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Multislice CT in the pre- and postinterventional evaluation of mesenteric perfusion

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Abstract Multislice computed tomography angiography (CTA) has been found feasible for the evaluation of visceral vasculature. The development of multislice technology has overcome past limitations. First, the faster scanning speed increases volume coverage during a single breath-hold and improves the exploitation of contrast medium. Second, the better spatial resolution results in nearly isotropic voxels allowing reconstruction of high-resolution three-dimensional images with different algorithms. Volume rendering is capable of displaying the visceral vasculature from any external vantage point. Compared to conventional angiography, CTA not only delineates vessels but also depicts the anatomical relationship to adjacent structures and allows the evaluation of perfused organs. CTA also has become an emerging tool for the pre- and post-interventional assessment of vascular anatomy. The purpose of this pictorial essay is to present a spectrum of visceral vascular diseases and interventional and surgical therapies, and to highlight the role of postprocessing for their evaluation.

Keywords Multislice computed tomography · Angiography · Postprocessing · Mesenteric perfusion

Introduction

Computed tomography angiography (CTA) is a valuable minimally invasive tool for the visualization of visceral vasculature [1, 2]. When compared to conventional angiography, CTA is less expensive, saves examination time, and may save iodinated contrast dose and radiation exposure of the patient [3, 4]. Moreover, CTA allows innumerable arbitrary projections and is not limited to a single opacification. The introduction of 16-row multislice computed tomography (MSCT) has overcome most of the limitations of earlier scanner generations. With regard to faster scanning speed and improved spatial resolution, MSCT enables an increase in scan volume during a single breath-hold with a sub-millimeter resolution. Compared to 4-row or 8-row MSCT, the improved temporal resolution of 16-row MSCT ameliorates the contrast bolus exploitation and therefore decreases the opacification of overlaying veins. The high z-plane resolution results in nearly isotropic voxels, allowing high-quality postprocessing algorithms. Multiplanar reformatted projections (MPR) are able to display the axial data sets in any desired oblique or curved plane. Another valuable algorithm is maximum intensity projection (MIP), which provides angiography-like displays. The volume rendering (VR) technique makes use of the entire data set, thus giving an overview and may convey more information than MPR and MIP. It can show multiple internal and overlying features, and the flexibility of the VR algorithm allows the protocol to be tailored to the actual clinical problem, but when improperly used has the potential hazard of loss of valuable information. Parameters such as brightness, opacity, window and level can be interactively modified, for example to better visualize small vessels at high opacity or to make organs more transparent at decreased opacity allowing the evaluation of intraparenchymal vasculature [5].

Imaging technique

CTA of the abdominal and pelvic vasculature was performed on a 16-row MSCT system (Sensation 16, Siemens Medical Solutions, Forchheim, Germany). After administration of 120 ml non-ionic intravenous contrast agent (Visipaque, Amersham Health, Little Chalfont, UK) at an injection rate of 3.0 ml/s and bolus tracking in the abdominal aorta, the CT scan was performed from the diaphragm to the pubic symphysis. The scanning parameters were: collimation 16×0.75 mm, table feed 12 mm/rotation, tube potential 100 kV and tube current 225 mA. Oral contrast agent is not routinely administered because opacified bowel would disturb postprocessing and segmentation of mesenteric vessels. We routinely perform dual phase imaging to allow both arterial and venous patency to be evaluated as well as the pattern of bowel wall and parenchyma enhancement to be defined. Axial images were reconstructed using a medium soft kernel (B30f). MPR, MIP, and VR images were routinely generated using a radiological workstation (Leonardo, Siemens Medical Solutions). For reconstruction of MPR and MIP a mean time of approximately 10 min was needed, whereas for reconstructing VR images between 15 and 30 min was required depending on the desired image quality and anatomical complexity of the individual case. Approximately 120 patients were examined with this protocol between December 2003 and June 2004. The estimated mean radiation dose delivered to the patients was 10 mSv.

