MULTIDETECTOR COMPUTED TOMOGRAPHY OF THE ABDOMEN

Multidetector computed tomography (MDCT) has vastly expanded the role of diagnostic CT imaging.

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Rapid technological advancement was made in the first few years after diagnostic imaging using computed tomography (CT) scanning began in the early 1970s. Thereafter, the field of CT scanning remained relatively static until the advent of slip-ring technology in the 1990s, which made possible spiral or helical scanning. Although abdominal CT was already commonplace with use of the older sequential CT scanners, spiral CT now allowed faster abdominal imaging in multiple phases of enhancement after intravenous contrast enhancement. This refined the diagnostic quality of CT images. Recently, advancement in CT soft- and hardware has led to the development of multidetector CT (MDCT) imaging. MDCT has not only further improved diagnostic CT imaging but has also expanded the role of CT, including CT angiography and CT colonography.

Put simply, MDCT involves spiral/helical scanning, replacing the single CT detector with up to 64 detectors, and the use of massive computing power for image reconstruction. Therefore, up to 64 image slices through the subject are obtained in a single 360° rotation of the X-ray tube. The two major advantages of MDCT are the production of volumetric data sets with truly isotropic voxels (imaged volume elements) and a significant increase in coverage speed allowing optimal use of intravenous contrast. This made reconstruction of various slice thicknesses possible and allows review of data using multiplanar reconsructions (MPR), maximum-intensity projections (MIP) and volume-rendered techniques (VRT), all of which improve the diagnostic quality of CT imaging.

MDCT ANGIOGRAPHY OF THE ABDOMEN

MDCT allows the acquisition of a large volume of data sets in the optimal contrast-enhanced phase, making it ideally suited for CT angiography. Imaging in the 'arterial phase' after intravenous administration of contrast can be reviewed using MPR, MIP or VRT.

Atherosclerotic complications of the abdominal aorta such as aneurysms, occlusions, ulceration and dissection can be exquisitely imaged using MDCT angiography, largely replacing diagnostic catheter angiography. MDCT has been proposed as the modality of choice for the evaluation of emergent, non-traumatic, abdominal aortic aneurysm and for the complete evaluation of the aorta with acute dissection. Using MDCT angiography, branch occlusions and other complications can be detected.

Accurate differentiation between supra- and juxtarenal aneurysms from infrarenal aneurysms can be achieved (Fig.1). MDCT is also ideally suited for the evaluation of leaking or ruptured aneurysms, to assess the suitability of aneurysms for endovascular repair, and to evaluate complications after endovascular repair, such as iliac limb thrombosis, graft migration and endoleaks.

HEPATOBILIARY MDCT

Accurate imaging in the hepatic arterial and portal venous phases is the major advantage of MDCT in terms of liver

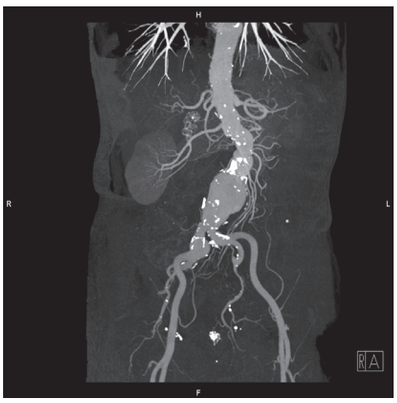

Fig. 1. MIP CT angiogram showing an infrarenal abdominal aortic aneurysm. Incidental gallstones are also present.

imaging. Subtle hyper-enhancing lesions, such as small hepatocellular carcinomas and highly vascular metastases, can be detected earlier and more accurately with improved enhancement and multiplanar imaging. Benign lesions such as focal nodular hyperplasia and cavernous haemangiomas can also be more accurately diagnosed, at times preventing further unnecessary intervention. Hepatic metastases are commonly hypodense compared with liver tissue in the portal venous phase. Accurate phasic scanning and 3-D post-processing techniques allow earlier and more accurate detailing of the number, location and size of metastases, which is of major importance if surgical resection is considered. Some authors have reported that the volume-rendered (VR) image of the liver is the most accurate way of detecting subtle lesions.

