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High-definition computed tomography for coronary artery stents imaging: Initial evaluation of the optimal reconstruction algorithm

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ABSTRACT

Objective: The aim of this study was to evaluate the in vivo performance of four image reconstruction algorithms in a high-definition CT (HDCT) scanner with improved spatial resolution for the evaluation of coronary artery stents and intrastent lumina.

Materials and methods: Thirty-nine consecutive patients with a total of 71 implanted coronary stents underwent coronary CT angiography (CCTA) on a HDCT (Discovery CT 750 HD; GE Healthcare) with the high-resolution scanning mode. Four different reconstruction algorithms (HD-stand, HD-detail; HD-stand-plus; HD-detail-plus) were applied to reconstruct the stented coronary arteries. Image quality for stent characterization was assessed. Image noise and intrastent luminal diameter were measured. The relationship between the measurement of inner stent diameter (ISD) and the true stent diameter (TSD) and stent type were analysed.

Results: The stent-dedicated kernel (HD-detail) offered the highest percentage (53.5%) of good image quality for stent characterization and the highest ratio (68.0 ± 8.4%) of visible stent lumen/true stent lumen for luminal diameter measurement at the expense of an increased overall image noise. The Pearson correlation coefficient between the ISD and TSD measurement and spearman correlation coefficient between the ISD measurement and stent type were 0.83 and 0.48, respectively.

Conclusions: Compared with standard reconstruction algorithms, high-definition CT imaging technique with dedicated high-resolution reconstruction algorithm provides more accurate stent characterization and intrastent luminal diameter measurement.

1. Introduction

Coronary artery stent implanting predominates myocardial revascularization therapies with a total of approximately 350,000 procedures performed in Europe and 900,000 procedures in the United States annually [1]. However in-stent restenosis is a common problem after stent implanting. It is reported that the rate of in-stent restenosis due to smooth-muscle cell proliferation is 10–30% for bare metal stents [2]. Although the rate of in-stent restenosis was decreased using drug-eluting stents (DES), the risk of stent thrombosis was increased [3]. Early identification of an in-stent restenosis to avoid recurrent myocardial infarction is a clinical concern. The conventional invasive coronary angiography is the gold standard for the diagnosis of in-stent restenosis [4]. However, it is invasive and costly. The current guidelines do not recommend Coronary CT angiography (CCTA) in patients with coronary artery stents due to the high numbers of non-assessable stents.

Previous studies using standard resolution CT have shown that the stent lumen is limited by blooming artifacts, which are more significant in stents ≤3 mm in diameter, even in novel 64-slice multi-detector single- and dual-source CT systems, which offer isotropic voxel resolution up to 0.4 mm [5–9]. Therefore, the spatial resolution is a key factor in the imaging of coronary artery stent and needs to be further improved from the standard resolution CT system for the stent lumen visualization. The emergence of the high-definition CT (HDCT) improves the *z*-spatial resolution from 0.4 mm to 0.23 mm and contrast resolution from 5 mm to 3 mm [10] and is becoming a promising tool to evaluate the coronary artery stent non-invasively. However, there are limited reports assessing the stents with the latest high resolution technologies including HDCT imaging techniques [10–12]. Dedicated reconstruction methods have also shown more desirable results regarding intrastent lumen visualization [13]. In the present study, the coronary stent was imaged with a HDCT scanner using the high-resolution scanning mode and reconstructed with four different reconstruction

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kernels. The purpose was to evaluate the in vivo performance of the different image reconstruction algorithms in a high-definition CT scanner with improved spatial resolution for the assessment of coronary artery stents and intrastent lumina.

2. Materials and methods

2.1. Patients

The study was approved by our institutional review board and informed consent for the participation in the study was obtained from each subject. From March 2012 through December 2012, thirty nine consecutive patients (30 males and 9 females aged from 39 to 78 years, mean age 62 ± 9 years) underwent CCTA examination after percutaneous coronary angioplasty and stent implantation. A total of 71 stents in 39 patients were implanted and evaluated. Five patients were symptomatic at the time of MDCT, including discomfort of the precordial area, short of breath. Exclusion criteria for CCTA included subjects with renal dysfunction (GFR < 60 ml/min), arrhythmia, known allergy to iodinated contrast media, inability to sustain a 15-s breath hold.

