ORIGINAL RESEARCH

Impact of Angiographic Residual Stenosis on Clinical Outcomes After New-Generation Drug-Eluting Stents Implantation: Insights From a Pooled Analysis of the RESET and NEXT Trials

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***Background*—**Previous intravascular ultrasound studies suggested the association of stent underexpansion with increased risk of stent thrombosis and restenosis. However, no previous study has addressed the association of the suboptimal angiographic result with target-lesion revascularization (TLR) in patients receiving new-generation drug-eluting stents (DES).

***Methods and Results*—**RESET (Randomized evaluation of sirolimus-eluting versus everolimus-eluting stent trial) and NEXT (NOBORI biolimus-eluting versus XIENCE/PROMUS everolimus-eluting stent trial) are prospective, multicenter, randomized "DES versus DES" trials; 3196 patients and 3235 patients were enrolled in the RESET and NEXT, respectively. Using the pooled individual patient-level data, the current study population consisted of 3679 patients who received single-lesion treatment using new-generation DES such as everolimus-eluting stent and biolimus-eluting stent. The study population was divided into 3 groups according to the residual in-stent % diameter stenosis (%DS) after stent implantation by offline quantitative coronary angiography assessed in a core angiographic laboratory (optimal group: %DS <10%, intermediate group: %DS=10% to 20%, suboptimal group: %DS ≧20%). The cumulative 3-year incidence of TLR was significantly higher in the suboptimal group than in the intermediate and optimal groups (9.8% versus 5.8% versus 5.7%, log-rank P=0.004). Even after adjusting for the clinical, angiographic, and procedural characteristics, the excess TLR risk of the suboptimal group relative to the optimal group remained significant (hazard ratio: 1.65, 95% confidence interval, 1.14–2.41, P=0.009). The excess TLR risk of the suboptimal group relative to the optimal group was consistently seen across all the subgroups including heavy calcification.

***Conclusions*—**The residual angiographic in-stent %DS ≥20% was associated with increased risk for TLR in patients treated with the new-generation DES. **(*J Am Heart Assoc*. 2018;7:e008718. DOI: 10.1161/JAHA.118.008718.)**

Key Words: coronary stent • restenosis • target-vessel revascularization

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Accompanying Appendix S1 and Table S1 are available at http://jaha.ahajournals.org/content/7/13/e008718/DC1/embed/inline-supplementary-material-1.pdf

*A complete list of the RESET and NEXT Investigators can be found in the Appendix S1.

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Clinical Perspective

What Is New?

- The current American College of Cardiology/American Heart Association guideline recommends the minimum residual percent diameter stenosis <10% with an optimal goal of as close to 0% as possible, which was not based on large-scale data.
- Using the pooled individual patient-level data, our study demonstrated the positive association of in-stent percent diameter stenosis ≥20% with increased target lesion revascularization in patients treated with the newer-generation drug-eluting stent.

What Are the Clinical Implications?

- Aggressive lesion modification before stent deployment and sufficient stent expansion might be relevant to the optimization of the residual diameter stenosis in the newer drug-eluting stent era.
- The current analysis was based solely on quantitative coronary angiography data. Future studies including intravascular ultrasound evaluation will be required to clarify the impact of the residual diameter stenosis on clinical outcomes.

According to the latest American College of Cardiology/American Heart Association guidelines, the optimal minimum diameter stenosis <10% with an optimal goal of as close to 0% as possible was the new benchmark regardless of the types of stents, because many previous studies suggested inadequately deployed stents as the culprit of increased in-stent restenosis (ISR) and stent thrombosis.[1–3] Nevertheless, very few reports have investigated the relation between the poststenting angiographic result and clinical outcomes after implantation of drug-eluting stents (DES), particularly new-generation DES.[4] In actual clinical practice, the prevalence of intravascular ultrasound (IVUS) is still low, and the angiographic result is the usual procedural end point. Hence, we sought to investigate the effect of angiographic residual percent diameter stenosis (%DS) after new-generation DES implantation on 3-year clinical outcomes in the patient-level pooled database from the 2 large "DES versus DES" trials conducted in Japan, namely, RESET (Randomized evaluation of sirolimus-eluting versus everolimus-eluting stent trial) and NEXT (NOBORI biolimus-eluting versus XIENCE/PROMUS everolimus-eluting stent trial).

Methods

We will not make the data, methods used in the analysis, and materials used to conduct the research available to any researcher for purposes of reproducing the results or replicating the procedure.

