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Original Research Article

Value of knowledge-based iterative model reconstruction in low-kV 256-slice coronary CT angiography

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ABSTRACT

Background: Most current iterative reconstruction algorithms for CT imaging are a mixture of iterative reconstruction and filtered back projection. The value of "fully" iterative reconstruction in coronary CT angiography remains poorly understood.

Objective: We aimed to assess the value of the knowledge-based iterative model reconstruction (IMR) algorithm on the qualitative and quantitative image quality at 256-slice cardiac CT.

Methods: We enrolled 21 patients (mean age: 69 ± 11 years) who underwent retrospectively ECG gated coronary CT anhgiography at 100 kVp tube voltage. Images were reconstructed with the filtered back projection (FBP), hybrid iterative reconstruction (IR), and IMR algorithms. CT attenuation and the contrast-to-noise ratio (CNR) of the coronary arteries were calculated. With the use of a 4-point scale, 2 reviewers visually evaluated the coronary arteries and cardiac structures.

Results: The mean CT attenuation of the proximal coronary arteries was 369.3 ± 73.6 HU, 363.9 ± 75.3 HU, and 363.3 ± 74.5 HU, respectively, for FBP, hybrid IR, and IMR and was not significantly different. The image noise of the proximal coronary arteries was significantly lower with IMR (11.3 ± 2.8 HU) than FBP (51.9 ± 12.9 HU) and hybrid IR (23.2 ± 5.2 HU). The mean CNR of the proximal coronary arteries was 9.4 ± 2.4, 20.2 ± 4.7, and 41.8 ± 9.5 with FBP, hybrid IR and IMR, respectively; it was significantly higher with IMR. The best

Conflict of interest: Shinichi Tokuyasu is an employee of Philips Electronics.

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subjective image quality for coronary vessels was obtained with IMR (proximal vessels: FBP, 2.6 ± 0.5; hybrid IR, 3.4 ± 0.5; IMR, 3.8 ± 0.4; distal vessels: FBP, 2.3 ± 0.5; hybrid IR. 3.1 ± 0.5; IMR, 3.7 ± 0.5). IMR also yielded the best visualization for cardiac systems, that is myocardium and heart valves.

Conclusion: The novel knowledge-based IMR algorithm yields significantly improved CNR and better subjective image quality of coronary vessels and cardiac systems with reliable CT number measurements for cardiac CT imaging.

1. Introduction

Cardiac CT has emerged as a useful diagnostic imaging method for the noninvasive and accurate evaluation of coronary artery disease[1–3] and cardiac structure.[4–6] A persistent problem with current cardiac CT imaging is the radiation dose.[7] Lowering the tube voltage is useful because it lowers the radiation dose and increases vascular enhancement in coronary CT angiography because the x-ray photon energy moves closer to the k-absorption edge of iodine.[8–12] However, low-kilovolt CT imaging with the filtered back projection (FBP) algorithm reconstruction results in a noticeable increase in image noise that has a detrimental effect on the image quality.[13,14] Although FBP is a fast and robust reconstruction technique, it involves incorrect assumptions in the generation of images,[14] and the radiation dose needs to be high to compensate for the increased image noise. Therefore, iterative reconstruction (IR) is important in cardiac CT imaging because it may yield appropriate image quality at considerably reduced radiation doses. Hybrid-type IR has been applied in the clinical setting, and 100-kVp CT imaging plus hybrid IR has been reported to reduce the radiation dose by 55% while yielding a contrast-to-noise ratio (CNR) equal to 120-kVp CT imaging with FBP.[15–18]

Hybrid IR can compensate for the increased noise. It involves 2 de-noising components, that is, iterative maximum likelihood-type sonogram restoration and local structure model fitting on image data, that iteratively decrease uncorrelated noise.[16–18] However, a certain amount of image noise and some artifacts continue to be present. A knowledge-based IR algorithm, iterative model reconstruction (IMR), is the latest advance in the field of CT image reconstruction. IMR models the process of physical data acquisition as accurately as possible through the iterative minimization of the difference between measured raw data and the estimated image via a penalty-based cost function. Although it requires a more complicated and advanced algorithm than hybrid IR, the reconstruction time on state-of-the-art hardware systems has been shortened to approximately 5 minutes per series. We posited that IMR may be applicable in clinical practice, although the effects of IMR on the quality of cardiac CT images are unclear. Therefore, we compared FBP, hybrid IR, and IMR techniques to assess their role in the identification of coronary artery disease and abnormalities in cardiac structures. Here, we report our findings on the effects of IMR on the objective and subjective image quality at 100-kVp cardiac CT.

2. Methods

This retrospective review study was approved by our institutional review board; informed patient consent was waived. This study was registered at Protocol Registration System of ClinicalTrials.gov as NCT01896674.

2.1. *Study population*

We enrolled 21 consecutive patients who underwent cardiac CT at 100 kVp between May 2012 and January 2013. Their clinical characteristics are shown in Table 1. All had suspected coronary artery disease and were referred for cardiac CT.[19] The inclusion criteria were a body mass index (BMI; calculated as weight divided by height squared; kg/m^2) of 27 or less and an Agatston score > 1000 Agatston units. Patients whose BMI exceeded 27 were examined at tube voltage of 120 kVp and not included in this study. Other exclusion criteria were renal dysfunction (serum creatinine level >1.5 mg/dL), atrial fibrillation, prior coronary artery bypass grafting, and heart failure (New York Heart Association class III–IV).

2.2. *Cardiac CT data acquisition*

Scanning of all patients was with a retrospectively gated cardiac protocol on a 256-slice CT scanner (Brilliance-iCT; Philips Healthcare, Cleveland, OH). The data acquisition parameters were 128 × 0.625-mm detector collimation with dynamic z-focal spot, 272-millisecond tube rotation time, 0.16 pitch factor, 127-mAs tube current-time product without electrocardiographic dose modulation, and 100-kVp tube

Table 1 – Patient characteristics.

Characteristics	Values
Age, y, mean ± SD (range)	69 ± 11 (45–85)
Men/women, n/n	6/15
Body weight, kg, mean ± SD	51.2 ± 8.4
Body mass index, mean ± SD	21.4 ± 2.4
Chest pain, n/N	15/21
Hypertension, n/N (%)	13/21 (62)
Hyperlipidemia, n/N (%)	4/21 (19)
Diabetes mellitus, n/N (%)	3/21 (14)
Heat rate, beats/min, mean ± SD	60 ± 7
Current smoking, n/N (%)	2/21 (10)
Prior smoking, n/N (%)	6/21 (29)