Effect of C-arm Angiographic CT on Transcatheter Arterial Chemoembolization of Liver Tumors

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Rotational C-arm angiographic computed tomography (CT) with a flat-panel radiography unit permits three-dimensional (3D) reconstruction of soft tissues and blood vessels. The usefulness of this C-arm technique during transcatheter arterial chemoembolization (TACE) is unknown. The authors analyzed the role of the C-arm technique in 18 patients with unresectable liver tumors during TACE. The technique altered the catheter position anticipated by attending interventional radiologists in seven of the 18 patients (39%; 95% confidence interval [CI]: 20%, 61%) and improved the diagnostic confidence in the selected catheter position in 14 of the 18 patients (78%; 95% CI: 55%, 91%). The technique provides CT-like images that are useful to interventional radiologists during TACE.


Abbreviations: CI = confidence interval, DSA = digital subtraction angiography, TACE = transcatheter arterial chemoembolization, 3D = three-dimensional

TRANSCATHETER arterial chemoembolization (TACE) is a minimally invasive palliative treatment for hepatocellular carcinoma (HCC) (1,2) and metastatic (3–5) liver tumors. TACE is usually performed by using planar two-dimensional digital subtraction angiography (DSA), which commonly requires additional oblique views and contrast medium injections to properly depict the feeding vessel(s) that supply the targeted tumor. Three-dimensional (3D) rotational DSA, which consists of 3D reconstruction of a rotational angiographic data set, offers the ability to view images at any angle with regard to patient positioning, using only one injection of contrast medium. This 3D technology has been predominantly used in neuroangiographic applications (6,7).

The rotational 3D DSA technology was applied by Liapi et al (8) to delineate the vascular anatomy before TACE in two patients. Recent technological innovations, however, have permitted 3D rotational C-arm computed tomographic (CT) scans to be reconstructed by using soft tissue windows, providing CT-like images with a flat-panel DSA unit. The technique, termed DynaCT on Siemens C-arm angiographic units (Siemens Medical Solutions, Erlangen, Germany), represents a technical advance over conventional two-dimensional planar or 3D rotational angiography because it generates similar vascular anatomy but now includes the corresponding soft tissues. This combination of vascular and soft tissue depiction has potential benefits within the context of TACE because the relationship of the targeted tumor with its arterial supply can be clearly identified.

The usefulness of DynaCT during TACE is unknown. We performed this preliminary study to determine whether DynaCT (a) alters anticipated catheter position and (b) increases operator confidence of catheter position during TACE. We hypothesized that DynaCT can substantially help interventional oncologists in positioning their catheters for TACE and increases their confidence in this catheter position.

MATERIAL AND METHODS

Clinical Setting and Patients

From the Department of Radiology (S.V., R.K.R., K.T.S., R.J.L., L.K., M.F.M., A.C.L., R.S., R.A.O.); the Department of Medicine, Divisions of Hepatology (L.K.) and Oncology (M.F.M., R.S.); and the Department of Biomedical Engineering (A.C.L., R.A.O.), Northwestern University, 448 E Ontario St, Ste 700, Chicago, IL 60611. Received January 24, 2007; final revision received July 5, 2007; accepted July 15, 2007. Address correspondence to R.A.O.; E-mail: reed@northwestern.edu


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This prospective, cohort study was approved by our local institutional review board and performed at a single tertiary care medical center in a large metropolitan area. Between March 2006 and September 2006, we enrolled 18 consecutive patients (11 men, seven women; mean age, 52 years; age range, 40–63 years) with unresectable HCC (n = 15) and metastatic neuroendocrine liver tumors (n = 3) who were scheduled to undergo TACE.
Patients were included in this study if they (a) had a confirmed diagnosis of unresectable HCC or metastatic neuroendocrine liver tumors; (b) were at least 18 years; (c) had an Eastern Cooperative Oncology group performance status of 0–2; (d) were able to undergo angiography and selective visceral catheterization; and (e) had adequate hematologic (granulocyte count ≥1,500/μL; platelet count >50,000/μL), renal (creatinine level <1.5 mg/dL [114 μmol/L]), and liver (including bilirubin level <4.0 mg/dL [68 μmol/L]) function. All cases were discussed at a multi-disciplinary conference featuring attending physicians from interventional oncology, medical oncology, hepatology, and transplant surgery departments. The attending transplant surgeon at the conference deemed these patients as unresectable. Patients were excluded if they had progressive extrahepatic disease or a life expectancy of less than 3 months.

