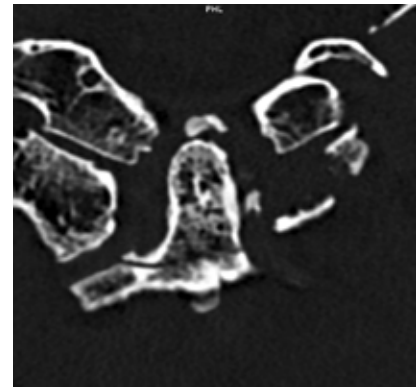
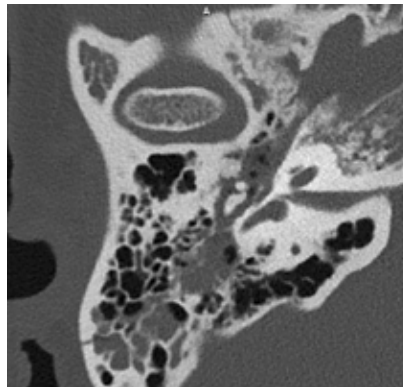
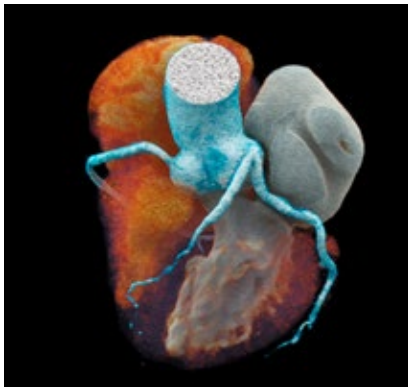


Impacting clinical outcomes with single source photon-counting CT

Clinical case reports –
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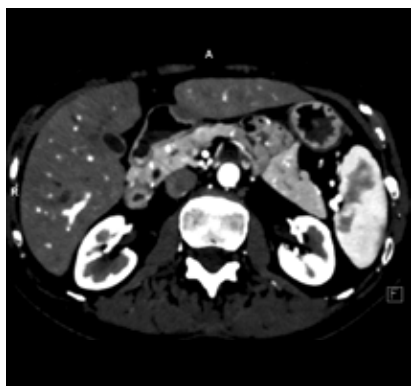
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All cases shown in this document were acquired either with a single-source photon-counting CT scanner or a dual-source CT scanner operated in single-source mode. Scans acquired in dual-source systems operated in single-source mode are considered representative of single-source photon-counting CT acquisitions.



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Triple-rule-out evaluation of acute chest pain using single source photon-counting CT

Lili Száraz, MD; Sámuel Beke, MD; Kristóf Nagy, MD; Barnabás Baksa, MD; Péter Hegedűs, MD, PhD; Prof. Pál Maurovich-Horvat, MD, PhD
Medical Imaging Centre, Semmelweis University, Budapest, Hungary

History

A 50-year-old male patient presented to the emergency department (ED) with massive hemoptysis, dyspnea, and chest pain. The patient's medical history included multiple cardiac risk factors and adverse events, including hypertension, chronic obstructive pulmonary disease, previous myocardial infarction, and mitral valvuloplasty. Notable physical exam findings included tachypnea, spastic respiratory sounds with left-sided crepitations, and diaphoretic skin. Laboratory findings revealed elevated inflammatory markers, high-sensitivity Troponin T, and D-dimer levels. Given the high suspicion of pulmonary embolism (PE), a targeted chest CT angiography (CTA) was performed, using ECG-gated helical acquisition with standard-resolution scan mode, to confirm the PE and evaluate the bronchial arteries, guiding further potential embolization therapy.

Diagnosis

The multiphase chest CTA confirmed a left-sided PE complicated by infarct pneumonia (see Figure 2). Thrombolytic therapy was not indicated, as determined in consultation with the intensive care unit. Likewise, bronchial artery embolization was considered unnecessary, since the hemoptysis was attributed to the severe infarct pneumonia. Empirical antibiotic therapy was initiated and later escalated to a combination of piperacillin–tazobactam and metronidazole. Due to significant hemopty-

sis, anticoagulation was administered at a reduced dose; nevertheless, anti-Xa levels remained within the therapeutic range. The chest CTA additionally revealed a left hilar mass infiltrating the pulmonary branches of the left lower lobe (see Figure 2), as well as a smaller, round lesion closely adherent to the pericardium at the base of the right lung. On a one-month follow-up scan, the left-sided mass had resolved, while the right-sided benign-appearing lesion remained unchanged. On a three-month follow-up scan, no malignancy was found, the atelectasis and consolidations showed signs of regression, however the segmental and subsegmental emboli were still visible.

Comments

While the ability of triple-rule-out-CT (TRO-CT) to rule out disorders in all three vascular beds (pulmonary embolism, PE; aortic dissection, AD; and coronary artery disease, CAD) has been demonstrated [1], a gap remains in the literature regarding the clinical impact of TRO-CT. Araoz P.A. et al. found that, based on accepted clinical risk scores, 65% of their patient cohort warranted work-up for at least two of either PE, AD or CAD suggesting that a large subset of patients would benefit from a comprehensive test like TRO-CT [2], even though the mean radiation dose (23.8 ± 12 mSv; range: 3.7–84.1 mSv) and contrast media usage (144.6 ± 31.2 mL;

range: 54–360 mL) varied widely. On the other hand, Takx et al. found that TRO-CT may reduce the length of stay and costs in ED in appropriate patients, but no difference in the diagnosis of PE, AD, or CAD was observed between TRO-CT versus standard-of-care strategies [3]. Currently, no major US or EU guidelines recommend routine TRO-CT as the initial ED test for undifferentiated acute chest pain, due to the limited contemporary comparative evidence. This case report serves as a reference, suggesting that PCD-CT may help revive the TRO-CT paradigm.

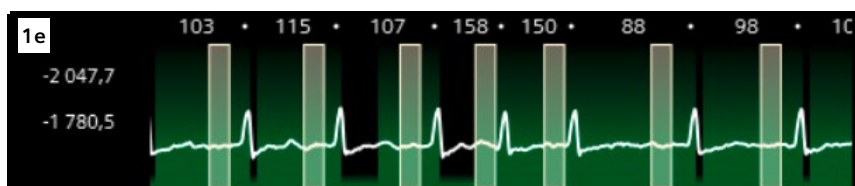
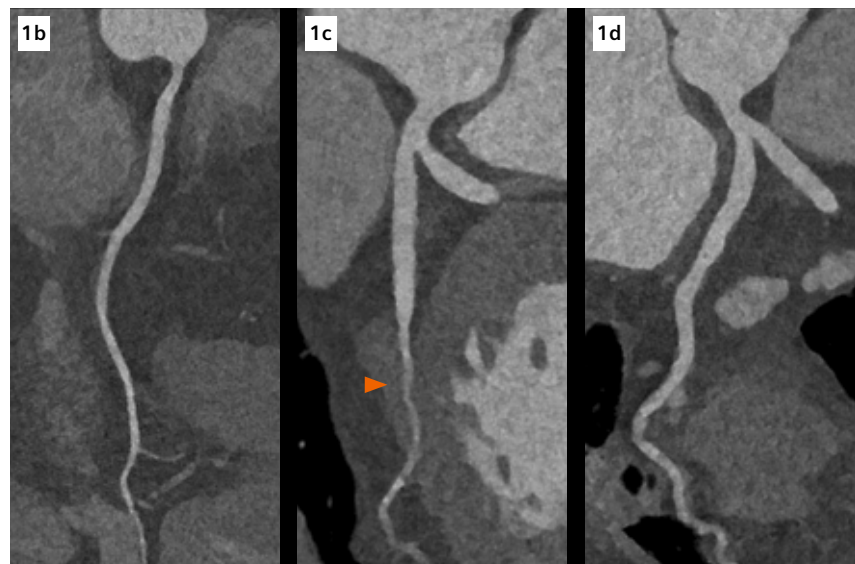
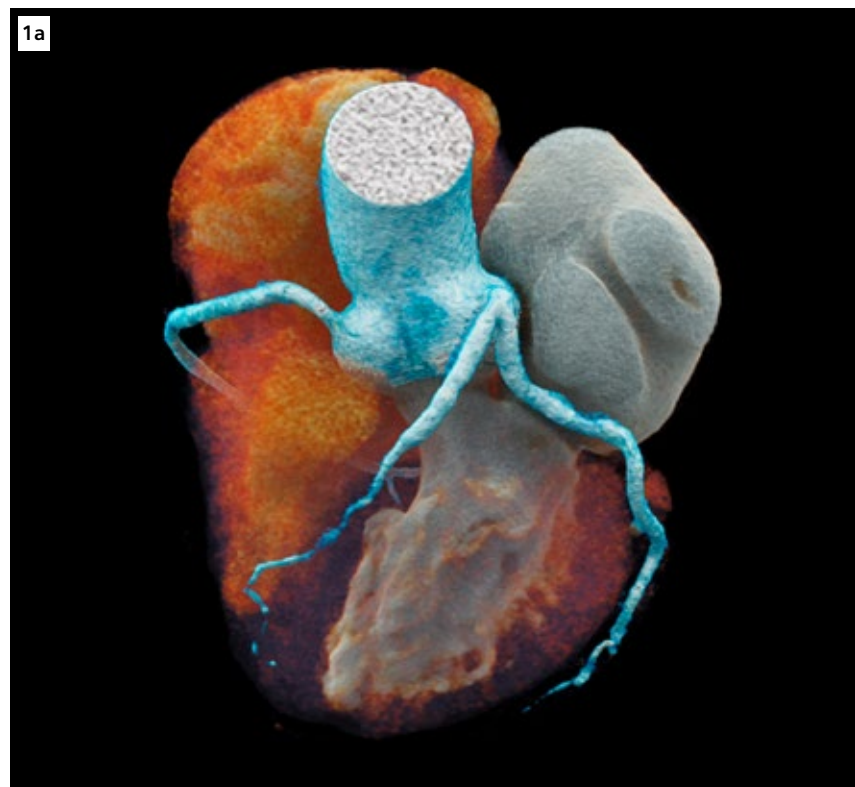
In this case, the targeted chest CTA enabled the use of a TRO-CT equivalent methodology. Therefore, the entire thoracic aorta was included in the scan range and timing was set to achieve optimal enhancement in the aorta and pulmonary arteries. Due to the high spatial resolution of the photon-counting detector, the coronary arteries could also be accurately evaluated.

The fine spatial detail (0.4 mm slice thickness) enabled an accurate evaluation of the coronary arteries to rule out severe CAD (as part of the differential diagnosis of chest pain) (see Figure 1). The use of advanced image reconstruction algorithms, such as ZeeFree, combined with the preview series function, resulted in only minor motion artifacts on the acquired scans, despite the high heart rate variability (Minimum: 86, Maximum: 158, average: 110).

Detector-based quantum spectral imaging capabilities (lung analysis reconstruction) made it impressively fast to detect lung perfusion deficits caused by the PE and aided further therapy decision-making by down-grading disease severity. A fair dose length product (636 mGy*cm) was achieved during the chest CTA, utilizing the NAEOTOM Alpha.Prime CT scanner with an optimized protocol, serving as a true “one-stop-shop” TRO-CT examination. ●

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1 Cinematic volume rendering technique (cVRT) image of the heart (a) and curved multiplanar reconstructions of the coronary arteries (b-d). (b) represents the right coronary artery, (c) represents the left main and left anterior descending (LAD) coronary artery, while (d) represents the left main and left circumflex coronary artery. The arrow indicates a complete myocardial bridge on the middle LAD. Note the excellent visualization of the coronary arteries despite high and irregular heart rate (e).



2 Coronal maximum intensity projection (MIP) image of the pulmonary vasculature (a) demonstrates a filling defect in the lower part of the left pulmonary artery. Volume rendering technique (VRT) reconstructions (b, c) depict the pulmonary vessel arborization: In (b), a cross-sectional view, the filling defect is visible in the left pulmonary artery (arrow). In (c), an oblique view, the embolus is highlighted in blue, while the consolidations in the lung can also be appreciated (small arrows).

Examination Protocol

Scanner	NAEOTOM Alpha.Prime
Scan area	Chest
Scan mode	QuantumPlus
Scan length	325.95 mm
Scan direction	Cranio-caudal
Scan time	4.881 s
Tube voltage	140 kV
Effective mAs	281.15 mAs
IQ level	64
Dose modulation	CARE Dose4D
CTDI _{vol}	22.4 mGy
DLP	636 mGy*cm
Rotation time	0.25 s
Pitch	0.29
Slice collimation	0.40 mm
Slice width	57.60 mm
Reconstruction increment	0.2 mm (cardiac), 1 mm (lung)

Reconstruction kernel	Bv44 (cardiac), Qr40 (lung)
keV level	70 (cardiac), 55 (lung)
Spectral reconstruction	VMI, Lung Analysis, VNC, Iodine
Heart rate	110 (range: 86–158)
Contrast	350 mg/mL
Volume	80 mL + 50 mL saline
Flow rate	4.5 mL/s
Start delay	Bolus tracking triggered at 200 HU in the ascending aorta

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Macromastia with severe ptosis

Chao Zhang, RT¹; Daming Zhang, MD¹; Man Wang, RT¹; Jin Chen, RN¹; Xi Zhao, MD²; Yun Wang, RT¹

¹ Department of Radiology, Peking Union Medical College, Beijing, P. R. China

² Siemens Healthineers, China

History

A 32-year-old female patient, suffering from bilateral symptomatic breast hypertrophy with severe ptosis (grade 3) after breastfeeding within the past eight years, was scheduled for a reduction mammoplasty. Prior to surgery, a CT angiography (CTA) was performed, using an ultra-high resolution (UHR) scan mode with a dual-source photon-counting detector (PCD) CT, NAEOTOM Alpha®, to assess the dominant blood supply of the nipple-areola complex (NAC) and its vascular sources.

Diagnosis

CTA images revealed a symmetrical pattern of a single source artery on both sides. The dominant arteries branched off the internal thoracic arteries at the first intercostal space on the right and at the second intercostal space on the left, supplying blood to the NAC region. Virtual monoenergetic images (VMI) displayed at 50 keV showed increased contrast enhancement and improved visualization of the terminal arteries for the NAC. These images were used to create three dimensional (3D) images with cinematic volume rendering technique (cVRT). Different presets were applied to demonstrate the anatomical relationship between the arteries and the bones, as well as the muscles and the fatty tissues, matching the surgical position of the patient. The rendering results were projected for holographic localization and the arteries were pre-operatively marked on the patient's body.

The patient underwent a successful reduction mammoplasty and pedicled nipple-areola reconstruction with a satisfactory outcome.

Comments

Macromastia, aka breast hypertrophy, is a medical condition characterized by an excessive growth of breast size, imposing physical and psychological challenges to the patients. There is no lasting non-operative treatment for symptomatic breast hypertrophy and its precise etiology remains elusive. [1] Surgical treatment by reduction mammoplasty has been recognized in the guidelines as the best approach to symptomatic relief and constitutes the most common therapy. [2] However, postoperative functional loss or even necrosis of the NAC, resulting from injuries of the arteries during the operation, may occur due to the complexity of the blood supply. An incidence rate of up to 13% has been reported. [3] Studies have shown that the blood supply pattern of the NAC is highly variable among individuals and even between the right and left breast of the same person. The source artery can be single or multiple, with a symmetrical or asymmetrical pattern. In some cases, the dominant artery may not be visualized, when the detectable diameter threshold is set to beyond 1.0 mm. [3] It is therefore important to have CTA images with a high resolution for a better understanding of the NAC blood supply to achieve a successful,

individualized design of the reduction mammoplasty.

This case was performed with a dual-source PCD-CT, NAEOTOM Alpha, which provides energy-resolved CT data at improved spatial resolution with inherent spectral information, without electronic noise. [4] These advanced techniques contribute to the improvement of imaging the details of the small terminal arteries to the NAC. The individual detector pixels of the PCD are defined by a strong electric field, instead of physical separation applied with the conventional energy-integrating detector (EID) CT, resulting in small subpixels without loss of radiation dose efficiency. The UHR mode therefore features a fine collimation of 120 x 0.2 mm and very high in-plane resolution. In addition, spectral information is available at a slice width of 0.4 mm, to display VMIs at a lower keV level (50 keV in this case), thus improving contrast enhancement. The absence of the electronic noise prompts a potential dose reduction (4.5 mGy in this case) while retaining optimal image quality.

As shown in this case, pre-operative CTA imaging facilitates a comprehensive understanding of the primary blood supply in the NAC region, and is thus a useful tool in the assistance of surgical planning for reduction mammoplasty. The UHR images acquired with PCD-CT demonstrate the potential of improving the vascular details at a reduced radiation dose. ●



1 cVRT images show a symmetrical pattern of a single source artery on both sides. The dominant arteries branch off the internal thoracic arteries at the first intercostal space on the right and at the second intercostal space on the left, supplying blood to the NAC region. The anatomical relationship between the arteries and the bones (Fig. 1a), the muscles (Fig. 1b), and the fatty tissues (Fig. 1c), is demonstrated using different presets, and matching surgical position of the patient.

Examination Protocol

Scanner	NAEOTOM Alpha
Scan area	Thorax
Scan mode	UHR mode (Quantum HD)
Scan length	264.8 mm
Scan direction	Cranio-caudal
Scan time	3.9 s
Tube voltage	120 kV
Effective mAs	56 mAs
IQ level	102
Dose modulation	CARE Dose4D
CTDI _{vol}	4.5 mGy
DLP	123 mGy*cm
Rotation time	0.25 s
Pitch	0.7
Slice collimation	120 x 0.2 mm
Slice width	0.2 / 0.4 mm
Reconstruction increment	0.2 / 0.2 mm
Reconstruction kernel	Bv60
Spectral reconstruction	Monoenergetic Plus
Contrast	370 mg/mL
Volume	50 mL + 40 mL (80%) + 20 mL saline
Flow rate	5 mL/s + 4.5 mL/s + 4 mL/s
Start delay	40 s

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A dens fracture – invisible to visible

Csaba Ellák Siket, MD; Nikolett Marton, MD, PhD; Ibolyka Dudás, MD
Semmelweis University, Medical Imaging Center, Budapest, Hungary

History

A 65-year-old male patient, struck by a car while cycling, was admitted to the Department of Traumatology. The patient had no recollection of the incident and his vital parameters had remained stable during transportation. There were no observed sensory or motor deficits. A CT scan was performed on an energy-integrating detector (EID) CT, which revealed multiple fractures of the cervical spine. 24 hours later, a control CT examination was performed on a newly introduced single source photon-counting detector (PCD) CT, NAEOTOM Alpha.Prime, for assessment.

Diagnosis

PCD CT images revealed a non-displaced, unstable fracture of the base of the C2 dens (IIIA – C2 type A NO), [1] which was not seen in the previous EID CT images (Fig. 1). Other findings, including dislocated fractures of the left anterior and posterior arches of the C1 vertebra (Jefferson fracture) and a left massa lateralis avulsion fracture with the dens axis dislocated to the left (IIB – C1 type B NO) (Fig. 2); [2] [3] fractures of the foramina transversaria of the C3 (left, dislocated) and the C4 (right, non-dislocated) (type A0 NO), the spinous processes of the C4 and C6 (type A0 NO), bilateral arcus of the C7 (type A0 BL F1) and the head of the first rib on the left (Fig. 3), showed no noticeable

changes. AO classification was applied. [4]

The patient underwent conservative treatment with a collar. A follow-up 3 months later showed no progression or instability.

Comments

Fractures of C2 dens, or odontoid process, are commonly classified by the Anderson and D'Alonzo classification system. A fracture at the base of the dens, such as this case, is classified as Type 2. This type of fracture is unstable due to its location and the potential of displacement or non-union. If not recognized in time, it could potentially lead to serious health impairment or an increased risk of mortality especially in older adults.

In this case, the dens fracture, not shown in EID CT images acquired at 0.625 mm, is depicted in PCD CT images acquired at 0.4 mm, owing to an increased spatial resolution. PCD has a smaller pixel electrode size, which decreases the partial volume effects and blooming artifacts. Its detector elements are separated by electric fields, instead of physical separators applied in EID, resulting in an increased efficiency of X-ray photon utilization and signal-to-noise ratio.

The high-resolution images, acquired routinely at thin slices and reconstructed with a sharper kernel for

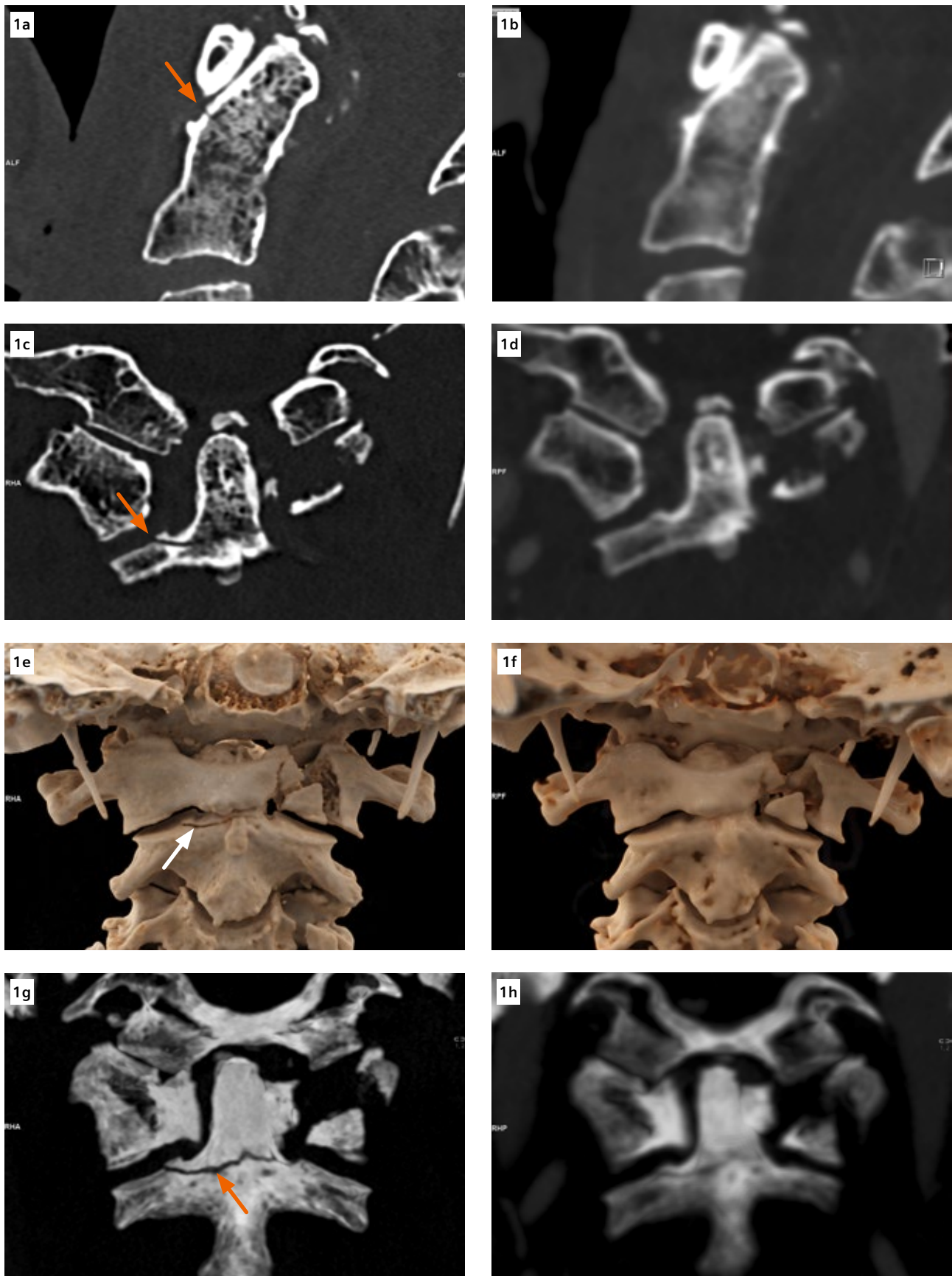
cervical spine, can also be used to create three dimensional images, with cinematic rendering technique (cVRT), for an in-depth, lifelike visualization of the fractures in detail. This facilitates the communication between physicians and helps in treatment planning. In trauma settings, PCD CT, with its increased spatial resolution in routine scans, may benefit the clinical outcome of the patients. ●

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1 A fracture of the base of the C2 dens (arrows), not seen in the EID CT images (right), is clearly seen in the PCD images (left). The visibility of the fracture line is improved in the thin slab MIP images (Figs. 1g and 1h).

FOOSH injury with screw fixation of the scaphoid

Ronald Booij, Ph.D.; Prof. Edwin Oei, MD, Ph.D.

Department of Radiology & Nuclear Medicine, Erasmus MC, Rotterdam, The Netherlands

History

A 20-year-old male patient had undergone surgery with a screw fixation of the scaphoid after a FOOSH (fall on outstretched hand) injury, 5 years ago. A revision surgery of the screw had had to be performed 4 years later, due to non-union of the fracture. A follow-up CT showed unclear bone structure around the screw with the presence of metal artifacts. Further evaluation was needed and performed using an ultra-high resolution (UHR) scan mode (Quantum HD) on a newly installed photon-counting CT (PCCT) scanner (NAEOTOM Alpha®) in our hospital.

Diagnosis

The UHR CT images showed a scaphoid fracture with the fixation screw in situ. The fracture in the scaphoid was still largely visible, with a sclerotically bordered fracture line. Minimal central bridging was shown; however, there was no obvious consolidation. Lucency at the tip of the screw, as well as in various parts around the screw, was visualized, signifying screw loosening. The screw protruded proximally into the radiocarpal joint with an impression of slight usuration of the head of the screw into the radius. There were no signs of osteolysis or evidence of migration of the screw. Early osteoarthritic changes of the radiocarpal and the scaphotrapezio-trapezoid (STT) joint were present. A slight dorsal tilting of the lunate was seen with a subtle increase in scapho-lunar distance compared to lunatum-triquetrum distance. In summary, CT findings suggested central, discrete bony bridging, with-

out clear consolidation, and screw loosening. Subsequently, the patient was scheduled for a surgical revision.

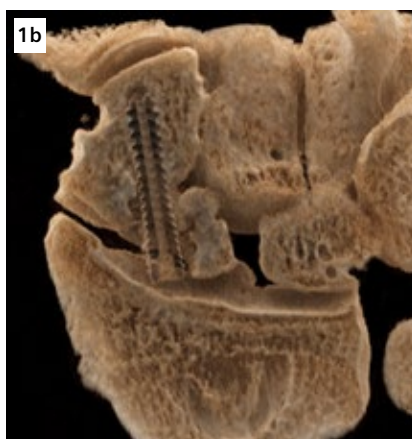
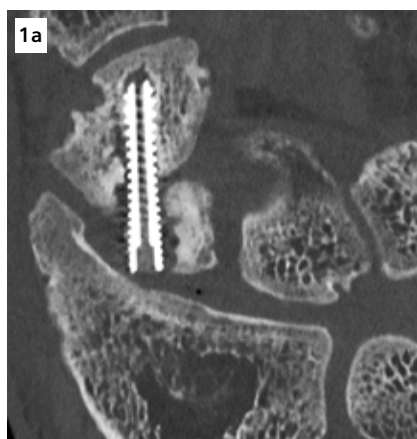
Comments

Scaphoid fractures due to a FOOSH injury are quite common. Non-union of the fracture may remain if the healing process is compromised which may then impact the wrist function. There are various techniques that can be applied for fracture fixation, one such is a screw fixation. CT follow-ups are often performed to confirm the bony union or non-union, to assess the screw position and to help surgical planning. [1-3] The opportunities of CT imaging are four-fold: high spatial resolution is required to visualize the trabecular bridging differentiating bony union from non-union; metal artifacts must be minimized to allow assessment of the bone structure around metal implants, confirming or ruling out loosening; low radiation dose is needed to reduce the exposure in repeated scans and last but not least, high quality three-dimensional demonstrations are helpful to determine the intra-scaphoid angle and elements of scaphoid collapse for surgical planning, as well as for an illustrative communication towards clinicians, but also especially to the patients.

This case is performed on NAEOTOM Alpha, a newly developed PCCT scanner, providing energy-resolved CT data at improved spatial resolution, without electronic noise. [4] The spatial resolution is improved by using an ultra-thin slice collimation of 120 x 0.2 mm. Although it is traditionally known that thin-slice images are associated with higher

image noise and not suitable for 3D image rendering, it is shown in this case that with PCCT even images acquired at 0.2 mm with low dose and reconstructed with a very sharp kernel of Br89 (with a 2% value of the modulation transfer function of 31 lp/cm) have low image noise. This is facilitated by UHR scan data acquisition at full dose efficiency without additional combs or grids to reduce the detector aperture, and further image noise reduction by a refined model based iterative reconstruction (Quantum Iterative Reconstruction, QIR). Therefore, UHR images are optimal for a photo-realistic 3D visualization using cinematic volume rendering technique (cVRT). Anatomical details such as the trabecular bone structure surrounding the fracture of the scaphoid can be appreciated. Metal artifacts reduction surrounding the screw helps the radiologist to clearly visualize the lucency and confirm the screw loosening with enhanced diagnostic confidence.

Furthermore, the electronic noise of a PCCT is eliminated by setting up a predefined digital threshold for counting well above the noise floor. As the electronic noise is dominant at low X-ray flux, its absence has a particular impact on low-dose CT, such as scanning with an integrated special tin filter. This case was acquired at the initial phase of our learning curve on PCCT, when we were still quite conservative about dose reduction. It didn't take us long to realize the potential of the scanner – we have further reduced the dose by half (3.5–4 mGy), in our routine scan protocol for wrist imaging, and the image quality remains optimal. ●



- 1** MPR images (Fig. 1a & 1c) and cVRT images (Fig. 1b & 1d), reconstructed parallel to the screw, show lucency on the tip of the screw and in various parts around the screw, confirming screw loosening. Metal artifact reduction surrounding the screw is remarkable, and the trabecular bone structure surrounding the fracture can be appreciated. The fracture in the scaphoid is still largely visible, with a sclerotically bordered fracture line.

Examination Protocol

Scanner	NAEOTOM Alpha
Scan area	Wrist
Scan mode	Quantum HD
Scan length	48.3 mm
Scan direction	Caudo-cranial
Scan time	3.5 s
Tube voltage	Sn140 kV
Effective mAs	216 mAs
Dose modulation	CARE Dose4D
CTDI _{vol}	7.8 mGy
DLP	65.3 mGy*cm
Rotation time	0.5 s
Pitch	0.4

Slice collimation	120 x 0.2 mm
Slice width	0.2 mm
Reconstruction increment	0.1 mm
Reconstruction kernel	Br89, QIR3

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Scaphoid fracture only seen in CT

Jan Baxa, MD, Ph.D.

Department of Imaging Methods, University Hospital Pilsen and
Medical Faculty of Charles University, Pilsen, Czech Republic

History

A 14-year-old girl presented herself to the emergency department due to a fall onto her outstretched right hand. A radiograph was performed with unremarkable findings. As, two weeks later, the pain and the movement limitations in the right wrist persisted, another radiograph was performed but this only revealed an equivocal result. A CT scan was requested for further evaluation, using an ultra-high resolution (UHR) mode on a photon-counting CT (PCCT) scanner NAEOTOM Alpha®.

Diagnosis

UHR CT images showed an oblique fracture line in the scaphoid. Neither dislocation nor distraction were seen. There were evident signs of increased density, or even sclerosis, in the fissure, suggesting partial healing. Based upon the CT findings, the patient was treated with an external splint fixation. Three weeks later, a follow-up radiograph was performed with evidence of advanced healing without complication.

