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ORIGINAL ARTICLE

Short- and long-term clinical impact of tissue protrusion after newer-generation drug-eluting stent implantation for acute coronary syndrome

Yoriyasu Suzuki[1] · Akira Murata[1] · Suguru Murase[1] · Yusuke Ochiumi[1] · Tatsuya Ito[1]

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Abstract
Although stent implantation may be associated with tissue protrusion (TP), especially in patients with acute coronary syndrome (ACS), its long-term clinical outcomes remain unknown. The aim of the current study was to evaluate the long-term clinical outcomes of ACS patients with TP after the implantation of newer-generation drug-eluting stents (DESs). We retrospectively evaluated 366 consecutive ACS patients who underwent primary percutaneous coronary intervention (PCI) with newer-generation DESs. All culprit lesions underwent pre- and post-PCI intravascular ultrasound (IVUS) examinations and were classified according to the presence or absence of post-stent TP. After primary PCI, 198 lesions (54.1%) displayed TP on IVUS examination. At the 12-month follow-up, the incidence of target lesion revascularization did not differ between patients with ($n=198$) and without ($n=168$) TP (3.5 vs. 4.2%, $p=0.790$). The incidence of recurrent ACS (r-ACS) was higher in patients with versus those without TP (7.1 vs. 2.4%; log-rank test $p=0.043$). Cox proportional hazard analysis showed that triple-vessel disease (HR = 9.258, $p=0.001$), TP (HR = 3.149, $p=0.008$), and low-density lipoprotein cholesterol reduction rate ≥ 50% (HR = 0.184, $p=0.008$) were the independent predictors of r-ACS. TP detected using IVUS after DES implantation may be associated with the occurrence of r-ACS after the 12-month follow-up, although short-term clinical outcomes were not worse during the 12-month follow-up.

Keywords Tissue protrusion · Drug-eluting stent · ACS

Introduction

Drug-eluting stents (DESs) are being increasingly used for the treatment of acute coronary syndrome (ACS). Previous randomized controlled trials and meta-analyses have demonstrated that DESs are superior to bare metal stents in minimizing the occurrence of stent restenosis. This has reduced the need for revascularization in patients with ACS [1–6], which was the major drawback of percutaneous coronary intervention (PCI) in the era of bare metal stents. Although it remains uncertain whether the clinical utility of various types of DESs in treating ACS in settings with higher possible thrombotic coronary lesions is identical, a meta-analysis reported that newer generation DESs improve safety and efficacy compared to bare metal stents [6]. Tissue protrusion (TP) is the extrusion of an intraluminal tissue (plaque and/or thrombus) through stent struts. This is easily detected using intravascular ultrasound (IVUS). Although TP is frequently detected by IVUS after stent implantation in patients with acute myocardial infarction (AMI), inconsistent results have been reported in previous studies on IVUS that examined the clinical impact of TP [7–11]. Furthermore, only a few studies have investigated the clinical course of patients with TP for longer than 12 months after the implantation of DESs. The aim of the current study was to evaluate the long-term clinical outcomes of ACS patients with TP after the implantation of newer-generation DESs.

✉ Yoriyasu Suzuki
yoriyasu55@gmail.com

[1] Division of Cardiovascular Medicine, Nagoya Heart Center, 1-1-14 Sunadabashi, Higashi-Ku, Nagoya, Aichi 461-0015, Japan

Methods

We identified and retrospectively evaluated 366 patients with a first ACS event that was treated with emergent PCI, using newer-generation DESs, at the Nagoya Heart Center between May 25, 2009 and April 30, 2015. ACS was defined as ischemic discomfort presenting with an elevation of troponin level.

All the patients had undergone pre-PCI IVUS, successful implantation of DES, and post-PCI IVUS.

The primary endpoint of this study was the incidence of major adverse cardiac and cerebrovascular events (MACCEs) at 12 months after DES implantation. MACCEs were defined as cardiac death, myocardial infarction, stroke, and urgent revascularization during the same admission or as target lesion revascularization (TLR) at 12 months after DES implantation. The secondary endpoint was the incidence of recurrent acute coronary syndrome (r-ACS) during the follow-up. In addition, r-ACS was defined as the development of an acute coronary event during the follow-up period.

