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Computed Tomography

White paper

Confidence in cardiac CT – from routine to challenging

8 cm coverage enables robust diagnostic-quality imaging, even in patients with high BMI, high HR and atrial fibrillation

Introduction

This paper explores advantages of CT systems with 8 cm Z-axis coverage. The use of CT for cardiac imaging has become more prevalent, making it the standard clinical test for a variety of cardiovascular conditions. With its high sensitivity and negative predictive value, cardiac CT has become the non-invasive modality of choice for the assessment of coronary artery disease (CAD) and its impact on cardiac function and perfusion.[1] Additionally, cardiac CT aids in the quantification of coronary plaque, the assessment of stents for in-stent restenosis, and the planning of complex coronary and structural interventions such as transcatheter aortic valve implantation (TAVI).

There are multiple challenges in imaging coronary arteries. These arteries are typically small, with a caliber approaching 1 mm in size at their most distal ends. These small vessels exhibit complex 3D motion during the cardiac cycle, which is a major cause of artifacts during coronary imaging.[2,3] This requires CT scanners to have the speed necessary to capture cardiac anatomy, good spatial resolution to visualize the small structures of coronary arteries and fast gantry rotation (i.e., excellent temporal resolution, which is critical to imaging moving structures). Some other challenges in imaging coronary arteries are the ability to deal with arrhythmias, variable heart rate during scanning and patients with high heart rates. There are also challenges associated with imaging the range of patient types and achieving consistent image quality, especially patients with high body-mass index (BMI) (obese patients).

Philips has CT scanners with 8 cm Z-axis coverage in axial and helical mode for cardiac acquisition and 0.27 sec rotation time (standard temporal resolution of 135 ms in Philips Step & Shoot Cardiac with added improvements via adaptive multi-cycle reconstruction in helical). The systems have all available Philips dose modulation tools. Image quality for each diagnostic task is specified by the DoseRight Index (DRI) for various scanning regions, to allow for appropriate dose to maintain consistent image quality within a single acquisition and between patients. Cardiac DoseRight is available in retrospective mode of scanning, allowing the user to reduce radiation dose during the phases of the EKG cycle that are not needed for final image interpretation.

Diagnostic performance

Diagnostic performance (sensitivity, specificity, positive predictive value [PPV] and negative predictive value [NPV] of Philips CT with 8 cm Z-axis coverage for segment-based analysis of coronary arteries is found in Table 1. Values are compared with other competitive systems based on information available in published literature.

Author	Vendor	Scanner	# of pts	HR (bpm)	Contrast	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Chao et al.	Philips	Brilliance iCT	104	65 (45-103)	60 ml	93.5	95	77.6	98.7
Liang et al.	GE	Revolution CT	64	82.5 (75-106)	50-60 ml	91.9	95.8	77.9	98.7
Albrecht et al.	Siemens	Somatom FORCE	60	78	86.6 ml	90.7	95.2	66.7	99
Song et al.	Canon	Aquilion ONE	381	61	100 ml	58	91	51	93

Table 1 Diagnostic performance comparison of different scanners

As noted in the table, the segment-level diagnostic performance across vendors is very comparable.

Also of note is that the study by Chao et al.[4] on a Philips 8 cm Z-axis coverage system included 104 patients with heart rates in the range of 45-103 bpm. The study included patients with atrial fibrillation, high heart rates, obesity, bypass grafts and high Agatston calcium scores. The average amount of contrast used was 60 ml, and the study did not use any iterative or motion compensation reconstruction.

In contrast, the study by Liang et al.[5] included 64 patients and did not include patients with atrial fibrillation and irregular heartbeats.

Similarly, diagnostic performance of CCTA for other vendors[6,7] is also comparable to the 8 cm Z-axis coverage system.

