaging during procedures in the interventional radiology suite. A review of the cases performed with images acquired using CBCT showed that CBCT was definitely useful in the majority of cases. CBCT-acquired images were particularly useful when the traditional DSA images were unable to demonstrate anatomical variations in vascular distribution. This was particularly so for hepatic arterial interventional procedures like TACE, where the CBCT-acquired images more clearly demonstrated chemotherapeutic agent distribution within the tumour.

Potential disadvantages of the additional CBCT sequence include additional radiation exposure to the patient and the interventional team, the need for additional contrast, and the increase in procedure time. On the other hand, with the additional information obtained from the CBCT-acquired images, the number of DSA acquisitions may be reduced.

One shortcoming of this study is its small sample size, which precludes statistical analysis. However, as more cases are performed using CBCT image acquisition, we will have, in future, a larger sample size to analyse.

Conclusion

CBCT, being an emerging technology, represents the next generation of imaging available in the interventional radiology suite. Our department's early experience with our CBCT unit has been a very positive one, and we anticipate that we will continue to expand the applications of CBCT in interventional radiology in the coming years.

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