AMI was diagnosed according to the consensus document of the Joint European Society of Cardiology/American College of Cardiology Committee for the Redefinition of Myocardial Infarction [12]. Infarct-related arteries (target vessel) were identified using a combination of electrocardiographic findings that included left ventricular wall motion abnormalities during left ventricular angiography or echocardiography and coronary angiographic findings.

After intracoronary administration of nitroglycerin, IVUS examinations were performed before and after stenting using a commercially available 40 MHz-IVUS system. The IVUS catheter was advanced distally to the target lesion, followed by imaging performed retrograde to the aorto-ostial junction at an automatic pullback speed of 0.5 mm/s.

IVUS analysis was performed according to the American College of Cardiology Clinical Expert Consensus Document on Standards for Acquisition, Measurement and Reporting of Intravascular Ultrasound Studies using validated software (QIVUS, Medis Medical Imaging Systems, Leiden, Netherlands) [13]. The culprit lesion was defined as the stented lesion. Proximal and distal 5 mm-long segments from each culprit lesion edge (pre-PCI) or stent edge (post-PCI) before a significant (> 1.5 mm in diameter) side branch, were defined as the reference segments.

Intra-stent TP was defined as a plaque and/or thrombus intrusion through the stent struts into the stent lumen (Fig. 1). In cases with a thrombolysis in myocardial infarction (TIMI) grade 0 or 1 in the initial coronary angiogram (CAG), pre-PCI IVUS was performed after reperfusion of the coronary artery via thrombectomy. In cases with a TIMI grade 2 or 3 in the initial CAG, pre-PCI IVUS was performed immediately after the guide wire was passed through the target lesion. Pre- and post-PCI qualitative IVUS morphologic analysis included positive remodelling and attenuation of the plaque [7, 14–16]. Quantitative measurements pre- and post-PCI were performed at every 1 mm of the external elastic membrane (EEM), lumen, and stent areas (post-PCI), and the plaque area (EEM minus lumen area) was calculated. The slice with the minimal luminal area (MLA) and minimal stent area (MSA) within each culprit lesion was identified and assessed. Volumes were calculated using the Simpson's rule.

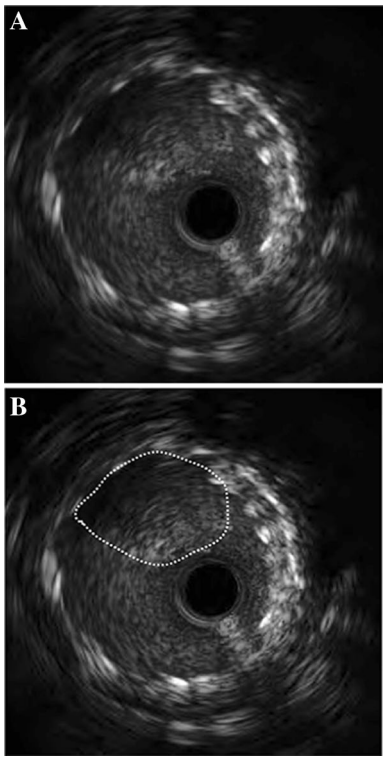

Fig. 1 Representative intravascular ultrasound image of tissue protrusion. Intravascular ultrasound images (**a**, **b**) show intrusion of the tissue through the stent struts into the lumen as tissue protrusion (dotted line in **b**)

Low-density lipoprotein cholesterol (LDL-C) level was measured at the initial admission and at 12 months after DES implantation. LDL-C reduction rate was calculated as (LDL-C at the initial admission minus LDL-C at 12 months after DES implantation)/LDL-C at the initial admission.

Continuous data are presented as mean ± SD. All differences were compared using Student's *t* test and nonparametric methods. Discrete variables are expressed as counts and percentages. These were assessed via Fisher's exact test or the Chi-square test, depending on the sample size. The multivariate logistic regression model was applied to

identify the risk of TP. Time-to-event data were summarized as Kaplan–Meier estimates according to TP status and were compared using the log-rank test. Cox proportional hazards model was used to identify the risk of r-ACS. In all analyses, $p < 0.05$ was considered to indicate statistical significance. Statistical analyses were performed using SPSS version 23 (IBM Corp., Armonk, NY, USA).

