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TOSHIBA MEDICAL SYSTEMS JOURNAL

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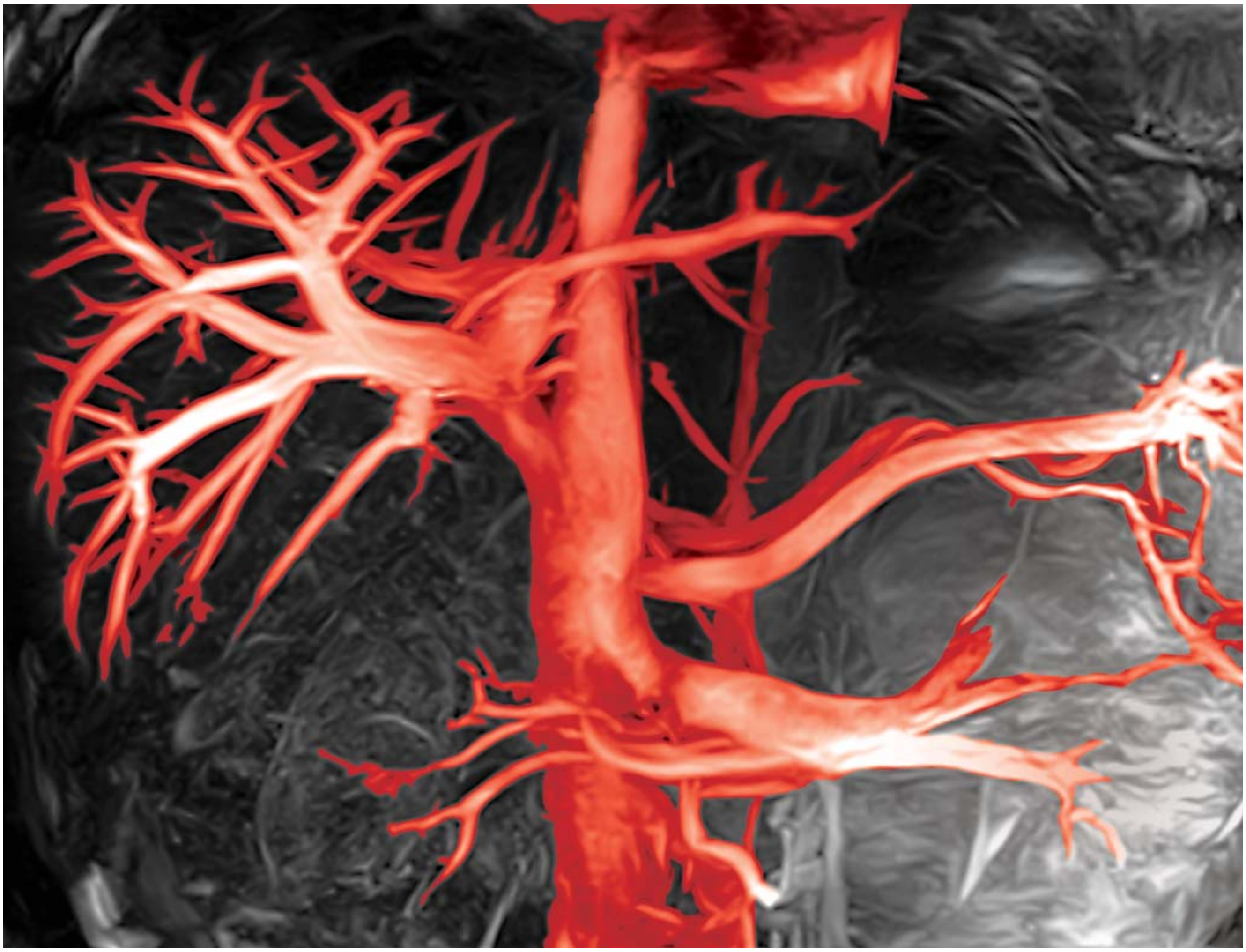
Leading Innovation >>>



X-Ray
Super Noise Reduction in Interventional Imaging

Cardiac CT
The robustness of the Aquilion ONE and Single Beat Coronary CTA

MR
Vantage Titan 3T: Unprecedented image quality and optimized patient comfort

Utrasound
VIAMO at Glastonbury Festival in the U.K.

VISIONS

15·2010

Creative processed clinical image of liver MRA without contrast agent acquired with Toshiba's new Vantage Titan 3T

TOSHIBA MEDICAL SYSTEMS

Imprint

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Dear reader,

True innovations only happen every once in a while. I'm not talking about the little improvements that make sense or small enhancements that make our lives easier or more comfortable. I'm talking about revolutionary, unprecedented innovations capable of supporting improved clinical outcomes at optimized economic value.

Toshiba's prime example of this is the AquilionONE volume CT scanner. A third party study undertaken in the United Kingdom investigated the economic value of the new system in patients with acute chest pain. Employing the prospective triggering technique with AquilionONE and capturing the entire heart in less than one heartbeat make it possible to perform routine low-dose imaging. Incorporating AquilionONE into the diagnostic pathway of patients with acute chest pain has the potential to generate significant economic benefits to a hospital. This innovative system has the potential to release capacities on the AMU (Acute Medical Unit = emergency unit) and in-patient units and at the same time save costs, potentially ranging from € 375.000 to € 1,800,000 per annum, depending on the usage, for a typical NHS (National Healthcare System) acute care hospital. Further research is ongoing to validate new diagnostic pathways with AquilionONE and derive associated economic and other benefits.

More about - for example - the robustness of the system for Cardiac CT examinations can be read in the article written by Dr. Russell Bull, Consultant Radiologist Royal Bournemouth Hospital, UK.

Another example is the introduction of the new Vantage TITAN 3T MRI system. This device sets new standards in comfort, imaging and productivity in the 3T segment. It is equipped with Toshiba's unique "Pianissimo" noise-reduction technology and provides uncompromised whole body image quality even without the need for contrast agents. In short: a true 3T whole body MRI system!

This edition of VISIONS magazine is published and distributed during Europe's largest radiology congress: ECR 2010. Toshiba's participation in this congress includes several workshops, a satellite symposium on Sunday and a 230 m^2 booth (#316 - area EXPO C).

Looking forward to seeing you at our booth showing you our innovations in Radiology!

Kind regards,

Jos Ruis
Vice President and Director
Toshiba Medical Systems Europe BV


STANDBYOU
ready to act

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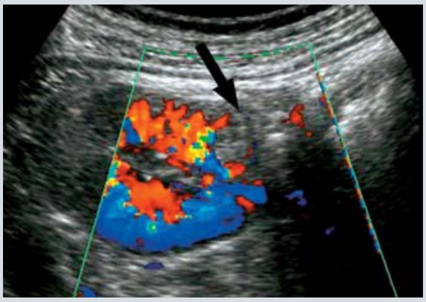
In the last decade, cardiac CT has gained widespread acceptance for noninvasive coronary artery angiography. Toshiba's Aquilion ONE is the only CT scanner in the world capable of capturing images of the entire heart and coronary arteries in a single rotation without any need for patient motion. Page 14



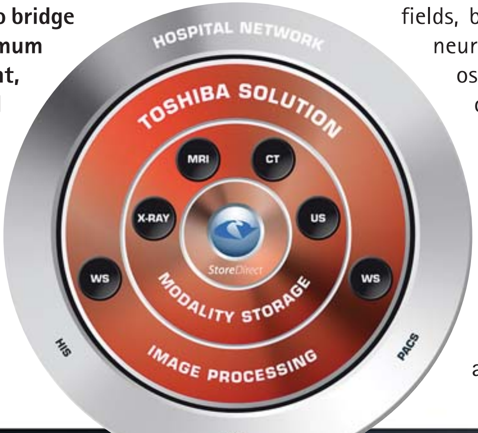
RFA radiofrequency ablation (RFA) of renal tumours is an efficient alternative to conservative surgery. Ultrasonography (US) and contrast-enhanced ultrasonography (CEUS) play a key role at each step of the management of renal RFA. Page 38

Toshiba's new Vantage TITAN 3T sets new standards in Comfort, Imaging and Productivity. Page 36

Bridging the Gap in Imaging IT

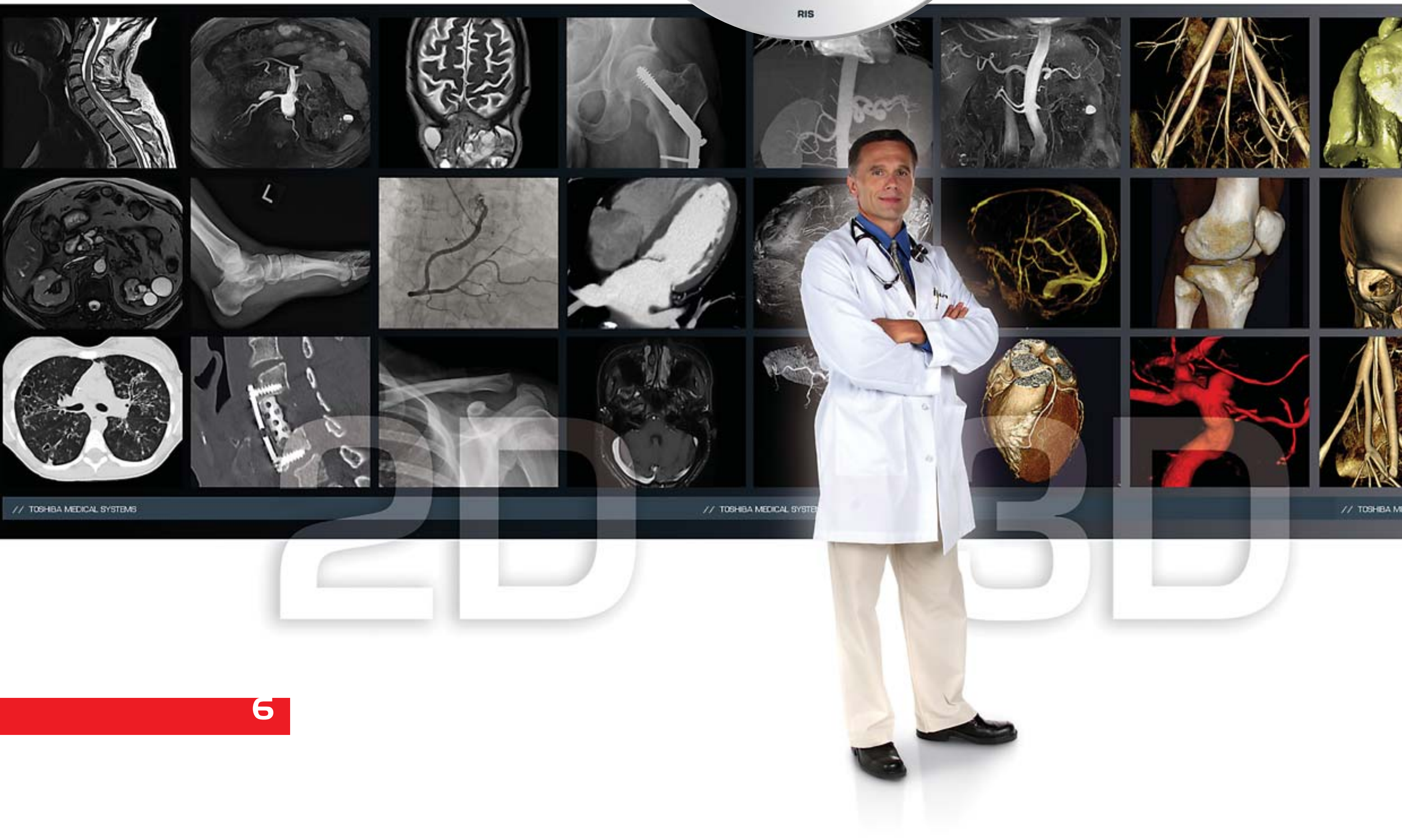
Interview with Dr Willem Overlaet, Senior Manager Connectivity
Solutions Group at Toshiba Medical Systems Europe

Technology is leading the way to enable hospitals to diagnose and treat more and more patients at earlier stages of disease and to deliver better clinical outcomes. VISIONS takes a look at how the introduction of new technologies requires a holistic approach to bridge IT gaps and to provide optimum benefits to physician, patient, radiology department and hospital, with Dr Willem Overlaet, Senior Manager Connectivity Solutions Group at Toshiba Medical Systems Europe.



VISIONS: *How has technology changed the lives of physicians and patients?*

Willem Overlaet: New image acquisition technologies, such as 3D and 4D imaging, offer considerable clinical benefits in a variety of medical fields, be it radiology, cardiology, neurology, women's health or osteoarticular systems. One of Toshiba's latest innovations in CT technology, the AquilionONE™, enables faster patient throughput and new dynamic volume imaging applications including 4D DSA CT, 4D moving joints CT, 4D perfusion in organs and 4D lung evaluation.



> “**New image acquisition** *technologies, such as 3D and 4D imaging, offer considerable clinical benefits in a variety of medical fields...”*

Radiologists all over the world have access to more and more diagnostic tools to carry out their work to a higher and higher standard and are able to diagnose more patients with higher precision, in a shorter space of time. Because of the level of clinical information which is now available with these new tools, technology, such as imaging is also playing an increasing role in treatment and post-treatment solutions as well as diagnosis.

Today's medical environment rapidly adopts new technology. Innovations which were once thought of as being the stuff of science fiction quickly become mainstream applications and as a consequence, the role and the communication of physicians is changing. They are able to create clinical value around new technology and develop more profound specialisms which in turn advances medical knowledge and treatment options for patients further.

VISIONS: *What impact does the introduction of new imaging technology have on the radiology department?*

Willem Overlaet: The modern radiology department is increasingly under pressure to deliver the best results in terms of accuracy, earlier diagnosis and achieve the highest possible patient throughput. Whilst the introduction of new technology brings with it new clinical opportunities, it also means there is more and more complex data to be processed. Integrating new technology into existing healthcare IT systems is an important potentially limiting factor in the development of the radiology department.

Take for example the introduction of 3D and 4D imaging equipment: this technology offers more settings, options and therefore more parameters for recording datasets. Post-processing will assume a more prominent place in the daily workflow, and it becomes more complex for the modern radiology department to manage using old methods.

In addition, hospital IT managers can become challenged in their investment priorities by the arrival of new 4D imaging equipment in radiology.

“**Innovations** *which we once thought of as being the stuff of science fiction quickly become mainstream applications...”*

Traditionally, hospital PACS serve for the long-term archiving of image datasets and diagnostic results, but in some instances 4D imaging may produce very large and complex image studies in an output format and size which may not be managed or retrieved smoothly via current systems.

The Connectivity Solutions Group of Toshiba Medical Systems is dedicated to developing solutions to allow physicians to optimize the use of new technology whilst easing the burden on the existing hospital IT infrastructure.

VISIONS: *What solutions are available to assist radiology departments with integrating new equipment?*

Willem Overlaet: We invest in two parallel activities to ensure our customers receive integrated solutions.

The first activity handles the interoperability of new equipment. Toshiba works with insight into the requirements of radiologists and IT specialists from all over the world. It follows closely the Technical Framework of the IHE – “Integrating the Healthcare Enterprise” – a group formed by a community of radiologists and information technology users and experts in 1998 to improve the way computer systems in healthcare share information. The very first IHE activities took place at the congresses of RSNA (Radiological Society of North America) 1999 and HIMSS (Healthcare Information and Management Systems Society) 2000, in which Toshiba was an active participant. Now, ten years later, IHE has expanded its activities beyond the domain of radiology and also has grown into a global initiative. Toshiba still contributes towards the development of this community in a two-way relationship. The success of IHE is based on a four-step process designed to allow true interoperability to be implemented. The IHE group gathers interoperability case requirements, identifies available standards, and develops technical guidelines that manufacturers can implement in new equipment and test in combination with products from other vendors.

The second activity is providing solutions to new challenges that surface with the introduction of new technology. Innovations in diagnostic imaging systems can create new integration challenges for imaging IT. This is well illustrated by our recent product release of the new StoreDirect (EOL-series). A temporal image repository that enables the integration of Toshiba’s latest CT technology, the Aquilion ONE, into any existing IT environment. In this solution concept, StoreDirect keeps the original image data available over a longer period of time for the broad spectrum of postprocessing techniques that are created by this CT modality. Full-sized patient studies can be stored at original resolution, in DICOM format and fast communication is set up with the diagnostic workstations for image processing.

Our diagnostic equipment users confirm that Store Direct gives the radiology department more control over managing its own data. This solution extends the access period to the original data sets for those performing diagnostic image processing at modality workstations. Radiologists, cardiologists and other imaging experts can advance clinical functioning at acquired high image resolution without having to depend on the long-term data storage environment of the IT department or being hindered by limitations in the communication with a legacy PACS.

> “**StoreDirect** *provides an efficient and economical solution that prevents an immediate extra burden on the existing IT infrastructure because of the communication of volume data from new modality installations.”*

For the managers of hospital PACS, StoreDirect provides an efficient and economical solution that prevents an immediate extra burden on the existing IT infrastructure because of the communication of volume data from new modality installations. It can also bridge the period until the PACS and other systems do support the DICOM Enhanced objects or until the next PACS upgrade.

VISIONS: *What are the other trends emerging in imaging IT?*
Willem Overlaet: The desire for users to have wider access to both diagnostic images and the speciality software applications for post-acquisition image processing is the driving force. This means viewing and processing of image studies are possible from any location on the hospital network and beyond, such as from home or a related imaging center. In this area, web-based technology is providing promise.

In the currently most common set-up the application software is automatically downloaded from a central server and runs on the client's workstation – so-called thick client architecture. This carries the advantage that the hardware of the end user determines the software performance, independent of potential other users at other locations. To a certain extent, the end user remains in control of the performance of the client station. The disadvantage is that large datasets still require transfer over the network between client and server. It means there is a minimum bandwidth required between client and server.

Over the next three to five years, it is anticipated that more and more software products will adopt thin-client architecture with multiplex study processing done at a central server. This will eliminate the need for high-end workstation hardware and make it easier to utilize image processing software applications from different manufacturers within the hospital PACS environment.

VISIONS: *Thank you!*

Toshiba's Newest Advanced Image Processing Technology Brings Clinical Advantages to Interventional Imaging

Fig. 1: Clear small collateral artery visualization during retrograde filling of the right coronary artery from a LCA injection when projected over the diaphragm

A new image processing technology developed by Toshiba called the Super Noise Reduction Filter is an exciting technology which drastically reduces noise in the image, enhances moving wire visibility and device contrast and eliminates image lag from moving structures at high imaging frame rates.

Introduction

Angiographic imaging provides a medium for both diagnosis and therapy via percutaneous intervention of the circulatory vessels. The angiographic unit of today is used more for therapy than before because CT and MRI are widely used for many diagnostic angiographic examinations. Recognizing this shift to therapeutic use, Toshiba have focused heavily in recent years on improving the image quality components required in interventional imaging, to provide enhanced visibility of guide wires, stents and other devices. Toshiba have also enhanced visualization of arteries, wires and devices in difficult imaging situations, by further compressing the density of dark structures in the background of the image such as spine and diaphragm or light structures such as the lungs. This compression makes the background closer to middle grey to enable the black wires and arteries to stand out in higher contrast, against the flatter background structures. Toshiba show strength in visualizing small feeding vessels which need to be demonstrated in today's complex interventions involving retrograde wire placement into co-lateral feeding arteries for examinations such as Chronic Total Occlusions (CTOs) (refer Fig.1).

To realize Advanced Image Processing, Toshiba optimized the entire imaging chain, after in-depth benchmark analysis and more than a year of component synthesis and optimization. Toshiba not only use the best technologies available today, but have also concentrated on the development of a brand new digital image processing technology to improve today's angiographic imaging, called the Super Noise Reduction Filter (SNRF).

This new SNRF technology from Toshiba greatly decreases the noise in the image and eliminates image lag or ghosting (Fig. 3) which happens when part of the previous image can be seen in the displayed still image. In conjunction with the very stable background of Toshiba imaging, a more precise visualization of arteries and enhanced visualization of wires, balloon markers stents and arteries is available, even when they are projected over bone or diaphragm. This new SNRF technology is now a part of

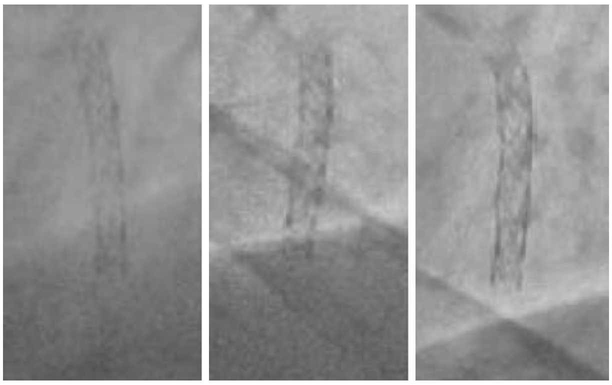


Fig. 2: Before AIP *AIP** *AIP + SNRF**

Fig. 2: The same stent in the same patient. Fluoroscopic images. SNRF reduces noise and enhances device visibility.
**AIP refers to Advanced Image Processing technologies released by Toshiba in 2007*
**SNRF refers to a new technology for the medical imaging industry developed and patented by Toshiba called Super Noise Reduction Filter - released in late 2008.*

the Advanced Image Processing (AIP) technologies from Toshiba which are available on the Infinix-i series angiographic systems. These enhancements in image quality have been achieved without increasing dose (Fig. 2). Customers who would like to upgrade to this exciting technology should talk to their Toshiba representatives about upgrade possibilities.

A breakthrough for angiographic imaging: no lag and less noise

Angiographic systems of today try to acquire high quality images with low levels of noise on every individual frame of moving structures like the coronary arteries at high acquisition frame rates such as 15 or 30 frames per second. A technology called recursive filtering has been used by most imaging companies for a long time to reduce noise in the image, by adding multiple frames together to reduce quantum mottle in the displayed image. The disadvantage of recursive filtering is that as frames are added, parts of those previous frames are seen in the displayed frame. An example of this image lag can be seen in the top image of Fig. 3 to the right which shows the number 6 three times at different contrast densities. If the recursive filtering settings are changed to reduce the amount of lag in the displayed image, amount of noise increases. Therefore recursive filtering always has a tradeoff between image noise and image lag.

The new SNRF technology from Toshiba reduces noise substantially and at the same time avoids lag imaging. Rather than adding images to reduce noise, SNRF technology reduces noise by looking at the information in each pixel and the surrounding pixels and analyses differences between relating pixels in the previous frame to determine what is signal and what is noise. This provides a far more efficient process for identification and reduction of noise in the original picture image, without the negative lag or ghosting effect caused from image addition.

What clinical benefits does SNRF bring to interventional imaging?

Wires in coronary arteries move position from frame to frame, and when recursive filtering is used the contrast display of that wire will have reduced visibility compared to the non-moving wire because of the adding of the images. However the new SNRF technology does not deteriorate wire contrast, and the result is a more visible wire display even in fast moving coronary arteries. Thus, SNRF has greatly enhanced moving fine wire visibility in fluoroscopic imaging when doctors need to see the wire to

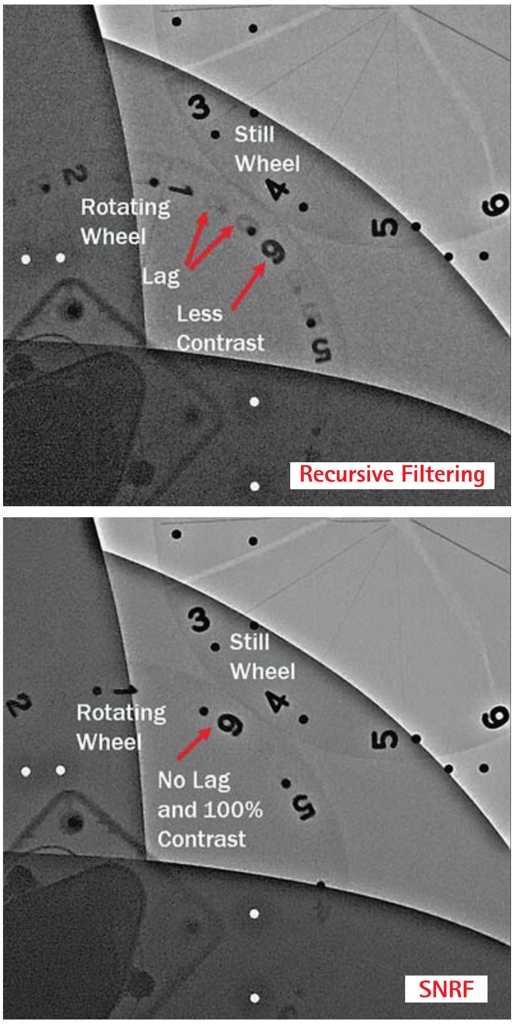
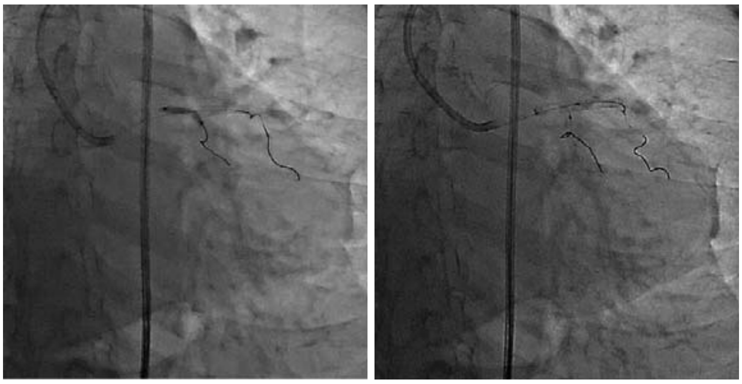


Fig. 3: With SNRF - no lag, less noise and 100 % device/wire contrast is displayed in the lower right rotating wheel

Fig. 4: Fluoroscopic image *DA (Digital Acquisition) image*



manipulate it into the correct position. Devices and markers are also more visible which means that doctors are much less inclined to do DA acquisitions to check positioning because they can see the increased contrast of wires and markers in Toshiba's fluoroscopic image. Toshiba have applied the new SNRF technology to fluoroscopy and also digital acquisition (DA) and DSA images (Fig. 4). Toshiba are achieving substantial reductions in noise and enhanced image clarity in DA and DSA, considering recursive filtering was not previously applied to these images at all. By synergizing this new SNRF technology into Toshiba's Advanced Image Processing (AIP), stable low noise fluoroscopic and acquired images are obtained for both cardiac and peripheral interventional imaging. Making wires, stents, balloon markers and arteries easier to see, helps physicians during complex interventions and difficult imaging situations in everyday work (Fig. 5).

SNRF enhances the doctor's ability to accurately place devices in a timely fashion. This can affect patient outcomes by reducing door to balloon times for STEMI patients. This also leads to reductions in dose for patients and staff.