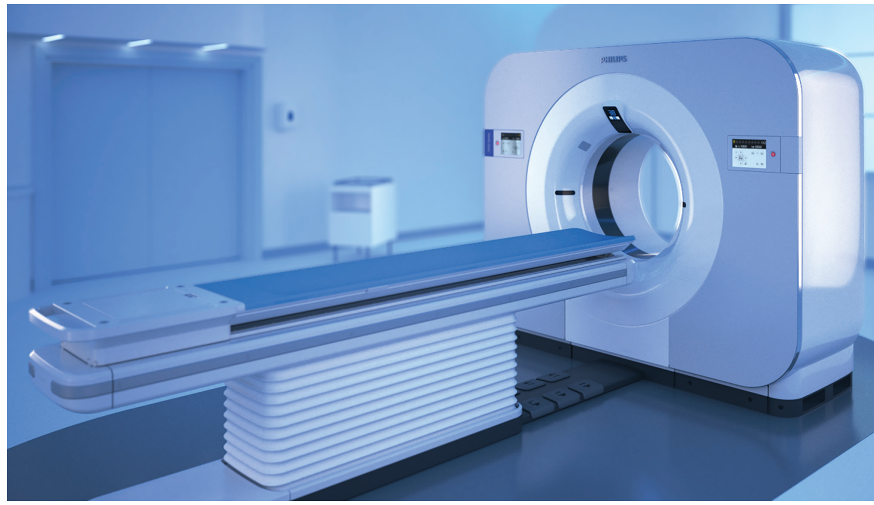
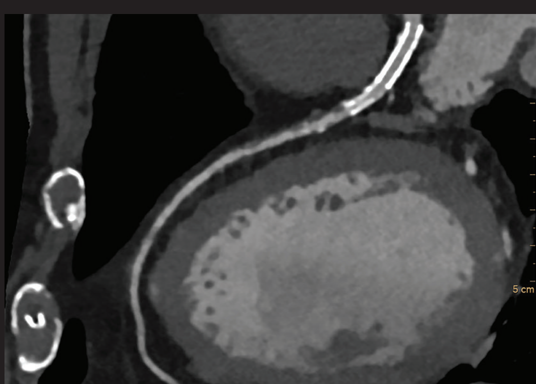
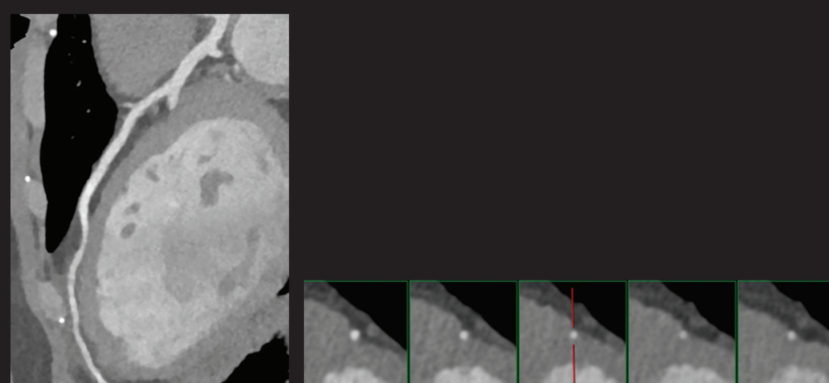


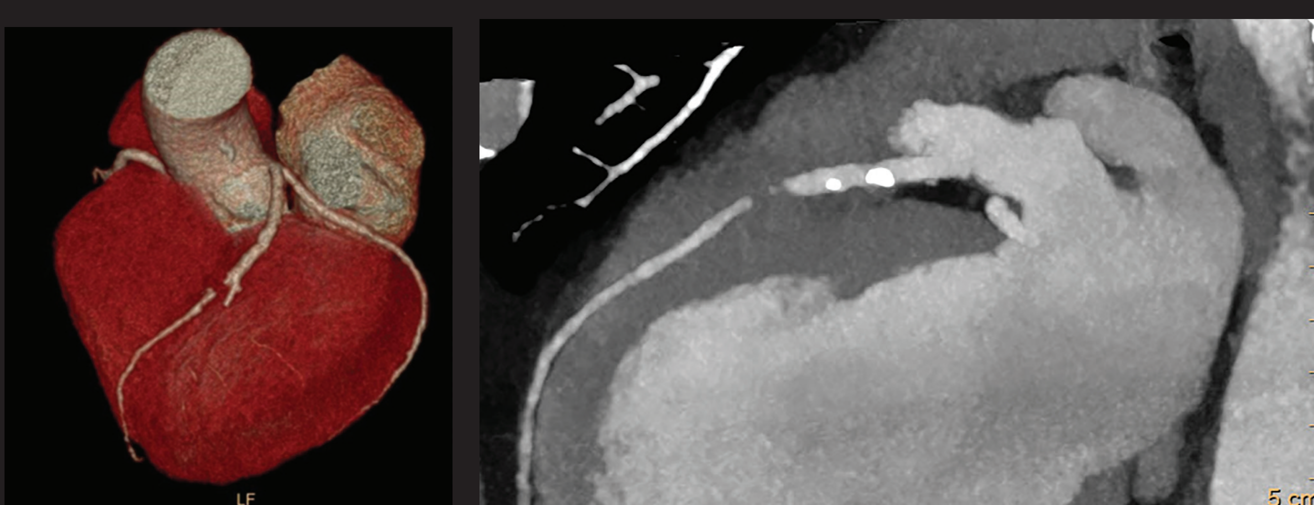
Figure 1 Cardiac cases from the scanner with 8 cm Z-axis coverage demonstrating cardiac pathology.