Results

After primary PCI, 198 (54.1%) lesions displayed TP on IVUS. After assigning the patients into two groups [TP (+), $n = 198$; TP (−), $n = 168$], we retrospectively compared the two groups.

Table 1 summarizes the comparisons of baseline patient profiles, baseline angiographic characteristics, and procedural results. TP was frequently observed in patients whose target vessel was the left anterior-descending coronary artery.

According to IVUS findings, there were also no significant differences in the incidence of positive remodelling or of attenuation plaque between the groups. Both pre- and post-PCI plaque volumes were higher in patients with versus those without TP. None of the patients had stent edge dissection, and only seven (1.9%) patients had incomplete stent apposition after stent implantation. Additional procedures such as additional prolonged ballooning, thrombectomy, and additional stenting to reduce the amount of TP were carried out at the discretion of the operator when haziness was observed in the stent after its implantation. There was a significantly higher incidence of additional procedures in patients with versus those without TP.

Table 2 and Fig. 2 summarize the results of a comparison between newer-generation DESs. There were significant differences among the stents in the distribution of the target vessel, stent size, stent length, post-balloon size, and the prevalence of TP.

Subacute stent thrombosis occurred in only one patient with TP (0.3%), and there was no significant difference between the groups in the incidence of TLR at the 12-month follow-up (patients with vs. those without TP, 3.5 vs. 4.2%, $p = 0.790$).

Table 3 shows the results of logistic regression analysis used to identify the risk factors of TP. Both uni- and multivariate analyses demonstrated that hypertension (OR = 0.489, 95% CI = 0.302–0.791, $p = 0.004$) and a pre-plaque volume of more than 300 mm^3 were independent predictors of TP (OR = 2.262, 95% CI = 1.396–3.666, $p = 0.001$).

Figure 3 shows the cumulative incidence of the primary and secondary endpoints (mean follow-up interval, 36.0 ± 22.2 months; range, 2.5–91.6 months; median follow-up interval, 29.6 months). MACCEs were observed in 26 (13.1%) of the patients with TP and in 14 (8.3%) of the patients without TP (log-rank test; $p = 0.138$). Additionally, r-ACS was observed in 14 (7.1%) of the patients with TP and in four (2.4%) of the patients without TP (log-rank test; $p = 0.043$). There were 7 events related to the initially treated sites in 18 patients with r-ACS and 11 events related to previously non-treated coronary segments in these patients. Table 4 summarizes the medication regimens in use at the end of the follow-up. No significant differences were observed between the two groups.

In Table 5, cox proportional hazard analysis shows that triple-vessel disease (HR, 9.258; $p = 0.002$), TP (HR, 3.149; $p = 0.045$), and LDL reduction rate ≥ 50% (HR = 0.184, $p = 0.008$) are risk factors for r-ACS.

Discussion

This study demonstrates the clinical outcomes of TP after the implantation of newer-generation DES in ACS patients. The main findings are as follows: (1) TP was often observed after stent implantation in ACS patients, especially in patients with a large plaque volume. Additional procedures to reduce the amount of TP after stent implantation were more frequently required in patients with TP as observed in these patients during primary PCI; (2) Although there was no difference in the incidence of TLR at the 12-month follow-up in patients with compared to those without TP, we found a higher incidence of r-ACS in patients with versus those without TP. Our findings demonstrate that the independent predictors of r-ACS were triple-vessel disease and TP. Furthermore, patients who achieved a ≥ 50% reduction in LDL-C level had a significantly reduced risk of r-ACS.