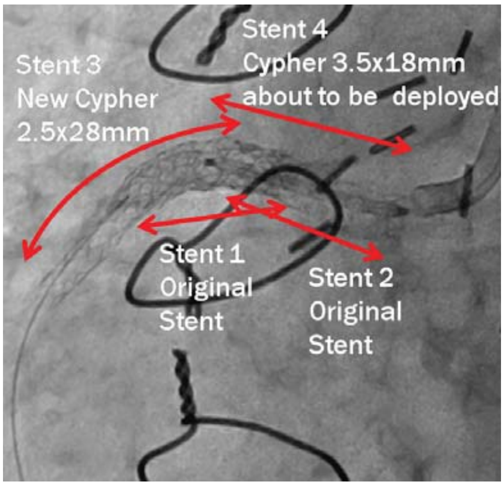


Fig. 5: Positioning of a fourth overlapping stent using high definition imaging of SNRF

Fig. 6 a + b show the drastic reduction in noise on a DSA phantom image using SNRF

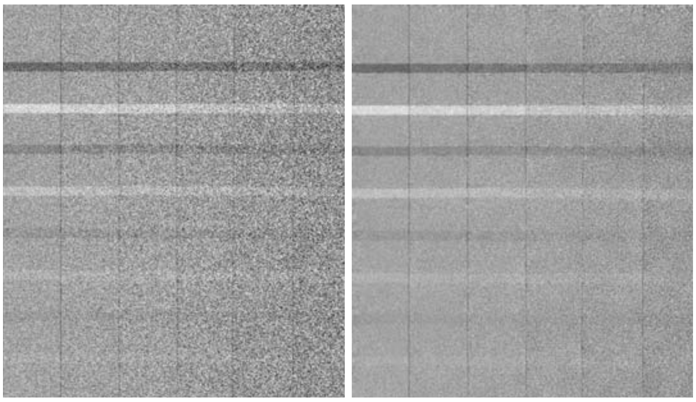
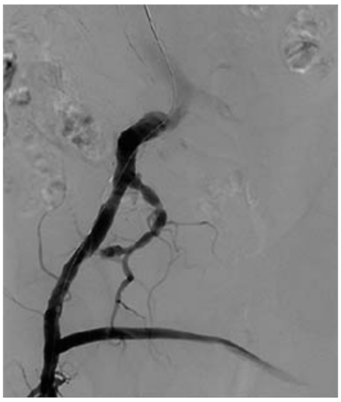
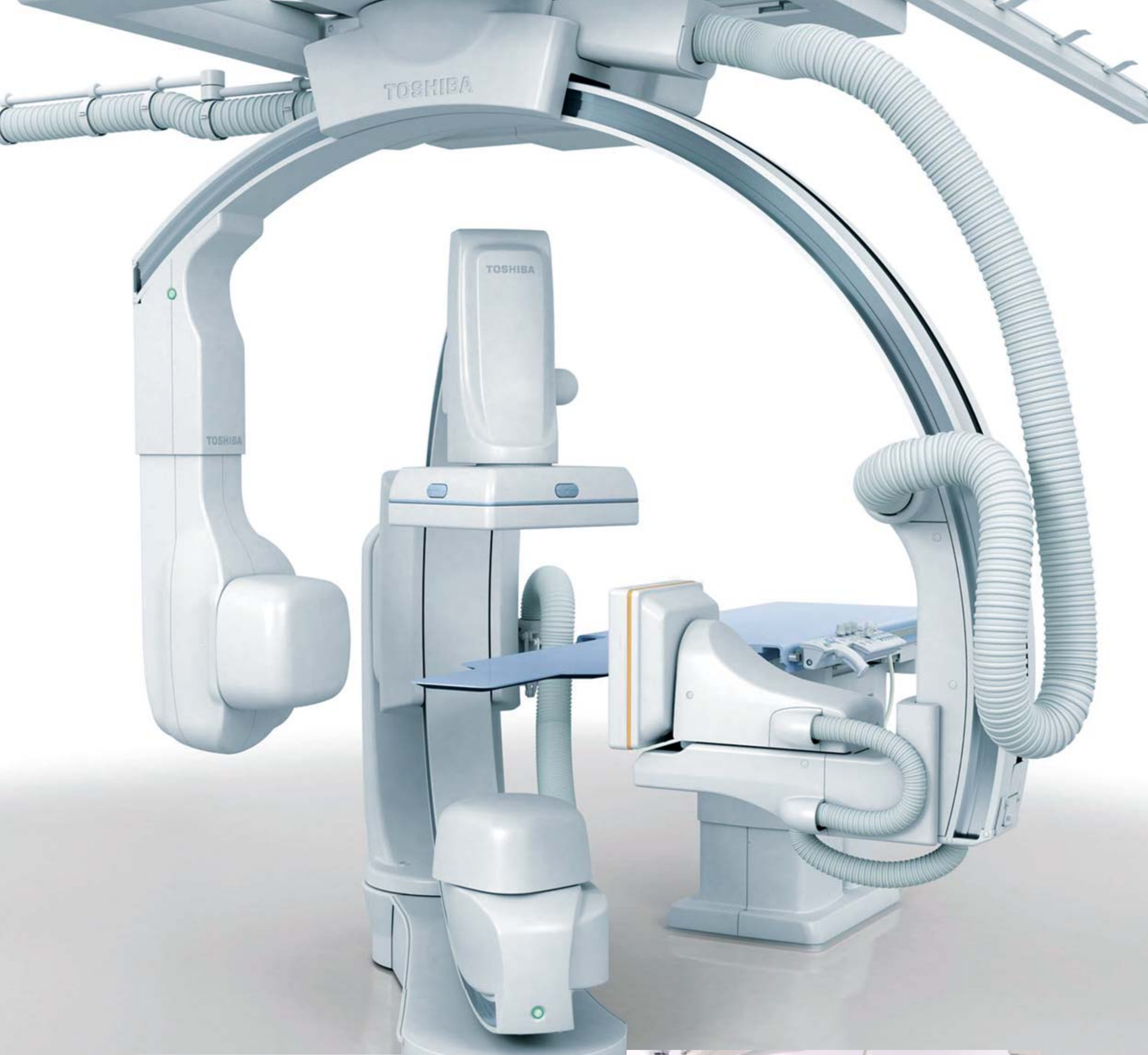


Fig. 6c shows a iliac/femoral artery bi-pass image demonstrating low noise even in the pelvic region





SNRF is available on all Infinix-i angiography systems

Dose-Optimized Single-Beat Coronary CT Angiography

A Lembcke, P Rogalla, J Mews, J Blobel

Introduction

Continuous improvements in multidetector row computed tomography (CT) technology with sub-second image acquisition and sub-millimeter isotropic voxels have lead to improved diagnostic accuracy of non-invasive coronary CT angiography. Nowadays multidetector row CT has gained wide-spread acceptance for non-invasive coronary artery angiography in selected patients[1].

New scanning techniques, such as the so-called step-and-shoot data acquisition, and reduced tube voltage may permit a significant reduction in radiation dose. However, todate few data exist regarding the diagnostic performance of sub mSv CT scan procedure and related image quality with a volume detector CT.

We analyzed a total of 32 consecutive individuals (16 males, 16 females) referred for coronary CT angiography to rule out coronary artery stenosis in patients with low or intermediate pre-test probability for obstructive coronary artery disease. Patients had a mean body mass index (BMI) of 24.9 kg/m^2 (median 25.7 kg/m^2, range 18.7-30.1 kg/m^2), height of 1.72 cm (median 1.72 cm, range 1.58-1.89 cm), and weight of 73.4 kg (median 74.0 kg, range 50-100 kg). Beta-blockers (50 mg Atenolol) were administered orally at least 30 minutes prior to the scan in all patients with a heart rate above 65 beats per minute (bpm). Fast acting sublingual nitrates (0.8 mg Glyceroltrinitrat) were administered at least three minutes prior to scanning. Mean heart rate at the time of data acquisition was 56.1 bpm (median 56.6 bpm, range 42-80 bpm).

A wide-area detector CT scanner (AquilionONE™, software release v 4.4, Toshiba Medical Systems, Japan) with a maximum detector width of 16 cm in the isocenter of the gantry was used. Data were acquired either at 240 x 0.5 mm, 256 x 0.5 mm or 280 x 0.5 mm (depending on the dimensions of the heart along the z-axis). With volume scan mode no table movement is required. An ECG signal was simultaneously recorded and data acquisition was performed using prospective ECG-scanning at 80% of the RR-interval during inspiratory breathhold. All patient scans were performed with 350 ms tube rotation time and 175 ms effective image acquisition time.

The scans were acquired with a fixed tube potential of 100 kV. The tube current was adapted to the individual habitus of each patient in order to achieve a constant image noise. A dual head power injector (Dual Shot alpha, Nemoto, Japan) was used for intravenous administration of contrast medium (CM, 370 mg Iodine mg/ml, Ultravist 370®, Bayer Schering, Berlin, Germany). Depending on the body weight, a total of 40-70 ml CM was injected at 4-7 ml/s flow rate (10 seconds injection duration in all patients), followed by a 50 ml saline flush at the same flow rate. A region of interest (ROI) was placed in the left ventricle and scanning was initiated when a threshold of 350 Hounsfield Units (HU) was reached. Axial images were reconstructed with standard filter kernel FC13 at 0.5 mm slice thickness with 50% overlap using double slice reconstruction mode to create isotropic voxels of 0.35 mm x 0.35 mm x 0.35 mm. For further

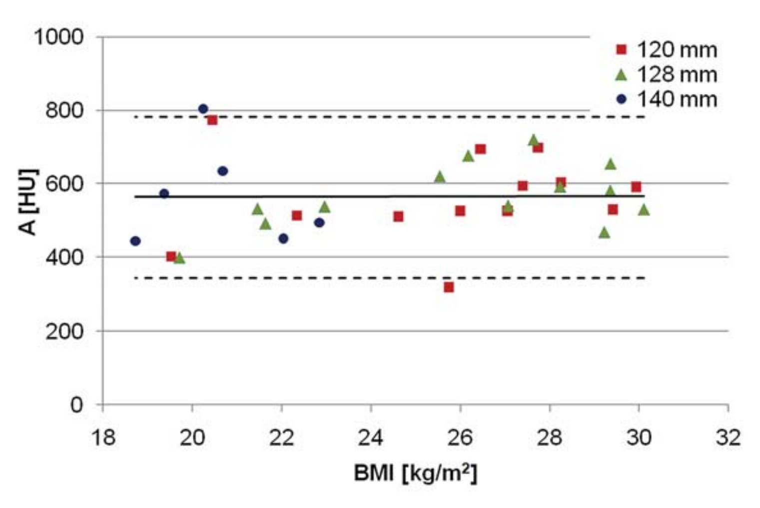


Fig. 1: Attenuation values in ascending aorta plotted against the BMI. The mean attenuation was of 563 ±108 HU with the limits of the 95% CI at 347 HU and 779 HU, respectively.

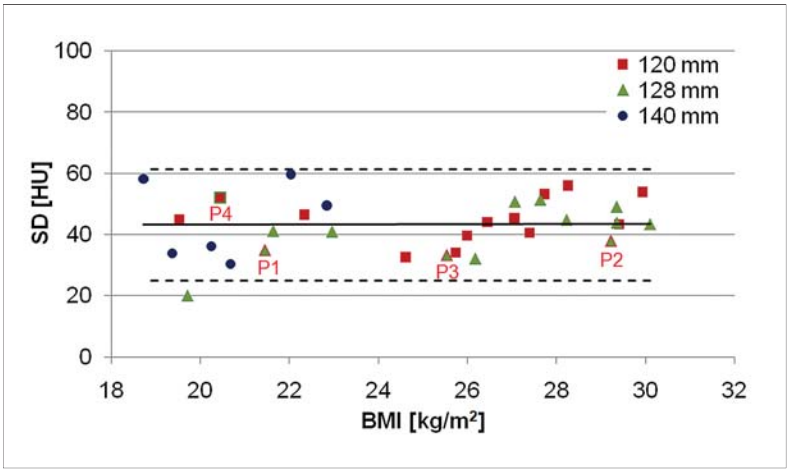


Fig. 2: Image noise (expressed as the standard deviation of the attenuation measurements in the ascending aorta) plotted against BMI. The mean SD was ±43.0 HU with the limits of the 95% CI at 24.9 HU and 61.2 HU, respectively. The four patient examples are marked (P1-P4).

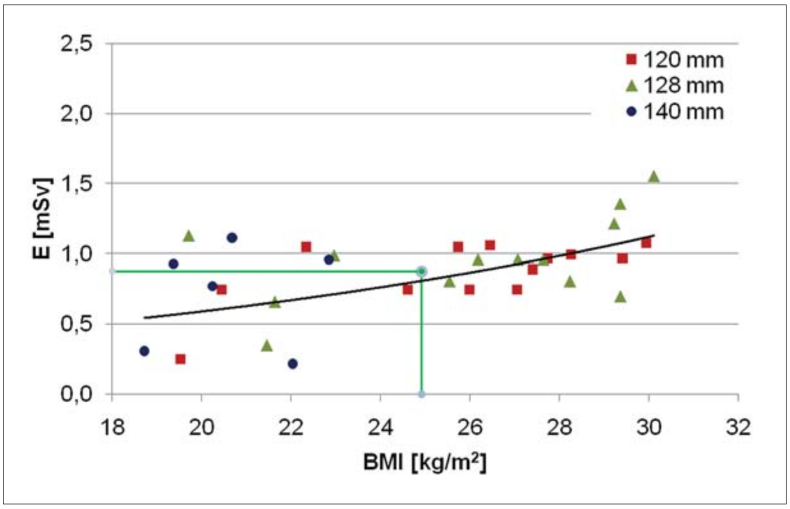


Fig. 3: Effective radiation dose for each patient plotted versus BMI shows an exponential regression function (black solid line). The average radiation dose E=0.887 mSv and average BMI= 4.9 kg/m^2 are also provided (green dot and lines).

post-processing, all data sets were transferred to a workstation (VitreaFX, Vital Images Inc., Minnetonka, USA).

For each data set, the absolute attenuation value A [HU] and respective standard deviation SD [HU] were measured within the lumen of the ascending aorta in order to determine the vascular contrast enhancement and image noise for image quality assessment. For the entire patient population, the mean values and the 95% confidential interval (95% CI) of vascular contrast enhancement and image noise were calculated. In addition, the Computed Tomography Dose Index (CTDI_{vol}) and Dose Length Product (DLP) data output from the CT console were recorded for each patient for the calculation of effective dose E [mSv]. The BMI is used as a suitable target parameter for presenting image quality and patient exposure results.

For the entire patient population, the absolute attenuation value in the ascending aorta was on average 563 HU ± 108 HU. The upper and lower limits of the 95% CI were 347 HU and 779 HU, respectively (Fig. 1). For only two patients of the group the intensity was less then 400 HU. On average an absolute amount of 58.4 ml ± 13.1 ml of CM was injected.

The image noise of the patient population was on average 43.0 ± 9.1 HU. The upper and lower limits of the 95% CI were 24.9 HU and 61.2 HU, respectively (Fig. 2).

The DLP values varied due to the scan field length along the z-axis and the chosen tube current setting. Using the conversion factor k=0.014 mSv/mGy/cm (ICRP102)[3] the estimated patient radiation exposure was E=0.887 mSv averaged for all patients. An increase with the patient's BMI was observed with a range between 0.22 mSv and 1.57 mSv. The exponential regression equation represents the trend line for the effective radiation dose dependent on the patients BMI while keeping the image noise at a constant level (Fig. 3).

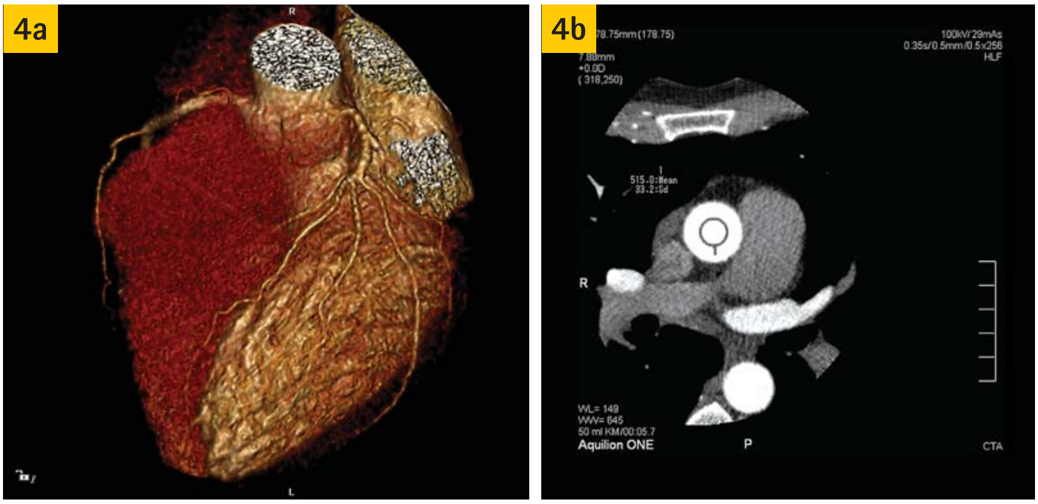
Case studies

Four patients are presented to illustrate the image quality obtained with this scan protocol.

Patient 1 with intermediate BMI

(Fig. 4 a-c)

For a female patient with a BMI=21.4 kg/m^2 the following scan parameters were selected: 100 kV, 130 mA, 350 ms rotation and 12.8 cm z-axis coverage. Based on a DLP=25 mGy*cm the calculated radiation exposure was E=0.35 mSv. Image noise was SD=33.2 HU (P1 marked in Fig. 2). The patient presented with low risk factors, but atypical chest pain. No coronary abnormality was seen on CT in three-dimensional (3D) image reconstruction and curved multiplanar image reformation (cMPR). Coronary artery disease could be excluded in this patient with an extremely low radiation exposure.



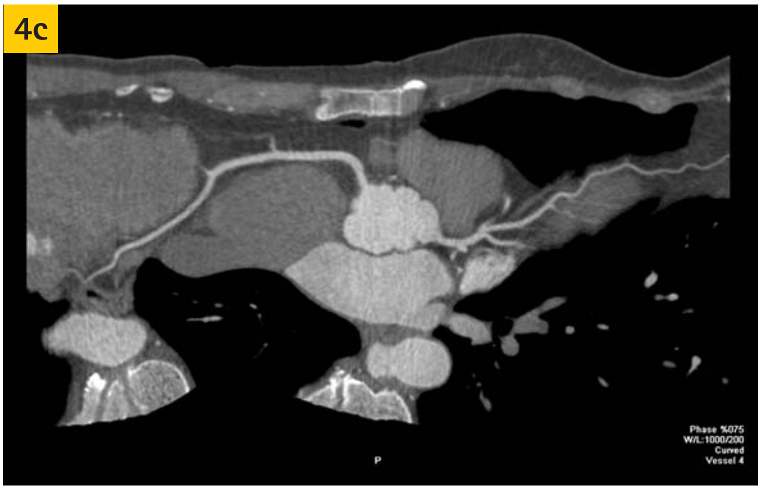


Fig 4: **Patient 1**

4a) 3D reconstruction showing the left coronary artery

4b) Noise measurement in an axial slice revealed an image noise of 33.2 HU

4c) cMPR showing both the left and right coronary artery without atheromatous lesions

Patient 2 with higher BMI

(Fig. 5 a-c)

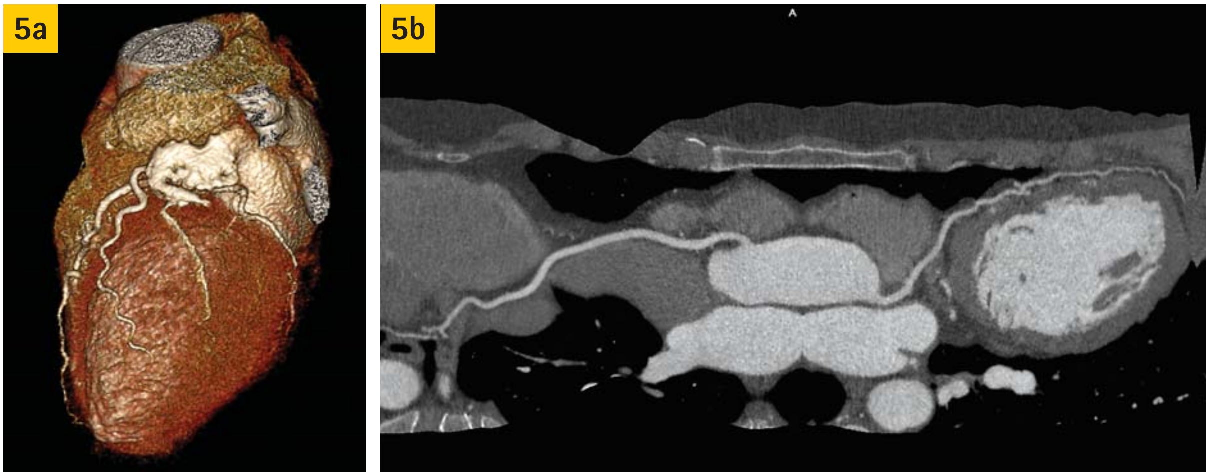
In a female patient with a BMI=28.1 kg/m^2 the following exposure parameters were selected: 100 kV, 260 mA, 350 ms rotation time and 12.8 cm z-axis coverage. A DLP=50.0 mGy*cm was displayed, resulting in an exposure of E=0.70 mSv. The image noise was measured as SD=37.6 HU (P2 marked in Fig. 2).

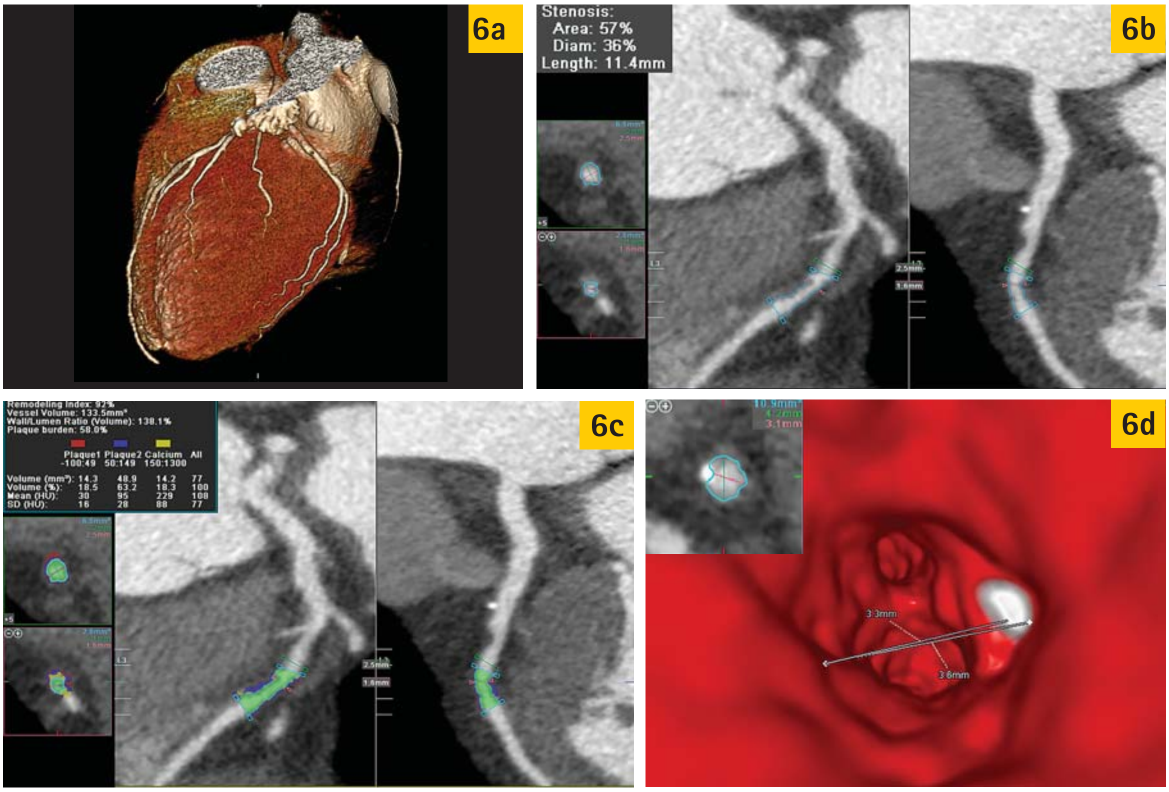
The patient also presented with low risk factors but atypical chest pain. No abnormal findings on the coronary arteries were noted.

Fig. 5: **Patient 2**

5a) 3D image reconstruction showing the left coronary artery

5b) cMPR showing both the right and left coronary artery without atheromatous lesions





Remodeling Index: 92%
Vessel Volume: 133.5mm³
Wall/Lumen Ratio (Volume): 138.1%
Plaque burden: 58.0%

	Plaque1 -100:49	Plaque2 50:149	Calcium 150:1300	All
Volume (mm³):	14.3	48.9	14.2	77
Volume (%):	18.5	63.2	18.3	100
Mean (HU):	30	95	229	108
SD (HU):	16	28	88	77

Fig 6: **Patient 3**

Fig 6a) 3D reconstruction showing the left coronary artery

Fig 6b) Measurement of degree of the coronary artery stenosis caused by a non-calcified plaque

Fig 6c) Quantification of the plaque composition revealed a lipid-rich, atheromatous lesion

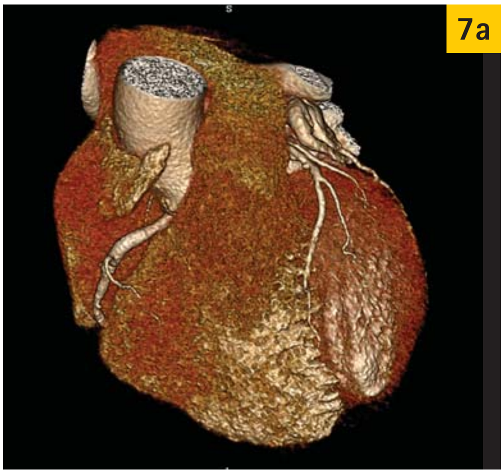
Fig 6d) Comparison of MPR cross section and 'Fly through' 3D reconstruction for stenosis measurement at the site of the spotty calcified plaque

Patient 3 with an intermediate BMI and both non-calcified and calcified plaques

(Fig. 6a-d)

This male patient with a BMI=25.5 kg/m^2 has two plaques in the mid RCA and a small, spotty calcification in the RCA vessel wall. Image noise was SD= 33.3 HU (P3 marked in Fig. 2). Despite scanning with low radiation exposure, the acquired image data allow for the determination of the degree of the stenosis with 57% area reduction and 36% diameter reduction (Fig. 6b) caused by a lipid-rich plaque (plaque density ranging between 50 and 149 HU). Fig. 6c illustrates the evaluation of the plaque composition with $^{\text{Sure}}$Plaque Software.

Interestingly, a comparison of the degree of stenosis of the spotty plaque with different MPR cross sections and 'Fly through' 3D reconstruction leads to the almost same vessel diameter with only marginal luminal narrowing of <10% (Fig. 6d). The patients radiation exposure was estimated to E=0.81 mSv.



