transverse OCT, an intact closed-cell design stent produced circumferential strut images, open-cell stents showed various strut patterns, depending on the position and inclination of a cross-sectional cut (1). Thus, although 3D OCT has not been used as an imaging modality in clinical practice until now, this technology may be helpful to conclusively diagnose SF of new metal stents, to estimate the area of the lesion that is not covered, and to guide optimal therapeutic and follow-up strategies.

In conclusion, the present report demonstrates the potential of ESI to suggest SF after stent implantation, a suspicion that may be confirmed by 3D OCT.

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Impact of In-Stent Tissue Type on Periprocedural Myocardial Infarction and 2-Year Clinical Outcomes After Treatment of Coronary Artery Restenosis

The development of neoatherosclerosis characterized by lipid core, in-stent thin-cap fibroatheroma (TCFA), calcification, and intimal rupture contribute to development of late stent failure (1,2). We assessed the impact of optical coherence tomography (OCT)-detected TCFA and intimal rupture on the occurrence of periprocedural myocardial infarction (MI) and 2-year major adverse cardiac events (MACE).

From August 1, 2008 to June 1, 2012, 518 patients with in-stent restenosis (ISR) underwent target lesion revascularization at the Asan Medical Center, Seoul, Korea. After excluding the patients with hemodynamic instability, inability of the OCT catheter to cross the tight stenosis, the presence of left main or saphenous vein graft lesions, acute MI, vessel size >4 mm, total stent length >40 mm, pre-dilation before OCT examination, or an angiographically visible thrombus, pre-procedural OCT images were available in 152 patients (41 bare-metal stents [BMS] and 111 drug-eluting stents [DES]). Periprocedural MI was defined as post-procedure peak creatine kinase-myocardial band (CK-MB) >15 ng/ml (>3 times the upper limit of normal). OCT image was obtained by occlusive (LightLab Imaging, Westford, Massachusetts) or nonocclusive (DragonFly catheter and C7XR, LightLab Imaging) technique. Calcific or lipidic intima, TCFA, intimal rupture, and thrombi were previously described (2,3).

All values were expressed as the median value (interquartile range [IQR]) or counts and percentages and compared by nonparametric Mann-Whitney or chi-square statistics. Multivariable analysis included the variables ($p < 0.2$) such as age, male sex, DES, unstable angina, stent duration, in-stent TCFA, intimal rupture, and thrombi.

The patient age was 64.0 (56.3 to 69.0) years, and 80% were men. Clinical presentation was stable angina in 77% and unstable angina in 23%. The stent duration was 52.8 (17.5 to 86.9) months (46.2 [IQR: 14.0 to 70.0] months in DES vs. 116.4 [IQR: 58.6 to 148.7] months in BMS; $p < 0001$). Peak CK-MB level before the procedure was normal in all patients. **Table 1** summarizes pre-procedural OCT findings.

ISR was treated with DES in 62%, cutting balloon in 26%, and other types of balloon in 12%. The patients with (vs. without) in-stent TCFA had a higher post-procedural peak CK-MB (2.0 [IQR: 1.0 to 5.0] vs. 1.4 [IQR: 0.8 to 2.2] ng/ml; $p = 0.012$) and more frequent periprocedural MI (13% vs. 2%; $p = 0.010$). Moreover, the patients with (vs. without) intimal rupture showed a higher post-procedural peak CK-MB (2.0 [IQR: 0.9 to 4.1] vs. 1.3 [IQR: 0.9 to 2.4] ng/ml; $p = 0.017$) and more frequent periprocedural MI (13% vs. 3%; $p = 0.015$). Stent duration ($r = -0.360$), fibrous cap thickness ($r = -0.176$), and length of in-stent TCFA ($r = 0.331$) significantly correlated

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TABLE 1 Pre-Procedural OCT Findings in ISR Lesions