TP is frequently detected using IVUS after stent implantation in patients with ACS. Several studies have reported a 17–70% incidence of TP after stent implantation [7–9]. In an IVUS substudy of ADAPT-DES (Assessment of Dual Antiplatelet Therapy with Drug-Eluting Stents), the overall incidence of TP detected using IVUS was 38.5%, while it was 54.3% for STEMI, 46.1% for NSTEMI, 34.3% for unstable angina, and 30.6% for stable ischemic heart disease [17]. Hong et al. detected TP in 33% of patients with STEMI and in 24% of patients with NSTEMI [18]. In our study, TP was detected in 54.1% of all ACS patients, which is similar to that reported in previous studies. Hong et al. additionally reported that lesion characteristics, such as plaque rupture and positive remodeling, as well as longer stent implantation, could be used to predict TP [7]. Moreover, in an IVUS substudy of ADAPT-DES, these authors also reported finding a significantly larger maximum device diameter, plaque burden, and plaque volume in patients with versus those without TP [17]. In the current study, our multivariate

Table 1 Baseline patient profile, baseline angiographic characteristics, and procedural results

	Protrusion (−), $n=168$	Protrusion (+), $n=198$	p values
Age	64.8 ± 10.1	63.9 ± 10.0	0.641
Male, %	82.1	82.8	0.485
Hypertension, %	51.2	36.9	0.006
Dyslipidemia, %	64.8	63.6	0.827
Diabetes, %	15.5	18.2	0.576
Present clinical syndrome, %			0.445
STEMI	78.0	82.8	
NSTEMI	6.5	7.1	
UAP	15.5	11.1	
No. of diseased vessels, %			0.938
Single	52.4	50.5	
Double	28.6	29.8	
Triple	19.0	19.7	
Target vessel, %			0.036
LAD	42.9	53.5	
LCX	17.3	8.6	
LMT	0	0.5	
RCA	39.9	37.4	
Initial TIMI grade, %			0.117
0/1	65.5	67.7	
2/3	34.5	32.3	
Direct stenting, %	20.8	17.2	0.422
Stent size, mm	3.04 ± 048	3.13 ± 0.37	0.078
Stent length, mm	23.3 ± 7.3	23.8 ± 6.8	0.120
Deploy pressure, atm	12.4 ± 3.2	12.8 ± 2.5	0.038
Post dilatation, %	78.6	81.3%	0.515
Post balloon size, mm	3.20 ± 0.53	3.28 ± 0.49	0.350
Post balloon pressure, atm	19.0 ± 4.3	18.3 ± 4.5	0.160
No. of deployed stents	1.3 ± 0.5	1.3 ± 0.5	0.315
IVUS findings			
Positive remodeling, %	50.0	56.1	0.146
Attenuation plaque, %	86.9	90.9	0.146
Pre-plaque volume, mm^3	297.2 ± 180.1	401.3 ± 555.6	0.035
Post-plaque volume, mm^3	250.4 ± 153.2	341.1 ± 509.2	0.049
Post MSA, mm^2	6.2 ± 2.1	6.6 ± 2.1	0.692
Post MSA ≤ 4.0 mm^2, %	9.4	8.6	0.845
Final TIMI 3, %	97.6	96.0	0.558
Slow flow, %	10.7	14.1	0.347
Additional procedure, %	4.8	15.2	0.001
Peak CK, U/L	1913 ± 1782	2439 ± 2015	0.075
EF, %	53.2 ± 11.0	51.2 ± 11.3	0.749
TLR, %	4.2	3.5	0.790

STEMI ST-elevation myocardial infarction, *NSTEMI* non-ST segment elevation myocardial infarction, *UAP* unstable angina pectoris, *LAD* left anterior descending coronary artery, *LCX* left circumflex coronary artery, *LMT* left main trunk, *RCA* right coronary artery, *MSA* minimal stent area, *CK* creatinine kinase, *EF* ejection fraction, *TLR* target lesion revascularization

logistic regression analysis demonstrates that a pre-plaque volume of more than 300 mm^3 is an independent predictor of TP. Therefore, a large plaque volume should be considered a risk of TP. To the best of our knowledge, this is the first report that mentioned the relationship between the incidence of TP and pre-plaque volume.