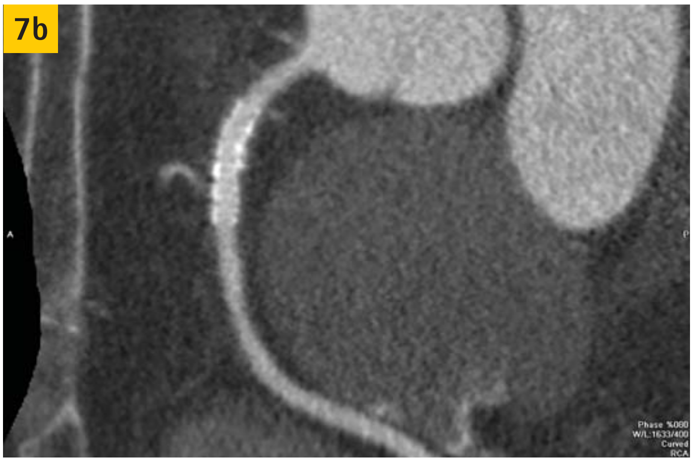
Patient 4 with low-to-intermediate BMI and a coronary artery stent

(Fig. 7a-c)

This male patient with a BMI=20.4 kg/m^2 who underwent implantation of a stent (diameter of 3 mm) in the RCA several years ago presented with the new onset of chest pain. The image noise was SD=45.6 HU (P4 marked in Fig. 2) and the effective dose E=0.75 mSv. Images clearly demonstrated stent patency. No relevant artefacts were noted.

Fig. 7: **Patient 4**

7a) 3D reconstruction showing both the proximal and medial RCA as well as the distal LAD



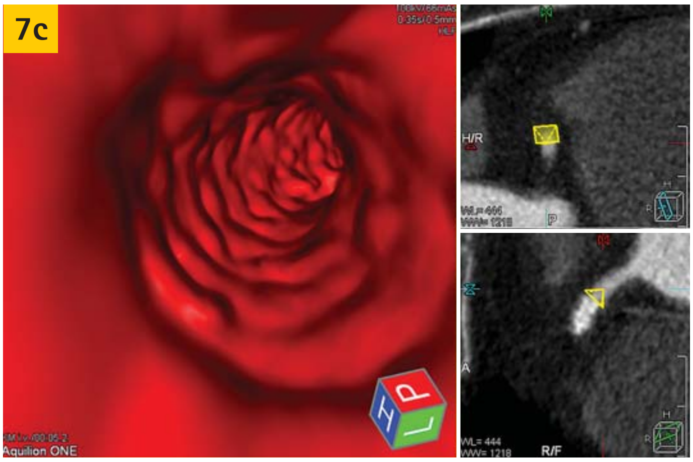


Fig. 7b) cMPR with RCA stent

Fig. 7c) 'Flying through' 3D reconstruction with view into RCA stent

Discussion

In the last decade, cardiac CT has gained widespread acceptance for non-invasive coronary artery angiography in selected patients. In general, CT image quality is influenced by different factors. Image noise and contrast attenuation are two of the key parameters describing the technical image quality[4]. Achieving sufficiently low image noise and adequate contrast attenuation values with reasonable patient exposure is a key issue in CT imaging and best described by the basic principle of radiation protection: "as low as reasonably achievable" (ALARA principle)[5].

However, our experience shows that 100 kV settings can be used for patients with a BMI of up to 30 kg/m^2 without significantly deteriorating technical imaging quality as expressed by image noise. Our data demonstrate that the effective radiation dose increases with the BMI because the tube current was individually adapted for each patient according to body habitus in order to achieve a comparable image quality (namely image noise as the main target parameter) for all patients. However, radiation exposure was kept at a very low level below 1.6 mSv with an average of 0.89 mSv. We found an acceptable level of average image noise of 43 ± 9 HU. However, it should be noted that all measurements were done on axial source images with a slice thickness of 0.5 mm.

Increasing slice thickness would further reduce image noise by the square root of the slice thickness quotient. For example, a reconstructed slice thickness of 1 mm would lead to a noise reduction of 40% compared to a slice thickness of 0.5 mm.

Because of the (inverse) direct (exponential) relationship between radiation dose and image noise, radiologists are required to determine the maximum noise level that still allows for accurate diagnosis. Unfortunately, image noise is influenced by several parameters during data acquisition and image reconstruction. There is no general agreement regarding acceptable noise levels in cardiac CT imaging. However, in our analysis the additional subjective evaluation shows that data sets of all patients had an adequate diagnostic image quality. Each data set allowed a definite diagnosis with regard to the presence of coronary artery lesions in general, and relevant coronary artery stenoses in particular. Representative examples are shown in Figures 4–7 which also demonstrate the ability of low-dose CT examinations to determine the composition of coronary artery plaques, to accurately estimate the degree of coronary artery stenosis and to visualize the lumen of coronary artery stents.

The above described prospective ECG-triggered scan protocol with a reduced tube voltage of 100 kV and individually adapted tube current is now routinely used in our daily clinical practice. Further studies are currently being conducted in order to determine the diagnostic accuracy of low-dose CT scan techniques for the detection of coronary artery stenosis in direct comparison with conventional (invasive) coronary angiography as the reference standard.

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Robustness of AquilionONE for Cardiac CT

R Bull

Introduction

After ten years of research and development, Toshiba released the AquilionONE™ CT scanner in November 2007. This scanner can cover 16 cm in the z-direction using an array of 320 x 0.5 mm detectors and is still is the only CT scanner in the world capable of capturing images of the entire heart and coronary arteries in a single rotation without any need for patient motion during the scan. Many previous articles have focused on the huge technical achievements of the AquilionONE, such as unmatched spatial and low contrast resolution, huge computing power or very low radiation dose. We purchased the AquilionONE in April 2009 and in this article I shall focus instead on the impact all this advanced technology has had on our cardiac CT service which has grown from rather a 'niche' service into one of the largest services in the UK. This has been made possible by the impressive robustness of the system. We can now provide diagnostic images of the heart and coronary arteries at low radiation dose in virtually all patients. Figure 1 shows the principle of generating slice data from a wide volume acquisition.

Why is it more robust?

All conventional 64-detector systems build up an image of the heart and coronary arteries over multiple heartbeats. This can be achieved in two ways:

Retrospective spiral technique

This is the original method used in cardiac CT which involves a spiral acquisition using a very low pitch in order to acquire an entire image dataset of the heart and coronary arteries at all phases of the cardiac cycle. A major drawback of this technique is radiation dose which is commonly >10 mSv, even when using ECG dose modulation techniques (which reduces tube current during systole and increases it during diastole – usually the phase at which the heart is stillest and the highest quality images are obtained).

Prospective gating ('step and shoot')

Prospective gating techniques have been introduced on all commercially available 64-detector systems in an attempt to address these radiation issues. An axial block of data is acquired at end-diastole using the full width of the 64 detectors (3.2-4 cm coverage). As this is insufficient to cover the entire heart, the image is again built up using multiple (typically 4-5) similar acquisitions performed over multiple heartbeats with the scanner moving between each acquisition. These separate blocks of data are acquired with some overlap allowing the images to be 'stitched' together afterwards in an attempt to create a single dataset of the entire heart and coronary arteries. Although this technique typically reduces radiation doses to the 5-10 mSv range, this comes at the price of robustness as the data

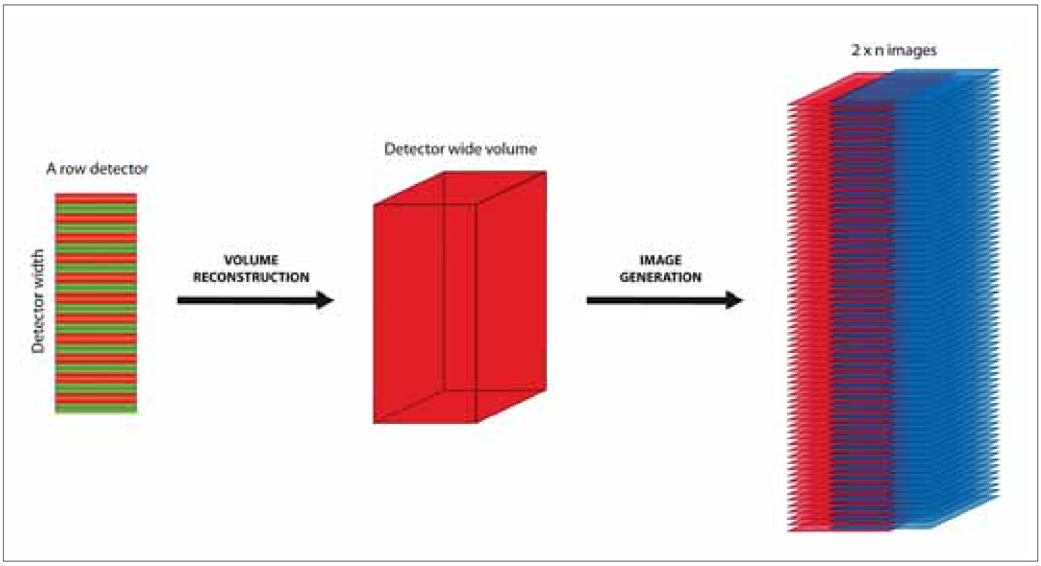

Fig. 1: Wide cone beam reconstruction algorithn reconstructs a volume and generates slices

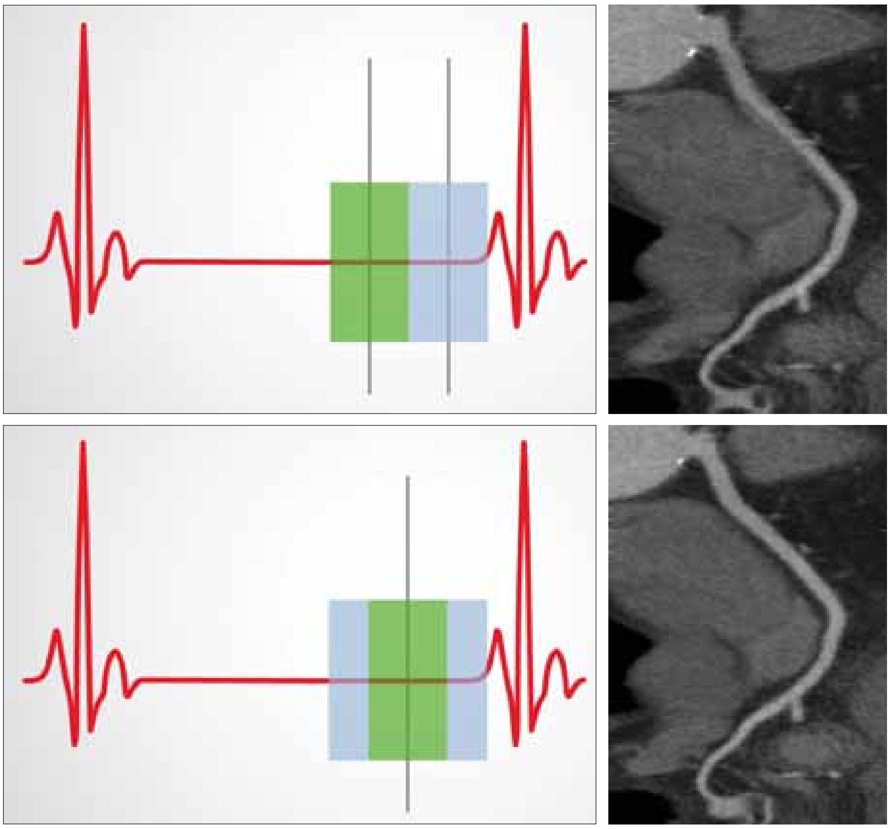

Fig. 2: ±10% padding allows robust image reconstruction

RCA image reconstructed at 70% of R-R interval – some movement

RCA image reconstructed at 75% of R-R interval – perfect

have been acquired at multiple separate timepoints. Conventional prospective gating techniques require a low resting heart rate (ideally <60 bpm) and are very sensitive to poor breath-holding and to any variation in heart rate during the study. They are completely unsuitable for patients with multiple ectopic beats or those in AF.

AquilionONE single rotation prospective gating ('shoot' without the 'steps')

The Toshiba AquilionONE uses a unique prospective technique in which the entire dataset is acquired in one heartbeat. This provides huge advantages compared to conventional techniques both in terms of radiation dose and robustness.

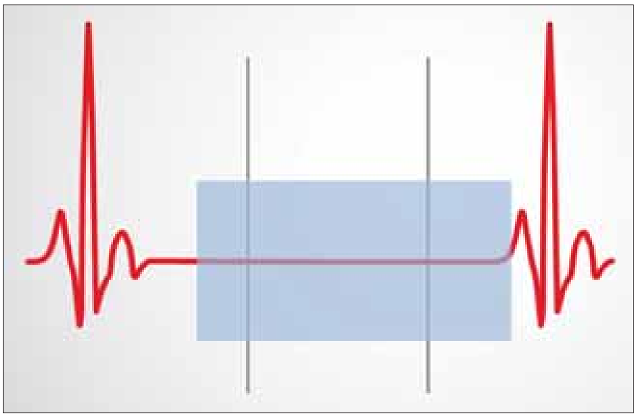

Fig. 3: Prospective CTA using SW 4.5 to reconstruct 30%-80% of the RR-interval

HR<65 bpm

We use up to 50 mg metoprolol IV to bring the patient's resting heart rate down to <65 bpm. A single-beat prospective radiation pulse is chosen that enables data to be acquired between 70% and 80% of the R-R interval. This technique is used for the vast majority of patients and provides reliably excellent images of the heart and coronary arteries at radiation doses which are typically below 3 mSv. In our experience the ±10% 'padding' means that it is almost always possible to generate a perfectly still isophasic dataset with no motion artefact (Figure 2).

HR >65 bpm and <75 bpm

This technique is used for patients in whom beta blockers are either contra-indicated or not completely effective. The radiation pulse is widened in this scenario to enable data to be acquired in a single beat between 30% and 80% of the R-R interval (Fig. 3). This option is unique to the AquilionONE as it enables end-systolic images to be reconstructed in addition to conventional end-diastolic images still using prospective ECG gating in a single heartbeat. End-systolic isovolumic relaxation is relatively short but unlike end-diastolic relaxation this is 'fixed' and does not shorten with increasing heart rate. Radiation doses are typically 3-5 mSv using this technique with excellent image quality.

HR >75 bpm

Two main options are available at these high heart rates (both unique to the AquilionONE). These options are rarely necessary as it is possible to reduce resting heart rates to <75 bpm in the vast majority of our patients.

The first option is to use a single-beat prospective technique acquiring data throughout a single entire cardiac cycle. This enables data to be reconstructed at any phase of the cardiac cycle. The reconstruction options (0-100% of R-R interval) are similar to conventional spiral 'retrospective' techniques but at greatly reduced radiation dose as this is still a prospective technique with no 'oversampling' required (typical radiation doses are 4-6 mSv with good image quality).

The second option is to use more than one heartbeat (typically 2 or 3) to provide a prospectively segmented reconstruction which summates the datasets to improve temporal resolution (the radiation pulses are typically given around end-systole allowing data to be reconstructed at end-systole). Athough this technique is associated with higher radiation dose (typically 5-15 mSv), the dose is still substantially less than that associated with conventional) retrospectively segmented spiral acquisitions (typical radiation dose 15-25 mSv).

What about arrhythmias?

Conventional cardiac CT scanners (including multiple tube systems)

Sinus rhythm with varying heart rate

In patients in sinus rhythm, even small variations in resting heart rate create major step artefacts with conventional cardiac CT scanners when using low-dose prospective techniques. This is due to the fact that conventional scanners acquire multiple datasets over multiple heartbeats. Heart rate variations mean that each separate block of data is acquired at a slightly different phase of the cardiac cycle. These step artefacts interfere with auto-segmentation software, increase reporting time and reduce diagnostic confidence and accuracy.

Multiple ectopic beats or atrial fibrillation

Although some degree of arrhythmia rejection is possible with conventional scanners using prospective gating, these systems are unable to cope with multiple ectopic beats or atrial fibrillation (AF). Even with conventional scanners with very fast rotation times and/or multiple tubes, the best that can be hoped for is multiple still blocks of data acquired at multiple different phases of multiple cardiac cycles. This creates very severe step artefacts meaning that most centres will use irregular heart rate/AF as an exclusion criteria for cardiac CT.

AquilionONE – any rhythm, no problem!

The Aquilion ONE's unique ability to acquire an entire cardiac dataset in a single beat with no table motion has particular advantages in arrhythmias. As long as ventricular rate is reasonably well controlled (approximately <75 bpm) excellent images are reliably acquired in all patients with neither motion nor step artefacts. In effect the AquilionONE is able to wait for a sufficiently long R-R interval in which to deliver the prospective radiation pulse (Fig. 4). We no longer use multiple ectopic beats or AF as an exclusion criterium for cardiac CT thus enabling these patients to benefit from this non-invasive technique.

What about obese patients?

It is a physical fact that obese patients cause more attenuation and scatter of the X-ray beam compared to thin patients. In order to overcome this, some CT vendors have produced extremely powerful CT X-ray tubes, allowing doses tube currents as high as 1000 mA to be selected. This improves image quality at the expense of high radiation doses. The AquilionONE has a medium-power tube coupled with extremely efficient detectors and advanced reconstruction techniques. This produces superior low-contrast resolution allowing high quality images to be produced in obese patients without having to increase tube current (and thus radiation dose) to very high levels.

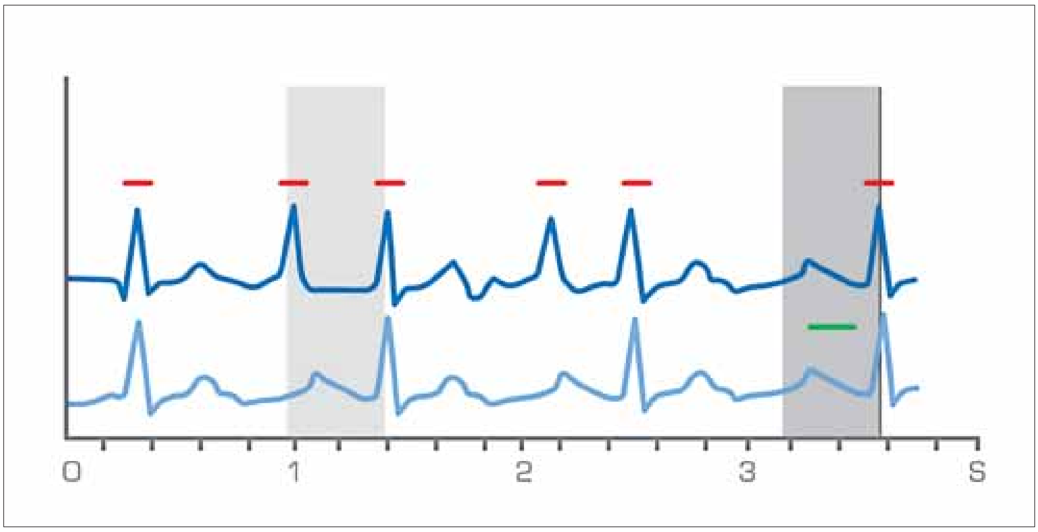

Fig. 4: Arrhythmia rejection – the system skips the irregular R-R intervals until it finds the best one (green line) within a clinically justified time limit

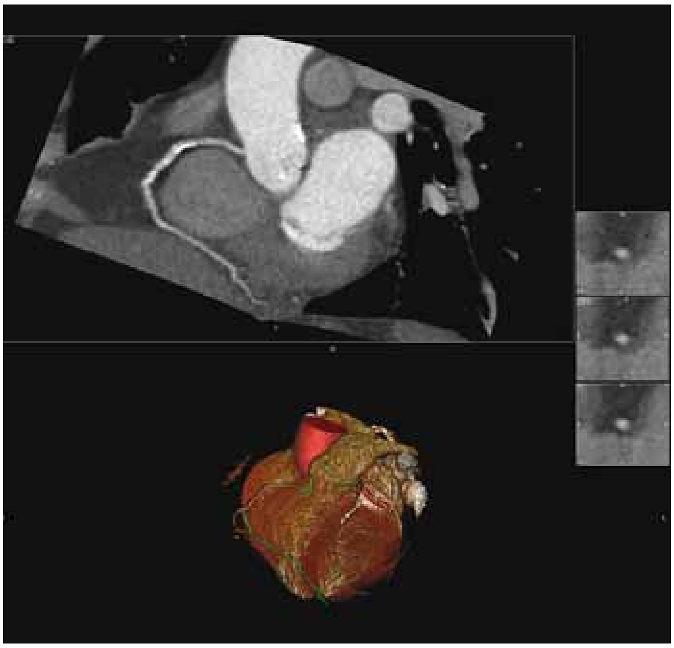

Fig. 4: Excellent views of right coronary artery in patient with atrial fibrillation (ventricular rate 50-70 bpm)

What effect has the technology had on the cardiac CT service?

Effect on scanning speed and staff training

The extraordinary robustness of the AquilionONE has transformed the cardiac CT service at our hospital. Cardiac CT is now one of the easiest and fastest examinations to perform rather than being the most difficult and slowest. We are now able to scan almost any patient, of any size, rhythm or rate. Our only real remaining exclusion criteria is inability to lie flat (e.g. due to poorly controlled left heart failure). Although the technology inside the AquilionONE is extremely complex, the scanning process is extremely fast and easy. Consequently all 16 of our radiographers are now able to scan cardiac patients as opposed to only three specialised radiographers with our old spiral technology. As the scanning process is now so straightforward, staff training has become much easier and the 'fear' of cardiac CT has disappeared, as the examinations are now almost invariably successful.

Effect on patient throughput

This has given us huge flexibility as regards patient booking. We are now able to scan up to twelve cardiac patients in a four hour session as opposed to less than five in the same time period with our old spiral technology. This has led to a huge increase in our capacity (Figure 5). This extra capacity has enabled us to cope with the huge increased demand for cardiac CT whilst still being able to cope with demand for general CT studies (which still constitute approximately 90% of our workload).

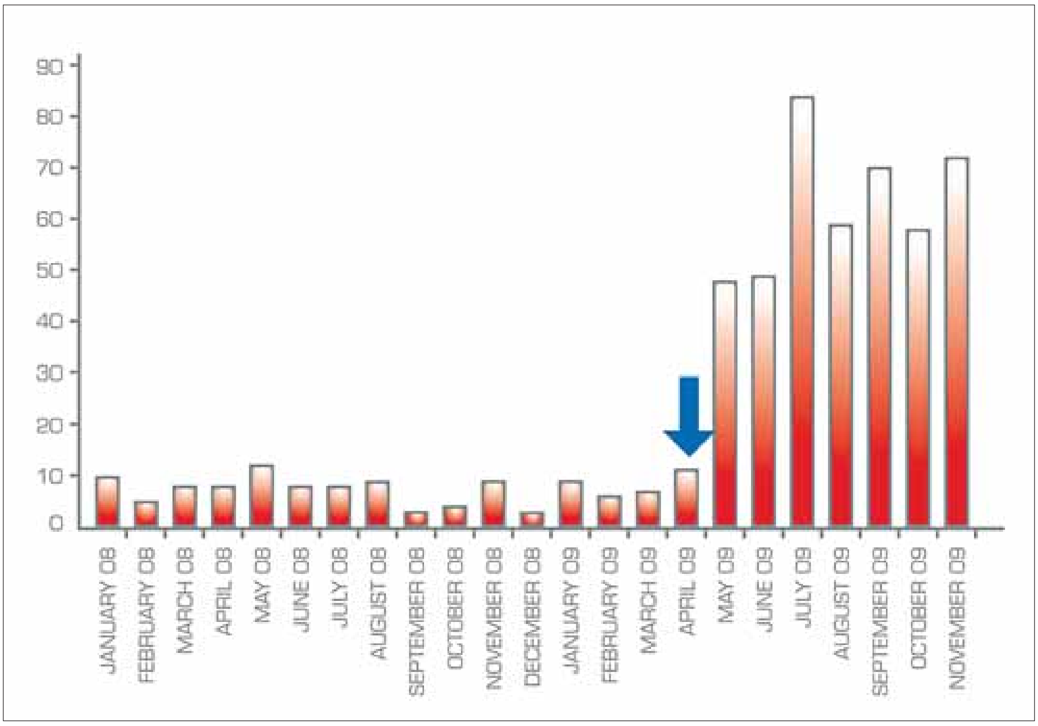

Fig. 5: Cardiac CT cases/month (blue arrow: AquilionOne installed)

Economic impact

Although single rotation technology is relatively expensive, this extra investment has proven to be cost-effective. We are now able to provide a high volume cardiac CT service as well as a high volume general CT service using only two scanners (Aquilion 16 and AquilionONE). We are now able to scan over 1000 cardiac patients and over 15,000 non-cardiac patients per year. Had we chosen a cheaper scanner than the AquilionONE, it is very likely that this cardiac and general throughput would not have been achievable and we would have required a third CT scanner (with additional hardware, building and maintenance costs). In addition, cardiac CT has also had a marked impact on cardiology services overall. We are now able to scan all patients with equivocal exercise stress tests as well as those patients who are unable to exercise (common in our relatively elderly population). We are also now able to use cardiac CT as a first-line test for patients at low to intermediate risk of coronary artery disease. The above developments have reduced cardiac catheterisation by approximately 20% and have reduced the number of negative coronary angiograms. This has improved the patient experience and has reduced overall costs.

Clinical Cases

Case 1

55-year-old woman with atypical chest pain. Negative exercise test but continued clinical concern. Single rotation, 70%-80% acquisition. Images show critical LAD stenosis subsequently treated with PCI.

Case 2

80-year-old man. Persistent fever post aortic valve replacement. Two-step protocol covering whole chest, HR 80 bpm. Each step single rotation, reconstructed at 40% of R-R interval. Images show large false aneurysm secondary to aortic root abscess.

Case 3

61-year-old woman. Presented with embolic lesions within fingers and toes. Two segment CT (HR 75 bpm) showing excellent visualization of a left atrial myxoma.

Dr Russell Bull,
Consultant
Radiologist
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Aquilion CX at Clemenshospital Münster – Initial Experience

BA Prümer

The Toshiba Aquilion CT scanner family is well known at Clemenshospital in Münster, Germany: For several years models with 16 and 64 detector rows had been in use when in September 2009 Germany's first Aquilion™ CX – which allows 128-slice reconstruction – was installed in this full-service healthcare facility.

The hospital's radiology department covers a broad range of applications - from routine diagnostics to highly specialised examinations such as cerebral perfusion in ischemia diagnostics or fluoroscopy in the context of major interventions and coronary diagnostics. Patients and staff alike hope to benefit from the Aquilion CX's advanced capabilities and high-quality imaging.

Coronary diagnostics

Prospectively gated helical scans significantly reduce radiation exposure in coronary diagnostics. During a helical scan, radiation and data acquisition are performed in a shortened interval triggered by the R-signal (Fig. 1).