Comments

Scaphoid fractures are the most common amongst the carpal bones. Missed or inconclusive diagnoses on wrist radiographs may cause a delay of initial treatment. This can lead to nonunion, and ultimately, loss of wrist motion and eventual arthritis. CT imaging plays an important role for improved accuracy in the diagnosis, as well as in the follow-ups of a scaphoid fracture. It provides detailed information using multiplanar reformation (MPR) as well as 3D reconstructions such as cinematic volume rendering technique (cVRT). The traditional challenge with conventional CT scanners is to improve the spatial resolution without increasing radiation dose or accepting excessive image noise. This has become possible with the introduction of PCCT, especially when using the UHR mode. Images are acquired on a dual source PCCT (NAEOTOM Alpha) at 0.2 mm slice width and reconstructed with a very sharp kernel of Br84, using a large image matrix of 1024 x 1024. UHR scan

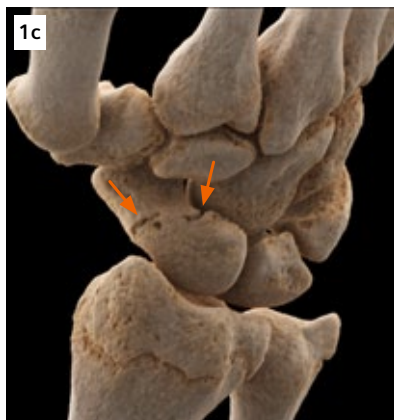
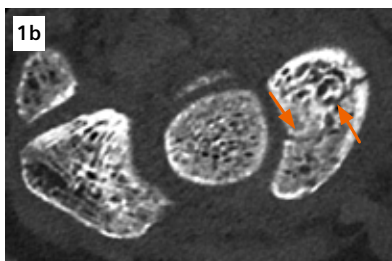
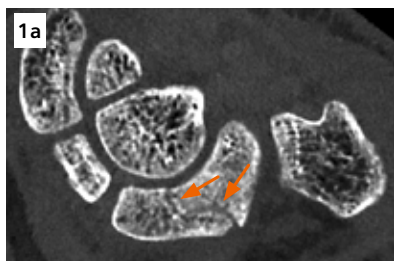
data acquisition is feasible at full dose efficiency without additional combs or grids to reduce the detector aperture at the cost of reduced dose efficiency and increased radiation dose as in previous equipment. A model-based iterative reconstruction approach – Quantum Iterative Reconstruction (QIR) – is applied in the image reconstruction process for further image noise reduction, resulting in a sharp visualization of trabecular bone structures with low image noise. PCCT with UHR scan data acquisition can be very beneficial in minor injuries of peripheral bones, particularly when the radiograph is inconclusive, and the clinical symptoms are atypical. As shown in this case, the fracture line that is missed on the radiograph is clearly depicted on the UHR CT images. Because of their low image noise, these images are also used as input to create cVRT images for a lifelike 3D visualization of the scaphoid, helping the physicians to make an optimal treatment decision. ●

Examination Protocol

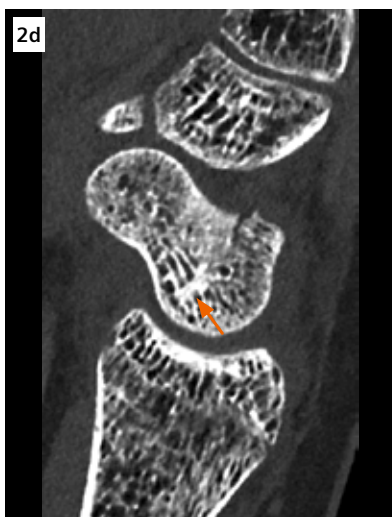
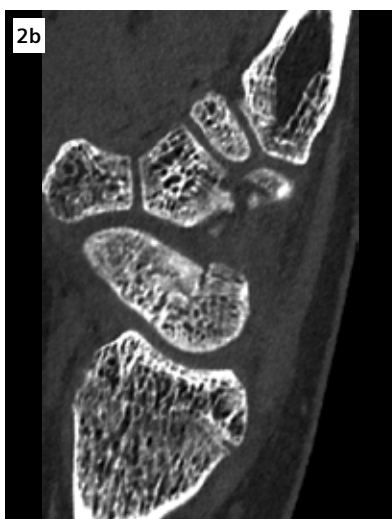
Scanner	NAEOTOM Alpha
Scan area	Wrist
Scan mode	Quantum HD
Scan length	96.2 mm
Scan direction	Cranio-caudal
Scan time	2.4 s

Tube voltage	120 kV
Effective mAs	40 mAs
Dose modulation	CARE Dose4D
CTDI _{vol}	3.2 mGy
DLP	56.1 mGy*cm
Rotation time	0.5 s
Pitch	0.85

Slice collimation	120 x 0.2 mm
Slice width	0.2 mm
Reconstruction increment	0.1 mm
Reconstruction kernel	Br84, QIR 3
Reconstruction matrix	1024 x 1024



- 1** UHR CT images (Figs. 1a & 1b) and cVRT images (Figs. 1c & 1d) show an oblique fracture line (arrows) in the scaphoid without dislocation or distraction. Note that the input images for cVRT creation are reconstructed at 0.2 mm, with a very sharp kernel of Br84 and an image matrix of 1024 x 1024.



- 2** cVRT images (Figs. 2a & 2c) and UHR CT images (Figs. 2b & 2d) show the fracture line in the scaphoid. Increased density is seen in the fissure (arrow) suggesting partial healing. Note that the input images for cVRT creation are reconstructed at 0.2 mm, with a very sharp kernel of Br84 and an image matrix of 1024 x 1024.

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The products/features (mentioned herein) are not commercially available in all countries. Their future availability cannot be guaranteed.

Non-osseous subtalar coalition

Adrian A. Marth, MD^{1,2}; Daniel Nanz, PhD¹; Reto Sutter, MD²

¹ Swiss Center for Musculoskeletal Imaging, Balgrist Campus AG, Zurich, Switzerland

² Balgrist University Hospital, University of Zurich, Zurich, Switzerland

History

A 22-year-old female patient, complaining of persistent pain in the right foot for the past 3 months, presented herself to our orthopedic clinic. The pain was localized at the medial side of the ankle and exacerbated during prolonged standing. Clinical examination revealed a hindfoot valgus and limited subtalar motion. Conventional radiographs showed a typical talar beak sign, suggestive of tarsal coalition. The patient underwent a conservation treatment phase with anti-inflammatory pain medications and responded well. She was then scheduled for surgery. CT was performed to evaluate the size, location and extent of the coalition for pre-operative workup. An ultra-high resolution (UHR) scan mode was performed on a photon-counting CT (PCCT), NAEOTOM Alpha®.

Diagnosis

UHR CT images showed an irregular and narrowed subtalar joint, involving both the middle and posterior subtalar facet, with more than 50% of the surface area. There was no evidence of adjacent osteoarthritis. An osseous outgrowth at the mid portion of the superior margin of the talus ("talar beak") was seen as a typical secondary sign of tarsal coalition. No osseous bridging of the subtalar joint was present. A diagnosis of non-osseous coalition was confirmed. The patient was scheduled for a subtalar arthrodesis.

Comments

Tarsal coalition is an abnormal, congenital bridging of two or more tarsal bones. The bridging can be osseous (bony bridging), or non-osseous (fibrous / cartilaginous bridging). Treatment options range from conservative to surgical. A CT evaluation on the size, location, presence of degenerative changes, additional coalitions and the degree of joint involvement is important for treatment planning.

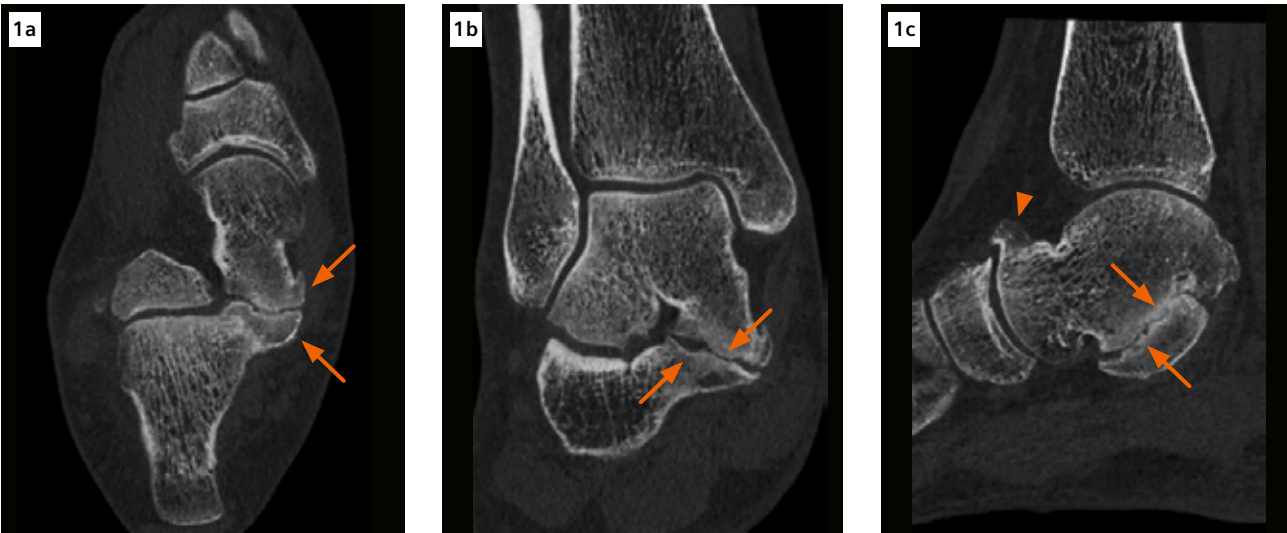
The first-line treatment is conservative consisting of foot arch support, cast immobilization and non-steroidal anti-inflammatory medications. In refractory cases, surgical treatment is performed, unless significant degeneration in the adjacent joints contraindicates. Arthroscopic or open resection can be performed with or without the use of additional interposition materials, however, in multiple coalitions, individual resections should not be pursued, as they are unlikely to establish a normal functional outcome. Arthrodesis is preferred if more than 50% of the joint surface area are involved and a higher degree of hindfoot valgus is present. Triple arthrodesis, instead of subtalar arthrodesis, is indicated when the midfoot joints show signs of osteoarthritis in subtalar coalitions.

In this case, since more than 50% of the surface area of the subtalar joint is involved, and there is no evidence of adjacent osteoarthritis, a subtalar arthrodesis is indicated. CT findings that are clearly depicted in UHR

images play an essential role in surgical planning. Despite the low radiation dose (1.3 mGy) applied to this young patient, high spatial resolution and low image noise are achieved. This is because UHR mode applies a fine collimation of 120 × 0.2 mm, without additional combs or grids to reduce the detector aperture, which improves the spatial resolution at full dose efficiency. Additionally, electronic noise is eliminated and a refined model based iterative reconstruction (Quantum Iterative Reconstruction, QIR) is applied in PCCT contributing to further image noise reduction. As a result, the UHR images can even be used in generating cinematic rendering 3D images which facilitate communications between the physicians and with the patient. The combination of improved spatial resolution with reduced image noise is highly beneficial for musculoskeletal imaging in clinical routine. ●

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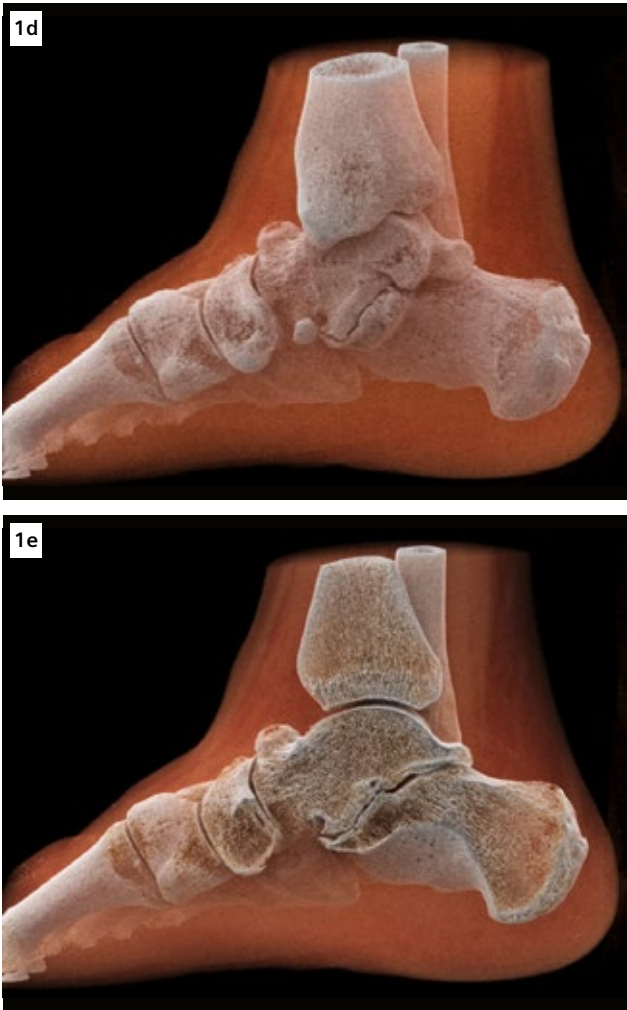
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1 MPR images (Fig. 1a–1c) and cVRT images (Fig. 1d–1e) of PCCT examination of the right foot show an irregular and narrowed subtalar joint involving both middle and posterior subtalar facet, which are deformed (arrows). There are no signs of bony bridging, confirming the diagnosis of a non-osseous talocalcaneal coalition. Additionally, a talar beak can be seen at the superior aspect of the talus head (arrowhead). Note that the input images for cVRT creation are reconstructed at 0.2 mm, with a very sharp kernel of Br84 and an image matrix of 1024 × 1024.

Examination Protocol

Scanner	NAEOTOM Alpha
Scan area	Right ankle
Scan mode	UHR mode (Quantum HD)
Scan length	118.3 mm
Scan direction	Cranio-caudal
Scan time	2.9 s
Tube voltage	120 kV
Effective mAs	16 mAs
Dose modulation	CARE Dose4D
CTDI _{vol}	1.3 mGy
DLP	17.6 mGy*cm
Rotation time	0.5 s
Pitch	0.85
Slice collimation	120 x 0.2 mm
Slice width	0.2 mm
Reconstruction increment	0.1 mm
Reconstruction kernel	Br84
Reconstruction matrix	1024 x 1024



Pseudarthrosis revision of a comminuted tibia fracture – consolidated?

Adrian A. Marth, MD^{1,2}; Daniel Nanz, PhD¹; Reto Sutter, MD²

¹ Swiss Center for Musculoskeletal Imaging, Balgrist Campus AG, Zurich, Switzerland

² Balgrist University Hospital, Zurich, Switzerland

History

A 46-year-old male patient, presenting with a comminuted tibia fracture, underwent pseudarthrosis revision with plate osteosynthesis and locking screws. Six weeks later, a follow-up CT examination was scheduled to evaluate the status of osseous healing. A scan in ultra-high resolution (UHR) mode with spectral shaping (tin filtration) was performed on a photon-counting CT (PCCT), NAEOTOM Alpha®.

Diagnosis

In the standard polychromatic UHR images, metal artifacts caused by the implants were present and partially obscured the visualization of the fracture clefts. Virtual monoenergetic images (VMI), reconstructed at 120 keV, 150 keV and 190 keV, showed substantial suppression of metal artifacts and improved visibility of the fracture clefts. No sign of osseous consolidation was evident. Spotty osteopenia was present in the tibia and the foot.

Following the CT scan, the patient was instructed to walk using forearm crutches and applying only 30% of his own body weight onto his feet. The patient was scheduled to return 6 weeks later for the next follow-up examination.

Comments

CT assessment following surgery is important to identify whether a fracture consolidates during the

healing process. This information is pivotal for surgeons to decide about patient mobility, or whether revision surgery is necessary in case of complications such as delayed union or non-union. Metal artifacts caused by implants, due to photon starvation and beam hardening, can significantly compromise image interpretability. It has been shown that a combined approach, using spectral shaping (tin filtration) and virtual monoenergetic image (VMI) reconstructions, is effective in reducing metal artifacts at improved dose efficiency compared to standard scans [1]. While spectral shaping excludes low-energy photons that contribute little to high contrast structures (i.e., bone, metal), VMIs further shift the mean photon energy to higher levels, thereby reducing beam hardening artifacts. VMIs can be easily reconstructed and implemented in routine imaging as spectral information is inherently available in PCCT. Furthermore, PCCT can acquire UHR images without using additional combs or grids to reduce the detector aperture, resulting in an increased spatial resolution at full dose efficiency.

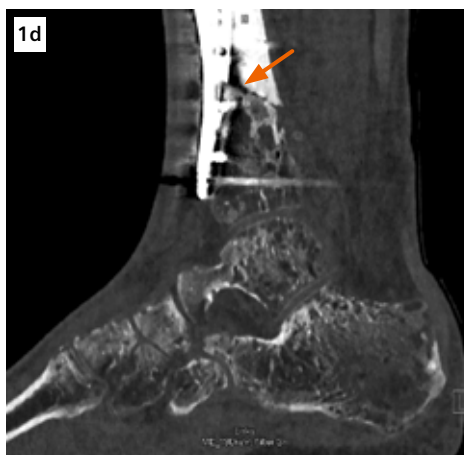
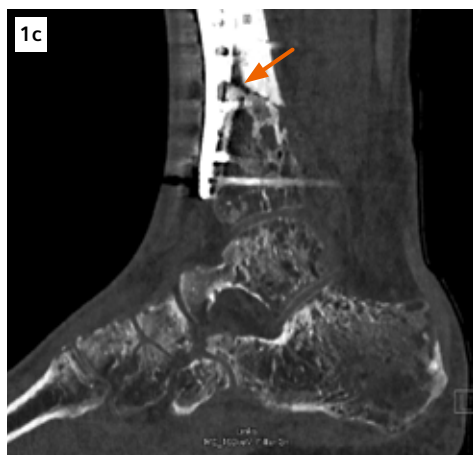
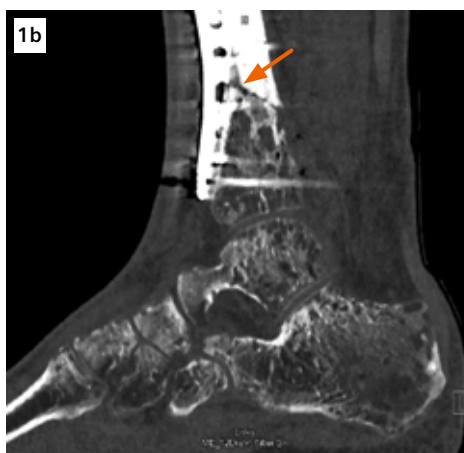
In this particular case, metal artifacts are better suppressed in VMIs reconstructed at higher keV levels (150 and 190 keV). However, a trade-off with reduced image contrast has to be recognized. Clear visualization of the fracture clefts is observed in VMIs reconstructed at 120 keV, while image contrast is still satisfactory. The improved visibility can increase diagnostic confidence for providing better patient care. ●

References

- [1] Adrian A. Marth, et al. Photon-Counting Detector CT – Clinical Utility of Virtual Monoenergetic Imaging Combined With Tin Prefiltration to Reduce Metal Artifacts in the Postoperative Ankle. *Invest Radiol.* 2024 Jan 10. DOI:10.1097/RLI.0000000000001058

Examination Protocol

Scanner	NAEOTOM Alpha
Scan area	Left lower extremity
Scan mode	UHR mode (Quantum HD)
Scan length	428.5 mm
Scan direction	Caudo-cranial
Scan time	3.5 s
Tube voltage	Sn140 kV
Effective mAs	97 mAs
Dose modulation	CARE Dose4D
CTDI _{vol}	3.5 mGy
DLP	150 mGy*cm
Rotation time	0.5 s
Pitch	0.86
Slice collimation	120 × 0.2 mm
Slice width	0.2 / 0.4 mm
Reconstruction increment	0.1 / 0.4 mm
Reconstruction kernel	Br84 / Br76 QIR 3
Spectral reconstruction	VMI (Mono-energetic Plus)



1 Sagittal MPR images show a fracture cleft (arrows) that is partially obscured by metal artifacts on the polychromatic image (Fig. 1a), and is however clearly visible on VMI images reconstructed at 120 keV (Fig. 1b), 150 keV (Fig. 1c) and 190 keV (Fig. 1d). No sign of osseous consolidation is evident.



2 Cinematic volume rendered images (a–d) show a 3D overview of the plate osteosynthesis and locking screws in relation to the fractured tibia and fibula.

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Traumatic incudomalleolar dislocation

Kolos Turtóczki, MD; Pál Maurovich-Horvat, MD, PhD, MPH; Ibolyka Dudás I, MD

Department of Radiology, Medical Imaging Centre, Semmelweis University, Budapest, Hungary

History

A 33-year-old female patient, who had sustained injuries following a fall, was presented to the emergency department. Upon arrival, she had altered consciousness with visible bleeding from the right ear and a superficial hematoma on the right side of the skull. A routine head CT scan, as a part of our institutional polytrauma protocol, was performed with a photon-counting detector (PCD) CT scanner (NAEOTOM Alpha.Prime) for further assessment.

Diagnosis

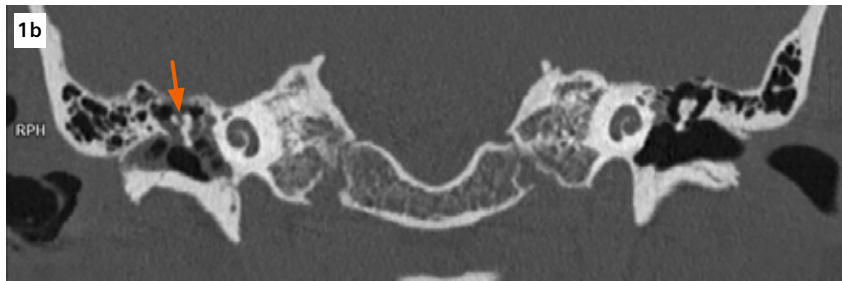
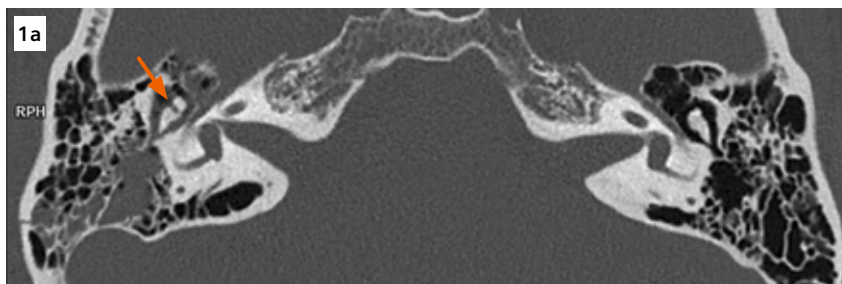
CT images showed an incudomalleolar dislocation with a typical “broken heart” sign in the thin-slice coronal multiplanar reformats (MPR). The displacement of the head of the malleus from the body and short process of the incus disarticulating the normal “ice cream cone” of the joint was also seen in axial images (Fig. 1). These structures were visualized in more details in zoomed reconstructions (Fig. 2). Longitudinal fractures of the right temporal bone (Fig. 3a), involving the mastoid cells, the external auditory canal, the middle ear and the ossicles, as well as complex fracture of the body of the sphenoid bone were present (Fig. 3b and 3c). Temporal subdural hematoma, subarachnoid bleeding as well as parenchymal brain contusion injuries on the left, due to the contrecoup mechanism, were seen. There was no evidence of extracranial traumatic lesions. A subsequent control CT examination demonstrated stable contusional injuries with mild progression of the perifocal edema and a regressing subdural hematoma. Immediate neurosurgical inter-

vention was not considered. The patient was treated conservatively on the intensive care unit for two days and was then transferred to the traumatology ward. Ear-nose-throat (ENT) consultation found a right-sided conductive hearing loss.

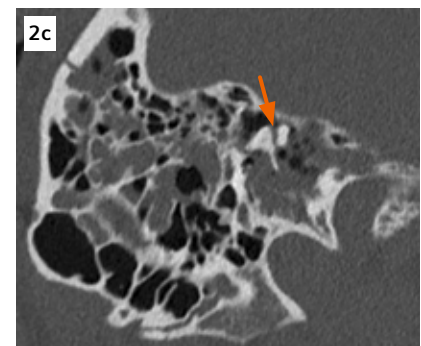
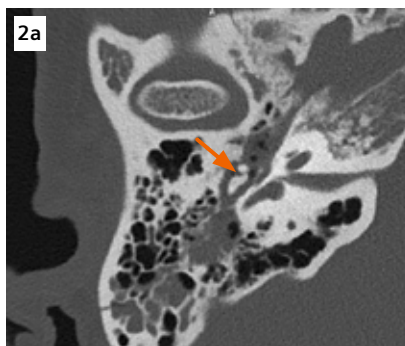
Comments

Temporal bone trauma is commonly encountered in the emergency department. The tympanic cavity and tegmen, the ossicular chain, the bony labyrinth, the facial canal, the internal carotid artery, the jugular foramen and venous sinuses, as well as the intracranial contents are all potential injury sites. A specific and thorough reporting approach is needed due to the unique composition of these anatomical structures. A delayed or missed diagnosis of injuries to these structures can result in severe and permanent disabilities for the patient. [1] Ossicular luxation or fracture, disrupting the conductive chain, may cause conductive hearing loss (CHL). Six months after temporal bone trauma, persistent CHL occurs in 50% of the patients. The most common sites of ossicular dislocation are the incudostapedial and the incudomalleolar joints. [2] In the latter case, the joint dislocation is marked with displacement of the scoop (head of the malleus) from the cone (body and short process of the incus), disarticulating the normal “ice cream cone” in axial images and the typical “broken heart” sign in coronal MPR. [3] [4] CT is the imaging modality of choice in cases of temporal bone trauma. Traditionally, CT examination for head and for temporal bones are two separate scans, with the former focused on

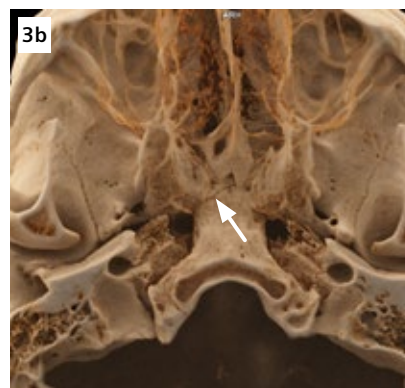
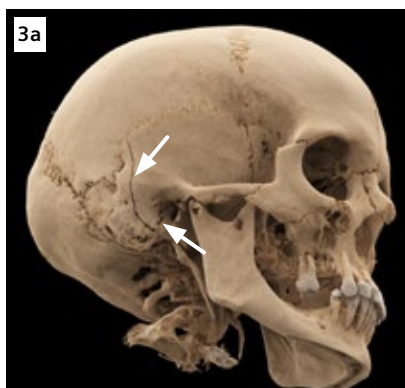
the low-contrast cerebrum and the latter, on high-contrast bony structures. This case is acquired with a newly developed single source PCD CT, NAEOTOM Alpha.Prime. The principle of PCD differs from that of conventional, energy-integrating detector (EID). With EID, X-ray photons are first converted into scintillation light and then into electrical signals, while with PCD, X-ray photons are converted directly into electrical signals. The detector elements in EID are separated by physical separators, while in PCD, they are separated by electric fields. The electronic circuit noise is also eliminated in PCD. These differences result in increased efficiency of X-ray photon utilization, and potentially, reduced image noise and radiation dose. Additionally, PCD has a smaller detector pixel size, which contributes to the decreased partial volume effects and blooming artifacts. This increases spatial resolution, which is especially important for imaging small, high-contrast structures, such as the ossicular chain. [5] Images acquired in routine head scan can be reconstructed both at 0.4 mm slice width with a sharp kernel (Hr76) for visualizing the temporal bones and at thicker slice width with a standard or smooth kernel for cerebrum imaging, obviating the necessity of having to do two separate scans. These high-resolution images can also be used to create three dimensional images, using cinematic rendering technique (cVRT), providing detailed, lifelike visualization. In trauma settings, PCD CT, with its increased spatial resolution in routine scans, may enable radiologists to reach diagnostic conclusions that were previously only possible with high resolution CT (HRCT) examinations. ●



1 An axial image (Fig. 1a) shows displacement of the head of the malleus from the body and short process of the incus (arrow) on the right. A typical "broken heart" sign (arrow) is seen in a coronal MPR image (Fig. 1b). Two cVRT images (Figs. 1c and 1d) created with thin slices (0.4 mm, sharp kernel of Hr76) demonstrate the incudomalleolar dislocation (Fig. 1c) in three dimensions.



2 Images from zoomed reconstructions show the incudomalleolar dislocation (arrows) with signs of disarticulated "ice cream cone" (Fig. 2a) and "broken heart" (Fig. 2b) in details.



3 cVRT images show longitudinal fractures (Fig. 3a, arrows) of the right temporal bone, involving the mastoid cells and the external auditory canal, as well as a complex fracture of the body of the sphenoid bone (Fig. 3b and 3c, arrows).

Examination Protocol

Scanner	NAEOTOM Alpha.Prime
Scan area	Head
Scan mode	Quantum Plus
Scan length	182 mm
Scan direction	Cranio-caudal
Scan time	69 s
Tube voltage	120 kV
Effective mAs	167 mAs
IQ level	225
Dose modulation	CARE Dose4D
CTDI _{vol}	28 mGy
DLP	554 mGy*cm
Rotation time	0.5 s
Pitch	0.35
Slice collimation	144 × 0.4 mm
Slice width	0.4 mm
Reconstruction increment	0.2 mm
Reconstruction kernel	Hr76

References

- [1] Kurihara YY, Fujikawa A, Tachizawa N, Takaya M, Ikeda H, Starkey J. Temporal Bone Trauma: Typical CT and MRI Appearances and Important Points for Evaluation. *Radiographics*. 2020;40(4):1148-1162. doi:10.1148/rg.2020190023
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- [3] Maillot O, Attyé A, Boutet C, et al. The relationship between post-traumatic ossicular injuries and conductive hearing loss: A 3D-CT study. *J Neuroradiol*. 2017;44(5):333-338. doi:10.1016/j.neurad.2017.04.001
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- [5] Nakamura Y, Higaki T, Kondo S, Kawashita I, Takahashi I, Awai K. An introduction to photon-counting detector CT (PCD CT) for radiologists. *Jpn J Radiol*. 2023;41(3):266-282. doi:10.1007/s11604-022-01350-6

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Cerebrospinal fluid-venous fistula detected in a patient with a long history of headaches

Fides Regina Schwartz, MD; Timothy Amrhein, MD

Department of Radiology, Duke University Health System, North Carolina, USA

History

A 58-year-old female patient with a 10-year history of migraine, tinnitus and orthostatic headache, was referred to the department of neuro-radiology for evaluation. Symptoms were typical for spontaneous intracranial hypotension (SIH) and a brain MRI with i.v. contrast material confirmed the diagnosis, demonstrating dural enhancement, venous distension, and brain sagging. A prior attempt at finding the causative spinal cerebrospinal fluid-venous fistula (CVF) three years earlier was unsuccessful. CT myelography (CTM) was performed on a dual source photon-counting CT (PCCT), NAEOTOM Alpha®, using an ultra-high resolution (UHR) scan mode (Quantum HD) to identify and localize the CVF prior to a definitive treatment.

Diagnosis

Previous CTM images, acquired at 0.625 mm slice thickness on an energy-integrating-detector (EID) CT, had revealed prominent spinal nerve root sleeves at multiple levels, however, was unable to identify the CVF (Fig. 1a). For this new exam, UHR CTM images were acquired at 0.2 mm slice thickness on PCCT in left lateral and right lateral decubitus, and prone position at rest, end-inspiration breath hold, and during Valsalva maneuver, after the injection of 10 mL of iopamidol (300 mg/mL) into the subarachnoid space via lumbar puncture. The UHR images in end-inspiration revealed the causative sub-millimeter

CVF arising from the right T5 level, evidenced by contrast in an adjacent paraspinal vein (Fig. 1b). Additional clarity was gained from the iodine map (Fig. 1c) as well as the 3D images created by cinematic volume rendering technique (cVRT, Fig. 1d). Identification and localization of this CVF allowed the patient to be referred to neurosurgery for definitive treatment with surgical ligation. Surgery was successful resulting in resolution of her symptoms and normalization of brain MRI findings of SIH.

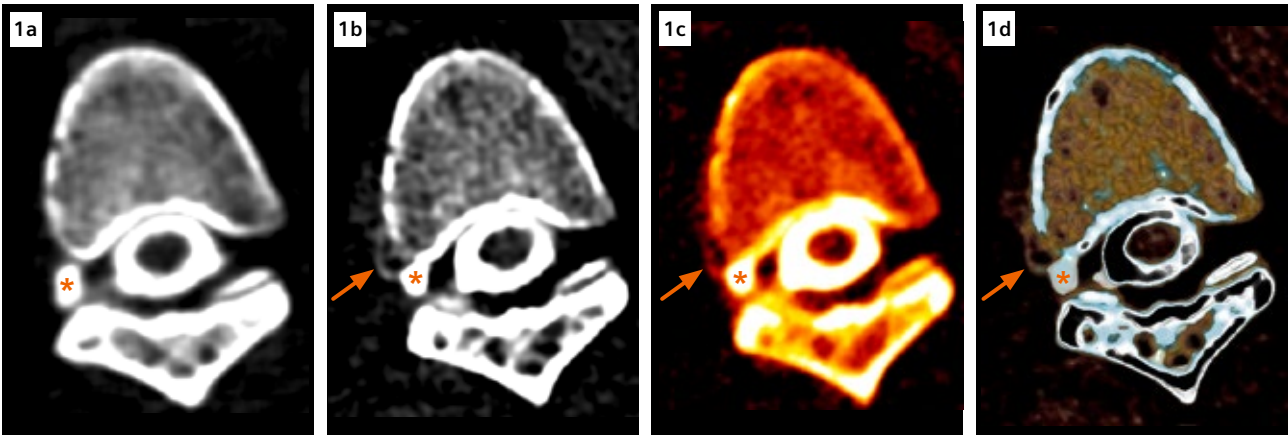
Comments

CVFs represent abnormal connections between the spinal subarachnoid space and adjacent paraspinal veins. These anomalous connections allow for uncontrolled outflow of cerebrospinal fluid (CSF) into the venous system, ultimately leading to intracranial hypotension. Although CVFs have been recognized only recently, they have rapidly emerged as a common underlying cause of spinal CSF leaks in patients with SIH, particularly in cases where initial spinal imaging fails to reveal any obvious leaks.