Discussion

Acute mesenteric ischemia

Acute mesenteric ischemia may be caused by occlusions of arteries or veins (Figs. 1, 2, 3), as well as by non-occlusive reduction of intestinal perfusion (Fig. 4) [6, 7]. Rare causes of acute intestinal ischemia include spontaneous dissection of mesenteric vessels or dissection of the abdominal aorta [8]. Previous studies have shown CTA to be highly sensitive and specific for the diagnosis of bowel ischemia by demonstrating arterial or venous thrombosis and alterations of bowel indicating ischemia [8–10]. Typical changes include bowel dilatation (small bowel >3 cm, large bowel >6 cm) and wall thickening, abnormal or absent bowel wall enhancement, intramural hemorrhage, intestinal pneumatosis, and focal or diffuse intraperitoneal fluid collections [11]. Evaluation of the mesenteric vasculature by CTA may sometimes enable the underlying cause, such as atherosclerotic plaques, thrombus or occlusion, to be detected. Alterations of the bowel and the main vessels can usually be evaluated on axial images, while VR images offer the advantage of allowing the evaluation

Fig. 1 A 47-year-old man with nonspecific abdominal pain. Axial image (**a**) and lateral MIP (**b**) reveal a filiform stenosis at the origin of the celiac artery (*arrows*) with poststenotic dilatation. VR images (**c** and magnified view **d**) demonstrate the stenosis (*arrows*) as well as the collateralization through the pancreaticoduodenal arcade. In addition, an aneurysm of the inferior pancreaticoduodenal artery (*arrowheads*) is depicted, most probably resulting from the high collateral flow through the superior mesenteric artery
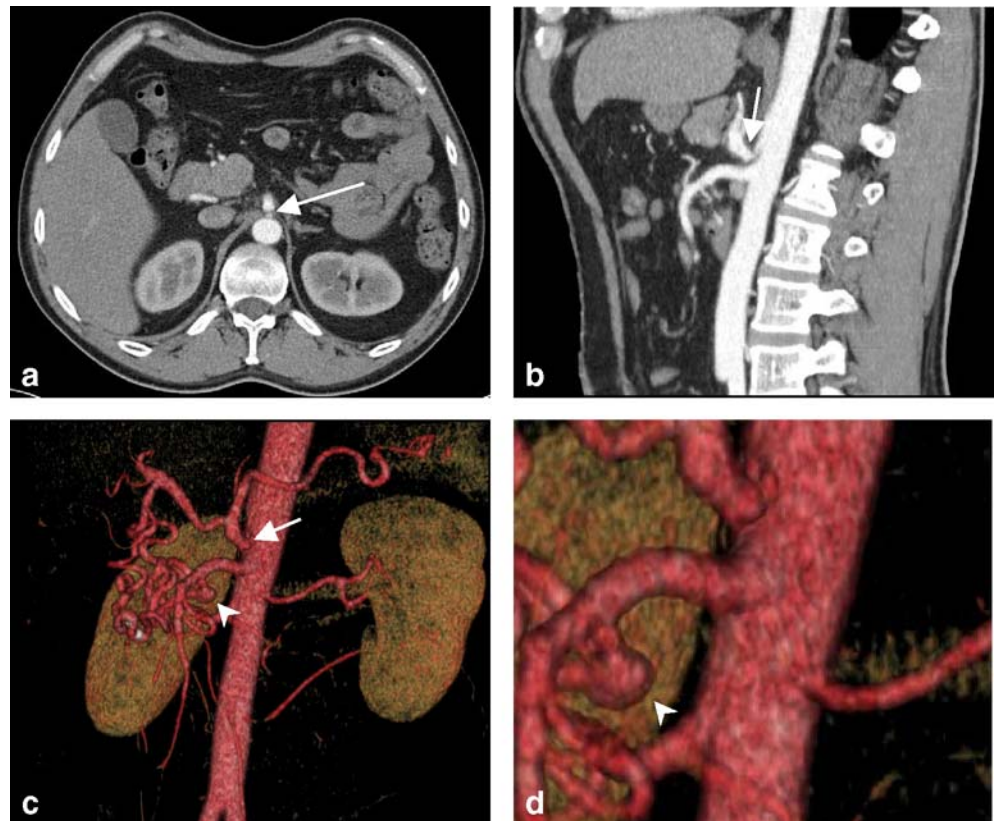
Fig. 2 A 59-year-old man with known cardiac aneurysm after myocardial infarction 1 year previously and sudden abdominal and left lower extremity pain. Axial image (**a**) displays a large mural thrombus in a left ventricular aneurysm (*arrow*) and multiple splenic infarctions (*arrowheads*). Coronal MPR (**b**) reveals segmental wall thickening of the ileum (*arrows*) indicating bowel ischemia. The thickslab VR image (**c**) depicts the source of the bowel ischemia as an embolus in the ileocolic artery (*arrow*). Additional thickslab VR image (**d**) also demonstrates thromboembolic occlusion of the left common iliac artery (*arrow*)
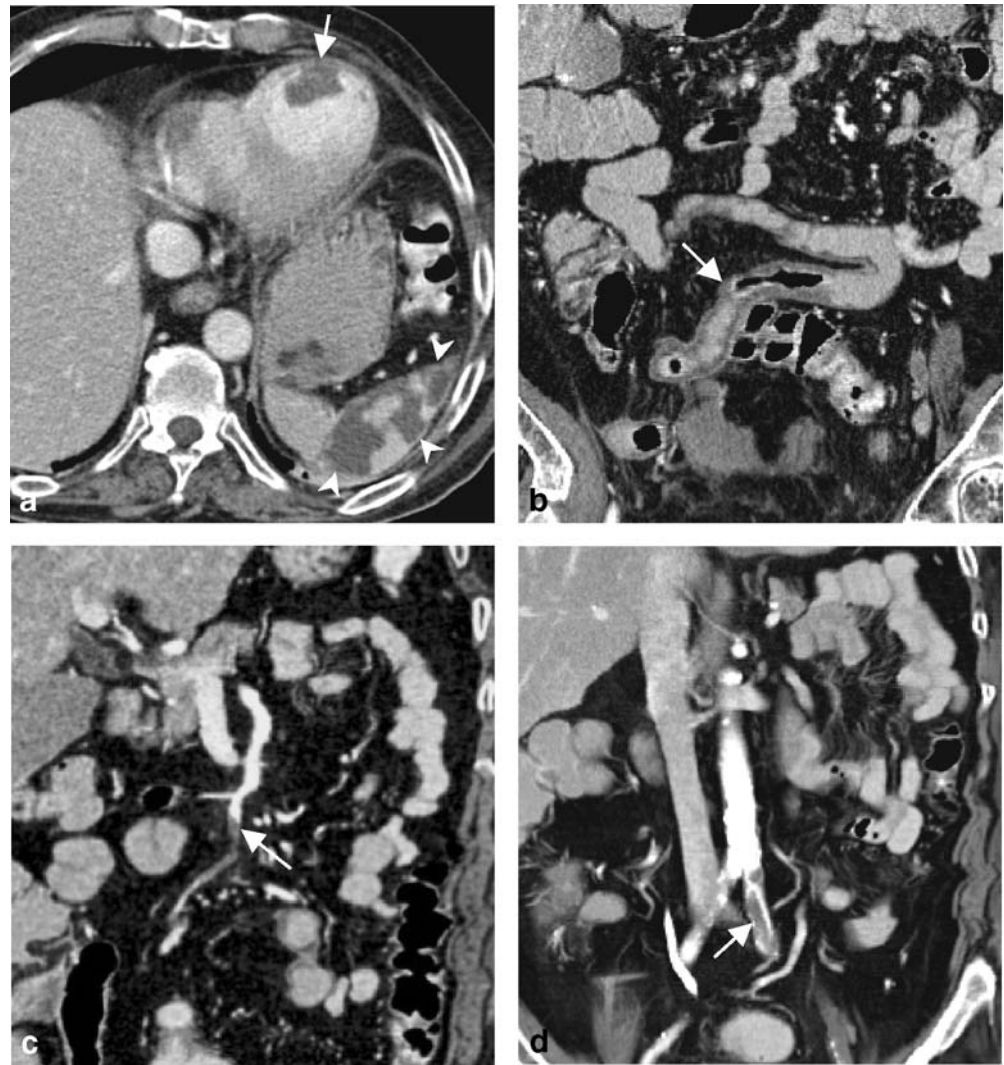
of mesenteric vessels from the origin to the distal branches on a single projection.