In a prospectively gated helical scan data are acquired in all subsequent R-R intervals. While in the step-and-shoot mode certain R-R-intervals have to be skipped due to the required table movement, continuous helical scan reduces the scan time by 50% and avoids artefacts caused by the steps. In routine clinical application this translates into a reduced level (3 to 4 mSv) of radiation exposure for an average-sized patient.

In the case study shown in Fig. 2, a 64-year-old female patient was examined with prospectively gated helical scan prior to planned Herceptin chemotherapy. The coronary arteries RCA, RCX and RIVA were imaged; heart rate was 58 beats per minute (bpm). In view of the fact that the scan was performed as a prognostic non-invasive rule-out diagnosis effective dose for this patient was reduced to E= 3,1 mSv.

Due to decreased radiation exposure the prospectively gated helical scan is indicated for a wider patient age bracket, and particularly female patients' breast tissues can be imaged with low doses. Be it in terms of quality, spatial resolution or signal-to-noise ratio, this dose-efficient scan mode offers excellent results. Today, only high heart rates (>75 bpm) require continuous radiation exposure during several ECG cycles (retrospective triggering) with a low pitch. Regular intake of beta-blockers, however, makes this scan mode with its comparatively high exposure more or less obsolete.

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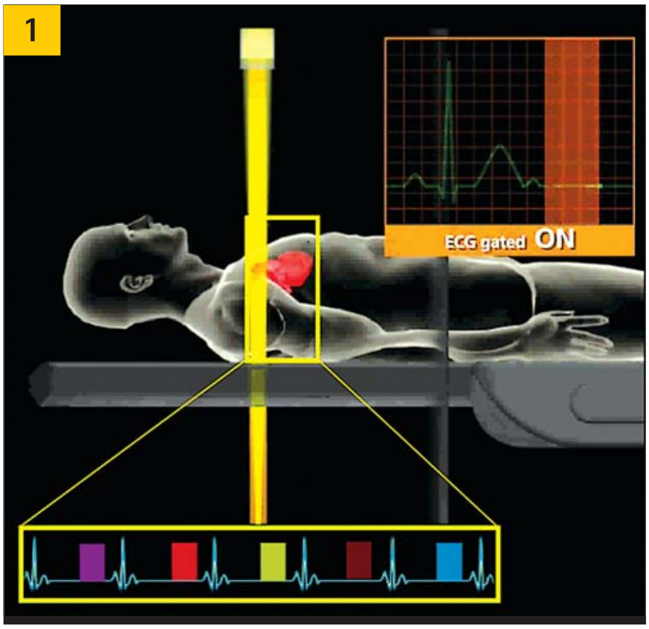

Fig. 1: Prospectively gated helical cardiac CT with subsequent R-R intervals

Triple rule-out

A further technical enhancement is variable helical pitch, a scan mode in which pitch is adjusted to the relevant field of view during the scan. Thus, during a thorax exam lung parenchyma and heart (for coronary diagnostics) are examined with different table speeds (pitch) as shown in Figure 3. Due to the short R-R interval (1000 ms with 60 bpm) and the comparatively high tube rotation speed of 350 ms the heart scan is

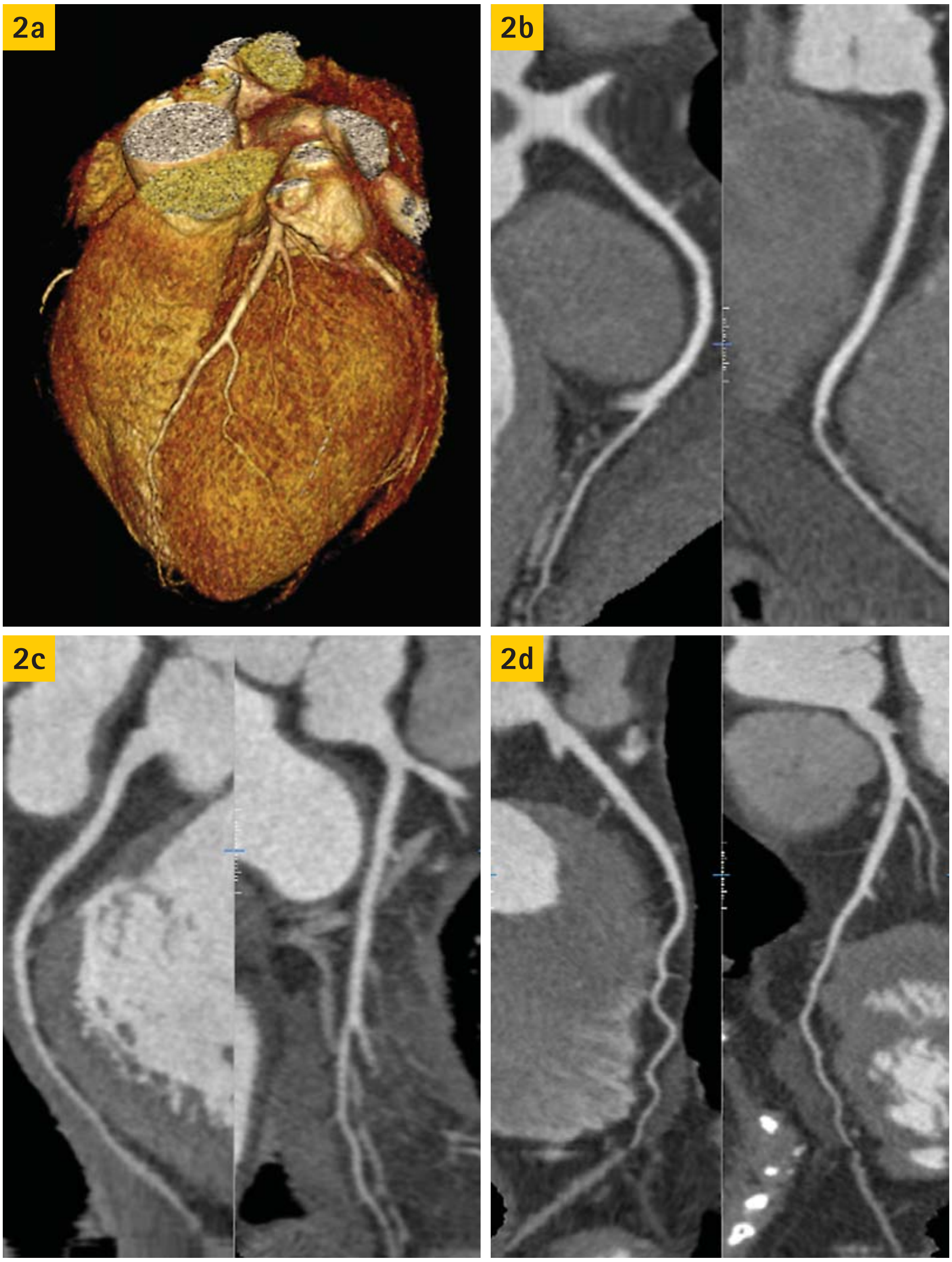

Fig. 2 a-d: Cardiac CT with prospective gating: 64-year-old female patient prior to planned Herceptin chemotherapy with visualization of a) 3D-VR, b) RCA-MPR, c) RCX-MPR and d) RIVA-MPR (E=3.1 mSv).

performed with a low pitch of 0.2 to 0.4. After leaving the heart region the pitch increases to approx. 1, reducing radiation exposure caused by unnecessary overlapped scanning while significantly shortening total scan time.

Variable helical pitch plays a crucial role in the triple rule-out (TRO) CT where coronary stenosis, pulmonary arterial embolism and aortic dissection can be ruled out or confirmed in one scan.

In its most recent publications, the American Heart Association (AHA) has recommended this protocol, which has gained ground very quickly in cardiology and traumatology, for acute left chest pain.

TRO replaces the conventional three-step examination of (1) pulmonary angio CT, (2) coronary diagnostics and (3) aorta angiography or angio CT. As a one-step procedure TRO not only reduces examination time but also radiation dose and contrast medium – not to mention cost – and increases patient workflow efficiency. Extended in-patient stays are no longer required and early detection of pathologies accelerates therapy initiation.

Variable helical pitch is also used when combining a triggered heart and abdominal examination and/or peripheral angiography with single contrast medium administration in a single scan.

Figure 4 shows the results of such an examination in a 71-year-old female patient. Despite a high heart rate of 95 to 200 bpm during the 21-second

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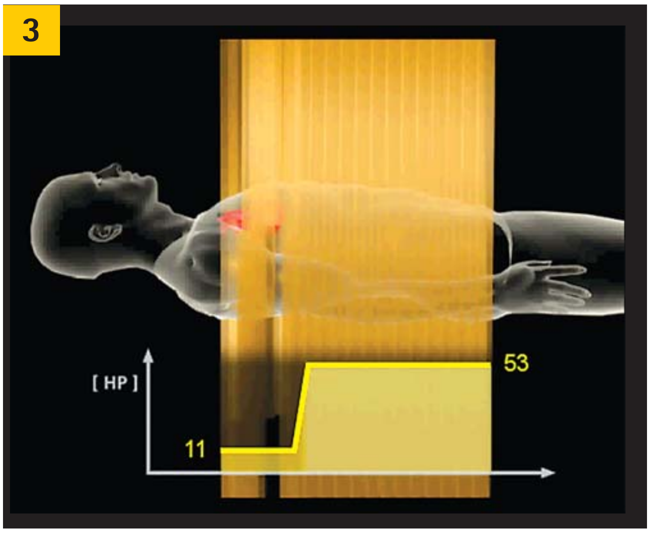


Fig. 3: Variable helical pitch: In this procedure the pitch is continuously increased. Here the ECG-triggered cardiac scan was combined with peripheral angiography.

scan the calcium score of the RCA coronary plaque could be determined. Following contrast medium application the abdominal and renal region could also be assessed. With a single administration of 80 ml (370 mgJ/ml) the contrast medium dose was cut by half compared to the conventionally performed two CT scans.

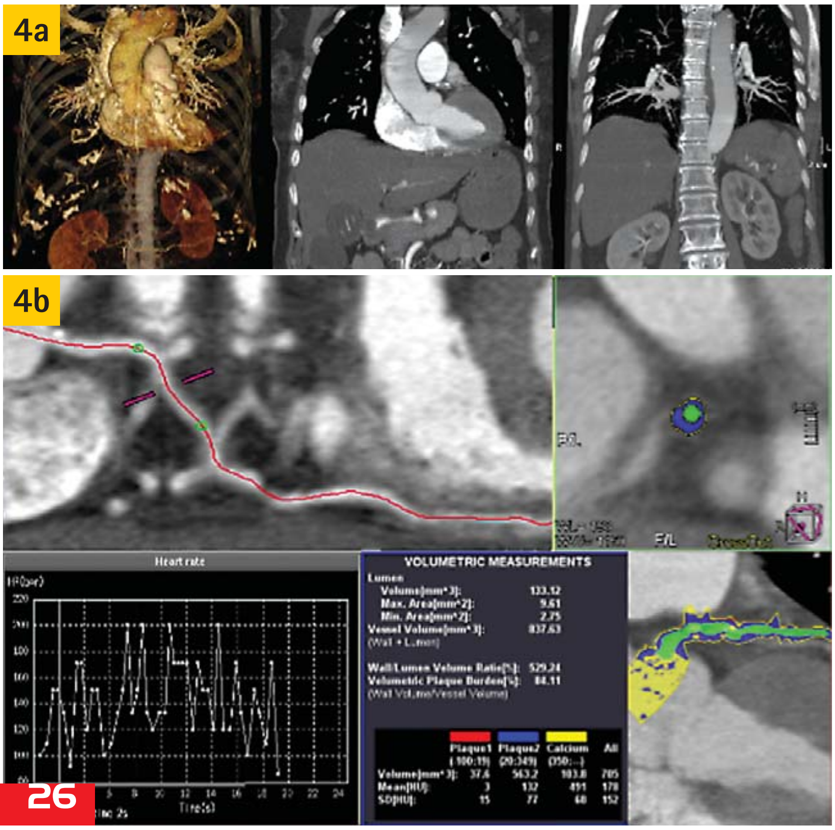
The scan region can be expanded to include peripheral angiography. The enlarged image of the pelvic/leg angiography in Fig. 5 shows an occlusion of the left arteria iliaca communis with sclerotic plaque and another occlusion in the arteria femoralis superficialis in the right thigh.

128-slice reconstruction

The 64-row detector technology which allows 128-slice reconstruction after one rotation offers many clinical benefits. When planning neurosurgical interventions, for example in the area of the cerebellopontine angle, the hypophysis or the craniocervical transition, higher axial resolution results in highly detailed images of the osseous structures and their relationship to the adjoining vessels. 128-slice reconstruction with a maximum spatial axial resolution of 0.31 mm combined with very good low contrast performance facilitates visualization of anastomoses of coronary bypasses and the assessment of small peripheral stents (<3 mm diameter).

The case study in Figure 6 shows the image of the skull base and the inner ear for the two reconstructions based on helical scan (0.31 mm z-resolution due to pitch 0.64) and one rotation scan (0.31 mm z-resolution due to 128 slice mode). The radiation

4a
4b



VOLUMETRIC MEASUREMENTS

Lumen
Volume[mm^3]: 133.12
Max. Area[mm^2]: 9.61
Min. Area[mm^2]: 2.75
Vessel Volume[mm^3]: 837.63
(Wall + Lumen)

Wall/Lumen Volume Ratio[%]: 529.24
Volumetric Plaque Burden[%]: 84.11
(Wall Volume/Vessel Volume)

	🟥 Plaque1 (-100:19)	🟦 Plaque2 (20:349)	🟨 Calcium (350:...)	All
Volume[mm^3]:	37.6	563.2	103.8	705
Mean[HU]:	3	132	491	178
SD[HU]:	15	77	68	152

Fig. 4: Variable helical pitch: The patient who presented with tachycardia, arrhythmia and dyspnoe underwent a combination of ECG-triggered coronary angiography, pulmonary angiography and imaging of the aorta abdominalis:
a) 3D-VR overview and coronary MPR covering heart, lung and renal vessels and b) results of RCA plaque quantification (heart rate 90-200 bpm).

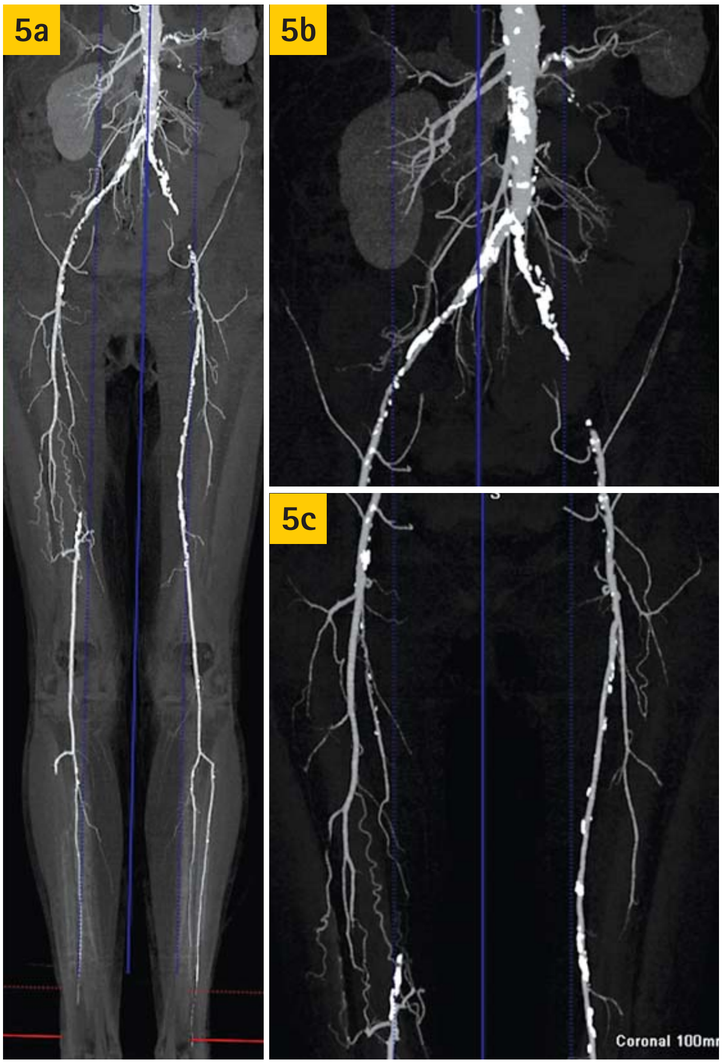


Fig. 5: Pelvic/leg CT angiography with
a) MIP overview,
b) enlargement of the pelvic/leg segments confirming occlusion of the left arteria iliaca communis with sclerotic plaque and
c) confirming an AFS occlusion in the area of the adductor canal in the right thigh.

exposure was reduced by 60% from 1.0 mSv (helical mode) to 0.4 mSv (128-slice mode).

Dynamic volume scan

The dynamic volume technology now integrated into the Aquilion CX allows the dynamic visualization of an axial scan area of 32 mm. That means functions can be imaged over time. At our hospital we were able to gather initial experience with imaging the wrist and the articulatio talocruralis (confirming osteochondritis dissecans). We also used the dynamic volume scan to clear up difficulties in swallowing in the area of larynx and hypopharynx. The sequence in Figure 7 shows the process of swallowing covering the hypopharynx, hyoid and mandible of a 52-year-old patient with dysphagia caused by a thyroid carcinoma.

Volume acquisition is also particularly useful in tumor, infection and vascular diagnostics. We were able to visualize the filling of a large intracranial aneurysm and to document the different dynamics of contrast media uptake in heterogeneous tumors which may allow assessment of different gradings. As far as infectious diseases such as rheumatoid arthritis are concerned, volume scanning visualized osseous pathologies as well as the process of contrast enhancement in the pannus.

Fig. 6: Thin-slice CT of the skull base of a 58-year-old female patient with progressing deafness: comparative visualization of the left inner ear with helical (6a) and 128-slice (6b) reconstruction (E= 0.4 mSv).

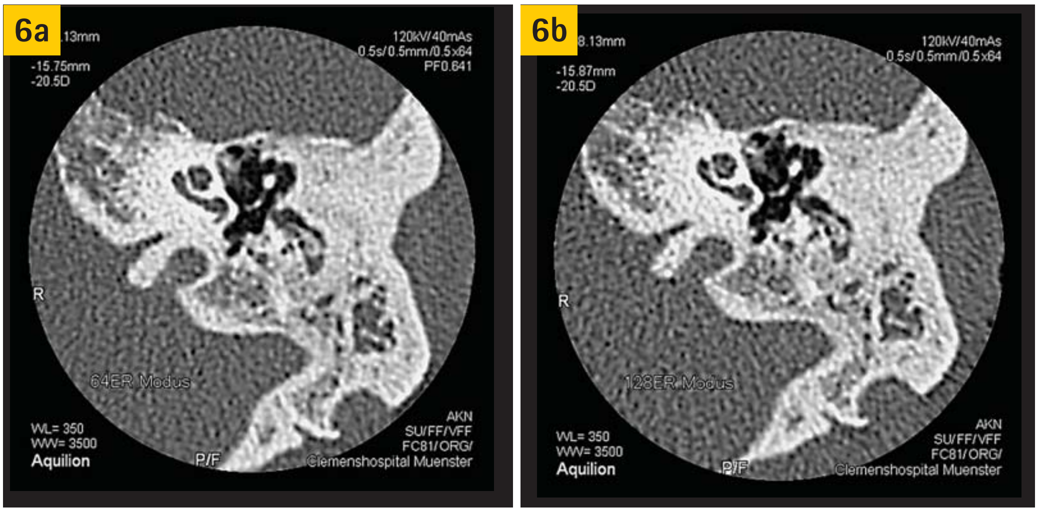
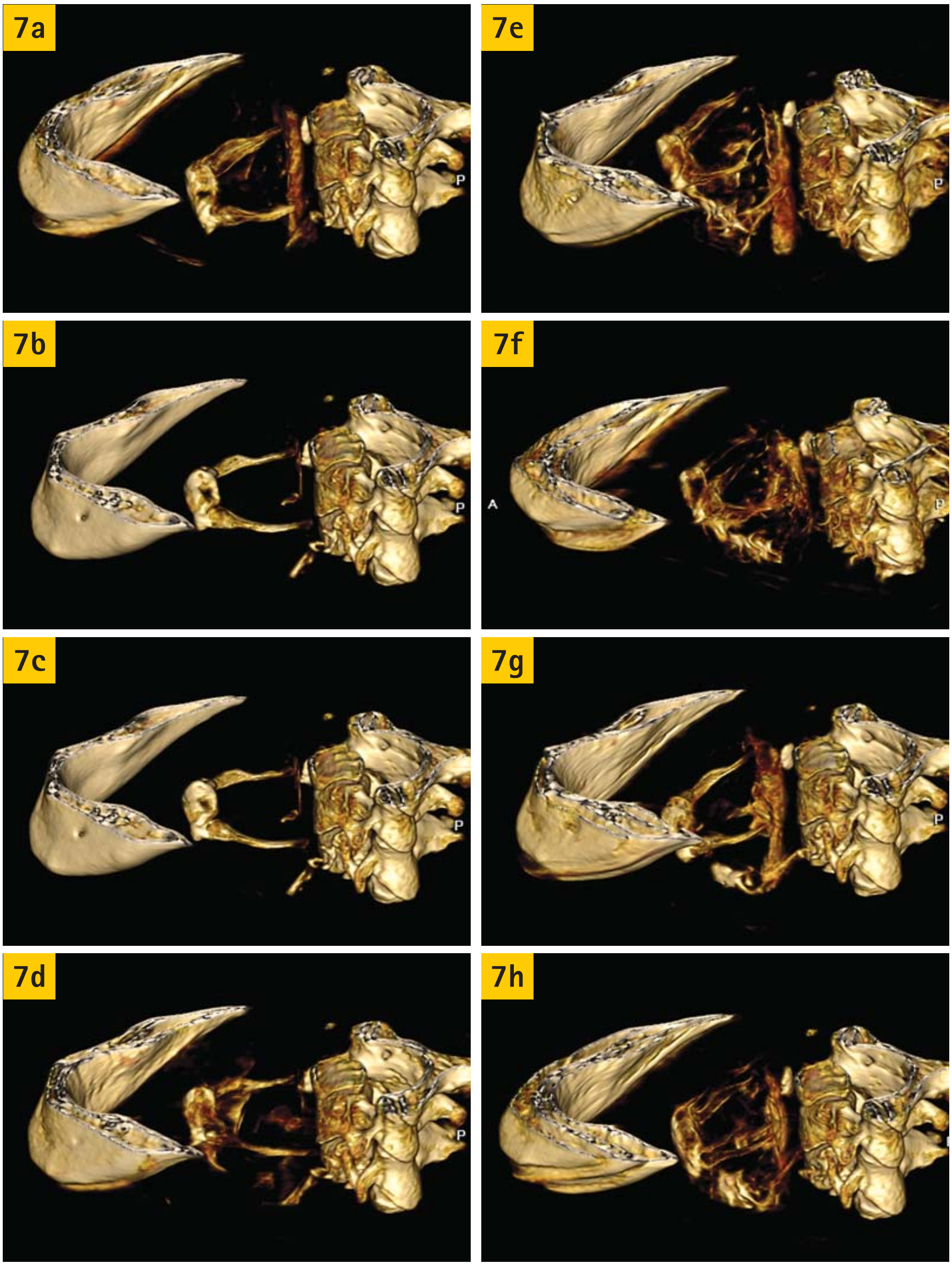


Fig 7 a–i: Image sequence showing the act of swallowing. The movement of the hypopharynx, the hyoid and the mandible is visible.



Perfusion diagnostics

Due to improved signal-to-noise ratio with lower kV values (e.g. 80 kV and 100 kV) the required contrast medium dose can be reduced which for example reduces radiation exposure during a kidney examination with only slightly increased mA value. The reduction of the kV values and thus radiation exposure in dynamic studies and perfusion imaging is highly welcome. Lower kV values generate very good contrast enhanced parameter images.

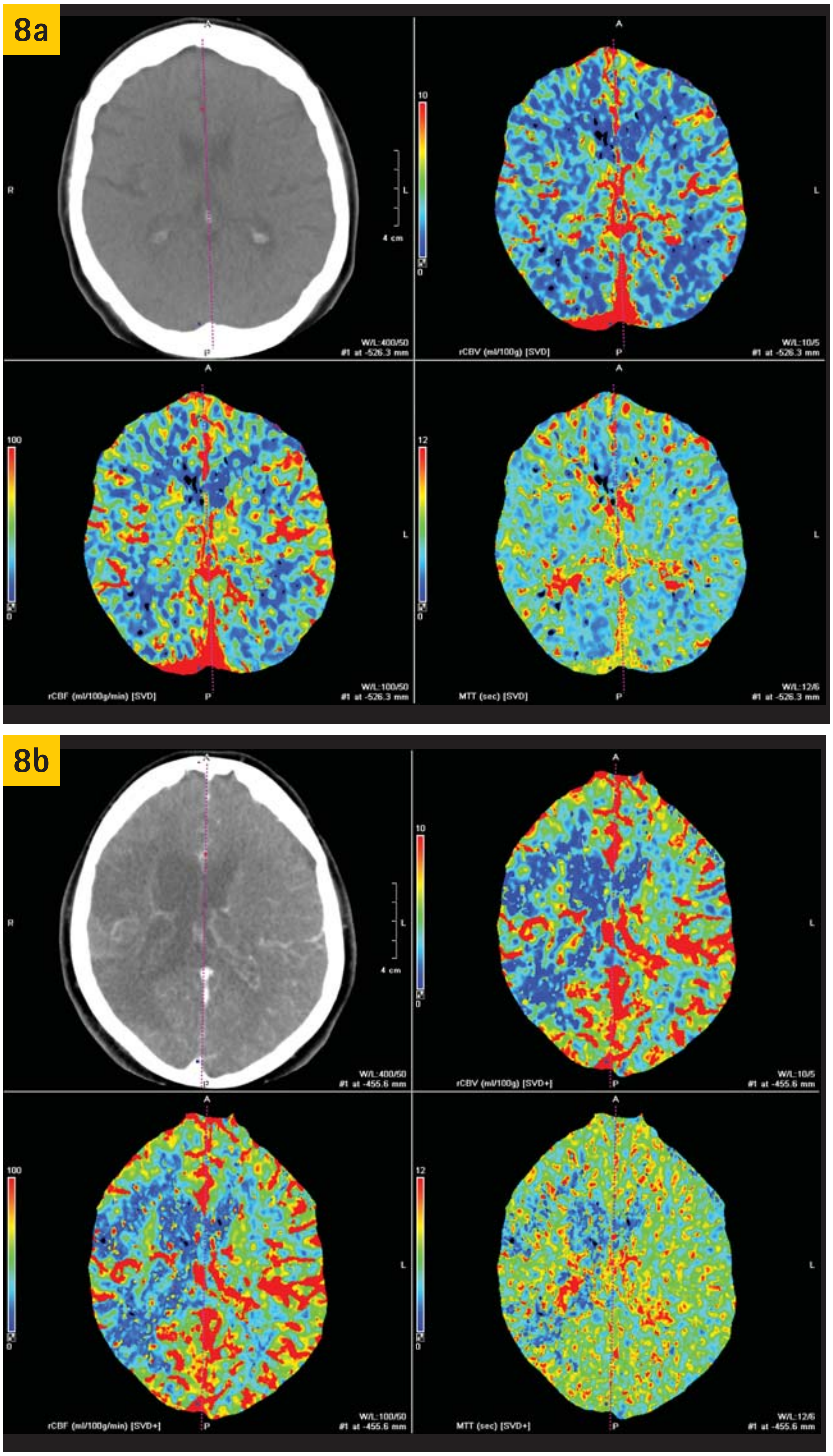


Fig. 8: Two case studies of cerebral perfusion: a) gliotic scars caused by a right-hemisphere stroke in the border area with reduced CBF and CBV and b) visualization of the capsula interna with a synopsis of the functional parameter images for CBV, CBF and MTT.

