Radiation Dose Reduction Strategies in Coronary CTA

Travis Corbett, R.T.(R)(CT)(MR)

Coronary computed tomography angiography (CTA) is a noninvasive method of imaging the heart to aid in the diagnosis of coronary artery disease (CAD).[1-3] The widespread availability and high diagnostic accuracy of CT scanners has made CTA an important tool in detecting CAD.[1-3] However, this imaging method introduces the risk of increased radiation in comparison to conventional angiography.[3] This article explores ways to reduce radiation dose in CTA, including use of a lower kilovoltage peak (kVp) setting, prospective gating methods instead of retrospective gating methods, and an iterative reconstruction technique.[1-3]

Coronary CTA vs Conventional Angiography

Although CTA and conventional angiography both can detect and diagnose CAD, each has advantages and limitations.[4] The primary strength of CTA is that it is a noninvasive method of imaging the heart.[4] It also offers the ability to resolve a 0.3% difference in adjacent structures, compared to the 2% that conventional angiography resolves, which means CTA offers substantial contrast resolution improvement compared to conventional angiography.[4] However, conventional angiography offers superior temporal resolution, which is approximately 17 ms to 33 ms, compared to CTA, which is approximately 165 ms for single-source CT systems and 83 ms for dual-source CT systems.[4] Other benefits of conventional angiography include increased spatial resolution and superior resolution, which generally is why it is preferred to CTA in patients who have a resting heart rate of higher than 75 bpm.[4]

Average Radiation Dose and Typical Scan Parameters

The average radiation dose with CTA ranges from 15 mSv to 21 mSv when performed without electrocardiogram pulsing and approximately 9 mSv when performed with electrocardiogram pulsing, which refers to the amount of time the tube is active during the scan.[3] The difference in radiation dose is because electrocardiogram pulsing modulates the tube current (milliamperage) during the scan, using the maximum amount of tube current during the most useful part of the R-R interval (the interval from 1 R peak on the electrocardiogram to the next R peak; represents the entire cardiac cycle), and the tube current is lowered during the rest of the cardiac cycle.[3,4] To put this into perspective, the average conventional angiography study of the coronary arteries results in a mean radiation dose of approximately 6 mSv.[3] Although scan parameters vary between facilities, patients, and vendors, a typical CTA protocol is approximately[4]:

- 120 kVp
- 200 mA to 400 mA
- a small scan field of view
- the thinnest slice thickness available

The scan covers approximately 12 mm above the origin of the left main coronary artery to approximately 9 mm below the cardiac apex.[4]

kVp as a Dose Reduction Tool

Lowering kVp can lower the radiation dose associated with CTA; however, it also can increase image noise and is, therefore, better suited for use on average-sized or smaller patients (ie, body mass index $< 30 \text{ kg/m}^2$).[4,5] In a study by Hausleiter et al, each of the 400 patients with a body mass index of less than 30 kg/m^2 underwent CTA.[5] Of the patients, 202 were scanned at 100 kVp, and the remaining 198 were scanned at 120 kVp.[5] The study found that the image quality between the groups was similar, but the group scanned at 100 kVp had a 31% reduction in dose length product compared to the group scanned at 120 kVp.[5] Other studies demonstrated similar findings, showing that reduced kVp in average-sized or smaller patients is a viable tool for lowering radiation dose in CTA.[4]

Retrospective vs Prospective Gating

Cardiac gating is used during coronary artery CTA to monitor the patient's heart rate and allow the CT scanner to reconstruct images during the most useful parts of the cardiac cycle, reducing the amount of motion in the image.[4] There are 2 types of cardiac gating that commonly are used in coronary artery CTA.[4] Retrospective gating is the most common method employed in CTA.[4] In this method, the x-ray tube is active throughout the cardiac cycle, which gives facilities more freedom when reconstructing the images, but delivers a higher radiation dose rate.[4] Prospective gating is another method of cardiac gating during CTA and is a form of axial, or *step-and-shoot*, scanning in which the tube is active only during a certain predetermined point in the cardiac cycle.[4] The point at which the tube is active varies based on the patient's heart rate at the time of scanning, but typically is 60% to 80% of the R-R interval. Patients who have a slower heart rate ($<$ 60 bpm) are closer to 60%, and patients who have a faster heart rate ($>$ 70 bpm) are closer to 80%.[4]