Study Design

This pooled analysis utilizes individual patient-level data from the RESET and NEXT trials, comparing the 3-year clinical outcomes according to the residual %DS after stent implantation. The designs and the 3-year clinical outcomes of RESET and NEXT have been previously described in detail.[5–7] In short, both RESET and NEXT are prospective, multicenter, randomized "DES versus DES" trials, in which eligible patients were randomly assigned to undergo percutaneous coronary intervention (PCI) with either everolimus-eluting stents (EES; Xience V, Abbott Vascular, CA/PROMUS, Boston Scientific, MA) or sirolimus-eluting stents (Cypher/Cypher select/Cypher Select-plus; Cordis Corporation, Johnson and Johnson, NJ) in the RESET, and with either biolimus-eluting stents (Nobori, Terumo, Tokyo) or EES in the NEXT. All the baseline (pre- and postprocedure) coronary angiograms were to be analyzed in the independent angiographic core laboratory (Cardiocore, Tokyo, Japan). Qualitative and quantitative coronary angiography (QCA) were assessed utilizing CAAS 5.9 (Pie Medical Imaging, Maastricht, Netherlands). Details of the angiographic analysis were previously presented.[5,6] In a subset of patients enrolled in the angiographic substudy, follow-up angiography was performed between 240 and 365 days after the index PCI procedure in both the RESET and NEXT trials.[7] Scheduled follow-up angiography was also allowed according to the discretion of the participating centers. The relevant review boards or ethics committees at all the participating centers approved the study protocol. Written informed consent was obtained from all the participants.

A total of 6431 patients with 7596 lesions were enrolled in the 2 trials. Among the 6431 enrolled patients, 4884 patients had a single lesion treated with stents. The current study population consisted of 3679 patients who received single-lesion treatment using new-generation DES (EES only or biolimus-eluting stents only), after excluding those patients in whom stents other than new-generation DES or different types of stents were used, and angiographic core laboratory data were missing (Figure 1). The study population was divided into the 3 groups according to the degree of final residual in-stent %DS after stent implantation: %DS <10% (optimal group), %DS ≥10% but <20% (intermediate group), and %DS ≥20% (suboptimal group).

Primary and Secondary Outcome Measures

The primary outcome measure in the current analysis was target-lesion revascularization (TLR) at 3-year follow-up. TLR

was defined as PCI or coronary artery bypass grafting because of restenosis or thrombosis of the target lesion, including the proximal and distal edge segments and the ostia of the side branches. All the angiograms of patients with target-vessel revascularization (TVR) were to be analyzed by the angiographic core laboratory in an attempt to adjudicate TLR and to discriminate TLR from non-TLR TVR. Secondary outcome measures included clinically driven TLR, TVR, clinically driven TVR, all-cause death, myocardial infarction (MI), and definite/probable stent thrombosis (ST). We do not have prespecified criteria for allowing TLR/TVR, but rather the decision whether or not to perform TLR/TVR was left to the attending physician and/or angiographic operator based on symptoms, visual estimation of angiograms, and/or fractional flow reserve. A TLR/TVR was considered clinically indicated if angiography during follow-up showed a diameter stenosis ≥50% (core laboratory QCA assessment) and if 1 of the following occurred: (1) a positive history of recurrent angina pectoris, presumably related to the target vessel; (2) objective signs of ischemia at rest (ECG changes) or during exercise test (or equivalent), presumably related to the target vessel; (3) abnormal results of any invasive functional diagnostic test (eg, fractional flow reserve); (4) a TLR with a diameter stenosis >70% even in the absence of the abovementioned ischemic signs or symptoms. Angiographic restenosis in the angiographic substudy was defined as %DS >50% by QCA in the angiographic core laboratory. Death, MI, and ST were adjudicated by the independent clinical event committee. MI and ST were defined according to the Academic Research Consortium definitions.[8]

Statistical Analysis

We expressed categorical variables as numbers and percentages, and continuous variables as mean±SD when they followed normal distribution or as median with interquartile range when they did not. The types of distribution were judged by illustrating the individual variables in a histogram. If it was a bell-shaped appearance, the variables were judged to follow normal distribution. We compared categorical variables with the χ^2 test when suitable; otherwise we used the Fisher exact test. We compared continuous variables with the Student *t* test or the Wilcoxon rank sum test based on their distributions. We conducted a multivariable logistic regression analysis to identify the independent predictors for the suboptimal angiographic result (%DS ≥20%). We used the Kaplan–Meier method to estimate the cumulative incidences of clinical events and evaluated the differences with the log-rank test. We also constructed the multivariable Cox proportional hazards models to estimate the effect of angiographic residual %DS on 3-year TLR across the 3 groups. In the multivariable models, we selected 20 clinically relevant factors listed in Tables 1 and 2 as potential risk-adjusting variables. The selected risk-adjusting variables mostly included those closely related to stent restenosis such as age >75 years, hypertension, dyslipidemia, peripheral vascular disease, hemodialysis, prior history of MI, prior history of stroke, liver cirrhosis, anemia (hemoglobin <11.0 g), insulin use for the treatment of diabetes mellitus, current smoker, statin use, calcium-channel blockers use, bifurcation treatment, chronic total occlusion treatment, total stent length ≥40 mm, the presence of severe tortuous lesion, the presence of ISR lesion, the presence of target lesion diameter ≤2.75 mm, and PCI for ST-segment–elevation MI culprit. We did not include "heavy calcification" as a risk-adjusting variable, because heavy calcification was so closely correlated with high degree of residual stenosis.[9] The effects of angiographic residual %DS 10% to 20% and %DS ≥20% relative to %DS <10% (reference) were assessed in the multivariable Cox proportional hazards models with dummy variables, which were expressed as adjusted hazard ratios and their 95% confidence intervals. We dichotomized the continuous variables by using clinically relevant reference values or median values. We also conducted subgroup analyses with those subgroup factors such as hemodialysis, total stent length (≥ or <40 mm), ISR, target lesion diameter (≤ or >2.75 mm), and heavy calcification. For the subgroup analysis, we did not perform multivariable adjustment because of a very small number of events in some subgroups. We conducted a formal interaction test between the subgroup factors and the effect of residual %DS on TLR. Statistical analyses were performed with the use of JMP 12.0 (SAS Institute Inc, Cary, NC) software. All the statistical analyses were 2-tailed. $P<0.05$ was considered statistically significant.

