Computed Tomography

White paper

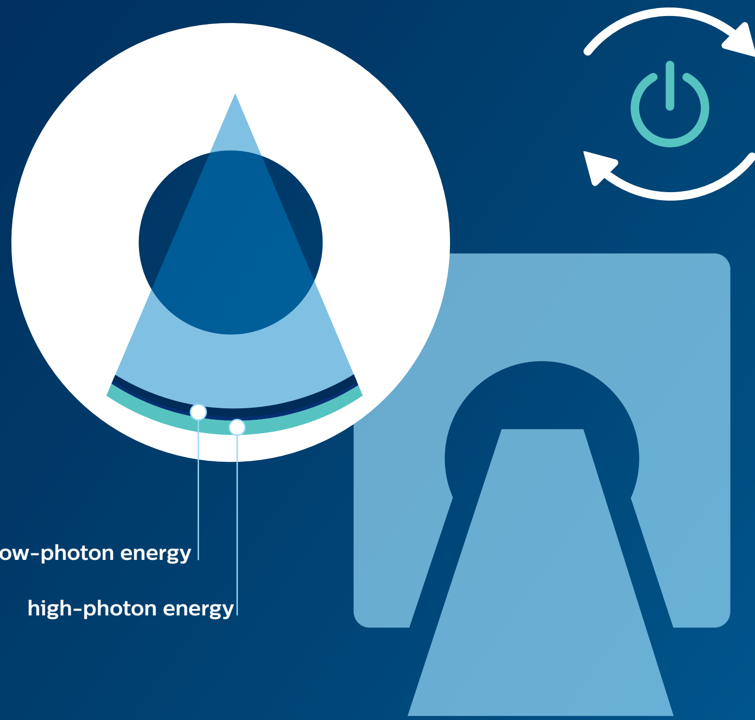
A new paradigm in cardiac CT

Detector-based spectral imaging expands full field-of-view capabilities across more populations

Introduction

Cardiac imaging presents special challenges. It requires full field-of-view (FOV) scanning, no compromise in temporal resolution, and the ability to scan even challenging patient populations, such as those with higher or irregular heart rates. In addition, cardiac imaging is further complicated by the presence of beam hardening artifacts and concerns about radiation or contrast dose. Philips Spectral CT 7500 provides detector-based spectral imaging to overcome all of these challenges.

Breakthroughs of spectral-detector CT



Spectral is always on

Simultaneously differentiates high- and low-photon energy in the same time and space

- Single exposure
- No special scan modes
- Spectral results on demand, even retrospectively

Spectral results 100% of the time

within 1-2 minutes

Every patient, every scan

Pediatric to bariatric, and other challenging populations such as cardiac

- Diagnostic confidence, with high image quality at low dose[1]
- No need to pre-select patients for spectral
- No trade-offs with image quality, dose, field of view or speed

Easy access to spectral results

Use exam cards to save a DICOM series with spectral base images and conventional images

- Read using Philips IntelliSpace Portal thin-client application or Philips Spectral Magic Glass on PACS
- Retrospective reconstruction always available with raw case data

What does full FOV spectral cardiac offer?

Coronary computed tomography angiography (CCTA) is a widely accepted and accurate tool for diagnostic and prognostic assessment of patients suspected to have coronary artery disease (CAD). With the new detector-based Philips Spectral CT 7500 system, there is no compromise on temporal resolution since there is no special spectral mode on a detector-based spectral scanner. This is not the case for source-based dual-energy scanners, because temporal resolution in dual-energy mode is compromised as compared to conventional scans, which could be due to slowing down the scanner for kVp switching or – in the case of dual-source CT – not having dual-energy capability in the high-pitch mode of scanning due to the two tubes operating at two different kVps.

With spectral always on, the Spectral CT 7500 system's scan parameters (including the scan time) are the same as for routine scans. As for source-based systems, the scan time is longer when the system is operating in dual-energy mode as compared to conventional scanning (e.g., rotation time must increase, and table speed has to be reduced in order to obtain dual-energy data).

Spectral CT 7500 generates true, uncompromised, conventional images that are essentially identical to single-energy CT. Photon data from the low- and high-energy layers is combined into a signal similar to a conventional (single-energy) detector. This is a unique capability of the spectral-detector CT scanner as compared to source-based dual-energy scanners because data is never acquired at a single kVp.