All 18 consecutive patients were scheduled for TACE and underwent magnetic resonance (MR) imaging or CT 1–4 weeks before TACE. These patients were not preselected because of potential difficulties on the basis of either clinical setting or pre-TACE cross-sectional imaging.

**DynaCT Technique**

The study was performed in an interventional radiography procedure room equipped with a commercially available, ceiling-mounted DSA unit (Axion Artis dTA, software version VB22K; Siemens). All patients were scheduled to undergo TACE with this commercially available flat-panel DSA unit. With use of standard femoral arterial access and a coaxial catheter technique (5), a 2.8-F-diameter microcatheter (Renegade Hi-fl o; Boston Scientific, Natick, Mass) was superselectively placed in the lobar or segmental hepatic artery identified to supply the targeted tumor, as determined with conventional planar DSA. The catheter tip was positioned in the location anticipated for subsequent TACE delivery. A single series of 3D rotational C-arm angiographic images was then obtained during breath-hold by using the DynaCT technique, with one continuous C-arm rotation that covered 200° of circular trajectory for approximately 7 seconds. With use of a power injector, iodinated contrast medium (Omnipaque 350; Amersham, Princeton, NJ) was injected at a flow rate of 1–3 mL/sec for 7 seconds at the initiation of DynaCT image acquisition, concurrent with the breath hold. The contrast medium was injected intravenously directly into the microcatheter. Acquired images (240 images; frame rate, 24.8/sec; 0.8° of increment for each frame; resolution, 1,024 pixels) were transferred to a workstation (Leonardo; Siemens), where 3D CT-like images were reconstructed in approximately 2 minutes.

**Data Analysis**

DynaCT images were analyzed by the attending interventional radiologist who performed the TACE procedure (R.A.O., K.T.S., K.K.R.). The radiologist had a Certificate of Added Qualification. This physician personally manipulated images on the workstation in sagittal, axial, and coronal planes to identify the vascular anatomy and targeted tumor. After manipulation of DynaCT images, this operator then noted in binary fashion (i.e., yes or no) whether the intended catheter position was appropriate and the confidence in the catheter position was increased. The operator then went on to complete the TACE procedure by using standard methods (5) if the catheter position was appropriate or altered the catheter position on the basis of the DynaCT results.

Descriptive statistics, including 95% confidence intervals (CIs), were used to determine the proportion of time that findings at DynaCT altered the anticipated catheter position and improved confidence in catheter position.

**RESULTS**

All 18 patients successfully completed TACE without complication. Qualitatively, DynaCT was effective at assisting the interventional oncologist to position catheters optimally for treating targeted tumors. Findings from DynaCT altered the intended catheter position for TACE in seven of the 18 patients (39%; 95% CI: 20%, 61%) and improved the diagnostic confidence in this catheter position in 14 of the 18 patients (78%; 95% CI: 55%, 91%).

For the seven patients in whom the catheter position was changed, the cystic artery was avoided in one patient (Fig 1) and the microcatheter could be advanced more superselectively in six patients. In these six patients, DynaCT improved the depiction of the selective blood supply to the tumor by demonstrating the relationship of visceral opacification to blood supply. This improved depiction enabled us to advance our catheter more distally for more localized delivery of chemoembolic material to the targeted tumor. Simultaneously, we could then spare delivery to a larger volume of uninvolved liver.

In 14 of the 18 patients, reconstructed DynaCT images improved diagnostic confidence in catheter position by confirming soft tissue enhancement of the targeted tumor. For example, as shown in Figure 2, DynaCT images helped confirm that the inferior phrenic artery supplied the residual enhancing tumor within the dome of the left lobe of the liver.

**DISCUSSION**

In this study, the intended catheter position during TACE was substantially altered due to findings at DynaCT. More than one-third of our patients undergoing TACE had their anticipated catheter position altered before chemoembolic delivery. The altered catheter position avoided delivery to the cystic artery in one patient and enabled us to advance our catheter more distally in six patients. DynaCT also increased operator confidence in the catheter position in more than three-fourths of patients.

3D rotational angiography can be considered superior to conventional planar angiography because it can provide multiple projections with use of only one contrast medium injection. Although 3D rotational angiography has been most commonly used in interventional neuroradiology procedures (6,7), it has also been applied to coronary (9), renal (10), and uterine (11) angiography with varying success. In a recent study, Liapi et al (8) performed conventional 3D rotational angiography in two patients with HCC who were undergoing TACE. Conventional 3D rotational angiography helped them delineate the complex vascular anatomy, facilitating the
subsequent delivery of chemoembolic material. In another similar study, Tani-gawa et al (12) compared the quality of visualization of tumor and feeder arter-ies as imaged with 3D rotational angiography with that of anteroposterior DSA. Their results showed that 3D rotational angiography alone may not be suitable for preprocedural mapping in transcatheter embolization of hepatic tumors but may be of value when information supplementary to anteroposterior DSA is needed.

