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TECHNICAL NOTE

Image Fusion of Preprocedural CTA with Real-time Fluoroscopy to Guide Proper Hepatic Artery Catheterization During Transarterial Chemoembolization of Hepatocellular Carcinoma: A Feasibility Study

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Abstract

Purpose To assess feasibility of proper hepatic artery catheterization using a 3D model obtained from preprocedural computed tomographic angiography (CTA), fused with real-time fluoroscopy, during transarterial chemoembolization of hepatocellular carcinoma.

Methods Twenty consecutive cirrhotic patients with hepatocellular carcinoma undergoing transarterial chemoembolization were prospectively enrolled onto the study. The early arterial phase axial images of the preprocedural CTA were postprocessed on an independent workstation connected to the angiographic system (Innova 4100; GE Healthcare, Milwaukee, WI), obtaining a 3D volume rendering image (VR) that included abdominal aorta, splanchnic arteries, and first and second lumbar vertebrae. The VR image was manually registered to the real-time X-ray fluoroscopy, with the lumbar spine used as the reference. The VR image was then used as guidance to selectively catheterize the proper hepatic artery. The procedure was considered successful when performed with no need for intraarterial contrast injections or angiographic acquisitions.

Results The procedure was successful in 19 (95 %) of 20 patients. In one patient, celiac trunk angiography was required for the presence of a significant ostial stenosis that was underestimated at computed tomography. Time for image reconstruction and registration was <10 min in all cases.

Conclusion The use of preprocedural CTA model with fluoroscopy enables confident and direct catheterization of the proper hepatic artery with no need for preliminary celiac trunk angiography, thus reducing radiation exposure and contrast media administration.

Keywords Catheterization · Chemoembolization · Computed tomography · Computer-assisted image processing · Fluoroscopy · Hepatocellular carcinoma

Introduction

C-arm computed tomography (CT) is progressively becoming more available in many angiographic suites, and its advantages have been described mainly in cardiac and neurologic applications, as well as in many oncologic interventions.

Several articles have described the usefulness of C-arm CT during transcatheter arterial treatments of liver nodules [1–3], improving lesion depiction [4, 5] and identification of intra and extrahepatic arterial feeders [6–8], and being able to modify and correct catheter placement in up to 50 % of procedures [3], thus increasing operators' confidence and treatment efficacy. However, potential increase of radiation exposure to the patient and to the operators requires an appropriate use of C-arm CT for specific clinical purposes [9, 10].

Recent angiographic equipment also provides specific applications that enable to overlay three-dimensional (3D) reconstructions obtained from computed tomographic angiography (CTA) or magnetic resonance angiography with the real-time X-ray fluoroscopy in order to guide arterial catheterization with no need for any digital subtraction angiographic (DSA) acquisition. However, no data are yet available describing feasibility and safety of this application during catheterization of hepatic arteries.

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The purpose of this prospective study was to assess feasibility of proper hepatic artery catheterization using preprocedural CTA images as guidance during transarterial chemoembolization (TACE) in patients with hepatocellular carcinoma.

Materials and Methods

The study conformed to the Declaration of Helsinki and was approved by our institutional review board. Written informed consent was obtained from all patients.

The study was designed as to prospectively include 20 consecutive cirrhotic patients with hepatocellular carcinoma scheduled for TACE after multidisciplinary tumor board discussion.

Patients were enrolled if they had undergone a preprocedural four-phase multidetector CT examination (LightSpeedPlus; GE Healthcare, Milwaukee, WI) less than 1 month before the scheduled TACE, including an early arterial phase acquisition, obtained from the diaphragm to the aortic bifurcation, with the following protocol: 64×0.625 mm detector configuration, 0.984:1 pitch, 0.625 mm slice thickness, 0.625 mm reconstruction interval, 0.6 s rotation speed, 120 kV, automA, 26 noise index. With a power injector (Medrad, Pittsburgh, PA), 120 mL of iodinate nonionic contrast medium was injected into an antecubital vein at a flow rate of 4 mL/s, followed by a 30 mL sterile saline flush at the same flow rate. Scan delay was individualized per patient using a bolus-tracking technique (SmartPrep; GE Healthcare) to capture 150 HU on the abdominal aorta at the level of the celiac trunk.

Patients were excluded if anatomic variants or stenotic lesions of the hepatic vessels were identified at CTA or if they had underwent previous DSA, in order to obtain a more homogeneous series of patients to test the feasibility of this technique.