Spectral CT 7500 has 8 cm Z-axis coverage and therefore offers benefits such as high diagnostic performance for cardiac imaging (sensitivity of 93.5%, specificity of 95%, NPV of 98.7%, PPV of 77.6%),[2] the ability to deal with patients who are traditionally challenging to scan, and high image quality in patients with irregular and higher heart rate, all with dose modulation tools that allow scanning with ALARA (As Low As Reasonably Achievable) principles.[2]

How does Spectral CT 7500 enhance cardiac imaging?

Spectral CT 7500 is the fastest spectral cardiac CT scanner. With 0.27 sec rotation time, 8 cm Z-axis coverage and spectral results available in every patient, every time, Spectral CT 7500 will revolutionize cardiac CT.

Expanding care to a challenging population

The presence of calcified plaque in coronary arteries is common in patients suspected of CAD, leading to overestimation of the plaque content and underestimation of lumen diameter. This could result in referral of a patient for an interventional procedure, which may not be required. In source-based dual-energy systems, the mismatch in high- and low-energy projections can also lead to sub-optimal reduction in calcium blooming.[3]

With Spectral CT 7500, monoenergetic (monoE) reconstructions in the range of 40-200 keV can be obtained with every cardiac scan without any trade-offs. Higher monoE results from the spectral system can demonstrate significantly reduced calcium blooming artifacts, allowing for more precise measurements of calcified plaque and lumen diameter.

A study performed by Hedent et al. investigated the effect of different monoE images on calcium blooming in coronary arteries.[3] The study showed a decrease in calcified plaque content in monoE reconstructions from 70-140 keV, and the degree of stenosis decreased gradually with an increase of monoE levels. The degree of stenosis decreased gradually with an increase of monoE levels from 70 to 140 keV. Subjective image quality was rated highest for 80 keV compared to conventional reconstruction. The authors concluded that the reduction in calcium blooming at higher monoE levels results in increased luminal diameter and thus a reduced luminal stenosis measurement. This could expand the use of CCTA exams in a high-risk population with moderate to heavy calcium burden. Decreased calcium blooming also leads to more definitive diagnosis and improved diagnostic confidence when evaluating coronary arteries.

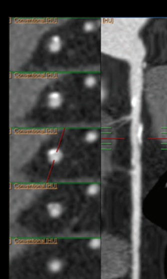
Cardiac computed tomography (CTA) is a well-established technique for the evaluation of left atrial and pulmonary vein anatomy.

Patients with atrial fibrillation usually have a CTA before a radiofrequency catheter ablation procedure to define the left atrium, pulmonary vein and left atrial appendage anatomy, as well as other structures within the heart. The clinician also wants to rule out left atrial appendage thrombus, which is mandatory before the ablation procedure to reduce the risk of subsequent thromboembolic events.[4] Typically, echocardiography is used for evaluation of thrombus because left atrial filling defects may appear as a thrombus on CTA.

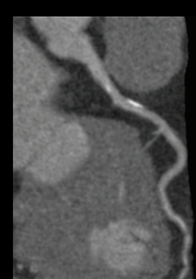
With Spectral CT 7500, we can use spectral results such as iodine map or low monoE to differentiate between thrombus and a slow flow of blood from the filling defect by using a delayed or late iodine enhancement scan. This provides all required information from the CT scan without the potential need for an additional ultrasound scan.

