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CLINICAL IMAGING

The Role of Noninvasive Vascular Imaging in Splanchnic and Mesenteric Pathology

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Traditionally, catheter angiography (CA) has been the mainstay of diagnosis for mesenteric arterial diseases. However, CA is invasive and is associated with complications that result from the procedure itself, depending on the experience of the operators, site of vascular access, ionized radiation that could be significant when combined with interventional procedures, and administered contrast material. During the past 2 decades, technical improvements in computed tomography (CT) and magnetic resonance hardware and methods have contributed new, noninvasive tools, specifically CT angiography (CTA) and 3-dimensional gadolinium-enhanced magnetic resonance angiography (3D Gd-MRA). This article outlines the current applications, strengths, and weaknesses of CTA and 3D Gd-MRA in imaging of the mesenteric vessels.

Techniques

For accurate grading of a luminal narrowing and depiction of small arteries, the volumetric data must be acquired with submillimeter isotropic or near isotropic voxel size. In-plane resolution of a computed tomography (CT) image is typically 0.5–0.7 mm. The longitudinal resolution is determined by the collimation. Thinner collimation provides higher spatial resolution in the longitudinal axis. Breath-hold imaging of a large anatomic region with submillimeter longitudinal resolution requires a CT scanner with fast gantry rotation. High-speed multi-detector CT (MDCT) systems allow simultaneous acquisition of 4 or more slices during a single gantry rotation of less than 0.5 seconds. As a result, today it is possible to obtain high spatial resolution mesenteric CT angiography (CTA) with submillimeter isotropic voxels that allow the depiction of the mesenteric arteries down to second-order branches and accurate grading of occlusive diseases during a single breath hold.

Meanwhile, 3-dimensional gadolinium-enhanced magnetic resonance angiography (3D Gd-MRA) has also evolved into standard of care in many diseases of the aorta and visceral branches. Some of the earliest studies have demonstrated a sensitivity and specificity of greater than 95% with 3D Gd-MRA in the evaluation of the proximal segments of the mesenteric arteries.[1–12] However, most authors have concluded that the spatial resolution of 3D Gd-MRA was too low for a reliable delineation and assessment of the small distal branches and inferior mesenteric artery. New MR scanners equipped with stronger gradients and parallel imaging techniques allow at least twice as fast imaging acquisitions, which partially overcomes this problem. Today, near isotropic 3D imaging with submillimeter voxel size of certain vascular territories is possible within a single breath hold.[13]

Catheter angiography (CA) is still superior to CTA and 3D Gd-MRA because of its excellent in-plane spatial resolution of 0.3×0.3 mm^2.[14]

The volumetric imaging capability of CT and MR has also led to the development of postprocessing techniques such as multiplanar reformation, maximum intensity projection (MIP), curved planar reconstruction, and volume rendering (VR). These techniques allow the production of images similar in appearance to CA. Compared with the limited number of imaging projections obtained with CA, isotropic CTA or 3D Gd-MRA datasets can be reformatted in any imaging plane. Specifically, MIP or MPR images perpendicular to the course of the artery allow precise assessment of the vessel lumen area at the site of stenosis. When combined with multiplanar reconstructions, CTA and 3D Gd-MRA might actually be more accurate than CA in the evaluation of the eccentric or irregular plaques and thrombosed dissection lumen, which can be underestimated or missed completely with CA.[13] The 3D MIP and VR reconstructions are useful to remove venous superimposition, and particularly preferable for demonstrating the collateral mesenteric circulation and the 3D relationship between the vessels and the abdominal organs and to demonstrate collateral mesenteric circulation.

Precontrast CT imaging might be required for detecting acute portal/mesenteric venous thrombosis (Figure 1) and fresh blood within the bowel lumen in patients with suspected gastrointestinal bleeding. Comprehensive CTA and 3D Gd-MRA protocols should include postcontrast portal and delayed venous phase imaging in addition to the arterial phase. Delayed phase images are required for the evaluation of portomesenteric and systemic veins as well as the dissections and aneurysms. Slow flow within a pseudoaneurysm or the false lumen of a

Abbreviations used in this paper: **AMI, acute mesenteric ischemia; APF, arterioportal fistula; CA, catheter angiography; CMI, chronic mesenteric ischemia; CT, computed tomography; CTA, computed tomographic angiography; MDCT, multi-detector computed tomography; MIP, maximum intensity projection; SMA, superior mesenteric artery; SMV, superior mesenteric vein; 3D Gd-MRA, three-dimensional gadolinium-enhanced magnetic resonance angiography; US, ultrasonography; VAA, visceral artery aneurysm; VR, volume rendering.**

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dissection can only be appreciated on delayed phases. Postcontrast equilibrium phase imaging is helpful for demonstrating organ perfusion patterns, vascular and nonvascular masses, arteriovenous malformations and fistulas, and perivascular inflammation associated with vasculitic syndromes.