Nonocclusive mesenteric ischemia (NOMI) is commonly caused by decreased cardiac output resulting in splanchnic hypoperfusion. Typical angiographic signs for the diagnosis of NOMI include narrowing and vasoconstriction of multiple branches of the superior mesenteric artery, alternate dilatation and narrowing of intestinal branches, spasms of mesenteric arcades, impaired filling or occlusion of intramural vessels, reflux of contrast into the abdominal aorta, and spread out segmental arteries due to distention of bowel loops [7]. Some of these findings are difficult to depict on CTA. In addition, because the therapy of patients with NOMI consists of selective vasodilator infusion [12], some authors have proposed that a first-line conventional angiography be performed instead of CTA.

Segmental mediolytic arteriopathy

Segmental mediolytic arteriopathy (SMA) was first described in 1976 by Slavin and Gonzalez-Vitale [13]. It is characterized by a noninflammatory arteriopathy causing medial lysis of adult visceral arteries. Typical CT findings consist of thickening and dissection of the artery wall, multiple aneurysms of small vessels, and retroperitoneal bleeding (Fig. 5) [14]. Arterial wall thickening and dissection can be clearly demonstrated on MPR or MIP, while the extent of saccular aneurysms is better delineated using the VR technique owing to the complex small vessel anatomy of the typically affected arteries. Because of its rarity, no reliable information about the optimal therapeutic option is available. Surgical or interventional repair of aneurysms and endovascular stenting of arterial dissections may be necessary. Because of the similarity of SMA to polyarteritis nodosa, surgery with histopathological analysis for better differentiation has been proposed [15].