MDCT angiography allows pre-operative, non-invasive evaluation of the hepatic arterial, hepatic venous and portal venous anatomy, which is of particular importance before transplant surgery. Post-transplant complications such as hepatic arterial occlusion or pseudo-aneurysm formation are also readily detectable. Portal venous thrombosis with venous collaterals (Figs 2 and 3) and early tumoral venous invasion (e.g. invasive hepatocellular carcinoma) can be evaluated.

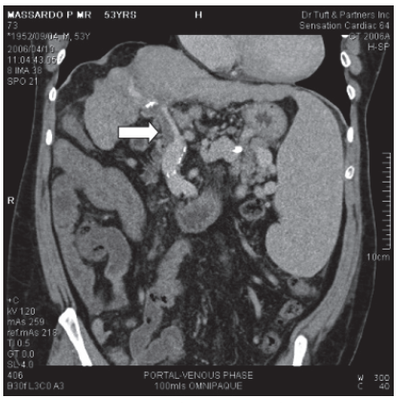

*Fig. 2. MPR portal venous phase image showing partial portal vein thrombosis (*white arrow*). Note the small irregular cirrhotic liver in a patient with alpha-1 antitrypsin deficiency.*

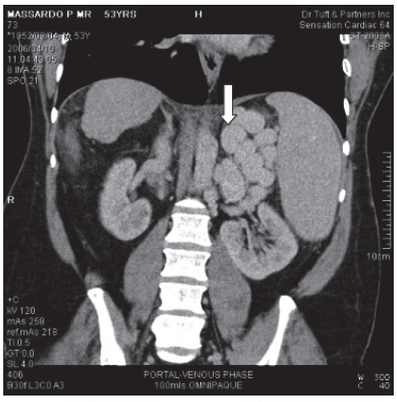

*Fig. 3. The same patient shown in Fig. 2, demonstrating multiple venous collaterals (*white arrow*) and splenomegaly as a consequence of portal hypertension.*

Diagnostic assessment of biliary disease with MDCT can be accurately performed with regard to obstructing lesions. Minimum-intensity projection (MinIP) images are particularly useful in evaluating the site of obstruction. CT cholangiography using biliary contrast media has long been described but is not widely used or accepted because of poor patient tolerance of contrast agents.

Hepatic trauma can be accurately and rapidly assessed with MDCT (Fig. 4).

PANCREATIC MDCT

CT has always been the investigation of choice in the full evaluation of the pancreas. Multiplanar and 3-D techniques with MDCT are ideally suited to imaging of the pancreas

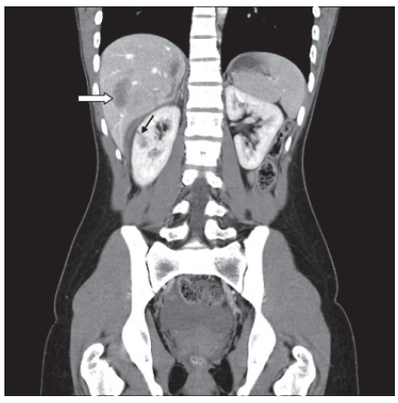

*Fig. 4. Patient with blunt abdominal trauma. The liver contusions (*white arrow*) and renal laceration (*black arrow*) are clearly shown on the MPR image. Note the haemoperitoneum in the hepatorenal pouch.*

owing to its orientation and position in the retroperitoneum. Acute and chronic pancreatitis and potential complications (particularly pancreatic necrosis and pseudocyst formation) can be evaluated well using MDCT (Fig. 5).

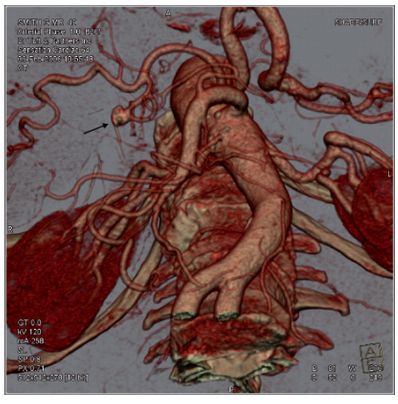

*Fig. 5. An arterial phase VRT image showing an aneurysm (*black arrow*) arising off the gastroduodenal artery in a patient with previous pancreatitis (courtesy Dr M Payne).*

The primary role of CT in imaging pancreatic adenocarcinoma lies in the assessment of potential resectability. In this regard, arterial-phase imaging can help to identify arterial encasement. Pancreatic-phase imaging with maximal enhancement of normal pancreatic tissue is useful in delineating the full extent of the hypo-enhancing lesion. Portal venous-phase imaging best evaluates the presence of liver metastases and peripancreatic lymphadenopathy.

