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Case Report

Dual energy CT for the identification of CSF-Venous Fistulas and CSF leaks in spontaneous intracranial hypotension: Report of four cases[☆]

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ABSTRACT

Spontaneous intracranial hypotension (SIH) is a debilitating condition caused by spinal CSF leaks or CSF-venous fistulas (CVFs). Localizing the causative CSF leak or CVF is critical for definitive treatment but can be difficult using conventional myelographic techniques because these lesions are often low contrast compared to background, diminutive, and in some cases may be mistaken for calcified structures. Dual energy CT (DECT) can increase the conspicuity of iodinated contrast compared to background and can provide the ability to distinguish materials based on differing anatomic properties, making it well suited to address the shortcomings of conventional myelography in SIH. The purpose of this report is to illustrate the potential benefits of using DECT as an adjunct to traditional myelographic techniques in order to increase the conspicuity of these often-subtle CVFs and CSF leaks. This retrospective case series included 4 adult patients with SIH who demonstrated findings equivocal for either CVF or CSF leak using our institution's standard initial CT myelogram and in whom subsequent evaluation with DECT ultimately helped to identify the CVF or CSF leak. DECT demonstrated utility by increasing the conspicuity of two subtle CVFs compared to background and also helped to differentiate between calcified osteophytes and extradural contrast in 2 CSF leaks, confirming their presence and identifying the causative pathology. Our observations demonstrate the benefit of DECT as a problem-solving tool in the accurate diagnosis and localization of CVFs and CSF leaks.

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Introduction

Spontaneous intracranial hypotension (SIH) is a debilitating condition typically characterized by an orthostatic headache

along with cranial nerve symptoms, that is caused by a spinal CSF leak or CSF-venous fistula (CVF) [1]. The identification and localization of these spinal causes of SIH remains a challenge when using traditional myelographic techniques with reported sensitivities ranging from 48%–76% [2]. CVFs can be

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especially challenging to visualize given their small size and low contrast compared to background. While technical modifications improving the sensitivity of traditional myelographic techniques have been reported, additional investigation is needed to optimize imaging techniques and maximize diagnostic yield [3–5]. Dual energy CT's (DECT) ability to distinguish materials based on differing anatomic properties and to increase the conspicuity of contrast is increasingly recognized in a variety of imaging applications [6–9]. We have observed that adding DECT to CT myelography (CTM) can aid in the diagnosis and localization of CVFs and CSF leaks by both using lower monoenergetic energies to enhance detection of contrast and by differentiating calcium from extradural iodine, respectively. DECT has previously been reported useful in cisternography as a tool to differentiate contrast from bone, however to our knowledge there are no published data describing the utility in identification of the underlying causes of SIH within the spine [10]. Here, we present 4 cases in which DECT as an adjunct to traditional myelographic techniques increased the conspicuity of both CVFs and CSF leaks, helping to both confirm and localize the causative spinal pathology.

Dual Energy CT Myelogram Technique

All procedures and imaging were performed on the same 64-detector row CT scanner (Discovery 750HD; GE Health Care; Waukesha, WI). All patients underwent an initial CTM as part of routine standard of care SIH workup at our institution, as previously described [4]. In brief, the lumbar puncture was performed under CT fluoroscopic guidance followed by intrathecal administration of contrast using approximately 10 mL 300 mg/mL iopamidol (Isovue-M300; Bracco, Princeton, NJ) [3]. CT images were acquired immediately thereafter, with the patient in prone positioning in 3 of the cases and in right lateral decubitus in 1 case [11]. Multiple contiguous axial CT images were acquired from the skull base to the sacrum during inspiration with thin section reconstructions at 0.625 mm.

Additional DECT images were acquired after real-time review of the initial CTM at the scanner console revealed findings concerning for, but not confirmatory of, a CSF leak or CVF. DECT was performed using a rapid kilovoltage-switching DECT technology system on the same scanner (RevolutionCT, GEHealthcare, Waukesha, WI). Patients were scanned cranio-caudally in DE mode with fast tube voltage switching between 80 and 140 kVp (Table 1).

Virtual monochromatic images were reconstructed at 50 and 75 keV. 75 keV represents the routine energy level for image interpretation as it is equivalent to a conventional 120-kVp polychromatic x-ray beam (mean energy=77 keV). The 50 keV lower monoenergetic dataset was reconstructed to increase iodine density, potentially improving the detection of subtle CSF leaks and CVFs.