Clinical Applications of Mesenteric Catheter Angiography and Magnetic Resonance Angiography

Variant Anatomy of the Splanchnic and Mesenteric Arteries and Veins

The conventional textbook description of a celiac trunk having 3 branches (hepatic, left gastric, and splenic) occurs in only 55% of the population.[15] Anatomic variations might alter the surgical approach in hepatobiliary and pancreaticoduodenal surgeries, liver transplantations, laparoscopic procedures, retroperitoneal mass resection, surgical shunting, and hepatic arterial infusion chemotherapy of advanced liver malignancies.[16–19] CTA is an excellent imaging technique in the assessment of the hepatic arteries up to their second-order branches (Figure 2) and the portal and hepatic venous anatomy.[20–23]

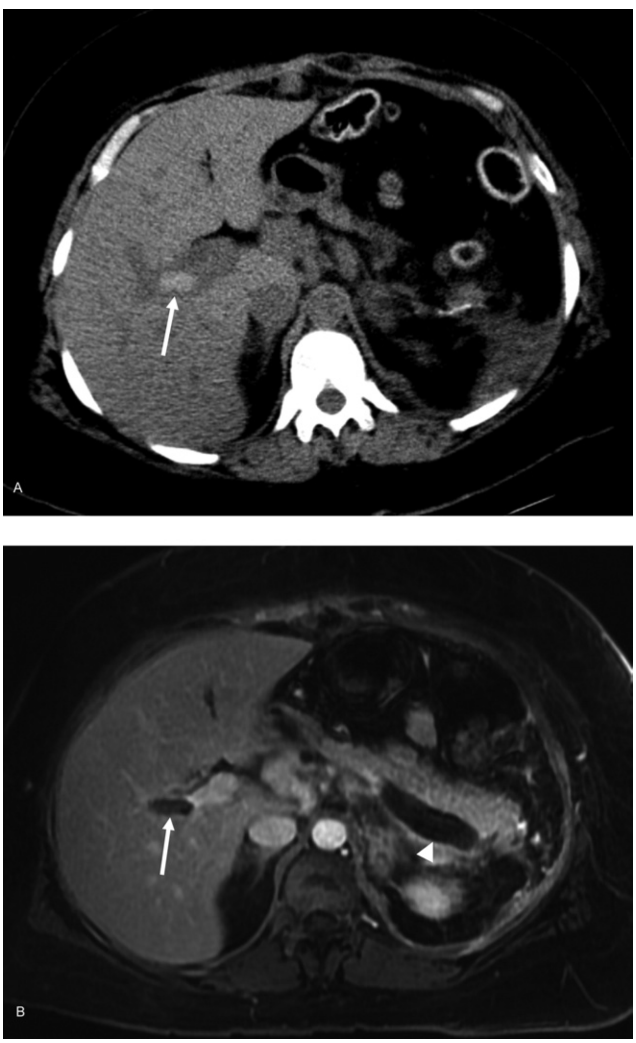

Figure 1. A 44-year-old woman with history of lymphoma and splenectomy presented with abdominal pain. (*A*) Precontrast CT study demonstrates hyperdensity within the right portal vein suggestive of acute thrombosis (*arrow*). (*B*) Axial post-contrast T1-weighted and fat-suppressed equilibrium phase MR image confirms the filling defect within the portal vein (*arrow*) as well as the splenic vein (*arrowhead*).

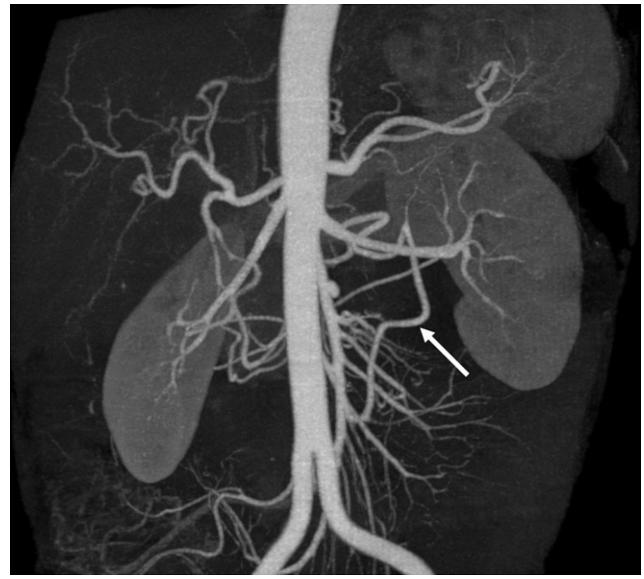

Figure 2. A 46-year-old woman, preoperative CTA study for potential liver donor. Scans were acquired with 64-slice MDCT at 100 kV and 120 mA. Coronal 3D MIP reconstruction demonstrates normal anatomic pattern of the splanchnic and mesenteric arteries. The arch of Riolan connecting the inferior mesenteric artery and middle colic branch of the SMA is also visualized (*arrow*).

Figure 3. A 66-year-old woman with arteriolosclerosis and end-stage renal failure on dialysis. A CTA study was obtained to determine the patency of the pelvic vessels for kidney transplantation. Axial CT images were acquired during breath hold in inspiration. Sagittal MIP reconstruction demonstrates the diaphragmatic crura causing wedge-shape indentation (*white arrow*) to the cranial aspect of the celiac trunk (median arcuate ligament syndrome) and associated moderate (50%–70%) diameter stenosis of the celiac trunk, compared with the normal proximal vessel segment. SMA is widely patent (*open black arrow*).