The incidence of TP was lower in patients with hypertension in our study. Similarly, in an IVUS substudy of

Table 2 Comparison between newer-generation DESs

	Endeavor, $n=70$	Nobori, $n=30$	Promus E, $n=69$	Promus P, $n=55$	Resolute, $n=36$	Xience, $n=106$	p values
Age	60.6 ± 10.4	63.6 ± 11.1	66.7 ± 10.6	62.2 ± 9.0	66.9 ± 7.7	65.6 ± 9.6	0.001
Male, %	95.7	90.0	72.5	85.5	86.1	75.5	0.002
Present clinical syndrome, %							0.094
STEMI	84.3	83.3	82.6	76.4	72.2	81.1	
NSTEMI	2.9	6.7	2.9	16.4	5.6	5.7	
UAP	12.9	10	14.5	7.3	22.2	13.2	
Target vessel, %							< 0.001
LAD	34.3	46.7	44.9	49.1	41.7	63.2	
LCX	5.7	10	14.5	12.7	16.7	15.1	
LMT	0	3.3	0	0	0	0	
RCA	60	40	40.6	38.2	41.7	21.7	
Stent size, mm	3.29 ± 0.44	3.25 ± 0.39	3.01 ± 0.37	3.11 ± 0.46	3.08 ± 0.43	2.96 ± 0.38	< 0.001
Stent length, mm	22.0 ± 6.5	21.1 ± 5.3	24.6 ± 8.0	25.4 ± 6.7	24.1 ± 6.3	23.4 ± 7.1	0.014
Deploy pressure, atm	13.6 ± 2.6	13.3 ± 3.7	13.4 ± 2.4	11.8 ± 2.3	11.4 ± 4.0	12.1 ± 2.4	< 0.001
Post BA size, mm	3.46 ± 0.47	3.63 ± 0.70	3.16 ± 0.52	3.25 ± 0.49	3.23 ± 0.34	3.04 ± 0.39	< 0.001
Post pressure, mm	20.1 ± 4.3	18.3 ± 4.4	18.5 ± 4.5	17.3 ± 4.8	17.9 ± 4.4	18.5 ± 4.1	0.055
TLR, %	12.9	0	1.4	1.8	0	2.8	0.001

STEMI ST-elevation myocardial infarction, *NSTEMI* non-ST segment elevation myocardial infarction, UAP; unstable angina pectoris, *LAD* left anterior descending coronary artery, *LCX* left circumflex coronary artery, *LMT* left main trunk, *RCA* right coronary artery, *BA* balloon, *TLR* target lesion revascularization

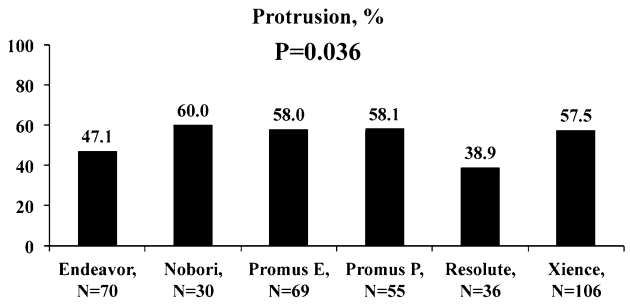

Fig. 2 Comparison of the incidence of tissue protrusion among different newer-generation drug-eluting stents

ADAPT-DES, TP was less frequently observed in patients with hypertension [17]. ACS may be associated with rapid plaque progression in the preceding weeks to months, with an acceleration of plaque progression mediated by subclinical cycles of plaque rupture and healing or intra-plaque hemorrhage. Thus, it seems to be a lipid-rich and less fibrous plaque. However, hypertension is one of the risk factors for atherosclerosis and patients with hypertension might likely develop fibrous advanced atherosclerotic plaque.

In 418 AMI patients included in a study [19], TP was associated with poor short-term clinical outcomes (more acute and subacute stent thrombosis and no-reflow