Reduced calcium blooming

Conventional curved MPR



Conventional lumen view

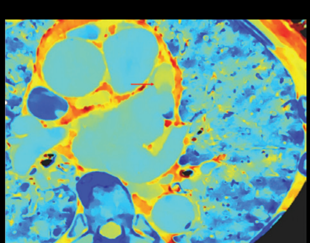


MonoE 140 keV curved MPR with decreased calcium blooming

Clot vs slow flow in left atrial appendage

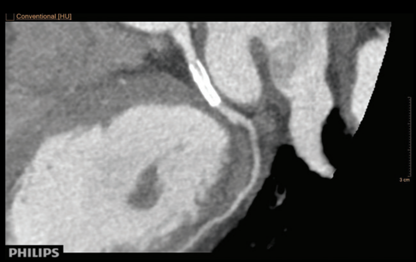
Conventional late iodine enhancement

MonoE 40 keV late iodine enhancement

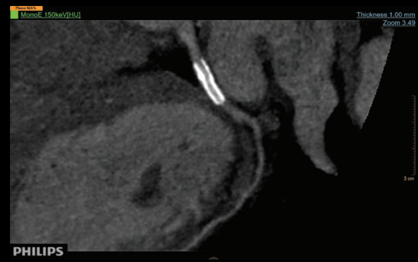


Fused Z-effective late iodine enhancement

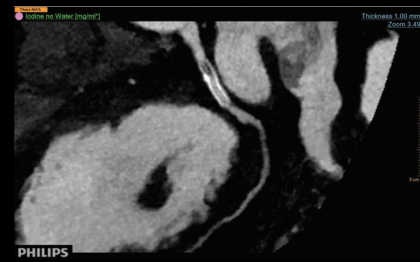
Improved stent imaging



Conventional

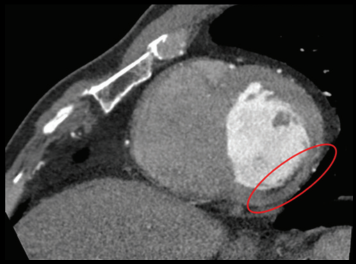


MonoE 150 keV reduced blooming artifact

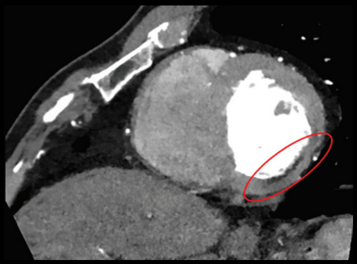


Iodine no water decreased enhancement proximal stent

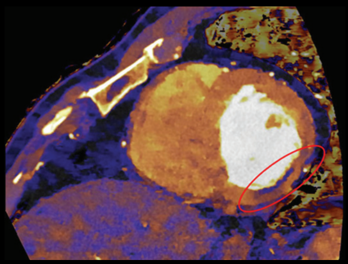
Myocardial perfusion defect



Iodine density fused



MonoE 50 keV



Z-effective fused

Reduction in beam hardening artifacts

CT myocardial perfusion enables evaluation of hemodynamically significant coronary lesions that cause ischemia. CT attenuation can be used to identify myocardial perfusion defects. When using conventional myocardial CT imaging, beam hardening (BH) artifacts can negatively affect the accuracy of perfusion estimates.

BH artifacts arise due to the polychromatic nature of the X-ray beam and preferential absorption of low energy X-rays by high-attenuating materials, such as bone or iodinated contrast agent. BH artifacts appear as cupping or streaks in the image. The use of Spectral CT 7500 may improve perfusion estimates by effectively reducing these artifacts in monoE (keV) images. Spectral results such as iodine no water or iodine density also allow for better quantification of myocardial perfusion.

A case study from Peking University College Hospital in China utilized CCTA with spectral-detector CT on a patient with recurring chest pain and implanted stents.[5] Curved multi-planar reformat (cMPR) images of the left circumflex artery (LCX) in the stent region were reviewed on conventional and spectral reconstructions, using the spectral Comprehensive Cardiac Analysis (sCCA) application on Philips IntelliSpace Portal. The ability to perform an assessment of the lumen within the stent was extremely limited using the conventional reconstruction, even after adjusting the window width and level. The high monoE (150 keV) result reduced the blooming artifact arising from the struts of the stent but also decreased contrast enhancement within the artery. The iodine no water image clearly showed a drop in the enhancement in the proximal end of the stent and reduced blooming off of the stent struts. Additionally, a review of the short-axis images showed the presence of a sub-endocardial perfusion defect in the inferior and infero-lateral walls of the myocardium (right coronary artery and LCX territories). This perfusion defect was more clearly seen on the 50 keV low monoE result and Z-effective color map. The conventional reconstructions showed an extremely limited ability for the assessment of the lumen within the stent. By reducing BH artifacts, the spectral results allowed for functional assessment of the myocardium along with the evaluation of coronary arteries from the same scan.