The early arterial phase CT axial images were postprocessed on an independent workstation (Advantage Windows VolumeShare 4.5; GE Healthcare) connected to the angiographic equipment (Innova 4100; GE Healthcare) by semiautomatic segmentation, obtaining a 3D volume rendering image (VR) that included abdominal aorta; celiac trunk; common, proper, left, and right hepatic arteries; superior mesenteric artery; origin of the renal arteries; and first and second lumbar vertebrae.

We used dedicated software (Innova Vision; GE Healthcare) to overlay the VR model to the live X-ray fluoroscopy by manual registration, aligning the segmented lumbar spine to the X-ray projection in the posterior–anterior view. After this registration procedure, there was complete freedom of motion of the X-ray table and C arm because the overlay software automatically maintained the registration. This meant that when the fluoroscopic projection was changed, the overlaid model automatically moved in the same projection, and vice versa. The time required for segmentation and registration was recorded.

Under fluoroscopic guidance, the overlaid VR model was used to selectively catheterize the proper hepatic artery via transfemoral arterial percutaneous access while the patient was under local anesthesia, using an adequately shaped 5F hydrophilic catheter (Hydrophilic Simmons 1 or Cobra; Terumo, Tokyo, Japan) and a 0.035 in. hydrophilic guide wire (Terumo). The procedure was considered successful when the catheter reached the desired position (i.e., the origin of the proper hepatic artery) with no need for intraarterial contrast injection or DSA acquisition.

Results

The mean time for image postprocessing was 2 ± 1.6 min, while the mean time for registration was 3.1 ± 2.5 min. In all cases, the overall time for segmentation and registration was less than 10 min. In all patients, the segmented VR model obtained from CTA was considered adequate to serve as guidance for catheterization by the interventional radiologist.

The catheterization procedure was successful in 19 (95 %) of 20 patients (Fig. 1). In one patient, DSA was required as a result of the presence of significant ostial stenosis of the celiac trunk that was underestimated at CTA (Fig. 2).

No procedure-related complications were observed.

Discussion

Several recent articles have described the usefulness of C-arm CT during transarterial treatments of hepatic nodules in being able to provide accurate lesion depiction and to identify intra and extrahepatic arterial feeders to the tumors, with a similar or even greater accuracy than CT [1–8]. More recent equipment provides specific software to overlay CTA or magnetic resonance angiography images to real-time fluoroscopy, creating a fused road-mapping display, to guide arterial catheterization.

In our preliminary prospective experience, this application was proven to be safe and feasible in the most cases; we could reach the proper hepatic artery with no need for DSA acquisitions of the celiac trunk and of the superior mesenteric artery, with a potential reduction in contrast media administration (about 20 mL for each acquisition) and of radiation exposure (with our equipment, dose area product of about 10–20 Gy/cm^2 for each acquisition). In only one patient was DSA required, the result of the presence of a significant celiac trunk stenosis that was not clearly depicted by CTA.