CVFs are most frequently found in the thoracic spine, particularly in the lower levels from T7 to T12. However, they can also occur in upper thoracic levels, as presented in this case. Fistulas in the upper lumbar or lower cervical levels are less common. CVFs are anatomically associated with a

nerve root sleeve, with the fistulous connection frequently originating from the nerve root sleeve itself, as seen in this case. While some case series have suggested a possible laterality preference, the evidence for such a predilection is not strong, and CVFs can occur on either side of the spine.

Unlike dural tears, which were the first described cause of intracranial hypotension, most CVFs do not lead to the pooling of CSF in the epidural space. This lack of epidural fluid accumulation makes it challenging to detect CVFs through conventional anatomical imaging. Instead, the use of a myelographic contrast agent specific to CSF is necessary for their visualization. Consequently, standard spine MRI, commonly employed for detecting epidural CSF leaks, is not effective for identifying CVFs and CTM has emerged as a better imaging modality. The traditional challenge with EID CT scanners is to improve the spatial resolution without increasing radiation dose or accepting excessive image noise. This has become possible with the introduction of PCCT. It is feasible to acquire UHR images at full dose efficiency without the application of additional hardware like combs or grids to reduce the detector aperture at the cost of reduced dose efficiency as this would be the case with EID CT. As shown in this case, the CVF was not visible on the previous scan conducted on an EID CT with the traditional thin-slice approach; but it was successfully identified now on



1 An axial image, acquired at 0.625 mm on an EID CT at the level of T5 (Fig. 1a), shows a prominent nerve root sleeve visible to the right of the spinal canal (asterisk). A CVF is not apparent. A UHR image, acquired at 0.2 mm on PCCT (Fig. 1b) shows a prominent nerve root sleeve (asterisk) and a visible CVF at the same level (arrow). An iodine map (Fig. 1c, 0.4 mm) and a thin slab cVRT image (Fig. 1d) show the CVF (arrows) at the same location.

the PCCT with its inherent UHR mode at 79% of radiation dose reduction (8.6 mGy with PCCT vs. 41.3 mGy with EID CT). A model-based iterative reconstruction approach – Quantum Iterative Reconstruction (QIR) – is applied in the image reconstruction process for further image noise reduction. It is worth noting that the combination of UHR images and spectral information (albeit at somewhat reduced resolution) is unique

for PCCT, providing UHR morphological images and the spectral images with chemical composition information (iodine map) from the same data. In this case, the iodine maps generated from the spectral information gave additional confidence in visualizing the CVF identified in the UHR images. The improved visualization helps the physicians make a confident diagnosis and facilitates an appropriate treatment planning.

The patient was relieved from a long history of headaches. ●

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Examination Protocol

Scanner	NAEOTOM Alpha
Scan area	Spine
Scan mode	UHR (Quantum HD)
Scan length	354 mm
Scan direction	Caudo-Cranial
Patient position	FFDR (Feet First Decubitus Right)
Scan time	7.6 s
Tube voltage	140 kV
Tube current	74 mAs
Dose modulation	CARE Dose4D
CTDI _{vol}	8.58 mGy

DLP	341 mGy cm
Rotation time	0.5 s
Pitch	0.85
Slice collimation	120 x 0.2 mm
Slice width	0.2 mm
Reconstruction increment	0.2 mm
Reconstruction kernel	Br48u, QIR 4
Contrast	iopamidol (300 mg/mL)
Volume	10 mL
Flow rate	Manual injection

A massive primary cerebral ALK-positive anaplastic large cell lymphoma in an adolescent

Xiangyu Liu, RT¹; Jiaxu Wei, RT¹; Xi Zhao, MD²; Ji Wang, RT¹

¹ Department of Radiology, Shanghai Jiao Tong University School of Medicine Affiliated Renji Hospital, Shanghai, P. R. China

² Siemens Healthineers, China

History

A 15-year-old male patient, complaining of a growing lump on the right of his forehead over the past 20 days, came to the hospital for a check-up. He was otherwise asymptomatic. His medical history was unremarkable. Physical examination revealed no abnormalities. A contrast-enhanced CT scan was performed with a dual source photon-counting CT (PCCT), NAEOTOM Alpha, using an ultra-high resolution (UHR) scan mode, for assessment.

Diagnosis

CT images showed an expansive frontotemporal mass, measuring 66 mm x 65 mm in size, protruding into the right orbit, the right frontal sinus and subcutaneously. It was also compressing the right lateral ventricle, shifting the cerebral midline and both the anterior cerebral arteries (ACA) leftwards, and the right middle cerebral artery (MCA) backwards, and causing bone erosion of the squamous part of the right temporal bone and posterolateral orbital wall. The mass, homogeneous and slightly hyperdense in the virtual non-contrast (VNC) images, showed uniformed contrast enhancement in the virtual monoenergetic images (VMI) displayed at 55 keV, as well as in the iodine maps, with multiple hyperdense foci inside. Hypodense areas around the mass were seen, suggesting edema. The intraorbital segment of the optic

nerve was compressed, however, not invaded. CT findings suspected a meningioma. A MRI was suggested for further assessment, also suspecting a meningioma. A lymphoma was considered in the differential diagnosis, however, there were no typical signs in either CT or MRI.

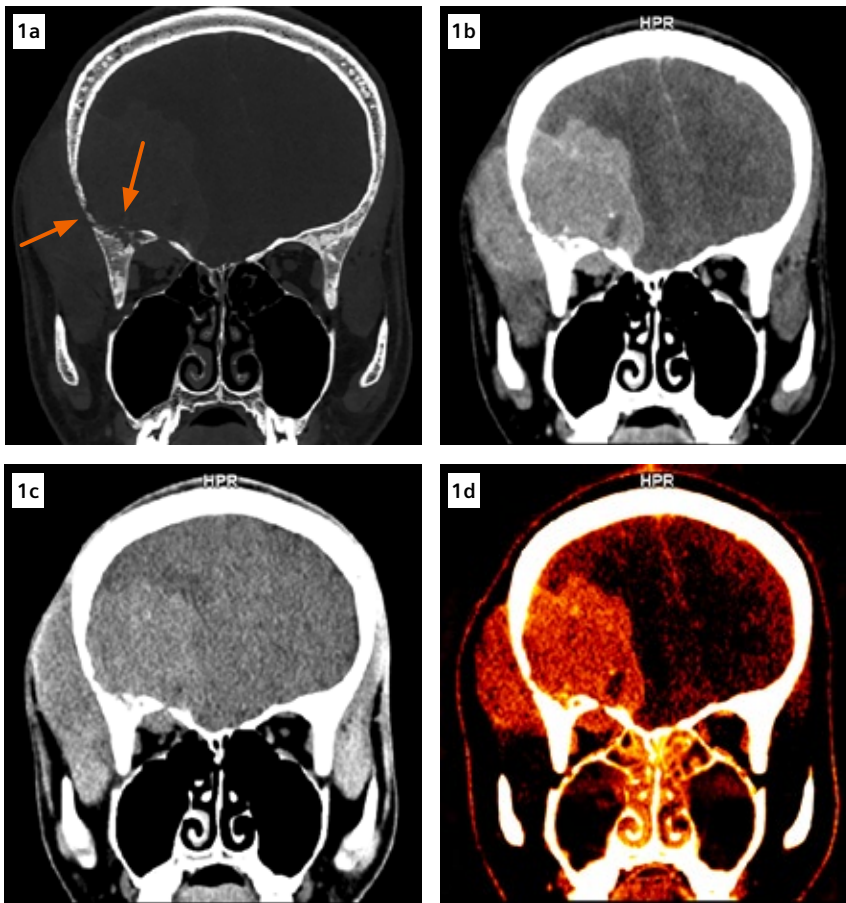
Subsequently, the patient underwent surgical removal of the mass. Histologic and immunophenotypic findings revealed an anaplastic large cell lymphoma (ALCL), anaplastic-lymphoma-kinase (ALK) positive. The patient recovered well and was discharged two weeks later with scheduled outpatient follow-ups.

Comments

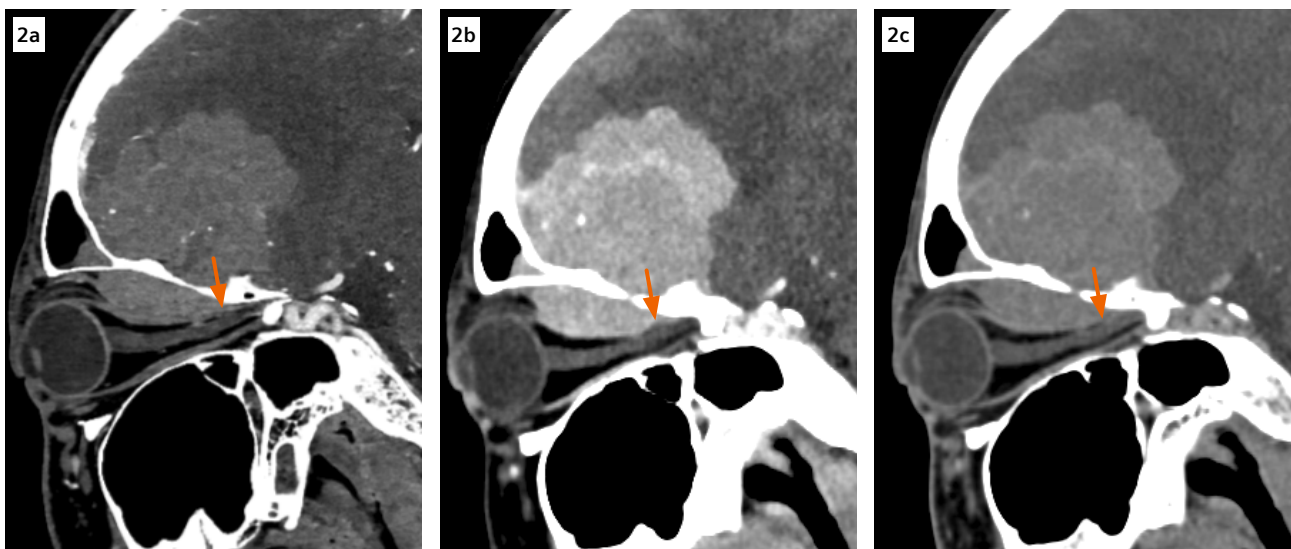
Primary ALCLs, occurring in the central nervous system (CNS), are extremely rare. They tend to occur in children and young adults, predominantly male patients, with a prognosis correlated with ALK positivity. A favorable course has been exhibited in younger patients with ALK-positive ALCL. As the imaging characteristics are atypical, diagnosis and differential diagnosis are difficult with traditional imaging alone, especially when the tumor is massive and invasive, such as in this case.

A unique combination of high spatial resolution and spectral information, provided by PCCT, is helpful in visualizing the detailed cerebral, vascular

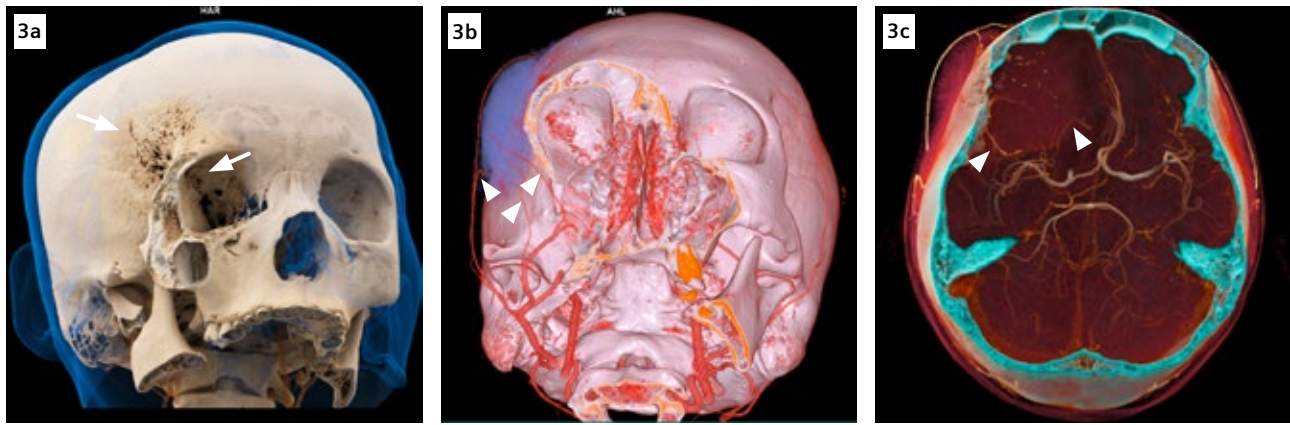
and bony structures using the image data acquired from one UHR scan. The VMI of the cerebrum are routinely set to be displayed at a low keV level (55 keV) allowing for enhanced contrast. VNC images can be displayed with one mouse click, without having to perform a native scan. In daily practice, these different image types – VMI, VNC and iodine – can be interactively toggled, using Interactive Spectral Imaging (ISI) technique available in image reading. In UHR mode, small sub-pixels are defined by electric fields, instead of physical separations, and are read out separately to increase the spatial resolution. This approach improves the geometrical dose efficiency of the detector to enable UHR imaging without radiation dose penalty. In addition, PCCT optimizes the contrast-to-noise ratio (CNR) with a combination of missing down-weighting of the lower energy X-ray photons, the absence of the electronic noise and the inherent spectral information. A practical example is that the UHR images, acquired and reconstructed at 0.2 mm slice width, can be used to create lifelike three-dimensional images with cinematic volume rendering technique (cVRT). In this very rare case, although diagnosis based on imaging differs from histologic and immunophenotypic results, the detailed visualization and demonstration help the neurosurgeons understand the complexity of the case prior to surgical planning. ●



1 Coronal view of a 0.2 mm UHR image (Fig. 1a) shows bone erosion (arrows) of the squamous part of the right temporal bone and the posterolateral orbital wall. 1 mm slices with spectral information are reconstructed from the UHR data to reformat coronal views of a VMI displayed at 55 keV (Fig. 1b), a VNC (Fig. 1c), and an iodine map (Fig. 1d). These images show an expansive frontotemporal mass, homogeneous and slightly hyperdense in VNC, uniformly contrast enhanced in VMI and iodine images, with multiple hyperdense foci inside, protruding into the right orbit and shifting the cerebral midline to the left.



2 Oblique MPR images show the tumor protruding into the right frontal sinus and the right orbit, compressing the intraorbital segment of the optic nerve. The fine separation (arrows) between the tumor edge and optic nerve is better seen in 0.2 mm UHR image (Fig. 2a) and in VMI displayed at 55 keV (Fig. 2b), in comparison to a VMI displayed at 70 keV (Fig. 2c) corresponding to an image acquired at 120 kV in standard scan.



3 cVRT images, reconstructed using 0.2 mm UHR slices, show bone erosion of the squamous part of the right temporal bone and the posterolateral orbital wall (Fig. 3a, arrows), the extracranial (Fig. 3b) and intracranial (Fig. 3c) feeding arteries (arrowheads) to the tumor in detail. Both ACA are shifted leftwards and the right MCA is shifted backwards.

Examination Protocol

Scanner	NAEOTOM Alpha
Scan area	Head
Scan mode	UHR mode (Quantum HD) Arterial/venous phase
Scan length	194.6 mm
Scan direction	Caudo-cranial
Scan time	2.4 s
Tube voltage	140 kV
Effective mAs	100 mAs
IQ level	125
Dose modulation	CARE Dose4D
CTDI _{vol}	24.3 mGy
DLP	526 mGy*cm
Rotation time	0.25 s
Pitch	0.85
Slice collimation	120 × 0.2 mm
Slice width	0.2/1.0 mm
Reconstruction increment	0.2/0.7 mm

Reconstruction kernel	Hv60/Qr40, QIR 4
keV level	55 keV
Spectral reconstruction	VMI, iodine, VNC
Contrast	350 mg/mL
Volume	45 mL + 40 mL saline
Flow rate	5.0 mL/s
Start delay	1, Arterial phase: scan manually triggered when contrast agent ap- peared in the carotid ar- tery at C4 level. 2, Venous phase: end of the arterial phase + 8 s.

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The products/features (mentioned herein) are not commercially available in all countries. Their future availability cannot be guaranteed.

Follow-up on an unruptured intracranial aneurysm treated with a flow diverter

Jiaxu Wei, RT¹; Xiao Li, MD¹; Huilin Zhao, MD¹; Shenghao Ding, MD²; Lang Liu, MD²; Xi Zhao, MD³; Yan Zhou, MD¹

¹ Department of Radiology, Renji Hospital, Shanghai Jiao Tong University School of Medicine, Shanghai, P. R. China

² Department of Neurosurgery, Renji Hospital, Shanghai Jiao Tong University School of Medicine, Shanghai, P. R. China

³ Siemens Healthineers, China

History

A 71-year-old female patient, complaining of dizziness for over two months, came to the hospital for a check-up. A native cerebral CT and a CT angiography (CTA) were performed on an energy-integrating detector (EID) CT for assessment.

Diagnosis

CTA images showed an irregular, saccular aneurysm with a narrow neck, at the A3 segment of the left anterior cerebral artery (ACA), directing forward and upward. The neck-to-dome distance was approximately 12.8 mm and the maximum dome width was 6.3 mm. A severe stenosis in the parent artery, proximal to the neck of the aneurysm, was seen. Native CT images were unremarkable with no signs of subarachnoid hemorrhage.

Subsequently, the patient underwent endovascular treatment. The implantation of a flow diverter, as well as a balloon angioplasty, were successfully performed. Post-interventional digital subtraction angiography (DSA) showed retained contrast agent near the neck of the aneurysm. Two days later, this residual filling of contrast agent was also seen in a follow-up CTA performed on a photon-counting detector (PCD) CT, using an ultra-high resolution (UHR) scan mode. The curved segment of the diverter appeared

slender. There was no evidence of braid deformation nor of lumen abnormalities of the parent artery.

The patient experienced no complications during her hospital stay and was discharged five days after the intervention. A six-month follow-up CTA was scheduled.

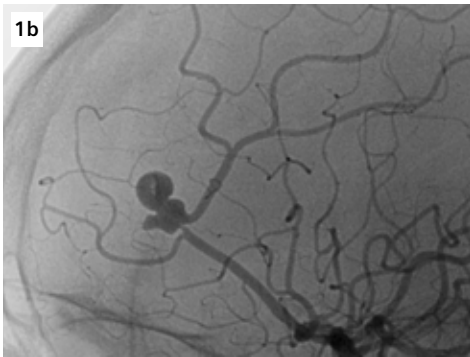
Comments

Unruptured intracranial aneurysms (UIAs) are often asymptomatic. When it ruptures, it may bleed into the brain parenchyma or the subarachnoid space, resulting in permanent disability or even death. DSA is considered the gold standard technique for the detection of cerebral aneurysms, offering both dynamic and morphological information on the intracranial circulation. However, it is relatively expensive, not widely available and carries a potential risk of complications. For an appropriate treatment planning, CTA offers valid diagnostic information, such as the location and the form of the aneurysm, the size of its neck and dome, the presence of collateral arteries, or abnormalities of the parent artery. With the introduction of PCD CT, it becomes possible to routinely acquire UHR images with high spatial resolution and reduced image noise at retained radiation dose efficiency. As shown in this case, the UHR images, acquired at 0.2 mm and

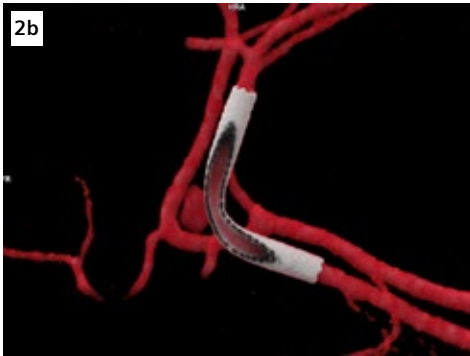
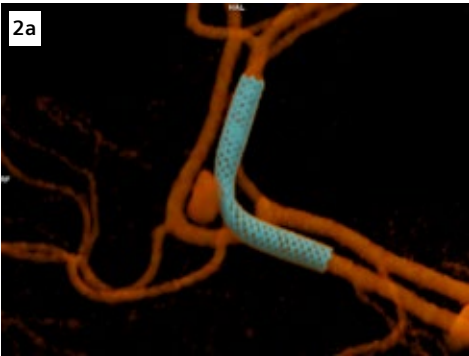
reconstructed with a sharp kernel of Hv89, can be properly used to create optimal three-dimensional (3D) images, using cinematic volume rendering technique (cVRT). This offers the possibility of visualizing the detailed structures of the vascular anatomy as well as of the flow diverter in both 2D and 3D using the same UHR images. The artifact interference, usually caused by the struts, is not seen. Comparing dose efficiency – the UHR images acquired at 0.2 mm on PCD CT applied a CTDI_{vol} of 24.1 mGy, and the standard images acquired at 1 mm on EID CT applied a CTDI_{vol} of 45.9 mGy. This case shows the potential improvement of the UHR mode with PCD CT in the evaluation on a flow diverter implementation for an intracranial aneurysm, which prompts the primary use of UHR CTA in post-interventional follow-up imaging in clinical routine. ●

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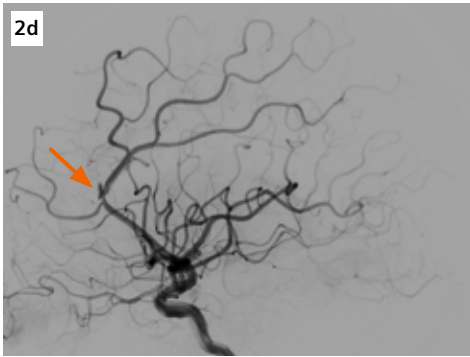
The products/features (mentioned herein) are not commercially available in all countries. Their future availability cannot be guaranteed.



1 A cVRT image (Fig. 1a), created using CTA images acquired on EID CT, shows an irregular, saccular aneurysm, with a narrow neck, at the A3 segment of the left ACA, directing forward and upward. A severe stenosis (arrow) in the parent artery proximal to the neck of the aneurysm is also seen. CT findings are confirmed in the DSA image (Fig. 1b).



2 cVRT images (Fig. 2a – 2c), created using UHR images acquired on PCD CT, show retained contrast agent near the neck of the aneurysm, corresponding to the residual filling of the contrast agent seen in the post-interventional DSA image (Fig. 2d, arrow). The curved segment of the flow diverter appears slender. The structures of the diverter are shown in detail in cVRT images without interference of artifacts caused by the struts.



Examination Protocol

Scanner	NAEOTOM Alpha
Scan area	Brain
Scan mode	UHR mode (Quantum HD)
Scan length	168.6 mm
Scan direction	Caudo-cranial
Scan time	2 s
Tube voltage	140 kV
Effective mAs	99 mAs
IQ level	125
Dose modulation	CARE Dose4D
CTDI _{vol}	24.1 mGy
DLP	454 mGy*cm
Rotation time	0.25 s

Pitch	0.85
Slice collimation	120 × 0.2 mm
Slice width	0.2 mm
Reconstruction increment	0.2 mm
Reconstruction kernel	Hv89

Contrast	400 mg/mL
Volume	55 mL + 30 mL saline
Flow rate	4.5 mL/s
Start delay	Bolus tracking triggered at 100 HU in the aortic arch + 4 s

Follow-up on an endovascular coiling embolization of a ruptured intracranial aneurysm

Xiangyu Liu, RT¹; Jiaxu Wei, RT¹; Xi Zhao, MD²; Ji Wang, RT¹

¹ Department of Radiology, Renji Hospital, Shanghai Jiao Tong University School of Medicine, Shanghai, P. R. China

² Siemens Healthineers, China

History

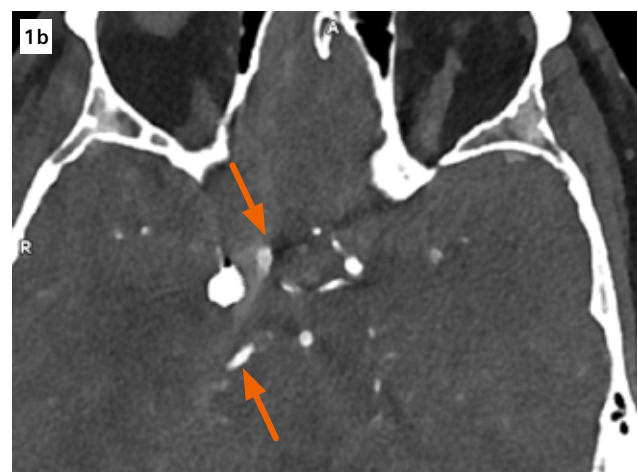
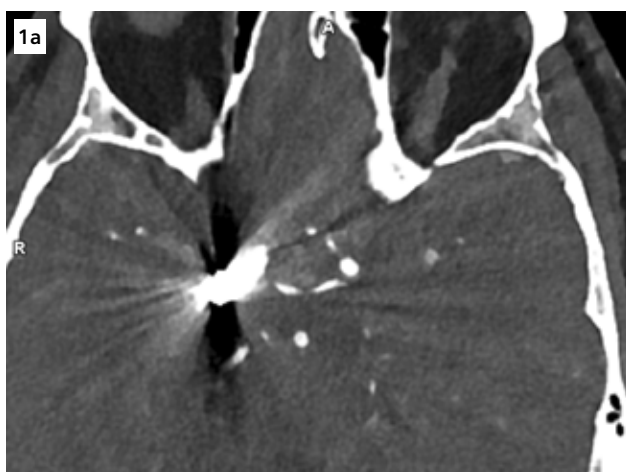
A 59-year-old female patient, suffering from a sudden onset of headache with nausea and vomiting 6 hours previously, was admitted to the hospital. The patient had a medical history of a primary hypertension, stage 3. A CT angiography (CTA) was performed on a conventional energy-integrating detector (EID) CT. This revealed a saccular aneurysm at the C7 segment of the right internal carotid artery (ICA), along with a subarachnoid hemorrhage. An endovascular coiling embolization of the aneurysm was carried out successfully. A follow-up CTA was performed on a dual source photon-counting detector (PCD) CT, NAEOTOM Alpha, for assessment.

Diagnosis

Follow-up CTA images acquired on the PCD-CT showed improved vessel delineation, sharpness and enhanced vessel contrast. However, metal artifacts occurred in the vicinity of the postcoiling aneurysm, obscuring the visualization of the vascular and parenchymal structures. These artifacts were effectively reduced in the images reconstructed with Iterative Metal Artifact Reduction (iMAR) using "Neuro coils" preset, resulting in improved visualization. The aneurysm showed a total occlusion without signs of remnants. The parental right ICA, the anterior cerebral artery (ACA) and the middle cerebral artery (MCA) were all patent without stenosis. The patient recovered uneventfully.

Comments

A ruptured intracranial aneurysm (IA) is an emergency and requires immediate treatment. Endovascular coiling embolization is routinely used to occlude a ruptured IA with the primary aim of preventing the long-term risk of rebleeding. This is associated with a poor prognosis and high morbidity and mortality. [1] Rebleeding can occur either due to a recanalized aneurysm or to a de novo aneurysm, therefore, imaging follow-ups are justified to provide an early preventive treatment when necessary. [2] As MRA is limited by contraindications and DSA is an invasive procedure bearing potential complications such as cerebral thromboembolism, CTA is frequently



1 An axial image prior to iMAR (Fig. 1a) shows an obscured visualization of the embolized aneurysm and the adjacent arteries due to artifacts. The visibility is clearly improved in the image reconstructed with iMAR (Fig. 1b, arrows).

Examination Protocol

Scanner	NAEOTOM Alpha
Scan area	Head
Scan mode	Quantumplus
Scan length	161 mm
Scan direction	Caudo-cranial
Scan time	0.8 s
Tube voltage	140 kV
Effective mAs	38 mAs
IQ level	105
Dose modulation	CARE Dose4D
CTDI _{vol}	9.0 mGy
DLP	186 mGy*cm
Rotation time	0.25 s
Pitch	0.8

Slice collimation	144 × 0.4 mm
Slice width	0.4 mm
Reconstruction increment	0.2 mm
Reconstruction kernel	Hv56
keV level	55 keV
Spectral reconstruction	Monoenergetic Plus

Contrast	370 mg/mL
Volume	40 mL + 40 mL saline
Flow rate	5 mL/s
Start delay	Bolus tracking triggered at 100 HU in the aortic arch + 3 s

used for diagnosis and follow-up. However, the challenge lies in the metal artifacts caused by the coils which lead to difficulties in image interpretation, or at worst, non-assessable datasets. To meet this challenge, an iMAR algorithm has been developed which combines beam hardening correction, normalized sinogram inpainting and frequency split to preserve fine anatomical details. The correction process is then iteratively applied for a refined correction result. [3] Consequently, metal artifacts are reduced and the visibility in the vicinity of the postcoiling aneurysm is improved.

This case is acquired with a PCD-CT, NAEOTOM Alpha, which provides energy-resolved CT data with increased spatial resolution and iodine

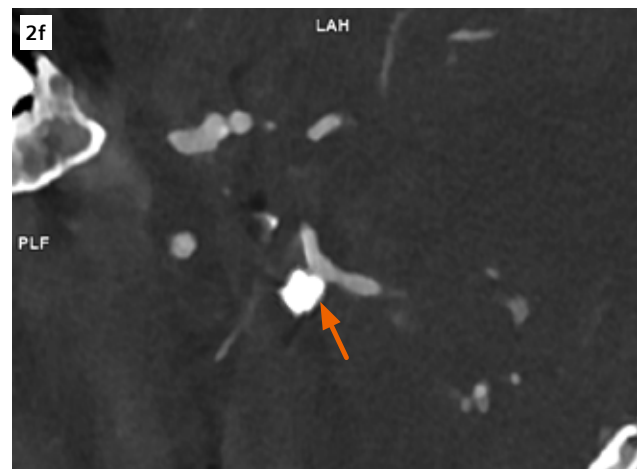
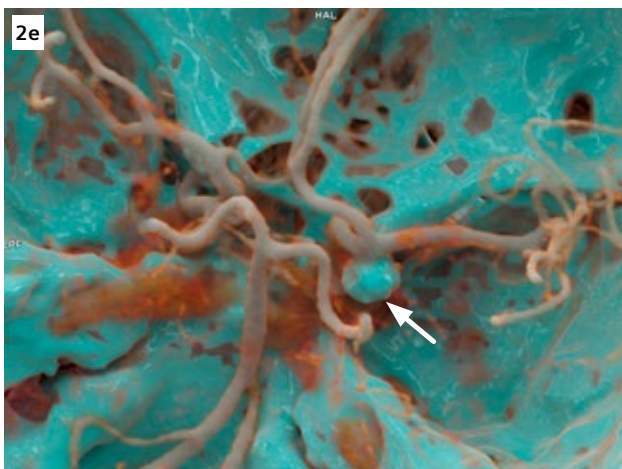
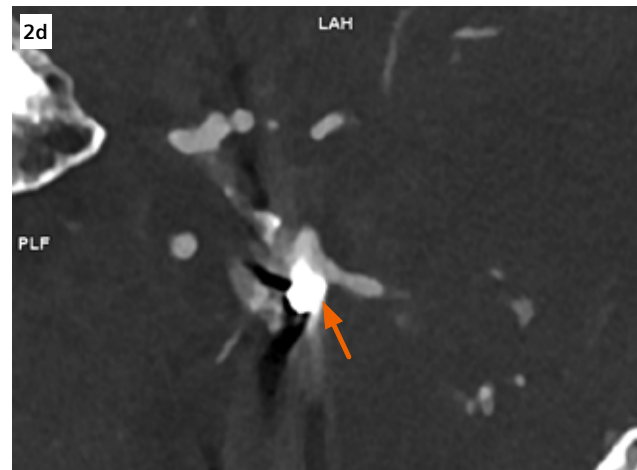
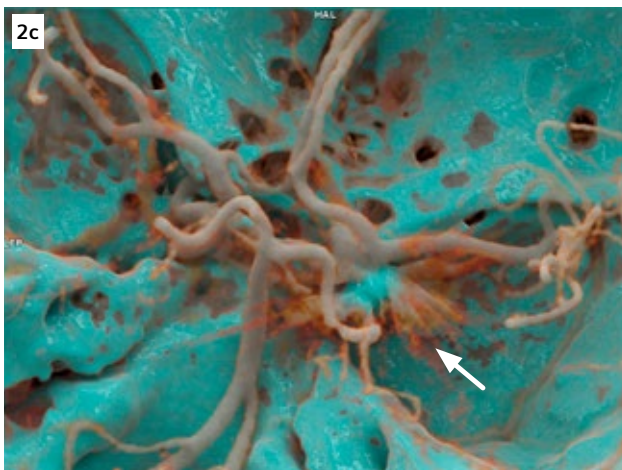
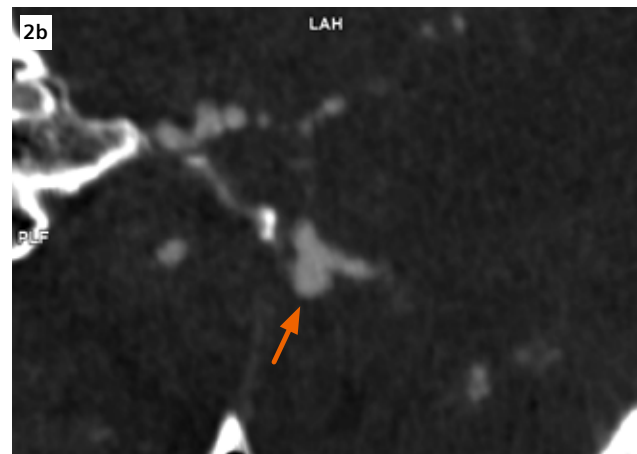
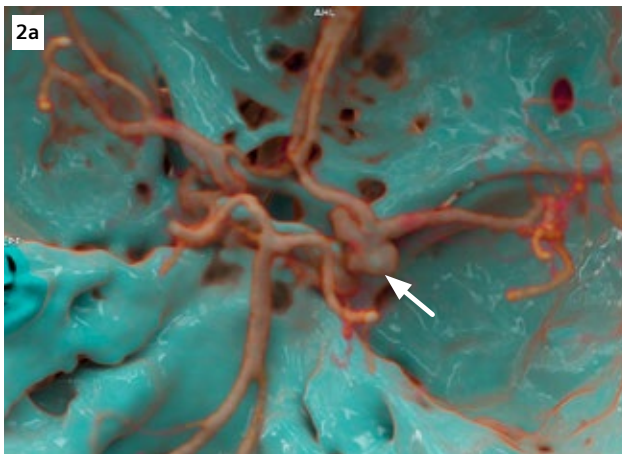
contrast, without electronic noise. Images are routinely acquired at 0.4 mm slice collimation with spectral information, allowing virtual monoenergetic image (VMI) display at low keV (55 keV in this case), which further enhances image contrast and improves visualization of vascular details. A dedicated sharper kernel (Hv56) is applied in image reconstruction to increase high contrast resolution and improve vessel delineation. These high-resolution images can also be used for three dimensional, in-depth, lifelike demonstration, using cinematic rendering technique (cVRT), facilitating the communication with the neurosurgeons and treatment planning.

