Optimized Subtraction Coronary CT Angiography Protocol for Clinical Use with Short Breath-Holding Time—Initial Experience

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Abbreviations and Acronyms

CCTA
coronary computed tomography angiography

CAD
coronary artery disease

Rationale and Objectives: Subtraction coronary computed tomography (CT) angiography (CCTA), which enables the removal of calcium and coronary stents from CCTA images, has been clinically introduced on a second-generation 320-row CT scanner. However, this technique for clinical use is not optimized. The long breath-holding time for two data acquisitions, which causes image misregistration and patient's discomfort, may limit the clinical availability of this subtraction technique.

Materials and Methods: This study received approval from the institutional review board; prior informed consent to participate was obtained from all patients. We performed subtraction CCTA of five patients using the test injection method and optimized the interval time between the first (pulmonary-arterial phase) and the second (coronary-arterial phase) scans to achieve robust subtraction. The patients' breath-holding times were recorded. We compared breath-holding times between our new protocol and previous study's protocol (estimated).

Results: Mean breath-holding time in our new protocol was 18.3 $\pm$ 3.4 seconds and that in previous protocol was 29.8 $\pm$ 3.6 seconds (difference in mean breath-holding time was 11.5 seconds). Misregistration artifacts were not shown in final subtraction CCTA images. These images improved luminal visualization in the calcified lesion.

Conclusions: Our test injection protocol can shorten the breath-holding time, which is helpful for successful subtraction CCTA imaging, potentially resulting in an increase of subtraction CCTA examinations in many institutions.

Key Words: Computed tomography; coronary CT angiography; contrast media; diagnosis.

A blooming artifact due to the presence of vascular calcium and/or coronary stents affects the evaluation of luminal stenosis by coronary computed tomography (CT) angiography (CCTA) (1). The appropriate use criteria 2010 reported that the usefulness of CCTA for coronary artery disease (CAD) detection is considered "uncertain" in patients with a calcium score of >400 Agatston units (2). The diagnosis of CAD in patients with a high calcium score on CCTA images remains challenging.

Recently, subtraction CCTA, a state-of-the-art technique that allows calcium to be subtracted from CCTA images, was clinically introduced on a second-generation 320-row CT scanner. Yoshioka et al. (3) and Tanaka et al. (4) assessed the clinical utility of subtraction CCTA and concluded that coronary calcium subtraction can improve the evaluation of calcified coronary segments in patients with suspected CAD.

To remove calcium from the images in CCTA, two CT data sets are required: one with and one without contrast enhancement in coronary arteries. Furthermore, to minimize misregistration artifacts between two CT data sets, two CT scans should be acquired in a single breath-hold. In the previous study (4), the first-phase scan (precontrast CT) was performed just before contrast injection, then the second-phase scan

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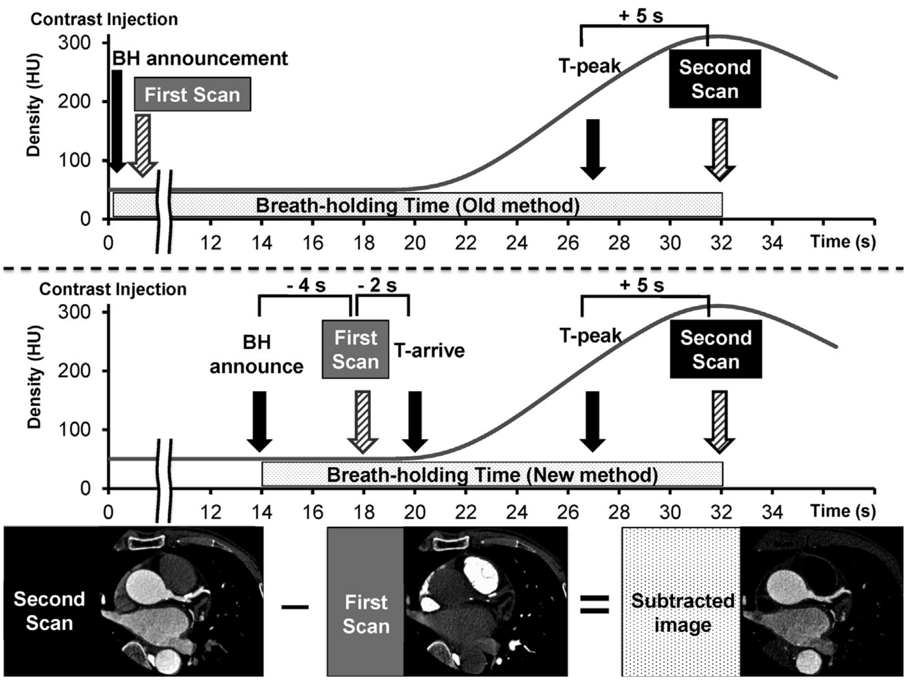

