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Original article

New quantitative method to diagnose coronary in-stent restenosis by 64-multislice computed tomography

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ABSTRACT

Background: The aim of this study is to evaluate the accuracy of a newly developed quantitative method using 64-multislice computed tomography angiography (CTA) to detect coronary in-stent restenosis (ISR).

Methods and results: CTA was performed in 45 patients who underwent stent implantation (79 lesions) and the accuracy to diagnose ISR was evaluated by comparing with invasive coronary angiography (ICA). CTA was evaluated both visually and quantitatively using a new stent restenosis index (SRI) utilizing CT densities at proximal and distal artery lumen from the stented region and the correction value depending on the stent diameter. ICA showed 11 ISR (14%). The sensitivity, specificity, positive predictive value, negative predictive value, and accuracy for visual evaluation were 78%, 75%, 35%, 95%, and 76%, respectively. On the other hand, the quantitative evaluation using SRI represents 82%, 93%, 64%, 97%, and 91%, respectively.

Conclusions: Evaluation of ISR using SRI is superior to the visual estimation of CTA.

Introduction

Coronary artery stenting has been a standard method for treating coronary artery stenosis in patients with angina pectoris or patients with acute myocardial infarction [1]. The clinical incidence of in-stent restenosis (ISR) after coronary stent implantation is 20–35% for bare metal stents and 5–10% for drug-eluting stents [2–5]. For the evaluation of ISR, invasive coronary angiography is a standard procedure to measure lumen narrowing after stent placement. However, the cost and burden of this procedure and the potential complications require an alternative non-invasive procedure to diagnose ISR [6]. Since the number of patients who received coronary artery stenting is increasing, non-invasive methods to rule out ISR is important to eliminate invasive coronary angiography. A number of studies have investigated the evaluation of ISR using multidetector row computed tomography (MDCT) angiography. It has been reported that the 64-slice MDCT can provide more accurate in-stent visualization and characterization than 16-slice MDCT due to improved spatial and temporal resolution [7]. However, artifacts caused by stent struts have hindered accurate diagnosis of ISR [8–12]. In particular, assessable stent number is dramatically decreased when the stent diameter is <3 mm [8]. Furthermore, most of the studies performed visual diagnosis instead of quantitative diagnosis using CT density (CTD). Kitagawa et al. [13] reported an objective evaluation of ISR using CT density.

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However, the increased attenuation of the stent lumen due to partial volume effect and blooming artifact hinders quantitative assessment [12]. In the present study, we developed a new index using CT density and compared it to the visual diagnosis.

Methods

From 2008 to 2010, 45 consecutive patients (37 males, mean age 65 ± 7 years) with suspected ISR underwent CT coronary angiography (CTA) and invasive coronary angiography (ICA). The accuracy to diagnose ISR by CTA was evaluated in 79 stented lesions by comparing them with ICA. The patients' characteristics are shown in Table 1. The protocol of this study conforms to the declaration of Helsinki and the protocol was approved by the ethics committee of Yamaguchi University Hospital. Informed consent was provided by all patients and written consent was obtained from all patients.

Table 1
Patients' characteristics ($N = 45$).

	(%)
Age (years)	65 ± 7
Male	37 (82%)
Body mass index (kg/m^2)	23.7 ± 2.0
Diabetes mellitus	17 (38%)
Dyslipidemia	33 (73%)
Hypertension	32 (71%)
Current smoking	18 (40%)
Angiography	
One-vessel disease	26 (57.8%)
Two-vessel disease	12 (26.7%)
Three-vessel disease	7 (15.6%)
Stent location	
RCA	28 (35.4%)
LAD	30 (38.0%)
LCx	20 (25.3%)
SVG	1 (1.3%)

LAD, left anterior descending artery; LCx, left circumflex coronary artery; RCA, right coronary artery; SVG, saphenous vein graft.

Invasive coronary angiography

ICA was performed with a standard method and the images were evaluated by two experienced cardiologists who were blinded to the patient characteristics. The restenosis evaluation was performed visually and with the caliper method according to the American Heart Association criteria. The diameter stenosis >50% in the stent lesion was considered significant ISR.