A Right coronary artery (RCA) curved multi-planar reconstruction (MPR) of a patent stent.



B Curved MPR and cross-sections of the LAD highlighting the intra-myocardial segment and demonstrating narrowing of the vessel caliber.



C Focal lesion in the mid LAD.

Dealing with challenging patients

Patients with high BMI

Obese patients often have an early stage of CAD and frequently require advanced cardiovascular assessment and intervention.[4] However, most non-invasive methods for cardiac imaging have a limited value in this group, despite obesity being a common and rapidly increasing risk factor for CAD.

A study performed by Segev et al.[8] on the 8 cm Z-axis scanner platform demonstrated that there is no significant difference in the subjective image quality between the obese (39 patients, BMI > 30 kg/m^2) and non-obese (29 patients, BMI < 30 kg/m^2) population. The average heart rate was 65 bpm in both groups. There were no significant differences between the enhancement (HU values) of left main and proximal right coronary artery in either group. There were no significant differences between signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) between the two groups, with noise being marginally higher in the obese group. The non-assessable coronary segments between the two groups were shown to be < 1%, with image quality preserved in obese patients. This study shows that the scanner, with its 8 cm coverage, has the ability to scan challenging cohorts without any degradation in overall image quality.

In contrast, a study by Yoneyama et al.[9] investigated the impact of image acquisition settings and patient characteristics on image quality and radiation dose for coronary angiography by 320-row CT (Aquilion ONE). Sixty-five subjects (41 men, 24 women) were included in the study to test the adequacy of the computed tomography angiography (CTA) acquisition protocol. Tube current, exposure window and number of cardiac beats per acquisition were adjusted according to subjects' gender, heart rate and BMI. Subjects with normal BMI had significantly better image quality than overweight and obese subjects (optimal image quality: normal 100.0%; overweight 56.0%; obese 30.8%; P<0.001).

64-slice CCTA has decreased accuracy in obese patients[8], and standard dual-source CCTA also showed decrease in specificity and positive predictive value in patients with BMI > 26 kg/m^2.[8] Improvements in image quality can be obtained on a dual-source scanner, but at higher radiation dose levels.