Figure 8 shows two case studies of cerebral perfusion. Pathological: gliotic scars caused by a right-hemisphere stroke in the border area with reduced CBF and CBV. Normal: capsula interna with a synopsis of the functional CBV, CBF and MTT parameter images.

Summary

Beyond routine diagnostic applications the Aquilion CX offers access to new areas of specialised examinations such as cerebral perfusion with low kV values, low-dose coronary diagnostics with prospective gating, dynamic functional imaging of smaller joints and optimisation of complex examinations with variable helical pitch scan in the context of triple rule-out diagnostics. 128-slice reconstruction improves axial resolution for the visualization of minute lesions.

Due to its clinical performance the Aquilion CX is increasingly becoming the crucial locus of patient care and patient management since it allows inter alia fast progress from diagnostics to therapy.

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First Experiences With 320-Row Detector Computed Tomography

NV Gagarina, MN Nagorniy, EV Fominykh

Introduction

Computed tomography (CT) systems are subject to continual improvement and currently can be considered one of the most advanced medical imaging tools. The most important area of CT usage is diagnosis of neurological, cardiovascular and oncological diseases.

CT equipment is constantly developing and in recent years new systems with multiple row detectors and enhanced scanning speed (temporal resolution) and imaging quality (spatial resolution) have appeared. Until recently the diagnostic abilities of CT in functional processes were limited by the small scanning area, no more than 40 mm axially. The Toshiba AquilionONE™ is the first computed tomography system capable of performing dynamic (or functional) scanning of the whole body. The scanning area in the axial direction reaches 16 cm in the gantry isocenter and therefore enables dynamic studies of the brain, heart, liver, pancreas, kidneys, etc. The detectors of the AquilionONE contain 320 rows, with 896 elements in each, and form a matrix of 286,720 elements with 0.5 x 0.5 mm spatial resolution. The scanning time for areas as large as 16 cm is determined only by the tube rotation speed and not by the combination of rotation speed and pitch.

Medical activities at Sechenov Medical Academy

The Sechenov Medical Academy in Moscow has been using an AquilionONE for clinical examinations since the beginning of 2009. This article describes our first impressions of this system, based on examination of more than 1500 patients. The AquilionONE is installed in a multiple-field clinic with various departments such as neurology, cardiology, cardiac surgery, general surgery, abdominal surgery, gastroenterology, internal medicine, oral surgery, endocrinology, urology, ENT, a myasthenia department, trauma and orthopedics.

CT examination of heart and coronary arteries is one of the priorities of modern radiology. Our first experience of coronary artery studies showed that the AquilionONE provides excellent image quality (Fig. 1).

In contrast to other CT scanners, such a study is not contra-indicated in arrhythmia and tachycardia (up to 130 bpm) (Fig. 2). Real-time evaluation of the R-R interval during scanning ensures the desired characteristics of the reconstructed image. In arrhythmia, extrasystole or abrupt changes of HR some images can contain insufficient data for reconstruction without artefacts. In these cases the system automatically scans one additional heart cycle after the next R-wave synchronization signal.

Heart examinations with the AquilionONE with volume acquisition lowers radiation exposure to 20-25% of the corresponding value for a similar study with a 64-helical scanner.

Dynamic studies

Dynamic studies can be defined as studies with simultaneous acquisition of spatial and temporal data, for instance, for visualization of joint movements, pulmonary ventilation or perfusion of various

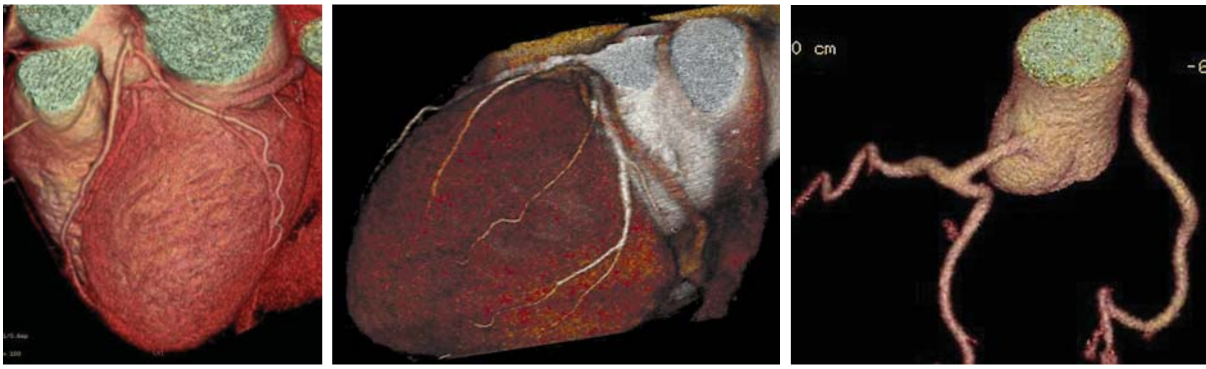


Fig. 1: Examples of CT angiograms of coronary arteries

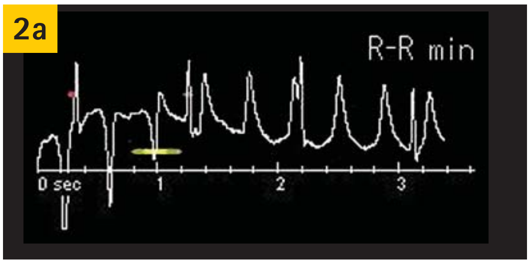
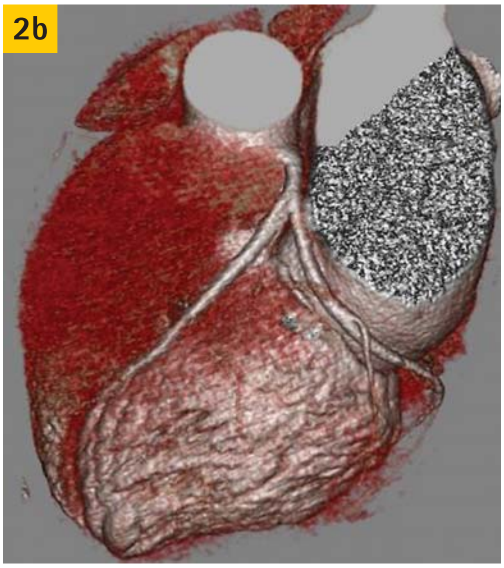
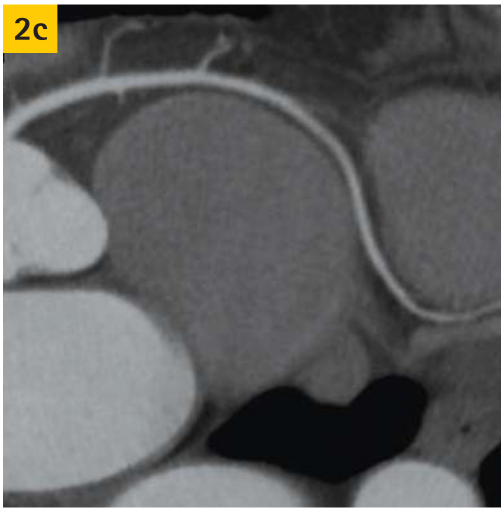
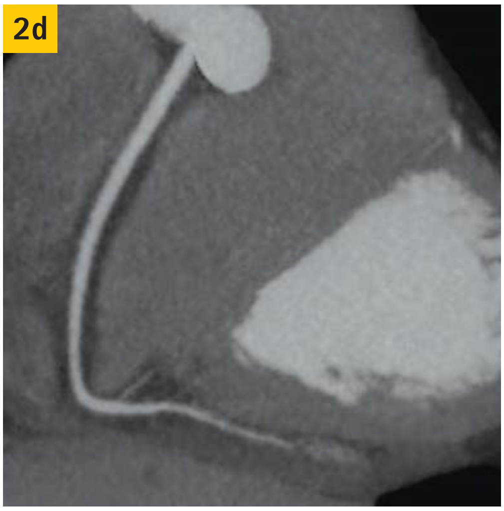


Fig. 2: ECG (a), three-dimensional (b) and multiplanar (c,d) reconstructions of images of coronary arteries of patient with cardiac rhythm disturbance







organs. The detector of the AquilionONE has an increased width of 16 cm which enables simultaneous visualization of large volumes. To keep the dose for diagnostic CT in the normal range, dynamic studies are usually performed in a low-dose regime which enables visualization of as many as 20 sequences without a substantial increase of radiation exposure compared to standard CT examination.

Dynamic scanning of hollow organs, for instance of the stomach, is very promising. In the first studies of dynamic scanning we obtained superior visualization of masses in the stomach. Previously CT visualization of hollow organs was substantially limited by peristalsis (even a full stomach did not always allow the differentiation of the mass from the folds of the gastric wall). In contrast, a dynamic study allows visualization of peristalsis in real time, and provides additional data on the wall condition. We perform dynamic scanning using a protocol consisting of native study in the spiral regime, two blocks of dynamic volume scanning of from 20 to 30 s with a 2-3 s interval with iv infusion of an X-ray contrast preparation at 5 ml/s, in total 100 ml, and delayed parenchymal phase in helical mode. The study was performed after filling the stomach with water (1–1.5 l immediately before the study). Dynamic study allows the location of masses even on the border of media (water/air) and therefore allows selection of the optimal phase for evaluation of size, typing of contrasting and spread of pathology (Fig. 3). Multiplanar reconstructions combined with dynamic data viewing allow visualization of any part of the hollow organ wall. Clear visualization of contrast accumulation in the gastric wall within damaged tissue (Fig. 4) allows a more precise selection of surgical tactics.

Dynamic studies can be divided into two areas:

A. Functional studies
B. Perfusion studies
which will be discussed below.

Functional studies

Functional studies include several methods of dynamic joint (temporomandibular, shoulder, cubital, wrist, knee, ankle joints), larynx, trachea, lung ventilation scanning.

Functional studies are performed without contrast medium and a series of dynamic CT slices continues up to 40 s with 1-3 s interval (depending on the objectives of the study). Dynamic examination of joints is performed during movement (for a temporomandibular joint that is opening-closing, for cubital, knee, ankle joints — flexion-extension, for wrist joint — flexion-extension or abduction-adduction), enabling the detection of functional and organic changes that cannot be detected by the usual scanning methods.

The aim of dynamic scanning of the trachea is to detect stenosis of membranous trachea during a deep inspiration-expiration cycle.

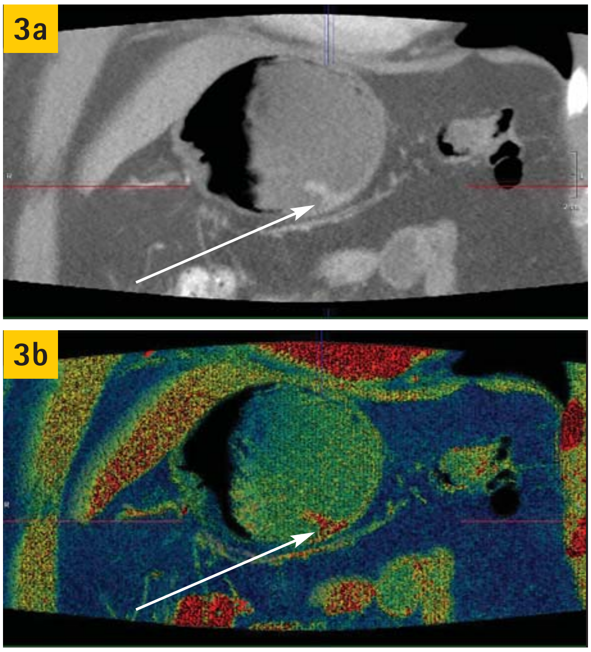


Fig. 3a and b: Gastric polyp

Perfusion studies

Perfusion studies allow the evaluation of blood flow and distribution of contrast medium in the organ of interest. The most widely used and extensively studied area of perfusion CT usage is the evaluation of brain perfusion.

In recent years many developments and modifications of CT-based tissue perfusion studies have been introduced[3,4]. But the usual CT detector widths, limited to 32 mm (64 rows of detector elements of 0.5 mm width), makes coverage of the whole brain impossible, and the study is limited to part of the brain at a pre-selected level, without the possibility of obtaining four-dimensional CTA of the whole brain. Continuous scanning with the AquilionONE enables dynamic imaging of intracranial vessels with time resolution (four-dimensional CT angiography).

We use the NeuroONE protocol with:

1. volume acquisition, performed one rotation before injection of the contrast medium, for evaluation of anatomical structures, detection of hemorrhage and development of a "mask" for segmentation of bone tissue, which is important for further correct data processing.
2. continuous scanning for four-dimension CTA during the passage through the first bolus of contrast medium and for analysis of perfusion (Fig. 5).
3. periodic scanning after a block of continuous scanning for obtaining additional data on perfusion.

Perfusion CT is performed with 120 kV tube voltage and a tube current of about 100 mAs. A dynamic series of CT cuts continues for 40-50 sec with 1-2 s interval with IV infusion of contrast medium at 5 ml/s to a total of 50 ml. The effective patient dose is about 5 mSv.

Quantitatively pathophysiological disorders of brain vascularization are characterized by several hemodynamic tissue parameters, for instance, mean cerebral blood flow (CBF), mean cerebral blood volume (CBV), mean transit time (MTT), calculated for 100 g of brain tissue. Classical visual perfusion analysis is performed by construction of parametric perfusion charts (Fig. 6).

The principal advantage of the Neuro ONE protocol in acute cerebrovascular accidents is the possibility of complex evaluation of brain parenchyma condition, brain perfusion, reversibility of changes, the condition of the main arteries of the brain and neck region. Thus MDCT can resolve all principal diagnostic issues of CVA in an emergency setting and replace several other diagnostic methods (MRI, US, angiography).

Furthermore, a new area for its usage is visualization of myocardial perfusion. Dynamic scanning enables volume acquisition for the whole heart (continuously during the preset interval, or stepwise in several intervals of time), which will enable quantitative evaluation of myocardial perfusion parameters during all phases of the heart cycle (Fig. 7) and in stress testing.

Fig. 4a,b: Gastric cancer

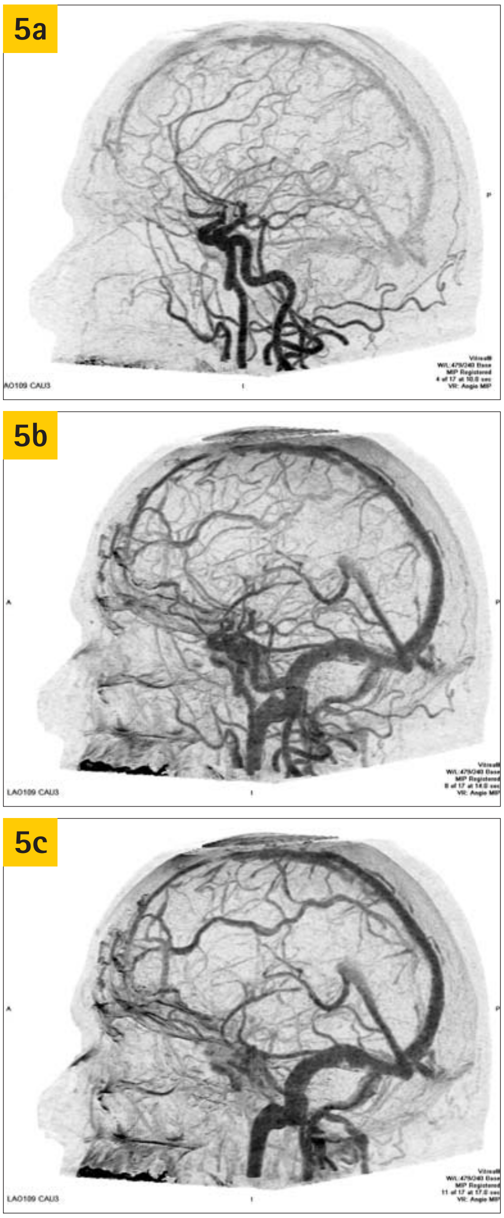


Fig. 5: Four-dimensional CT angiography of intracranial arteries. From top to bottom: early arterial, arteriovenous and venous phases of contrast passage.

Some clinical applications

Usage of the dynamic scanning regime for the neck and mediastinal region enables clearer visualization of masses in this region that pose diagnostic difficulties, for instance in the thyroid and parathyroid glands. Detection of thyroid masses in this regime is supported by clear delineation of the pathological zone from surrounding parenchyma with selection of the best contrasting phase and with determination of the precise characteristics of contrast accumulation. An early arterial phase can be visualized which increases the accuracy of detection of parathyroid adenomas. The dynamics of contrast accumulation (not only time to peak of contrast, but velocity of contrast washout as well) allows visualization of atypically located parathyroid adenomas (for instance, under the thyroid capsule, see Fig. 8).

We use the following scanning protocol: Native study in helical mode, then two blocks of dynamic volume scanning of duration 20 s with 2 s interval with iv infusion of X-ray contrast preparation at 5 ml/s, to a total of 60 ml, and delayed parenchymatous phase.

Perfusion liver scanning allows differentiation of various masses with high precision, depending on the characteristics of contrast preparation accumulation. Dynamic CT with sequential scanning enables an increase of CT density on images obtained during the first pass of contrast preparation through bolus tissue. The first images in the series contain no contrast substance and are used for determination of base signal level without contrast enhancement. Mathematical processing of a dynamic series of slices from the moment of appearance of contrast

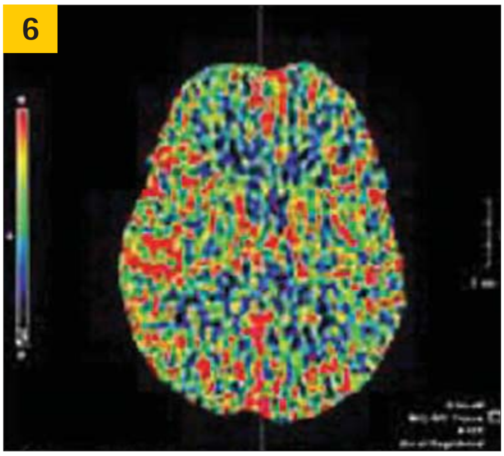


Fig. 6: CT maps of brain blood supply

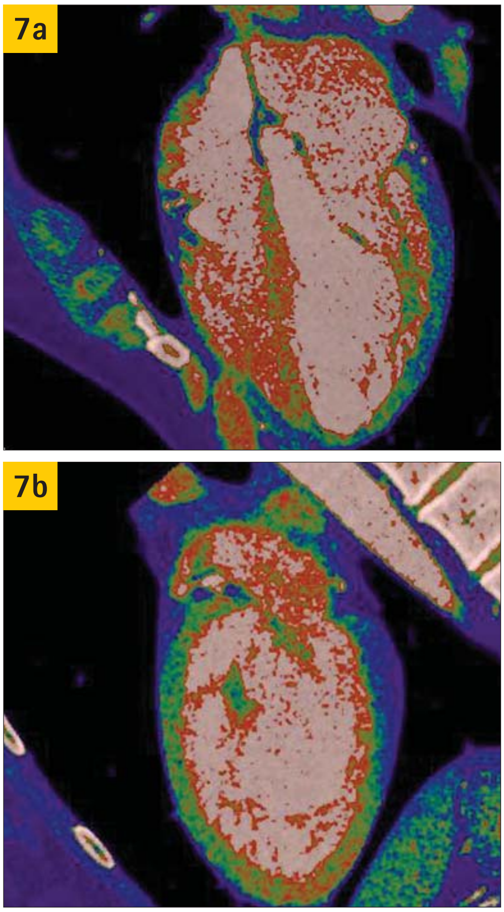


Fig. 7: Myocardial perfusion in systolic (a) and diastolic (b) phases

Fig. 8: Adenoma of left parathyroid gland

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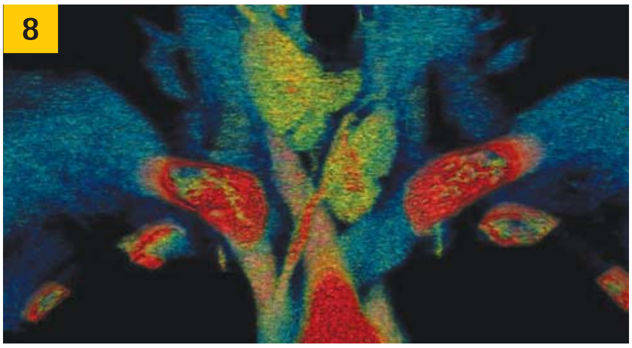

Fig. 9: Early arterial, portal and venous phases in dynamic liver study

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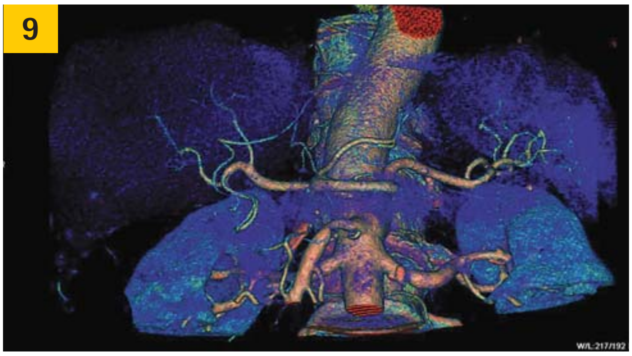

Fig. 10: Scan of patient with thrombosis of portal vein

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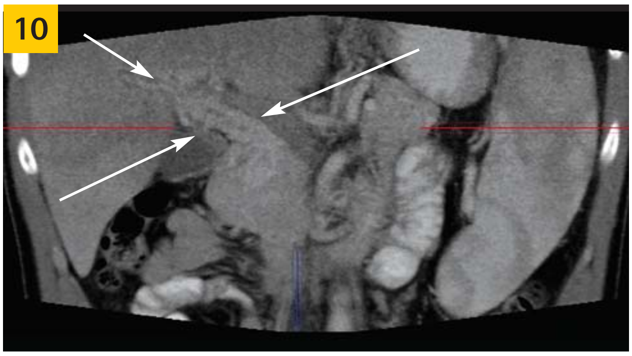


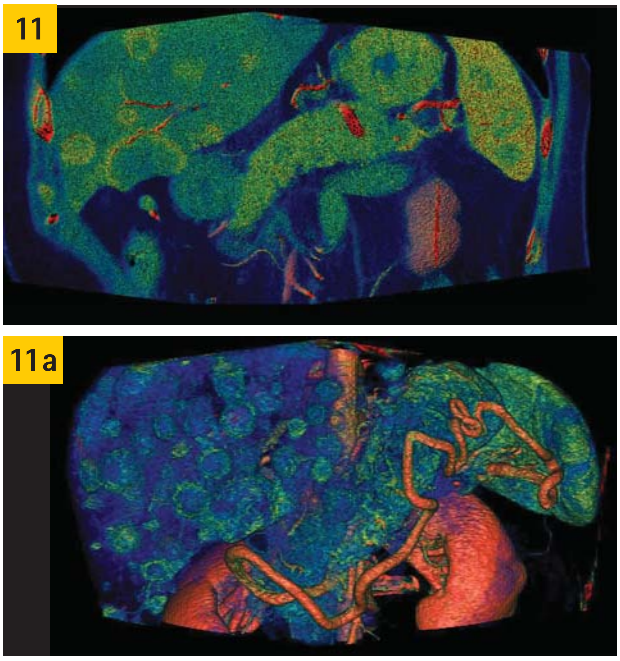
preparation in the examined tissue to its elimination allows quantitative evaluation of the blood volume passing through the selected element of tissue volume, or voxel, against time.

We use the following scanning protocol: Native study in helical mode, then two blocks of dynamic volume scanning of duration 20-30 s with 2-3 s interval with iv infusion of X-ray contrast preparation at 5 ml/s, to a total of 100 ml, and delayed parenchymatous phase. An additional block of dynamic scanning is allowed as needed. Total radiation exposure does not exceed the total exposure for usual abdominal study.

The protocol enables detection of zones of abnormal liver tissue perfusion, which are often interpreted as tumors, with high precision, evaluation of features of contrasting liver masses, differentiation of several groups of masses depending on their blood flow, and visualization of all vascular structures at the level of interest in phases optimal for each vessel (Fig. 9). Optimal visualization of the celiac trunk and its branches, portal (portography), inferior vena cava as well as porto-caval anastomoses in a single block of scanning significantly increases the precision of diagnostics, particularly of venous thromboses (Fig. 10 presents scans of thrombosis of portal, splenic, superior mesenteric veins, detected by dynamic scanning).

The protocol for pancreas perfusion study is the same as for hepatic perfusion. Dynamic scanning of the pancreas is used predominantly when hormonally active tumors of the pancreas are suspected (mostly insulinomas), featuring active accumulation of contrast preparation in the early arterial phase (Fig. 11); for differentiation of pseudotumorous pancreatitis and pancreatic tumors; in acute destructive pancreatitis (Fig. 12) for precise calculation of the volume of a functioning parenchyma gland which is important for prognosis and treatment.

Fig. 11: Insulinoma of pancreas, metastasis in liver



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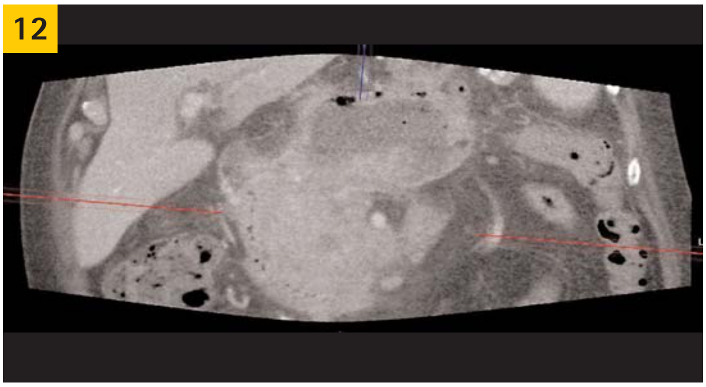

Fig. 12: Acute destructive pancreatitis

Discussion

Our first results of visualization of prostatic masses are very promising. The method allows analysis of speed and features of distribution of contrast medium in parenchyma of the gland, significantly increasing the diagnostic value for nodular (hyper- and hypovascular) masses and for diffuse prostatic lesions (Fig. 13). Also, dynamic scanning significantly improves detail visualization of the prostate (allowing, for instance, evaluation of the prostatic part of the urethra) and of seminal vesicles. The study is performed with a full bladder which allows evaluation of its wall. We use a protocol essentially identical to that for the liver, but the tube voltage is increased to 135 kV to minimize artifacts from pelvic bones.