Results

Patient, Angiographic, and Procedural Characteristics

Baseline patient characteristics were mostly similar across the 3 groups except for a few variables; patients in the suboptimal group more often had insulin-treated diabetes mellitus, hemodialysis, and prior history of coronary artery bypass grafting, which were the previously reported risk factors for ISR (Table 1). Regarding the baseline lesion characteristics, the suboptimal group more often had complex lesion characteristics such as long lesions, smaller minimum-lumen diameter, bifurcation lesion, and heavily calcified lesions than in the other 2 groups (Table 2). Regarding the procedural characteristics, the total stent length was significantly longer, and lesion preparation with balloon predilatation and/or rotablator was more frequently performed in the

suboptimal group than in the other groups (Table 2). Postdilatation was performed in a large proportion of patients (75%–80%) with numerically higher rate in the suboptimal group. Maximum stent inflation pressure was uniformly high across the 3 groups. Balloon–artery ratio (final balloon size divided by reference vessel diameter) was smaller in the suboptimal group. IVUS was used in a large proportion of patients without any difference across the 3 groups (Table 2).

The independent predictors for the suboptimal angiographic result (%DS ≥20%) were bifurcation treatment, total stent length ≥40 mm, and heavy calcification (Table 3).

Clinical Outcomes

Complete 3-year follow-up was achieved in 93.6% of patients with median follow-up interval of 607 (interquartile range: 284–844) days in patients with incomplete follow-up. Follow-up angiography was performed in 90.6% of patients including those procedures with or without clinical indications.

The cumulative 3-year incidence of TLR (primary outcome measure) in the suboptimal group was significantly higher than that in the optimal group (9.8% versus 5.7%, log-rank P=0.002), while there was no significant difference in the cumulative 3-year incidence of TLR between the intermediate and optimal groups (5.8% versus 5.7%, log-rank P=0.91) (Figure 2 and Table 4). Even after adjusting for confounders, the excess risk of the suboptimal group relative to the optimal group for TLR remained significant (hazard ratio: 1.61, 95% confidence interval, 1.11–2.33, P=0.01), while the risk of the intermediate group relative to the optimal group for TLR was neutral (hazard ratio: 0.97, 95% confidence interval, 0.72–1.31, P=0.85) (Table 4). The cumulative 3-year incidences of clinically driven TLR, MI, and ST were also significantly higher in the suboptimal group than in the optimal group. However,