As shown in this case, comprehensive PCD CT imaging combined with iMAR technology can improve vessel delin-

eation and sharpness, enhance vessel contrast and reduce metal artifacts. This benefits a follow-up of patients with treated IAs. An interventional procedure for the follow up of this patient was not necessary. ●

iMAR is intended to reduce metal artifacts in CT images when metal is present in the scanned object. The extent of artifact reduction and image quality improvement depends on factors such as metal composition and size, patient size, anatomical location, and clinical practice. iMAR images must always be interpreted alongside standard reconstructions.

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2 cVRT and MPR images show the head view of the cerebral arteries. Images acquired with an EID-CT prior to the coiling embolization (Fig. 2a–2b) show an aneurysm located at the C7 segment of the right ICA (arrows). Postcoiling images acquired with PCD-CT without iMAR (Fig. 2c–2d) show metal artifacts obscuring the visibility of the aneurysm and the adjacent structures (arrows). The completely embolized aneurysm, without signs of remnants, as well as patent right ICA, ACA and MCA, are clearly visualized in the images with iMAR (Fig. 2e–2f, arrows). Note the improvement of the vessel delineation, sharpness and contrast in the PCD-CT images (Figs. 2c–2f).

References

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Stapes prosthesis dislocation

Hunor Sükösd, MD; Éva Juhász, RT

Medical Imaging Centre, Semmelweis University, Budapest, Hungary

History

A 74-year-old female patient, with a history of bilateral stapedectomy and stapes prosthesis insertion 10 years ago, came to the hospital complaining of a progressive, worsening conductive hearing loss on the left side for over the past 2 years. A CT examination using a ultra-high resolution (UHR) scan mode was performed for evaluation.

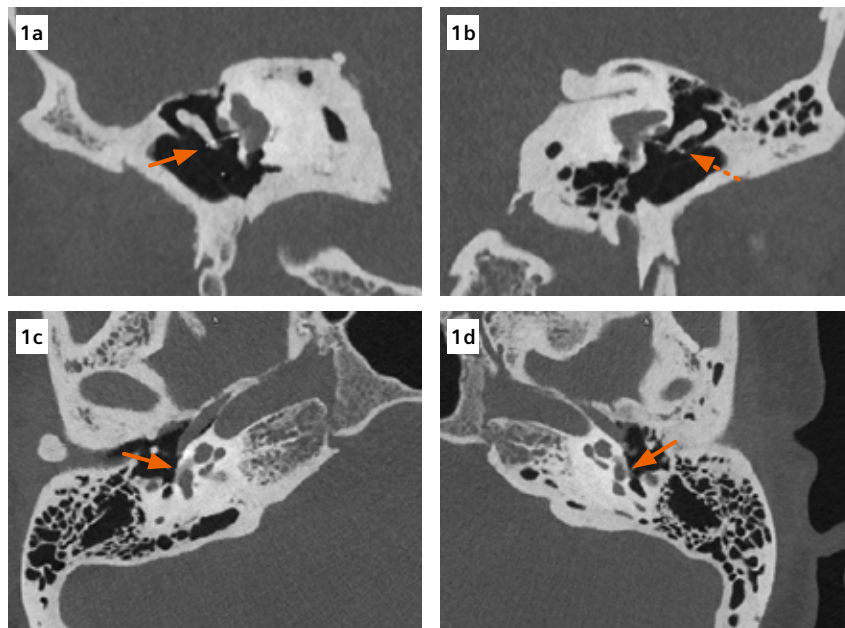
Diagnosis

CT images showed a piston wire prosthesis (PWP) on each side. The right PWP was normally positioned, with one end hooked onto the long process of the incus and the other attached to the oval window. A second PWP was also seen inside the right middle ear below the auditory ossicles. The left PWP was dislocated, with its loop slipped out of the long process of the incus and detached, from the other end, from the oval window. Otosclerosis was visualized bilaterally.

Subsequently, the patient was scheduled for revision surgery on the left. The second PWP on the right was considered a failed insertion attempt (10 years ago) that was accidentally left there, and a revision tympanoplasty for retrieval was not planned as the patient had no complaint at all on that side.

Comments

The stapes is the innermost bone of the auditory ossicles in the middle ear. It has a footplate which seals the oval window and conducts vibrations to the cochlea. Otosclerosis is an abnormal bone remodeling which



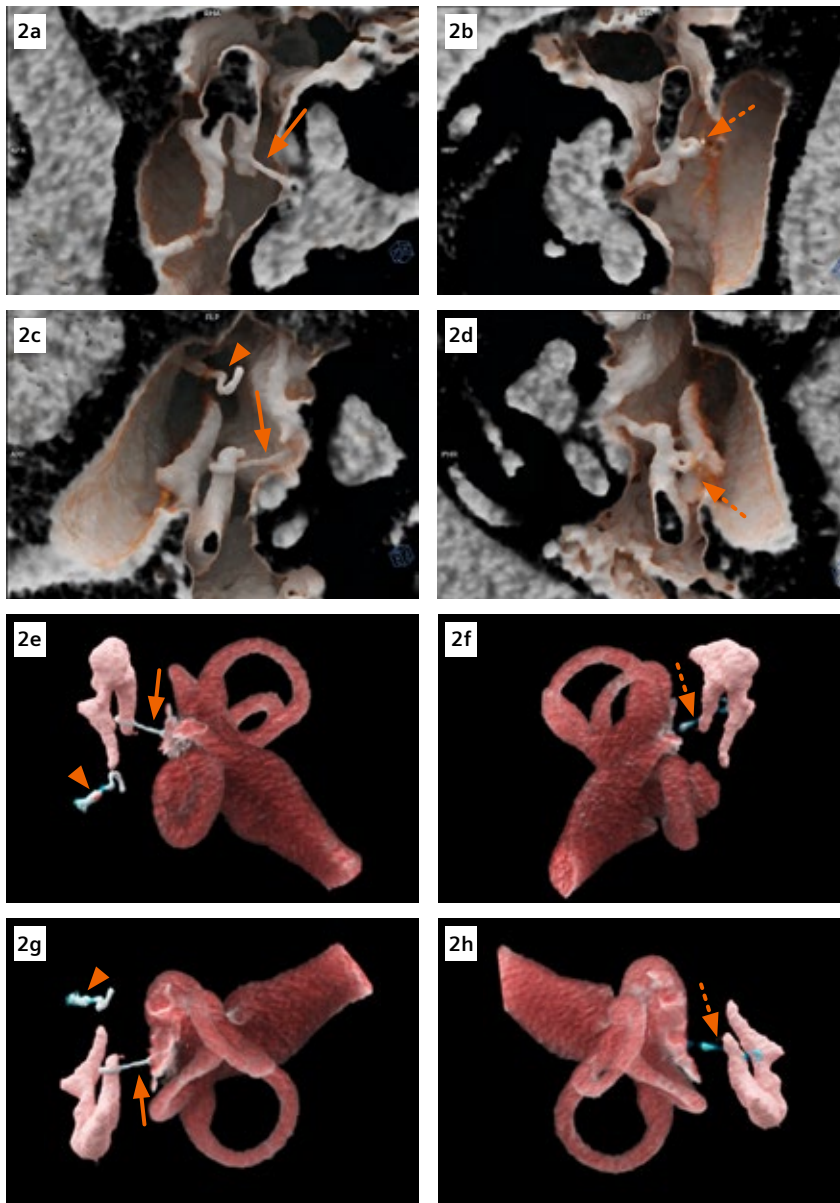
1 Oblique MPR images show a 3 mm long PWP on each side (Figs. 1a & 1b). The right PWP (Fig. 1a, arrow) is in a normal position, and the left PWP (Fig. 1b, dotted arrow) is dislocated. Otosclerosis is visualized bilaterally with subtle lucency in the bones near the cochlea (Figs. 1c & 1d, arrows).

can affect the movement of the stapes causing conductive hearing loss. This may be corrected by stapedectomy, a surgical replacement of the stapes with a prosthesis. High resolution CT scans of the temporal bones have been routinely performed for both pre-surgery diagnosis as well as for post-surgery follow-up. The prosthetic position in the middle ear can be determined with high resolution CT. However, the thin metallic wires are difficult to detect due to volume averaging. [1]

This case is performed on NAEOTOM Alpha®, a newly developed Dual Source CT scanner with photon-counting detectors (QuantaMax®), providing energy-resolved CT data at improved spatial resolution, without electronic noise. [2] A UHR mode featuring a slice collimation of

120 x 0.2 mm is applied in which the sub-pixels of the detector, with a size of 0.15 x 0.18 mm² (at the isocenter), are read out individually. There are no physical septa between the pixels, each group of 4 x 6 sub-pixels is confined by collimator grids.

Therefore, the full radiation dose efficiency of the detector is preserved in UHR mode. Furthermore, electronic noise is eliminated by setting up a predefined digital threshold for counting X-ray photons far above the electronic noise floor. A refined iterative reconstruction technique (Quantum Iterative Reconstruction QIR) is used to efficiently reduce image noise at ultra-high resolution without negatively affecting image sharpness or image noise texture. This combination – image noise reduction and ultra-thin image slices at full dose



2 cVRT images show the PWP, the auditory ossicles and the cochlea on both sides. The right PWP (Figs. 2a, 2c, 2e & 2g, arrows) is in a normal position, with one end hooked onto the long process of the incus and the other attached to the oval window. A second right PWP (arrowheads) is also seen inside the middle ear below the auditory ossicles. The left PWP (Figs. 2b, 2d, 2f & 2h, dotted arrows) is dislocated, with its loop slipped out of the long process of the incus and detached, from the other end, from the oval window. Note that the axial images used for cVRT creation are slices reconstructed at 0.2 mm with a very sharp kernel of Hr84.

efficiency – allows not only for improved anatomic conspicuity, due to increased spatial resolution, but also for a photo-realistic three-dimensional visualization of anatomical details using cinematic volume rendering technique (cVRT). As shown in this case, even images reconstructed at 0.2 mm with a very sharp kernel of Hr84, can be used to render incredible details of the only 3 mm long PWP. CT findings clearly show the prosthesis dislocation, explaining the progressive hearing loss, and assist the otologist in making an appropriate surgical revision plan for the patient. ●

References

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Examination Protocol

Scanner	NAEOTOM Alpha
Scan area	Temporal Bone
Scan mode	Quantum HD
Scan length	60 mm
Scan direction	Caudo-cranial
Scan time	1.5 s
Tube voltage	120 kV
Effective mAs	91 mAs
Dose modulation	CARE Dose4D
CTDI _{vol}	15.5 mGy
DLP	120 mGy*cm
Rotation time	0.5 s
Pitch	0.85
Slice collimation	120 x 0.2 mm
Slice width	0.2 mm
Reconstruction increment	0.1 mm
Reconstruction kernel	Hr84

Congenital cholesteatoma

Hunor Sükösd, MD; Éva Juhász, RT

Medical Imaging Centre, Semmelweis University, Budapest, Hungary

History

A 7-year-old girl suffering from bilateral progressive conductive hearing loss, worse on the left side, was presented to the hospital. Physical examination was unremarkable on both eardrums. There were no signs of a middle ear infection present. A CT examination was indicated for further assessment of the middle ear structures. An ultra-high resolution (UHR) scan mode (Quantum HD) was performed on a dual source photon-counting CT (NAEOTOM Alpha®).

Diagnosis

UHR CT images showed a soft tissue mass in the left middle ear, extending into the mastoid antrum. Erosion of the long process of the incus and the stapes were seen. The eardrum and the scutum were intact and the Prussak's space was free. No effusion or developmental anomalies were present. CT findings were consistent with congenital cholesteatoma, Potsic stage IV. There were no pathological findings visualized on the right side. An MRI examination was performed to confirm the diagnosis which showed increased diffusion restriction of the mass, characterizing a cholesteatoma. No abnormalities were visualized on the right side in the MRI.

As the symptoms were worse on the left side, and there were no pathological findings on the right side, the patient was primarily treated for the left side. Surgical findings confirmed

CT diagnosis. A diagnostic tympanoplasty was considered on the other side later on, if the symptoms persisted post-operatively.

Comments

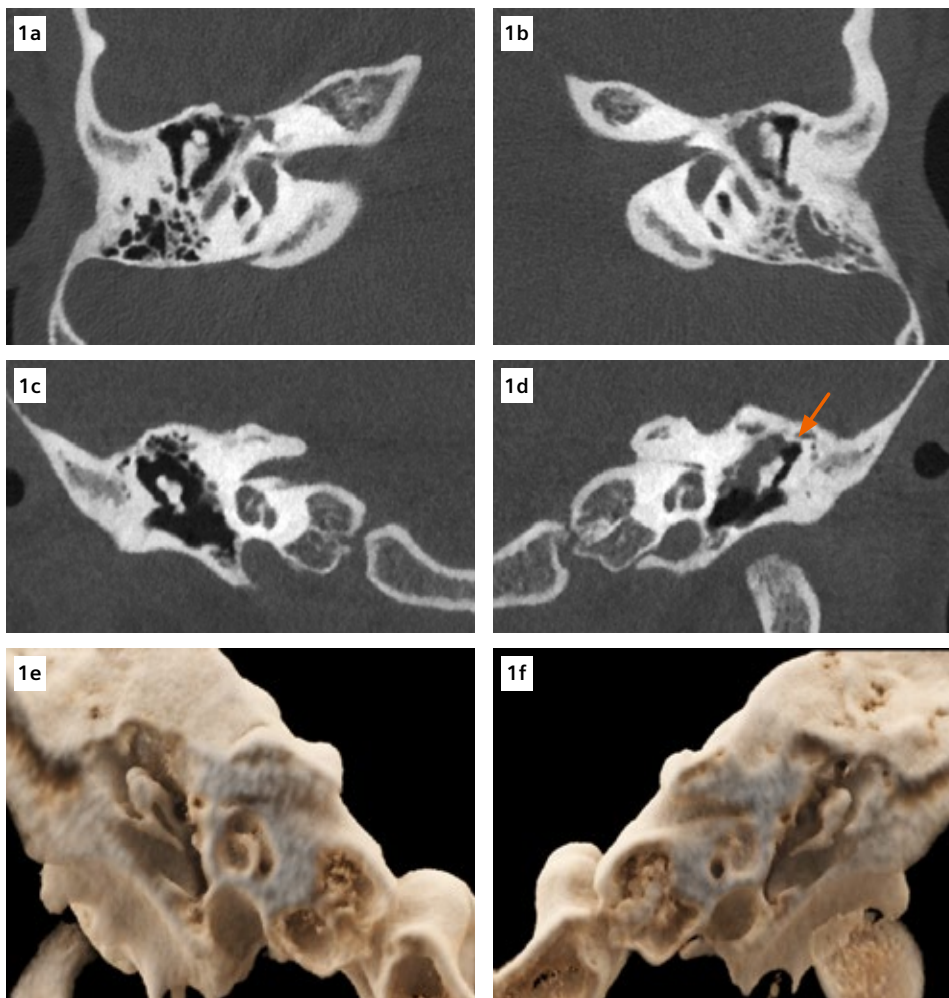
Congenital cholesteatomas are inclusion cysts of the ectoderm and are comprised of keratin debris and cholesterol. They are one of the more common causes of pediatric conductive hearing loss besides otitis media with effusion. [1] If undiagnosed, cholesteatomas can lead to the vast destruction of the middle ear structures and permanent damage to the hearing apparatus. Early diagnosis is essential to prevent extensive surgery and preserve hearing. [2] However, most children are asymptomatic and frequently resist attempts to conduct a thorough examination. A pre-operative CT scan is essential in defining the extent of existing pathology, assessing the bony labyrinth and hearing ossicles, as well as planning potential surgery. This especially requires high spatial resolution for evaluating the detailed structures and low dose for pediatric patients.

This case is performed on a dual source photon-counting CT (NAEOTOM Alpha) using an UHR mode, acquiring scan data at 120 x 0.2 mm collimation and reconstructing images at 0.2 mm slice width with a very sharp bone kernel (Hr84). In this mode, each sub-pixel of the photon-counting detector is read-out individually to

improve spatial resolution at full dose-efficiency. [3] By using an optimized 70 kV protocol, a very low dose-length product (DLP) of only 92.3 mGy*cm could be achieved, substantially lower than the typical DLPs of 200-400 mGy*cm for this type of examination. Photon-counting CT enables UHR scanning at low radiation dose without substantial increase in image noise, since UHR scan data are acquired at full dose efficiency without additional combs or grids to reduce the detector aperture. Image noise is further reduced by using a refined model based iterative reconstruction approach (Quantum Iterative Reconstruction, QIR). The UHR images can even be used as input for creating a photo-realistic three-dimensional demonstration of the anatomical details, using cinematic volume rendering technique (cVRT), assisting the otologist in setting up an appropriate surgical plan for the patient. ●

References

- [1] David Walker; Michael J. Shinnars. Congenital Cholesteatoma. *Pediatr Ann.* 2016;45(5):e167-e170.
- [2] M.A. El-Bitar et al. Congenital middle ear cholesteatoma: need for early recognition – role of computed tomography scan. *International Journal of Pediatric Otorhinolaryngology* (2003) 67, 231-235.
- [3] Thomas Flohr, et al. Photon-counting CT review. *Physica Medica* 79 (2020) 126–136.



1 Axial images (Figs. 1a & 1b) and coronal MPR images (Figs. 1c & 1d) show a soft tissue mass in the left middle ear, eroding the long process of the incus and the stapes.

The Prussak's space (Fig. 1d, arrow) is free and the scutum was intact. No remarkable findings on the right side.

cVRT images (Figs. 1e & 1f) show a 3D view of bilateral ossicles – normal on the right and eroded on the left. Note that the input images for cVRT creation are the UHR images reconstructed at 0.2 mm with a very sharp kernel of Hr84.

Examination Protocol

Scanner	NAEOTOM Alpha		
Scan area	Temporal bone	DLP	92.3 mGy*cm
Scan mode	Quantum HD	Rotation time	0.5 s
Scan length	53.8 mm	Pitch	0.85
Scan direction	Caudo-cranial	Slice collimation	120 x 0.2 mm
Scan time	1.3 s	Slice width	0.2 mm
Tube voltage	70 kV	Reconstruction increment	0.2 mm
Effective mAs	340 mAs	Reconstruction kernel	Hr84, QIR3
Dose modulation	CARE Dose4D		
CTDI _{vol}	13 mGy (16 cm phantom)		

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Severe ureteral obstruction secondary to an upper urinary tract urothelial carcinoma

Jan Baxa, MD, Ph.D.; Jiří Ferda, MD, Ph.D.

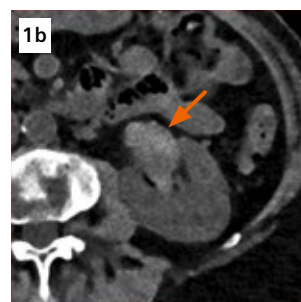
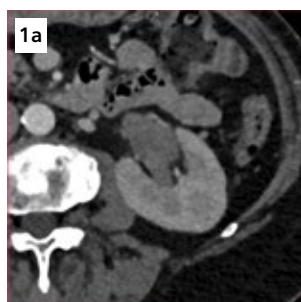
Department of Imaging Methods, University Hospital Pilsen and Medical Faculty of Charles University, Pilsen, Czech Republic

History

A 55-year-old female patient, suffering from hematuria for the past few weeks, came to the hospital for a check-up. An ultrasound examination revealed a dilatation of the left renal calyces and pelvis, however, could not report upon the cause. A urine cytology analysis did not prove urothelial carcinoma (UC), and the patient reported no other significant symptoms. A contrast CT examination was requested for further evaluation.

Diagnosis

CT images, with spectral reconstructions, showed dilated left renal calyces and pelvis which were hyperdense in the Virtual Non-Contrast (VNC) images, suggesting blood content (Fig. 1). Two small lesions, measuring 6 x 5 mm in the central part of the renal pelvis and 4 x 5 mm at the pelviureteric junction, were visualized in the Monoenergetic Plus images displayed at 45 keV, as well as in the iodine maps fused with VNC. Both lesions were not visible in standard CT images (Monoenergetic images displayed at 70 keV, corresponding to images acquired at 120 kV), presumably due to their small size and being obscured by the hyperdense blood content. The small lesion at the pelviureteric junction could most probably be considered as a discrete tumor infiltration and the cause of a severe ureteral obstruction (Figs. 2 & 3).



1 Axial images show a dilated left renal pelvis in a standard image (Fig. 1a) with hyperdense blood content identified in a VNC image (Fig. 2b, arrow).

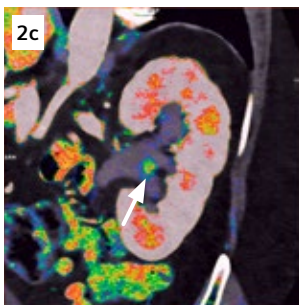
A delayed scan, performed 4 hours later, showed no excretion of contrast agent (Fig. 4). Subsequently, an ureteroscopy was performed and the histological results confirmed the diagnosis of an UC. The patient was then scheduled for surgery.

Comments

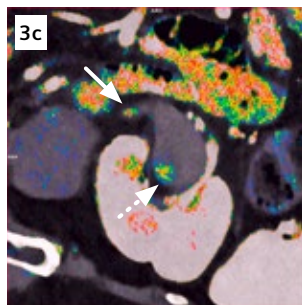
Urothelial tumors affecting the upper urinary tract are relatively rare, accounting for only approximately 1% of all urothelial tumors. The most common histological type is UC found in 90% of the cases. It can cause ureteral obstruction leading to hydronephrosis, infection or spontaneous rupture. Traditionally, a CT evaluation for hematuria with suspected UC would require both non-contrast and contrast scans. [1] In this case, only one contrast scan is performed, acquiring spectral CT data which can be used for further spectral reconstructions, such as VNC, Monoenergetic Plus and iodine maps. The blood content in the renal pelvis is identified in the VNC images and the proportion of the

bleeding to the renal pelvis can also be determined. Both lesions, especially the tiny discrete infiltration at the pelviureteric junction causing severe ureteral obstruction, are not visible and could have been missed in standard CT images. However, they are significantly enhanced and clearly visible in the Monoenergetic Plus images displayed at 45 keV as well as in the iodine maps fused with VNC images.

This case is performed with NAEOTOM Alpha®, a newly developed CT scanner with photon-counting detectors. It provides energy-resolved CT data with a very high spatial resolution, without electronic noise. [2] One of the key benefits of photon-counting CT is the availability of spectral CT data in any scan, without having to consider and decide on the type of the scan before data acquisition or to recall the patient after scanning. This has a major impact on improving clinical routine practice and helping the physicians make confident diagnoses. ●



2 Coronal images show a small lesion in the central part of the left renal pelvis, unidentifiable in a standard image (Fig. 2a), but significantly enhanced and clearly visible in a Monoenergetic Plus image displayed at 45 keV (Fig. 2b, arrow) and an iodine map fused with VNC (Fig. 2c, arrow).



3 Oblique images show a small lesion in the central part of the left renal pelvis (dotted arrows), as well as a tiny lesion at the pelviureteric junction (arrows), both invisible in a standard image (Fig. 3a), but clearly seen in a Monoenergetic Plus image displayed at 45 keV (Fig. 3b) and an iodine map fused with VNC (Fig. 3c).

References

- [1] Abouelkheir RT, Elawdy MM, Taha DE, El-Hamid MA, Osman Y, El-Diasty T. The accuracy of computed tomography in the diagnosis of upper urinary tract urothelial carcinoma in correlation with the final histopathology: A retrospective study in 275 patients at a Tertiary Urology Institute. *Urol Ann* 2021;13:356-61.
- [2] Thomas Flohr, Martin Petersilka, Andre Henning, Stefan Ulzheimer, Jiří Ferda, Bernhard Schmidt. Photon-counting CT review. *Physica Medica* 79 (2020) 126–136.

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4 A VRT image from a delayed scan (4 hours later) shows no excretion of the left kidney due to a severe obstruction at the pelviureteric junction.

Examination Protocol

Scanner	NAEOTOM Alpha
Scan area	Abdomen/Pelvis
Scan mode	QuantumPlus
Scan length	209 mm
Scan direction	Cranio-caudal
Scan time	2.3 s
Tube voltage	120 kV
Effective mAs	105 mAs
Dose modulation	CARE Dose4D
CTDI _{vol}	8.25 mGy
DLP	369 mGy*cm
Rotation time	0.5 s
Pitch	0.8
Slice collimation	144 x 0.4 mm
Slice width	0.4 mm
Reconstruction increment	0.2 mm
Reconstruction kernel	Br36, QIR 3
Spectral Reconstruction	VNC, Monoenergetic Plus, iodine map
Contrast	370 mg/mL
Volume	1 st bolus (70 mL + 40 mL saline) – 20 s pause – 2 nd bolus (30 mL + 20 mL saline)
Flow rate	4 mL/s
Start delay	Bolus tracking triggered in the 2 nd bolus with 100 HU in the distal descending aorta + 5 s

Note: A so-called "Split bolus" technique was applied, acquiring portal/venous phase with the first bolus, and arterial phase with the second bolus, scanning only once.

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Atypical pancreatic neuroendocrine tumor secondary to metastatic renal cell carcinoma

Bettina K. Budai¹, Márton Benke², Ákos Szücs², Pál N. Kaposi¹, Attila Szijártó², Pál Maurovich-Horvat¹, Ibolyka Dudás¹

¹ Department of Radiology, Medical Imaging Centre, Semmelweis University, Budapest, Hungary

² Department of Surgery, Transplantation and Gastroenterology, Semmelweis University, Budapest, Hungary

History

A 64-year-old female patient had undergone nephrectomy twelve years ago due to T2 N0 M0 clear cell renal cell carcinoma (ccRCC). One year later, a single lymph node metastasis was found, which triggered systemic therapy with sunitinib over two years, resulting in complete response. However, the therapy was re-started six years later after an adrenal metastasis occurred which was treated surgically as well. On a recent follow-up CT, another novel lesion was visualized in the pancreatic head. This partially obstructed the portal vein, raising the concern of either tumor invasion or thrombus formation. For further assessment and surgical planning, a three-phase (arterial, pancreatic, venous) contrast-enhanced CT scan was requested and performed on our newly installed photon-counting CT (PCCT).

Diagnosis

CT images of the native scan showed an enlarged, isodense pancreatic head, in which a hypo-attenuating, well circumscribed mass measuring 4.5 x 4.0 x 6.7 cm was depicted in the virtual-monoenergetic images displayed at 65 keV in the pancreatic phase. The mass was iso-attenuating in both the arterial and venous phases, showing delayed enhancement. It extended into the portal vein, causing a partial dislocation and obstruction without signs of invasion. No biliary or pancreatic duct obstruction was present. CT findings suggested a surgically resectable tumor,

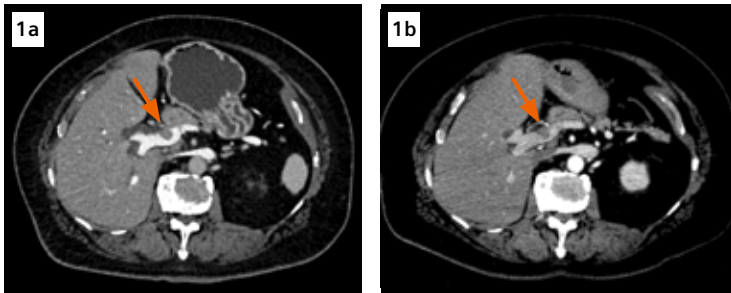
accounting for the possibility of an atypical pancreatic neuroendocrine tumor (pNET), or an atypical ccRCC metastasis, or an adenocarcinoma. The patient was then referred to endoscopic ultrasound (EUS) with biopsy. Histological analysis resulted in a pNET and the patient was scheduled for surgery.

Comments

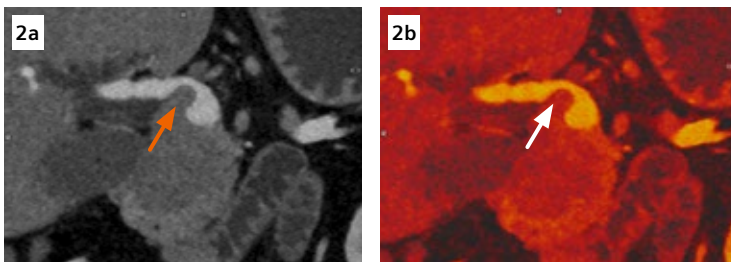
Pancreatic head masses have a broad variety of conditions. Typically, pNETs and ccRCC metastases are well-circumscribed, hypervascular lesions, best seen on (early) arterial phase and cause no significant biliary or pancreatic duct dilatation. However, although rare, atypical forms of both tumors exist, which appear as hypodense masses, mimicking pancreatic adenocarcinoma. [1,2] For differential diagnosis, the atypical form of the tumors and the medical history of the patient must be considered. Tumor resectability needs to be carefully assessed prior to surgery, where signs of tumor invasion into adjacent vessels play the crucial role. In order to deliver a diagnosis most precise, high image sharpness and low image noise are mandatory, which impose technical difficulties and challenges to conventional CT.

This case is performed on a NAEOTOM Alpha®, a newly developed Dual Source CT scanner with photon-counting detectors (QuantaMax®), providing energy-resolved CT data with inherent spectral information at

improved spatial resolution, without electronic noise. [3] Image acquisition with a thin slice collimation of 144 x 0.4 mm, and image reconstruction with a sharper kernel of Br44 are routinely applied for abdominal imaging, improving image sharpness while obtaining full spectral information. A refined iterative reconstruction technique (Quantum Iterative Reconstruction, QIR) is used to efficiently reduce image noise in these thin slices, without negatively affecting image sharpness or image noise texture. Owing to the availability of the spectral data and reduced image noise, virtual-monoenergetic images can be routinely displayed at lower keV levels for enhanced soft tissue contrast, and iodine maps can be reconstructed for improved visualization of boundaries differentiating the tumor from the pancreas parenchyma as well as from the portal vein. These thin slices can also be used to generate a photo-realistic three-dimensional visualization of the anatomical details using cinematic volume rendering technique (cVRT), facilitating the communication between the radiologists and the surgeons. As shown in this very rare case – an atypical pNET as a second primary tumor in a patient with a metastatic ccRCC – the combination of increased image sharpness and contrast with reduced image noise offered by PCCT improves anatomic conspicuity, enhancing the confidence of the radiologists when making a differential diagnosis and assessing tumor resectability. ●



1 A comparison, between an axial image acquired on PCCT (Fig. 1a) with an axial image acquired on a conventional CT 4 months earlier (Fig. 1b), shows a clearer boundary between the lesion (arrows) and the portal vein in the former.



2 Coronal views of a MPR (Fig. 2a) and an iodine map (Fig. 2b) show the hypodense pancreatic head lesion, extending into the portal vein (arrows) without signs of invasion.



3 cVRT images show the hypodense pancreatic head lesion, extending into the portal vein without signs of invasion, and its surrounding structures in three dimensions.