Perfusion study also enables evaluation of malformations of any location, because visualization of arterial and venous components is performed in the optimal phase, and the provision of additional information on the location of afferent vessels, needed for decision-making for surgical and minimally invasive interventions. The possibilities of dynamic scanning in the study of veins, especially for detection of float thrombi in areas where US is less informative (firstly, in pelvic veins), remain to be explored. The data of perfusion studies can be quickly transformed into dynamic series and shown on a monitor for interactive review.

Conclusion

In conclusion, one can note that CT with a 320-row detector opens up new opportunities for comprehensive visualization of various organs. Dynamic data collection enables unprecedented study quality, with the development of four-dimensional images of vessels and of blood supply maps, enabling detection of even minimal functional disturbances.

Furthermore, the new quality of information demands increased volume of data (perfusion and dynamic studies are accompanied by production of about 10,000 images that must be processed and saved during a reasonable time), and this means serious demands on network infrastructure and archiving systems.

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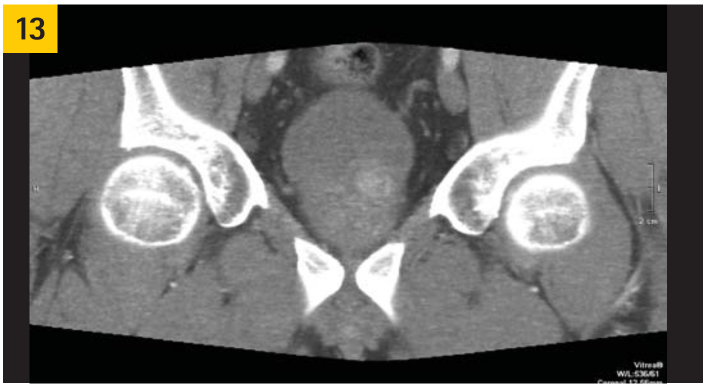

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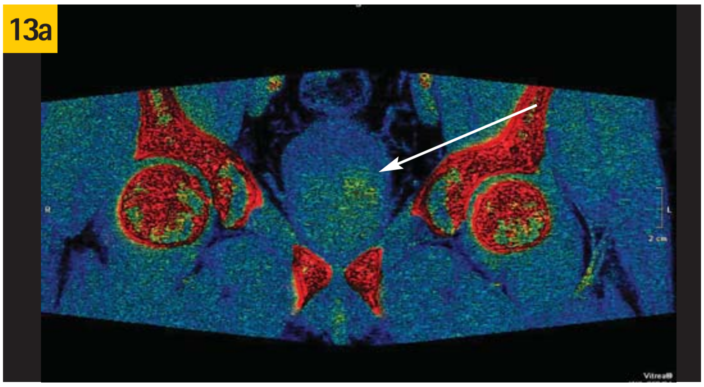

Fig. 13: Prostate cancer, node in the left lobe

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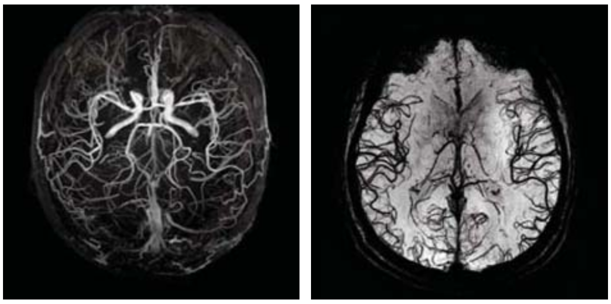

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The quietest...

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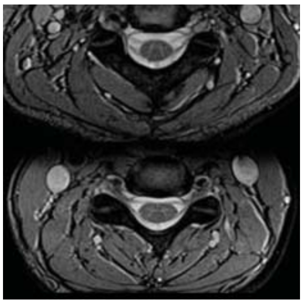
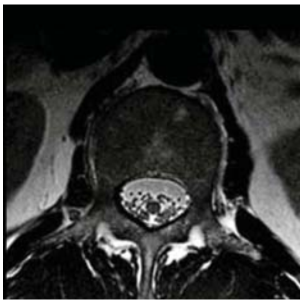
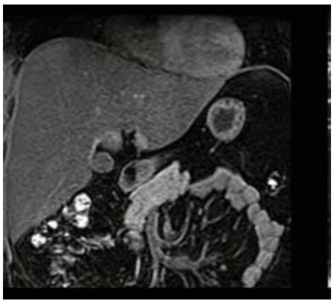





Titan 3T sets new standards in Imaging

While conventional MR systems offer a spherical homogeneous area centered at the iso-center of the scanner, a cylinder corresponds better to the form of the human body. With Conform technology, Titan 3T offers a 50 x 50 x 45 cm cylindrical homogenous magnetic field (B_0).

It uses optimized amplitude and phase transmission RF Field (B_1) called "Multi phase Transmit" for optimal B1 homogenity. It removes shading artifacts, improves SAR and reduces scan times by up to 40%.

The system also incorporates the ability to perform contrast-free MRA exams, including Fresh Blood Imaging (FBI) for evaluating peripheral vascular diseases of the lower legs and extremities; Flow Spoiled FBI for easier visualization of smaller vessels; Time-Spatial Labeling Inversion Pulse (Time-SLIP) for evaluating hemodynamic, functional assessments and visualization of vascular structures; and Time and Space Angiography (TSA) to create non-contrast time-resolved imaging with high temporal resolution. Toshiba is the only imaging vendor to offer advanced contrast-free MRA techniques.

Titan 3T sets new standards in Workflow

The Vantage Titan 3T also utilizes Toshiba's Atlas integrated matrix coil technology to reduce exam time and improve the overall exam experience for patients. Because the coils are integrated into the table, patients do not need to be continually repositioned for many exams, which saves time and improves patient comfort. The Atlas coil concept prevents frequent coil exchange because the three major components, Head, Spine & Body coil, facilitate boundary free whole body imaging. Therefore it eases the workload for the radiographer and improves patient throughput at the same time.

Additionally, the Vantage Titan 3T is equipped with the new cross modality user interface – M-Power – to further improve ease of use for technologists. It uses 2 quad processors and parallel procession for ultra fast image reconstruction. M-Power offers advanced image processing, such as perfusion, diffusion, 3D volume rendering, spectroscopy and more.

Conventional and Contrast-enhanced Ultrasonography in the Management of Percutaneous Renal Tumor Ablation

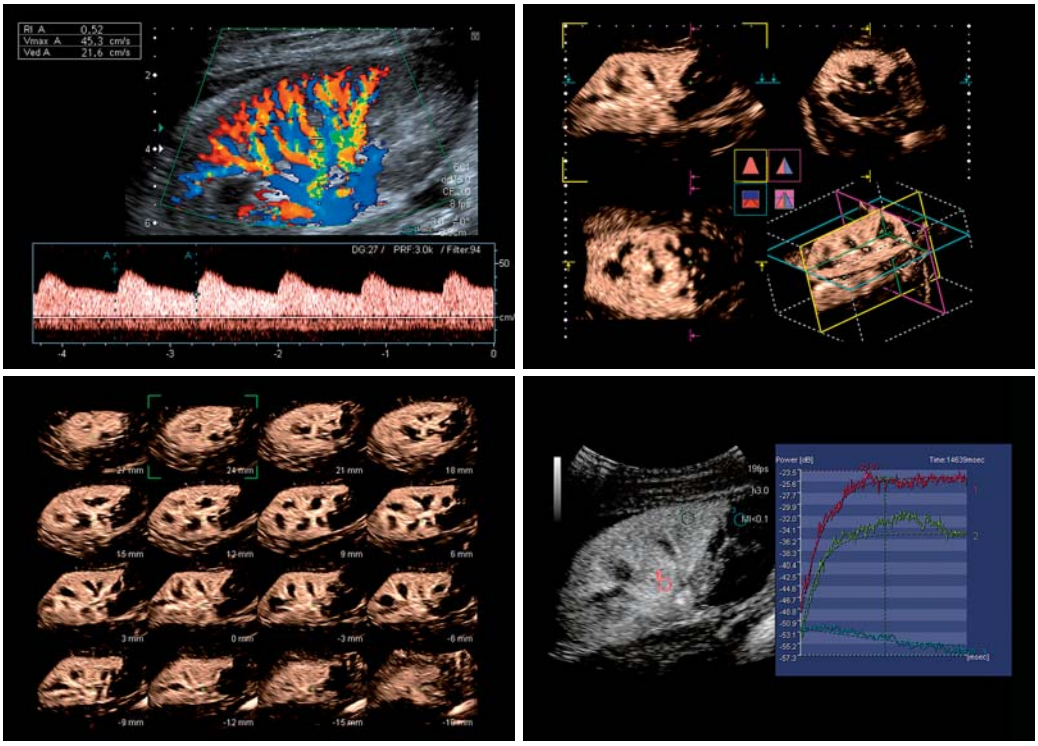
JM Correas[1,2,3], C Hoeffel[4], MO Timsit[1,5], A Khairoune[2], A Méjean[1,5], O Hélénon[1,2]

Introduction

The number of small renal tumors is increasing due to the large number of imaging examinations of the kidneys performed with various modalities and the true increasing incidence of renal cancer[1]. Conservative therapy is now widely recognized as the reference technique for treatment of small renal tumors, with typically lower pathology scores. The increasing rate of chronic renal failure in the elderly and the efficacy of conservative therapy to treat cancer as demonstrated by the urologists performing partial nephrectomy and tumorectomy emphasize the role of percutanaeous minimally invasive ablative procedures, particularly in patients with surgical contraindications. Radiofrequency ablation (RFA) is preferred when the procedure is performed percutaneously[2–5]. RFA of small renal cell carcinoma (RCC) is also a routine alternative to nephron sparing surgery from a cost-effectiveness perspective. The evaluation of the success of the procedure relies on imaging techniques showing the lack of enhancement within the lesion and the size and shape of the necrosis covering the entire tumor area.

Ultrasonography and contrast-enhanced ultrasonography (CEUS) play a key role at each step of renal tumor management using RFA. CEUS profits from recent improvements such as the introduction of third-generation ultrasound contrast agents with high acoustic response at low acoustic power and the development of US imaging techniques detecting the specific microbubble signature.

Available USCAs and particularly SonoVue® (Bracco, Milano, Italy) are only approved for the visualization of the renal macrovascular bed and not for renal tumor detection, staging or therapy evaluation. However, this application has been included in the recent updated version of the Guidelines and Good Clinical practise recommendations for CEUS[6].



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[5] Necker University Hospital, Department of Adult Urology, Paris, France

Fig. 1: Evaluation of the renal tumor before percutaneous ablation

Figures 1, 2 and 3 refer to the same patient, a 45-year-old male with vascular nephropathy, solitary right functioning kidney and mild chronic renal failure (creatinine clearance of 53 ml/min). During an ultrasound examination, a 2 cm renal tumor was incidentally discovered, corresponding to a papillary cancer at pathology. The patient was referred for radiofrequency ablation (RFA) due to several comorbidity factors, including platelet aggregation inhibitors. However, the lesion was poorly located against the right colon.

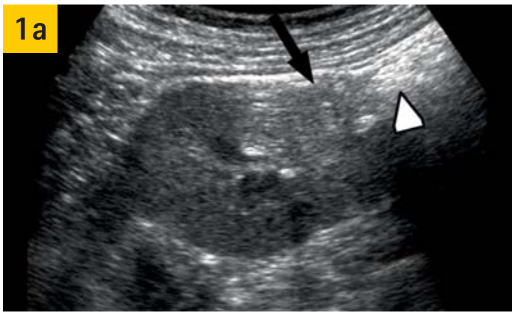


Fig. 1a: Using the abdominal broadband transducer (C6–1), the tumor was found to be slightly hyperechoic (black arrow). The bowel touched the tumor (arrow head).

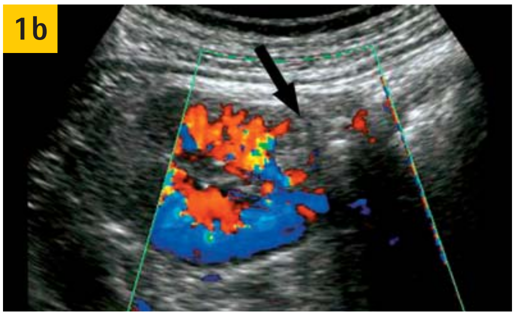


Fig. 1b: At color Doppler US, the lesion appeared poorly vascular compared to the adjacent cortex.

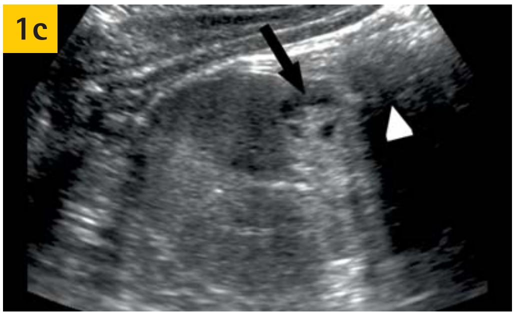


Fig. 1c: Using the convex high frequency transducer (C10–3), the lesion was better depicted (black arrow). Despite abdominal maneuvers, the bowel still touched the tumor (arrow head).

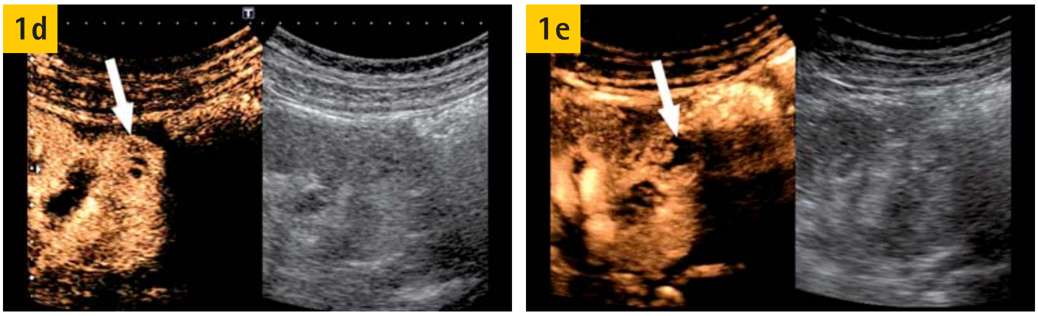


Fig. 1d and e: At contrast-enhanced US performed after a bolus injection of SonoVue® (Bracco, Milan, Italy), the lesion appeared strongly perfused (Fig. 1d). MicroFlow Imaging (MFI) improved lesion conspicuity compared to pulse subtraction acquisition (Fig. 1e).

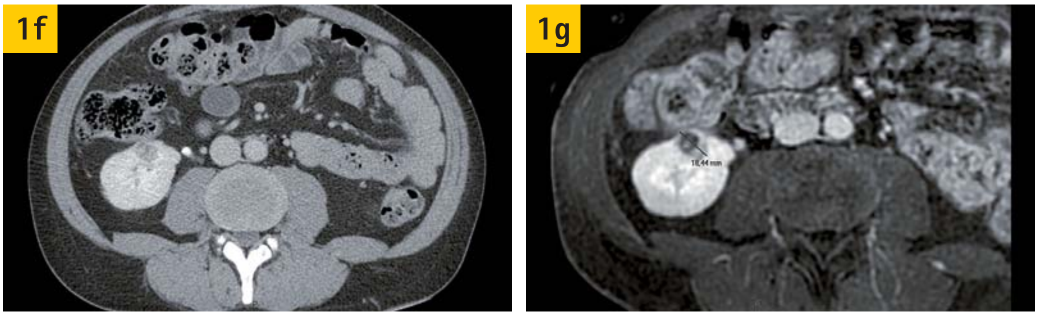


Fig. 1f and g: Contrast-enhanced CT and MRI were performed with a limited amount of contrast media, following intravenous perfusion of saline. They confirmed the US and CEUS findings and allowed staging of the lesion (including adrenal glands, pancreas, liver and lungs).

RFA of renal tumors

The RFA principles applied to renal tumor ablation do not differ strongly from those of liver tumor treatment. Various types of systems can be used including single and multiple cool-tip electrodes (Covidien, Boulder, CO, USA), expandable electrodes (Boston Scientific Corp, Natick, MA, USA; RITA Medical Systems INC, Mountain View, CA, USA), bi- and multipolar systems (Celon AG – Olympus, Teltow, Germany). Most protocols are derived from liver RFA

Fig. 2: The role of US and CEUS during RFA

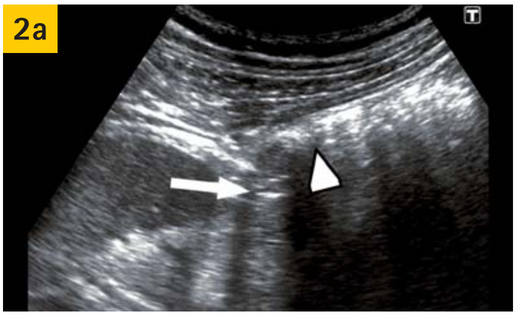


Fig. 2a: The tumor biopsy was performed under real-time US guidance to avoid bowel damage. The tip of the true-cut needle was perfectly followed up to the renal tumor (arrow), despite the adjacent bowel (arrow head).

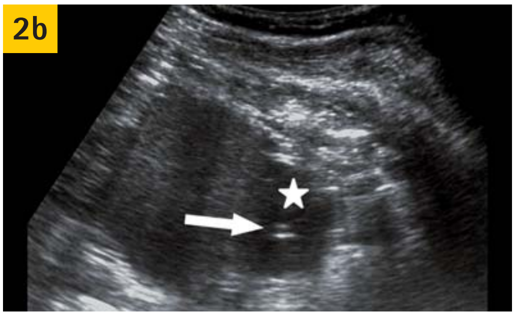


Fig. 2b: Hydrodissection was performed by locating the tip of a fine needle (22 Ga) between the renal tumor and the right colon and injection 10 ml of glucose solution at 30%. The tip of the needle (arrow) was easily seen in the fluid (star).

Fig. 2c: The CT control confirmed the presence of the glucose fluid spontaneously hyperdense (star) between the tumor (arrow head) and the colon. This small amount of fluid moved the bowel, improving the safety of the RFA procedure.

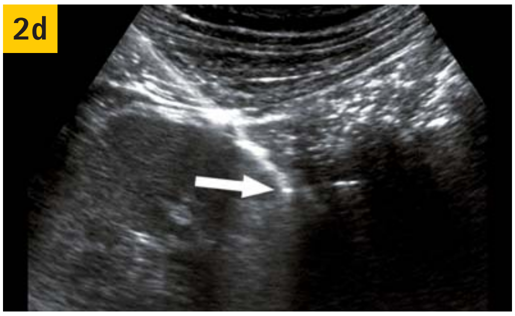


Fig. 2d: The RFA electrode is safely located within the tumor under US guidance, with good visualization of the needle tip (arrow).

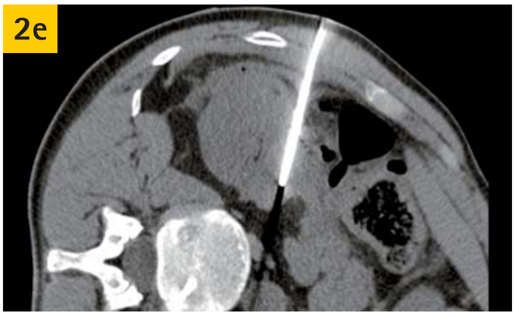


Fig. 2e: The CT scan confirmed the appropriate placement of the electrode and the presence of a safe distance to the bowel.

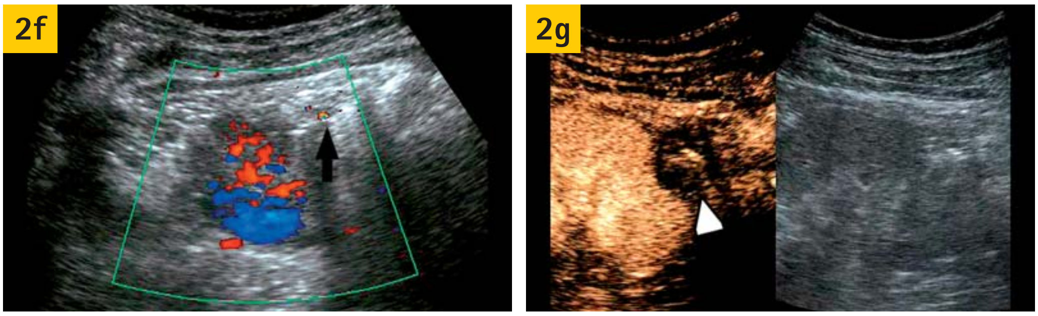


Fig. 2f and 2g: After RFA treatment, color Doppler US (Fig. 2f) did not generate additional information except the presence of some bubbles surrounding the treated area (black arrow). CEUS confirmed the lack of enhancement at the level of the tumor (arrow head). The tumor remained heterogeneous and some hypersignals corresponding with some bubbles resulting from the heat of the RFA procedure were noted despite the delay of 20 min between the end of the treatment and the US examination.

Fig. 3: The role of US and CEUS after the RFA procedure

3a

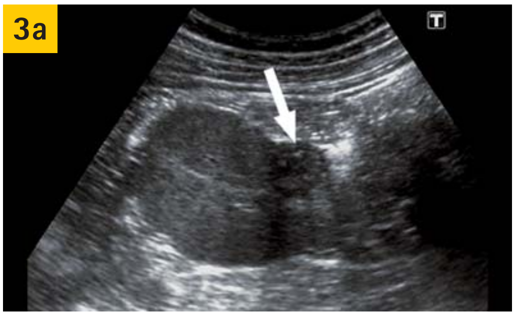


Fig. 3a: The tumor is better detected eight weeks after RFA (arrow).

3b

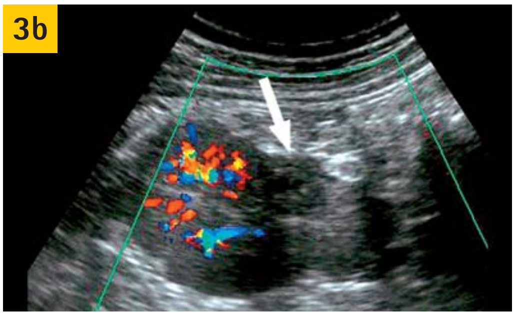


Fig. 3b: Color Doppler US did not reveal any residual vascularity or vascular complication such as renal arterio-venous fistula and false aneurysm.

3c

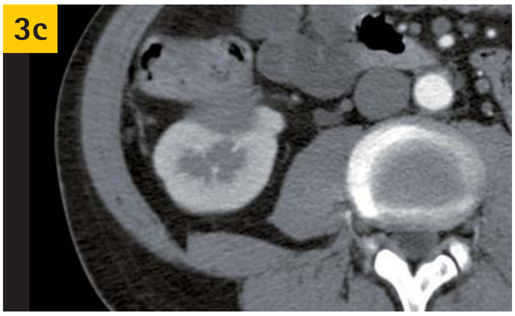
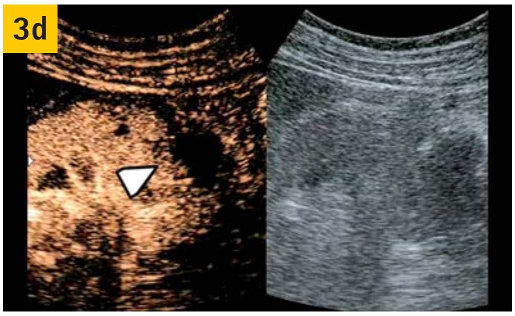


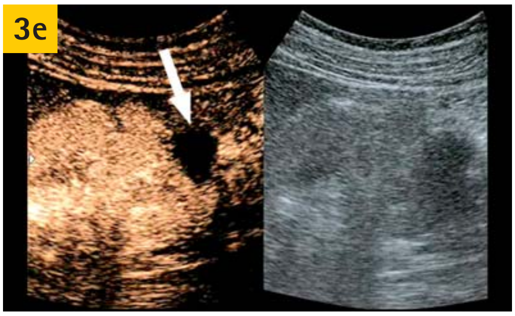
Fig. 3c: Despite the mild chronic renal failure, contrast-enhanced CT was performed after hyper-hydratation using reduced dose of iodinated contrast medium (1 ml/kg body weight). The lesion was perfectly homogeneous and did not enhance at all. There was no fat interface between the tumor and the right colon.

Fig. 3d, e and f: Contrast-enhanced US confirmed the lack of enhancement of the lesion. At the early arterial phase (Fig. 3d), the normal renal tissue at the deep pole of the lesion was slightly delayed and weaker. It remained completely homogeneous during venous and delayed phases (Fig. 3e). Four-dimensional contrast US study might generate additional information as it allows assessment of the entire treated volume.

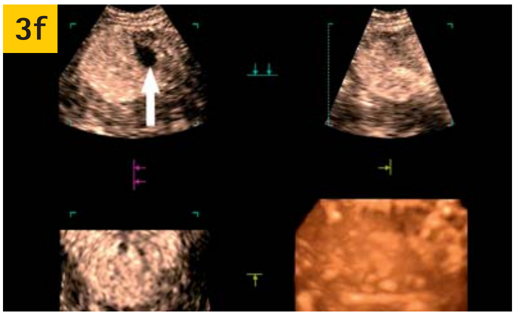
3d



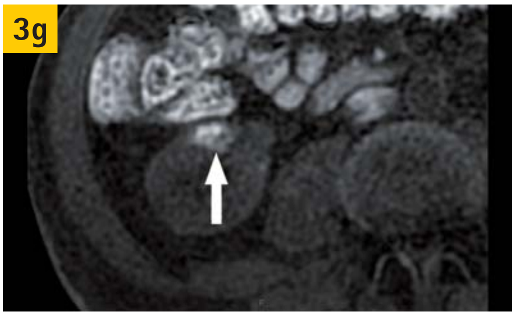
3e



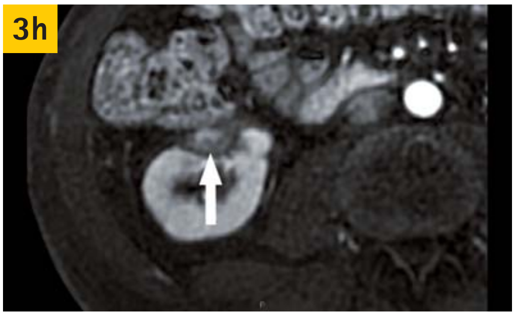
3f



3g



3h



3i

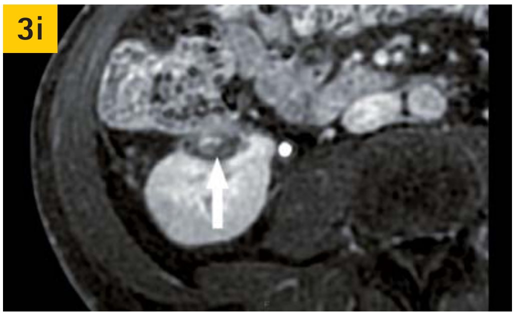


Fig. 3g, h and i: Contrast-enhanced MRI confirmed the successful treatment after one year. Note that the non-enhanced fat suppressed T1-weighted gradient acquisition is mandatory to detect the hypersignals due to coagulation necrosis, and avoid misdiagnosis of tumor recurrence.

protocols and are based either on temperature or impedance control.