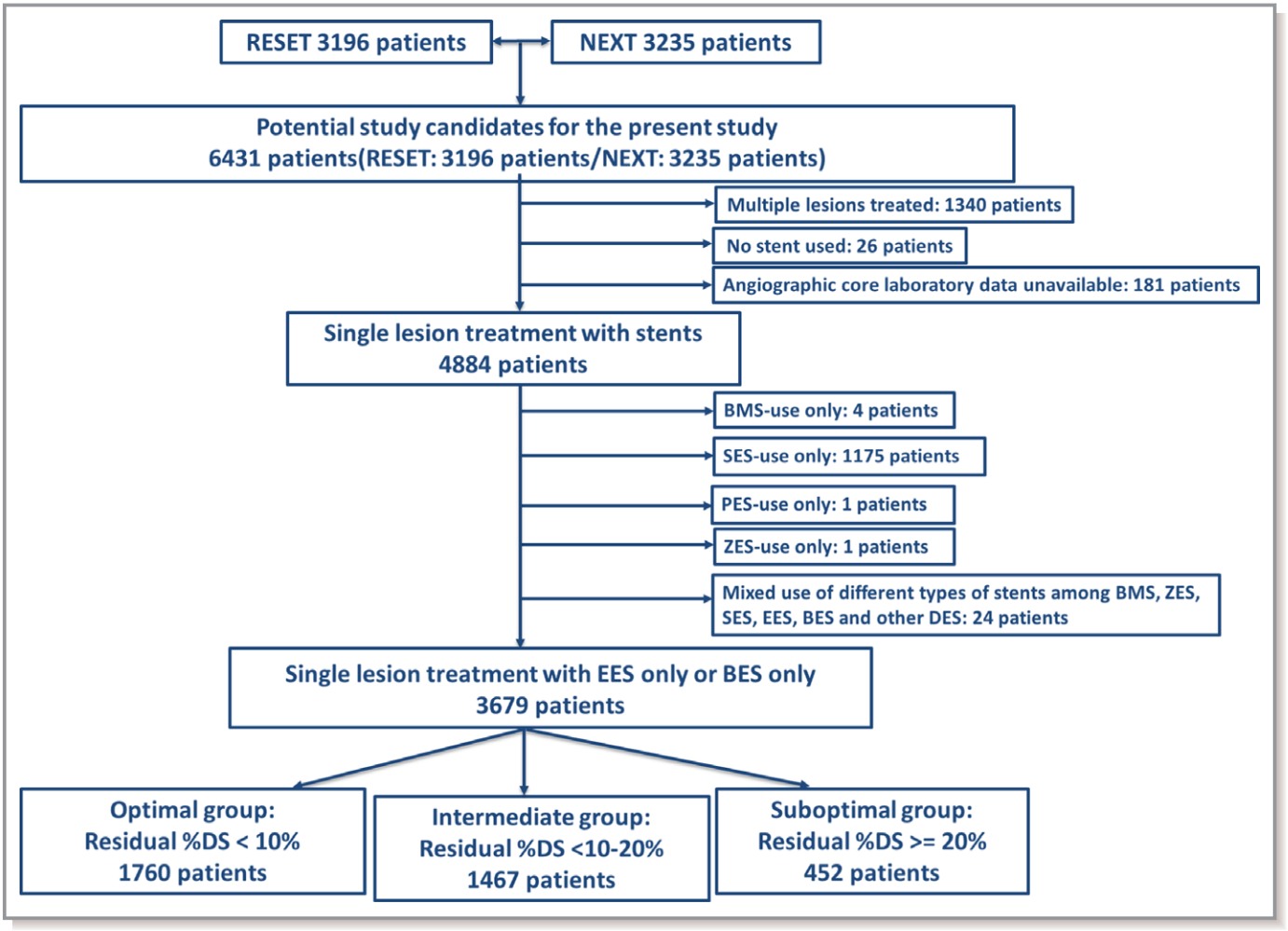


Figure 1. Study population. BES indicates biolimus-eluting stent; BMS, bare metal stent; DES, drug-eluting stent; %DS, percent diameter stenosis; EES, everolimus-eluting stent; NEXT, NOBORI Biolimus-eluting versus XIENCE/PROMUS everolimus-eluting stent trial; PES, paclitaxel-eluting stent; RESET, Randomized evaluation of sirolimus-eluting versus everolimus-eluting stent trial; SES, sirolimus-eluting stent; ZES, zotarolimus-eluting stent.

Table 1. Baseline Patient Characteristics

Variables	Optimal Group Residual %DS <10% N=1760	Intermediate Group Residual %DS 10%–20% N=1467	Suboptimal Group Residual %DS ≥20% N=452	*P* Value
Patient characteristics				
Age, y	68.7±10.1	69.4±9.7	69.5±9.5	0.12
>75 y*	569 (32%)	468 (32%)	146 (32%)	0.96
Male sex	1350 (77%)	1142 (78%)	337 (75%)	0.34
Body mass index	24.2±3.5 (N=1746)	24.2±3.8 (N=1455)	24.1±3.3 (N=450)	0.99
Coexisting conditions				
Hypertension*	1399 (79%)	1189 (81%)	365 (81%)	0.52
Diabetes mellitus	782 (44%)	638 (43%)	216 (48%)	0.28
Treated with insulin*	172 (9.8%)	148 (10%)	61 (14%)	0.07
Treated with oral medication only	428 (24%)	346 (24%)	108 (24%)	0.89
Treated with diet therapy only	107 (6.1%)	89 (6.1%)	27 (6.0%)	1.00
Dyslipidemia*	1368 (78%)	1108 (76%)	339 (75%)	0.25
ESRD not on hemodialysis	126 (7.2%)	122 (8.4%)	45 (10%)	0.13
Hemodialysis*	86 (4.9%)	92 (6.3%)	33 (7.3%)	0.08
Atrial fibrillation	112 (6.4%)	87 (5.9%)	33 (7.3%)	0.58
Anemia (hemoglobin <11.0 g/dL)*	182 (10%)	190 (13%)	68 (15%)	0.008
COPD	53 (3.0%)	31 (2.1%)	9 (2.0%)	0.20
Liver cirrhosis*	16 (0.9%)	10 (0.7%)	2 (0.4%)	0.52
Malignancy	135 (7.7%)	96 (6.5%)	33 (7.3%)	0.46
Cardiac risk factors				
Current smoker*	352 (20%)	284 (19%)	82 (18%)	0.66
Family history of CAD	286/1651 (17%)	206/1373 (15%)	68/427 (16%)	0.22
Prior myocardial infarction*	495 (28%)	441 (30%)	125 (28%)	0.40
Prior stroke*	178 (10%)	153 (10%)	56 (12%)	0.38
Prior heart failure	161 (9.2%)	116 (7.9%)	41 (9.1%)	0.43
Peripheral vascular disease*	138 (7.8%)	94 (6.4%)	44 (9.7%)	0.05
Prior history of PCI	853 (48%)	735 (50%)	227 (50%)	0.60
Prior history of CABG	64 (3.6%)	75 (5.1%)	29 (6.4%)	0.02
Clinical characteristics				
Clinical presentation				0.67
Stable CAD	1438 (82%)	1221 (83%)	377 (83%)	
Unstable angina	219 (12%)	163 (11%)	47 (10%)	
Acute myocardial infarction	103 (5.9%)	83 (5.7%)	28 (6.2%)	
LVEF <30%	32/1523 (2.1%)	14/1283 (1.1%)	10/381 (2.6%)	0.04
Target-vessel location				
LMCA	27 (1.5%)	38 (2.6%)	15 (3.3%)	0.03
LAD	822 (47%)	700 (48%)	211 (47%)	0.83
LCX	383 (22%)	281 (19%)	103 (23%)	0.11
RCA	514 (29%)	436 (30%)	119 (26%)	0.37
Saphenous vein graft	8 (0.5%)	8 (0.6%)	4 (0.9%)	0.58