A benefit of prospective gating is that it reduces the radiation dose associated with CTA.[1,4] In a study by Arnoldi et al, patients who were scanned with prospective gating techniques received an average effective dose of approximately 3 mSv, whereas those who were scanned with a retrospective gating technique received an effective dose of approximately 9 mSv. Prospective gating reduced the 67% of the radiation dose.[3] However, prospective gating might not be effective for patients whose heart rates exceed 70 bpm because those patients might need the additional imaging data produced during retrospective gating to reconstruct a set of diagnostic images.[3,4] In addition, ejection fraction, valve motion, and myocardial function cannot be evaluated with prospective gating techniques.[4]

Iterative Reconstruction

The traditional method for image reconstruction in CT, known as *filtered back projection*, uses data generated from multiple angles to produce an image.[4] Because this method of image reconstruction introduces noise into the image, the tube current needs to be increased.[4] Iterative reconstruction is another method of image reconstruction, which typically is blended with filtered back projection, and uses statistical models to reduce the amount of noise compared to filtered back projection.[4] Hou et al found that a 63% reduction in effective dose can be achieved when using iterative reconstruction techniques in CTA.[2] Improved contrast and spatial resolution are additional benefits of iterative reconstruction.[4] Most vendors offer several stations that set the level of iterative reconstruction used, and using a level that is too high can result in images with altered appearances and reduced diagnostic quality.[2]

Conclusion

As advances in CT technology continue, coronary CTA is becoming an increasingly valuable diagnostic tool, despite the relatively high radiation dose it delivers compared to conventional angiography. However, 3 methods to lower radiation dose are to use an appropriate kVp, scan with prospective gating instead of retrospective gating, and use an iterative reconstruction technique for image reconstruction. Although each of these methods substantially decreases radiation dose, each also comes with drawbacks. Each method can be used independently or in conjunction with one another, and no 1 method is preferred over the others.

Travis Corbett, R.T.(R)(CT)(MR), is a computed tomography department supervisor for North Alabama

Medical Center in Florence. He graduated from Wallace State Community College's Radiologic Technology Program in 2014 and recently graduated from Mercy College of Ohio's Bachelor of Science in Medical Imaging program.

References

1. Stocker TJ, Deseive S, Leipsic J, et al; PROTECTION VI investigators. Reduction in radiation exposure in cardiovascular computed tomography imaging: results from the PROspective multicenter registry on radiaTion dose Estimates of cardiac CT angIOgraphy iN daily practice in 2017 (PROTECTION VI). *Eur Heart J*. 2018;39(41):3715-3723. doi:10.1093/eurheartj/ehy546
2. Hou Y, Xu S, Guo W, Vembar M, Guo Q. The optimal dose reduction level using iterative reconstruction with prospective ECG-triggered coronary CTA using 256-slice MDCT. *Eur J Radiol*. 2012;81(12):3905-3911. doi:10.1016/j.ejrad.2012.06.022
3. Arnoldi E, Johnson TR, Rist C, et al. Adequate image quality with reduced radiation dose in prospectively triggered coronary CTA compared with retrospective techniques. *Eur Radiol*. 2009;19(9):2147-2155. doi:10.1007/s00330-009-1411-9
4. Abramson S. *The Complete Guide to Cardiac CT*. New York, NY: McGraw-Hill; 2012.
5. Hausleiter J, Martinoff S, Hadamitzky M, et al. Image quality and radiation exposure with a low tube voltage protocol for coronary CT angiography results of the PROTECTION II Trial. *JACC Cardiovasc Imaging*. 2010;3(11):1113-1123. doi:10.1016/j.jcmg.2010.08.016