However, renal RFA exhibits some significant differences compared to liver RFA leading to a lower success rate. These differences should be taken into account in order to improve the success rate and bring it to the same level as surgical tumorectomy. The major difference between renal and liver ablation is due to the higher blood flow of both normal renal parenchyma and tumors. Firstly, the cooling effect is much higher and requires optimal positioning of the electrodes to cover the entire volume of the lesion, particularly for the portion of the tumor adjacent to the normal cortex and to the sinus. Central tumors are more difficult to treat not because of their depth but mainly because of the cooling effect resulting from the presence of sinusal veins and arteries. The collecting system participates in this cooling effect particularly if an infusion of cold saline is performed through a ureteral catheter in order to avoid damage of the caliceal and pelvis structures. It is therefore even more critical to ensure perfect positioning of the electrodes within the tumor volume and to avoid passing through the tumor and entering the sinus with the risk of caliceal and vascular burning.

Secondly, the volume of normal renal parenchyma stabilizing the needle electrodes is limited compared to the liver and the large displacement of the system with the respiratory movements. The limited amount of parenchyma surrounding the lesion is affecting the stability of the electrodes within the tumor if non-expandable needles are used. Large respiratory movements particularly in patients undergoing RFA under conscious sedation can induce secondary displacement of the active tip. Expandable electrodes, although more stable, can result in puncture of vessels or excretory structures within the renal sinus if they are inserted too deep in central lesions. The most appropriate position for the system opening is not easily defined, as the kidney is not fixed within the retroperitoneum and can be pushed and moved during the expansion of the multitined electrodes.

Thirdly, renal function is very sensitive to the reduction of effective renal tissue particularly in case of previous reduction of renal parenchyma (previous controlateral nephrectomy, tumorectomy or polar nephrectomy on the same kidney) or pre-existing disease affecting the renal function (mellitus diabetes, nephroangiosclerosis, etc.). Renal RFA should limit as much as possible the destruction of normal parenchyma surrounding the tumour itself. In patients referred for renal RFA, the renal function should be estimated using Glomerular Filtration Rate (GFR), as it is regarded as the best overall measure of the kidney function[7]. About one fourth of patients with normal preoperative serum creatinine levels referred for renal surgery can exhibit mild chronic renal failure with an estimated GFR lower than 60 mL/min per 1.73m[28]. The risk of renal function decrease is significantly different in patients undergoing partial nephrectomy compared to radical nephrectomy ($p<0.0001$[8]). Only 3% of patients undergoing partial nephrectomy presented a new onset of GFR lower than 45 ml/min per 1.73 m^2, compared to 36% of patients undergoing radical nephrectomy. These numbers strongly prompt the preservation of renal parenchyma particularly in patients with small renal tumors who typically present longer lifetime.

The RFA procedure

In our centre, the RFA procedure is performed during a short hospitalisation of 36 hours after approval of the indication by the local multidisciplinary renal committee (including urologists, nephrologists, radiologists and oncologists).

The US system (Toshiba Aplio XV, Nasu, Japan) is moved to the CT suite. The patient is positioned in the CT bed and turned around in order to better visualize the lesion using US and optimise access. As the treatment is conducted under conscious sedation, even the prone position can be adopted. Non-enhanced CT is performed to evaluate the precise anatomical relationship of the needle track, particularly with the colon and the pleura (for interior lesions or lesions located at the upper pole of the kidney). After cutaneous disinfection and local anaesthesia, the RFA electrode is inserted under real-time US guidance. If the lesion is not visible with conventional US, contrast-enhanced US can be used to facilitate needle positioning. In our institution, most procedures are performed using a 200 W generator and saline-cooled electrodes (Cool-tip system, Covidien, Boulder, CO, USA). The number of electrodes and the size of the active tip are adapted to the tumor diameter and vascularity. When the lesion's maximum diameter is below 2 cm, a single electrode is typically used. When it is between 2 and 3 cm, the number of electrodes depends upon the degree of tumor vascularity: hypovascular tumors can be treated with a single electrode of 30 mm active tip, while hypervascular lesions require multiple electrodes. When the tumor diameter is above 3 cm, multiple electrodes are used systematically (either cluster electrode or 2 to 3 individual electrodes connected to the switching controller).

CT and MRI before and after RFA

Contrast-enhanced CT or MRI is requested before renal RFA to evaluate the lesion in terms of size, number, location, vascularity, relationship to adjacent structures and renal sinus and detection of metastases. They are also used during follow-up to confirm the lack of residual tumor and other tumor localization.

Multidetector CT is our preferred technique in the absence of contra-indication to iodinated contrast

Fig. 4: Evaluation of the lesion before percutaneous renal tumor ablation

Figures 4, 5 and 6 also refer to the same patient, a 79-year-old female with a few comobordity factors (including platelet aggregation inhibitors for cardiac arrhythmia, systemic hypertension, and age). A 4 cm left renal tumor was incidentally discovered at CT. The renal biopsy was performed immediately before the RFA procedure in order to simplify patient management, and pathology revealed the presence of a sarcomatoid tumor. The indication of radiofrequency ablation (RFA) was approved by our local multidisciplinary committee.

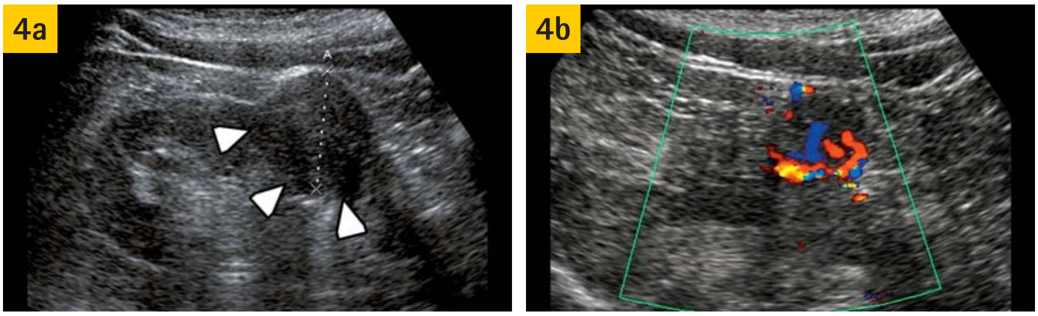


Fig. 4a and b: The tumor was isoechoic to the surrounding cortex and mainly identified due to the mass effect (Fig. 4a). Large vessels were detected within and around the tumor at color Doppler US (Fig. 4b).

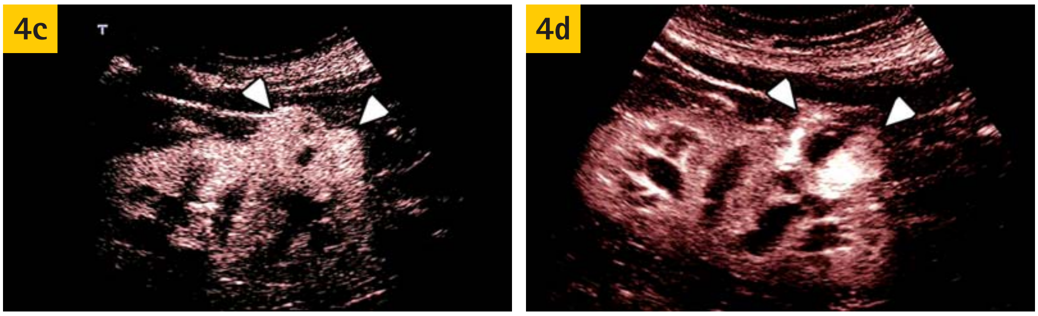
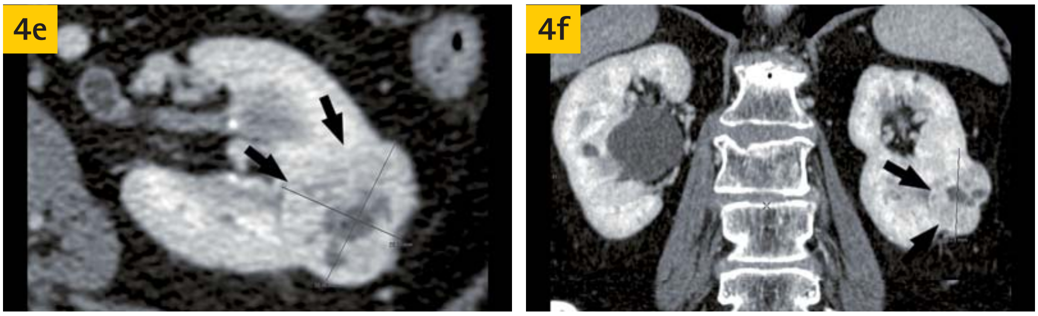


Fig. 4c and d: CEUS confirmed the presence of an almost homogeneous hypervascular tumor. MFI (Fig. 4d) better showed the hypervascular pattern of the lesion with some areas enhancing much more than the normal cortex.



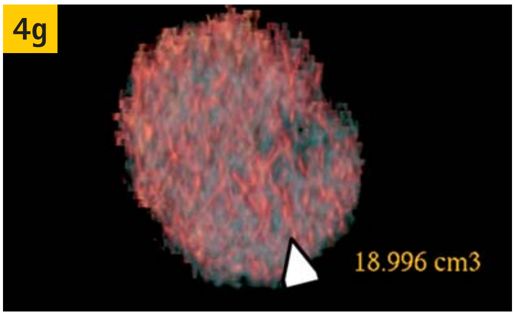


Fig. 4e, f and g: At contrast-enhanced CT, the lesion was as much enhanced as the normal cortex. However, the cranio-caudal length was underestimated and was over 4 cm. The true tumor volume was almost reaching 19 cm^3.

agent administration (mainly chronic renal failure and severe allergic reactions to previous administration). Multiplanar reformats (MPR) provide key information for anatomical relationships to the adjacent organs such as the spleen and the liver, the pleura and the digestive structures. Low osmolality iodinated contrast medium is administered at sufficient dose (2 ml/kg body weight) to localize the lesion and assess the relationship to the vascular structures as well as to the excretory system. Renal MRI is an alternative technique in case of contraindications to iodinated contrast agents. It is performed using a torso phased-array coil on a 1.5 Tesla unit and includes axial fat-suppressed T2-weighted sequence, in and out of phase acquisition, 3D breath-hold fat-suppressed T1-weighted fat-saturated spoiled gradient-echo sequence before and after Gadolinium chelates administration (Dotarem®, Guerbet SA, Aulnay-ss-Bois, France). MRI is increasingly used in the follow-up of young patients to reduce exposure to radiation (hereditary renal cancer, young population) and the risk of renal dysfunction after iodinated contrast medium administration (particularly in case of pre-existing renal failure and in the elderly).

Typical follow-up is performed for assessment of residual unablated tumor or detection of tumor recurrence. Unlike surgical procedures, the success rate of RFA varies according to tumor size and location from 85 to 95%[2–4,9]. Most incomplete treatments can be detected during the first three months of follow-up. Contrast-enhanced computed tomography (CECT) is typically used for most monitoring purposes, but it can induce renal failure or accelerate renal function deterioration due to nephrotoxicity. However, this technique cannot be used in non-cooperative patients and may not be easily available. Recently, a major concern has been raised on nephrogenic systemic fibrosis (NSF) which may be associated with the use of gadolinium contrast agents in patients with chronic renal failure[10].

Today, there is no clear consensus nor are there any evidence-based criteria for method or timing of post-treatment surveillance imaging[2,3]. The optimal imaging technique should be inexpensive, easy to perform, non-invasive, well accepted and tolerated by the patients, providing high sensitivity and specificity for the detection of residual disease.

US and CEUS modality

The detection of renal tumors by US depends on size, echogenicity, localization and appearance of the normal kidney (size and echostructure). Renal solid masses are better seen when they are located in the right kidney and involve the mid-portion with extra-renal development. The detection of renal cell carcinoma is incidental in almost 83% of the cases but conventional US sensitivity remains lower for lesions smaller than 3 cm in diameter compared to CT[11,12]. CEUS is not recommended for systematic detection of renal tumors[6] but can be useful in selected indications.

CEUS improves the depiction of normal renal blood flow[13] and tumor vascularity using real-time low mechanical index (MI) pulse subtraction with high temporal and spatial resolution[6,14]. Moreover, US contrast agents such as SonoVue® (BR1, Bracco, Milano, Italy) are well tolerated and do not exhibit any renal toxicity in clinical practice. CEUS can be considered as an alternative to CT and MRI in the follow-up of renal tumors treated with RFA[15]. Following the baseline examination using Tissue Harmonic Imaging and color Doppler US, the US system is switched to pulse subtraction with a double screen technique with gray-scale anatomical reference. After IV bolus administration of 2.4 ml of SonoVue® followed by 10 ml saline flush, the transit of the microbubbles is monitored continuously at low MI (< 0.1) within the normal renal parenchyma and the tumor. The kidney and the tumor can be imaged in different planes until the disappearance of the microbubbles. Cineloops are stored digitally for the review.

The role of US before RFA

Before RFA, US and color Doppler US are systematically used to evaluate the renal mass in terms of identification, anatomical relationship, vascularity and accessibility. The examination is performed in supine and oblique positions in order to optimize visualization and access of the lesion prior to the procedure. For tumors located at the upper pole of the kidney, it is critical to localize the pleura and its displacement with respiration. The liver and gallbladder must be identified for right-side and the spleen and pancreas tail for left-side lesions. The precise relationship to bowel structures can be difficult to analyze and requires non-enhanced CT. Color Doppler US is useful to detect tumor vascularity and vessels that might cross the needle path.

In our experience, CEUS has demonstrated to be extremely useful to evaluate tumor perfusion. At the beginning, this parameter was simply evaluated in comparison to the normal adjacent renal parenchyma as an hyper-, iso- or hypo-enhancing lesion. Recently, tumor perfusion quantification has become feasible in routine practise using SonoTumour®, a software developed by Bracco Research. One or two cineloops are acquired during a breath-hold at the arrival of the microbubbles for approximately one minute and saved in DICOM format. This software is able to linearize the data and to aggregate two cineloops. It can also compensate for breathing movements when the displacement of the organ is limited to the imaging plane (at a certain degree). The quantitative parameters are extracted from the time intensity curves modelled with complex exponential function. Absolute as well as relative values are obtained from a reference area. Thus, regions of interest (ROI) are placed upon the entire tumor and the reference area. In our experience, the normal renal parenchyma adjacent to the tumor was found to be the more suitable reference area. After that first minute dedicated to perfusion estimation, the entire kidney is scanned on the two orthogonal planes. The tumor area with the highest perfusion is carefully localized for the further RFA procedure. The electrode should target this area in order to avoid early recurrence due to the persistence of tumor parenchyma and improve the performance of the technique.

Fig. 5: The role of US and CEUS during and after the first RFA procedure

5a

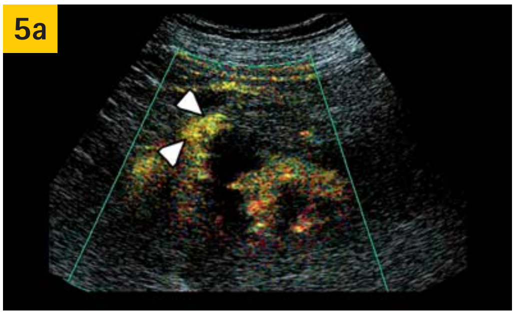


Fig. 5a: Immediately after RFA (performed with a cluster electrode, Covidien – Valleylab, Boulder, CO, USA), CEUS was performed using the VRI mode, after a bolus injection of SonoVue® (2.4 ml). Strong persisting enhancement was detected at the upper pole of the lesion (arrow heads) and immediately retreated by inserting a single cool-tip RF electrode.

5b

Fig. 5b: At day 1, gray-scale imaging showed no complications such as collection or dilatation of the excretory system.

5c

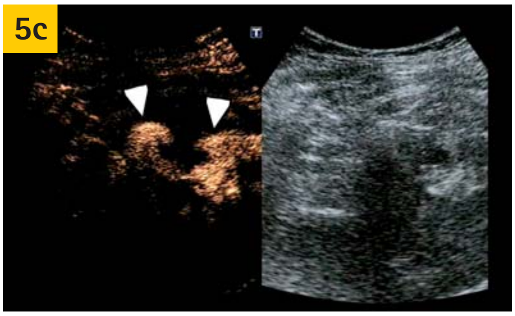
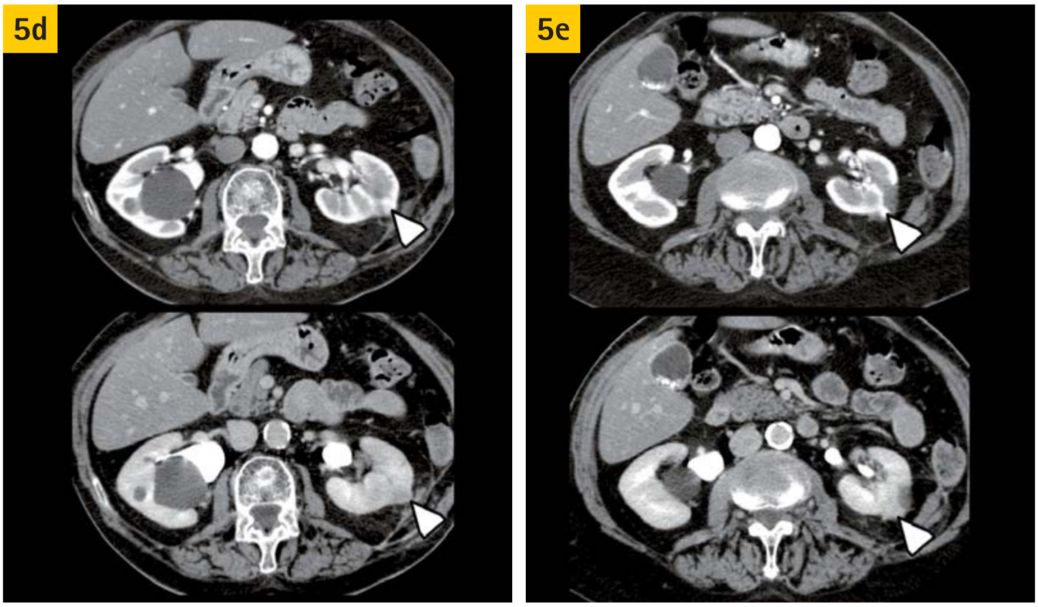


Fig. 5c: CEUS revealed two bulky areas enhancing at the upper and lower part of the tumor (arrow heads) at day 1. This information was critical to schedule the next RFA session.

Fig. 5d and e: Contrast-enhanced CT performed at six weeks (immediately before the second RFA session) confirmed the diagnosis of 2 renal tumor residues at the upper anterior part of the ablated area (Fig. 5d) and lower posterior part of the ablated area (Fig. 5e).

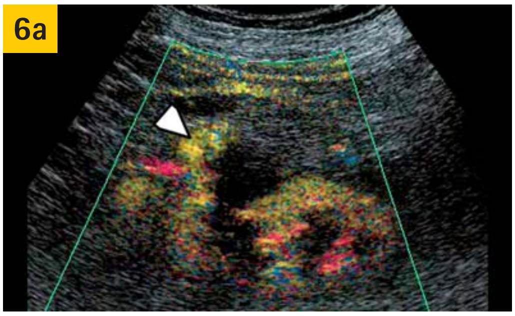
5d 5e

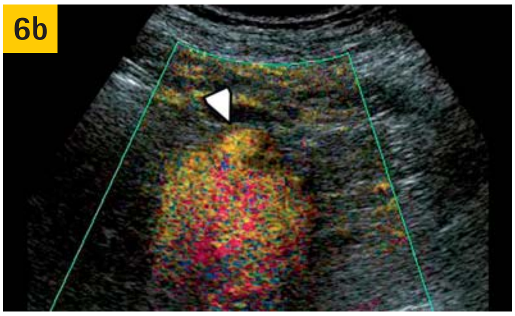


The role of US during RFA

During RFA, US plays a key role in optimizing electrode placement and reducing the duration of the procedure. Patient position is determined in order to reduce the distance between the skin and the target and to avoid anatomical structures sensitive to heat. If this is done by US, a non-enhanced CT is performed to verify that the position is optimal. After skin disinfection and local anaesthesia combined with IV sedation, the electrode(s) is/are inserted using US because of its real-time performance and high spatial resolution. The appropriate selection of the transducer is critical. The wide-band abdominal transducer (C6–1) is the reference probe because it offers high resolution and contrast. If the lesion is really superficial, higher frequency transducers, such as the curvilinear C10–3 or even the linear transducer L12–5 with abdominal preset can be useful. However, with high frequency transducers image quality can be rapidly affected by the presence of peri-renal bleeding or gas deposition. We found that the micro-convex transducer (6C1) is extremely helpful when the lesion is poorly visible due to

Fig. 6: US and CEUS during and after the second RFA procedure





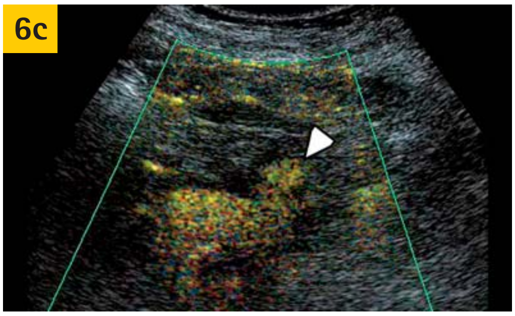


Fig. 6a, b and c: CEUS was performed immediately before the RFA procedure in the longitudinal (Fig. 6a) and transverse planes (Fig. 6b and c). The residual tumor areas were easily detected (arrow heads).

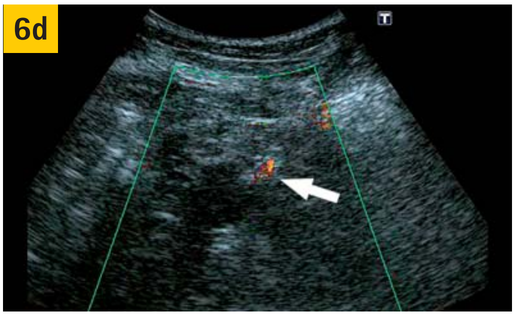


Fig. 6d: The cool-tip electrode was inserted and the tip of the needle was located close to the suspected area. The colour artifact (arrow) was extremely useful to identify the tip of the electrode.

Contrast-enhanced US using VRI mode was used to guide the second RFA procedure exactly to the site of the persisting tumor areas. The entire RFA procedure for retreating the two tumor residues took less than one hour.

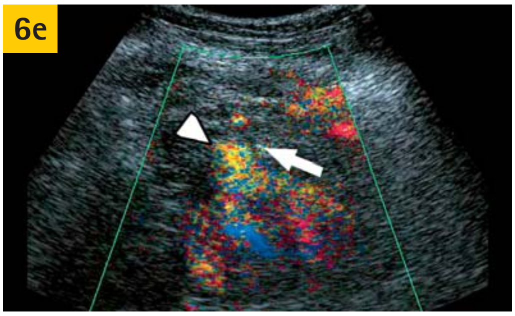


Fig. 6e: CEUS was then performed in the same plane to precisely detect the residual tumor area (arrow head) and the tip of the electrode (arrow) was immediately advanced onto the tumor.

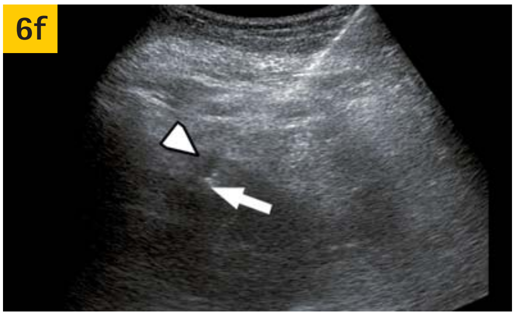


Fig. 6f: By switching back to conventional THI mode, the position of the electrode was controlled. The same procedure was applied for the treatment of the lower pole residue.

limited intercostal accessibility. In our department, guidance is always performed free-hand to allow better visualization of the electrode track and detection of the tip. When the position of the electrode seems adequate, a non-enhanced CT scan is performed in order to check the electrode position through the entire tumor and the relationship to the surrounding structures.

If the lesion was not correctly assessed during conventional US, administration of an ultrasound contrast agent is useful in order to improve lesion detection and conspicuity. All contrast imaging techniques can be used. Split-screen technology with pulse/power modulation is particularly suitable for guiding electrode insertion for tumors with poor accessibility (either central or anterior, or located at the upper pole). The electrode is visible on the anatomical display while the targeted tumor is enhanced on the contrast display. Vascular Recognition Imaging (VRI) was also found to be useful as the electrode is visible on the anatomical greyscale background. The tip of the electrode is seen as an hyperechoic dot with both techniques. However, at peak enhancement, its detection becomes difficult due to the strong enhancement of the normal cortex and the tumor.

CEUS is also very useful after insertion of the electrodes, particularly when the lesion is small and poorly seen with conventional US. In fact, the kidney is highly mobile in the retroperitoneum and the needle introduction can affect the position of the lesion by rotating or translating the kidney. In patients with chronic renal failure, the reference imaging technique is MRI and the procedure is guided by combined US and non-enhanced CT. When baseline US is not helpful, the position of the lesion obtained from the reference MRI cannot be matched with non-enhanced CT due to some kidney displacement. The injection of SonoVue® improves visualization of the lesion and confirms the appropriate position of the electrode within the tumor volume.

CEUS plays a critical role in the treatment of persisting tumor tissue (residual tumor following RFA or tumor recurrence) after a previous ablation session. In this case, the electrode should be placed within the residual tumor detected as a persisting enhancing area. MRI might be the technique of choice but due to the limited access to this modality and the technical requirements (open system, MRI compatible equipment, etc.) this might not be feasible. CT value is limited by the required admiistration of iodinated contrast agent and the transient enhancement of the residual tumor (mainly during arterial phase which cannot be repeated during the procedure). The lack of real-time guidance is an additional limitation as most residual tumors are small and should be treated at an early stage to take opportunity of the size reduction. CEUS is in our experience the preferred guiding imaging modality, as the duration of the enhancement is typically short (less than five minutes) and bolus administration of USCA can be repeated in order to localize the enhancing area with no limitation in case of renal failure. High spatial and temporal resolutions are extremely useful to reduce the duration of the new procedure and increase the success rate. Due to this approach, the failure rate for the second procedure does not exceed the failure rate of the first one.