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Examination Protocol

Scanner	NAEOTOM Alpha
Scan area	Abdomen
Scan mode	QuantumPlus (native/arterial/pancreatic/venous)
Scan length	216/216/116/426 mm
Scan direction	Cranio-caudal
Scan time	2.2/2.2/1.1/4.5 s
Tube voltage	120 kV
Effective mAs	143/163/123/124 mAs
Dose modulation	CARE Dose4D
CTDI _{vol}	11.2/12.8/9.7/9.8 mGy
DLP	284/323/145/454 mGy*cm
Rotation time	0.5 s
Pitch	0.8
Slice collimation	144 × 0.4 mm
Slice width	0.4, 1.0, 2.0, 3.0 mm
Reconstruction increment	0.4, 0.5, 1.5, 3.0 mm
Reconstruction kernel	Br44, Qr40
Spectral reconstruction	Monoenergetic Plus, iodine maps
Contrast	370 mg/mL
Volume	78 mL + 40 mL saline
Flow rate	3 mL/s
Start delay	Arterial phase: 23 s Pancreatic phase: 45 s Venous phase: 75 s

References

- [1] Shankar PR, et al. Hypervascular pancreatic "lesions": a pattern-based approach to differentiation. *Abdominal radiology* (New York). 2018; 43(4):1013-1028.
- [2] Coakley FV, et al. Pancreatic imaging mimics: part 1, imaging mimics of pancreatic adenocarcinoma. *199(2):301-308.*
- [3] Thomas Flohr, et al. Photon-counting CT review. *Physica Medica* 79 (2020)126–136.

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A small pulmonary nodule in an obese patient

Prof. Anders Persson, MD, Ph.D.¹; Lilian Henriksson, M.Sc.^{2,3}

¹ Center for Medical Image Science and Visualization (CMIV), Medical Faculty/Radiology, Linköping University, Linköping, Sweden

² Center for Medical Image Science and Visualization (CMIV), Linköping University, Linköping, Sweden

³ Department of Radiology, Department of Health, Medicine and Caring Sciences, Linköping University, Linköping, Sweden

History

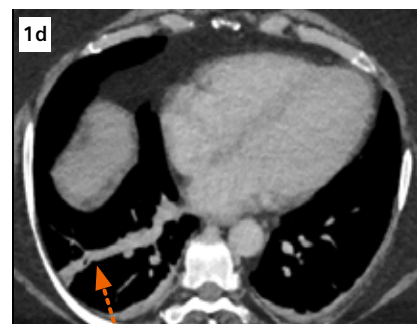
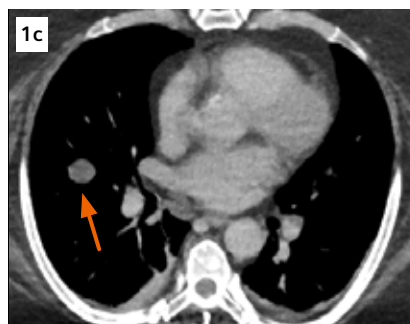
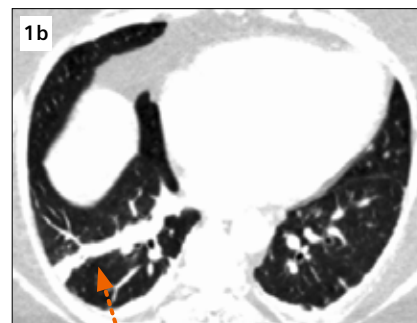
A 60-year-old female patient with severe obesity (300 kg body weight) was admitted to the hospital due to widespread erysipelas in her left leg, sepsis with streptococcus and acute renal failure. Her medical history included Levaxin-substituted hypothyroidism and psoriasis. After treatment, her renal function was normalized with a serum creatinine value of 34 $\mu\text{mol/L}$, and she was generally feeling better. A lung X-ray was performed and revealed a round, well-defined lesion, measuring 23 mm in diameter, at the level of the right pulmonary hilus with an unclear nature. Contrast enhanced chest and abdominal CTs were requested for further investigation.

Diagnosis

CT images showed a small, well-defined round lesion, 17 mm in diameter and without contrast enhancement in the right middle lobe. Further, there was a segmental atelectasis of the right lower lobe. No signs of bronchial obstruction were evident. With the side finding of a single gallbladder stone, the rest of the scan was unremarkable. The appearance of the lung lesion was regarded as benign.

Comments

The prevalence of obese and morbidly obese patients increases. [1] As image noise increases exponentially with increasing patient diameter due to greater photon attenuation and



1 Axial images (0.5 mm) show a small, well-defined round lesion, without contrast enhancement, in the right middle lobe (arrows). A segmental atelectasis is seen in the right lower lobe (dotted arrows).

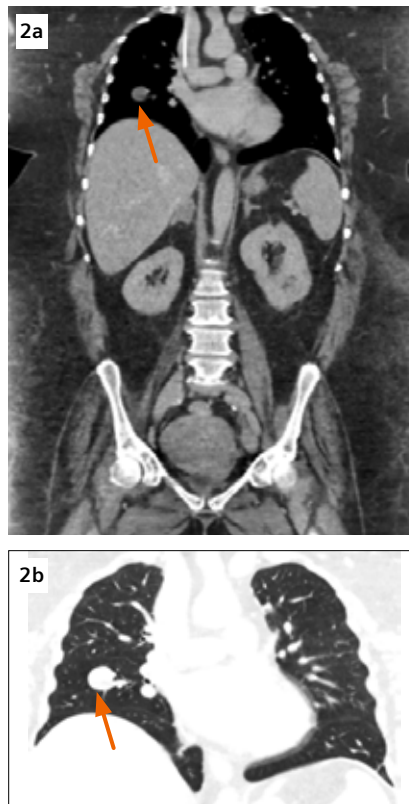
scattering, anatomical conspicuity in pertinent pathologic conditions is correspondingly decreased. This causes difficulties in image interpretation and may lead to repeated radiological or further clinical examinations, resulting in higher cumulative radiation dose and increased costs. If only considering the statistical noise of X-rays, the dose needs to be quadrupled to halve the image noise. The situation is even worse with the presence of substantial electronic noise. Therefore, image noise reduction comes at the cost of increased radiation dose which requires higher power output of the X-ray tube. The classical way of maximizing X-ray

flux and tube output is lowering the pitch and increasing the rotation time; these measures, however, slow down the scan speed and increase breath-hold time with inherently increased presence of motion artifacts. Hence, despite all the advances made in conventional detector CT in recent years, obese patients are still a difficult target group for CT.

This case was performed on a NAEOTOM Alpha®, a newly developed dual source CT scanner with photon-counting detectors (Quanta-Max®), providing energy-resolved CT data without electronic noise. [2] Electronic noise is eliminated by setting up a predefined digital threshold

Examination Protocol

Scanner	NAEOTOM Alpha
Scan area	Trunk
Scan mode	QuantumPlus
Scan length	719 mm
Scan direction	Cranio-caudal
Scan time	10 s
Tube voltage	120 kV
Effective mAs	262 mAs
Dose modulation	CARE Dose4D
CTDI _{vol}	20.6 mGy
DLP	1,540 mGy*cm
Rotation time	0.5 s
Pitch	0.6
Slice collimation	144 x 0.4 mm
Slice width	0.8 mm
Reconstruction increment	0.5 mm
Reconstruction kernel	Qr40
Contrast	350 mg/mL
Volume	113 mL + 30 mL saline
Flow rate	3.8 mL/s
Start delay	70 s



2 Coronal MPR images (Figs. 2a & 2b, 0.5 mm) show a small, well-defined round lesion, without enhancement, in the right middle lobe (arrows). A centimeter-sized round gallstone with a hyperdense ring is seen in an axial image (Fig. 2c, dotted arrow). A cVRT image (Fig. 2d) reconstructed with 0.5 mm slices show both the lung lesion (arrow) and the gallstone (dotted arrow) in three dimensions.

for counting X-ray photons far above the electronic noise floor, leading to less image noise and, potentially, to the reduction of radiation dose. As electronic noise is dominant at low X-ray flux at the detector, such as in the case of a low dose or bariatric CT scan, its absence has a particular impact on the improvement of the image quality. Another important advancement is the higher contrast-to-noise ratio (CNR) in iodine contrast enhanced CT scans, due to the absence of down-weighting of lower energy X-ray photons. In the image reconstruction process, a model based iterative reconstruction approach – Quantum Iterative Reconstruction (QIR) – is applied

for further image noise reduction. All of these improvements contribute to the reduction of image noise as well as radiation dose. For example – even slices as thin as 0.5 mm can be used for three-dimensional demonstration with great image details using cinematic volume rendering technique (cVRT). As presented in this case, although the patient weighs 300 kg, the CT scan required only 314 mA – less than one-third of the maximum power of a single X-ray tube (1,000 mA at 120 kV) – achieving optimal image quality that helped the physicians make a confident diagnosis. ●

References

- [1] D. M. Fursevich, et al. Bariatric CT Imaging: Challenges and Solutions. *RadioGraphics* 2016; 36:0000–0000.
- [2] Thomas Flohr, et al. Photon-counting CT review. *Physica Medica* 79 (2020) 126–136.

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Small bowel infarction secondary to an acquired diaphragmatic hernia

Nicholas H. Shaheen, MD¹; Maxwell Stroebel, MD¹; Cynthia Welsh, MD²; Barry Gibney, DO³; Andrew D. Hardie, MD¹

¹ Department of Radiology and Radiological Sciences, The Medical University of South Carolina, Charleston, SC, USA

² Department of Pathology, The Medical University of South Carolina, Charleston, SC, USA

³ Department of Surgery, The Medical University of South Carolina, Charleston, SC, USA

History

A 75-year-old male patient, with a history of esophagectomy 10 years ago, presented to the emergency department with an acute onset of epigastric pain radiating to the left upper quadrant, chest pain, obstipation and numerous episodes of vomiting. On physical examination, the patient was diaphoretic and tachycardic, showing guarding in the upper abdomen. Laboratory results revealed a lactate level of 3.0 mmol/L, an estimated GFR of > 60 and a WBC of 11. A CT examination of the abdomen and pelvis with contrast was immediately performed for evaluation.

Diagnosis

CT images revealed multiple dilated loops of small bowel herniating into the thoracic cavity through a defect in the left hemidiaphragm. A thin rim of hyperdensity within the wall of the herniated bowel loops was seen in the images reconstructed conventionally, indeterminate of mucosal enhancement (suggesting no ischemia) or hemorrhage within the submucosa (suggestive of infarction). In the assessment of spectral imaging data, a complete lack of enhancement within the herniated loops of bowel was shown in the iodine maps, compatible with infarction.

The hyperdensity in the bowel wall was present in the virtual non-contrast (VNC) images, suggestive of hemorrhage in the submucosa. With this

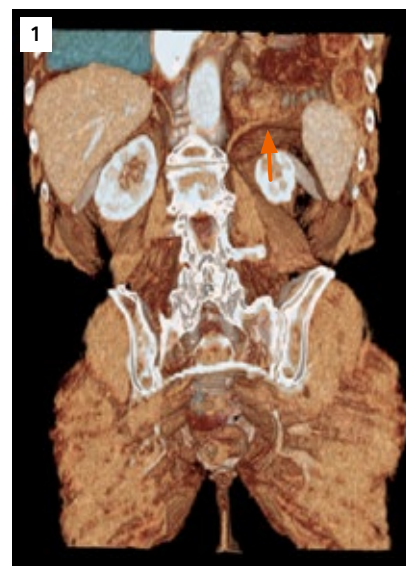
added spectral information, a diagnosis of small bowel infarction was made, and the patient was taken rapidly to surgery for small bowel resection. Pathological evaluation on the resected bowel confirmed complete bowel necrosis with hemorrhagic blood products throughout all bowel layers and sloughing of the mucosa. The patient recovered with good outcome.

Comments

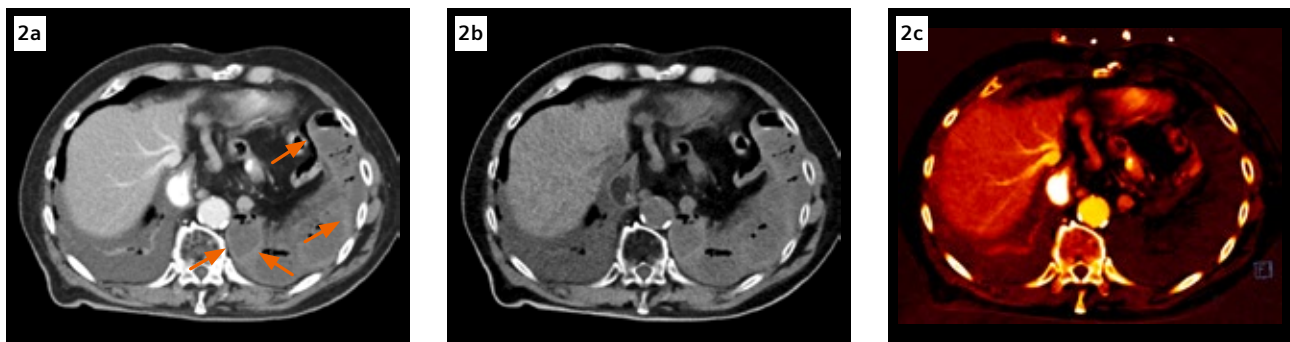
Bowel infarction refers to vascular compromise of portions of the bowel. It can occur secondarily to an acquired diaphragmatic hernia in patients with prior surgery due to altered anatomy, such as this case. The initial clinical presentations including physical exam and laboratory abnormalities are usually nonspecific. However, the progress from an initial necrosis of the bowel wall to a final sepsis and multiorgan failure can go rapidly. Treatment is often surgical and imaging is relied upon for rapid diagnosis. In recent years, CT has largely replaced conventional angiography due to rapid access and accuracy. On CT imaging, ischemic segments of bowel are often found to have a different density and enhancement compared to non-ischemic segments. However, the subtlety of positive image findings may go underappreciated and can lead to unnecessary delay or even misdiagnosis. In this case, the thin

rim of hyperdensity demonstrated in the bowel wall could have been interpreted as normal mucosal enhancement in viable bowel. However, its presence in the VNC images and absence in the iodine maps characterize an infarction. The added spectral information improves reader confidence, and then, taking into account the clinical and laboratory findings, a rapid diagnosis can be made which is essential for the patient to receive prompt treatment.

The CT scan was performed with NAEOTOM Alpha®, a newly developed CT scanner with



1 A coronal view of a VRT image shows herniated loops of small bowel (arrow) into the left thoracic cavity.



2 A contrast enhanced axial image (Fig. 2a) shows a thin rim of hyperdensity within the wall of the herniated bowel loops (arrows), which are also seen in the VNC image (Fig. 2b), but not seen in the iodine map (Fig. 2c), suggesting submucosal hemorrhage, compatible with infarction.

photon-counting detectors. It provides energy-resolved CT data with a high spatial resolution, without electronic noise. [1]

The availability of spectral imaging data in routine scans is one of the major improvements in workflow. Conventional CT image reading can be freely switched to spectral image

reading with just one mouse click, making the assessment of diagnostic information more efficient and fast. As presented in this case, spectral CT may overcome the traditional shortcomings of conventional CT in detecting bowel infarction by adding iodine-sensitive information, enabling the differentiation of hemorrhage from true contrast-material

uptake, i.e., blood perfusion, with distinctive image findings. ●

Reference

- [1] Thomas Flohr, Martin Petersilka, Andre Henning, Stefan Ulzheimer, Jiří Ferda, Bernhard Schmidt. Photon-counting CT review. Physica Medica 79 (2020) 126–136.

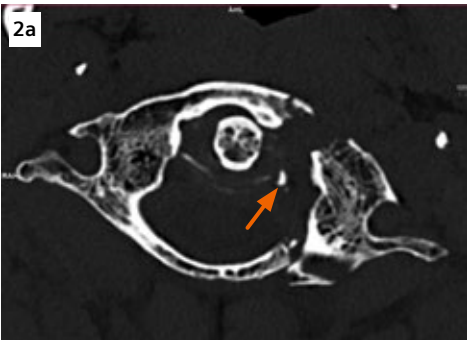
Examination Protocol

Scanner	NAEOTOM Alpha
Scan area	Abdomen/Pelvis
Scan mode	QuantumPlus
Scan length	426 mm
Scan direction	Cranio-caudal
Scan time	7 s
Tube voltage	120 kV
Effective mAs	161 mAs
Dose modulation	CARE Dose4D
CTDI _{vol}	12.6 mGy
DLP	584 mGy*cm
Rotation time	0.5 s
Pitch	0.8
Slice collimation	144 x 0.4 mm
Slice width	3 mm
Reconstruction increment	3 mm
Reconstruction kernel	Br36f
Spectral reconstruction	VNC, iodine map

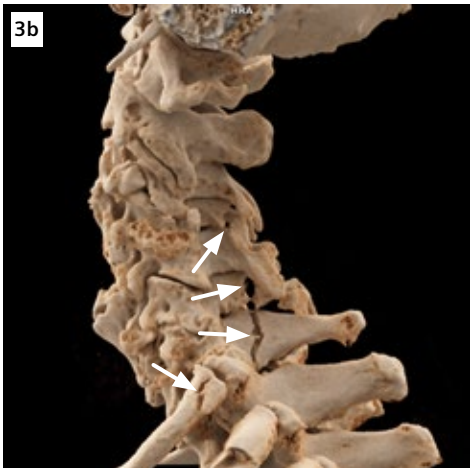
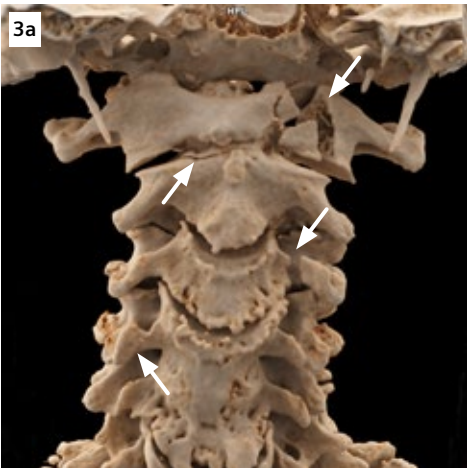
Contrast	350 mg/mL
Volume	94 mL + 39 mL saline
Flow rate	3 mL/s
Start delay	Bolus tracking triggered at 100 HU in the abdominal aorta + 5 s

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The products/features (mentioned herein) are not commercially available in all countries. Their future availability cannot be guaranteed.



2 An axial image (Fig. 2a) and a cVRT image (Fig. 2b) show dislocated fractures of the anterior and posterior arches of C1 and a left massa lateralis avulsion fracture (arrow), with the dens axis dislocated to the left.



3 cVRT images show fractures (arrows) of the C1, C2 dens, foramina transversaria of the C3 and the C4, spinous processes of the C4 and C6, bilateral arcs of the C7 and the head of the first rib on the left.

Examination Protocol

Scanner	NAEOTOM Alpha.Prime	
Scan area	Cervical spine	CTDI _{vol}
Scan mode	Quantumplus	16.5 mGy
Scan length	182.6 mm	DLP
Scan direction	Cranio-caudal	351 mGy*cm
Scan time	2 s	Rotation time
Tube voltage	140 kV	0.5 s
Effective mAs	145 mAs	Pitch
IQ level	195	0.8
Dose modulation	CARE Dose4D	Slice collimation
		144 × 0.4 mm
		Slice width
		0.4 mm
		Reconstruction increment
		0.2 mm
		Reconstruction kernel
		Br60

Metastatic pulmonary adenocarcinoma – complicated by PE?

Prof. Martine Rémy-Jardin, MD¹, Ph.D.; Prof. Jacques Rémy, MD²

¹ Department of Thoracic Imaging, University Centre of Lille, France

² Department of Radiology, Hospital Center of Valenciennes, France

History

A 51-year-old male patient, suffering from pulmonary adenocarcinoma with lymphangitic carcinomatosis, bone and neuro metastases, had undergone chemotherapy as well as immunotherapy. A contrast chest and abdomen CT examination was requested for a follow-up evaluation of treatment response.

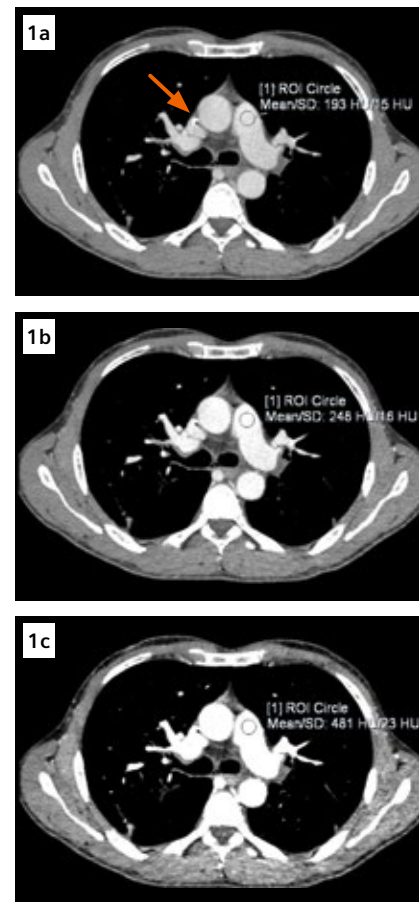
Diagnosis

Virtual monoenergetic CT images, displayed at 60 keV, revealed a partial regression of several nodules and areas of consolidation, also of the lymphangitic carcinomatosis. The hilar and mediastinal adenopathy had decreased in size. The evolution of the bone metastases in the sternum and in the 7th left-sided rib was also seen. The azygos and hemiazygos veins were dilated. A slight blunting of the right costophrenic angle was noticed, indicating a small, newly formed pleural effusion. A thickening of the bilateral adrenal glands and of two small hypodense lesions in the liver were visualized, suspicious of metastases. For the evaluation of the pulmonary arteries (PA), image display was switched from 60 keV to 40 keV. This increased the attenuation in the main PA (MPA) from 248 HU to 481 HU which was sufficient for the visualization of endo- and perivascular abnormalities. There were no signs of incidental pulmonary embolism (PE) seen, and the lung perfused blood volume (Lung PBV*) images showed no perfusion defect.

Based upon the CT findings, a satisfactory response to the initiated treatment was anticipated, leading to the upholding of the proposed immuno-chemotherapy.

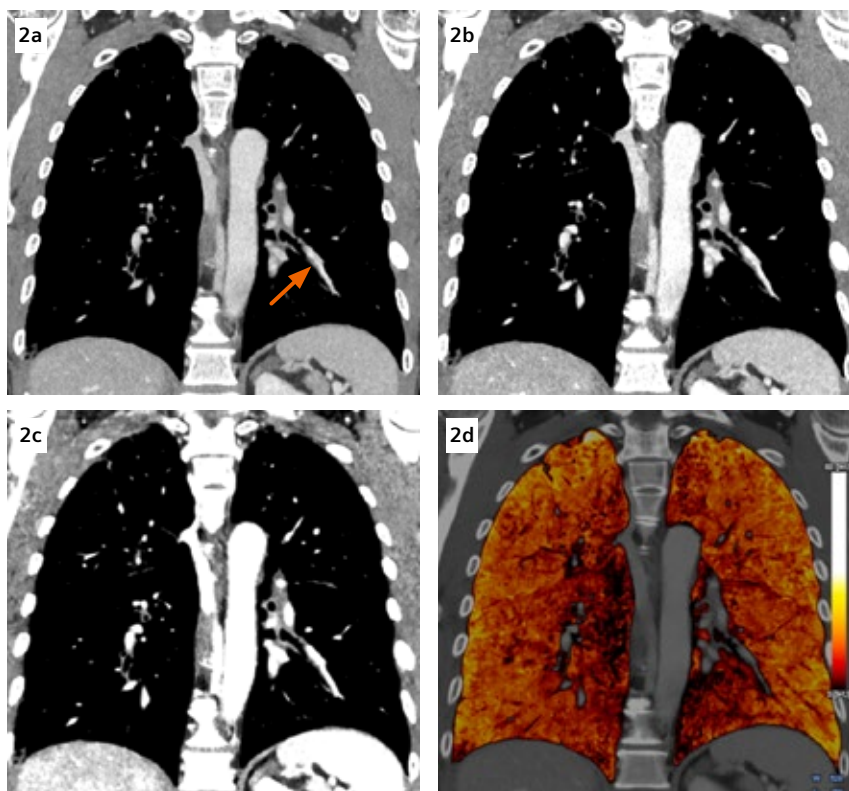
Comments

Non-small cell lung cancer (NSCLC) is the most common type, representing 84% of all lung cancers. Among its various histotypes, adenocarcinomas are most predominant, accounting for approximately 40%. [1] Lung cancer staging and follow-up evaluation on treatment response are commonly performed with a contrast-enhanced CT. An optimal scan protocol has been broadly investigated and recent literature has suggested that imaging during the venous phase can aid in nodal, pleural, and parenchymal assessment. [1, 2] At this phase, tumoral structures, e.g., necrotic areas, as well as lesions at the level of the pleura and pericardium, are better enhanced and visualized. The contrast material in the superior vena cava (SVC) and brachiocephalic veins is diluted due to recirculation, and no longer causes streak artifacts. This improves visualization and characterization of the lymph nodes. However, a potential drawback of the venous-phase CT is the potential reduction in the identification of incidental PE, which is not an uncommon finding in this patient demographic – these patients are at increased risk of thromboembolic disease, and detection would allow for appropriate



1 Axial images displayed at 70 keV (Fig. 1a), 60 keV (Fig. 1b) and 40 keV (Fig. 1c) show a difference in the attenuation of the MPA (193 HU, 248 HU and 481 HU). The contrast material in the SVC is homogeneous and causes no streak artifacts. A central venous catheter (arrow) is also seen.

treatment. [2] With the introduction of Dual Energy CT imaging, studies have been explored and shown that virtual monoenergetic images



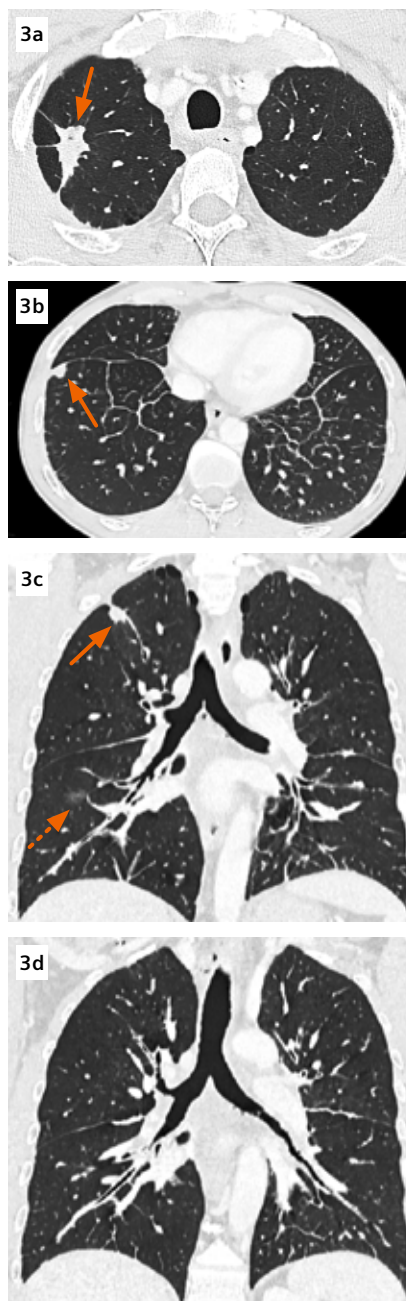
2 A coronal image displayed at 70 keV (Fig. 2a) shows an insufficient and slightly heterogeneous attenuation in the posterior basal segmental PA (arrow). The attenuation is increased in the image displayed at 60 keV (Fig. 2b) and is clearly restored in the image displayed at 40 keV (Fig. 2c), confirming an absence of PE. A Lung PBV image (Fig. 2d) shows a homogeneous iodine distribution in the lungs without perfusion defect. A slight blunting of the right costophrenic angle is seen, indicating a small pleural effusion. The azygos and hemiazygos veins are dilated.

displayed at lower keV levels can, increase iodine attenuation and improve diagnostic image quality for detecting PE as an incidental finding in portal-venous phase CT scans. [3]

This case is performed on NAEOTOM Alpha®, a newly developed Dual Source CT scanner with photon-counting detectors (QuantaMax®), providing energy-resolved CT data with inherent spectral information and improved tissue contrasts, without electronic noise. [4] The spectral data is available in all routine scans allowing for an easy switch of image display at different monoenergetic keV settings. This is especially helpful in cases of sub-optimal contrast attenuation – virtual monoenergetic images can be displayed at lower keV settings (low-energy) to improve contrast enhancement. To illustrate, images that were traditionally displayed at 70 keV (equivalent to a standard 120 kV acquisition), are now routinely displayed at 60 keV, as the standard energy level for images acquired during the venous phase,

to obtain an acceptable compromise for contrast-enhanced soft tissue structures as well as vasculatures. When necessary, images can be displayed at an even lower energy level, e.g., 40 keV, to further increase the iodine enhancement in the PAs for a more confident PE evaluation. The spectral data can also be used to create iodine maps (Lung PBV), resulting in a simultaneous assessment of the pulmonary vasculature as well as the analysis of the parenchymal iodine distribution. The combination of the absence of electronic noise and the missing down-weighting of the lower energy X-ray photons increases the iodine contrast-to-noise ratio (CNR) to an optimal extent, improving the image quality at low-energy display for routine diagnosis, as well as

3 Axial images (Figs. 3a & 3b) and coronal MPR images (Figs. 3c & 3d) show lung nodules (arrows) in the right upper and lower lobes. A small area of consolidation (dotted arrow) is also seen in the right lower lobe. Both central and peripheral lymphatic carcinomatosis are visualized.



- 4** A coronal and an axial view show a bone metastasis in the sternum (Figs. 4a & 4b, arrows). A rib cage unfolding image (Fig. 4c) shows a metastatic lesion in the 7th left-sided rib (dotted arrow).

prompting a potential reduction of the radiation dose and the amount of contrast agent needed.

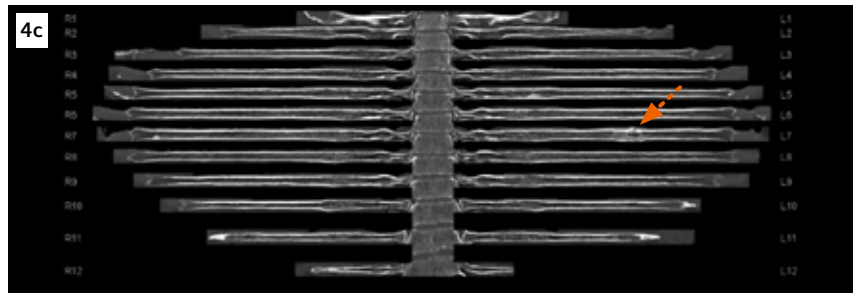
As shown in this case, the availability of spectral CT data provided by photon-counting CT plays an important role in clinical routine. The easy switching between energy levels, for image display, enables the physicians to make a comprehensive evaluation of treatment response and to rule out incidental PE, using just a single acquisition during the venous phase. ●

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- 5** Axial images show a thickening of bilateral adrenal glands (Fig. 5a, arrows) and two small hypodense lesions in the liver (Figs. 5b & 5c, dotted arrows), suspicious of metastases.

* 510k pending.

Examination Protocol

Scanner	NAEOTOM Alpha
Scan area	Chest/Abdomen
Scan mode	QuantumPlus
Scan length	487 mm
Scan direction	Cranio-caudal
Scan time	1.4 s
Tube voltage	120 kV
Effective mAs	68 mAs
Dose modulation	CARE Dose4D
CTDI _{vol}	5.3 mGy
DLP	282 mGy*cm
Rotation time	0.25 s
Pitch	1.5
Slice collimation	144 x 0.4 mm
Slice width	1.0 mm
Reconstruction increment	1.0 mm
Reconstruction kernel	Br36/BI60
Spectral reconstruction	Monoenergetic Plus; Lung PBV

Contrast	400 mg/mL
Volume	60 mL + 40 mL saline
Flow rate	3 mL/s
Start delay	70 s

Pancreatic cystic neoplasm – malignant or benign?

Bettina K. Budai¹, Márton Benke², Ákos Szücs², Pál N. Kaposi¹, Attila Szijártó²,
Pál Maurovich-Horvat¹, Ibolyka Dudás¹

¹ Department of Radiology, Medical Imaging Centre, Semmelweis University, Budapest, Hungary

² Department of Surgery, Transplantation and Gastroenterology, Semmelweis University, Budapest, Hungary

History

A 76-year-old female patient, had had abdominal CT 6 years ago with the finding of an incidental pancreatic cystic lesion. The lesion had recently shown a slight increase in size and therefore the patient was referred to our hospital for an endoscopic ultrasound (EUS) examination.

