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Effect of saline flush on enhancement of proximal and distal segments using 320-row coronary CT angiography

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ABSTRACT

Objective: To investigate the effect of saline flush on coronary CT angiography of proximal, middle, and distal coronary artery segments, using 320-row CT, and to compare two injection duration protocols as to amount of contrast in the right heart chambers.
Methods: This retrospective study was approved by the local ethics committee, and the requirement for informed consent to participate in this study was waived. The final study group included 108 patients who underwent coronary CT angiography. The first 36 patients received contrast medium without saline flush (group 1); the next 36 patients received contrast medium for 14 s and saline flush (group 2); the last 36 patients received contrast medium for 12 s and saline flush (group 3). The CT number, noise, contrast-to-noise ratio (CNR), and number of segments with a CT number greater than 325 Hounsfield units (HU) were recorded for proximal, middle, and distal segments.
Results: The CT numbers and the CNR in groups 2 and 3 were significantly higher than that in group 1 ($p < 0.005$); the difference between groups 2 and 3 was not significant. The proportion of segments greater than 325 HU improved with saline flush ($p < 0.05$), with a larger improvement in the distal segments.
Conclusions: Saline flush improves enhancement and CNR of coronary arteries, particularly of distal segments, in coronary CT angiography using 320-row CT. An average contrast medium injection of 44 mL was feasible using a saline flush.

1. Introduction

Wide-area coverage multidetector CT scanners, such as the 256-row and 320-row CT scanners, have enabled volumetric imaging of the entire heart within a single cardiac cycle in coronary CT angiography (CTA) [1]. The rapid scan time for these advanced scanners has enabled a reduction of the contrast medium volume, which could benefit patients with renal impairment and decrease the risk of contrast-induced nephropathy.

A saline flush is helpful when a small volume of contrast medium is used because it pushes the last of the injected contrast medium into the central blood volume, making use of contrast medium that would have otherwise remained in the injection tubing and peripheral veins [2]. A saline flush also reduces streak artifacts attributable to dense contrast medium from the superior vena cava and right ventricle that can limit diagnosis of the right coronary artery [2–5]. In previous studies, a saline flush allowed the use of significantly less contrast medium while maintaining the coronary enhancement obtained with a larger volume of contrast medium [3,6]. However, the coronary enhancement analyses in those studies were limited to the proximal segments, and the effect of a saline flush on distal segments remains unknown. Other study [7] showed that low contrast dose protocol was feasible in 320-row coronary CT angiography, but they investigated patients with normal body weight and low heart rate.

The objective of our study was to investigate the effect of saline flush on coronary CT angiography of proximal, middle, and distal coronary artery segments, using 320-row CT, and to compare two injection duration protocols as to amount of contrast in the right heart chambers.

2. Materials and methods

The present retrospective study was approved by the local ethics committee and the requirement for informed consent to participate in the present study was waived.

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2.1. Patients

The records of 140 consecutive patients who underwent coronary CTA from December 2011 to May 2012 were retrospectively examined. Patients with several risk factors for coronary artery disease, chest pain and/or dyspnea, or abnormal results on electrocardiography, echocardiography, or a treadmill test were included in our study. The exclusion criteria were as follows: post-coronary artery bypass graft surgery ($n = 10$); simultaneous right ventricular evaluation ($n = 2$); intense calcification or severe stenoses in all three coronary arteries ($n = 11$); presence of a shunt ($n = 4$); contrast medium injection from the left side ($n = 1$); leak of contrast medium ($n = 3$); and a left ventricular assist device ($n = 1$). The final study group included 108 patients. The first 36 patients received contrast medium without saline flush (group 1); the next 36 patients received contrast medium for 14 s and saline flush (group 2); the last 36 patients received contrast medium for 12 s and saline flush (group 3). Saline flush during CT was prohibited for risk management which was allowed only for coronary CTA from February 2012. The contrast medium injected in the antecubital vein arrives to the heart in approximately 10 s [2]. The tail of the injected contrast medium of the 14 s protocol (group 2) would arrive to the heart at 24 s, which is a typical time for scanning. We postulated that reducing the injection time for 2 s (group 3) would avoid the contrast medium to remain in the right ventricle while maintaining the contrast enhancement of the coronary arteries.

2.2. CT data acquisition

All examinations were performed using a 320-row CT scanner (Aquilion ONE Dynamic Volume CT; Toshiba, Tochigi, Japan) with prospectively electrocardiogram-triggered axial scans. The scanning parameters were as follows: detector configuration, 320 mm × 0.5 mm; rotation time, 350, 375, or 400 ms depending on the heart rate; tube potential, 120 kV; tube current, 200–450 mA depending on the body weight.