The role of US during follow-up of renal RFA

The frequency of incomplete RFA treatment (persisting tumor) and tumor recurrence is ranging between 7% and 20% of the procedures, depending on tumor size, location and perfusion[3,4,9,16]. The ability to timely and accurately diagnose the tumor while minimizing the inconvenience of the imaging modality and its potential renal toxicity is critical. MDCT is the reference imaging modality for surveillance as it allows not only the detection of residual and recurrent tumors but also the evaluation of metastatic sites including the lungs. However, the administration of iodinated contrast media is mandatory for the abdominal study and their nephrotoxicity remains a limitation[17,18]. In patients undergoing RF ablation of a renal tumor, the rate of decreased renal function can reach 16%, particularly in the case of solitary functioning kidney. RFA can also contribute to the acceleration of the impaired renal function, limiting the use of contrast-enhanced CT[18].

Fig. 7: The role of US and CEUS after the RFA procedure

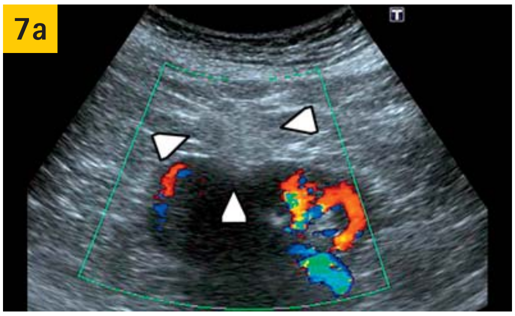


Fig. 7a: At day 1, the lesion did not exhibit any color Doppler signals (arrow heads).

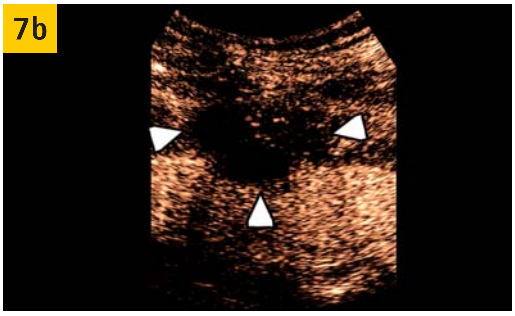


Fig. 7b: CEUS confirmed the lack of any abnormal enhancing area within the tumor area, and particularly at the upper and lower poles.

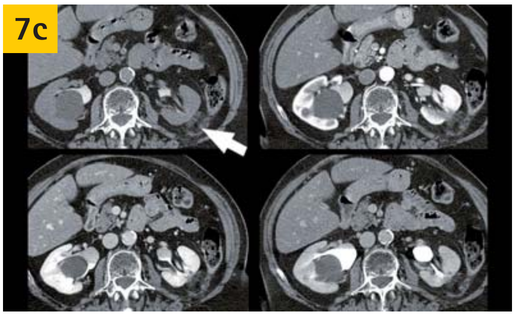


Fig. 7c: Contrast-enhanced CT at two years confirmed the success of the procedure.

Patients with chronic renal insufficiency can take advantage of the lack of nephrotoxicity of Gadolinium chelates. Pre-and post-contrast MRI is an alternative imaging modality that can be used for RFA follow-up, particularly in case of renal failure and in young patients in order to reduce the amount of ionizing radiations[19,20]. However, with MRI spatial resolution is lower than with MDCT. There is no comparison study evaluating the performance of CEMRI in comparison to CECT. Some concerns have been raised about the rare association between nephrogenic systemic fibrosis and the use of intravenous gadolinium contrast material in patients with chronic renal failure[21].

Immediate assessment of RFA efficacy

CEUS can be used during the RFA procedure itself to evaluate the immediate result of the ablation. The increase in temperature results in hyperechoic appearance due to large bubble production involving both the targeted tumor and the surrounding tissues (adjacent renal tissue and perirenal fat). After fifteen to twenty minutes, the artefacts within the adjacent renal tissue and the tumor are reduced and CEUS can be performed varying the imaging plane to limit the shadowing effect of residual bubbles. When the perirenal fat is involved in the treatment, the persistence of these artefacts is increased and it is critical to use a field of view that avoids the path of the electrodes. The detection of residual tumor relies on the presence of a nodular or crescent-like enhancement displaying characteristics identical to those observed before treatment. Meticulous comparison with pre-contrast examinations is critical and the CEUS performed immediately before RFA should be performed in the same position and view as the control.

CEUS is also useful to verify the position of the electrode within the tumor when its identification is poor using baseline US. The comparison before MRI and/or CT performed previously can be of limited value due to the possible rotation or translation of the kidney during the insertion of the electrode. CT can be useful if the administration of iodinated contrast media is not contra-indicated. In this case, CEUS is the only imaging technique that allows confirmation of the right location of the electrode. In the case of chronic renal failure, it is even more critical to avoid the destruction of normal parenchyma.

Follow-up assessment of RFA efficacy

CEUS offers some definite advantage in the follow-up of renal tumors treated by RFA. The concept of CEUS follow-up of tumors after ablation was introduced first for hepatocellular carcinoma[23–24]. Four years ago, we decided to develop this imaging technique for RFA follow-up when it appeared clear that it was a useful tool. Recently, Meloni published a retrospective study evaluating the performance of CEUS during RFA follow-up[15]. Despite the fact that there is only one published paper, the interest in this indication is growing fast.

In our institution, an initial evaluation of RFA efficacy is performed within 24 hours immediately before discharging the patient using CEUS and CE-CT depending on the renal function. A second evaluation is scheduled six to eight weeks later. In our experience, this second evaluation offers best sensitivity for the detection of residual tumor. Any contrast enhancement within the ablation zone should be considered residual tumor tissue[15,25–27]. To avoid misinterpretating vascular structures for residual disease, particularly the common reactive hyperemia seen at CEUS, we consider as residual disease any nodular or crescent-like enhancement displaying characteristics reflecting those observed before treatment. Meticulous comparison with pre-contrast examinations is thus of paramount importance. The evaluation of RFA efficacy by any imaging modality is not so obvious than it could appear from the literature. Discrepancies between the imaging techniques are not unusual. The identification of the residual tumor is made possible by a slight difference of contrast enhancement that can last only a few seconds. False positive results can be found at 24 hour CEUS and CT due to enhancing areas within the treated area that will disappear during follow-up. They can be attributed to detached normal renal cortex or patent peripheral vessels that underwent necrosis or occlusion over time.

CEUS limitations are encountered in obese patients and for central lesions, particularly in patients with multiple tumors, cysts and previous RFA procedures. This situation is usual in hereditary renal cancers such as von Hippel Lindau disease. In this case, MDCT performance is superior to CEUS. CEUS is superior to CT/MRI for the depiction of normal and abnormal vessels, such as small RFA-induced arteriovenous fistula that is misinterpreted as residual disease in most cases.

Perspectives

Perspectives involving US improvements are extremely promising for the management of renal tumor by RFA. The basic requirement is excellent contrast resolution and spatial resolution for the perfect assessment of tumor shape and limits. The detection of the needle track and visualization of the needle tip remain a challenge. The use of real-time 3D (4D) (including multiple planes) should be useful for appropriate electrode positioning within the tumor volume. 3D acquisition will bring better spatial visualization of the distribution of electrodes in the lesion, improving the detection of areas not included in the ablated volume. Treatment planning will be facilitated, particularly if the modality is also available in conjunction with USCA administration. The injection will facilitate the identification of residual tumor and guide retreatment. These new modalities are also expected to reduce the duration of the procedure including the immediate evaluation of the procedure efficacy.

Elastography can also be applied in order to improve the immediate and follow-up evaluation of the procedure with regard to detection of residual tumor. However, the presence of large bubbles can affect the compliance of the tissue.

Fusion imaging of US and CT/MRI is also a very promising tool for renal RFA procedures. However, the technique must be able to use previous CT/MRI volumes acquired in different positions. In practise, RFA is performed in most cases in prone or oblique positions, while previous references CT/MRI were acquired in supine position. Another clear issue results from the fusion precision. Because the efficacy of the heat production is limited by the huge perfusion from both normal and tumor tissues, the electrodes should be perfectly distributed within the tumor volume. Precision of less than 3 to 4 mm seems reasonable here.

Conclusion

RFA of renal tumors is an efficient alternative to conservative surgery. However, the rate of success remains lower due to the higher tissue perfusion of both normal renal parenchyma and renal cell carcinomas. Technical issues include the limited amount of renal tissue stabilizing the electrodes and the increasing incidence of renal failure. US and CEUS play a critical role at each step of the management of renal RFA, including renal biopsy, treatment planning, guidance of the electrodes and immediate and delayed follow-up. Further developments including 3D-US, 3D-CEUS, elastography and fusion imaging should increase the role of US. Contrast-enhanced CT and MRI are still major players in the evaluation of renal tumors before and after ablation. However, their cost, limited access and potential risks with contrast agents can represent a limitation compared to US, despite higher sensitivity for the detection of residual tumors.

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Portable Ultrasound Headlines at Glastonbury Festival

JM Regi, S Hanlon

As the summer months peak, 200,000 festival lovers descend on Worthy farm in Summerset for the largest music festival of the year. Most people's vision of the Glastonbury Festival includes muddy fields, endless rows of tents and an enormous diversity of headline acts. Few contemplate the logistical challenges of providing high quality healthcare to a population equivalent to that of a city such as Norwich or Newcastle.

Every year for the last 25 years Festival Medical Services (FMS) has provided a team of doctors and nurses to look after this transient crowd of festival goers. Each year FMS supplies 600 staff and sees close to 4000 patients over the six days of Glastonbury, almost double the figures of most emergency departments in the UK. The patients suffer a variety of mishaps from trivial insect bites and sprains through to potentially life-threatening conditions. This year there were three cases of Swine Flu, two Glastonbury babies and one death.

Musculoskeletal injuries are the most common presentation and for the last two years FMS has offered a fully digital radiography service. Approximately 150 X-ray examinations were carried out and digital images of positive X-rays were copied to CD-ROM to prevent duplication of radiological examinations at fracture clinics. This year in partnership with Toshiba Medical Systems, FMS expanded to provide a 24 hour on-call ultrasound service. This was provided by a team of six radiologists of different specialties using the brand new pre-released version of Toshiba's Viamo portable ultrasound system. The system's array of probes allows for a wide range of examinations including abdominal, gynaecological, musculoskeletal and cardiac imaging. In addition to the team and scanner, application support was on hand to help exploit the Viamo's potential.

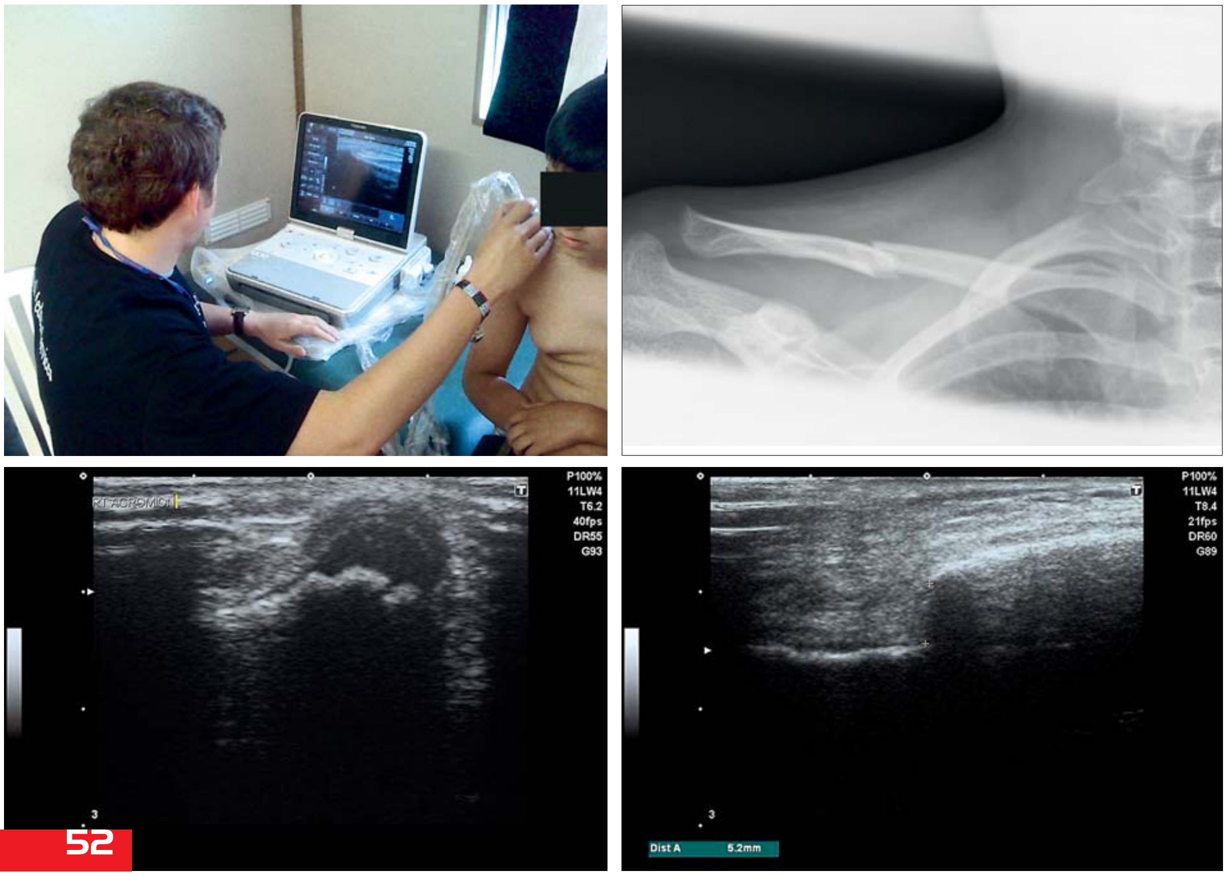
Justification for on-site imaging is to make diagnoses to support valid transfers to a hospital and prevent unnecessary admissions to the busy on-take

Fig. 1: 10-week live intrauterine pregnancy with an adjacent 24 mm subchorionic bleed

Fig. 2: Third-trimester scan for confirmation of viability demonstrating the foetal face

hospitals supporting the festival. The team of radiologists encouraged the FMS emergency doctors to request ultrasound investigations in the same fashion as they would do in their normal practice. There were twenty requests for ultrasound investigation and twelve scans performed. Many of the ultrasound requests were for pregnant patients with suspected miscarriage (Fig. 1) or third trimester patients (Fig. 2) with anxiety due to lack of recent foetal movement. The ability to image these patients for confirmation of foetal viability eased patient anxiety and prevented unnecessary transfer.

Fig. 3: Ultrasound of right shoulder demonstrating acromiclavicular joint effusion with mid-shaft clavicle fracture and corresponding X-ray



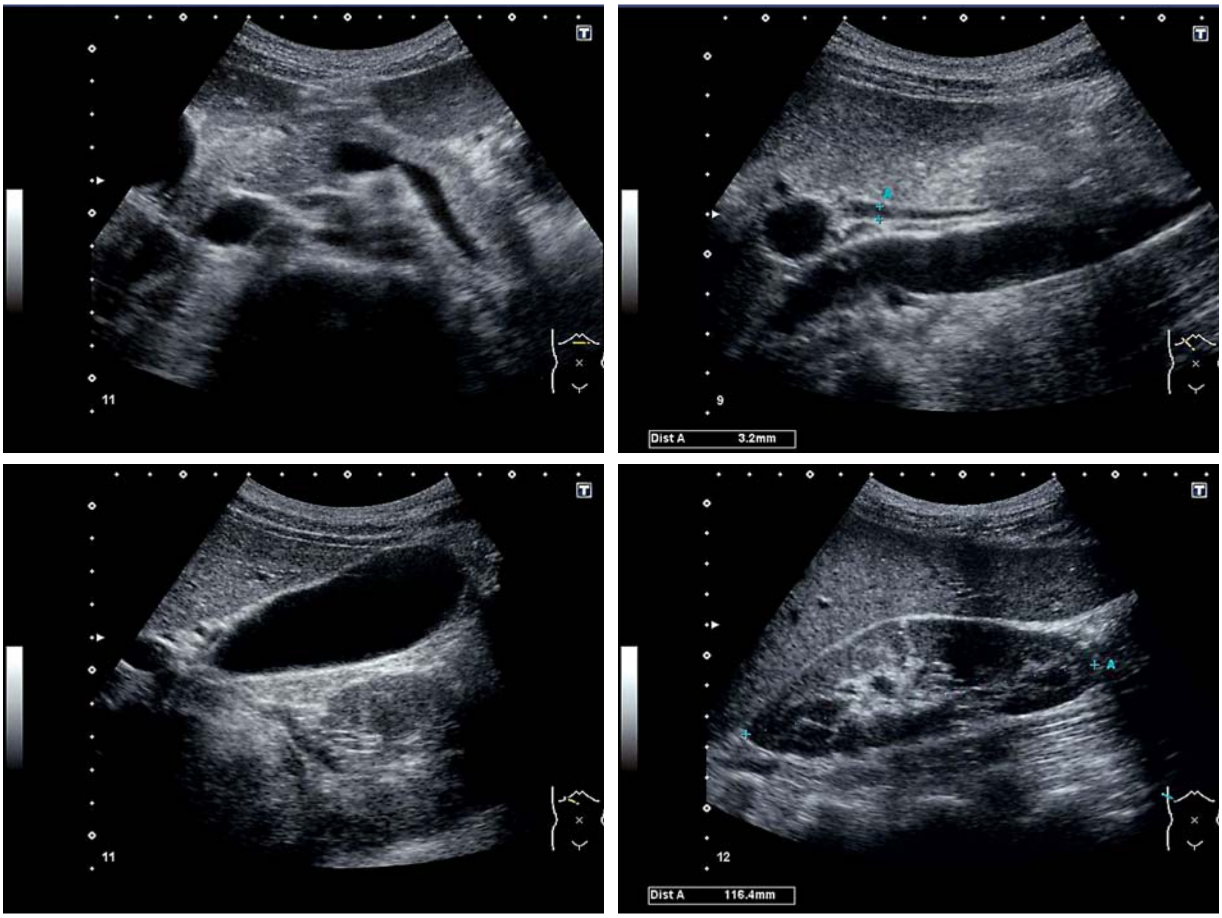


Fig. 4: Ultrasound of the upper abdomen. Images show the usual suspects for RUQ pathology: pancreas, distal common bile duct, gall bladder and right kidney

Examinations were also performed for pyelonephritis, acute abdominal/pelvic pain and musculoskeletal injuries. Figure 3 shows the first ultrasound examination of Glastonbury 2009. A 12-year-old male presented with a history of trauma to the right shoulder and a decreased range of movement. Ultrasound examination diagnosed a mid-shaft clavicular fracture and associated acromioclavicular joint effusion. The patient was treated conservatively and returned to the festival. The Viamo also proved useful for foreign body localisation and the identification of ligament and tendon injuries.

In a typical fashion to many emergency department presentations, a 29-year -ld female attended with a 24 hour history of right upper quadrant pain. The ultrasound examination excluded renal obstruction and significant pathology which requires surgery. After urine analysis the patient was treated for right sided pyelonephritis. A different case of left flank pain demonstrated a localised large bowel wall thickening and probable diverticulitis.

The Viamo combines all the advantages of a portable ultrasound system with the diagnostic quality, comfort and ease of use of a premium cart-based system. The Viamo's 15 inch built-in touch control screen demonstrated intuitive functions which our radiologists found easy to use. It provided excellent resolution imaging which gave the radiology team confidence in their diagnoses. Captured images and video clips were transfered directly to USB memory stick in either DICOM or Windows format. Each of the patients examined with ultrasound were offered copies of the their clinical images on CD-ROM with the the associated radiological report. This prevented futher re-imaging and provided documented evidence of the clinical episode.

The ultrasound service at Glastonbury Festival made a positive impact in the treatment and potential hospital transfer in three quarters of the patients examined. Whilst examination should never delay the transfer of a seriously unwell patient it changed the management and prevented many unnecessary hospital admissions.

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TV Reloaded: 3D and Web Access with Toshiba's CELL TV

No doubt, 2010 will be the year of 3D – be it hardware- or content-wise. Even before this year's CES opened its doors in Las Vegas, the major players such as Toshiba, Samsung, Sony, Panasonic and LG presented their visions on how to shake off the inertia that has beset TV for many years and revive the medium with leading-edge technology.

Boosted by recent 3D movie successes such as James Cameron's smash hit Avatar the consumer electronics industry is poised to satisfy the demand with innovative hardware. With its new high-end product Cell TV Toshiba focuses on unmatched processing power.

CELL makes everything better

The heart of CELL TV is the powerful CELL Engine which has 143 times the processing power available in current TV models. This massive power manifests itself in incredibly enhanced picture quality that is certainly the new state-of-the-art. The new Super Resolution Technology ensures precise image accuracy by sampling multiple frames and restoring the native pre-sampling signal curve. This process enhances both SD and HD signals for the clearest possible 1080 p Full HD picture. Net Resolution+ adds Compression Noise Canceling to significantly enhance the internet content. This system detects noise compression inherent in low resolution internet content and separates and corrects the image data to produce sharper, cleaner internet images, even on super large screens. In addition, AutoView™ RGB combines an ambient light sensor and a new RGB sensor to automatically set brightness, contrast, gamma, sharpness, color saturation, and now color temperature to ensure the best possible picture in any lighting condition.

Watch everything in 3D

CELL TV has true 3D TV capability and much more. For native 3D content, CELL TV utilizes a Frame Sequential System that changes from 240 Hz in 2D mode, to 120 Hz for the right eye and 120 Hz for the left eye in 3D mode. This system accepts multiple 3D input formats. However, when true 3D content is not available, CELL TV has the solution. TriVector™ 2D to 3D Conversion takes any 2D content and converts it into 3D in real time. This means that TV viewers now can "Watch Everything in 3D!" including 2D sports, movies, TV shows, video games, and more. 3D TV creates a more immersive home theater experience and significantly expands 3D time, truly setting itself apart.

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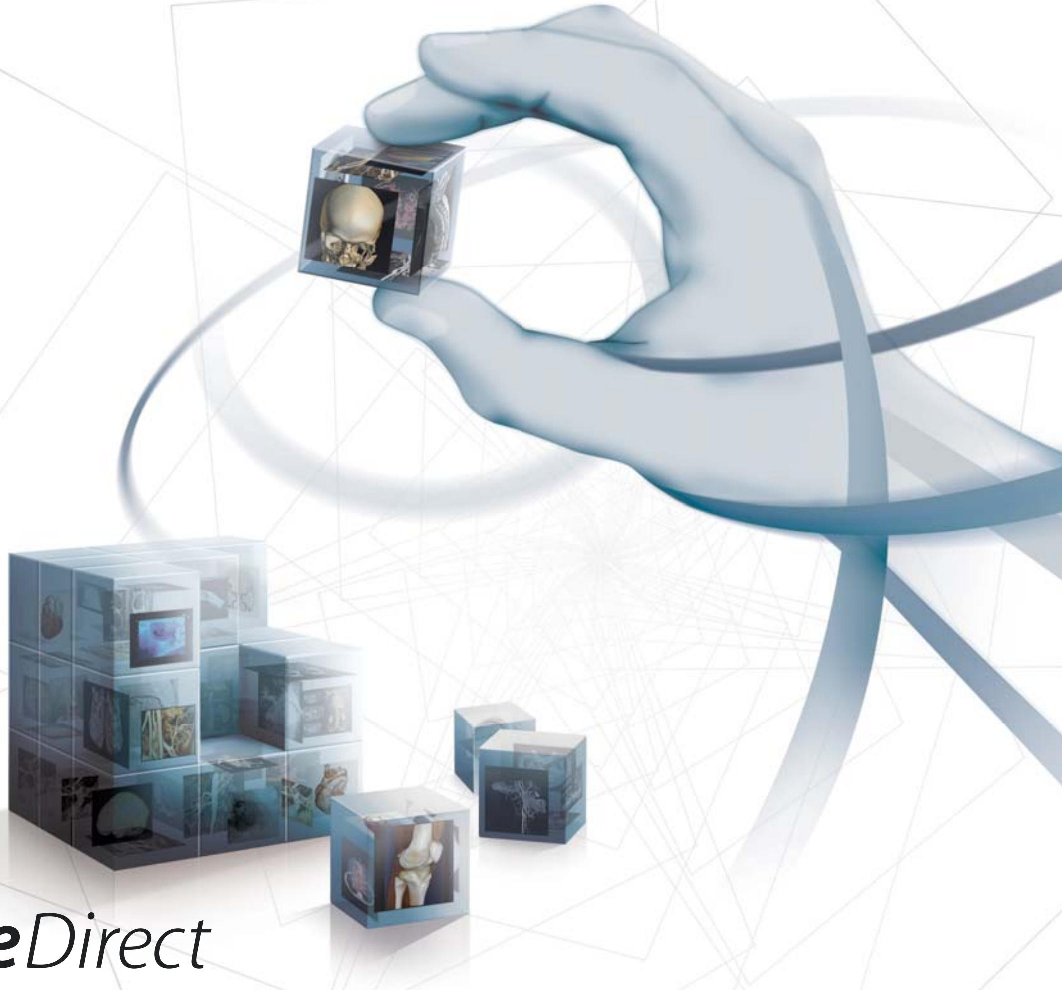
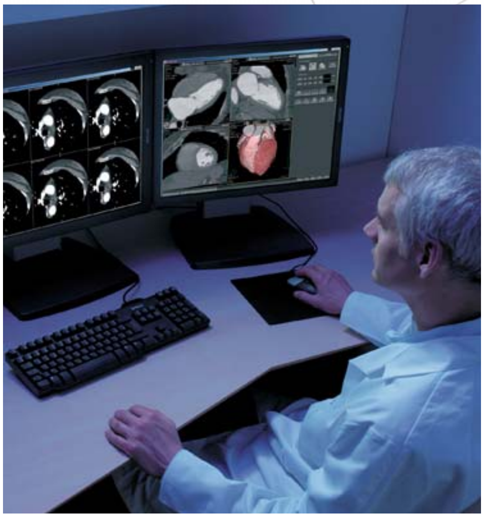
For more information on the CELL TV, please visit **http://www.ToshibaTV.com.**





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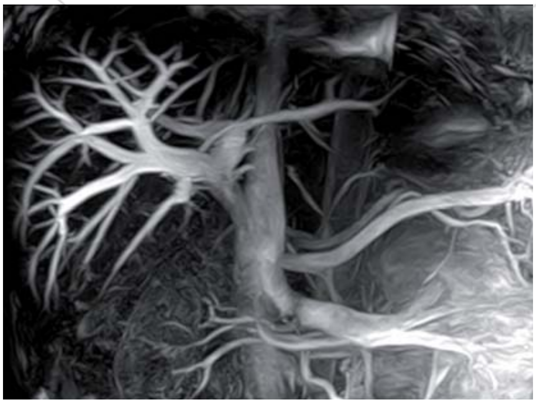

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