Continued

Table 1. Continued

Variables	Optimal Group Residual %DS <10% N=1760	Intermediate Group Residual %DS 10%–20% N=1467	Suboptimal Group Residual %DS ≥20% N=452	*P* Value
Arterial graft	4 (0.2%)	2 (0.1%)	0	0.38
Medications				
Aspirin	1755 (99.7%)	1460 (99.5%)	451 (99.8%)	0.58
Thienopyridines	1752 (99.6%)	1454 (99%)	452 (100%)	0.02
Clopidogrel	1507 (86%)	1238 (84%)	391 (87%)	0.44
Ticlopidine	227 (13%)	208 (14%)	58 (13%)	0.53
Statins*	1390 (79%)	1108 (76%)	333 (74%)	0.01
ACE-I/ARB	1091 (62%)	891 (61%)	269 (60%)	0.57
β-Blockers	652 (37%)	542 (37%)	171 (38%)	0.94
Calcium-channel blockers*	772 (44%)	663 (45%)	198 (44%)	0.72
Nitrates	416 (24%)	388 (26%)	128 (28%)	0.06
Coumadin	122 (6.9%)	113 (7.7%)	31 (6.9%)	0.66

Categorical variables are expressed as number (%) unless otherwise indicated. Continuous variables are shown as mean±SD. %DS indicates percent diameter stenosis; ACE-I/ARB, angiotensin-converting enzyme inhibitor/angiotensin receptor blocker; CABG, coronary artery bypass grafting; CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; eGFR, estimated glomerular filtration rate; ESRD, end-stage renal disease (eGFR <30 mL/min per 1.73 m^2); LAD, left anterior descending coronary artery; LCX, left circumflex coronary artery; LMCA, left main coronary artery; LVEF, left ventricular ejection fraction; PCI, percutaneous coronary intervention; RCA, right coronary artery.
*Potential independent variables selected for multivariable analysis.

after adjusting the confounders, the risks of the suboptimal group relative to the optimal group did not reach statistical significance for all the secondary outcome measures (Table 4). There were no significant differences in the cumulative incidences of and the adjusted risks for all the secondary outcome measures between the intermediate and optimal groups (Table 4).

The excess TLR risk of the suboptimal group relative to the optimal group was consistently seen across all the subgroups including heavy calcification (Table 5). However, there was no significant interaction between all the subgroup factors (hemodialysis, total stent length, in-stent restenosis, reference vessel diameter, heavy calcification, stent type, and bifurcation treatment) and the TLR risk of the suboptimal group relative to the optimal group (Table 5).

Angiographic Follow-Up Substudy

In the angiographic follow-up substudy, follow-up angiography was performed in 527 patients (14.3%) with median follow-up interval of 259 (interquartile range: 245–291) days after index stent implantation. At follow-up, in-stent minimum lumen diameter, but not in-segment minimum lumen diameter, was significantly smaller in the suboptimal group, while both in-stent and in-segment %DS was greater in the suboptimal group (Table S1). In-stent late loss was the largest in the optimal group and the smallest in the intermediate group. There was no significant difference in in-segment late loss, late-acquired peri-stent contrast staining, and stent fracture among the 3 groups (Table S1).

Discussion

The main findings in the current analysis were the following: (1) Suboptimal angiographic result with residual in-stent %DS ≥20% after implantation of the new-generation DES was associated with an increased risk for TLR as compared with optimal angiographic result with residual in-stent %DS <10%; (2) Intermediate angiographic result with residual %DS 10% to 20% was associated with a TLR risk similar to that of an optimal angiographic result.