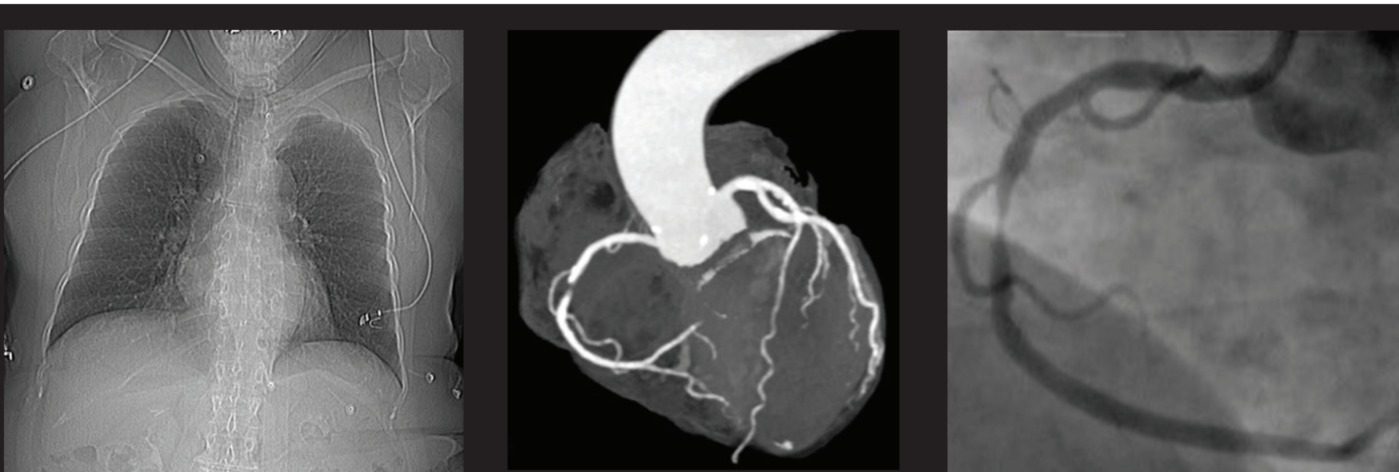


Figure 2 Bariatric patient (BMI 50) with a non-calcified plaque in the RCA confirmed on angiography, scanned using Step & Shoot Cardiac and Philips IMR. **Scan parameters:** 100 kVp, 327 mAs, $CTDI_{vol}$ 17 mGy, DLP 211 mGy*cm

Patients with irregular and higher heart rate

CCTA has been shown to provide high diagnostic quality imaging in patients with normal sinus rhythm. However, challenges in patients with atrial fibrillation had remained because of the difficulty in synchronizing an irregular heart beat with table gantry movement, which often leads to severe motion artifacts in images. A system with 8 cm Z-axis coverage and advanced cardiovascular tools can handle patients with arrhythmia and higher heart rates.

The Society of Cardiovascular Computed Tomography recommends the use of beta-blockers depending on the requirement as indicated by scanner, patient factors and indication for imaging. A target heart rate of 60 bpm or less is usually appropriate for CCTA. A single low-dose of oral beta blockade should be considered to reduce heart rate variability for patients presenting with low resting heart rates. While patients presenting with resting heart rates of < 60 bpm do not require beta blockade for heart rate reduction, many advocate that a low dose of metoprolol is helpful to reduce heart rate variability and improve image quality.

Considering the current guidelines, several studies have evaluated the image quality of CCTA scans on patients with higher heart rates.

A study by Chen et al.[10] demonstrated no significant difference in image quality in patients with arrhythmia versus regular sinus rhythm using the 8 cm Z-axis detector system. The study found that 99.7% and 100% of all segments were of sufficient quality for diagnostic assessment in patients with atrial fibrillation and normal sinus rhythm, respectively. This demonstrated the potential of using this scanner for CCTA in an atrial fibrillation patient group using an appropriate reconstruction timing window.

A study by Wang et al.[11] showed no significant differences in sensitivity and specificity of assessable segments in patients with higher heart rates (HR > 90 bpm) compared to patients with low heart rates (HR < 75 bpm).

A total of 100 patients underwent CCTA and invasive coronary angiography, with intervals between the two methods of 3 to 15 days (average, 8 days). HR during the CT scans ranged between 39 and 107 bpm. Patients were divided into three groups based on HR: low HR (n=40 patients; HR < 75 bpm); moderate HR (n=35 patients; 75 ≤ HR < 90 bpm); and high HR (n=25; HR ≥ 90 bpm). As shown in Table 2, the system demonstrated excellent diagnostic performance for the detection and rule-out of CAD.

Heart rate group	Sensitivity (%)	Specificity (%)
Low HR (n=40 patients; HR <75 bpm)	95	98.4
Moderate HR (n=35; 75≤ HR <90 bpm)	93.7	96
High HR (n=25; HR ≥90 bpm)	92.2	97.6

Table 2 Sensitivity and specificity by heart rate in the detection and rule-out of CAD using 8cm Z-axis detector system