2.2. Coronary stent CTA protocol

All patients underwent CCTA on a HDCT scanner (Discovery CT 750 HD; GE Healthcare, Pewaukee, WI) with the high-resolution scanning mode with the dynamic focal spot control to provide 0.23 mm spatial resolution in *Z*-direction. In all patients with a heart rate (HR) > 65 bpm, β-blocker (metoprolol tartrate; AstraZeneca, London, UK) was orally administered with a dose of 25–50 mg to achieve a target HR ≤ 65 bpm 2 h before CT examination. Administration of sublingual nitroglycerin (LGC, Teddington, UK) was used to enhance coronary vasodilation at the time of imaging. A test bolus technique was used to monitor the CT value of ascending aorta to optimize scan delay time with 20 ml contrast media followed by 20 ml saline. The scan delay time of CCTA was calculated as the peak time of region of interest plus 8 s. Each patient received 75 ml contrast media (Omnipaque 350 mgI/ml, GE Healthcare, Pewaukee, WI) intravenously at the speed of 5 ml/s, followed by 40 ml of saline at the same speed. CCTA was performed using a prospective ECG-triggering (SnapShot Pulse, GE Healthcare) protocol if the HR of the patients was lower than 65 bpm. Otherwise, a retrospective ECG-triggering protocol was used. For prospective ECG-triggering protocol, CCTA was performed using the following parameters: slice configuration 64×0.625 mm, gantry rotation time 350 ms, tube voltage 120 kVp, effective tube current 228 mAs, the slice was 0.625 mm without increment. The X-ray window ("padding") varied with HR variability: paddings of 0, 100 ms and 200 ms for patients without HR variability, with HR variability ⩽2 bpm, and with HR variability >2 bpm, respectively. For retrospective ECG-triggering protocol, helical pitches of 0.18–0.24 were used dependent on patient heart rates. ECG tube current modulation technique was used with a maximum tube current of 228 mAs between 40% and 80% of the *R*–*R* cardiac cycle and 46 mAs for the rest of the cycles [14]. The effective slice thickness was 0.625 mm with 0.625 mm reconstruction increment.

2.3. Coronary CT image post-processing and data analysis

CCTA images were reconstructed with four different convolution kernels for stent characterization and intrastent lumen visualization. These four different convolution kernels included HD-stand, HD-detail, HD-stand-plus, and HD-detail-plus (Fig. 1). HD-stand is recommended as standard algorithm for coronary angiography. HD-stand-plus is sharper than HD-stand. HD-detail and HD-detail-plus have higher cutoff frequencies than the HD-stand-plus with the HD-detail-plus having the highest. HD-detail and HD-detail-plus are better suited for providing higher spatial resolution. The adaptive statistical interative reconstruction (ASIR) technique was utilized for reconstruction to control image noise with ASIR strength of 30%. Thus, the images were composed of 30% data reconstructed by ASIR and 70% by the conventional filtered back projection (FBP).

The reconstructed axial images were transferred to an advanced workstation for post-processing (AW4.6 with CardIQ software package, GE Healthcare, Milwaukee, Wis). CCTA images were reformatted using multiplanar reconstruction (MPR) and curved

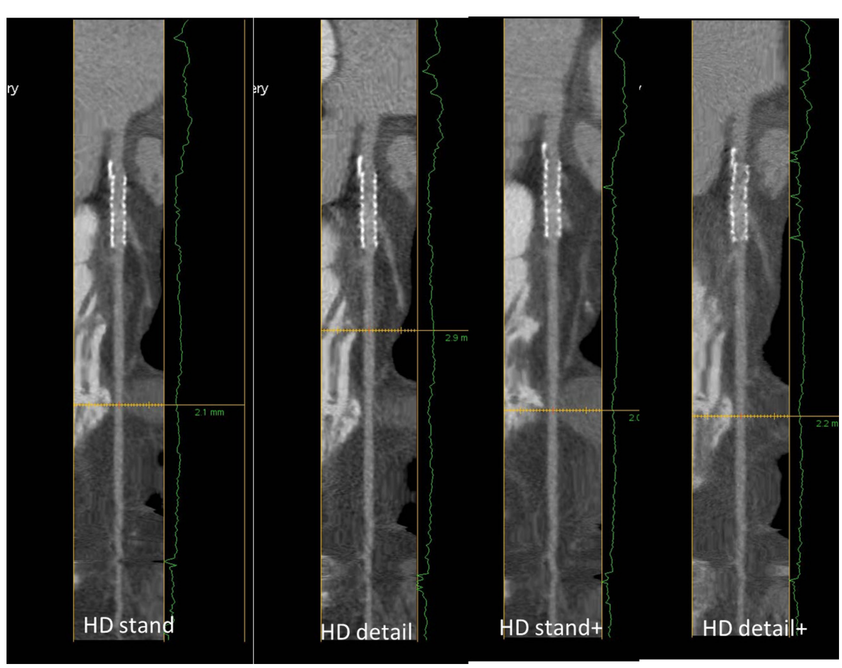

Fig. 1. M 62, Four different reconstruction approaches (HD-stand, HD-detail, HD-stand-plus, HD-detail-plus).