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Diagnostic Accuracy of 320-Row CT and Challenging Case Scenarios

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Introduction

Computed tomography coronary angiography (CTA) is an emerging non-invasive tool for detecting significant coronary artery disease (CAD). With the introduction of 320-row CTA, with 320 simultaneous detector rows each 0.5 mm wide, the non-invasive evaluation of the entire heart in a single heartbeat and volume has become possible (Figure 1). While previous helical and step-and-shoot 64-row CT systems have a craniocaudal coverage of 3.2 cm per gantry rotation, 320-row CTA allows the volumetric coverage of up to 16 cm per scanner rotation (Figure 2). Volumetric scanning in combination with prospective ECG triggering enables image acquisition during a small portion of a single cardiac cycle, thus allowing for single heartbeat image acquisition. Due to fast image acquisition in a single volume, CT examination may be performed at low contrast and low radiation doses.

Diagnostic performance

Recent studies have determined excellent diagnostic performance of 320-row CTA in the evaluation of significant CAD (defined as ≥ 50 % luminal narrowing). A study by Dewey et al, evaluating 30 patients with an intermediate pre-test likelihood of CAD, reported sensitivity, negativity, positive and negative predictive values of 100, 94, 92 and 100 %, respectively, on a patient basis[2]. These findings were confirmed in a study assessing 64 patients using 320-row CTA[2]. Furthermore, excellent diagnostic accuracy of this technique in the evaluation of stenosis ≥ 70 % luminal narrowing was reported[3]. Accordingly, due to the high negative predictive value, this technique is particularly useful to rule out significant CAD in patients with a low to intermediate pre-test likelihood. In case CTA results are normal, the patient may be safely discharged, at a low contrast and radiation dose. Figure 3 illustrates the use of 320-row CTA to exclude significant stenosis in a patient with suspected CAD. Furthermore, the sensitivity and negative predictive value of 100 % show that this technique is not only suitable for the exclusion of CAD, but may also be useful for the diagnosis of significant stenosis as it is very unlikely to miss severe CAD. Figure 4 shows an example of 320-row CTA, identifying the presence of severe CAD.

320-row CTA in clinical practice

With the introduction of wide-detector CTA, such as 320-row CTA, volumetric image acquisition has become possible, thus reducing time of image acquisition, time of breath-hold and contrast doses. Furthermore, using a volumetric imaging technique, the need for helical oversampling, observed in helical scanning approaches, is eliminated, thus reducing radiation exposure, while maintaining image quality and diagnostic performance. Moreover, patient-adapted scanning protocols allow for

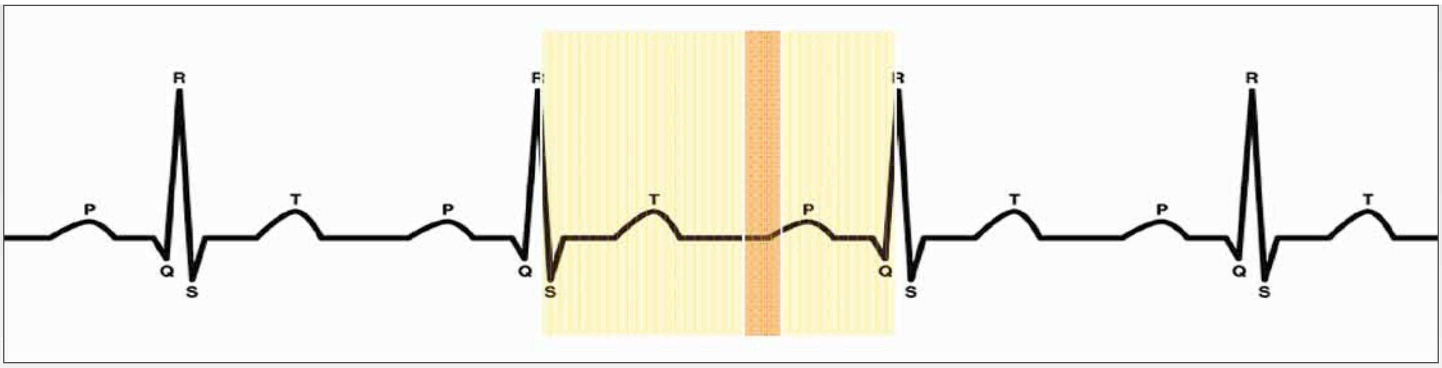

Fig. 1: Volumetric 320-row CTA enables image acquisition in a single R-R interval. Using prospective ECG triggering, image acquisition is performed during a small, pre-defined portion of the R-R interval (red bar).