The patients received 22.2 mg I/kg/s of iopamidol (370 mg I/mL; Iopamiron 370; Bayer, Osaka, Japan). A 20- or 22-gauge catheter was placed in the right antecubital vein. The first 36 patients received contrast medium for 14 s without saline flush (group 1); the next 36 patients received contrast medium for 14 s with a 30-mL saline flush (group 2); the last 36 patients received contrast medium for 12 s with a 30-mL saline flush (group 3). As a result, the patients in groups 1 and 2 received 0.84 mL/kg while the patients in group 3 received 0.72 mL/kg of contrast medium. The injection speed of the saline chaser was the same as that of the contrast medium. When the body weight was over 85 kg, a constant amount of contrast medium was used (71 mL in groups 1 and 2, 61 mL in group 3) with an injection speed of 5.1 mL/s. A bolus tracking method was used to determine the scan timing. Patients were instructed to breathe in and hold their breath when the left ventricle reached 90 HU. The scan started when the descending aorta reached 260 HU. Compared with the single threshold protocol, the double threshold protocol with a shorter delay time for coronary CTA yielded more consistent aortic enhancement with reduced interpatient variability [8]. The time when the diagnostic scan started was recorded.

Twenty-two patients received an oral β-blocker as part of baseline medication, and an oral β-blocker (20–40 mg of metoprolol or propranolol) was administered to 36 outpatients with a heart rate of >65 beats per minute. The patients were told to take the medicine 2 h prior to CTA. No additional β-blocker was used when the heart rate was >65 beats per minute at the time of imaging. No patient had a contraindication to β-blockers, and no β-blocker side effects were observed or reported. All patients received 2.5 mg of isosorbide dinitrate sublingually (Nitorol; Eisai, Tokyo, Japan) before imaging.

For each patient, the phase with minimum artifacts was determined at the CT console using cardiac-phase search software (PhaseNavi). The reconstructed slice thickness was 0.50 mm, and the increment was 0.25 mm. For processing, images were transformed to a workstation (ZIO Station System; Ziosoft, Tokyo, Japan).

2.3. Objective data analysis

A single radiologist (NT) with 5 years of coronary CTA experience collected the values. Regions of interest (ROIs) for the proximal, middle, and distal segments (≥1.5 mm) of the right coronary, left anterior descending, and left circumflex arteries were drawn on a cross-sectional image. The average CT number (in HU) was recorded for each coronary segment using a circular ROI. The ROI was chosen to be as large as possible while carefully avoiding inclusion of the vessel wall to prevent partial volume effects (Fig. 1). An ROI was placed immediately next to the vessel contour on an axial image, and the average and standard deviation of the CT number were recorded (Fig. 1). The standard deviation of this ROI was defined as the noise of the coronary segment. The contrast-to-noise ratio (CNR) was calculated as the difference in the CT number between the lumen and connective tissue divided by the image noise. An ROI was also placed inside the right ventricle at the mid-ventricular level, and the average CT number was recorded. Cademartiri et al. [9] showed that intracoronary enhancement greater than 325 HU resulted in better diagnostic accuracy for the detection of coronary artery stenosis. The number of segments with a CT number greater than 325 HU was also recorded for the proximal, middle, and distal segments.

2.4. Subjective analysis of streak artifacts from the right ventricle

Streak artifacts on segment 2 of the right coronary artery were subjectively analyzed and rated by two cardiovascular readers with 5 years and 1 year of experience (NT and FS, respectively). The results were scored according to a 3-point scale: 0 – excellent, no artifact; 1 – acceptable, artifact present, but images are interpretable; and 2 – unable to evaluate, severe artifact makes interpretation impossible. When scores differed between the two readers, the final score was determined by consensus.

2.5. Statistical analysis

All statistical analyses were performed using JMP software (version 9.0.0; SAS, Cary, NC). Quantitative variables are expressed as means ± standard deviation, unless otherwise described. The difference in the CT number of the right ventricle was assessed by the Steel–Dwass test. Otherwise, continuous variables were tested by Tukey's honestly significant difference test. Categorical values were compared using the chi-squared (χ^2) test. A p-value <0.05 was deemed to indicate significance.

3. Results

The proportions of patients who received an oral β-blocker in groups 2 and 3 were significantly higher than that in group 1 ($p < 0.05$) (Table 1). The mean heart rate was significantly lower in group 3 compared with group 1 ($p < 0.01$) and group 2 ($p < 0.05$). The amount of contrast medium injected in group 3 was significantly less than that in group 1 ($p < 0.05$). No significant difference was noted in other patient demographics (Table 1). The average weight in this study was lower compared with the typical western population. The average times when the diagnostic scan started