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Heart-rate dependent improvement in image quality and diagnostic accuracy of coronary computed tomographic angiography by novel intracycle motion correction algorithm

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ABSTRACT

Background: To determine the effect of a novel intracycle motion correction algorithm (MCA) on diagnostic accuracy of coronary computed tomographic angiography.
Methods: Coronary artery phantom models were scanned at static and heart rate (HR) simulation of 60–100 beat/min and reconstructed with a conventional algorithm and MCA.
Results: Among 144 coronary segments, improvements in image interpretability, quality, and diagnostic accuracy by MCA were observed for HRs of 80 and 100 ($P<.05$ for all), but not for HR of 60.
Conclusion: Novel intracycle MCA demonstrates improved HR-dependent image interpretability, and quality and accuracy, particularly at higher HRs.

1. Introduction

Since the introduction of 64-slice multidetector computed tomography, cardiac computed tomographic angiography (CCTA) has been widely utilized as a noninvasive diagnostic modality for visualizing the coronary arteries to detect coronary artery disease (CAD). Although the diagnostic accuracy of CCTA for detection of obstructive CAD has been validated by numerous retrospective and prospective trials, most of the available study samples consisted of selecting patients whose heart rate (HR) was deemed optimal (i.e., <60–80 beats per minute [bpm]) for CCTA [1–5]. Further still, the diagnostic accuracy of CCTA is known to be diminished by elevations in the HR due to motion artifact, and while efforts have been made to minimize this limitation (i.e., increasing gantry rotational speed and use of dual sources scanners), motion artifact still remains a major challenge for the diagnostic interpretability of CCTA [6,7].

More recently, there have been additional attempts to mitigate motion artifact by using a novel intracycle motion correction reconstruction algorithm (MCA) [8]. MCA adjusts the motion of coronary arteries and defines the actual vessel location by using the adjacent cardiac phase information [9]. To date, however, few studies have evaluated the beneficial effects of MCA, and how it might augment image quality and diagnostic accuracy beyond current conventional image reconstruction strategies are sparse [10]. Therefore, in this experimental study using a coronary motion phantom model, we systematically investigated the efficacy of a novel MCA for enhancing the image quality and diagnostic performance according to varying levels of HR.

2. Materials and methods

2.1. Ex vivo motion phantom model and CTA scanning protocol

We utilized a quantitative pulsating coronary phantom (Mocomo, Fuyo Corp, Japan) for the analysis (Fig. 1A). The simulated coronary artery tubes were attached to two small and large rings, permitting the tubes to move in a 15-degree rotational angle with *z*-axis directional movement by 20 mm. The simulated coronary artery tubes were constructed with diameters of 3 and 4 mm. Each tube comprised six segments: segments 1 and 6 without stenosis; segments 5, 3, and 4 with 25%, 50%, and 75% noncalcified plaque stenosis, respectively; and segment 2 displaying 50% stenosis with calcified plaque (Fig. 1B and C). Tubes were filled with iodixanol 270 mg/ml (GE Healthcare, Princeton, NJ, USA) diluted with deionized water at a concentration of 20:1, resulting in target attenuation of approximately 350 Hounsfield units. We positioned the phantom on the multidetector computed tomography (CT) table to move into the scan field of view during image acquisition.

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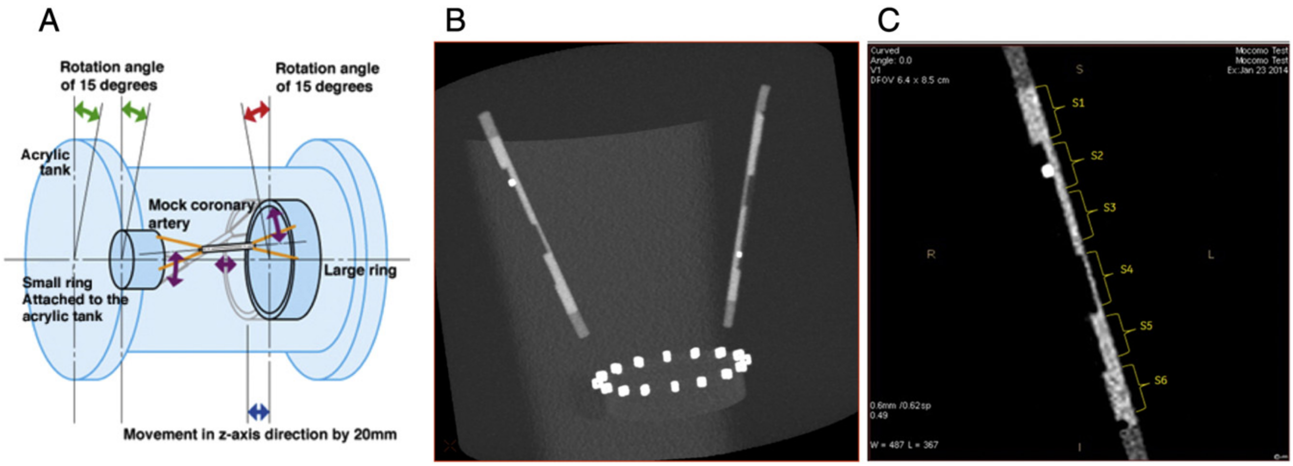

Fig. 1. Schematic figure (A) and maximum intensity projection image (B) with an example image of segment information (C) of a coronary motion phantom.