Fig. 3 A 46-year-old woman admitted for evaluation of venous bypasses. After occlusion of multiple visceral arteries 2 years previously, one bypass was connected from the inferior aorta to the celiac axis and superior mesenteric artery, and another from the right common iliac artery to branches of the superior mesenteric and common hepatic artery. Axial image (**a**) and axial MIP (**b**) show occlusion of the bypass (*arrows*). Lateral MIP (**c**) demonstrates the occluded bypass (*arrow*) and the unaltered occlusion of the celiac and superior mesenteric artery (*arrowhead*). VR image (**d**) depicts the occluded first bypass (*arrow*) and open second bypass (*arrowhead*). Another VR image (**e**) reveals the complex anatomy of the postoperative visceral vasculature and the advantage of reconstruction from 16-row CT data as compared to the 4-row CT examination 2 years previously (**f**); the shorter scanning time results in an improved contrast bolus exploitation and less venous overlay
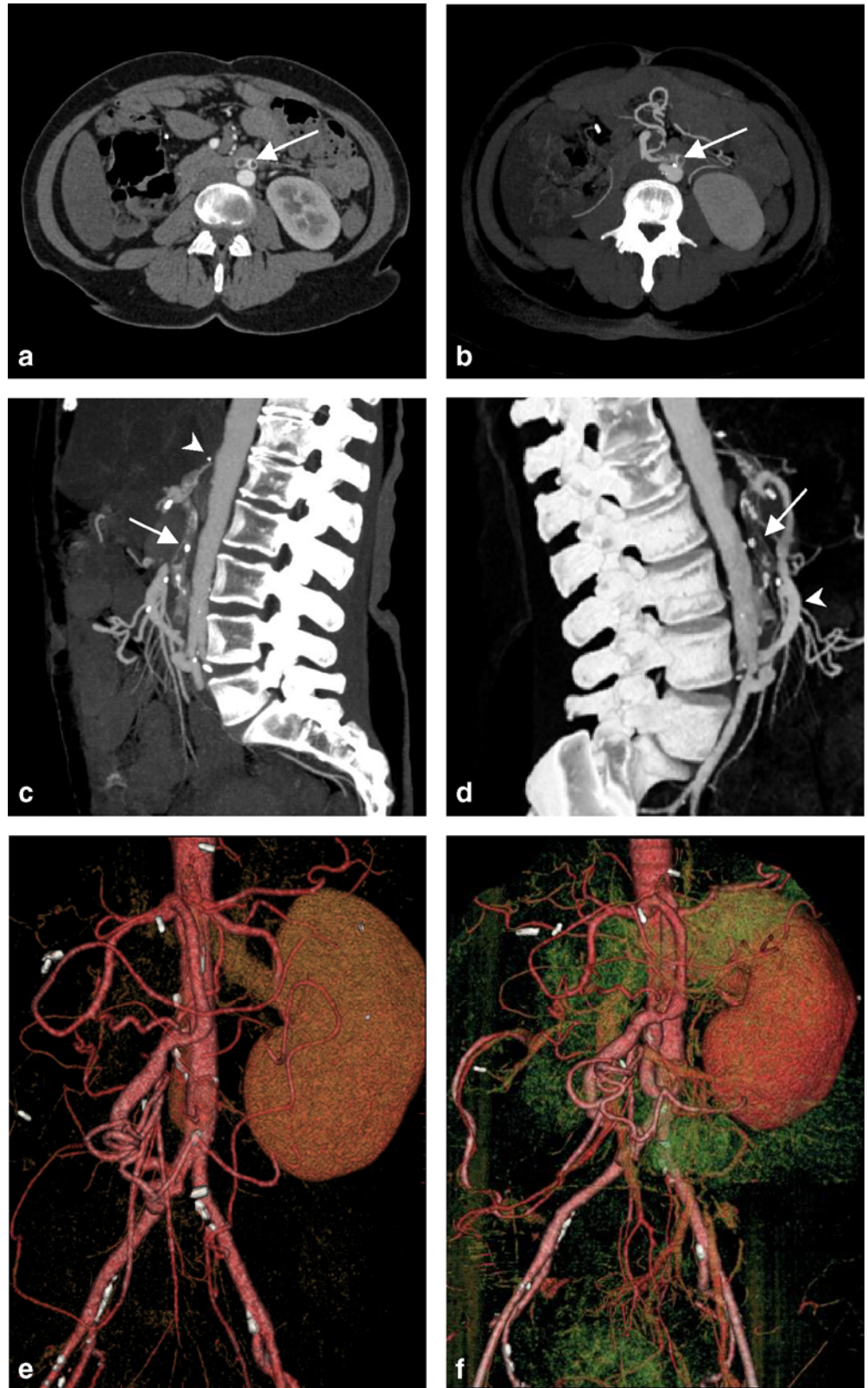
Fig. 4 A 61-year-old woman with elevated liver enzymes and abdominal pain after aortic and mitral valve replacement and known cardiac arrhythmia. Axial image (**a**) and coronal MIP (**b**) depict massive wall thickening and pneumatosis of the ascending and transverse colon indicating edema and ischemic necrosis (*arrows*). The coronal MIP (**b**) displays the normal opacification of the superior mesenteric vein, whereas the VR image (**c**) demonstrates the normal superior mesenteric artery branches without evidence of vessel occlusion (*arrowhead*). Considering the normally perfused mesenteric vessels, hypoperfusion due to low cardiac output is the most probable cause of the bowel ischemia in this case
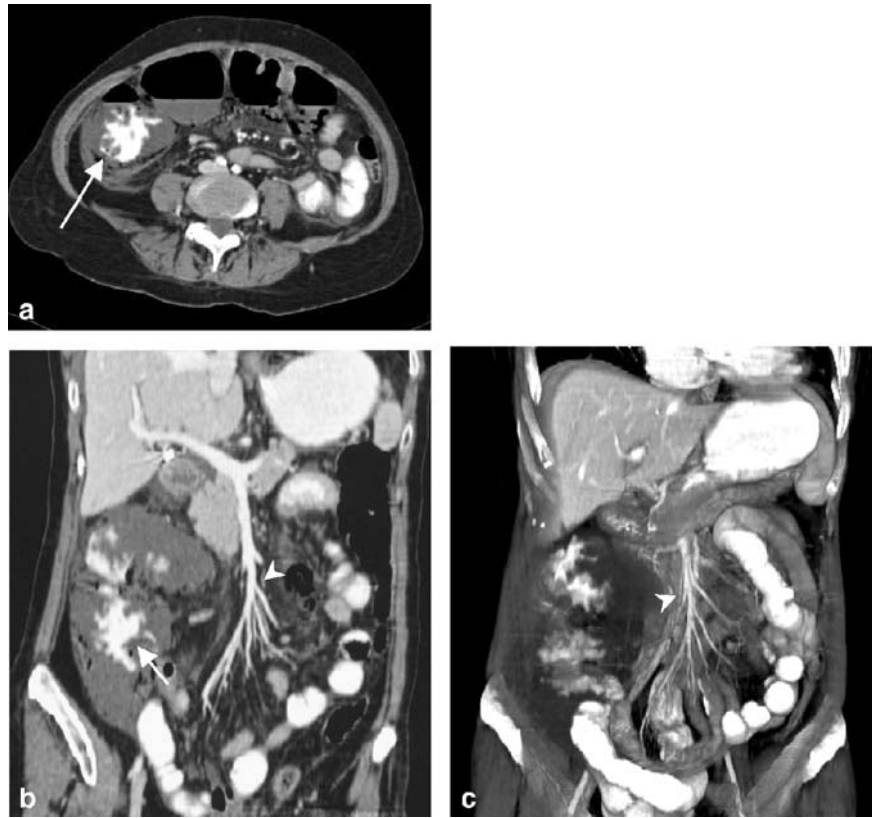