	Total (N = 152)	Presence of Periprocedural MI (n = 11)	Absence of Periprocedural MI (n = 141)	p Value
Stent duration, months	52.8 (17.5–86.9)	87.5 (80.2–142.7)	51.9 (16.3–83.8)	0.008
MLA, mm^2	1.5 (1.0–2.0)	1.2 (1.0–1.8)	1.5 (1.0–2.0)	0.596
Stent area at the MLA, mm^2	7.1 (5.7–8.5)	7.2 (6.7–8.0)	7.1 (5.7–8.5)	0.586
%Intimal hyperplasia	80.1 (69.2–86.5)	81.3 (75.0–87.3)	80.0 (68.5–86.4)	0.355
Lipid neointima	139 (91)	11 (8)	129 (91)	0.361
Calcium	20 (13)	1 (9)	19 (14)	0.650
Minimal thickness of fibrous cap, μm	80.0 (60.0–150.0)	60.0 (50.0–60.0)	90.0 (60.0–150.0)	0.016
Thrombi	84 (55)	10 (91)	74 (52)	0.010
Red thrombi	10 (7)	1 (9)	9 (6)	0.539
Intimal rupture	71 (47)	9 (82)	62 (44)	0.016
In-stent TCFA	68 (45)	9 (82)	59 (42)	0.011
Neoatherosclerosis*	143 (94)	11 (100)	132 (94)	0.499
Neoatherosclerosis without in-stent TCFA or intimal rupture*	56 (37)	0 (0)	56 (40)	0.005
Malapposition	24 (16)	1 (9)	23 (16)	0.342

Values are median (interquartile range) or n (%). *Neoatherosclerosis is defined as the composite of lipidic neointima, in-stent TCFA, intimal rupture, and in-stent calcification. Continuous variables are compared using the nonparametric, Mann-Whitney test.

ISR = in-stent restenosis; MI = myocardial infarction; MLA = minimal lumen area; OCT = optical coherence tomography; TCFA = thin-cap fibroatheroma.

with post-procedural peak CK-MB (all $p < 0.05$). On receiver-operating characteristic curve analysis, fibrous cap thickness ≤60 μm predicted periprocedural MI (sensitivity = 91%, specificity = 58%, area under curve = 0.744). In 11 patients with periprocedural MI, the mechanism was distal embolization in 5 (45%) patients, side-branch occlusion in 5 (45%) patients, and undetermined mechanism in 1 (10%) patient. Old age (estimated coefficient = 0.024), unstable angina (0.610), DES (−0.422), and intimal rupture (0.431) were independently associated with post-procedural peak CK-MB (all $p < 0.05$).

With a follow-up time of 32.1 (25.7 to 37.3) months, MACE occurred in 13.8% (cardiac death 1.3%, MI 0.7%, target lesion revascularization 5.3%, and periprocedural MI 7.2%). The MACE rate was significantly higher in the patients with and without in-stent TCFA (20.6% vs. 8.3%; $p = 0.026$) or intimal rupture (19.7% vs. 8.6%; $p = 0.041$). However, there was no significant difference in the rates of MACE excluding periprocedural MI between the patients with and without in-stent TCFA (7.4% vs. 6.0%) or intimal rupture (7.0% vs. 6.2%; all $p > 0.05$).

DISCUSSION

This current study demonstrates the impact of neoatherosclerosis with high-risk features on the occurrence of periprocedural MI after target lesion revascularization. Although in-stent neoatherosclerosis may have diverse features, the presence of intimal rupture, TCFA or thrombi was significantly associated with the high risk of periprocedural MI. Fibrous cap thickness ≤60 μm predicted periprocedural MI, and intimal rupture independently affected post-procedural CK-MB elevation. However, in the majority, the elevation of CK-MB was only modest and the underlying mechanism of periprocedural MI was side-branch occlusion (not a large dissection or no reflow), which partly account for the lack of association with 2-year MACE excluding periprocedural MI.

Because of the relatively small sample size, low event rate and selection bias, the results cannot be applied to the general population. Also, the study did not compare the risk of periprocedural MI among various methods of ISR treatment. Second, with different stent duration, this study could not compare the frequency and implication of neoatherosclerosis between DES and BMS. Finally, the definition and clinical impact of periprocedural MI according to the magnitude of cardiac enzyme remain uncertain.

In conclusion, vulnerable intimal characteristics in restenotic tissue within previously implanted stents were associated with the occurrence of periprocedural MI, but rarely affected long-term clinical outcomes after target lesion revascularization.