Figure 1. Overview of the test injection method for subtraction coronary computed tomography angiography (CCTA): For test injection, contrast arrival time (T-arrive) and peak enhancement time (T-peak) from the contrast injection are obtained on the basis of the time–density curve analysis. For subtraction CCTA (full injection), breath-holding starts from 6 seconds (margin time + announcement) before T-arrive to 5 seconds after T-peak, resulting in approximately 20 seconds of total breath-holding time (*top*). We estimated the breath-holding time in previous study protocol; the estimated breath-holding time was defined as the interval time between the start of injection of the contrast material and the second-phase scan. Subtraction CCTA can be produced by subtraction of the first scan from the second scan (*bottom*). HU, Hounsfield unit.

(CCTA) was performed at the peak of vascular enhancement; however, this subtraction CCTA protocol required a long interval between the first and the second scans (approximately 30–40 seconds). The long breath-holding time for two data acquisitions may limit the clinical availability of this subtraction technique because it may cause image misregistration and patient's discomfort. We hypothesized that the breath-holding time during subtraction CCTA can be shortened by determination of scan timings on the basis of time–density curve obtained by test injection method, resulting in an increase of subtraction CCTA examinations in many institutions. Here, we present our initial experience with the optimized protocol of data acquisition for subtraction CCTA.

MATERIALS AND METHODS

This study received approval from the institutional review board approval; prior informed consent to participate was obtained from all patients. Images of five patients (two male and three female, 70 ± 6 years) with suspected CAD were obtained using a second-generation 320 detector-row CT scanner (Aquilion ONE ViSION Edition; Toshiba Medical Systems, Otawara, Japan). Their average heart rate was 52 beats/minute, and the average total calcium score was 672 Agatston units.

The overview of our protocol is shown in Figure 1. Initially, a test injection scan was performed. A small amount of contrast material (8.0 mL) was delivered over 2 seconds, followed by the administration of 30 mL of saline solution delivered at the same injection rate as the contrast material (4.0 mL/s). To construct a time–density curve, real-time serial monitoring was started 10 seconds after injecting the contrast material. A region of interest was drawn inside the ascending aorta to generate an enhancement curve to show the time of contrast arrival in the ascending aorta. The contrast arrival time was determined when the attenuation value of the ascending aorta exceeded 50 Hounsfield units. The first-phase timing for CCTA was determined as 2 seconds (margin time) before the contrast arrival time in the ascending aorta; the second-phase timing was 5 seconds after peak enhancement in the ascending aorta at the test injection scan. On the basis of time–density curve analysis, we determined that the optimal scan timing for the first- and the second-phase scans.

For subtraction CCTA, the contrast material (300 mgI/kg) was delivered over 12 seconds, followed by the administration of 30 mL of saline solution delivered at the same injection rate as the contrast material. The announcement of breath-hold was made 4 seconds before starting the first scan.

A dedicated algorithm (Volumetric CT Digital Subtraction Angiography; Toshiba Medical Systems) automatically subtracted calcification from the CCTA data set, while retaining images of both soft tissue and contrast-enhanced coronary arteries.

The five patients' breath-holding times were recorded. In addition, we estimated the breath-holding time in previous study protocol (4); the estimated breath-holding time was defined as the interval time between the start of injection of the contrast material and the second-phase scan (coronary-arterial phase; Fig 1). We compared breath-holding time between our new protocol and the previous protocol.

RESULTS

Mean breath-holding time in our new protocol was 18.3 ± 3.4 seconds and that in previous protocol was