Fig. 5 A 38-year-old female with acute abdominal pain and vomiting. Axial image (**a**) shows caliber variability in the superior mesenteric artery (*arrow*). Another axial image (**b**) demonstrates an arterial gap reaching into the lumen (*arrowhead*). The VR image (**c**) clearly visualizes the caliber variability of the superior mesenteric artery. The diagnosis of segmental mediolytic arteriopathy was confirmed by selective conventional angiography (**d**)
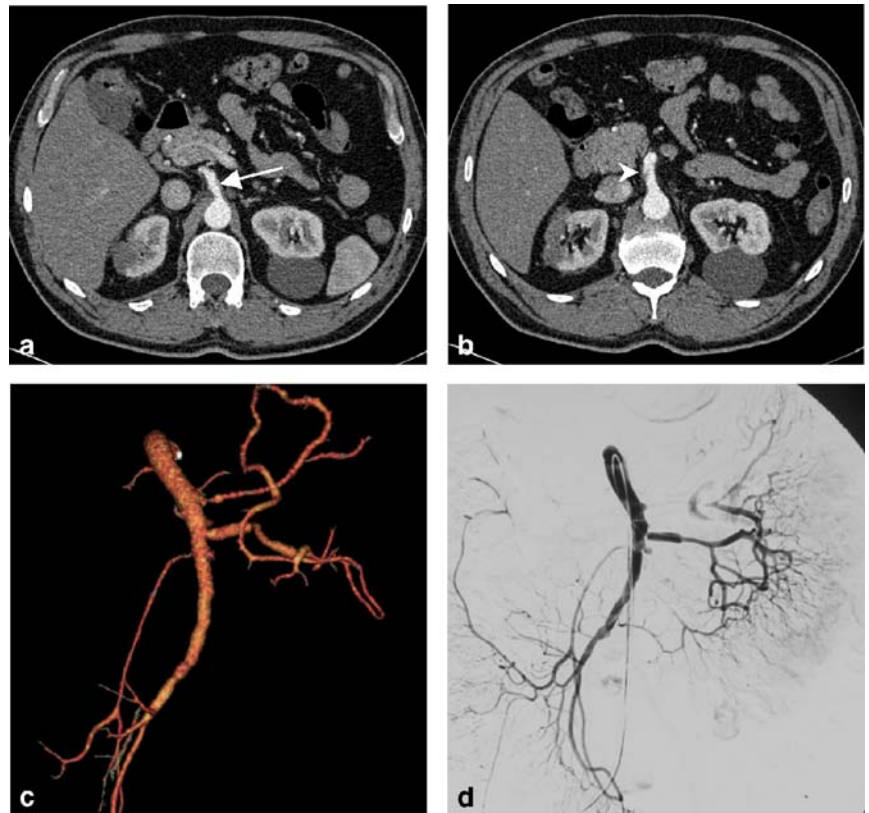
Fig. 6 An 84-year-old woman with penetrating aortic aneurysm ulcer and emergency stent-grafting. Due to the extent of the aortic aneurysm, the stent graft needed to be inserted in the nondilated part of the aorta covering the celiac axis. To maintain visceral perfusion, a mesentericotruncal Shelhigh bypass had to be placed. Post-interventional axial image (**a**) depicts the excluded aneurysm sac (*arrow*) and the stent graft (*arrowhead*) in a normal position. Lateral MIP (**b**) and oblique VR image (**c**) delineate the anatomy after endovascular intervention and successful surgery showing the perfused Shelhigh bypass from the superior mesenteric to the common hepatic artery
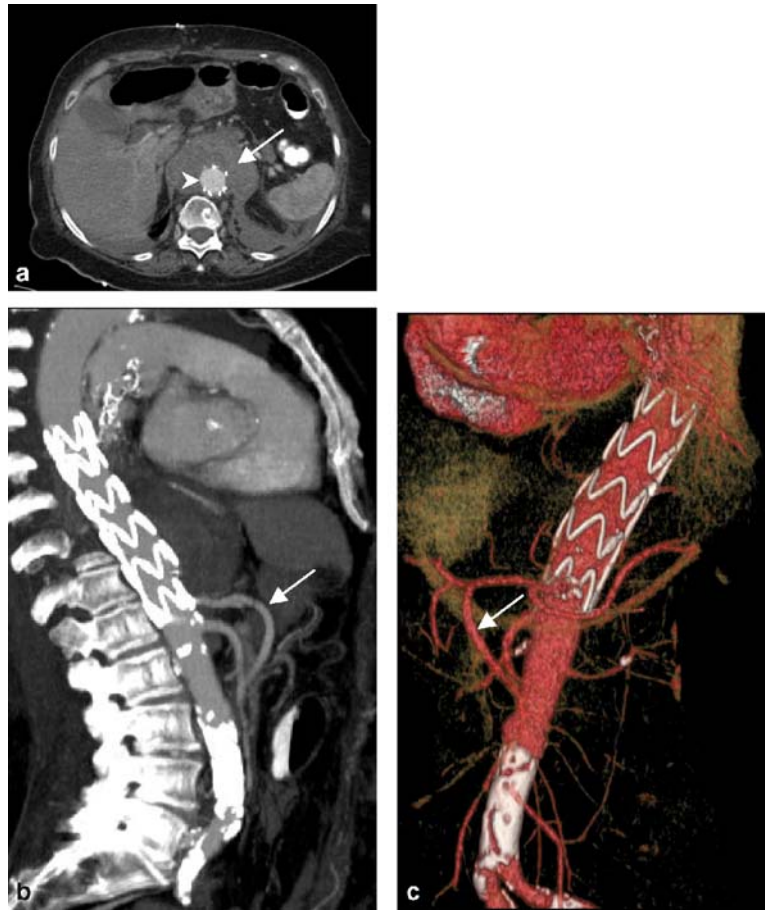