Late-enhancement cardiac scans are used in the evaluation of the myocardium, including for the presence of myocardial scar and myocarditis. While myocardial scar is typically seen as a hyper-enhanced sub-endocardial region of the myocardium, myocarditis is seen as sign of sub-epicardial hyper-enhancement.[6]

Typically, magnetic resonance imaging (MRI) is used for such assessments, but its use is limited because of accessibility, especially for acute patients. Late enhancement CT can also be used for such applications. Conventional reconstructions of such scans are impacted by factors such as noise and BH, affecting the ability to differentiate between the hyper-enhanced regions and the rest of the myocardial regions. However, spectral-detector CT provides an opportunity to get this information from a late-enhancement scan. In addition to reducing the BH artifacts, spectral results such as low monoE can boost the contrast presence and therefore the visualization of enhanced structures; additionally, iodine-based images such as iodine no water and iodine density enable quantification of iodine in the myocardium. More recently, myocardial extracellular volume (ECV) has been used to identify focal myocardial fibrosis, as with scar and myocarditis, MRI is considered the gold standard for this. With conventional CT, this requires multiple scans – a native (non-contrast) and a late-enhancement CT scan – which then need to be registered and subtracted to extract and quantify iodine under equilibrium conditions. However, with spectral CT, one can extract the same information from a single late-enhancement scan. Using iodine-based reconstructions (iodine no water or iodine density) and the patient's hematocrit value, one can derive the myocardial ECV.[7] With the use of Spectral CT 7500, a late-enhancement spectral scan can be performed using low-dose Step & Shoot Cardiac.

Reduction in iodinated contrast load

CT is the modality of choice for pre-procedure planning for trans-catheter aortic valve implantation (TAVI), and is considered the gold standard for valve evaluation – including size of aortic annulus, distance to coronary ostia, distance and size of left ventricular outflow tract (LVOT), sino-tubular junction, and sinus of Valsalva and ascending aorta. The CT scan can be used to determine the optimum deployment angle, saving contrast and radiation dose in the catheterization laboratory or hybrid operating room during the procedure. Non-gated CT is used for access route planning, size of ilio-femoral arteries, amount of calcification and tortuosity.

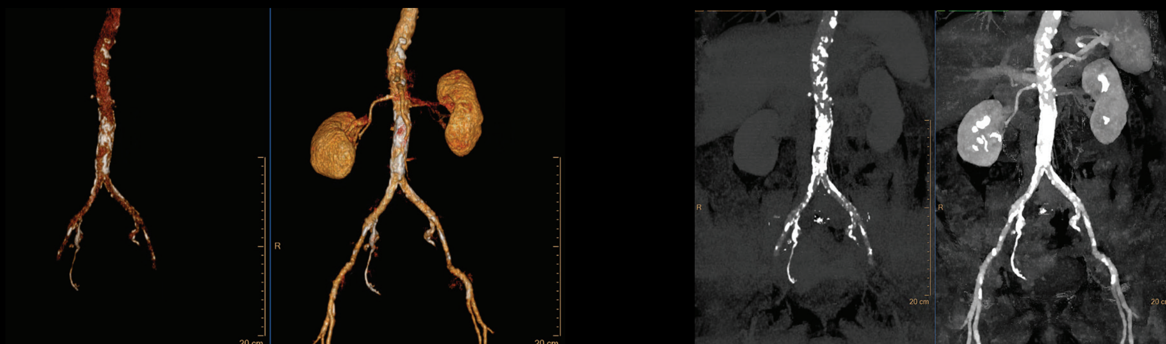
Additionally, CT can be useful after the procedure to evaluate deployment depth in the setting of conduction disturbances and assess the presence of hypo-attenuated leaflet thickening, also known as HALT. Because the age of the TAVI patient population, the amount of contrast medium used for a CT scan can pose significant challenges. A majority of TAVI patients suffer from renal insufficiency and are at risk for acute kidney failure. Low monoE images on spectral-detector CT allow a reduced contrast dose to be delivered to the patient by accentuating contrast enhancement in the vessels.

