Coronary Computed Tomographic Angiography at Low Concentration of Contrast Agent and Low Tube Voltage in Patients with Obesity: A Feasibility Study

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Rationale and Objectives: Using lower tube voltage can reduce the exposure to radiation and the dose of contrast agent. However, lower tube voltage is often linked to more noise and poor image quality, which create a need for more effective technology to resolve this problem. To explore the feasibility of coronary computed tomographic angiography (CCTA) in patients with obesity at low tube voltage (100 kV) and low contrast agent concentration (270 mg/mL) using iterative reconstruction.

Materials and Methods: A total of 48 patients with body mass index greater than 30 kg/m^2 were included and randomly divided into two groups. Group A received a traditional protocol (iopromide 370 mg/mL + 120 kV); group B received a protocol with low tube voltage (100 kV), low contrast agent concentration (270 mg/mL), and iterative reconstruction. The effective dose (ED), average attenuation values, signal-to-noise ratio (SNR), contrast-to-noise ratio (CNR), the figure of merit (FOM), image quality scores, and the total iodine intake were compared.

Results: No significant differences in average CT attenuations, SNR, CNR, and subjective scores were noticed between the two groups ($P > 0.05$), whereas the FOM of group B was significantly higher than that of group A. Effective radiation dose, total iodine, and iodine injection rate in group B were lower than those of group A ($P < 0.01$).

Conclusions: In patients with obesity, isotonic contrast agent with low iodine concentration and low-dose CCTA were feasible. Substantial reduction in radiation dose and the iodine intake could be achieved without compromising the image quality.

Key Words: Obesity; coronary vessels; tomography; X-ray computer; radiation dosage; contrast media.

INTRODUCTION

Currently, coronary computed tomographic angiography (CCTA) is being widely used in clinical practice with remarkable accuracy. However, the exposure to X-ray radiation and the risk of renal impairment associated with contrast agents are the main limitations (1,2). In recent years, rational use of radiation (as lower as reasonably achievable) has been recommended (3), and research on reducing the radiation dose while maintaining the diagnostic performance of CT scan has become a hot topic (4,5). Using lower tube voltage is an effective way to reduce the radiation dose. At the same time, decreasing the dose of contrast agent has also drawn attention as it can reduce the risk of contrast-induced nephropathy (CIN) (6). On the contrary, lower tube voltage is often linked to more noise and poor image quality. Therefore, iterative reconstruction (IR) technology was developed to reduce the image noises and improve image quality, thereby showing advantages over traditional filtered back projection (FBP) technology (7–9), which lays the foundation for the application of low concentrations of contrast agents. Recently, adaptive iterative dose reduction (AIDR) IR algorithm has been used in clinical practice. It compares the imaging data to a noise model based on statistics that takes into account the electronic and photon noise. This method can greatly improve the image reconstruction speed, reduce wax-like artifacts in the reconstructed image, and improve the SNR and the CNR (7–9).

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Obesity is closely associated with coronary artery disease (CAD), and it has a high degree of correlation with coronary artery calcification. In recent years, there has been a steady growth in the prevalence of obesity (10). On coronary artery examination in patients with obesity, increased noise and decreased image quality are often noticed due to the decreased X-ray penetration, which may even affect the diagnostic accuracy (11). The process of conducting a low-dose examination in patients with obesity is challenging. According to the International Steering Committee of Cardiovascular CT recommendations, while performing CCTA in patients weighing <85 kg or with a body mass index (BMI) of <30 kg/m^2, 100 kV tube voltage is preferred (12). Many previous reports have demonstrated the feasibility of low concentrations of contrast agents and low tube voltage applied to CCTA in patients with BMI < 30 kg/m^2 (9,13,14). In a recent study, a "double low" scanning protocol (low tube voltage/low iodine dose contrast agent) and the AIDR reconstruction algorithm were used for CCTA in patients with a BMI of 26–30 kg/m^2 (15). The results showed that the use of 320-row CT with a "double low" scanning protocol not only provided images of diagnostic quality, but also reduced both radiation dose and the iodine intake during scanning (15).