Fig. 7 A 40-year-old woman with known Takayasu arteritis. After complete occlusion of the aortic bifurcation, an extraanatomical aortic bypass was installed. To ensure visceral perfusion the celiac trunk and superior mesenteric artery had to be reinserted side-to-side to the bypass. Postoperative axial MIP (**a**) depicts the site of reinsertion to the celiac axis (*arrow*). The VR images (**b** and **c**) visualize the complex anatomy after surgery: The site of reinsertion of the celiac axis (*thin arrow*) and the side-to-side anastomosis of the superior mesenteric artery (*black arrowhead*) are excellently visualized. In addition, a stenosis with poststenotic dilatation at the origin of the inferior mesenteric artery (*thick arrow* in **b**) is shown
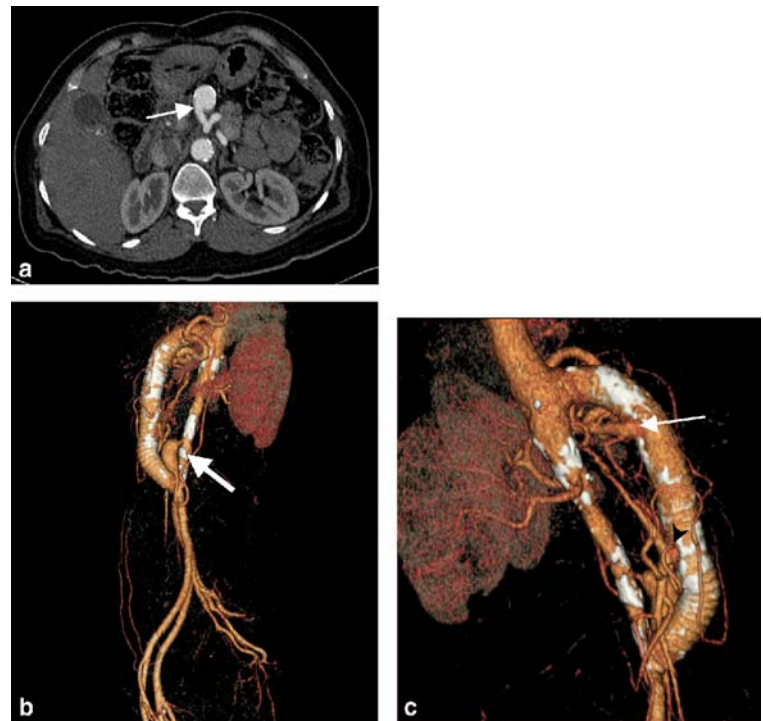
Fig. 8 A 65-year-old female with ruptured aortic abdominal aneurysm. The patient received an aortic graft with reinsertion of the visceral vasculature. Axial data sets, MPR and MIP (**a**) failed to clearly depict the new anatomy of the reinserted vessels. Owing to the three-dimensional effect and rotation capabilities, only VR images (**b**–**d**) are able to sufficiently demonstrate the reinserted renal and celiac arteries. Note the small aneurysm in the middle of the right renal artery (*thin arrow* in **b**), the tortuous course of the left renal artery around the celiac trunk (*arrowhead* in **c**), and the opacification of the renal parenchyma. The VR image (**d**) from a lateral oblique view shows the origin of the obstructed inferior mesenteric artery (*thick arrow*)
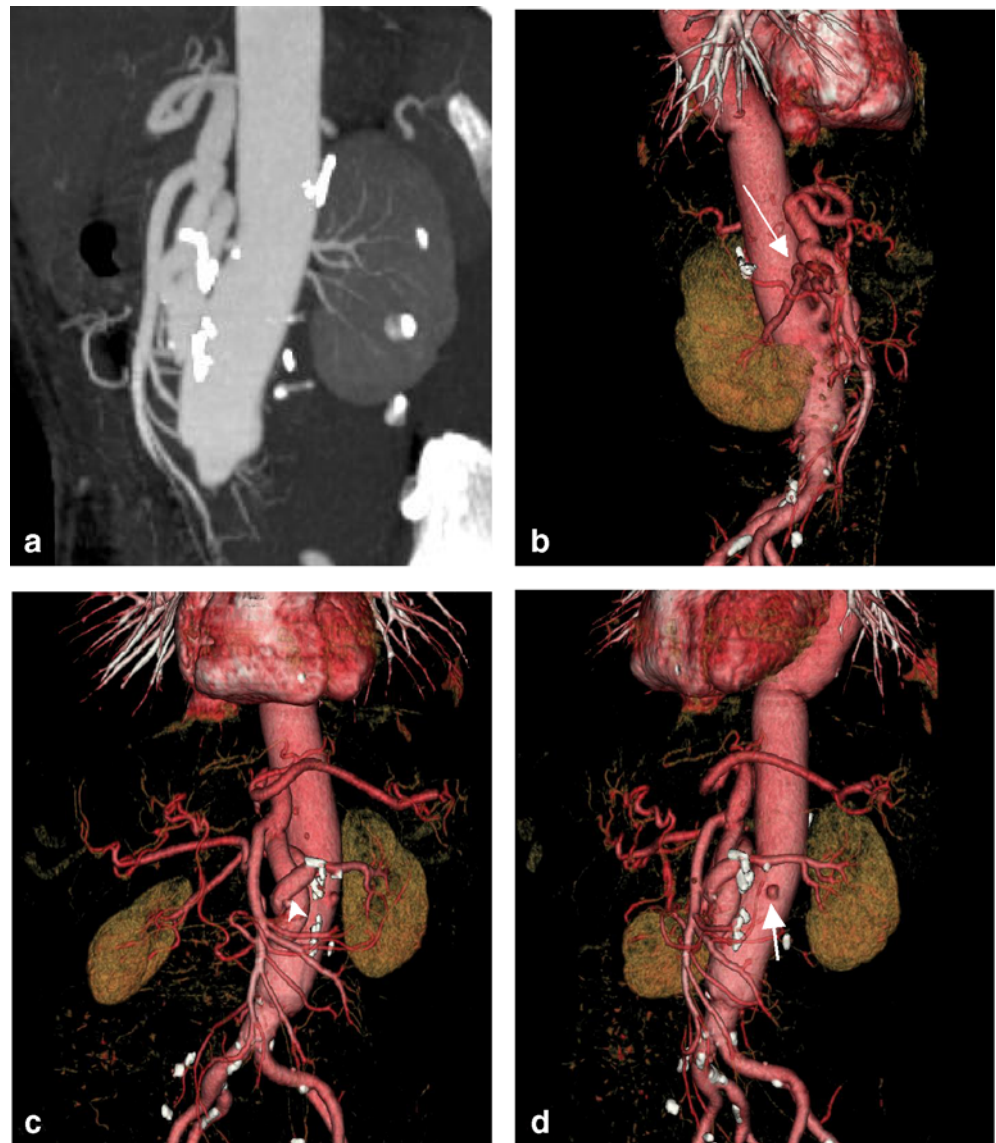
Pre- and postinterventional and postsurgical imaging