Material decomposition images with iodine-water and water-iodine base pairs were reconstructed using 1.25 mm section collimation and a projection-based material decomposition algorithm on a commercially available gemstone spectral imaging viewer (AWSer2, release5.5; GEHealthcare, Waukesha, WI). All image data sets were networked to our picture archiving and communication system (Visage7.1; Vis-

Table 1 – MDCT acquisition parameters.

MDCT Parameters	Dual Energy Scan
Detector configuration (mm)	40
Tube voltage (kV)	80/140
Tube current (mA)	600
Gantry revolution time (sec)	0.8
Acquisition mode	GSI-Helical
Helical Pitch	0.984:1
Field-of-view (cm)	Max 50
CTDI _{vol} (mGy)	26.69
Slice Thickness (mm)	1.25-2.5
Mono-energetic (keV)	50, 75
Material Decomposition	Iodine (Water), Water (Iodine)

ageImaging, Berlin, Germany) and loaded onto our proxy server.

Case Series

Case 1

A 46-year-old female with no significant past medical history presented with chronic, orthostatic headaches (ie, improved when recumbent) that began abruptly several months prior without an inciting event. The patient described the headaches as occipital in location with associated symptoms including tinnitus and vertigo, as well as intermittent nausea. Her symptoms were severe enough that she presented to the emergency department on 3 separate occasions, finally undergoing a brain MRI with contrast. This demonstrated findings diagnostic of SIH including pachymeningeal enhancement, brain sagging, and bilateral subdural collections. The patient had undergone 3 blind epidural blood patches (EBPs) without relief prior to presenting to our institution for further work up with CTM.

A CTM was deemed critical in order to identify and localize the causative spinal CSF leak. First, a CT fluoroscopy guided lumbar puncture at our institution revealed an opening pressure of 6.8 cm H₂O. Next, a standard CTM was performed in the left lateral decubitus position and a large ventral CSF leak was identified. A disc osteophyte spur was the suspected cause but remained occult, precluding localization of the dural defect. DECT with water-iodine base pair, iodine subtracted images revealed a calcified disc osteophyte spur at the apex of a disc protrusion confirming the location of the dural tear (Fig. 1). The patient underwent targeted EBP at this level and reported 75% reduction in symptoms.

Case 2

A 39-year-old female with no significant past medical history or history of headaches presented with sudden onset of severe bifrontal headaches without known inciting event. The headaches worsened throughout the day with a significant orthostatic component, experiencing near complete resolution upon lying recumbent and immediate onset upon standing

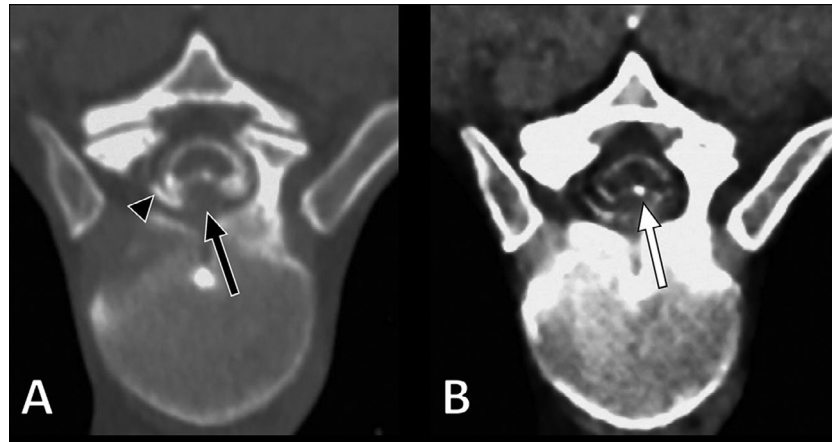


Fig. 1 – Differentiating osteophyte spurs from contrast using dual energy images. Case 1: (A) Axial image from a standard CT myelogram demonstrates a central disc protrusion at T9/T10 (black arrow) as well as extradural contrast representing an accompanying CSF leak (black arrowhead). **(B)** Axial image at the same level from a CT myelogram using dual energy, material-specific for water (iodine subtraction). Focal high density is identified at the apex of the disc protrusion confirming the presence of a previously occult calcified disc osteophyte spur that was previously indiscernible from contrast and can now be seen to pierce the dura, causing the CSF leak. Please note that window level settings were kept constant between the 2 data sets.