A study by Cavallo et al. assessed the use of a low-dose (50 ml) iodinated contrast protocol (25 ml for the gated chest scan and 25 ml for non-gated abdomen and pelvis) in 116 consecutive TAVI patients using the spectral-detector CT scanner.[8] The standard contrast volume for conventional CT scans ranges from 90-140 ml. 40 keV monoE images provided optimal signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR), resulting in good image quality, allowing easy and reliable assessment of the aortic root and access vessels.

The low-contrast dose TAVI scans on the Spectral CT 7500 system are complemented by the TAVI application on IntelliSpace Portal. The TAVI application has an easy-to-use task-guided workflow, enabling time savings (98 seconds per patient[9] for the TAVI planning procedure) for device-sizing results and a better work experience for pre-operational planning for TAVI procedures. The advanced vessel analysis (AVA) application is used to evaluate the access route from the non-gated scan.

The value of low monoE imaging for reduction in contrast has also been explored for CCTA exams. A study by Yi et al. demonstrated that CCTA exams can be performed using 36 ml of iodinated contrast.[10] 40-60 keV monoE reconstructions can boost the contrast enhancement in vessels, providing improved image quality and reduced noise, as compared to conventional images and allowing significant reduction in contrast dose delivered to the patient.[10,11]

Evaluation of TAVI patients



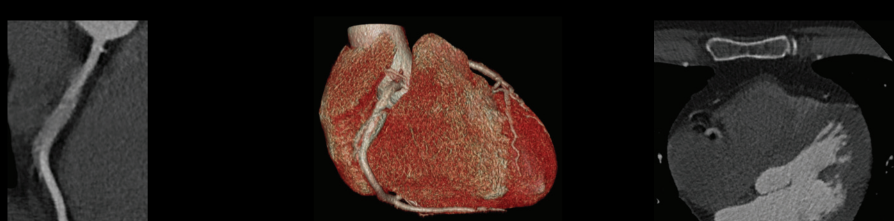
Conventional image | MonoE 40 keV | Conventional image | MonoE 40 keV

Improved image quality at higher heart rate

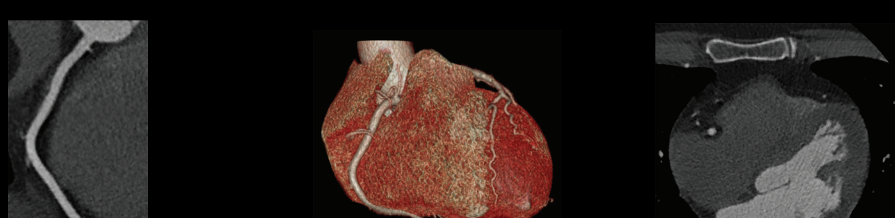
CCTA has been shown to provide high diagnostic quality imaging in patients with normal sinus rhythm. However, imaging of patients with higher and irregular heart rate remains a challenge because of the difficulty in synchronizing the heart rhythm with table gantry movement. Severe motion artifacts are often seen on CCTA images of patients with higher heart rates.

Spectral CT 7500 with 8 cm Z-axis coverage and Philips Precise Cardiac can reduce the motion artifacts in these images and improve the image quality of coronary vessels. A study performed at University of Chicago by Balaney et al. demonstrated that in patients with higher heart rates (mean heart rate 86 ± 11 bpm, range 68–114 bpm) the use of motion-compensated reconstruction of Precise Cardiac can minimize motion artifacts, improving the visualization of the coronary arteries on CT images by salvaging some of the segments deemed non-diagnostic on conventional reconstruction.[12] With this new reconstruction algorithm, CCTA can be performed in patients with higher heart rates (e.g., average heart rate of 86 bpm) without compromising image quality.

Precise cardiac images



RCA curved MPR with motion | 3D with motion in RCA | Axial with RCA motion



RCA curved MPR with motion eliminated by Precise Cardiac | 3D with motion eliminated by Precise Cardiac | Axial with motion eliminated by Precise Cardiac

Conclusion

New Spectral CT 7500 system offers full FOV spectral cardiac imaging by reducing calcium blooming in coronary arteries and expanding cardiac imaging to challenging patient populations. The system generates anatomical and functional results from the same scan by reducing BH artifacts. Spectral cardiac results potentially eliminate the need for a calcium scoring scan. In addition, spectral scanning can be used to reduce contrast dose in older patients and provide high-quality cardiac imaging in patients with higher heart rates.

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