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Influence of hemodynamic parameters on coronary artery attenuation with 320-detector coronary CT angiography

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ABSTRACT

Objectives: To investigate the relationship between cardiac output, end diastolic volume and the contrast enhancement in coronary CT angiography using 320-detector CT.
Materials and methods: A total of 38 patients underwent coronary CT angiography by using a 320-detector CT scanner (detector configuration, 320 × 0.5 mm). The attenuation value of the ascending aorta at the level of the orifice of the left main trunk was measured. The cardiac output (CO), end diastolic volume (EDV) and stroke volume (SV) were measured by echocardiography. The EDV was normalized to the body surface area (BSA). The total blood volume injected from the left ventricle from the beginning of the contrast agent injection to the time of image acquisition was determined to be the total injected blood volume (TIV), which is a product of SV and the number of heart beats from the initiation of contrast agent injection to the scan.
Results: There was a negative correlation between the attenuation of the ascending aorta and CO ($r = -0.44$, $P = 0.0053$). However, the negative correlation between the attenuation of the ascending aorta and TIV was stronger ($r = -0.52$, $P = 0.0007$). There was a negative correlation between the attenuation of the ascending aorta and EDV/BSA ($r = -0.45$, $P = 0.0039$).
Conclusion: In 320-detector CT, contrast enhancement in CCTA with a lesser amount of contrast medium decreases when cardiac output is high. Patients with larger EDV/BSA may also show decreased attenuation.

1. Introduction

Low attenuation plaque on the coronary artery wall is a risk factor for acute coronary syndrome [1]. In one study, plaque with attenuation lower than 30 Hounsfield units (HU) correlated well with lipid rich plaque on intravascular ultrasonography [2]. However, the attenuation of plaque changes with the opacity of the coronary arteries [3]. Thus, it is important to keep the attenuation within an appropriate range for coronary CT angiography (CCTA). It is difficult to differentiate between the lumen and calcified plaque when the attenuation of the lumen is too high. On the other hand, it is difficult to visualize stenoses or small coronary vessels when the attenuation of the lumen is too low [4]. For these reasons, attenuation of 300–350 HU is optimal for CCTA [5].

Patient-related factors such as body habitus and hemodynamic parameters as well as technique-related factors such as iodine dose, injection rate and injection duration contribute to aortic enhancement in CCTA [6–9]. In protocols in which the iodine dose was adjusted to the patient total body weight (TBW), the attenuation of the vascular lumen was too high in obese patients [6,8]. Yanaga et al. reported that protocols in which the dose was adjusted by estimated lean body weight or body surface area yielded more consistent enhancement [6,7]. However, interpatient variability in the attenuation persisted in those protocols. Patient-related factors other than body habitus, including cardiac output may be reasons for this variability [8]. According to the compartment model for contrast enhancement pharmacokinetics by Bae et al., patients with larger blood volume would result in lower opacification of arteries [10].

Previous studies have investigated the influence of hemodynamic parameters on contrast enhancement with 4-detector [11]

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and 64-detector [12] CT, but not with 320-detector CT using a lesser contrast agent. There have been no studies which showed relationship between the blood volume and the attenuation of the aorta. Thus, the purpose of this study was to investigate the relationship between cardiac output, blood volume and the contrast enhancement in CCTA using 320-detector CT. We used end diastolic volume as a parameter to represent the blood volume.

2. Materials and methods

The authors who were not employees of or consultants for Toshiba Medical Systems (Tokyo, Japan) had control of the inclusion of any data and information that might have presented a conflict of interest for another author (R.T.), who was an employee of Toshiba Medical Systems. This retrospective study was approved by the local ethics committee, and the requirement for informed consent to participate in this study was waived.

2.1. Patients

In a retrospectively review, the records of 46 consecutive patients (26 men, 18 women; mean age, 64.6 years ± 13.7; age range, 29–86 years; mean body weight, 63.9 kg ± 14.3, range 40–97 kg) who underwent CCTA and echocardiography during May to July of 2010 were examined. All patients had clinical indications for CCTA and provided written informed consent for the examination. The patients were either suspected of having coronary artery disease or had a history of myocardial infarction. As the duration of injection time was longer (≥17 s) for obese patients with TBW of more than 83 kg ($n = 6$) and for post coronary artery bypass graft patients ($n = 2$), these patients were excluded from the present study. The final study group included 38 patients (22 men, 16 women; mean age, 66.6 years ± 12.5; age range, 51–84 years; body weight, 59.7 kg ± 10.9, range 40–77 kg). CT exam was performed twice for one patient due to tachycardia, with a heart rate (HR) of 90 beats per minute (bpm), during the first exam: thus, a total of 39 exams were included in this study.

