

320-row CT: does beat-to-beat motion of the coronary arteries affect image quality?

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With its high negative predictive value, cardiac computed tomography, CT is optimally suited for the evaluation of patients with a low or intermediate risk of coronary disease, allowing the non-invasive exclusion of coronary disease at relatively low cost and risk [1–35]. Nevertheless, the acceptable radiation dose remains an important issue in cardiac CT. On one hand, using higher radiation exposure levels may put patients at unnecessary risk of radiation damage [36–48]. On the other hand, a too low radiation dose may result in a high level of image noise and therefore in a poor image quality [49–59].

Recently, 320-row CT angiography has been introduced in the clinical arena [60–62]. Whole-heart 320-row CT angiography avoids exposure-intensive overscanning, offering the potential to significantly reduce radiation dose. Apart from reducing radiation dose, temporal resolution is crucial for good image quality in CT coronary angiography. A high temporal resolution yields less image degradation due to coronary artery motion. In order to improve temporal resolution, data from two or three cardiac cycles may

be used when available for image reconstruction which is called multi-segment reconstruction. When the gantry rotation time is 350 ms, temporal resolution of multi-segment reconstruction images can be theoretically improved to 88 or 58 ms. The reconstruction algorithm that uses data from a single heart beat is called half-scan reconstruction algorithm. Although half-scan reconstruction in single heart beat imaging may result in lower radiation exposure than multi-segment reconstruction in multiple heart-beats imaging, image quality of patients with more rapid heart rate might be impaired due to the lower temporal resolution of the half-scan reconstruction algorithm. On the other hand, multi-segment reconstruction imaging improves temporal resolution, but image quality could be degraded by beat-to-beat movement of the coronary arteries. Until now, there have been no studies that directly investigated the relationship between coronary artery displacement and image quality in consecutive heart beat imaging using 320-row CT angiography.

In the current issue of the *International Journal of Cardiovascular Imaging*, Tomizawa et al. [63] investigated the influence of the beat-to-beat movement of the coronary arteries on image quality of multi-segment reconstruction images. The authors studied 18 patients (mean age 67 years) who underwent coronary CT coronary angiography using prospectively ECG-triggered 320-detector row CT angiography. The displacement and diameter of coronary artery segments for each of the identified

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nine landmarks was recorded. The motion ratio was calculated as the division of the displacement by the diameter. Image quality was graded on a four-point scale. When the image quality score of at least one of the two half-scan reconstruction images was better than the score of multi-segment reconstruction image, the half-scan reconstruction image was considered better than the multi-segment reconstruction image (group A). On the other hand, image quality of multi-segment reconstruction image was considered better than that of the half-scan reconstruction images when the image quality score of the multi-segment reconstruction image was better than the scores of both half-scan reconstruction images (group C). Otherwise, image quality was considered equivalent (group B). The authors demonstrated that the correlation between multi-segment reconstruction image quality score and the motion ratio showed stronger negative correlation than that between multi-segment reconstruction image quality score and the displacement. The average motion ratio for segments in which half-scan reconstruction image quality was better than multi-segment reconstruction image quality (29.1%, group A) was higher than that for segments in which multi-segment reconstruction image quality was better than half-scan reconstruction image quality (16%, group C). The motion ratio in group C was lower than 25%. Difference in image quality scores of the half-scan reconstruction images was more frequent in group A than in the remaining segments in which the motion ratio was significantly lower than 25% (16.7 vs. 66%). It was concluded that the motion ratio is a better index than displacement to evaluate the influence of the motion of coronary arteries on multi-segment reconstruction image quality. These data imply that smaller coronary artery segments are more susceptible to image degradation due to cardiac motion than larger coronary artery segments. Multi-segment reconstruction images would be impaired by a motion ratio above 25%. Image impairment of one of the half-scan reconstruction images might also impair multi-segment reconstruction images.

The study warrants several comments. First, it is important to note that, although multi-segment reconstruction improves temporal resolution, multiple heart beat imaging significantly increases patient radiation exposure as compared to single heart beat imaging using 320-row CT. As a result, multiple heart beat imaging should be carefully weighed

against the increase in radiation dose, and single-heart beat image acquisition should be strived for. In this setting, pre-scan heart rate control using beta-blocking agents is important [64]. Nevertheless, whenever available, multi-segment reconstructions may enhance image quality. Second, as also recognized by the authors, a restricted number of landmarks on the coronary arteries were used. However, motion of coronary arteries is non-uniform and characterized by changes in the magnitude and direction of vessel motion. Next, a substantial number of patients (33%) received beta-blocking agents; therefore actual coronary movements may have been underestimated. Patients with various degrees of cardiac disease were included. The patients were either suspected of having coronary artery disease ($n = 13$) or had a history of myocardial infarction with recurrent angina ($n = 5$). The degree of impairment in ventricular motion caused by a previously sustained myocardial infarction might result in deviations of the motion patterns in deformed ventricles. The study was subjected to two-dimensional analysis, and coronary artery segments were assessed on a single plane. As coronary arteries move in a three-dimensional way, the data do not show the exact movement of each segment. Third, the time resolution for multi-segment reconstruction images was not analyzed. By using two-beat multi-segment reconstruction, temporal resolution oscillates between one-half and one-fourth of the gantry rotation time, depending on heart rate. Finally, we would add that the study is limited by the small patient population. As a result, further studies into the relationship between coronary artery motion and image quality of multi-segment reconstruction images is warranted.

Several studies have addressed the effects of coronary artery motion on image quality using CT angiography [65–69]. Law et al. [67] studied 252 patients with a 256-row multi-detector CT with a 270-ms gantry rotation system in performing CT coronary angiograms using both prospectively triggered step-and-shoot and retrospectively gated helical techniques. No significant differences in image quality between prospectively triggered step-and-shoot and retrospectively gated helical techniques were observed. Although providing similar image quality as retrospectively gated helical techniques, prospectively triggered step-and-shoot was associated with a 62% reduction in effective radiation dose.

Goetti et al. [68] assessed the effect of systolic data acquisition for electrocardiography-triggered high-pitch CT on motion artifacts of coronary arteries in 80 patients with high heart rates. It was shown that a systolic acquisition window for high-pitch dual-source CTA in patients with high heart rates ≥ 70 beats/min significantly improves coronary artery image quality at a low radiation dose. In an interesting study, Uehara et al. [69] evaluated coronary arterial image quality on 320-row CT scans in 92 subjects with chronic atrial fibrillation ($n = 46$) versus normal sinus rhythm ($n = 46$). The overall length of visualized coronary arteries, motion artifact-free length, and image quality using a five-point scale showed values equal to or slightly lower in chronic atrial fibrillation than in normal sinus rhythm, but the absolute values were quite acceptable in both groups. By contrast, the study by Tomizawa et al. [63] only included patients in whom the heart rate variability was less than 2%. As a result, future research is required to investigate the relationship between the motion ratio and heart rate variability.

In conclusion, Tomizawa et al. [63] clearly showed that the motion ratio is a better index than displacement to evaluate the influence of the motion of coronary arteries on multi-segment reconstruction image quality. Multi-segment reconstruction images could be impaired by a motion ratio above 25%. Image impairment of one of the half-scan reconstruction images might also impair multi-segment reconstruction images. However, there was no significant relationship between motion ratio and heart rate, body mass index, and total body weight. Further investigation is necessary to indicate the factors which may influence coronary motion in consecutive heart beats.

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