Table 3 Logistic regression analysis to identify the risk of tissue protrusion

Univariate analysis				Multivariate analysis			
	OR	95% CI	p value		OR	95% CI	p value
Pre-plaque volume > 300 mm^3	2.092	1.334–3.281	0.001	Pre-plaque volume > 300 mm^3	2.262	1.396–3.666	0.001
TVD	1.002	0.580–1.731	0.554	TVD	1.054	0.560–1.982	0.368
Positive remodeling	1.253	0.805–1.951	0.367	Positive remodeling	1.012	0.607–3.422	0.336
Attenuation plaque	1.603	0.786–3.270	0.204	Attenuation plaque	1.499	0.657–3.422	0.336
Male	1.030	0.934–1.134	0.652	Male	1.388	0.733–2.627	0.314
Hypertension	0.705	0.544–0.914	0.009	Hypertension	0.489	0.302–0.791	0.004
Dyslipidemia	1.083	0.686–1.709	0.816	Dyslipidemia	1.042	0.642–1.693	0.868
Diabetes	1.041	0.590–1.837	0.505	Diabetes	1.14	0.617–1.693	0.668
Target vessel; LAD	1.536	1.015–2.324	0.046	Target vessel; LAD	1.395	0.832–2.340	0.207

TVD triple-vessel disease, *LAD* left anterior descending coronary artery

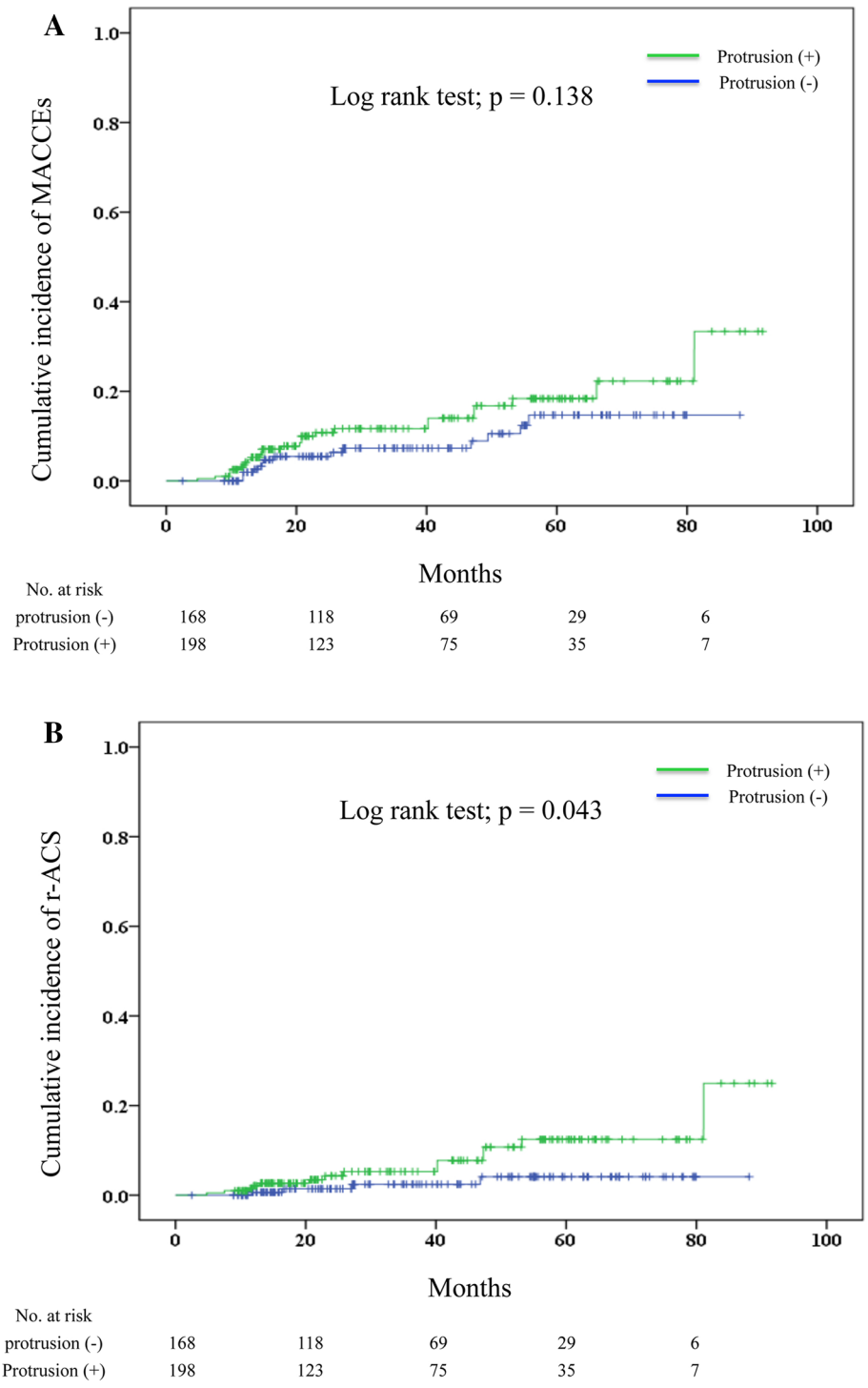

Fig. 3 Cumulative incidence of cardiovascular and cerebrovascular events. **a** Shows the cumulative incidence of major adverse cardiac and cerebrovascular events (death, myocardial infarction, stroke, and urgent revascularization during the same admission or target vessel revascularization at 12 months after the implantation of a DES). **b** shows the cumulative incidence of recurrent acute coronary syndrome (r-ACS). The incidence of r-ACS was significantly higher in patients with versus those without TP during the 36-month follow-up period

phenomenon during primary PCI). However, TP was not associated with worse clinical outcomes at 1 year after stent implantation in infarct-related arteries in patients with AMI [19]. Choi et al. reported that patients with early stent thrombosis (within 30 days post implantation) had at least one of the following significant features: MLA < 5 mm^2, edge dissection, residual stenosis, and TP [20]. In our current study, IVUS findings such as MSA < 4 mm^2 and edge dissection were rarely observed, subacute stent thrombosis was uncommon (0.3%), and the incidence of MACCEs at the 12-month follow-up was not different between the two groups. In Japan, IVUS is frequently performed during PCI. Thus, this discrepancy in results might be explained by the fact that we used IVUS during primary PCI for all cases