EUS demonstrated a multi-lobulated, septated cystic lesion, with a maximum diameter of 28 mm, located between the head and the body of the pancreas. The pancreatic duct showed neither dilatation, nor visible communication with the lesion. Analysis of the cyst fluid revealed an elevated CEA (1847.0 ng/mL), low glucose content (0.9 mmol/L) and high amylase level (1240 U/L). These results are more characteristic of an intraductal papillary mucinous neoplasm (IPMN), which – depending on its subtype and location – transformation presents a precursor lesion of invasive pancreatic carcinoma. However, in rare cases, a serous cystic neoplasm (SCN), which is considered as a benign entity, can also show high CEA and amylase levels. The cytological analysis was inconclusive, raising the possibility of a pseudocyst, while malignancy could not be confirmed. Further assessment was requested by contrast-enhanced CT and this examination was conducted on the newly installed photon-counting CT (PCCT) in our hospital.

Diagnosis

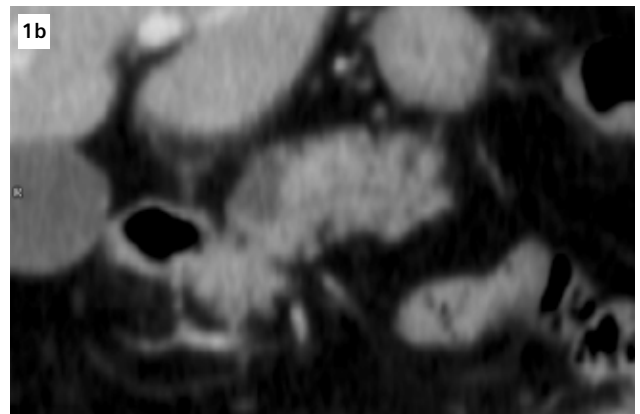
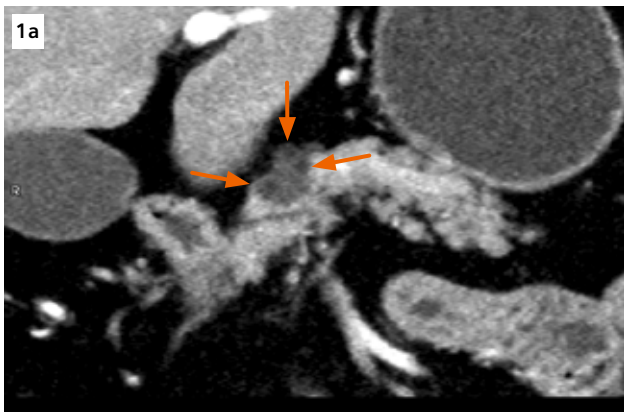
Virtual-monoenergetic images displayed at 65 keV revealed a lobulated, hypodense lesion located between the pancreatic head and body, measuring 19 × 21 × 17 mm. Multiple microcystic internal structures, with a maximum diameter of less than 4.5 mm each, as well as enhancement of the internal septa in the portal-venous contrast phase, were visualized. The pancreatic duct was not dilated and showed no signs of lesion invasion. These CT findings suggested a diagnosis of a typical SCN without any worrisome features. Subsequently, the multi-disciplinary team agreed with the patient on close follow-up examinations without the immediate need for surgical intervention.

Comments

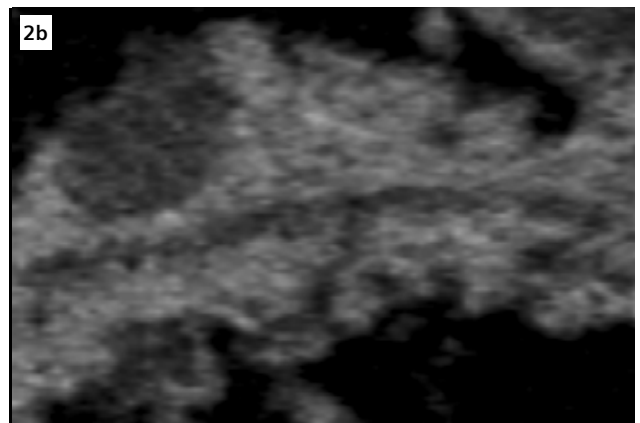
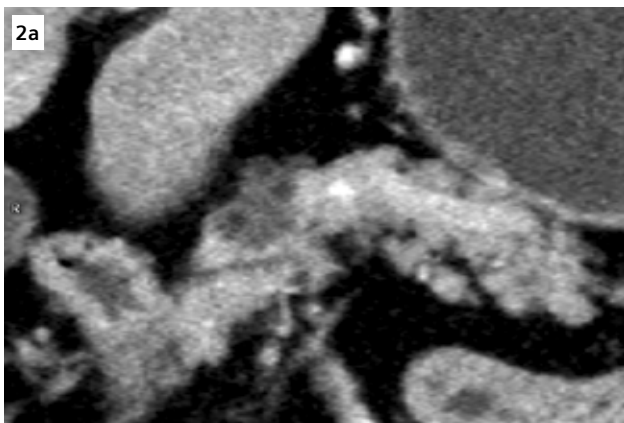
Pancreatic cystic neoplasm (PCN) is a collective term for pancreatic cystic tumors which have markedly different biological behavior. Main-duct-IPMN, for example, is considered a precursor lesion with a high risk of malignancy, while a SCN is classified as a benign entity with an extremely low risk of turning into invasive cancer. In the management of patients diagnosed with PCNs, high-end imaging with CT, MRI or EUS plays a central role. The goal is to provide accurate diagnosis in order to avoid unnecessary surgery on the one hand side, and to prevent

delayed diagnosis when a precursor lesion has already progressed into invasive cancer. [1–2] Due to the increased availability and improved image quality, the probability of detecting PCNs has increased. [3–5] However, in some cases, differential diagnosis of PCNs can still be challenging.

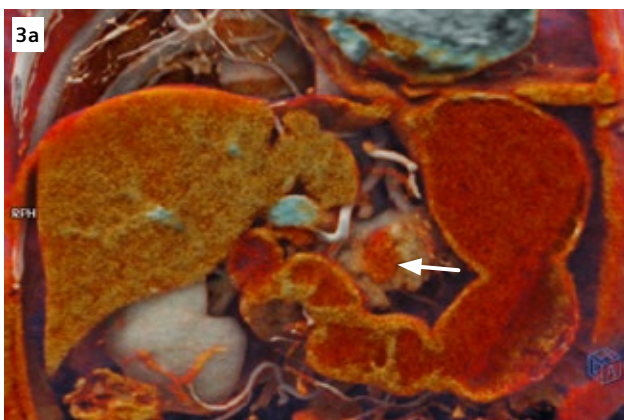
This case is performed on a NAEOTOM Alpha®, a newly developed Dual Source CT scanner with photon-counting detectors (Quanta-Max®), providing energy-resolved CT data with inherent spectral information at improved spatial resolution and tissue contrasts, without electronic noise. [6] The spectral data is available in all routine scans, allowing for an easy switch of image display at different monoenergetic keV settings for an optimal image visualization. The images acquired during the portal and venous phases, which were traditionally displayed at 70 keV (equivalent to a standard 120 kV acquisition), now are routinely displayed at 65 keV, set as the standard energy level for an optimal visualization of the contrast-enhanced soft tissue structures because of the increased iodine contrast compared to 70 keV. The combination of the absence of electronic noise and the missing down-weighting of the lower energy X-ray photons further increases the iodine contrast-to-noise ratio (CNR), improving the image quality at low-energy display for routine diagnosis. Images are routinely



1 A coronal MPR image acquired on PCCT (Fig. 1a, 3 mm) shows a lobulated, hypodense lesion at the junction of the pancreatic head and body. Multiple microcystic internal structures (arrows) are clearly visualized. In a similar coronal view acquired 6 months earlier on a conventional CT (Fig. 1b, 3 mm), these microcysts are not depicted.



2 Two enlarged views show the microcysts (Fig. 2a, arrows), and a clear separation between the lesion and the pancreatic duct, characterizing a typical SCN.



3 Cinematic VRT images show the lesion (Fig. 3a, arrow) and the adjacent structures. An enlarged view (Fig. 3b) shows the microcysts in the lesion and the separation between the lesion and the pancreatic duct in three dimensions.

acquired at 0.4 mm slices and reconstructed with a sharper kernel of Br44, providing increased spatial resolution compared to conventional standard abdominal CT. As shown in this case, owing to the improved CNR and the spatial resolution, the detailed visualization of the microcystic internal structures, the enhancing internal septa in the portal phase and the clear separation between the tumor and the pancreatic duct, help the radiologists make a confident differential diagnosis on PCNs, preventing unnecessary surgical interventions and potential complications for the patient. ●

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- [6] Thomas Flohr, et al. Photon-counting CT review. Physica Medica 79 (2020) 126–136.

Examination Protocol

Scanner	NAEOTOM Alpha
Scan area	Abdomen
Scan mode	QuantumPlus (native/arterial/portal/venous)
Scan length	414 / 209 / 122 / 415 mm
Scan direction	Cranio-caudal
Scan time	4.4 / 2.2 / 1.2 / 4.4 s
Tube voltage	120 kV
Effective mAs	145 / 157 / 115 / 114 mAs
Dose modulation	CARE Dose4D
CTDI _{vol}	11.5 / 12.3 / 9 / 8.9 mGy
DLP	516 / 199 / 141 / 404 mGy*cm
Rotation time	0.5 s
Pitch	0.8
Slice collimation	144 × 0.4 mm
Slice width	0.4, 1.0, 2.0, 3.0 mm
Reconstruction increment	0.4, 0.5, 1.5, 3.0 mm
Reconstruction kernel	Br44, Qr40
Spectral reconstruction	Monoenergetic Plus

Contrast 350 mg/mL

Volume	77 mL + 40 mL saline
Flow rate	3.1 mL/s + 3.2 mL/s
Start delay	Arterial phase: 23 s Portal phase: 45 s Venous phase: 75 s

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Inside an incidental solid renal mass

Jan Baxa, MD, Ph.D.

Department of Imaging Methods, University Hospital Pilsen and
Medical Faculty of Charles University, Pilsen, Czech Republic

History

An 89-year-old male patient, complaining of unspecific abdominal pain and hematuria, came to the hospital for a checkup. Physical examination and laboratory tests suggested a prostatic hyperplasia as the cause of hematuria. For further assessment and to rule out any other potential cause of hematuria, an abdominal contrast CT scan on a dual source photon-counting CT (PCCT), NAEOTOM Alpha®, was performed.

Diagnosis

Standard CT images (Monoenergetic Plus images displayed at 70 keV, corresponding to conventional CT images acquired at 120 kV) showed an incidental renal mass in the right kidney, homogeneously enhanced (75 HU), well marginated with an imperceptible wall, measuring 2.0 x 1.6 cm² in size. The enhancement pattern in the arterial, venous, and delayed phases showed no remarkable differences. In the virtual unenhanced (VNC) images, the mass was slightly hyperdense (49 HU), with no calcifications present. Monoenergetic Plus images displayed at 40 keV revealed a significantly enhanced small lesion (112 HU), dorsally in the mass, invisible in the standard CT images, measuring 0.4 x 0.5 cm² in size. In the iodine maps fused with VNC images, the iodine density was measured to be 0.92 mg/mL for the mass and 1.8 mg/mL for the small lesion. In the 3D visualization, using thin maximum intensity projection (MIP) and cinematic volume rendering techniques (cVRT), a tiny branch of the renal artery supplying the mass was depicted.

CT findings were compatible with a renal neoplasm. However, due to the patient's age and physical condition, no immediate surgery nor further examinations were performed. Medication for the prostatic hyperplasia and surveillance for the renal mass were recommended.

Comments

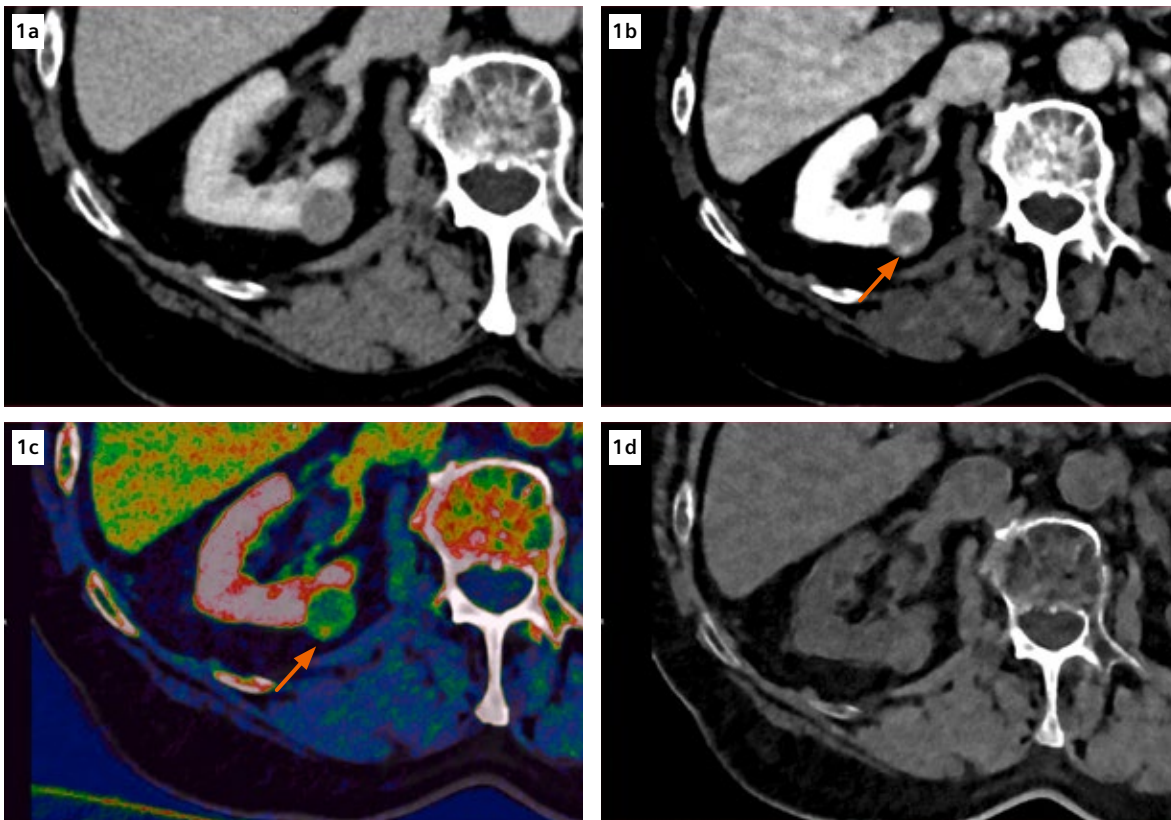
Incidental findings in the kidneys are common and most of these are renal masses. [1] Solid masses are defined as those that contain little or no fluid attenuating (<20 HU) components and usually predominantly consist of enhancing tissue. [2] When hyperdensities are identified in small renal masses, it is of utmost importance to differentiate between a cyst, with only hyperdense content (hemorrhage or proteins), and a tumor with contrast enhancement. In a clinical routine, using conventional CT scanners, additional non-contrast CT or MRI must be performed to confirm or exclude post-contrast enhancement. If an incidental renal mass is visualized in contrast scans, such as this case, the patient needs to be re-scheduled for a non-contrast scan. For a proper diagnosis and subsequent patient management, a small renal mass needs to be completely characterized, which can be challenging and requires optimal iodine contrast-to-noise ratio (CNR).

This case is performed on NAEOTOM Alpha, a newly developed dual source CT scanner with photon-counting detectors (QuantaMax®), providing energy-resolved CT data with inherent spectral information and improved tissue contrasts in routine scans. [3] Owing to the

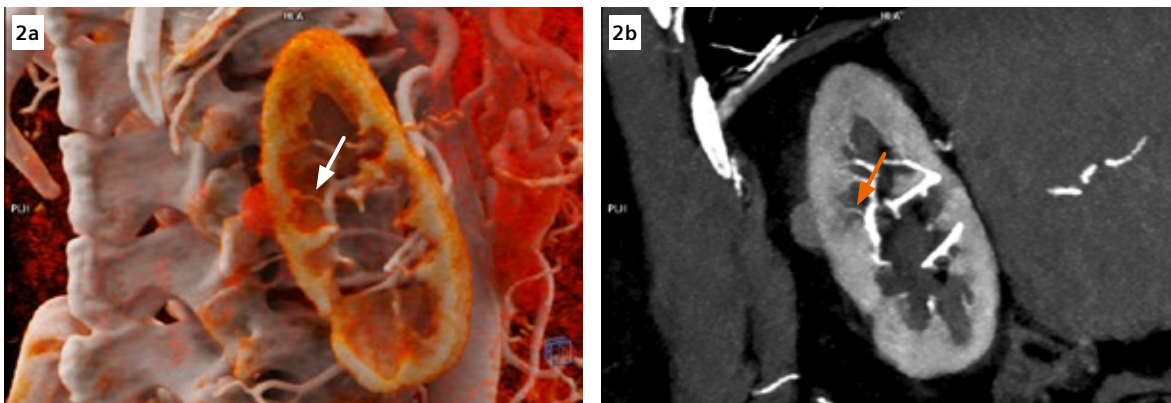
improved iodine CNR, due to the missing down-weighting of the lower energy X-ray photons, the absence of the electronic noise, and the inherent spectral information, the small, enhanced lesion inside the mass, invisible and likely missed in standard CT images, is clearly depicted in the Monoenergetic Plus images displayed at 40 keV, as well as in the iodine maps fused with VNC images.

The VNC images are routinely derived from the contrast scan, avoiding the necessity of having to perform a non-contrast scan or to call the patient back. Furthermore, the improved spatial resolution of PCCT facilitates the characterization of the small enhancing lesion with a diameter of only few millimeters and the tiny branch of the renal artery that supplies it. In the routine workflow, viewing of different image types, such as standard CT image, Monoenergetic Plus images displayed at different keV levels, VNC image, iodine image and iodine/VNC fused image, can be toggled interactively, using Interactive Spectral Imaging (ISI) technique, which greatly facilitates image reading and improves the efficiency of routine diagnosis.

In this case, a conservative approach for the subsequent patient's management is chosen, considering limited life expectancy and possible comorbidities, therefore the nature of the renal mass with the small lesion inside is not pathologically confirmed. However, this case demonstrates the great potential of PCCT in depicting such a small, enhanced lesion as well as a tiny supplying artery, helping the physicians to make a confident diagnosis. ●



1 A standard axial image (Fig. 1a) shows a homogeneously contrast enhanced mass in the right kidney. A Monoenergetic Plus image displayed at 40 keV (Fig. 1b) and an iodine map fused with VNC image (Fig. 1c) reveal a significantly enhanced small lesion dorsally in the mass, which is invisible in the standard image. In a VNC image (Fig. 1d), the mass is slightly hyperdense with no calcifications present.



2 A cvRT image (Fig. 2a) and a thin MIP image (Fig. 2b) show a tiny branch of the renal artery supplying the mass (arrows).

Examination Protocol

Scanner	NAEOTOM Alpha
Scan area	Abdomen
Scan mode	QuantumPlus (Arterial/Venous/delayed)
Scan length	420/334/373 mm
Scan direction	Cr-ca / ca-cr / cr-ca
Scan time	4.5/3.6/3.6 s
Tube voltage	120/120/90 kV
Effective mAs	108/108/112 mAs
Dose modulation	CARE Dose4D
CTDI _{vol}	8.4/8.5/4.0 mGy
DLP	386/367/165 mGy*cm
Rotation time	0.5 s
Pitch	0.8/0.8/0.9
Slice collimation	144 x 0.4 mm
Slice width	0.6/0.4/0.6 mm
Reconstruction increment	0.4/0.2/0.4 mm
Reconstruction kernel	Br40/Qr40/Br40, QIR 3
Spectral reconstruction	Monoenergetic Plus, iodine map, VNC
Contrast	350 mg/mL
Volume	100 mL + 40 mL saline
Flow rate	4 mL/s
Start delay	Arterial phase: Bolus tracking triggered at 100HU in the distal thoracic aorta + 5 s. Venous phase: 35 s after finishing of the arterial phase. Delayed phase: 10 minutes after the finishing of the venous phase.

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Two small non-invasive papillary urothelial carcinomas in the left renal pelvis and ureter

Prof. Jan Baxa, MD, Ph.D.

Department of Imaging Methods, University Hospital Pilsen and
Medical Faculty of Charles University, Pilsen, Czech Republic

History

A 76-year-old male patient, suffering from repeated episodes of renal colic associated with hematuria, had undergone two non-contrast CT scans to detect renal calculi; however, both were negative. Urine cytology analysis, to detect urothelial cancer, also resulted negatively. A contrast enhanced CT scan was requested and performed, in both the venous and late excretory phase, with a photon-counting CT (PCCT), NAEOTOM Alpha®, for further assessment.

Diagnosis

CT images acquired in the venous phase revealed two small lesions, measuring 7 mm × 5 mm in size, in the left ureteropelvic junction and, 8 mm × 7 mm, in the left middle ureter. Both lesions were contrast enhanced. Using spectral reconstructions, the enhancement was clearly improved in the iodine maps and in the Monoenergetic Plus images displayed at 40 keV, compared to standard CT images (displayed at 70 keV, corresponding to images acquired at 120 kV). In the virtual non-contrast (VNC) images, both lesions appeared isodense. The left renal pelvis was dilated. No abnormalities, neither in the right renal pelvis and ureter nor in the bladder, were seen.

Subsequently, a low grade non-invasive papillary urothelial carcinoma

(staging pTa, N0, M0) was histologically confirmed through biopsy and ureteroscopy. The patient underwent laser ablation of the tumors through cystoscopy, without adjuvant therapy recommended.

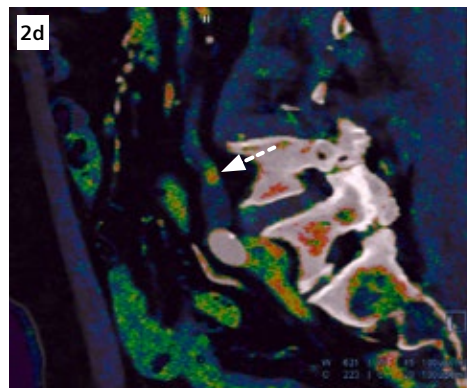
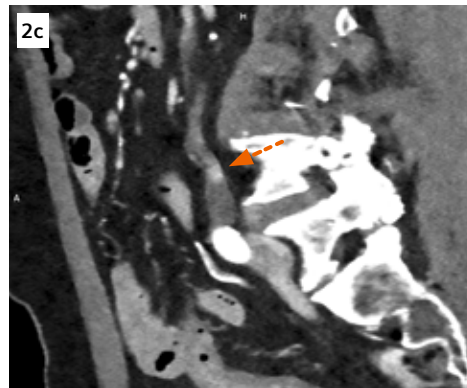
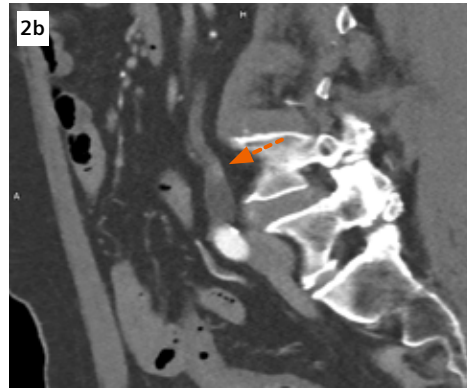
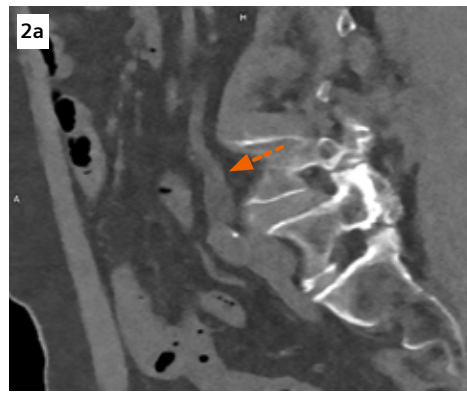
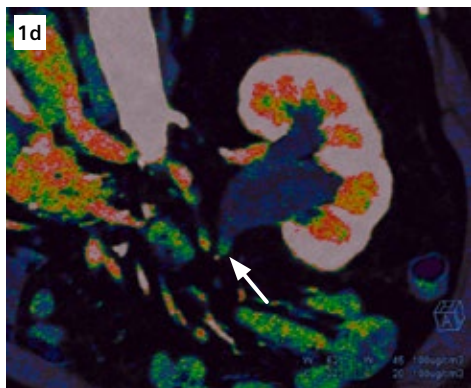
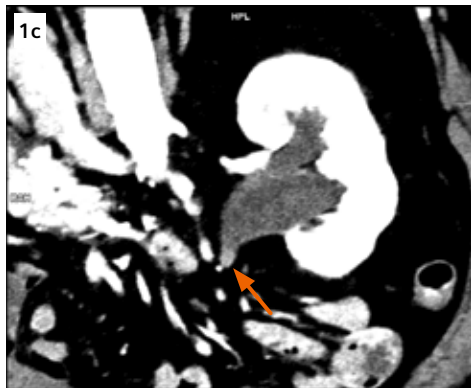
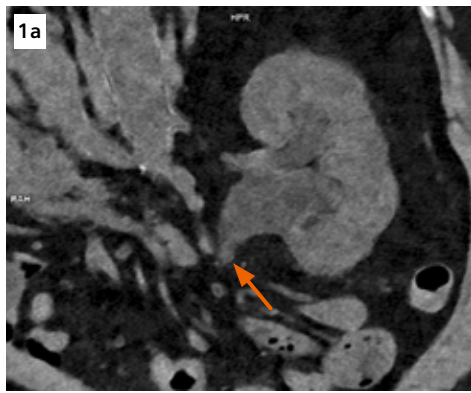
Comments

Urothelial carcinoma, also called transitional cell carcinoma, originates in the urothelial cells. It is the most common cancer of the renal pelvis or ureter, making up about 90% of all upper urinary tract tumors. If the cancer is confined to the urothelium, it is non-invasive and curable in more than 90% of the patients. If it has infiltrated into deeper layers of the urothelial wall, the likelihood of cure is 10–15%. In case it has infiltrated through the urothelial wall or distant metastases have occurred, it is usually incurable with available treatment. The depth of infiltration is a major prognostic factor at the time of diagnosis, therefore, a proper early diagnosis is relevant. In CT imaging, the identification and characterization of small lesions at an early stage require both high spatial resolution and optimal tissue contrasts, and ideally, not at the cost of radiation dose efficiency. This is technically very challenging.

PCCT provides energy-resolved CT data at increased spatial resolution without electronic noise and with improved tissue contrasts. [1] An electric field, instead of physical separation, is applied to define

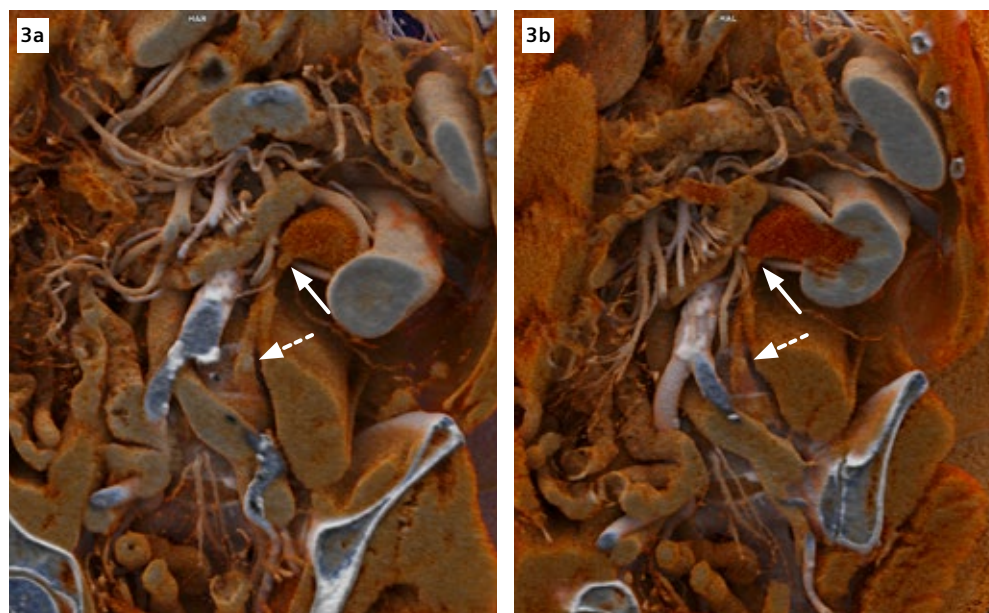
smaller sub-pixels which are read out separately to increase the spatial resolution. This approach also improves the geometrical dose efficiency of the detector. In this case, the entire range of the abdomen and pelvis is acquired with 0.4 mm slices at a radiation dose of only 7.2 mGy. The CNR is optimized due to a combination of missing down-weighting of the lower energy X-ray photons, the absence of the electronic noise and the inherent spectral information. CT data acquired in a contrast scan can then be used for further spectral reconstructions, such as virtual non-contrast (VNC) images, virtual monoenergetic images (Monoenergetic Plus) displayed at different keV levels, iodine maps and iodine/VNC fused images. In fact, reading these different image types in daily practice is quite straightforward, as they can be interactively toggled, using Interactive Spectral Imaging (ISI) technique available with image viewing. As one of the key benefits of PCCT, spectral information is available in any scan. It is highly recommended to utilize this information in image reading for routine diagnosis.

As shown in this case, the identification and characterization of the two small enhancing lesions, only a few millimeters in size, benefit from the advantages provided by PCCT, helping the physicians make a confident diagnosis. ●



1 2

Two small lesions are shown in the left ureteropelvic junction (Fig. 1, arrows) and in the middle ureter (Fig. 2, dotted arrows). The lesions appear isodense in the VNC images (Fig. a), slightly enhanced in standard CT images (Fig. b) and clearly enhanced in the Monoenergetic Plus images displayed at 40 keV (Fig. c) as well as in the iodine/VNC fused images (Fig. d). The left renal pelvis is dilated (Fig. 1).



3 Cinematic VRT images show three dimensional views of the two small lesions in the left ureteropelvic junction (arrows) and in the middle ureter (dotted arrows).

Examination Protocol

Scanner	NAEOTOM Alpha
Scan area	Abdomen/Pelvis
Scan mode	QuantumPlus
Scan length	489 mm
Scan direction	Cranio-caudal
Scan time	5.3 s
Tube voltage	120 kV
Effective mAs	91 mAs
IQ level	135
Dose modulation	CARE Dose4D
CTDI _{vol}	7.2 mGy
DLP	382 mGy*cm
Rotation time	0.5 s
Pitch	0.8
Slice collimation	144 × 0.4 mm

Slice width	0.4 mm
Reconstruction increment	0.2 mm
Reconstruction kernel	Br40 QIR 3
keV level	60 keV
Spectral reconstruction	VNC, Monoenergetic Plus, iodine map

Contrast	370 mg/mL
Volume	1 st bolus (70 mL + 40 mL saline) – 20 s pause – 2 nd bolus (30 mL + 20 mL saline)
Flow rate	4 mL/s
Start delay	Bolus tracking triggered in the 2 nd bolus with 100 HU in the distal descending aorta + 5 s

References

- [1] Thomas Flohr, et al. Photon-counting CT review. *Physica Medica* 79 (2020) 126–136.

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Pancreatic insulinoma in a patient with a history of hypoglycemia

Antonella Del Gaudio, MD; Daniele Marin, MD
Department of Radiology, Duke University, Durham, NC, USA

History

A 63-year-old female patient (BMI 19.57 kg/m²), with a history of hypothyroidism, fatigue, weakness, loss of appetite and hypoglycemia, was referred to the Department of Radiology for evaluation. A calcium stimulation challenge test showed diffuse insulin secretion throughout the pancreas. A pancreatic insulinoma was suspected. However, a previous CT examination performed with an Energy Integrating Detector CT (EID-CT) did not reveal any pancreatic lesion. A contrast CT scan with a dual source photon-counting detector CT (PCD-CT), NAEOTOM Alpha®, was performed for further evaluation.

Diagnosis

Virtual monoenergetic images (VMIs), displayed at 50 KeV, revealed a hypervascular nodular lesion in the pancreatic body in the arterial phase, measuring 1 cm in size. The lesion was also seen in the iodine maps and the VNC/iodine fused images. In the virtual non-contrast (VNC) images, it appeared isodense, and in the standard image reconstructions, it was invident. Subsequently, the lesion was confirmed by a Dotatate PET/CT scan as well as an Endoscopy Ultrasound (EUS) examination. The patient underwent a distal pancreatectomy with splenectomy. The pathology result confirmed the diagnosis of a G1 well-differentiated neuroendocrine tumor with insulin hyperproduction.

Comments

Insulinoma is a type of functional pancreatic neuroendocrine tumor (pNET) originating from the endocrine cells of the pancreas. It is often confined to the pancreatic gland and characterized by hypersecretion of insulin causing hypoglycemia. Surgery is the only potentially curative therapeutic strategy in localized disease, and generally, small pancreatic insulinomas have a very good prognosis. [1] The challenge, though, lies in the identification of the primary tumor due to its small size.