The DynaCT technique represents a substantial improvement over conven-tional 3D rotational angiography because it can help delineate complex vascular anatomy in relationship to the targeted tumor. As long as the catheter tip is located in a proximal artery supplying the tumor, the soft tissue enhancement of the tumor should also be seen. Conversely, if the operator inadvertently superselects the wrong artery before performing DynaCT, the relevant vascular anatomy and tumor enhancement will not be displayed.

3D rotational DSA in combination with flat detectors enables users of angiographic C-arm systems to create soft tissue images based on the principles of CT. According to the manufacturer, these CT-like images enable soft tissue differentiation in the form of section images, displaying objects of up to 10 HU difference and 10 mm in size. The DynaCT technique can potentially reduce the need to transfer patients from the angiography suite to a CT unit for catheter-directed CT angiography (13). Alternatively, although not the subject of this study, DynaCT could potentially be used after TACE to determine the distribution of injected Ethiodol. This technique might then reduce the practice of sending patients for post-TACE unenhanced CT to verify Ethiodol distribution.

There were several important limita-
tions to this study. First, this study was designed to evaluate the usefulness of DynaCT during TACE in relationship to the catheter placement and operator’s confidence. Long-term clinical outcomes were not assessed. Nevertheless, more selective catheter placement targeting predominantly tumor-involved parenchyma ultimately should reduce nontarget chemoembolic delivery and increase the effective dose delivered to the tumor. This is of particular importance in patients with underlying cirrhosis who usually have poor liver function and other associated co-morbid conditions. Second, we did not determine the effect of DynaCT on radiation exposure (6,14), procedural time, and reduced contrast medium load to the patient. This determination would require a control arm of patients treated without DynaCT. 3D rotational angiography has been shown to benefit patients with renal insufficiency during coronary angiography (9). Third, our experimental design assessed subjective binary changes in operator confidence and catheter position after DynaCT rather than employing quantitative questionnaires before and after imaging, as used in some previous MR studies (15,16). Fourth, the accuracy of DynaCT in the diagnosis of small tumors was not assessed and awaits further studies. Finally, this efficacy study was performed at a single tertiary-care academic medical center. The relative effectiveness of this technique when generalized elsewhere and to all indications versus niche indications remains unknown. Interventional oncologists need to determine in their own practices whether the benefits of visceral opacification outweigh any possible inconveniences of using DynaCT.

In conclusion, DynaCT represents an important technologic adjunct that can assist interventional oncologists in performing TACE. By providing con-

Figure 2. Comparative images in a 40-year-old man with HCC who had previously undergone separate lobar TACE sessions for a right lobe tumor (by means of the right hepatic artery) and a left lobe tumor (by means of the left hepatic artery). (a) Transverse contrast-enhanced CT scan shows two large HCC foci in the liver. The HCC in the right lobe (black arrows) measures 5.8 × 8.3 × 11.5 cm³, and the HCC in the left lobe (white arrows) measures 7.1 × 8.7 × 3.9 cm³. The left lobe tumor was to be targeted with follow-up TACE because it was growing in an exophytic fashion. High-attenuation material within both liver tumors is due to residual Ethiodol staining from previous TACE sessions. (b, c) Superselective left inferior phrenic angiograms obtained in the early (b) and late (c) arterial phases suggest that the left inferior phrenic artery may be supplying the enlarging and untreated portion of the left lobe tumor. (d) Coronal reconstruction from DynaCT obtained by means of left inferior phrenic artery injection verifies that the enlarging left dome tumor would be adequately targeted with the catheter in this position. (e) Completion left inferior phrenic angiogram obtained after TACE shows markedly increased Ethiodol staining within the entire large left dome tumor.
current blood vessel and soft tissue depiction, it enhances decision-making at TACE. Catheter position is altered in a substantial number of patients, and the confidence in catheter position is improved in most patients. If the proper angiographic equipment is available, we recommend the use of DynaCT for TACE. Future studies can examine the utility of DynaCT in the reduction of contrast medium load, procedure time, and radiation dose and in allowing co-registered 3D road mapping. The potential benefit on patient outcomes also awaits verification from future studies.

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References