Table 4 Cox proportional hazards analysis for risk of recurrent ACS

Univariate analysis				Multivariate analysis			
	HR	95% CI	*p* value		HR	95% CI	*p* value
TVD	4.613	1.759–12.094	0.003	TVD	9.258	2.550–33.610	0.001
Positive remodeling	1.803	0.662–4.913	0.334	Positive remodeling	1.898	0.527–6.835	0.327
Attenuation plaque	0.981	0.217–4.431	0.607	Attenuation plaque	1.015	0.146–7.066	0.988
Male	1.150	0.860–1.537	0.218	Male	2.023	0.618–6.620	0.244
Hypertension	0.628	0.886–1.335	0.224	Hypertension	0.966	0.290–3.215	0.956
Dyslipidemia	2.011	0.648–6.241	0.314	Dyslipidemia	2.273	0.695–7.437	0.175
Diabetes	1.552	0.412–5.848	0.749	Diabetes	1.130	0.228–5.593	0.881
Tissue protrusion	3.120	1.007–9.666	0.031	Tissue protrusion	3.149	1.018–12.128	0.045
Binary restenosis	2.782	0.533–14.529	0.225	Binary restenosis	2.782	0.533–14.529	0.225
LDL reduction rate > 50%	0.221	0.028–0.647	0.037	LDL reduction rate > 50%	0.184	0.052–0.642	0.008
Statin therapy	0.861	0.762–0.974	0.132	Statin therapy	0.129	0.013–1.238	0.076
RAS therapy	0.432	0.167–1.119	0.114	RAS therapy	0.159	0.018–1.373	0.095
β-blocker therapy	0.905	0.591–1.386	0.810	β-blocker therapy	1.129	0.376–3.391	0.829
Pre-plaque volume > 300 mm^3	5.176	1.003–26.700	0.050	Pre-plaque volume > 300 mm^3	1.507	0.511–4.445	0.317

TVD triple-vessel disease, *LDL-C* low-density lipoprotein cholesterol level, *RAS* angiotensin-converting enzyme inhibitor or angiotensin receptor blocker

Table 5 Clinical outcomes at the end of follow-up

	Protrusion (−), *n* = 168	Protrusion (+), *n* = 198	*p* value
Continuation of DAPT, %	44.0	51.5	0.309
RAS therapy, %	72.0	66.1	0.258
Statin therapy, %	81.5	82.3	0.892
β-blocker therapy, %	47.0	53.5	0.249
Baseline LDL-C	137.0 ± 34.8	137.4 ± 38.1	0.188
LDL-C at 12 months after PCI	84.9 ± 24.8	90.3 ± 27.1	0.687