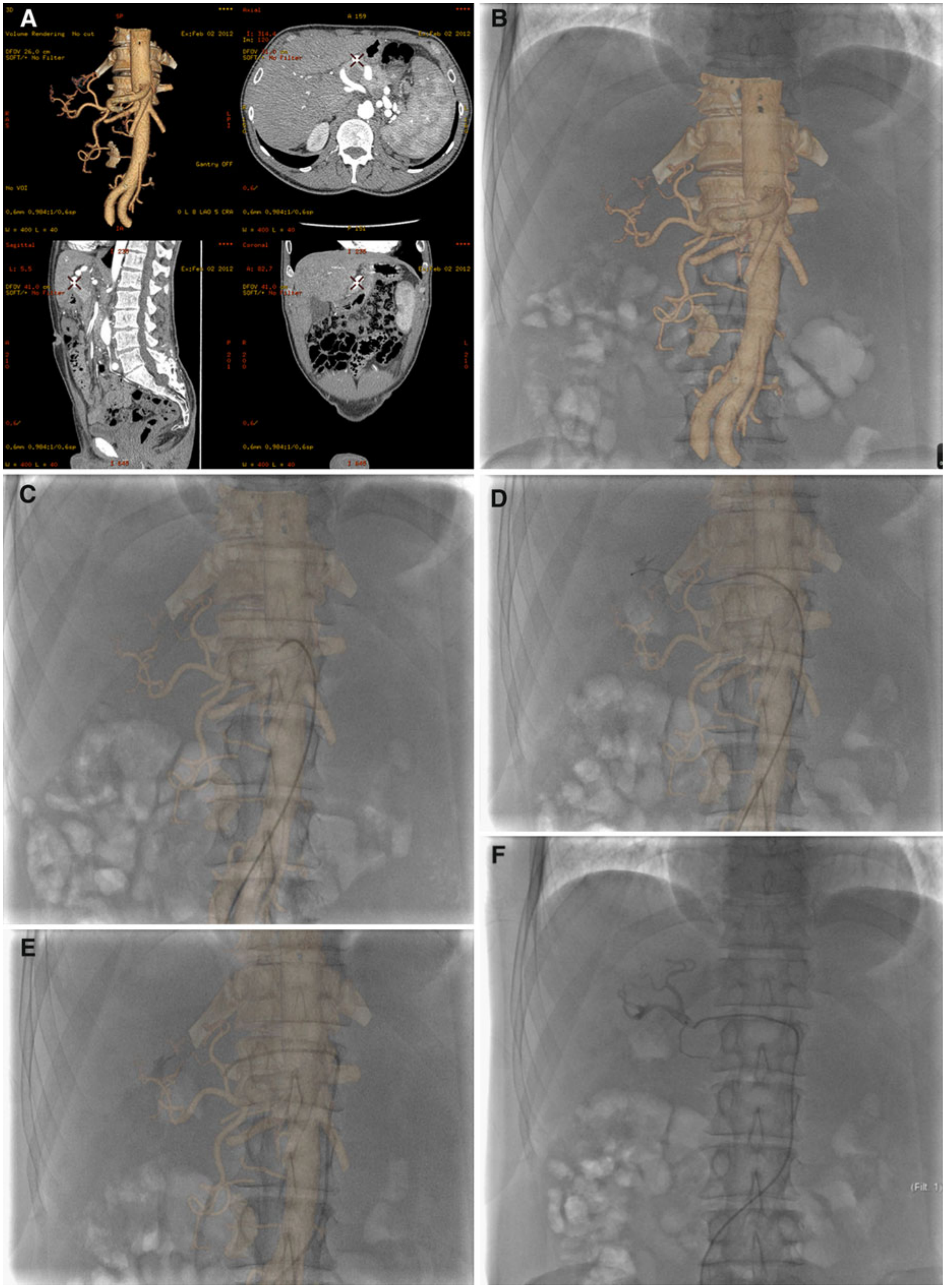

Fig. 1 Early arterial phase CT images are postprocessed on an independent workstation by semiautomatic segmentation, obtaining the VR model of abdominal aorta and splanchnic arteries (**A**). The 3D model is then manually registered to the real-time fluoroscopic image using the bone structures as reference (**B**), and it is used to catheterize the celiac trunk (**C**) and the proper hepatic artery (**D, E**). Only at this time is 3 mL of contrast medium injected to check the correct catheter position (**F**)

Fig. 2 After failed direct catheterization of the celiac trunk using the 3D model as guidance, DSA is acquired, demonstrating abnormal visualization of the hepatic arteries from the celiac trunk (**A**) with retrograde recanalization from the superior mesenteric artery (**B**). At CTA (**C**, volume rendering and maximum intensity projection), the significant stenosis at the origin of the celiac trunk is not clearly demonstrated

The use of a 3D model can potentially increase the operators' confidence during the catheterization procedure; the model can be rotated in real time with simultaneous rotation of the fluoroscopic image, enabling the selection of the best projection for a better display of tortuous hepatic vessels.

In experienced hands, CTA postprocessing and registration may require no more than 10 min. Postprocessing can also be performed before the scheduled procedure, with the user saving the VR model on the workstation and recalling it at the time the procedure is performed, thus reducing occupation time of the angiographic suite. The minutes required for manual registration can be compensated by the time saved by skipping the celiac trunk DSA acquisition.

A potential disadvantage of this system is related to the manual registration of the 3D model to the X-ray fluoroscopy, which is imperfect by definition. Moreover, the mismatch of the two images is unavoidable because CTA is acquired during breath hold, whereas fluoroscopy is performed under free breathing. The software does not provide an indication of the accuracy of the overlay, as for other fusion imaging techniques, such as those that use ultrasound and cross-sectional imaging (CT and magnetic resonance imaging); nor does there seem to be a potential technical solution in the near future to compensate mismatching that results from respiratory movements. Nonetheless, this imperfect overlay seems to be sufficient to guide the catheterization, at least up to the proper hepatic artery.

For homogeneity, patients with anatomic variants of hepatic vessels were excluded from the study; however, this does not represent a contraindication to the use of 3D CTA images as guidance in clinical practice.

In conclusion, our preliminary study demonstrates that fusion of 3D models obtained from preprocedural CTA with real-time fluoroscopy is feasible and enables confident and direct proper hepatic artery catheterization before TACE with no need for preliminary angiographic acquisitions, thus potentially reducing radiation exposure and contrast media administration.

Conflict of interest The authors declare that they have no conflict of interest.

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