the evaluation of more challenging patients with good diagnostic accuracy.

Patient-adapted scanning approaches

320-row CTA allows for a patient-adapted scanning approach, enabling image acquisition of the heart with good image quality, even in more challenging patients, such as patients with elevated heart rates or unexpected arrhythmias.

Elevated heart rate

Using 320-row CTA, single heartbeat imaging is performed in patients with low heart rates (heart rate below 65 bpm). Nevertheless, it is important to note that also in patients with elevated heart rate image acquisition may be performed at good image quality. At elevated heart rate above 65 bpm, image acquisition is performed during multiple cardiac cycles and multi-segmental image reconstruction is performed. As compared to half-segment reconstruction, used in scans acquired during a single cardiac cycle, multi-segment reconstruction improves temporal resolution, thereby improving image quality. As a result, good image quality may be attained in patients with elevated heart rates. Figure 5 shows an example of 320-row CTA of excellent image quality in a patient with persistent elevated heart rate despite beta-blocker administration.

Arrhythmia rejection protocol

Importantly, even in patients with irregular heart rates, such as patients with cardiac arrhythmias, image acquisition of the coronary arteries is possible with this technique, using an arrhythmia rejection protocol[4]. When a scheduled R-R interval for image acquisition is abnormally short due to an R wave appearing prior to completion of imaging, such a protocol asks the system to reject this beat and to image the next R-R interval (Figure 6). Accordingly, even in patients with irregular heart rates good image quality of the coronaries is obtained at acceptable radiation doses. Recent data suggest that 320-row CTA indeed allows the evaluation of patients with atrial fibrillation, showing good CTA image quality in this patient population[5]. Figure 7 shows an example of a CT scan which was performed in a patient with an irregular heart rate demonstrating good image quality despite irregular heart rate during image acquisition.

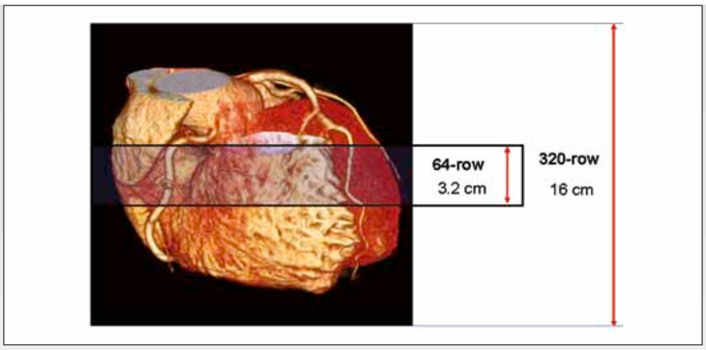

Fig. 2: 320-row CTA, with 320 simultaneous detector rows each 0.5 mm wide allows for a maximum of 16 cm volumetric coverage, enabling image acquisition of the heart in a single gantry rotation (Photo: courtesy of Toshiba Medical Systems).