In emergency abdominal vascular disease, CTA provides the single most effective imaging tool [14]. In contrast to conventional angiography, CTA is not only able to detect the pathological vascular condition but also its effects on organs by delineating parenchymal perfusion [5]. In addition, CTA can help the surgeon or interventional radiologist plan treatment, for example by allowing the occluded vessel's diameter to be measured or the communication points for stent graft placement to be defined [16]. Due to these advantages and the wide availability of CT, CTA with two- and three-dimensional reconstructions is increasingly becoming the initial and single imaging method for planning surgical or angiographic interventions [14].

Postsurgical evaluation of vascular anatomy is often complex and can only hardly be appreciated on axial images alone. Therefore postprocessing modalities, and in particular the VR technique, can be extremely helpful in understanding the extra-anatomical course of the postoperative mesenteric vessels (Figs. 3, 6, 7, 8).

Conclusion

Multislice CTA is an excellent tool to assess a wide variety of abdominal vascular diseases and offers a noninvasive imaging method for pre- and postinterventional evaluation of mesenteric perfusion.

The VR technique in particular provides images of high quality with excellent visualization of pathological conditions and their anatomical relationship with adjacent structures, that often cannot be confidently assessed by axial CT images alone.

CTA allows the success or failure of vascular intervention to be determined and is consequently the preferred imaging modality for both pre- and postinterventional planning and follow-up studies.

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