Scanning protocol and image reconstruction of coronary CT angiography

Renal failure and allergy to contrast agents were exclusion criteria for the study.

Images were acquired using a 64-slice dual-source CT scanner (Somatom Definition™; Siemens Healthcare, Erlangen, Germany), with 32 detector rows × 0.6 mm collimation, 330 ms rotation time, and a table feed of 0.2–0.4 mm per rotation. All patients received one puff of nitroglycerine spray (0.3 mg; Astellas, Tokyo, Japan) sublingually immediately prior to scanning. A bolus of iodinated contrast agent (Omnipaque 350; Daiichi Sankyo Co. Ltd., Tokyo, Japan), which varied between 40 and 60 ml, depending on the expected scan time × flow rate, was injected at a flow rate of 0.07 ml s^{-1} kg^{-1} × body weight (kg) into the right antecubital vein followed by a saline injection (30 ml; same flow rate as of the contrast agent). The scan delay time was determined by the transit time in a test injection (10 ml contrast injection followed by 30 ml saline injection). The tube voltage was 120 kV and the tube current was 400 mAs. The optimal cardiac phase with the least motion artifacts was chosen from the original axial and multi-planar reconstruction images. All reconstructions were performed by mono-phasic reconstruction. Image reconstruction and analysis were performed on a dedicated workstation (Ziostation; Ziosoft Inc., Tokyo, Japan). The data sets constructed with a medium-to-smooth (B26f) convolution kernel were used for all analyses. Curved multi-planar reconstructions were used to evaluate the implanted coronary stents. Images were displayed at a window level of 300 Hounsfield units (HU) with a window width of 1200 HU.

The preliminary study for CT density of stent lumen

To evaluate the augmentation of CTD in stent lumen, we measured CTD in stent lumen and the native coronary lumen proximal to the stent as ΔCTD using a region of interest of 1 mm^2 in the consecutive 73 stents (the stents' characteristics are shown in Supplementary Table 1). To investigate whether ΔCTD is influenced by the thickness of stent struts, ΔCTD was compared between the groups with stent strut thickness less than 0.005 in. and with more than 0.005 in. in 3.0 mm diameter stents (Fig. 1).

Supplementary Table 1 related to this article can be found, in the online version, at http://dx.doi.org/10.1016/j.jjcc.2014.03.013.

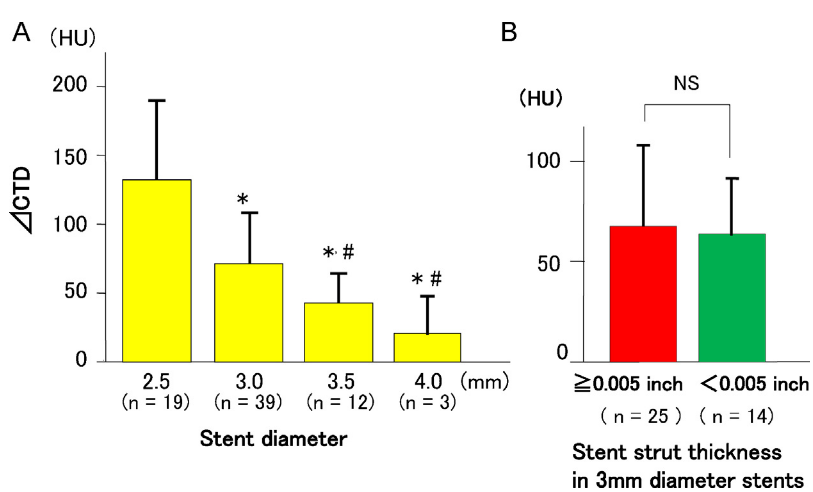

Fig. 1. (A) Comparison of ΔCTD for each stent diameter. (B) Comparison of ΔCTD between the strut thickness ≧0.005 in. and <0.005 in. HU, Hounsfield units. *$p < 0.05$ vs. 2.5 mm and #$p < 0.05$ vs. 3.0 mm. NS, not significant. ΔCTD: the difference in computed tomography density between proximal native artery and the in-stent lumen.