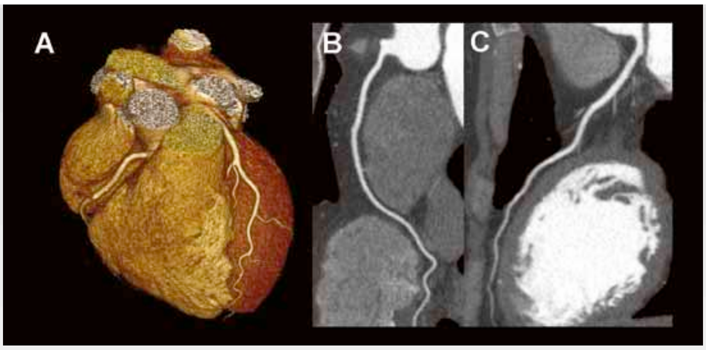

Fig. 3: Single heartbeat 320-row CTA in a 39 year old female with atypical chest pain and with positive family history for CAD. CTA ruled out the presence of CAD and the patient was safely discharged. Panel A shows a three-dimensional volume rendered reconstruction of the heart. Panel B shows a normal right coronary artery. Panel C shows a normal left anterior descending coronary artery.

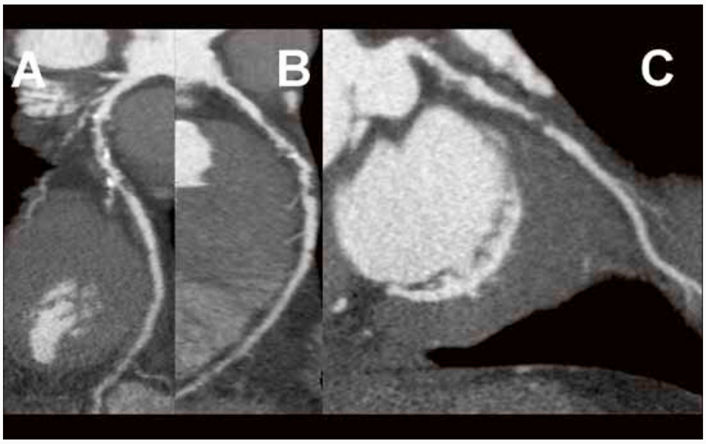

Fig. 4: 320-row CTA of a 64 year old male with no previous cardiac history, presenting to the emergency department with unstable chest pain. ECG showed no abnormalities and troponin levels were normal. Curved multiplanar reformations revealing significant stenosis in the left anterior descending coronary artery (panels A and B) and left circumflex coronary artery (panel C).

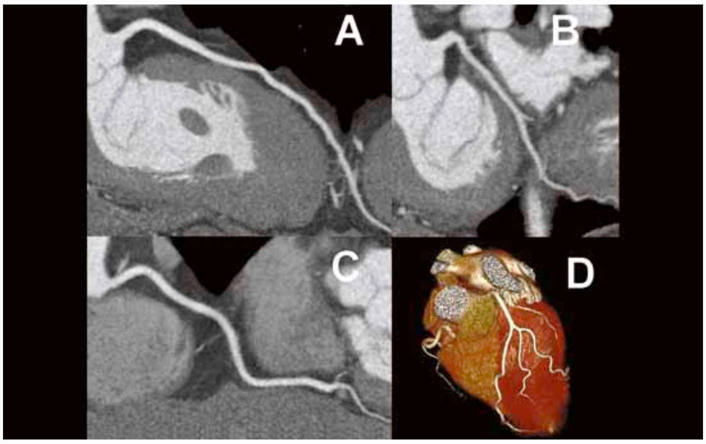

Fig. 5: 320-row CTA of excellent image quality in a patient with an elevated heart rate, showing normal coronary arteries. Despite beta-blockers, heart rate remained 75 bpm during breath-hold. Panel A, B and C show the curved multiplanar reformations of a normal left coronary artery, left circumflex coronary artery and right coronary artery, respectively. Panel D shows a three-dimensional volume rendered reconstruction of the heart, with normal coronary arteries.

Patients with a history of revascularization

Recently, the diagnostic performance of 320-row CTA in the assessment of coronary in-stent restenosis was assessed. In a group of 53 patients, with a total of 89 stents, sensitivity, specificity, positive and negative predictive values of 100, 81, 58 and 100 %, respectively were shown[6]. Although the positive predictive value remained relatively low, the high negative predictive value showed that 320-row CTA has a high capacity for the exclusion of significant in-stent restenosis. Importantly, this study also showed that, in contrast to most studies performed using 64-row CTA, no significant effect of heart rate on CTA image quality was observed. This is most likely due to the fact that in patients with an elevated heart rate (a heart rate above 65 bpm) CTA image acquisition is performed during multiple cardiac cycles. Subsequently, multi-segment reconstructions may be performed, still yielding diagnostic image CTA image quality even at increased heart rates. However, it is important to note that the diagnostic accuracy in small stents (<3 mm in diameter) and stents with thick struts (>140 µm) was decreased. These data imply that this modality may be useful for the evaluation of in-stent restenosis in carefully selected patients.