upright. Other associated symptoms included hyperacusis, blurry vision with reduced visual acuity, disequilibrium, severe neck pain, and memory loss and/or cognitive difficulties. MRI of the brain with contrast performed at an outside institution demonstrated signs of SIH including pachymeningeal enhancement, venous distention sign and bilateral subdural effusions. MRI of the spine was subsequently performed which demonstrated a large volume CSF leak in the cervical and lumbar spine. The patient had undergone a blind EBP previously without sustained improvement. A lumbar puncture at our institution demonstrated an opening pressure of 17 cm of water.

A standard CTM at our institution performed in the left lateral decubitus position demonstrated an extradural density adjacent to the right L3 nerve root and immediately posterior to the disc. It was unclear whether this represented a calcified foraminal disc extrusion or a CSF leak. This density was not present on DECT iodine subtraction images, confirming the presence of extradural iodinated contrast, consistent with a CSF leak (Fig. 2). A dural defect was confirmed intraoperatively and duraplasty was performed with successful repair.

Case 3

A 42-year-old female without significant past medical history presented with a history of chronic headaches for >10 years with significant orthostatic component, nearly resolving when in the recumbent position. The patient reported possible inciting events such as a fall from a horse. Her headaches had steadily worsened over the 3 years prior to her presentation. She underwent an MRI with contrast at an outside institution which demonstrated signs of SIH including brain sagging, dural enhancement and venous distention. Follow-

ing her diagnosis of SIH, the patient had undergone 4 separate blind EBPs at outside institutions, each resulting in only 1 week of pain relief.

A standard CTM performed in the right lateral decubitus position was performed at our institution which demonstrated a contrast opacified nerve root but no definite CVF. Sagittal CT myelogram image at the same location using dual energy, material-specific for iodine, demonstrate a contrast opacified vein extending inferiorly from the nerve root consistent with a CVF (Fig. 3). The patient elected to undergo operative repair of the CVF. Intraoperatively, a large right T12 nerve root diverticulum was identified as well as many abnormal surrounding veins. The nerve root itself was tied and the surrounding veins were coagulated. The patient reported greatly improved headaches 3 months postoperatively.

Case 4

A 56-year-old male without significant past medical history presented with 8 months of severe headaches. His headaches moderately improved while in the recumbent position and were refractory to pain management interventions. An MRI of the brain with contrast was consistent with SIH demonstrating dural enhancement, brain sagging, venous distention, and bilateral subdural collections. A prior CT myelogram at an outside institution raised suspicion for a possible CVF arising from the right T11 nerve root sleeve, but this remained uncertain. The patient had undergone a blind EBP at an outside institution with mild relief of symptoms.

A lumbar puncture at our institution demonstrated an opening pressure of 4 cm of water. A standard CTM was performed with the patient in right lateral decubitus position followed by DECT. The DECT revealed a contrast opacified vein