In the bare-metal stent era, "the bigger, the better" hypothesis was advocated to reduce the rates of ISR, promoting those efforts to maximize the luminal dimension with use of debulking devices and/or high pressure dilatation by slightly oversized balloon.[10,11] A previous IVUS study by de Feyter et al confirmed that minimal stent area was one of the independent risk factors for ISR of bare metal stents.[12] In the first-generation DES era, another report focused on less stringent criteria of minimal stent area <5.5 cm^2 as a risk factor for angiographic restenosis after sirolimus-eluting stents implantation.[13] Therefore, many interventional operators have tended to adopt the less-stringent procedural end point for the final luminal dimension with less frequent use of debulking devices and

Table 2. Angiographic and Procedural Characteristics

Variables	Optimal Group N=1760	Intermediate Group N=1467	Suboptimal Group N=452	*P* Value
Lesion and procedural characteristics				
Before index procedure				
Lesion length, mm	13.9 (9.4–21.5) (N=1639)	17.2 (11.0–25.8) (N=1391)	20.9 (13.5–34.1) (N=418)	<0.0001
Reference vessel diameter, mm	2.60±0.57 (N=1758)	2.64±0.60 (N=1463)	2.64±0.62 (N=451)	0.25
≤2.75 mm*	1098/1758 (62%)	890/1463 (61%)	272/451 (60%)	0.54
Minimum lumen diameter	0.75±0.45	0.77±0.43 (N=1466)	0.71±0.43	0.01
Diameter stenosis, %	71.7±15.6	71.0±14.8 (N=1466)	73.5±15.2	0.01
Thrombus	82/1759 (4.7%)	80/1466 (5.5%)	18 (4.0%)	0.36
Chronic total occlusion*	122 (6.9%)	88 (6.0%)	39 (8.6%)	0.15
In-stent restenosis*	208 (12%)	178 (12%)	55 (12%)	0.96
Culprit for STEMI*	73 (4.2%)	55 (3.8%)	17 (3.8%)	0.83
Bifurcation*	336 (19%)	334/1466 (23%)	143 (32%)	<0.0001
Heavy calcification	196 (11%)	212/1465 (14%)	88 (19%)	<0.0001
Severe tortuosity*	72 (4.1%)	76/1466 (5.2%)	24 (5.3%)	0.27
After index procedure				
Direct stenting	485 (28%)	326 (22%)	76 (17%)	<0.0001
Lesion preparation				
POBA	1223 (69%)	1098 (75%)	364 (81%)	<0.0001
Cutting balloon	33 (1.9%)	34 (2.3%)	10 (2.2%)	0.67
Rotablator	46 (2.6%)	63 (4.3%)	32 (7.1%)	<0.0001
Bifurcation 2-stent approach	15 (0.9%)	14 (1.0%)	10 (2.2%)	0.07
Intravascular ultrasound use	1520 (86%)	1244 (85%)	383 (85%)	0.4
EES use	1149 (65%)	971 (66%)	316 (70%)	0.17
BES use	611 (35%)	496 (34%)	136 (30%)	0.17
Number of stents used				
Median	1 (1–1)	1 (1–2)	1 (1–2)	<0.0001
Mean±SD	1.3±0.6	1.4±0.6	1.6±0.8	
Stent length, mm				
Median	23 (15–28)	24 (18–36)	28 (18–46)	<0.0001
Mean±SD	25.5±14.7	28.9±16.4	34.3±20.8	
Total stent length ≥40 mm*	278/1759 (16%)	339 (23%)	158 (35%)	<0.0001
Stent diameter, mm				
Median	3 (2.75–3.5)	3 (2.7–3.3)	3 (2.6–3.0)	<0.0001
Mean±SD	3.0±0.4	3.0±0.4	2.9±0.3	
Maximum stent inflation pressure, atmosphere	17.1±4.2	17.2±4.4	17.2±4.5	0.89
Postdilatation	1327 (75%)	1130 (77%)	363 (80%)	0.08
Final balloon size, mm				
Median	3 (2.75–3.5)	3 (2.75–3.5)	3 (2.75–3.5)	0.001
Mean±SD	3.15±0.50	3.11±0.49	3.07±0.47	
Balloon–artery ratio	1.20 (1.09–1.34) (N=1758)	1.18 (1.05–1.32) (N=1463)	1.16 (1.03–1.34) (N=451)	<0.0001
Minimum lumen diameter, mm				

Continued

Table 2. Continued

Variables	Optimal Group N=1760	Intermediate Group N=1467	Suboptimal Group N=452	*P* Value
In-stent	2.61±0.46	2.44±0.44	2.15±0.41	<0.0001
In-segment	2.08±0.55	2.12±0.54	1.95±0.49	
Diameter stenosis, %				
In-stent	3.5±4.9	13.7±2.7	24.5±4.6	<0.0001
In-segment	20.5±12.2	21.3±11.0	27.6±10.3	<0.0001
Acute gain				
In-stent	1.86±0.51	1.67±0.51 (N=1466)	1.45±0.48	<0.0001
In-segment	1.33±0.55	1.35±0.56 (N=1466)	1.24±0.51	0.002
Duration of procedure, min	55 (38–80)	59 (38–84)	92 (62.5–92)	<0.0001
Staged PCI procedures	405 (23%)	384 (26%)	126 (28%)	0.03

Categorical variables are expressed as number (%) unless otherwise indicated. Continuous variables are shown as mean±SD or as median (interquartile range). Potential independent variables selected for multivariate analysis. In cases without postdilatation, final balloon size indicates the stent size. %DS indicates percent diameter stenosis; BES, biolimus-eluting stent; EES, everolimus-eluting stent; PCI, percutaneous coronary intervention; POBA, plain old balloon angioplasty; RVD, reference vessel diameter; STEMI, ST-segment–elevation myocardial infarction.

