Modified Subtraction Coronary CT Angiography Method for Patients Unable to Perform Long Breath-Holds:

A Preliminary Study

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Rationale and Objectives: Severe calcifications of the coronary arteries are still a major challenge in coronary computed tomography (CT) angiography (CCTA). Subtraction CCTA using a 320-detector row CT scanner has recently been introduced for patients with severe calcifications. However, the conventional subtraction CCTA method requires a long breath-holding time of approximately 20–40 seconds. This is a major problem in clinical practice because many patients may not be able to perform such a long breath-hold. We explored a modified subtraction CCTA method with a short breath-holding time to overcome this problem.

Materials and Methods: This study was approved by our institutional review board, and all patients gave written informed consent. A total of 12 patients with a coronary calcium score of >400 were enrolled in this study. All patients were unable to hold their breath for more than 20 seconds. Modified subtraction CCTA was performed using the bolus-tracking method. The acquisition protocol was adjusted so that the mask scan was acquired 10 seconds after the postcontrast scan during a single breath-hold. The subtraction image was obtained by subtracting the mask image data from the postcontrast image data. The breath-holding times were recorded. Enhancement of the coronary arteries in the subtraction images was assessed. Subjective image quality was evaluated in a total of 32 segments using a 4-point scale.

Results: The mean breath-holding time was 12.8 ± 0.8 seconds (range, 12–14 seconds). The average CT number in the coronary arteries was 288.6 ± 80.5 Hounsfield units (HU) in the subtraction images. Average image quality was significantly increased from 2.1 ± 0.9 with conventional CCTA to 3.1 ± 0.7 with subtraction CCTA ($P < 0.001$). With subtraction CCTA, the number of non-diagnostic segments was significantly reduced from 53% to 19% ($P = 0.001$).

Conclusions: This preliminary study has shown that our modified subtraction CCTA method allows the breath-holding time to be shortened to <15 seconds. This may substantially improve the success rate of subtraction CCTA by reducing artifacts and allowing this technique to be applied to patients who are unable to perform a long breath-hold.

Key Words: Computed tomography; coronary CT angiography; coronary artery calcification; subtraction.

INTRODUCTION

One of the major challenges in coronary computed tomography (CT) angiography (CCTA) is the presence of severe calcifications in the coronary arteries, which frequently reduces diagnostic accuracy and may even make it impossible to evaluate the presence of stenosis (1–3).

Subtraction CCTA has recently been introduced using first- and second-generation 320-detector row CT technology (4–7). In subtraction CCTA, scanning is performed twice to acquire both a precontrast (mask image) and a postcontrast image

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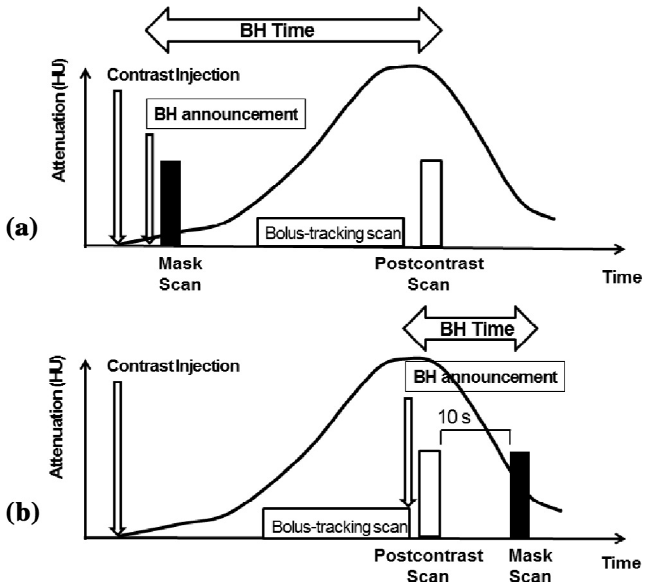