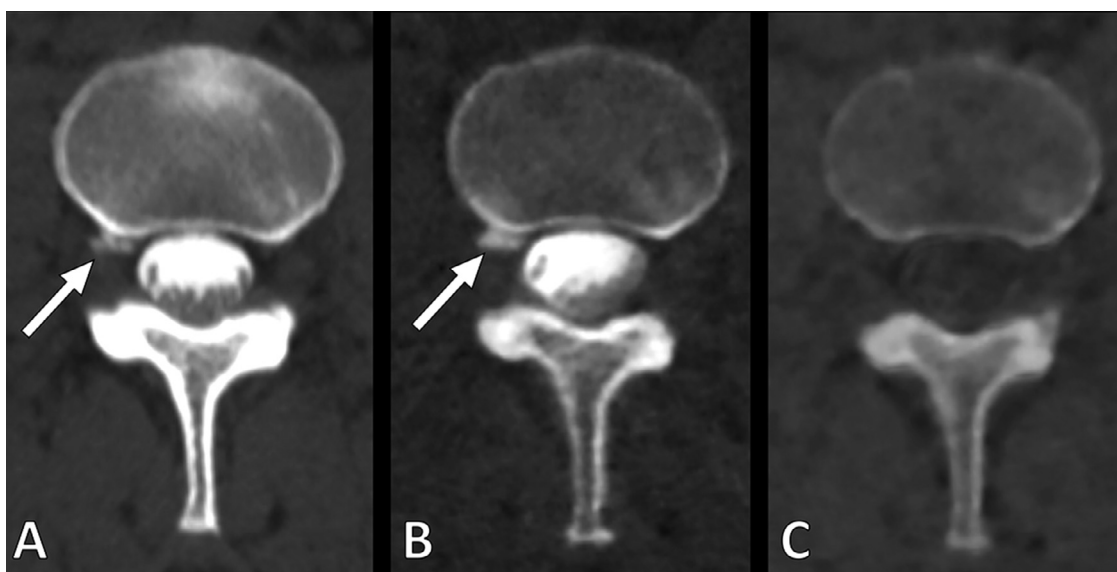


Fig. 2 – Differentiating a CSF leak from an osteophyte spur using dual energy images. (A) Axial image from a standard CT myelogram demonstrates extradural density immediately posterior to the right foraminial disc and adjacent to the anterior right L3 nerve root sleeve (arrow). It was uncertain if this represented a calcified disc osteophyte associated with a foraminal disc herniation or a CSF leak. **(B)** Axial image at the same level from a CT myelogram using dual energy with virtual monoenergetic image at 50 keV at the same window and level settings. Note the increased conspicuity of this finding (arrow), suggesting that it represents iodinated contrast. **(C)** Axial CT myelogram image at the same level using dual energy, material-specific for water (iodine subtraction). The finding is no longer visualized, confirming that this represents a CSF leak. Please note that window level settings were kept constant between the 2 data sets.

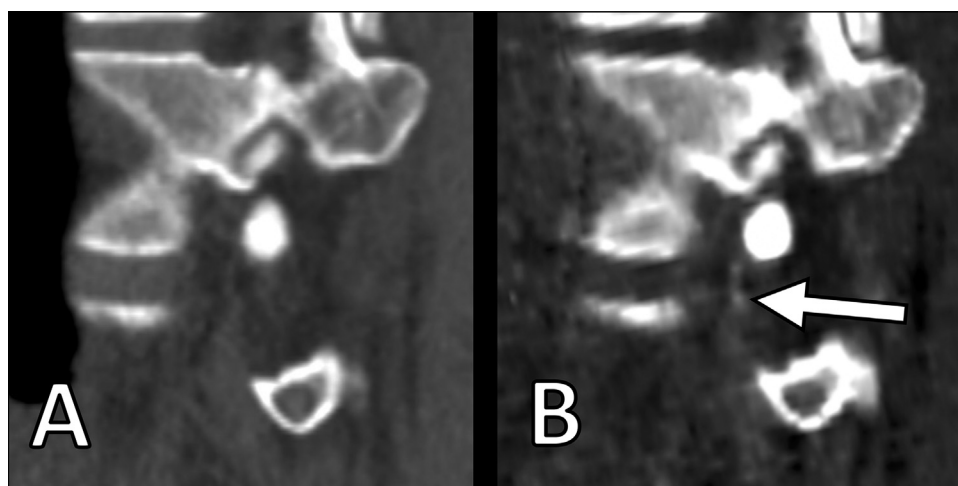


Fig. 3 – Improved conspicuity of subtle CSF to venous fistula (CVF) on dual energy images. (A and B) Off midline sagittal images from a CT myelogram in a patient with SIH and a surgically proven right T12 CVF. **(A)** Sagittal standard CT myelogram image through the right T12 neural foramen demonstrates a contrast opacified nerve root but no CVF. **(B)** Sagittal CT myelogram image at the same location using dual energy, material-specific for iodine (water subtracted) demonstrates a contrast opacified vein extending inferiorly from the nerve root (white arrow) confirming the presence of a CVF. Please note that window level settings were kept constant between the 2 data sets.

extending inferiorly from the axilla of the T11 nerve root with much greater conspicuity than standard CTM, confirming the presence of a CVF (Fig. 4). The patient underwent a targeted epidural blood patch at this level with 95% improvement in symptoms.