DAPT dual antiplatelet therapy, *RAS* angiotensin-converting enzyme inhibitor or angiotensin receptor blocker, *LDL-C* low-density lipoprotein cholesterol level

in the current study to avoid smaller MSAs, edge dissection, and residual stenosis, and to reduce the amount of TPs requiring additional procedures such as prolonged ballooning, thrombectomy after stent implantation, and additional stenting. IVUS-guided stent implantation appears to be associated with a reduction in both early and short-term clinical events. Unlike our results, a study that employed optical coherence tomography (OCT) demonstrated that irregular protrusions after stent implantation, as assessed using OCT, were independent predictors of device-oriented clinical endpoints at 1 year [21]. This study mentioned that severity of vessel injury caused by stent implantation might be critical in predicting clinical events and irregular protrusions, representing moderate to severe vessel injury with a high likelihood of medial disruption and lipid core penetration. However, the resolution of IVUS imaging is 10 times lower than that of OCT imaging and it is, therefore, more difficult to identify the characterization of the protruded substance.

Stone et al. reported that the 3-year cumulative rate of major adverse cardiovascular events was 20.4%. In addition, this study also reported that during the 3.4-year follow-up, the incidence rates of a larger plaque burden, presence of thin-cap fibroatheroma, and lower MLA (< 4.0 mm^2) were strong predictors of recurrent coronary events [22]. A subsequent study that examined patients using OCT and coronary angioscopy reported that TP observed after stent implantation was associated with high-grade yellow plaques with thrombi [23]. Ueda et al. reported that the presence of in-stent yellow plaques after DES implantation was a risk factor for very late stent failure [24]. A further prospective study demonstrated that patients with yellow plaques in their coronary arteries have a higher risk of future ACS [25]. [26] These previous results suggest that r-ACS occurs in patients with a large plaque burden and the presence of TP indicates a higher risk of future coronary events. Similarly, our current study

demonstrates that TP was strongly associated with a large amount of plaque, and strong risk factors for r-ACS, including triple-vessel disease and TP.

Several other trials have additionally demonstrated that lowering LDL-C reduces cardiovascular events [27–29]. Ridker et al. evaluated the impact of a ≥ 50% reduction in LDL-C on the risk of a first cardiovascular event and found that percentage reduction in LDL-C was directly related to efficacy [30]. The current statin guidelines in Europe and Canada advocate achieving a fixed LDL-C target or a reduction in LDL-C of ≥ 50% [31]. Our findings demonstrate that achieving a ≥ 50% reduction in LDL-C significantly reduced the risk of r-ACS in daily clinical settings.

Limitations

There were several limitations to this study. First, this was a retrospective study conducted at a single center and the number of study participants was small; thus, the statistic power might be low. Second, we did not have a core laboratory for this study. Third, IVUS-guided PCI was performed in all cases in this study, as previous findings suggest that IVUS-guided stent implantations are useful in reducing both early and long-term clinical events. Thus, while IVUS is commonly performed during PCI in Japan, it is not routinely conducted in other countries. Therefore, it might be difficult to apply our current results to daily clinical scenarios worldwide. Fourth, the results of our study do not indicate what needs be done with TP when it is observed after stenting. It is possible that the use of IIb/IIIa inhibitors could be potential treatment strategies. However, since IIb/IIIa inhibitors are not available in Japan, it was not possible to evaluate this potential treatment in our study.

Conclusions

We evaluated the clinical outcomes of ACS patients with TP after newer-generation DES implantation. TP was frequently observed in patients with a large plaque volume. The incidence of TLR at the 12-month follow-up did not differ between patients with and without TP.

A higher incidence of r-ACS was observed in patients with TP during the 36-month follow-up period. The independent predictors of r-ACS were triple-vessel disease and TP.

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Compliance with ethical standards

Conflict of interest All authors have no conflicts of interest to declare.

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