Figure 1. Overview of the conventional and modified subtraction coronary computed tomography angiography (CCTA) methods. **(a)** Conventional subtraction CCTA: The bolus-tracking technique is used. The mask image is obtained immediately after the breath-hold announcement is issued. Subsequently, the postcontrast scan is triggered when the CT number in the ascending aorta reaches 150 Hounsfield units (HU). The breath-holding (BH) time is the interval between the end of the breath-hold announcement and the end of the postcontrast scan. **(b)** Modified subtraction CCTA: The bolus-tracking technique is used. The postcontrast scan is triggered when the CT number in the ascending aorta reaches 150 HU. The mask scan is acquired 10 seconds after the postcontrast scan. The BH time is the interval between the end of the breath-hold announcement and the end of the mask scan.

datasets. To minimize misregistration artifacts due to differences in the breath-hold position, the two scans should preferably be acquired during a single breath-hold (4). In the conventional subtraction CCTA protocol, the scan for obtaining the mask image (mask scan) is acquired immediately after contrast injection, with the postcontrast scan acquired after the contrast medium has reached the coronary arteries (Fig 1a). In this protocol, a long breath-holding time of approximately 20–40 seconds is required between the mask and the postcontrast scans (4–7).

The long breath-holding time required in the conventional subtraction CCTA protocol is a major problem because it excludes patients who are unable to perform a long breath-hold. We hypothesized that the breath-holding time for subtraction CCTA could be shortened by acquiring the mask scan after the postcontrast scan (Fig 1b) rather than before (Fig 1a). As a result, this modified approach may allow imaging of patients who are ineligible for conventional subtraction CCTA because of limited breath-hold capability. We report our initial experience with this modified acquisition protocol for subtraction CCTA in patients unable to perform a long breath-hold.

MATERIALS AND METHODS

From patients clinically referred for CCTA because of suspected or known coronary artery disease, 12 consecutive patients (5 men and 7 women, average age 71.5 ± 7.7 years) with a coronary calcium score (Agatston score) of >400 and unable to perform a breath-hold of >20 seconds were enrolled in the current feasibility study. The coronary calcium-scoring scan had been performed before CCTA. All 12 patients were excluded from conventional subtraction CCTA because of their limited breath-hold capability. Exclusion criteria were known allergy to iodinated contrast media, estimated glomerular filtration rate of <45 mL/min/1.73 m^2, arrhythmia, previous cardiac surgery, evidence of acute coronary syndrome, aortic stenosis, intolerance to beta-blockers, and body mass index >40 kg/m^2.

The study was approved by our institutional review board, and all patients gave written informed consent.

Axial imaging was performed using a second-generation 320-detector row CT scanner (Aquilion One ViSION Edition; Toshiba Medical Systems, Otawara, Japan). All patients were imaged using prospective electrocardiographic (ECG) gating. The tube voltage was 120 kV, and the target noise for the tube current was set at 28 Hounsfield units (HU). The acquisition phase window (padding) was 65–80% of the RR interval for patients with a heart rate of ≤60 bpm and 35–80% of the RR interval for patients with a heart rate of >60 bpm. The coverage of both the postcontrast and mask scan was up to 16 cm. Images were reconstructed with a 512×512 matrix and 0.5-mm slice thickness using kernel FC44 with iterative reconstruction (Adaptive Iterative Dose Reduction 3D [AIDR 3D]; Toshiba Medical Systems) at the standard setting. Before scanning, 8 patients with a heart rate greater than 65 beats/minute received intravenous beta-blockade (landiolol hydrochloride; Ono Pharmaceutical, Osaka, Japan; 0.125 mg/kg).

Modified subtraction CCTA was performed with iodinated contrast agent (iohexol 350; Daiichi Sankyo Company, Tokyo, Japan) injected intravenously at a rate of $0.07 \times$ body weight (kg) mL/s in 9 seconds, followed by a 30-mL saline chaser bolus. The bolus-tracking method was used to determine the postcontrast scan start time. When the CT number in the ascending aorta reached 150 HU, a breath-hold announcement was issued automatically. The duration of the breath-hold announcement was 4 seconds in Japanese, which is identical to the default setting in English, but could be different in other languages. Two seconds after the end of the announcement, a prospective ECG-gated scan at 0.275 seconds/rotation was triggered by the R wave to acquire the postcontrast image. Then, the mask scan (same protocol as the postcontrast scan) was acquired 10 seconds after the postcontrast scan during the same breath-hold. Therefore, the breath-holding time in this method extended from the end of the breath-hold announcement to the end of the mask scan (Fig 1b). The breath-holding time was recorded for all patients.