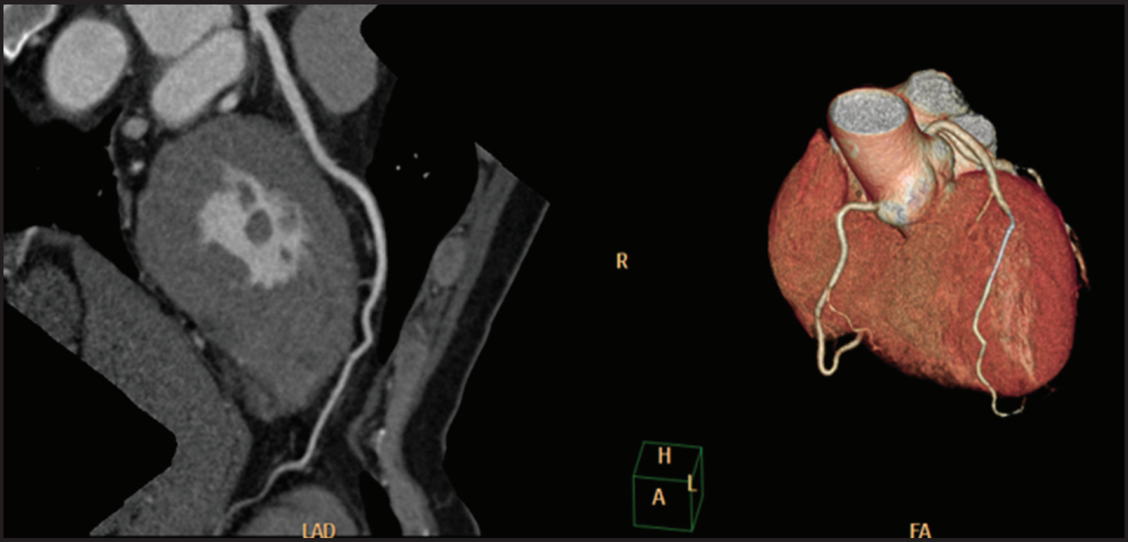


Figure 3A A coronary CCTA scan performed on a patient with a mean heart rate of 117 bpm revealed both the RCA and LAD to be normal.

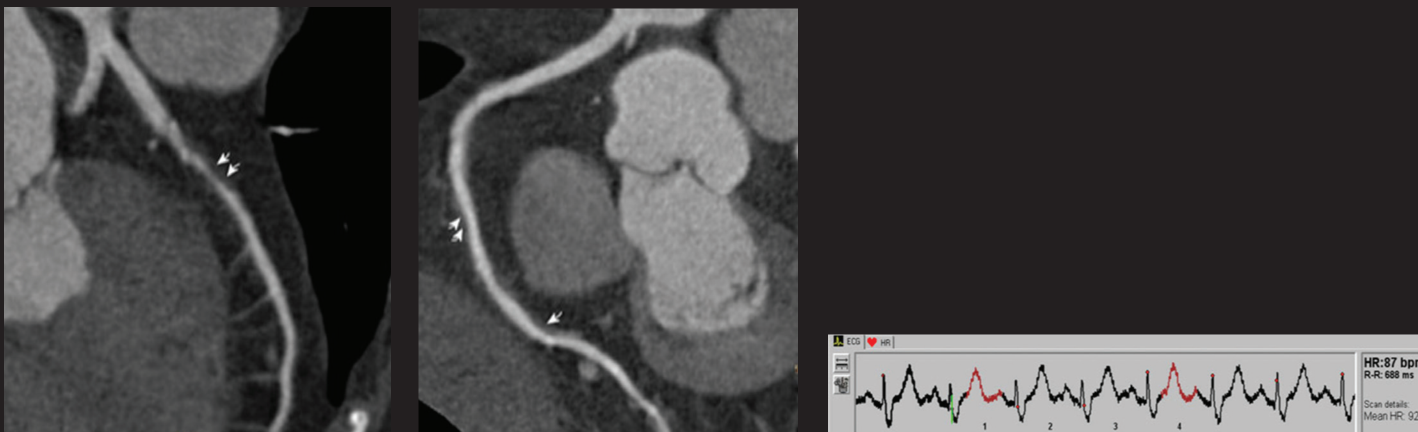


Figure 3B Non-calcified plaque identified in both the RCA and LAD on a patient with a mean heart rate of 92 bpm and scanned using Step & Shoot Cardiac with scan triggered at end-systolic phase.

Radiation dose

With the introduction of several technological advancements over the years, whether it is prospectively gated axial CCTA exams or the introduction of iterative reconstruction techniques, the radiation dose on CCTA exams has decreased significantly. Results from the Prospective Multicenter Study On Radiation Dose Estimates Of Cardiac CT Angiography In Daily Practice (PROTECTION) III demonstrated a 69% reduction in estimated radiation dose using prospectively ECG-triggered axial scanning as compared with retrospectively ECG-gated helical scanning. The 8 cm Z-axis coverage system was included in the trial and demonstrated that the dose from Philips CT was lower than most of the competitors.[12]

Conclusion

A CT system with 8 cm Z-axis coverage features technology that has demonstrated excellent diagnostic performance, with the ability to provide diagnostic CAD in a wide variety of challenging patient cohorts, such as patients with atrial fibrillation, high BMI and high heart rates.

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