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Intraprocedural TAVR Annulus Sizing Using 3D TEE and the "Turnaround Rule"

The success of transcatheter aortic valve replacement (TAVR) depends on the appropriate evaluation of the aortic annulus because significant errors in sizing can lead to post-procedure paravalvular leak, prosthesis migration, coronary artery occlusion, or annulus rupture. In a previously published review, Kasel et al. (1) proposed a novel method called the "turnaround rule" as a technique to improve annular measurements by 3-dimensional (3D) transesophageal echocardiography (TEE). We present data validating the use of this method for intraoperative, real-time measurement of annular dimensions that can be used to confirm values obtained from multidetector computed tomography (MDCT) and thus ensure appropriate sizing of the aortic prosthesis.

From September 1, 2012 to July 31, 2014, 141 consecutive patients with severe aortic stenosis underwent TAVR at our institution and were considered for this study. Of this patient population, 74 had both pre-procedure MDCT and intraprocedural 3D-TEE. (Excluded patients had 2-dimensional transthoracic echocardiogram at the time of the procedure.) Within this cohort, 4 patients had bioprosthetic valves and were excluded from this study. Therefore, the final study cohort included 70 patients. Fifty-five patients received SAPIEN 9000TFX (Edwards Lifesciences, Irvine, California) and 15 patients received CoreValve (Medtronic, Inc., Minneapolis, Minnesota) valves. The patients were nonconsecutive because patients who did not undergo both imaging modalities were excluded. No patients were excluded due to poor image quality.

TEE was performed and processed with a commercially available 3D software package (Vivid, GE Healthcare, Fairfield, Connecticut). The aortic valve annulus was measured using the "turnaround rule" technique as described by Kasel et al. (1) (**Figure 1**). With this technique, 3D-TEE is performed over zoom mode to obtain a loop containing the entire aortic root, the left ventricular outflow tract, and part of the ascending aorta. With the short-axis view of the aortic valve in the transverse plane as the reference point, the orthogonal sagittal and coronal planes are aligned parallel to the long axis of the ascending aorta. Rotation of the sagittal and coronal planes identifies the most caudal hinge points of the aortic cusps. The level of the hinge points in the transverse plane defines the virtual aortic annulus. The average diameter (D_{area}) was calculated from the annular area ($D_{area} = 2 \times \sqrt{[area/\pi]}$). The mean diameter ($D_{mean}$) was calculated from the average of the maximum and minimum diameters. Eccentricity index was calculated as the ratio of maximal diameter over minimal diameter and is a measure of the elliptical nature of the valve.

MDCT imaging was acquired using a 256-slice MDCT imager (Brilliance iCT, Philips Healthcare, Andover, Massachusetts) or 64-slice MDCT imager (LightSpeed VCT, GE Healthcare). MDCT images were analyzed independently from the 3D-TEE and by different personnel, using either Philips Intellispace Portal or Osirix MD version 1.4.2 software. All measurements presented in this study were acquired for the specific purpose of clinical TAVR sizing and implantation and, therefore, represent "real-world" data.

The mean annular area was 40.45 ± 7.71 mm^2 by 3D-TEE and 42.11 ± 7.51 mm^2 by MDCT (mean difference 1.66 ± 4.32 mm^2; $p = 0.002$). The mean perimeter was 71.45 ± 6.84 mm by 3D-TEE and 74.42 ± 6.52 mm by MDCT (mean difference 2.97 ± 4.29 mm; $p < 0.001$). The D_{mean} was 22.86 ± 2.22 mm by 3D-TEE and 23.52 ± 2.20 mm by MDCT (mean difference 0.68 ± 1.60 mm; $p = 0.003$). The D_{area} was 22.59 ± 2.15 mm by 3D-TEE and 23.07 ± 2.03 mm by MDCT (mean difference 0.47 ± 1.21 mm; $p = 0.002$).

The Pearson coefficient correlations (D_{area} $r = 0.8337$, $p < 0.0001$; D_{mean} $r = 0.7396$; $p < 0.0001$; annular area $r = 0.8392$, $p < 0.0001$; perimeter $r = 0.7949$, $p < 0.0001$) showed a strong correlation between 3D-TEE and MDCT measurements. Bland-Altman plots showed that 3D-TEE mean values were smaller than those of MDCT. The plots had the following mean differences and 95% limits of agreement: D_{area} −0.47 mm (−2.84 and 1.89 mm), D_{mean} −0.67 mm (−3.80 and 2.50 mm), annular area −1.66 mm^2 (−10.13 and 6.80 mm^2), and perimeter −2.97 mm (−11.38 and 5.43 mm).