The stepwise processes for the image acquisition, reconstruction, and interpretation were summarized in Fig. 2. The phantom model was scanned by a multidetector row CT scanner (Revolution CT; GE Healthcare). Scanner parameters included 256×0.625 collimation, and detector coverage was 160 mm, with a reconstruction slice thickness of 0.6 mm. All acquisitions happened within one heart cycle and the padding required was 80 ms. Gantry rotation time was 0.28 s per rotation and the maximum tube current was 455 mA with a tube voltage of 120 kVp. The initial scan was conducted without motion for reference, followed by motion that simulated HR values of 60, 80, and 100 bpm.

2.2. Image reconstruction and analysis

All images were reconstructed using conventional algorithm (CA) and MCA techniques (SnapShot Freeze; GE Healthcare) using both 45% and 75% of the R-R intervals (Fig. 3). Two experienced independent readers, who were masked to the tube size, stenosis, and reconstruction methods, evaluated image quality and measured the diameter and area of the inner lumen. Image qualities were evaluated using a 4-point Likert scale on a per-segment level: 1=noninterpretable; 2=suboptimal but interpretable; 3=good but mild motion; and 4=excellent. Motion artifacts were scored using a 5-point Likert scale on a per-

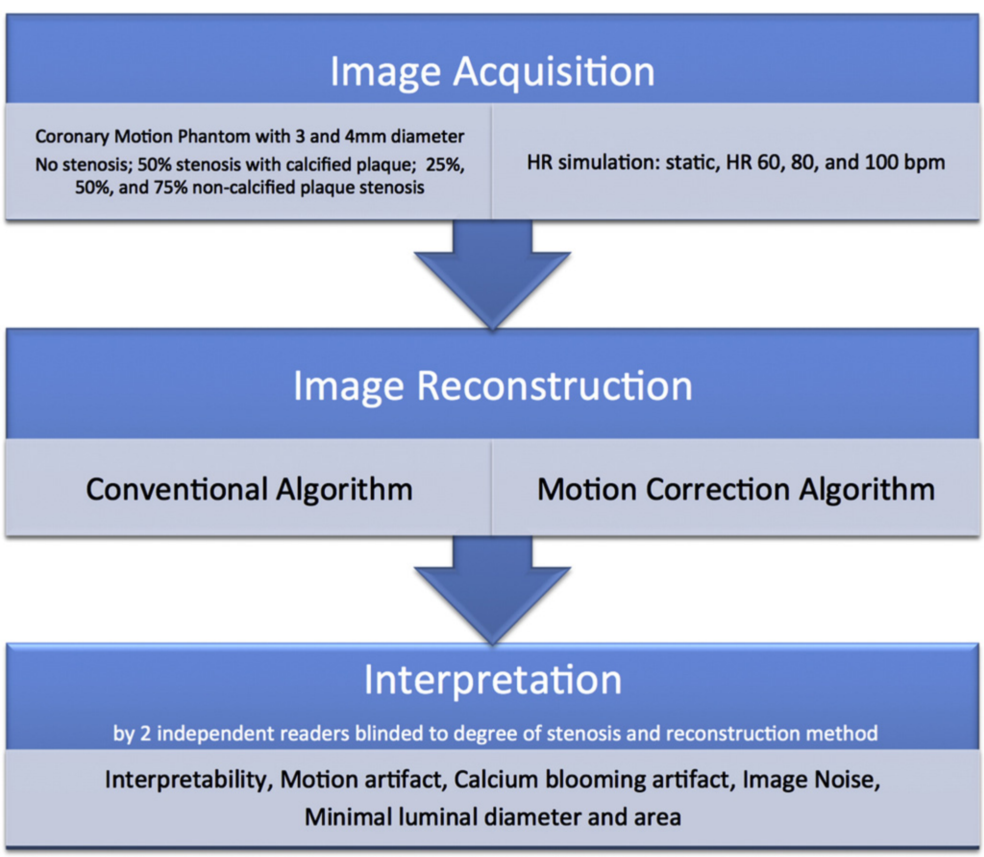

Fig. 2. Summary of image acquisition, reconstruction, and interpretation process.