Also in the evaluation of patients with a history of coronary artery bypass grafting, CTA may allow evaluation of graft disease, as well as native coronary arteries and distal runoff vessels with good diagnostic accuracy[7]. Although studies addressing the diagnostic accuracy of 320-row CTA in the evaluation of coronary artery bypass grafts are currently not available, previous studies using 64-row CTA have reported diagnostic accuracies ranging between 90 and 95 %[8]. Figure 8 shows an example of CTA in a patient with a history of coronary artery bypass grafting. Volumetric 320-row CTA in patients with previous coronary artery bypass grafting gives an immediate overview of anatomy and patency of bypass grafts and native coronary arteries, as well as distal runoff vessels.

Simultaneous imaging of anatomy and perfusion

Volumetric CTA allows simultaneous imaging of anatomy and perfusion in a single examination. Myocardial perfusion imaging of the entire heart may be performed, resulting in full cardiac coverage with homogenous attenuation of the myocardium.

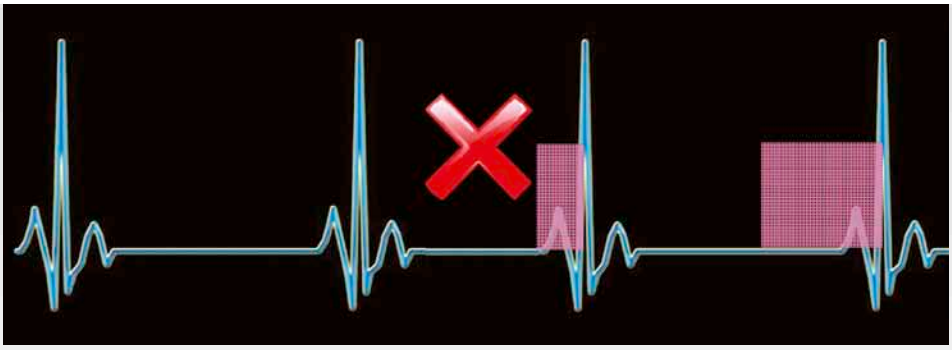

Fig. 6: Arrhythmia rejection protocol allows CTA image acquisition in patients with irregular heart rate (Photo: courtesy of Toshiba Medical Systems).

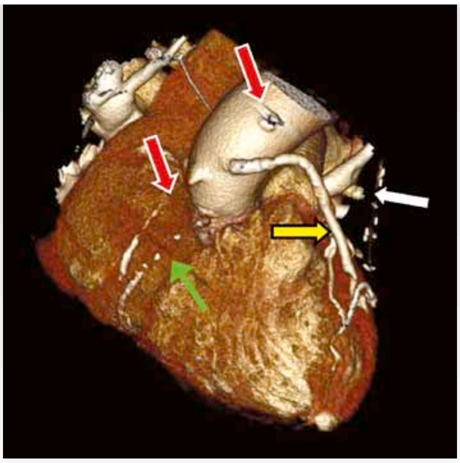

Fig. 8: Single volume 320-row CTA providing an immediate overview of anatomy and patency of coronary artery bypass grafts and native vessels in a patient with previous coronary artery bypass grafting. Two occluded venous bypass grafts to the right coronary artery (red arrows), an occluded arterial (LIMA) graft to the left anterior descending coronary artery (white arrow), an occluded right coronary artery (green arrow) and a patent sequential venous graft to the left anterior descending coronary artery and first diagonal branch are observed. Definitions: LIMA: left internal mammary artery

