3-D CT angiography aids in liver surgery planning

May 01, 2006
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CT angiography is a powerful technique for assessing visceral arteries that may obviate catheter angiography. A quality CTA with good contrast timing, minimal visual noise, and proper 3D postprocessing techniques provides excellent detail of arterial anatomy. CTAs are particularly important for patients with unresectable liver metastases, in whom regional chemotherapy is an alternative treatment option.

The treatment involves use of a hepatic arterial infusion pump. The pump is connected via catheter to the patient's proper hepatic artery through the gastroduodenal artery, which is ligated, to deliver chemotherapy directly to the liver. Surgeons need to know the exact hepatic vasculature before placement of the infusion pump.

Mapping the hepatic artery and its branches not only gives surgeons a 3D view of the anatomy, it also helps determine if a patient is suitable for the procedure. At Memorial Sloan-Kettering Cancer Center, imaging specialists provide radiologists with 3D postprocessed volume renderings of the hepatic anatomy for their interpretation of the CTA.

The hepatic artery is responsible for the bulk of the blood supply to liver metastases, while the portal vein provides the major blood supply to normal hepatic parenchyma. Surgeons must be alerted preoperatively of any variant hepatic anatomy in order to ensure that chemotherapy is delivered only to the liver and not, for example, to the pancreas or duodenum. Three-D views are critical to preoperative evaluation of hepatic anatomy.

In classic arterial anatomy, the celiac axis bifurcates into the common hepatic and splenic arteries. The common hepatic artery becomes the proper hepatic artery after the takeoff of the gastroduodenal artery. The proper hepatic artery then divides into the right and left hepatic arteries (Figure 1).

Knowledge of variant anatomy is also important to ensure uniform hepatic perfusion of chemotherapy. Standard arterial anatomy allows for conventional pump placement; variant anatomy may require alteration in surgical technique or may preclude pump placement entirely.

Common variants in hepatic anatomy include accessory or replaced hepatic arteries on the left or right. An accessory left hepatic artery arises from the left gastric artery. It is defined as an "extra" artery that arises from an unusual location (Figure 2). The presence of accessory arteries almost never precludes surgery, but it is important that they are pointed out to the surgeon for possible ligation.

Another common variant, a left hepatic artery replaced to the left gastric artery, can be seen in Figure 3. Since this artery is feeding the left lobe of the liver and would not be in the path of chemotherapy, the surgeon might choose to ligate it. Ligation of the replaced left hepatic artery cuts off the blood supply to the left lobe, and as a result, collateral vessels would develop from the right hepatic territory to supply the left side of the liver.

A final oft-seen variant is a replaced right hepatic artery, which occurs when the entire right hepatic artery arises from the superior mesenteric artery (Figure 4). Occasionally, one may see a combination of variants, such as accessory right and left hepatic arteries (Figure 5). The accessory left arises from the left gastric artery. The large accessory right hepatic artery takes origin from the very proximal common hepatic artery. This variant anatomy may preclude pump placement.

A few other variant types are rarely seen but notable, such as variant celiac anatomy branching into the left gastric artery, splenic artery, a combined left and gastroduodenal artery, and right hepatic artery (Figure 6). This type of anatomy, also known as "double hepatic artery" might preclude...
surgery because the entire right hepatic artery would not receive chemotherapy (Covey AM, Brody LA, Maluccio MA, et al. Variant hepatic arterial anatomy revisited: digital subtraction angiography performed in 600 patients. Radiology 2002;224:542-547).

Occasionally, the splenic, left gastric, and common hepatic arteries arise independently from the aorta. In such cases, two distinct left hepatic arteries are identified, both originating from the proper hepatic artery distal to the gastroduodenal artery.

A final variant of which to be aware occurs when the entire common hepatic artery is replaced to the superior mesenteric artery. This does not preclude pump placement, since the entire liver blood supply is replaced to the superior mesenteric artery and the other branches are normal.

In order to obtain high-quality 3D images, our CTA technique involves close attention to specific principles of protocol design. These include contrast and data acquisition timing in addition to dual-phase (arterial and portal) imaging with thin axial sections (1.25 mm) for 3D postprocessing. The dual-phase protocol design minimizes radiation dose to the patient while allowing for thin reconstructions (see table). To accurately determine the peak contrast in the hepatic phase, a 20 cc test bolus is injected and the patient scanned at a stationary location for 15 to 20 seconds. This "pseudo-SmartPrep" method is our twist on GE Healthcare's protocol.

Digital thin-section axial images (1.25-mm arterial phase; 0.625-mm portal phase) are acquired and then transferred to a dedicated 3D workstation for postprocessing. In addition to color and black-and-white volume rendering, the 3D workstation provides software for creating reformatted images such as coronal and sagittal plane images and maximum intensity projections. A projected image such as a MIP misrepresents the spatial relationships of the anatomy, however. Figure 6B shows the distribution of the combined gastroduodenal artery and left hepatic artery, but unlike Figure 6A, does not illustrate that it is posterior to the right hepatic artery.

CTA provides an excellent road map of hepatic arterial anatomy. Certain vascular anomalies may preclude hepatic arterial infusion pump placement, and 3D volume rendering techniques contribute added confidence to the diagnosis of variant arterial anatomy.

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