*Variables selected for the multivariable analysis.

more conservative choice of final balloon size and/or postdilatation pressure after DES implantation.

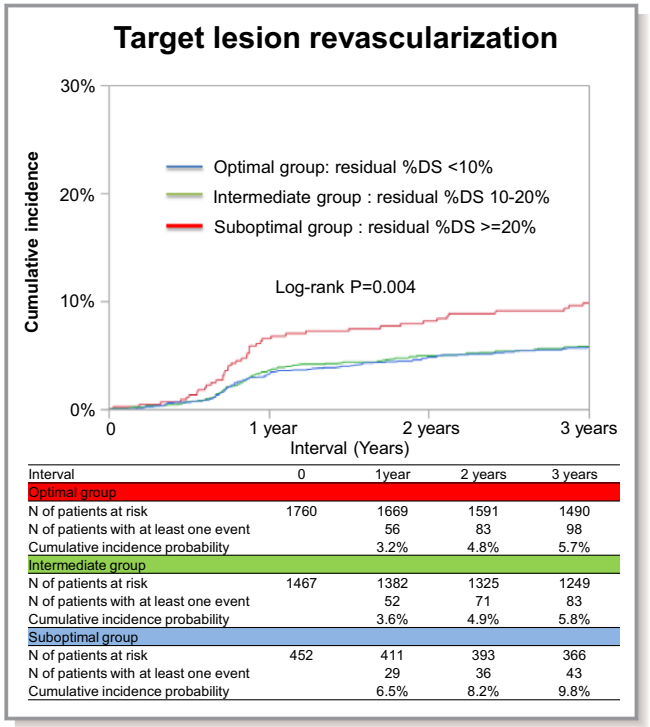
Recently, the IVUS-XPL (Impact of intravascular ultrasound guidance on outcomes of Xience prime stents in long lesions) randomized, multicenter trial demonstrated that IVUS-guided PCI as compared with angiography-guided PCI reduced TLR in patients with long coronary lesions (>28 mm) treated with the new-generation EES.[14] The final residual in-stent %DS was significantly smaller in the IVUS-guided group than in the angiography-guided group. However, there is a scarcity of data evaluating the risk of TLR according to angiographic residual stenosis, although angiography-guided PCI is more prevalent than IVUS-guided PCI in real-world practice. The American College of Cardiology/American Heart Association guideline recommends the minimum residual %DS <10% with an optimal goal of as close to 0% as possible. However, it is important to note that an aggressive strategy targeting 0% residual stenosis is inevitably associated with higher risk for procedural complications such as dissection and/or perforation. Furthermore, the recommendation was based on the extrapolation from the findings in the studies using IVUS or fractional flow reserve.[2,3] Few studies have ever investigated the relationship between the angiographic residual stenosis and clinical outcomes in patients undergoing PCI using DES. Moreover, the new-generation DES is widely used in current clinical practice, with reduced rates of ST as well as restenosis.[15–17] However, the optimal angiographic residual stenosis in the new-generation DES era still needs discussion. A previous study by Issac et al investigated the effect of the optimal angiographic result on the restenosis rate in patients with chronic total occlusion revascularization (second-generation DES use: 41%), suggesting that the immediate post-PCI residual stenosis >10% was associated with a higher binary restenosis rate.[4] This is the first study evaluating the association between the immediate residual stenosis after stent implantation and the restenosis rate in the new-generation DES era. However, their study had several limitations such as small sample size and lack of applicability to other subsets of patients undergoing PCI. The present study evaluating a large number of patients with QCA evaluation in the core laboratory clearly demonstrated that the suboptimal angiographic result with residual in-stent %DS ≥20% after implantation of the new-generation DES was associated with an increased risk for TLR as compared with optimal angiographic result with residual in-stent %DS <10%, while the intermediate angiographic result with residual in-stent %DS 10% to 20% had a TLR risk comparable to that of the optimal angiographic result. Therefore, residual %DS <20% might be a reasonable procedural end point balancing the safety and efficacy of PCI in the new-generation DES era. We identified those factors such as bifurcation treatment, total stent length ≥40 mm, and heavy calcification as the independent predictors for the suboptimal angiographic result (% DS ≥20%). Therefore, we should pay more attention to the optimization of the angiographic residual stenosis, particularly in treating these subsets of lesions.