However, the usefulness of double low technology has not been demonstrated in patients with obesity with BMI > 30 kg/m^2. Therefore, in the present study, we tried to explore the feasibility of CCTA at low tube voltage (100 kV), using contrast agent with low iodine concentration (270 mgI/mL) in patients with obesity with BMI > 30 kg/m^2. Parameters including image quality, radiation dose, and total iodine intake were compared to the conventional CCTA protocols to explore the feasibility of the diagnosis of CAD in obese population.

MATERIALS AND METHODS

Patients

The current study was approved by the Hospital Ethics Committee, and the written informed consent was obtained from all the participants. In our hospital, from October 2014 to April 2015, 48 patients with obesity (including 36 males and 12 females) aged 36–87 (59 ± 12) years, with suspected CAD (BMI ≥ 30 kg/m^2) (16) were included and underwent CCTA in a 320-row CT system. The patients were randomly divided into two groups of 24 patients each. Exclusion criteria were as follows: severe arrhythmia; heart failure; coronary stent implantation or coronary artery bypass surgery; severe renal insufficiency (creatinine clearance ≤ 120 μmol/L); pregnant or allergy to iodinated contrast; and atrial fibrillation or frequent premature systole.

Scanning Parameters

All CT examinations were performed on a 320-row CT scanner (Aquilion ONE, Toshiba, Japan). All the participants were provided with rigorous training on proper breath holding. Patients with a heart rate of >70 beats/min and no other contraindications, received 50 mg of oral metoprolol 1 h before the CT. All patients received sublingual nitroglycerin (0.5 mg; Beijing Yimin Pharmaceutical Co., Ltd.) 5 min before the examination to dilate the coronary arteries.

The parameters used included a detector width of 0.5 mm, gantry rotation time of 0.35 s, and Z-axis coverage of 16 cm. Scan range covered the entire heart, from the trachea bifurcation up to the diaphragm. Field of view was adjusted to exactly include the entire heart. The median Z-axis scanning range was 14.0 cm (12 cases of 16.0 cm, 28 cases of 14.0 cm, and 8 cases of 12.0 cm). Tube current was adjusted according to the BMI automatically, based on the tube voltage ranging from 330 mA to 400 mA. All the patients were examined using prospectively ECG-gated scan trigger sequence.

The phase window was set at 65–75% of the R-R interval if the heart rate was ≤70 beats/min, and 35–45% interval if the heart rate was ≥70 beats/min. Both the groups used nonionic contrast agent, which was kept in a 37 °C incubator before injecting. The subjects in group A were injected with conventional concentration of hypertonic contrast agent (iodine 370 mgI/mL, iopromide, Bayer HealthCare Pharmaceuticals Inc.), scanned at a conventional tube voltage kV (120 kV), and a traditional FBP image reconstruction method was used. The subjects in group B were injected with isotonic low concentrations of contrast agent (iodine 270 mgI/mL, iodixanol, GE Healthcare Inc.), scanned at a lower tube voltage (100 kV), and AIDR reconstruction algorithm was used. Using a dual-chamber power injector (Stellant, Medrad, USA), the contrast agent was delivered at the same injection time (12 s) via a 20-G indwelling venous catheter in the right elbow for all the patients. According to a previous study, contrast dose (mL) = body weight (kg) × 0.8 mL/kg, contrast agent flow rate (mL/s) = the amount of contrast agent (mL)/12 s (12), and followed by injecting of 30 mL of normal saline flush at the same rate. Using the bolus tracking system, a region of interest (ROI) with an area of 100 mm^2 in the aortic root level was monitored, when the value reached 180 HU, the scan was automatically triggered after a delay of 4 s.

Image Reconstruction and Postprocessing

For group B, AIDR reconstruction algorithm was used, whereas the traditional FBP reconstruction algorithm was used for group A. The section thickness for reconstruction was 0.5 mm, with an interval of 0.25 mm, a matrix size of 512 × 512, and the soft tissue convolution function were used. The reconstructed images were transferred to the postprocessing workstation (Vitrea Fx4.0) for further analysis. Maximum intensity projection, curved planar reconstruction, and volume rendering were performed.

Subjective Evaluation of Image Quality

According to the American Heart Association (17), the coronary artery is divided into the following 16 segments: right