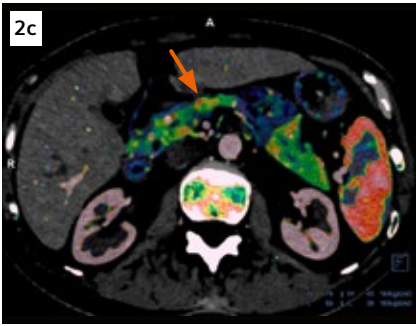
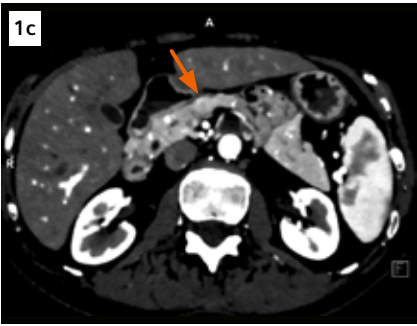
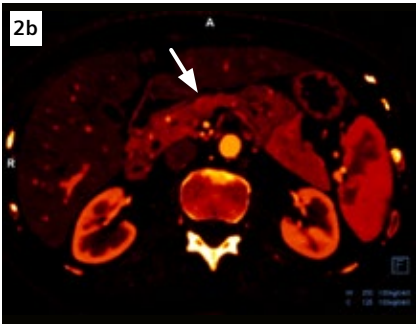
PCD-CT provides energy-resolved CT data with increased spatial resolution and inherent spectral information. [2] Tissue contrast is optimized by a combination of missing down-weighting of the lower energy X-ray photons and absence of electronic noise. In this case, an ultra-high resolution (UHR) mode was performed, using a fine collimation of 120 x 0.2 mm, in the arterial phase. This mode uses smaller sub-pixels, defined by a strong electric field without further mechanical separation, which are read out separately to increase the spatial resolution. VMIs are then reconstructed at 0.4 mm and displayed at 50 keV to enhance the contrast. The small insulinoma, initially missed by EID-CT, is clearly visualized owing to the combination of increased spatial resolution and tissue contrast. This facilitates an appropriate surgical planning and thereby an optimal patient outcome. ●

References

- [1] Marc Díez, Alexandre Teulé, Ramon Salazar. Gastroenteropancreatic neuroendocrine tumors: diagnosis and treatment. *Ann Gastroenterol.* 2013; 26(1): 29–36.
- [2] Thomas Flohr, et al. Photon-counting CT review. *Physica Medica* 79 (2020) 126–136.

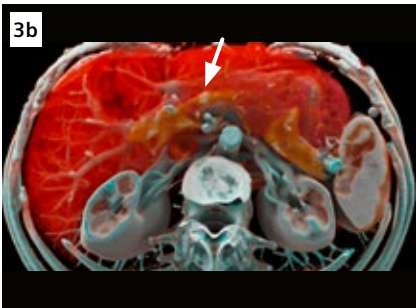
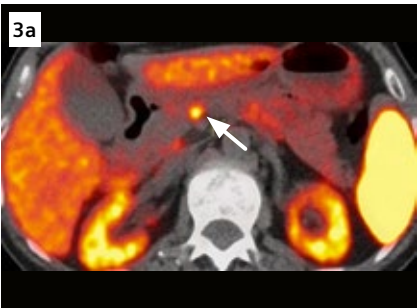
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1 An axial VMI, acquired in the arterial phase and displayed at 50 keV, show a small hypervascular nodular lesion in the pancreatic body (Fig. 1c, arrow). The lesion is neither shown in a previous EID-CT image (Fig. 1a) nor evident in a standard image reconstruction (Fig. 1b).

2 An iodine map (Fig. 2b) and a VNC/iodine fused image (Fig. 2c) show a contrast enhanced lesion (arrows) in the pancreatic body. The lesion appears isodense in the VNC image (Fig. 2a)



3 A Dotatate PET/CT image shows a small lesion spotted in the pancreatic body (Fig. 3a, arrow). The lesion is clearly seen in a cinematic VRT image created with UHR images as well (Fig. 3b, arrow).

Examination Protocol

Scanner	NAEOTOM Alpha
Scan area	Abdomen / Abdomen-Pelvis
Scan mode	UHR / Quantum-plus (Arterial / venous phases)
Scan length	249.6 / 423.2 mm
Scan direction	Cranio-caudal
Scan time	5.2 / 4.5 s
Tube voltage	140 kV
Effective mAs	156 / 67 mAs
IQ level	280 / 227
Dose modulation	CARE Dose4D
CTDI _{vol}	18.2 / 7.7 mGy
DLP	487 / 352 mGy*cm
Rotation time	0.5 s
Pitch	1.0 / 0.8
Slice collimation	120 × 0.2 / 144 × 0.4 mm
Slice width	0.2, 0.4 / 0.4 mm
Reconstruction increment	0.2 / 0.4 mm
Reconstruction kernel	Br48, Qr40 / Qr40
keV level	50 keV
Spectral reconstruction	Monoenergetic Plus
Contrast	300 mg/mL
Volume	150 mL
Flow rate	4 mL/s
Start delay	1, Arterial phase: bolus tracking triggered at 150 HU in the descending aorta + 17 s 2, Venous phase: 45 s

A well-differentiated, invasive ductal adenocarcinoma in the pancreatic body

Prof. Jan Baxa, MD, PhD

Department of imaging methods, University Hospital Pilsen and
Medical Faculty of Charles University, Pilsen, Czech Republic

History

A 69-year-old male patient, complaining of abdominal pain and discomfort slowly progressing over the past three months, came to the hospital for a check-up. The patient had a new onset of diabetes mellitus. Ultrasound examination revealed a partially solid and partially cystic mass in the pancreatic body, with suspicious invasion into the gastric wall. A contrast-enhanced CT examination was requested and performed with a dual source, photon-counting detector (PCD) CT, NAEOTOM Alpha®, for further local assessment of the pancreatic mass and disease staging.

Diagnosis

CT images showed a well-defined, exophytic mass in the pancreatic body, causing obstruction with upstream dilatation of the main pancreatic duct. The mass, measuring 4.5 cm x 4.6 cm in size, was hypo-attenuating in the virtual non-contrast (VNC) images, and hypovascular in the arterial and portal-venous contrast phases. Virtual mono-energetic images (VMI) displayed at 40 keV showed an increased contrast enhancement, resulting in an improved visualization of a brighter rim of the tumor adjacent to the gastric wall and the fatty tissue between the tumor and the gastric wall. This indicated the likelihood of a desmoplastic reaction rather than an invasion of the tumor. There

was no evidence of vascular encasement. The celiac artery (CA), the superior mesenteric artery (SMA) and the portal vein did not show CT-signs of invasion. No metastases of the liver or local lymph nodes were seen, neither on CT, nor on liver MRI. A subsequent endoscopic ultrasound examination revealed no tumor invasion into the gastric wall. After completed staging, imaging findings suggested a resectable pancreatic ductal adenocarcinoma (PDAC), stage IIa, T3 N0 M0.

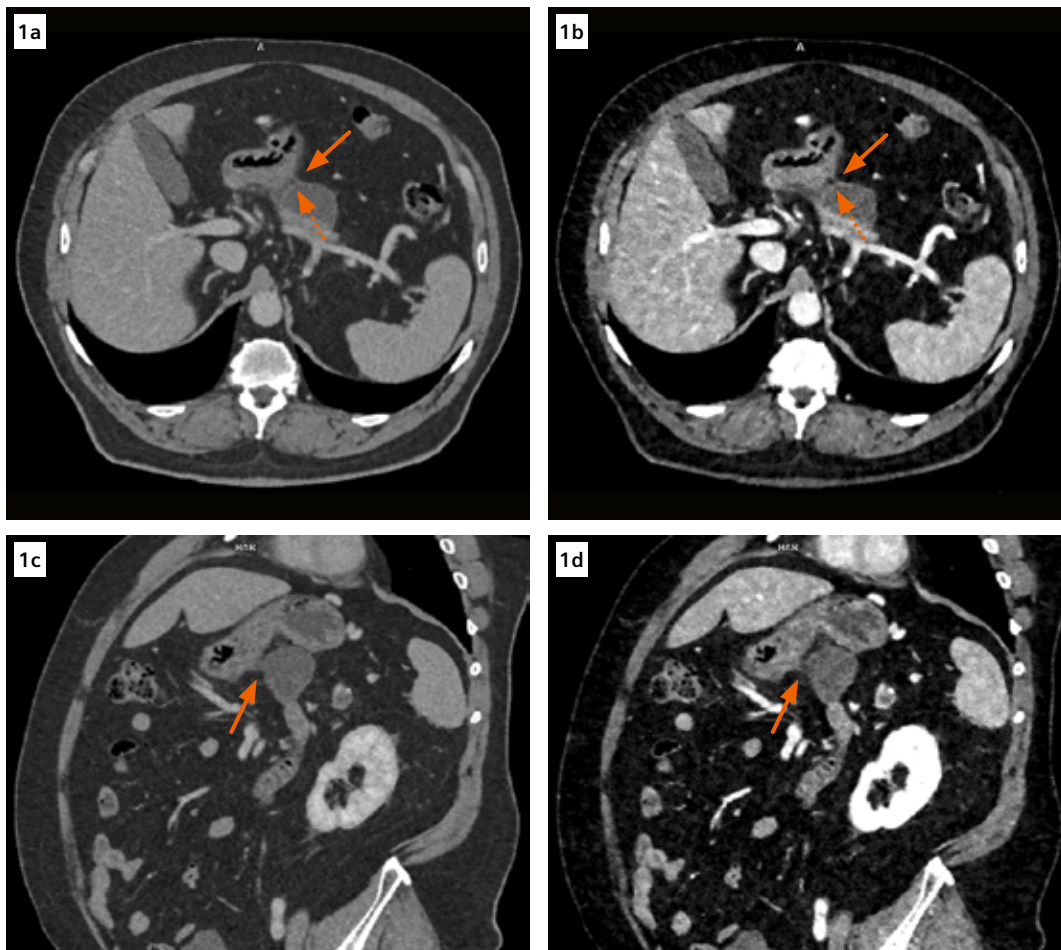
The patient underwent surgical resection of the tumor. CT findings were intra-operatively confirmed. A post-operative pathological evaluation confirmed a complete tumor resection with free resection margins (R0). A histological analysis revealed a well-differentiated invasive ductal adenocarcinoma. The patient continued with neoadjuvant chemotherapy and has been, to-date, free from recurrence.

Comments

PDAC is the most common pancreatic malignancy, accounting for more than 85% of pancreatic tumors, with poor prognosis and rising incidence. In early stages, it is usually asymptomatic. Approximately 80% of the cases are diagnosed at an advanced stage (T3 or T4). [1] The only potential curative treatment is

a complete surgical resection. [2] Therefore, a careful pre-operative assessment is crucial for an upfront patient stratification. CT is considered the modality of choice for tumor staging. Pre-operative evaluations on vascular variations and stenoses are also important for the surgeons, allowing for a proper surgical planning, avoiding intra-operative vascular injuries and post-operative complications.

PCD-CT provides energy-resolved CT data with increased spatial resolution and inherent spectral information. [3] VMI can be reconstructed and displayed at different keV levels in routine scans. The tissue contrast is increased in VMI displayed at 40 keV compared to VMI displayed at 70 keV (equivalent to a standard image acquired at 120 kV) and is further optimized by a combination of missing down-weighting of the lower energy X-ray photons and absence of electronic noise. As shown in this case, the combination of increased spatial resolution and tissue contrast is beneficial for the visualization of a thin rim of the tumor and the fatty tissue between the tumor and the gastric wall. This helps enhancing physician's confidence in differentiating desmoplastic reaction from tumor invasion, critical for assessment on tumor resectability, and subsequently, patient's outcome. ●



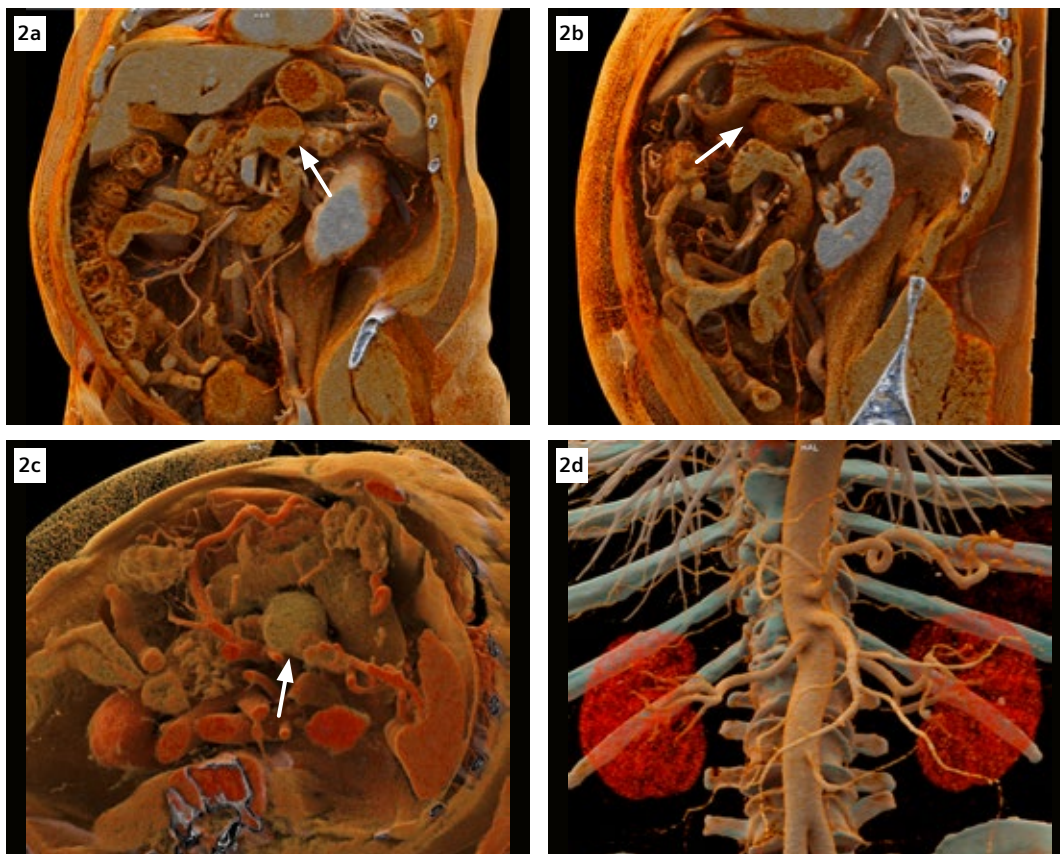
1 Axial images (Fig. 1a & 1b) and oblique MPR images (Fig. 1c & 1d) show a well-defined, hypovascular mass in the pancreatic body. Compared to VMI images displayed at 70 keV (Fig. 1a & 1c), the VMI images displayed at 40 keV (Fig. 1b & 1d) show an increased contrast enhancement, resulting in an improved visualization of a brighter rim of the tumor (Fig. 1a & 1b, dotted arrows) adjacent to the gastric wall and the fatty tissue between the tumor and the gastric wall (arrows), indicating the likelihood of a desmoplastic reaction, rather than an invasion of the tumor.

References

- [1] K. Schawkat, et al. Pancreatic Ductal Adenocarcinoma and Its Variants: Pearls and Perils. *RadioGraphics* 2020; 40:1219–1239. <https://doi.org/10.1148/rg.2020190184>.
- [2] Khaled Y. Elbanna, Hyun-Jung Jang and Tae Kyoung Kim. Imaging diagnosis and staging of pancreatic ductal adenocarcinoma: a comprehensive review. *Insights into Imaging* (2020) 11:58. <https://doi.org/10.1186/s13244-020-00861-y>.
- [3] Thomas Flohr, et al. Photon-counting CT review. *Physica Medica* 79 (2020) 126–136.

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2 Cinematic VRT images show a three-dimensional view of the tumor (Fig. 2a–2c) and the arteries (Fig. 2d). The tumor is located in the pancreatic body (arrows), showing no evidence of gastric wall invasion. Normal branches of the CA and the SMA are shown, without variation or stenoses.

Examination Protocol

Scanner	NAEOTOM Alpha
Scan area	Abdomen/Pelvis
Scan mode	Quantumplus (arterial & portal-venous phases)
Scan length	541 mm
Scan direction	Cranio-caudal
Scan time	5.8 s
Tube voltage	120 kV
Effective mAs	152 mAs
IQ level	125
Dose modulation	CARE Dose4D
CTDI _{vol}	12 mGy
DLP	702 mGy*cm
Rotation time	0.5 s
Pitch	0.8
Slice collimation	144 × 0.4 mm
Slice width	0.4 mm

Reconstruction increment	0.2 mm
Reconstruction kernel	Bv40, QIR 3
keV level	70, 60, 40 keV
Spectral reconstruction	VNC, VMI

Contrast	370 mg/mL
Volume	1 st bolus (70 mL + 40 mL saline) – 20 s pause – 2 nd bolus (30 mL + 20 mL saline)
Flow rate	4 mL/s
Start delay	Arterial phase was triggered immediately after 100 HU is reached in descending aorta in the 2nd bolus; the venous phase was started 25 s after the end of the arterial phase.

Pediatric ureterocele complicated by urolithiasis

Jan Baxa, MD, Ph.D.

Department of Imaging Methods, University Hospital Pilsen and Medical Faculty of Charles University, Pilsen, Czech Republic

History

A 9-year-old boy, suffering from frequent urination, weak stream and enuresis, was presented to the hospital for a check-up. Ultrasonography and cystoradiography revealed hydronephrosis and hydroureter on the right side, accompanied by multiple stones in the distal ureter. An abdominal contrast CT examination was requested for further evaluation, prior to the cystourethroscopy procedure.

Diagnosis

CT images showed a markedly dilated right renal pelvis and calyces as well as the right ureter, indicating hydronephrosis and hydroureter. Multiple smooth round stones, measuring 4–5 mm in diameter, were seen in the distal segment of a single dilated right ureter, which protruded into the bladder lumen. The right ureteral orifice was not visible. A single stone, located inferiorly in the dilated renal calyx and posteriorly in the protruded ureterocele, was also seen. The left renal system was unremarkable. CT findings suggested an ureterocele with urolithiasis.

Subsequently, the patient underwent a successful ureterocele resection, stones extraction and stent implementation between the renal pelvis and the bladder via cystoscopy. 25 stone pieces were extracted and the laboratory analysis revealed calcium-oxalate stones with 50/50

weddellite and whewellite. A follow-up session of cystourethroscopy was scheduled to extract the residual stones in the kidney.

Comments

An ureterocele is a congenital abnormal dilation of the distal-most portion of the ureter, protruding into the bladder. It can be asymptomatic and is often diagnosed later in life due to urolithiasis or is incidentally found through diagnostic imaging performed for other reasons than a suspicious ureterocele. Ureteroceles complicated by urolithiasis are not uncommon. Ultrasonography is primarily used for imaging diagnosis in pediatric patients. CT or MRI are valuable to further define the ureterocele anatomy in complex cases to guide surgical procedures.

This case is performed on a dual source photon-counting CT (PCCT), NAEOTOM Alpha®. It provides energy-resolved CT data without electronic noise, which is eliminated by setting up a predefined digital threshold for counting X-ray photons far above the electronic noise floor. [2] In the image reconstruction process, a model based iterative reconstruction approach – Quantum Iterative Reconstruction (QIR) – is applied for further image noise reduction. These improvements contribute to the reduction of image noise as well as radiation dose. By using an optimized 70 kV protocol,

a CTDI value as low as 0.77 mGy is achieved for the entire abdominal and pelvic scan. Less image noise also contributes to a three-dimensional demonstration of anatomical details. Slices, as thin as 0.4 mm, can be used to create lifelike images using cinematic volume rendering technique (cVRT), assisting the surgeons in planning an appropriate procedure. Note that the contrast agent is administered using a two-bolus protocol – 30 mL in the first bolus and 25 mL in the second, both with a 25 mL saline chaser. After the first contrast bolus, there is a waiting period of 1.5 hours to secure a well-filled dilated excretory system. A start delay of 40 seconds is applied after the second bolus for better vascular and parenchymal enhancement. Using this approach, only one scan, instead of two, is necessary, further reducing the radiation exposure to the pediatric patient. As shown in this case, with the advanced PCCT Quantum technology, optimal image quality with reduced radiation dose can be achieved for pediatric scans in clinical routine. ●

References

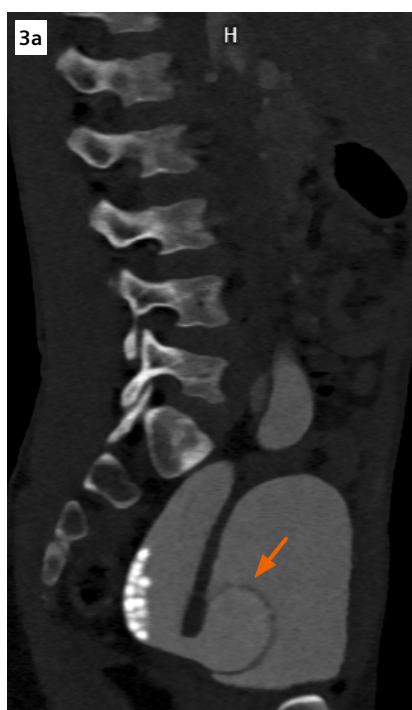
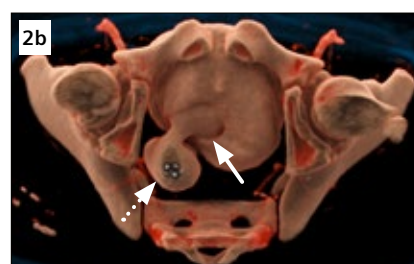
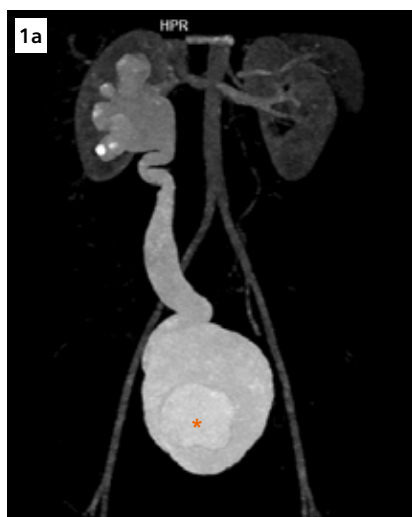
- [1] Xie et al. Ureterocele: Review of Presentations, Types and Coexisting Diseases. *Int Arch Urol Complic* 2017, 3:024. DOI: 10.23937/2469-5742/1510024.
- [2] Thomas Flohr, et al. Photon-counting CT review. *Physica Medica* 79 (2020) 126–136.

Examination Protocol

Scanner	NAEOTOM Alpha
Scan area	Abdomen/Pelvis
Scan mode	Quantum
Scan length	271.4 mm
Scan direction	Cranio-caudal
Scan time	1.6 s
Tube voltage	70 kV
Effective mAs	67 mAs
Dose modulation	CARE Dose4D
CTDI _{vol}	0.77 mGy
DLP	24.9 mGy*cm
Rotation time	0.5 s
Pitch	1.5
Slice collimation	144 x 0.4 mm
Slice width	0.4 mm
Reconstruction increment	0.2 mm
Reconstruction kernel	Br36, QIR 3
Spectral reconstruction	Monoenergetic Plus
Contrast	350 mg/mL
Volume	1 st bolus (30 mL + 25 mL saline) – 1.5 hrs pause – 2 nd bolus (25 mL + 20 mL saline)
Flow rate	1.5 mL/s
Start delay	40 s

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- 1 A thin MIP image (Fig. 1a) shows a markedly dilated right renal pelvis and calyces as well as the right ureter. The distal-most portion of the ureter, protruding into the bladder lumen, is also seen (asterisk). A cVRT image (Fig. 1b) shows the locations of multiple stones (arrows).
- 2 An axial image (Fig. 2a) and a cVRT image (Fig. 2b) show the ureterocele protruding into the bladder (arrows) and multiple stones in the dilated distal ureter (dotted arrow).
- 3 A sagittal MPR image (Fig. 3a) and a cVRT image (Fig. 3b) show the ureterocele protruding into the bladder (arrows) and multiple stones in the dilated distal ureter.

Osteochondritis dissecans of the capitellum

Ronald Booij, Ph.D.; Prof. Edwin Oei, MD, Ph.D.

Department of Radiology & Nuclear Medicine, Erasmus MC, Rotterdam, The Netherlands

History

A 13-year-old female patient, a gymnast, with left elbow complaints for the past 18 months, presented herself to our hospital. A radiograph of the elbow showed a suspicious osteochondritis dissecans (OCD) of the capitellum. To further evaluate the dimension of the lesion and the possible existence of loose fragments, an ultra-high resolution (UHR) scan mode (Quantum HD) on a photon-counting CT (PCCT) scanner (NAEOTOM Alpha®) was requested.

Diagnosis

The UHR CT images showed a cortical defect at the capitulum of the left humerus, with an approximate size of 9.2 mm (coronal) x 9.8 mm (sagittal) x 4.1 mm (depth) on the medial side. There were two loose fragments – one was about 5.1 mm in size, next to the capitulum, and the other was about 6.2 mm in size, seen dorsally on the lateral side of the olecranon. There were no signs of any focal osseous abnormalities elsewhere, nor evidence of focal muscle abnormalities. The trabeculation of the radial head was normal.

CT findings suggested an OCD focus at the capitellum of the left humerus with two loose bone fragments, demonstrating an unstable lesion. Subsequently, the patient was scheduled for arthroscopic surgery.

Comments

OCD is a disorder of the articular cartilage and subchondral bone which most commonly occurs in

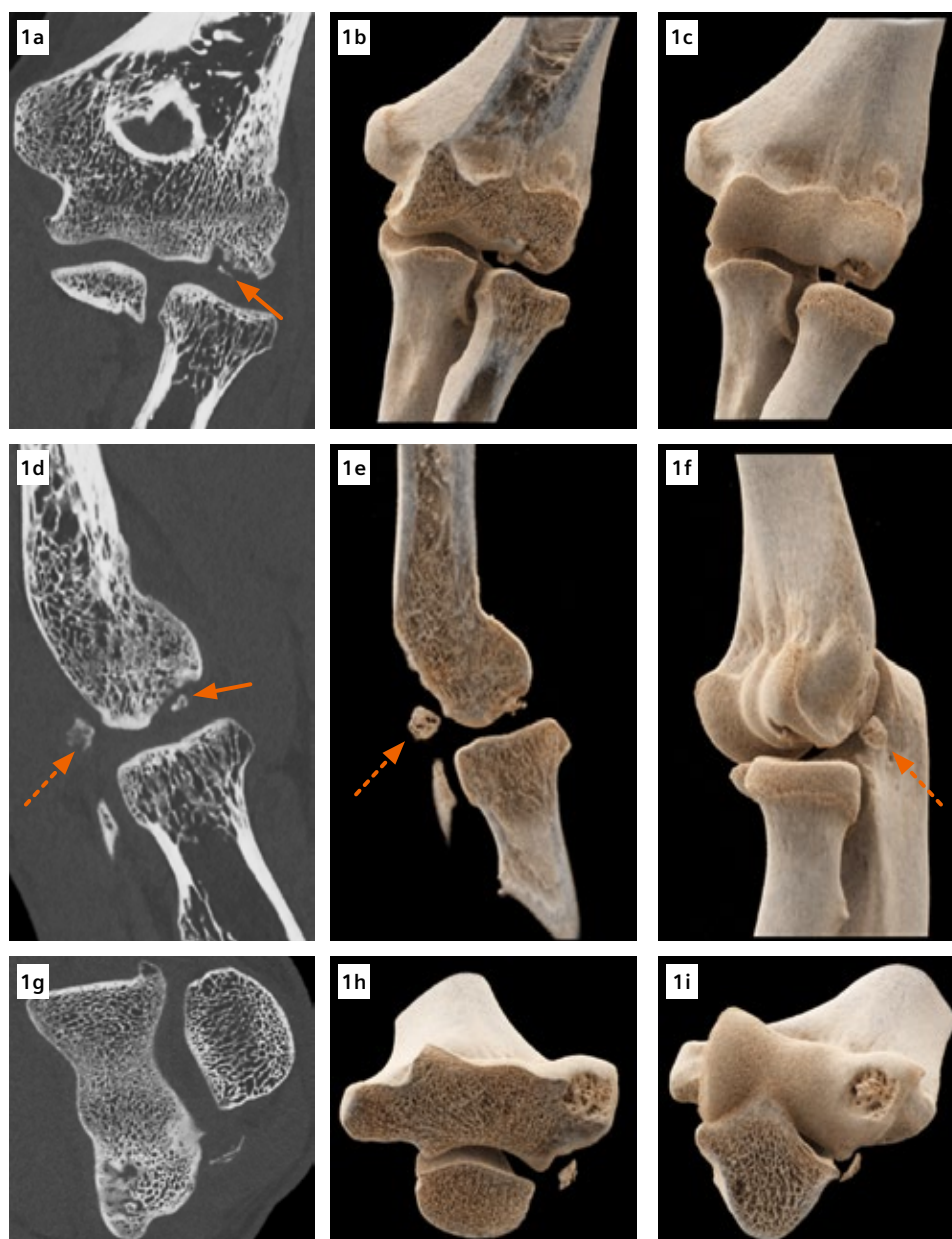
adolescent athletes. [1] In the elbow, it typically affects the humeral capitellum. Early recognition and appropriate intervention may protect adolescents from fragmentation of the OCD lesion and the development of irreversible cartilage damage. It is important to differentiate between stable and unstable OCD lesions, hereby is a CT considered more sensitive than a radiograph, to determine the best treatment option. [2] An unstable lesion would require a surgical approach, and prior to that, it would be essential to acquire detailed diagnostic information, such as the lesion size, the stability and viability of the lesion fragment and the number of present loose bodies, for surgical planning.

This case is performed on a NAEOTOM Alpha, a newly developed dual source PCCT scanner, providing energy-resolved CT data at improved spatial resolution, without electronic noise. [3] UHR images are acquired at 0.2 mm slice width and reconstructed using a very sharp kernel (Br89) with a 2% value of the modulation transfer function of 31 lp/cm. This provides improved visualization of the cortical and trabecular bone microarchitecture, enhancing the diagnostic confidence of the radiologists. Traditionally, with conventional CT, UHR images are associated with higher image noise and require higher radiation dose. However, PCCT enables UHR scanning without substantial increase in image noise, because UHR scan data are acquired at full dose efficiency without additional

combs or grids to reduce the detector aperture, and image noise is further reduced by a refined model based iterative reconstruction approach (Quantum Iterative Reconstruction, QIR). The low image noise even enables the use of the UHR images for cinematic volume rendering technique (cVRT), providing an excellent photo-realistic 3D visualization and facilitating surgery planning. Potentially, image noise reduction also leads to a reduction of the radiation dose, which is important especially for young patients. As shown in this case, the combination of improved spatial resolution with reduced image noise, provided by UHR imaging with PCCT, greatly benefits the musculoskeletal imaging. ●

References

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- [2] van den Ende KIM, Keijsers R, van den Bekerom MPJ, Eygendaal D. Imaging and classification of osteochondritis dissecans of the capitellum: X-ray, magnetic resonance imaging or computed tomography? *Shoulder Elbow.* 2019 Apr;11(2):129-136. doi: 10.1177/1758573218756866. Epub 2018 Feb 13. PMID: 30941202; PMCID: PMC6415488.
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1 MPR images (Figs. 1a, 1d & 1g) and cVRT images (Figs. 1b, 1c, 1e, 1f, 1h & 1i), reconstructed in 3D views, show a cortical defect at the capitulum of the left humerus with two loose fragments – one next to the capitulum (arrows), and the other seen dorsally on the lateral side of the olecranon (dotted arrows). The trabeculation of the radial head shows normal structures. Note that the input images for cVRT creation are reconstructed with 0.2mm slice thickness and a very sharp kernel of Br89.

Examination Protocol

Scanner	NAEOTOM Alpha
Scan area	Left elbow
Scan mode	Quantum HD
Scan length	103 mm
Scan direction	Caudo-cranial
Scan time	3.8 s
Tube voltage	120 kV
Effective mAs	56 mAs
Dose modulation	CARE Dose4D

CTDI _{vol}	4.5 mGy
DLP	50.8 mGy*cm
Rotation time	0.5 s
Pitch	0.55
Slice collimation	120 x 0.2 mm
Slice width	0.2 mm
Reconstruction increment	0.1 mm
Reconstruction kernel	Br89, QIR3

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Follow-up of an acute pulmonary embolism in an obese patient with an unknown patent foramen ovale

Prof. Martine Rémy-Jardin, MD¹, Ph.D.; Prof. Jacques Rémy, MD²

¹ Department of Thoracic Imaging, University Centre of Lille, France

² Department of Radiology, Hospital Center of Valenciennes, France

History

A 38-year-old female obese patient (165 cm height, 109 kg weight, BMI 40) suffered from an acute pulmonary embolism (PE) eighteen months ago. Her medical history included severe thrombotic context with several episodes of extensive lower extremity phlebitis, venous thrombosis and cryptogenic stroke. Despite adequate anticoagulant treatment of the acute PE episode, her dyspnea persisted. The patient was referred for a CT pulmonary angiography (CTPA) to clarify a potential evolution towards chronic pulmonary embolism.