2.2. CT data acquisition and postprocessing

All examinations were performed by using a 320-detector CT scanner (Aquilion ONE Dynamic Volume CT, Toshiba, Tochigi, Japan) with prospective ECG gating axial scans. The parameters were as follows: detector configuration, 320 × 0.5 mm; gantry rotation time, 350, 375 or 400 ms depending on R-R time; tube potential, 120 kV; and tube current, from 270 mA to 550 mA depending on body habitus. Patients received 22.2 mgI/kgTBW/s of iopamidol 370 mgI/mL (Iopamiron 370: Bayer, Osaka, Japan, mean volume administered 50.0 mL ± 8.8; range, 33–64 mL) over 14 s. Bolus tracking in the ascending aorta was performed using a double threshold of 150 HU and 230 HU. Patients were assigned to breathe in and hold their breath after the first threshold. The scan started just after the second threshold. Tatsugami et al. [13] showed that CCTA protocol using a double threshold yielded more consistent aortic enhancement with reduced interpatient variability than protocol using a single threshold.

Five patients were receiving oral β-blocker as part of baseline medication. An oral β-blocker (40 mg of metoprolol) was administered to 20 outpatients with HRs higher than 65 bpm. The patients were assigned to take the medicine 2 h prior to the exam. No additional β-blocker was used when the HR was higher than 65 bpm at the time of the exam. There were no patients with contraindications to β-blockers, and there were no observed or reported side effects from β-blockers. All patients received 2.5 mg sublingual isosorbide dinitrate (Nitorol: Eisai, Tokyo, Japan) before imaging.

For each patient, the reconstruction phase with minimum artifact was determined at the CT console by using the cardiac-phase search software (Phase Navi). A half-scan reconstructed image using data from a single heart beat was used for evaluation. When two or more beats were scanned, the half-scan image for each heart beat was reconstructed.

2.3. CT data analysis

One radiologist (N.T.) with 2 years of experience with cardiac CT performed and collected all the measurements at the workstation.

The attenuation values were assessed on an axial plane. The attenuation value (in HU) of the ascending aorta at the level of the orifice of the left main trunk was measured by placing a circular region of interest on the contrast-enhanced half-scan reconstructed image. When two or more beats were scanned, the highest attenuation value was used for further analysis.

2.4. Measurements of hemodynamic parameters

The cardiac output (CO, mL/min), end diastolic volume (EDV, mL) and stroke volume (SV, mL/stroke) were measured by echocardiography. EDV was normalized to the body surface area (BSA) [14].

The HR was recorded on an electrocardiograph (IVY Model 3000: Chronos, Chiba, Japan) from the beginning of the contrast agent injection to the end of the exam. The number of heart beats from the initiation of contrast agent injection to the scan (HB) was recorded. The total blood volume injected from the left ventricle from the beginning of the contrast agent injection to the time of image acquisition was determined to be the total injected blood volume (TIV), which is a product of SV and HB.

2.5. Statistical analysis

All statistical analyses were performed using JMP software (version 8.0.2; SAS, Cary, NC). Quantitative variables were expressed as means ± standard deviation. Pearson correlation analysis was used to investigate the relationships between attenuation values of the ascending aorta and CO, TIV, and EDV/BSA. The significance level was adjusted using a Bonferroni correction to 0.05/3 = 0.017.

3. Results

CT was successfully performed on all patients without complications.

The mean SV, EDV and CO were 61.3 mL ± 14.0 (range, 37.0–89.6 mL), 92.8 mL ± 22.7 (range, 44.5–138.0 mL), and 4.1 L/min ± 1.2 (range, 2.1–7.3 L/min) respectively. The mean HR and HB during scanning were 65.7 bpm ± 11.5 (range, 56.3–94.8 bpm) and 27.1 beats ± 4.6 (range, 24–46 beats) respectively. The mean TIV was 1.7 L ± 0.6 (range, 1.0–3.1 L).

Mean attenuation of the ascending aorta was 460.9 HU ± 65.9 (range, 359.8–606.0 HU).

3.1. Hemodynamic parameters and the attenuation of the ascending aorta

There was a negative correlation between the attenuation of the ascending aorta and CO ($r = -0.44$, $P = 0.0053$) (Fig. 1A). However, the negative correlation between the attenuation of the ascending aorta and TIV was stronger ($r = -0.52$, $P = 0.0007$) (Fig. 1B).