Recently, advancement in CT soft- and hardware has led to the development of multi-detector CT (MDCT) imaging.

MDCT allows the acquisition of a large volume of data sets in the optimal contrast-enhanced phase, making it ideally suited for CT angiography.

Accurate imaging in the hepatic arterial and portal venous phases is the major advantage of MDCT in terms of liver imaging.

An increased rate of detection of islet-cell tumours with MDCT has been reported. The sensitivity of MDCT in the detection of insulinomas has been reported as 63% using the pancreatic phase. However, this remains far below the sensitivity of endoscopic ultrasonography. Other pancreatic tumours such as cystic pancreatic neoplasms (serous and mucinous adenomas and adenocarcinomas) and intraductal papillary tumours are well evaluated using MDCT with high sensitivity.

RENAL MDCT

Spiral CT is well established in the evaluation of renal calculi. MDCT further improves on the accuracy of spiral CT in detecting the presence and location of calculi (Fig. 6). Most renal calculi are radio-opaque. Of note is the fact that renal calculi related to certain antiretroviral therapeutic agents in HIV-infected patients are commonly radiolucent.

Benign and malignant renal tumours can be fully evaluated using MDCT (Fig. 7). More accurate classification of renal cysts can be made by differentiating simple cysts from cystic renal cell tumours. The extent of renal cell carcinoma, particularly with regard to venous invasion, is more effectively evaluated. Benign tumours such as angiomyolipomas can also be evaluated fully, demonstrating arterial feeding vessels for subsequent embolisation. Similarly, MDCT has advantages in imaging inflammatory renal lesions such as renal abscesses and xanthogranulomatous pyelonephritis.

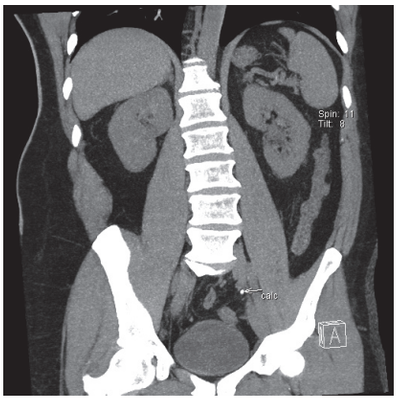

*Fig. 6. An impacted distal left ureteric calculus (*small white arrow*) resulting in left hydronephrosis with perinephric stranding, shown on an MPR image without intravenous contrast.*

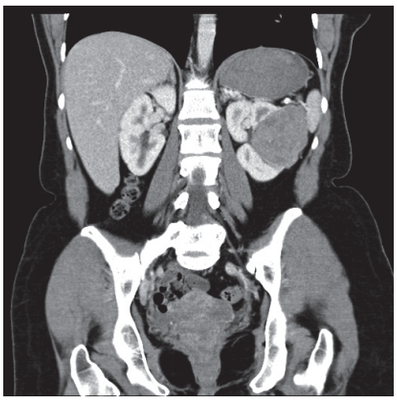

Fig. 7. A large renal cell carcinoma involving the interpolar region of the left kidney on a contrast-enhanced MPR image.

MDCT angiography is a particularly useful non-invasive method of assessing renal artery stenosis (RAS) and the evaluation of renal hypertension, with sensitivity and specificity in detecting haemodynamically significant RAS reported to be as high as 92% and 99%, respectively. In renal donor evaluation, MDCT angiography can identify accessory renal arteries and variant venous anatomy. However, it should be borne in mind that MR angiography offfers similar sensitivity and specificity without the use of ionising radiation, but requires a co-operative patient and involves a longer imaging time.

CT urography has been extensively investigated with the aim of using MDCT as the one-stop evaluation of the renal system (Fig. 8). Currently, MDCT has not surpassed conventional contrast urography in the evaluation of subtle urothelial lesions, but does however allow evaluation of the wall of the urinary tract and its surrounding structures.

MDCT COLONOGRAPHY

MDCT colonography is a relatively new technique requiring bowel preparation and colonic gas insufflation with administration of a muscle relaxant (commonly hyoscine butylbromide). The best diagnostic images are obtained by scanning subjects in the prone and supine positions. Images are reviewed using 2-D and 3-D (endoluminal view) reconstructions (Figs 9 - 11).