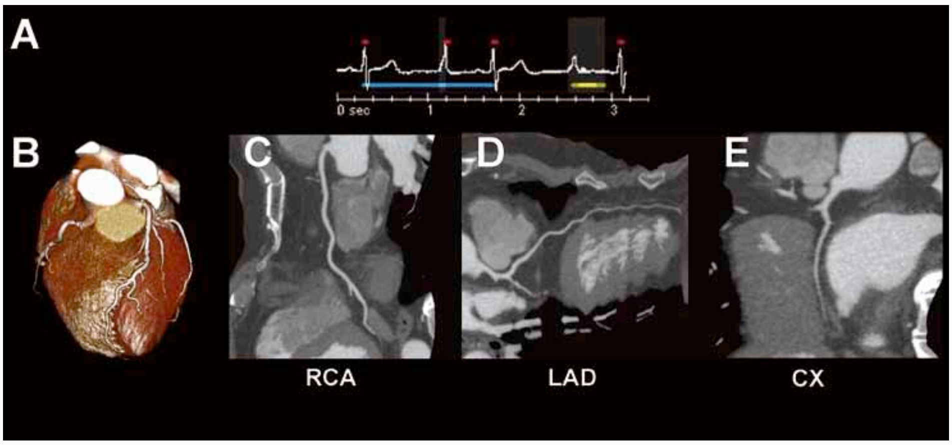

Fig. 7: Arrhythmia rejection protocol resulting in good image quality in a patient with irregular heart rate during image acquisition. Panel A shows the ECG during image acquisition of a patient referred for 320-row CTA. The scheduled R-R interval for image acquisition is abnormally short, as the R wave appears prior to completion of imaging. The system rejects the abnormally short beat (blue) and images a next R-R interval (yellow). Panel B shows a three-dimensional volume rendered reconstruction of the heart. Panels B, C and E illustrate curved multiplanar reformations of normal coronary arteries. Definitions: CX: left circumflex coronary artery; LAD: left anterior descending coronary artery; RCA: right coronary artery.

Using this approach, the combined anatomical and perfusion imaging may be performed in a single investigation, allowing the detection of CAD causing perfusion abnormalities[9].

Limitations

Although 320-row CTA allows for fast image acquisition at low contrast and low radiation doses in patients with previous revascularization, CT is also associated with several limitations. Firstly, CT is inherently associated with patient radiation exposure. However, novel imaging techniques, such as prospective ECG triggering and volumetric imaging, have reduced radiation exposure. Second, in patients with surgical clips, extensive coronary calcifications or small stents or thick stent struts, the positive predictive value is decreased. Therefore, careful patient selection is important. Although it is important to note that this technique is most suitable for the exclusion of CAD in patients with a low to intermediate pre-test likelihood, in selected cases CTA may aid the diagnosis of patients with known CAD, such as patients with prior CABG in whom graft anatomy and patency are lacking. Lastly, in all patients referred for CTA, heart rate reduction remains important to reduce radiation exposure and optimize image quality.

Conclusion

Novel 320-row CTA allows for a volumetric scanning approach, offering excellent diagnostic performance in the evaluation of CAD. As image acquisition is performed in a single heartbeat or volume, this technique enables fast image acquisition with short breath-hold at low contrast and low radiation doses. Moreover, due to the volumetric imaging approach, step-artefacts are eliminated. Furthermore, this technique allows for the simultaneous imaging of anatomy and perfusion.

Due to patient-adapted scan protocols, this modality enables evaluation of CAD in a variety of patients. High diagnostic accuracy has been reported for single heartbeat imaging in patients with suspected CAD. However, also in patients with elevated heart rate, multi-segment reconstructions may still yield good image quality. Even in patients with irregular heart rates due to cardiac arrhythmias such as atrial fibrillation, good image quality may be achieved using an arrhythmia rejection protocol. Furthermore, good diagnostic accuracy of 320-row CTA has been determined for the evaluation of patients with a history of revascularization such as the evaluation of in-stent restenosis. Last, the presence of graft anatomy and graft disease may be determined using volumetric CTA.

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