Discussion

DECT demonstrated utility in increasing the conspicuity of 2 subtle CVFs and in differentiating between calcified

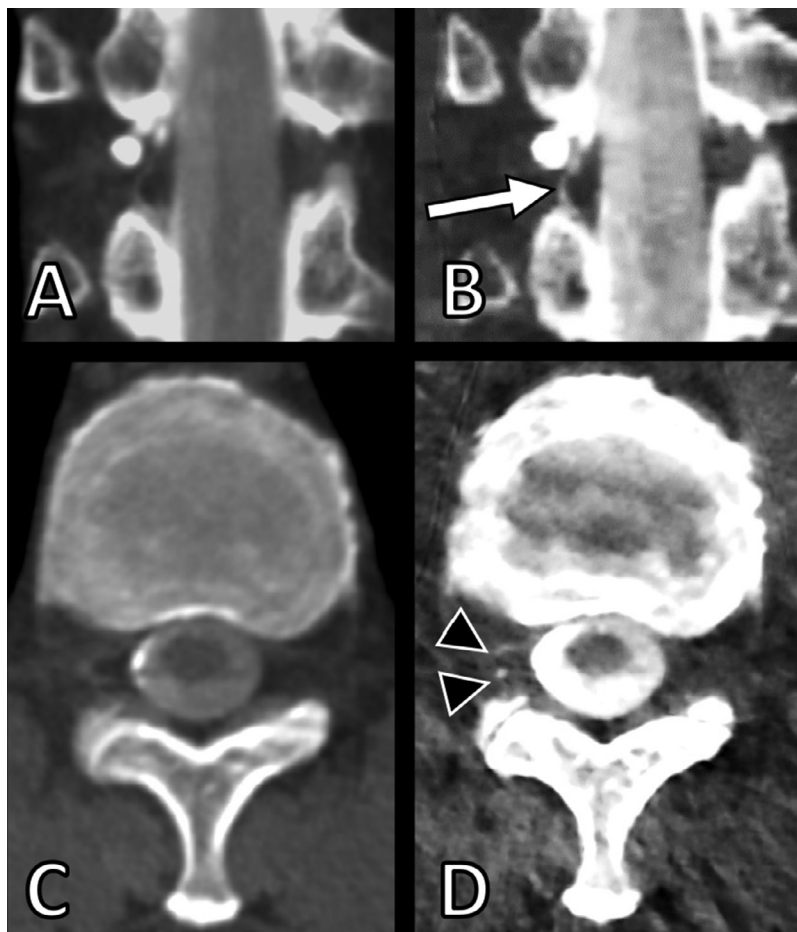


Fig. 4 – Improved conspicuity of subtle CSF to venous fistula (CVF) on dual energy images. (A, B, C, and D) CT myelogram images in a patient with SIH and a right T11 CVF. (A) Coronal multi-planar reformatted standard CT myelogram image through the right T11 nerve root. (B) Coronal multi-planar reformatted CT myelogram image at the same location using dual energy, material-specific for iodine (water subtracted), demonstrates with much greater conspicuity a contrast opacified vein extending inferiorly from the nerve root (white arrow) confirming the presence of a CVF. (C) Axial standard CT myelogram image in the same patient through the right T11 nerve root. (D) Corresponding axial CT myelogram image at the same location using dual energy, material-specific for iodine (water subtracted), demonstrating contrast opacification of the internal epidural venous plexus (black arrowheads) and confirming the presence of a CVF. Please note that window level settings were kept constant between the 2 data sets.

osteophytes and extradural contrast in the case of 2 CSF leaks. The observations described in this report demonstrate that the addition of DECT to standard CTM can benefit some SIH patients with occult CSF leaks or CVFs. Identifying the underlying spinal cause of SIH using conventional imaging can be challenging and recent literature reflects the need to improve the diagnostic yield of spinal imaging in SIH [5, 12, 13]. This case series adds to this discourse by reporting for the first time, to our knowledge, that DECT is a promising adjunctive tool. In this initial report we found that virtual monoenergetic images near the k-edge of iodine as well as the iodine only material differentiation images in DECT can increase the conspicuity of contrast for subtle CVFs. Furthermore, material differentiation capabilities of DECT are helpful in discerning iodinated contrast from calcified disc when hyperdense extradural material is identified. This is critical in both confirming the presence of a suspected CSF

leak and in identification of disc osteophytes that penetrate the dura, causing a CSF leak. Accurate identification and localization of both entities is imperative for directing therapeutic approaches either with targeted EBP or surgical repair.