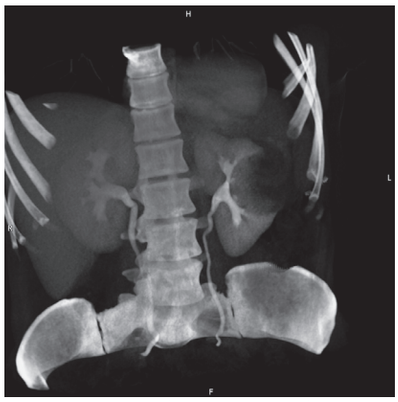

Fig. 8. 'Urographic' image in the same patient shown in Fig. 7 showing the displacement of the pelvicalyces by the renal tumour.

The accuracy of MDCT colonography in detecting colorectal polyps in high-risk groups has long been reported. MDCT colonography, or virtual colonography as it is commonly referred to, always offered the promise of a non-invasive screening tool for colorectal carcinoma, which is reported to be the third most fatal cancer in men and women. A recent landmark publication has confirmed

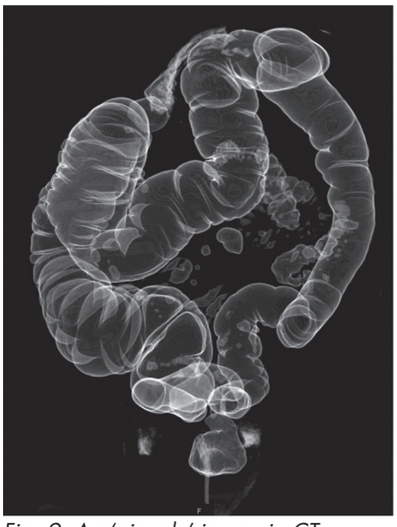

Fig. 9. An 'air-only' image in CT colonography providing an overview of the colon.

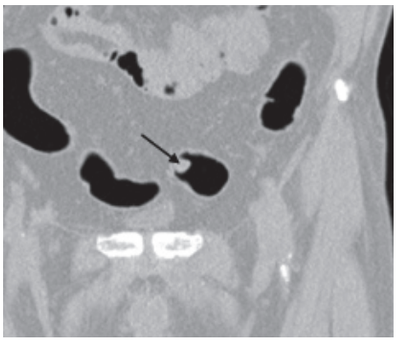

*Fig. 10. A 2D coronal image showing a small colonic polyp (*black arrow*).*

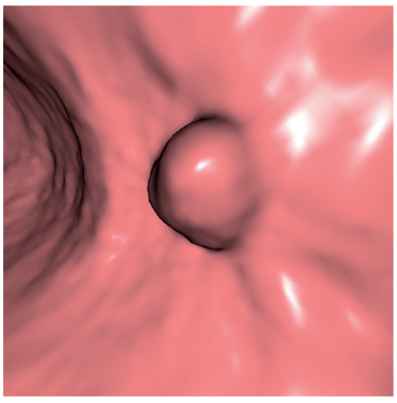

Fig. 11. A 3D 'endoluminal' view showing the same colonic polyp shown in Fig. 10.

the effectiveness of the technique in a low-risk population, making it suitable for screening. New developments have further refined the technique. These include computer-aided detection, faecal tagging agents and computed faecal subtraction. It is hoped that MDCT colonography may some day provide a method of screening for colonic polyps without the use of cathartic agents.

Other uses of MDCT colonography include assessment after incomplete colonoscopy and assessment of proximal synchronous lesions with occlusive carcinoma.

SMALL-BOWEL MDCT

Imaging with orally administered positive contrast, negative contrast and MDCT enteroclysis has been proposed. Applications include Crohn's disease, small-bowel tumours, obstruction and ischaemia (Figs 12 - 15).

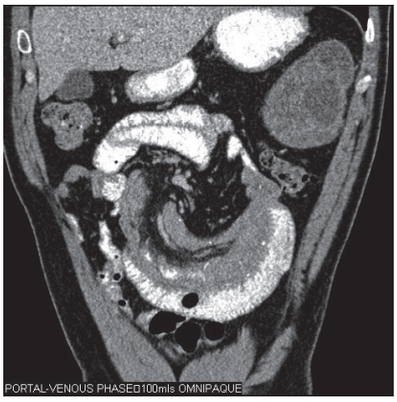

Fig. 12. Enterocolic intussusception shown in a coronal MPR image with oral contrast. Note the small-bowel dilatation (courtesy Dr D Solomon).