Diagnosis

CTPA images displayed at 70 keV (equivalent to a standard 120 kV acquisition) showed a poor opacification of the pulmonary arteries (158 HU within the pulmonary trunk) and a good opacification in the aorta, indicating the potential existence of a patent foramen ovale (PFO) with a right-to-left shunt. The upper and lower thirds of the acquisition were not affected despite this shunt – the segmental artery of the right upper lobe (RA1), previously obstructed and dilated by the acute thrombus, presented severe stenosis, confirming focal chronic PE. A clot in the lateral segmental artery of the right lower lobe (RA9) was persistently seen.

However, in the middle third of the acquisition, the opacification in the pulmonary arteries (PA) was insufficient and slightly heterogeneous, raising concerns about persistent clots in the left interlobar PA and bilateral proximal lower lobe PAs. When switching image display from 70 keV to 40 keV, the attenuation within the pulmonary trunk (457 HU), as well as in the segmental PAs, was restored to a diagnostic level and the absence of residual clots could be confirmed.

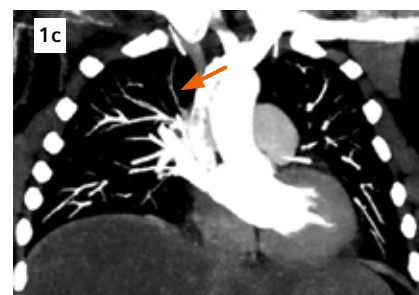
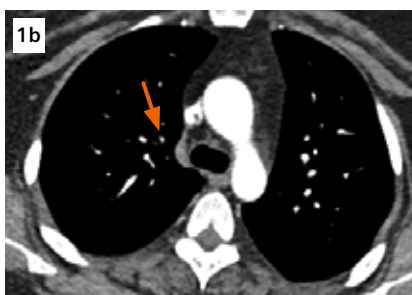
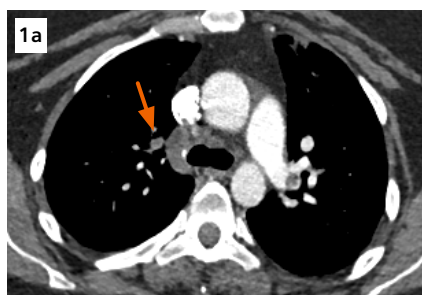
Based on CT findings, the treating physician considered that the patient was resistant to the anticoagulant she had been receiving since previous thrombotic events, and subsequently, switched her treatment plan to a different anticoagulant.

Comments

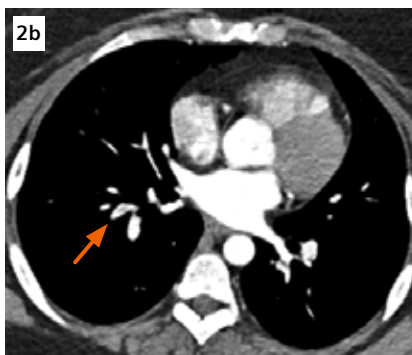
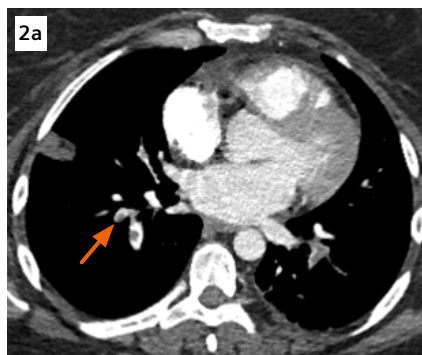
PFO is a communication between the right and left atria which fails to close postpartum. It has a high incidence in the general population, existing approximately in one-third of the adults. [1] Most people with a PFO remain asymptomatic and do not require any treatment. [2] However, the presence of a PFO may facilitate a paradoxical thromboembolus to transit from the venous to the systemic circulation and cause

a systemic embolization, such as the cryptogenic stroke which this patient had suffered. In a CT chest examination, a reversal blood flow (right-to-left shunt) can also occur when the patient takes a deep breath and holds it while executing a Valsalva maneuver. As a consequence, the contrast is directed from the right atrium to the left atrium, although a “jet sign” may not be present, leading to a poor opacification of pulmonary arteries and a good opacification of the aorta, such as in this case. This may potentially limit the diagnosis of PE requiring repeated scans with re-administration of contrast material.

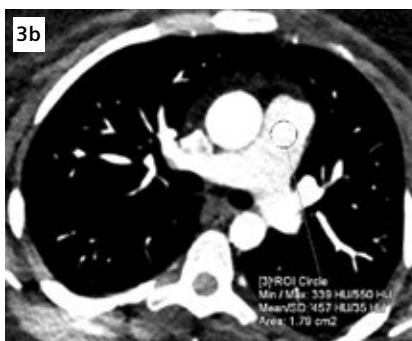
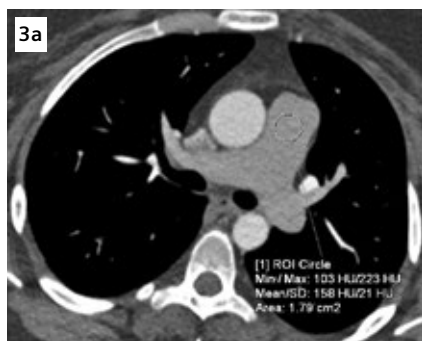
This case is performed on a NAEOTOM Alpha®, a newly developed Dual Source CT scanner with photon-counting detectors (QuantaMax®), providing energy-resolved CT data without electronic noise. [3] One of the key benefits of photon-counting CT (PCCT) is the availability of spectral CT data in any scan, allowing for an easy switch of the image display at different monoenergetic keV settings. By displaying the images at a lower keV setting, an acquisition which missed the contrast bolus due to the opening of a PFO can be salvaged. It is also worth noting that the overall image quality in this investigation achieved an optimal level despite the patient morphotype – obesity is usually



1 The segmental artery of the right upper lobe (RA1), previously obstructed and dilated at the time of acute PE (Fig. 1a, arrow), is poorly perfused in images displayed at 70 keV and shows severe retraction (Figs. 1b and 1c, arrows), confirming focal chronic PE.



2 A clot previously shown in the lateral segmental artery of the right lower lobe (RA9) (Fig. 2a, arrow) is persistently seen in an image displayed at 70 keV (Fig. 2b, arrow).



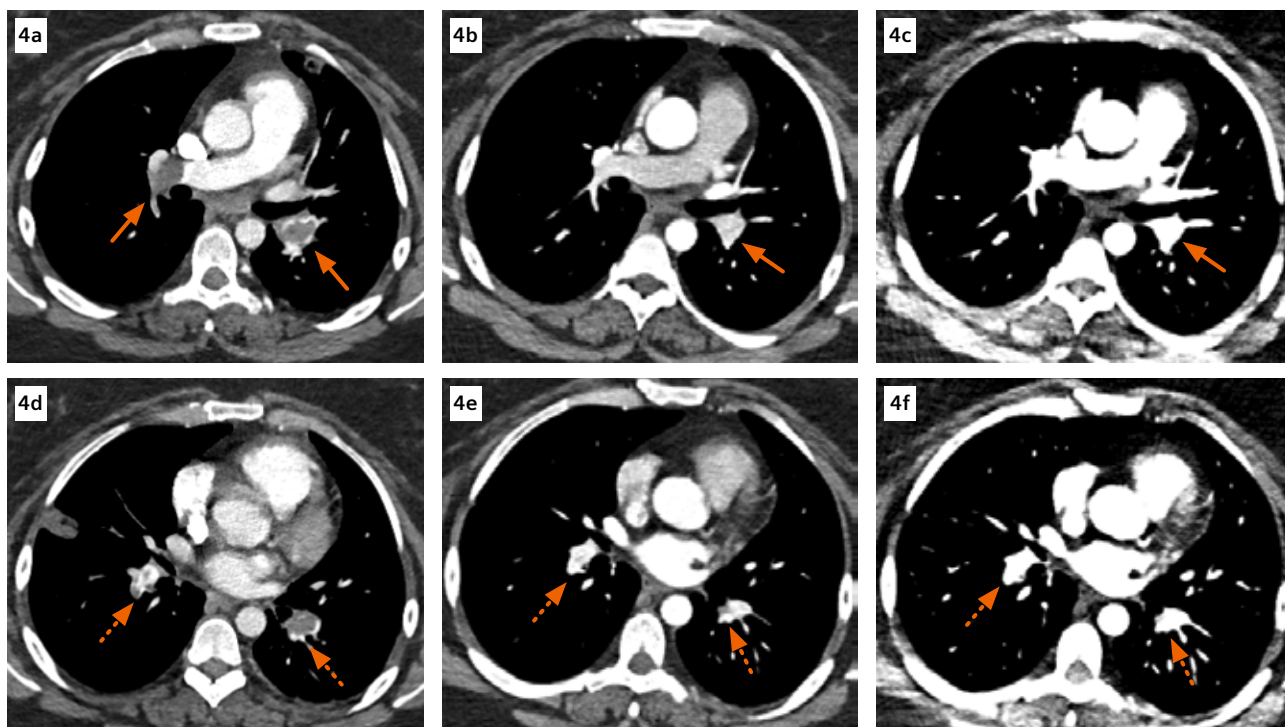
3 The poor opacification of 158 HU in the pulmonary trunk in the image displayed at 70 keV (Fig. 3a) is restored to a diagnostic level of 457 HU in the image displayed at 40 keV (Fig. 3b).

associated with image graininess due to noise, hampering precise analysis of pulmonary arterial sections, especially in the distal divisions. The reduction of image noise is particularly enhanced by the absence of electronic noise which is dominant at low X-ray flux at the detector, such as in the case of a bariatric CT scan. Additionally, a model based iterative reconstruction approach – Quantum Iterative Reconstruction (QIR) – is also applied in the image reconstruction process, contributing to further image noise reduction.

As shown in this case, the availability of spectral CT data provided by Quantum Technology plays an important role in clinical routine. In an obese patient with an unknown PFO, the use of low-energy images enables the physicians to restore the diagnostic image quality and perform a complete analysis of pulmonary arteries, without having to repeat the scan and re-administer contrast material. CT findings allow the physician to explain the worsening of the patient's situation and to consider changing the treatment plan. ●

References

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- [2] Ahmed R Gonnah, et al. Patent foramen ovale: diagnostic evaluation and the role of device closure. *Clinical Medicine* 2022 Vol 22, No 5: 441–8.
- [3] Thomas Flohr, et al. Photon-counting CT review. *Physica Medica* 79 (2020) 126–136.



4 Previous acute PE (Figs. 4a & 4d) are shown in bilateral interlobar PA (arrows) and bilateral basal trunks (dotted arrows). Images displayed at 70 keV (Figs. 4b and 4e) show slightly heterogeneous opacification and raise the concern about persistent clots. This is ruled out in the images displayed at 40 keV (Figs. 4c and 4f).

Examination Protocol

Scanner	NAEOTOM Alpha
Scan area	Thorax
Scan mode	QuantumPlus
Scan length	280 mm
Scan direction	Caudo-cranial
Scan time	0.8 s
Tube voltage	120 kV
Effective mAs	134 mAs
Dose modulation	CARE Dose4D
CTDI _{vol}	10.4 mGy
DLP	356 mGy*cm
Rotation time	0.25 s
Pitch	1.5
Slice collimation	144 x 0.4 mm
Slice width	1.0 mm
Reconstruction increment	1.0 mm
Reconstruction kernel	Br36 / BI60
Spectral reconstruction	Mono +

Contrast	400 mg/mL
Volume	60 mL + 40 mL saline
Flow rate	3 mL/s
Start delay	Bolus tracking triggered at 150 HU in the ascending aorta + 3 s

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Chronic thromboembolic pulmonary hypertension diagnosed after COVID-19

Prof. Martine Rémy-Jardin, MD¹, Ph.D.; Prof. Jacques Rémy, MD²

¹ Department of Thoracic Imaging, University Centre of Lille, France

² Department of Radiology, Hospital Center of Valenciennes, France

History

An 83-year-old male patient, with a previous episode of massive acute thromboembolic disease within the context of COVID-19, was diagnosed with pre-capillary pulmonary hypertension (PH). He was referred for a contrast enhanced chest CT to evaluate the etiology of the PH. The cardiologist in charge suspected that the chronic thromboembolic pulmonary hypertension (CTEPH) was pre-existent to the hospitalization for COVID-19 and was searching for potential fibrotic sequelae of COVID-19 in the lungs.

Diagnosis

CT angiography (CTA) images showed dilation of the central pulmonary arteries (PA), tapering and pruning of the peripheral PA, significant enlargement of the right atrium as well as a moderate enlargement of the right ventricle, intravascular webs and filling defects, a dilated bronchial artery, along with a pattern of mosaic perfusion in both lungs. In the spectral image data assessment of the lung perfused blood volume (LungPBV*), multiple peripheral wedge-shaped perfusion defects were evident bilaterally. These findings were consistent with CTEPH. There were no features of any COVID-19 sequelae.

The patient was transferred to the national reference center for therapeutic decision. Owing to the presence of proximal obstruction of the pulmonary arterial circulation

on the chest CTA, the patient was considered as eligible for pulmonary thromboendarterectomy (PTE), after medical treatment to decrease the level of pulmonary vascular resistance prior to surgery.

Comments

PH is a hemodynamic condition defined by a mean PA pressure (PAP) greater than 20 mm Hg and is clinically classified into five different groups, sharing similar pathophysiologic mechanisms, hemodynamic characteristics and therapeutic management. [1] CTEPH is classified in group 4 in which pulmonary artery obstructions are responsible for PH.

The incidence of PE in the context of COVID-19 has been reported but there is no data on post COVID-19 CTEPH. [2] An acute PE may lead to CTEPH due to an abnormal persistent obstruction of the PAs by residual organized thrombi, combined with a variable degree of microscopic vasculopathy. CTEPH has a poor prognosis when left untreated, leading to right heart failure as a result of progressive right ventricular dysfunction. An early recognition of CTEPH is essential since chronic thromboembolism is potentially curable using PTE.

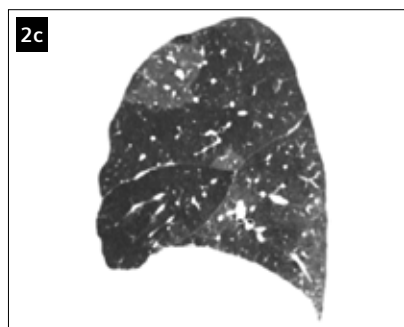
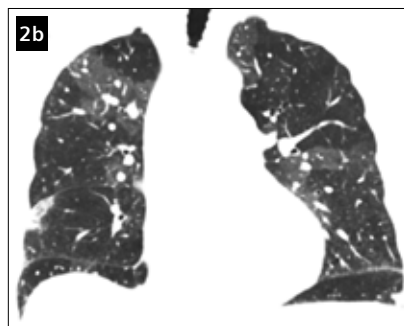
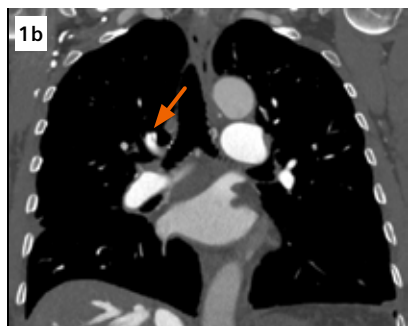
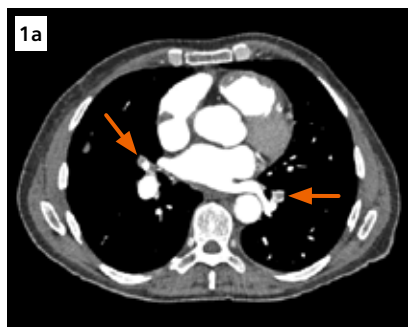
Lately, the role of CT in the diagnostic approach of PH etiology has been evolving and the growing importance of modern CT techniques in the diagnosis of CTEPH has been reinforced.

This case was performed with NAEOTOM Alpha®, a newly devel-

oped CT scanner with photon-counting detectors, providing energy-resolved CT data at improved spatial resolution, with inherent spectral information and improved tissue contrasts, without electronic noise. [3] All of these contribute to benefits and improvements in chest CT imaging. As an example, the iodine contrast-to-noise ratio (CNR) is improved due to the missing down-weighting of the lower energy X-ray photons and the absence of electronic noise, prompting a potential reduction of the radiation dose and the amount of contrast agent needed. Another benefit is the availability of spectral CT data in each contrast scan, i.e., the iodine maps – also known as LungPBV – can be created with each CTA dataset, resulting in a simultaneous assessment of the pulmonary vasculature as well as analysis of the parenchymal iodine distribution. Due to the high scan speed, spectral data of the entire thorax can be obtained in less than 2 s. This has a major impact on improving routine workflow. In the clinical context of PH, previous studies have shown agreement between LungPBV and scintigraphy for the detection of perfusion defects. [4] As shown in this case, chest CTA helped the radiologist to assess the presence of CT features of a chronic PE and to identify a dilation of pulmonary arteries and right ventricular dysfunction secondary to PH. CTEPH was clearly assessed as the etiology of PH, which helped the physician to make a proper treatment plan for the patient. ●

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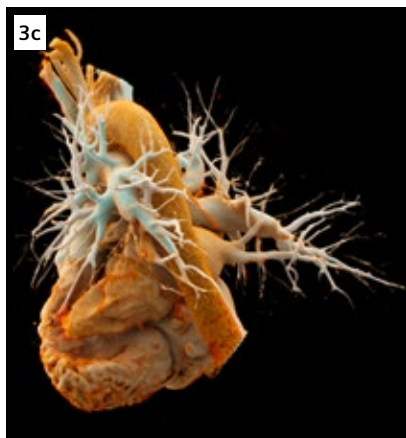
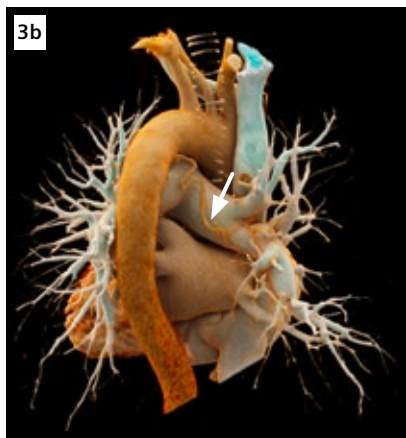
1 An axial image shows proximal filling defects in the PA of the right middle lobe as well as in the anterior segmental PA of the left lower lobe (Fig. 1a, arrows). A coronal MPR image shows a “web” sign in the segmental PA of the right upper lobe (Fig. 1b, arrow). A significant enlargement of the right atrium and moderate enlargement of the right ventricle are also seen (Fig. 1c).

2 Axial (Fig. 2a), coronal (Fig. 2b) and sagittal (Fig. 2c) MPR images show a pattern of mosaic perfusion in both lungs.

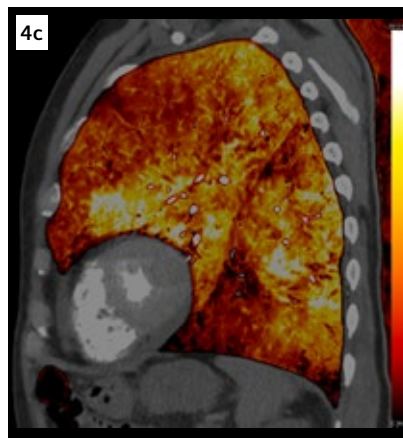
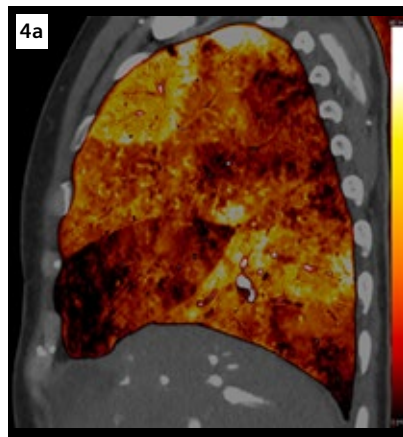
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* 510k pending.



3 Cinematic VRT images show the dilation of the central PA, tapering and pruning of the peripheral PA, as well as a dilated bronchial artery (arrow, Fig. 3b).



4 Sagittal (Figs. 4a & 4c) and coronal views (Fig. 4b) of the LungPBV image show multiple peripheral wedge-shaped perfusion defects bilaterally.

Examination Protocol

Scanner	NAEOTOM Alpha
Scan area	Thorax
Scan mode	QuantumPlus
Scan length	350 mm
Scan direction	Cranio-caudal
Scan time	1 s
Tube voltage	120 kV
Effective mAs	56 mAs
Dose modulation	CARE Dose4D
CTDI _{vol}	4.3 mGy
DLP	168 mGy*cm
Rotation time	0.25 s
Pitch	1.5
Slice collimation	144 x 0.4 mm
Slice width	1.0 mm
Reconstruction increment	1.0 mm
Reconstruction kernel	Qr40, QIR3
Spectral reconstruction	LungPBV
Contrast	400 mg/mL
Volume	60 mL + 40 mL saline
Flow rate	4 mL/s
Start delay	Bolus tracking triggered at 100 HU in the ascending aorta + 5 s

Severe emphysema treated with endobronchial valves

Prof. Martine Rémy-Jardin, MD¹, Ph.D.; Prof. Jacques Rémy, MD²

¹ Department of Thoracic Imaging, University Centre of Lille, France

² Department of Radiology, Hospital Center of Valenciennes, France

History

A 53-year-old male patient, suffering from progressive worsening of dyspnea with mild productive cough within the context of tobacco consumption (45 pack-years) over the last decade, was diagnosed with chronic obstructive pulmonary disease (COPD), grade GOLD 3, with severe emphysema and hyperinflation. The predominance of emphysematous lesions in the right upper lobe (RUL) led to the consideration of an endobronchial treatment of emphysema by endobronchial valve (EBV) deposition – an interventional procedure aiming to reduce the lung volume in order to improve ipsilateral diaphragmatic motion and subsequently, the patient's respiratory condition. The EBV treatment was targeted at the RUL. An ultra-high resolution (UHR) chest CT was indicated for post-procedural evaluation.

Diagnosis

The chest CT prior to the EBV deposition revealed the completeness of the right major and minor fissures, providing key information to ensure the absence of collateral ventilation. CT images, obtained 3 months after EBV deposition, showed three valves deposited in the right apical, posterior and anterior segmental bronchi enabling obstructions of the corresponding bronchi. An upward and anterior displacement of the right major fissure with complete atelectasis of the RUL was visualized. Numer-

ous low-attenuation areas were seen bilaterally in both lungs, indicating a heterogeneous emphysema distribution.

EBV treatment had favorable effects on the patient's outcome including a reduction of his dyspnea and improved results at the six-minute walk test.

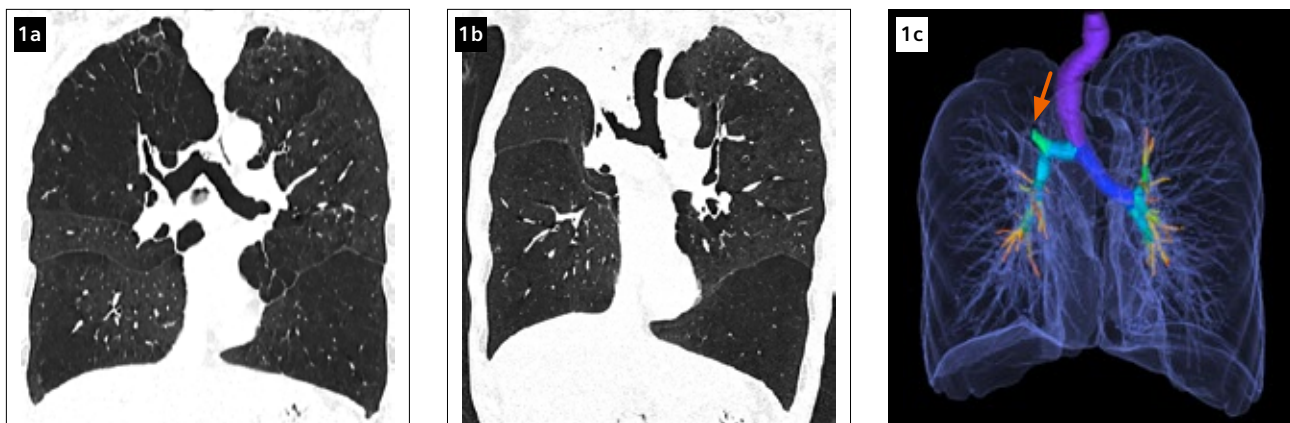
Comments

Emphysema is a major subtype of COPD, a progressive lung disease characterized by long-term breathing problems and poor airflow. It cannot be cured; however, different treatments are available to help manage the symptoms, e.g., EBV deposition. This treatment has shown favorable effects on patients' outcomes, including effective improvements in lung function, exercise tolerance and quality of life. [1] [2] [3] The eligibility of EBV treatment requires a thorough analysis of the emphysema distribution as well as the absence of collateral ventilation that could hamper atelectasis of the treated lobe. [4] All these pieces of information are provided by the chest CT examination prior to the procedure. The post-procedural chest CT validates the correct position of the deposited valves and provides analysis of the lobar atelectasis induced by the valves.

This case was performed with NAEOTOM Alpha®, a newly developed CT scanner with photon-count-

ing detectors (QuantaMax®), providing energy-resolved CT data at improved spatial resolution, with inherent spectral information and improved tissue contrasts, without electronic noise. [5] A low-dose UHR scan mode was applied, using a special tin filter optimizing the X-ray spectrum. The UHR mode features a slice collimation of 120 x 0.2 mm, in which the sub-pixels of the detector with a size of 0.15 x 0.18 mm² (at the isocenter) are read out individually. There are no physical septa between the pixels, each group of 4 x 6 sub-pixels is confined by collimator grids.

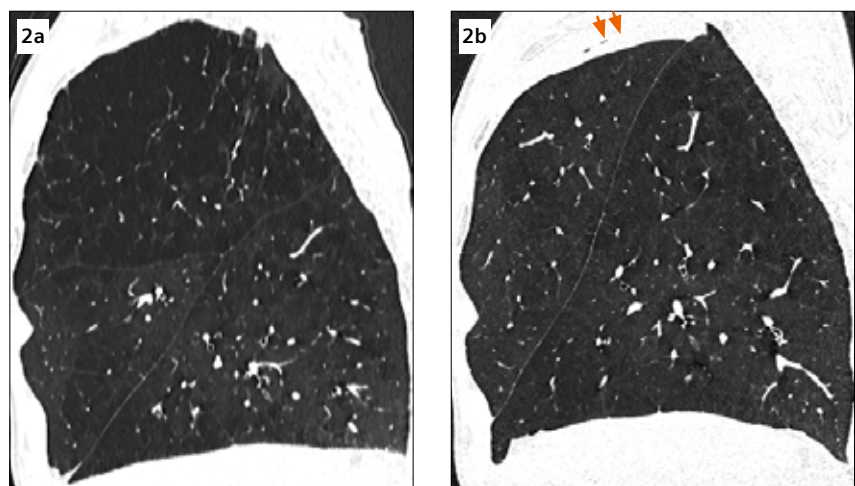
This increases the spatial resolution without degrading the geometric dose efficiency of the detector, resulting in an improved anatomic conspicuity in CT imaging at low radiation dose. Furthermore, electronic noise is eliminated by setting up a predefined digital threshold for counting X-ray photons far above the electronic noise floor, which leads to less image noise and potentially a reduction of the radiation dose. As the electronic noise is particularly dominant at low X-ray flux, its absence has a particular impact on the low-dose chest CT scanning with improved image quality. Another important improvement in chest CT is the higher contrast-to-noise ratio (CNR) due to the missing down-weighting of lower energy X-ray photons. In the image reconstruction process, a model based iterative reconstruc-



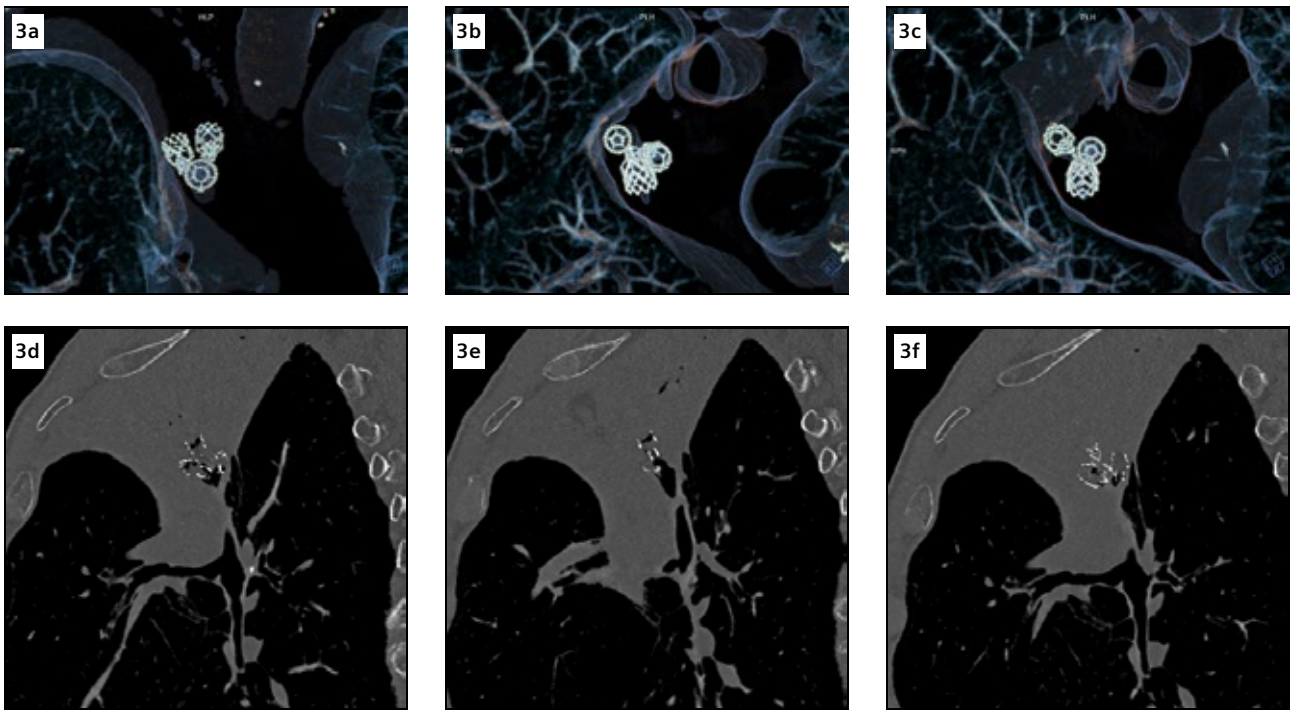
1 A coronal MPR image of pre-EBV deposition (Fig. 1a) shows low-attenuation areas in both lungs, with a predominant distribution in the RUL, indicating severe emphysema. The RUL is seen completely collapsed in the post EBV deposition image (Fig. 1b). A VRT image (Fig. 1c) shows the interrupted bronchus of the RUL (arrow).

tion approach – Quantum Iterative Reconstruction (QIR) – is applied for further image noise reduction. Owing to the reduced image noise, even low-dose UHR images (0.2 mm) can be used for three-dimensional reconstructions, such as cinematic volume rendering technique (cVRT), demonstrating a photo-realistic visualization of anatomical details.

As shown in this case, chest CT imaging plays an important role in patient selection prior to an EBV treatment and follow-up evaluation after the treatment. High-resolution (HR) images are traditionally associated with higher dose necessary for image noise reduction in thinner slices, but now, UHR images can be acquired with low dose providing the level of image details needed. ●



2 A sagittal MPR image of the pre-EBV deposition (Fig. 2a) shows the completeness of the right major and minor fissures. The same view of the post EBV deposition (Fig. 2b) shows the upward and anterior displacement of the right major fissure with complete atelectasis of the RUL (arrowheads).



3 cVRT images (Figs. 3a–3c) and oblique MPR images (Figs. 3d–3f) show three valves deposited in the right apical, posterior and anterior segmental bronchi and a completely collapsed RUL. Both cVRT and MPR views are reconstructed using 0.2 mm low-dose UHR images.

References

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- [4] Global Initiative for Chronic Obstructive Lung Disease. Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease (2022 report). <https://goldcopd.org/2022-gold-reports-2>.
- [5] Thomas Flohr, et al. Photon-counting CT review. *Physica Medica* 79 (2020) 126–136.

Examination Protocol

Scanner	NAEOTOM Alpha
Scan area	Thorax
Scan mode	Quantum HD + Sn
Scan length	355 mm
Scan direction	Cranio-caudal
Scan time	3.7 s
Tube voltage	Sn140 kV
Effective mAs	55 mAs
Dose modulation	CARE Dose4D
CTDI _{vol}	1.98 mGy
DLP	73.1 mGy*cm
Rotation time	0.25 s
Pitch	1.0
Slice collimation	120 x 0.2 mm
Slice width	0.2 mm
Reconstruction increment	0.2 mm
Reconstruction kernel	BI60, QIR4

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Siemens Healthineers Headquarters

Siemens Healthineers AG
Siemensstr. 3
91301 Forchheim, Germany
Phone: +49 9191 18-0
siemens-healthineers.com