While a non-contrast CT prior to standard CTM could be an additional method to help differentiate between extradural contrast and disc osteophytes, the DECT technique described in this report is felt to be superior given that the single acquisition negates the possibility of misregistration and minimizes radiation dose.

In conclusion, DECT demonstrates promise as a useful problem-solving tool in the identification and localization of CVFs and CSF leaks in patients with SIH and equivocal findings on standard myelographic techniques. Optimization of diagnostic imaging is imperative for the accurate and timely treatment of SIH patients. Future studies investigating DECT

protocol optimization as well as the application of promising future technologies, such as photon counting CT, are warranted [14].

Patient Consent

Patient consent has been obtained for the publication of this Case Report.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.radcr.2022.02.053.

REFERENCES

- [1] Amrhein TJ, Kranz PG. Spontaneous intracranial hypotension: imaging in diagnosis and treatment. *Radiol Clin North Am* 2019;57:439–51.
- [2] D'Antona L, Jaime Merchan MA, Vassiliou A, Watkins LD, Davagnanam I, Toma AK, et al. Clinical presentation, investigation findings, and treatment outcomes of spontaneous intracranial hypotension syndrome: a systematic review and meta-analysis. *JAMA Neurol* 2021;78:329–37.
- [3] Kranz PG, Amrhein TJ, Gray L, Venous CSF. Fistulas in spontaneous intracranial hypotension: imaging characteristics on dynamic and CT myelography. *AJR Am J Roentgenol* 2017;209:1360–6.
- [4] Kranz PG, Gray L, Amrhein TJ. Decubitus CT myelography for detecting subtle CSF leaks in spontaneous intracranial hypotension. *AJNR Am J Neuroradiol* 2019;40:754–6.
- [5] Amrhein TJ, Gray L, Malinzak MD, Kranz PG. Respiratory phase affects the conspicuity of CSF-venous fistulas in spontaneous intracranial hypotension. *AJNR Am J Neuroradiol* 2020;41:1754–6.
- [6] Nair JR, Burrows C, Jerome S, Ribeiro L, Larrazabal R, Gupta R, et al. Dual energy CT: a step ahead in brain and spine imaging. *Br J Radiol* 2020;93:20190872.
- [7] Patino M, Prochowski A, Agrawal MD, Simeone FJ, Gupta R, Hahn PF, et al. Material separation using dual-energy CT: current and emerging applications. *Radiographics* 2016;36:1087–105.
- [8] Goo HW, Goo JM. Dual-Energy CT: new horizon in medical imaging. *Korean J Radiol* 2017;18:555–69.
- [9] Potter CA, Sodickson AD. Dual-Energy CT in emergency neuroimaging: added value and novel applications. *Radiographics* 2016;36:2186–98.
- [10] Foust AM, Nguyen XV, Prevedello L, Bourekas EC, Boulter DJ. Dual-energy CT cisternography in the evaluation of CSF leaks: a novel approach. *Radiol Case Rep* 2018;13:237–40.
- [11] Mamlouk MD, Ochi RP, Jun P, Shen PY. Decubitus CT myelography for CSF-venous fistulas: a procedural approach. *AJNR Am J Neuroradiol* 2021;42:32–6.
- [12] Kim DK, Carr CM, Benson JC, Diehn FE, Lehman VT, Liebo GB, et al. Diagnostic yield of lateral decubitus digital subtraction myelogram stratified by brain MRI findings. *Neurology* 2021;96:e1312–18.
- [13] Piechowiak EI, Pospieszny K, Haeni L, Jesse CM, Peschi G, Mosimann PJ, et al. Role of conventional dynamic myelography for detection of high-flow cerebrospinal fluid leaks: optimizing the technique. *Clin Neuroradiol* 2020.
- [14] Willemink MJ, Persson M, Pourmorteza A, Pelc NJ, Fleischmann D. Photon-counting CT: technical principles and clinical prospects. *Radiology* 2018;289:293–312.