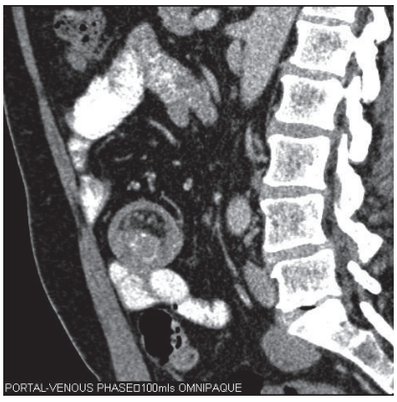

Fig. 13. The same patient as in Fig.12, with a cross-section reconstructed through the intussusception. Note the loop of small bowel and a part of the mesentery (low-density structure) within the large-bowel segment (courtesy Dr D Solomon).

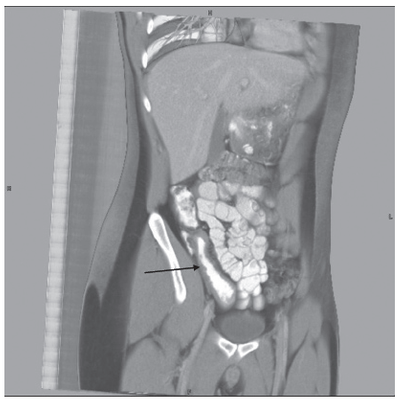

*Fig. 14. A VRT image with orally administered contrast showing extensive, irregular mural thickening of the terminal ileum (*arrow*) in a patient with active Crohn's disease.*

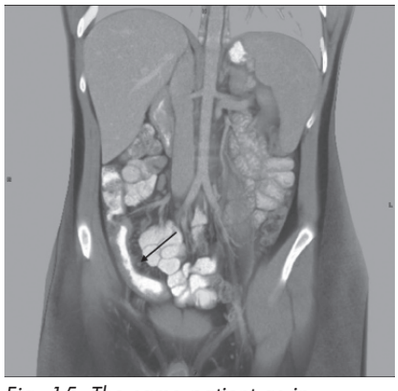

*Fig. 15. The same patient as in Fig.14, showing extensive thickening of the vasa recta (*arrow*) secondary to inflammation of the terminal ileum – the so-called comb sign in Crohn's disease.*

MDCT is gaining acceptance as a primary imaging technique in Crohn's disease. The reported sensitivity and specificity for advanced disease is 95% and 96%, respectively. These values for early disease are both only 70%. A very effective method in assessing early disease is capsular endoscopy, but it should only be used in the absence of strictures because of the risk of obstruction. Therefore some authors have advocated MDCT of the small bowel prior to capsular endoscopy in all patients.

Acute mesenteric arterial occlusions can be well evaluated non-invasively using MDCT angiography with a sensitivity similar to that of conventional catheter angiography. Even gastrointestinal arterial bleeds can often be identified on MDCT angiography (Fig. 16).

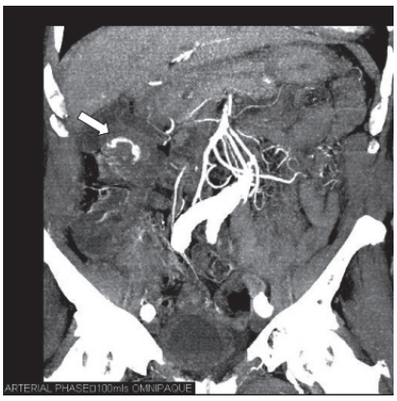

Fig. 16. An active bleed into the ascending colon (arrow) shown in this arterial phase coronal MPR image. Note that oral contrast was not given (courtesy Dr D Solomon).

CONCLUSION

MDCT had made diagnostic CT scanning faster and more accurate. The role and applications of abdominal MDCT scanning are expanding rapidly. One should bear in mind that for all advancements, MDCT is still based on the use of ionising radiation. Therefore, the available literature must be reviewed regularly to guide appropriate clinical use.

Further reading

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IN A NUTSHELL

The development of multidetector CT (MDCT) imaging has not only further improved diagnostic CT imaging, but has also expanded the role of CT, including CT angiography and CT colonography.

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