The important question 1 step further from the current study is "How could the angiographic residual stenosis be optimized, particularly in patients with complex lesions?" First, lesion modification such as aggressive predilatation and/or use of a rotablator would be important to optimize the residual stenosis. Previous IVUS studies have strongly

Table 3. Independent Predictors for the Suboptimal Angiographic Result (%DS ≥20%)

Variables	Odds Ratio	95% CI	*P* Value
Bifurcation treatment	1.7	1.4 to 2.1	<0.0001
Total stent length ≥40 mm	2.1	1.7 to 2.7	<0.0001
Heavy calcification	1.4	1.1 to 1.8	0.02
DM requiring insulin use	1.3	1.0 to 1.8	0.09
Statin use	0.8	0.6 to 1.1	0.13
IVUS use	0.8	0.6 to 1.1	0.15
RVD ≤2.75 mm	0.9	0.7 to 1.1	0.19
Hb <11.0 g/dL	1.2	0.9 to 1.6	0.23
Peripheral vascular disease	1.2	0.8 to 1.7	0.29
Prior MI	0.9	0.7 to 1.1	0.34
Current smoker	0.9	0.7 to 1.1	0.36
Prior stroke	1.1	0.8 to 1.6	0.40
In-stent restenosis	1.1	0.8 to 1.5	0.46
Age ≥75 y	0.9	0.8 to 1.2	0.63
CCB use	1.0	0.8 to 1.2	0.69
Dyslipidemia	1.1	0.8 to 1.4	0.71
STEMI culprit PCI	1.1	0.6 to 1.8	0.71
Severe tortuosity	1.1	0.7 to 1.7	0.76
CTO treatment	1.0	0.6 to 1.4	0.86
Hypertension	1.0	0.8 to 1.3	1.00

Hemodialysis was not included in the model because of its strong colinearity with heavy calcification. CCB indicates calcium channel blocker; CI, confidence interval; CTO, chronic total occlusion; DM, diabetes mellitus; %DS, percent diameter stenosis; Hb, hemoglobin; IVUS, intravascular ultrasound; MI, myocardial infarction; PCI, percutaneous coronary intervention; RVD, reference vessel diameter; STEMI, ST-segment–elevation myocardial infarction.



Interval	0	1year	2 years	3 years
Optimal group				
N of patients at risk	1760	1669	1591	1490
N of patients with at least one event		56	83	98
Cumulative incidence probability		3.2%	4.8%	5.7%
Intermediate group				
N of patients at risk	1467	1382	1325	1249
N of patients with at least one event		52	71	83
Cumulative incidence probability		3.6%	4.9%	5.8%
Suboptimal group				
N of patients at risk	452	411	393	366
N of patients with at least one event		29	36	43
Cumulative incidence probability		6.5%	8.2%	9.8%

Figure 2. A Kaplan–Meier curve for the cumulative incidence of target-lesion revascularization according to the magnitudes of residual stenosis after stent implantation. %DS indicates percent diameter stenosis.

suggested that optimal stent expansion is crucially important to prevent restenosis and stent thrombosis. At least theoretically, aggressive lesion preparation would lead to more optimal stent expansion. In the present study, the prevalence of pre-dilatation and the use of a rotablator tended to be higher in the suboptimal group than in the other 2 groups. However, we do not know how aggressive the lesion preparation was in the suboptimal group. We should further explore optimal lesion preparation. Also, the prevalence of postdilatation tended to be higher in the suboptimal group than in the other 2 groups, while the final balloon inflation pressure was similar across the 3 groups, and the final balloon size tended to be smaller in the suboptimal group than in the other 2 groups. Therefore, we should further define the optimal stent implantation technique in terms of postdilatation balloon size and inflation pressure, when we encounter the initial suboptimal result.

The utility of IVUS-guided PCI in reducing ISR and ST is still controversial.[14,18,19] In the present study, IVUS was used in a large proportion of patients without any difference across the 3 groups. In these suboptimal cases, an appropriate additional procedure might not have been undertaken, or the lesions were undilatable despite an adequate optimization procedure. We should also revisit the optimal IVUS-guided stent optimization procedure.

Study Limitations

The current study has several important limitations. First, this is a post hoc analysis using data of randomized studies, and therefore, residual confounders might have influenced the outcomes even after multivariable adjustment. Nevertheless, randomization of residual stenosis after stent implantation was practically impossible in clinical practice. Second, the current study only included those patients treated with 2 types of the new-generation stent, namely, EES and biolimus-eluting stents. It is unknown whether we could generalize the present study result to patients treated with other types of stents. Third, QCA is mainly used for research purposes, and is rarely performed in daily clinical practice, where the degree of stenosis is intuitively judged by the visual estimation. Visual assessment overestimates stenosis more than QCA measurement in highly stenotic lesions, while it underestimates stenosis in mildly stenotic ones.[20,21] It could be possible that the suboptimal results might be underestimated by visual

Table 4. Clinical Outcomes: Optimal Versus Intermediate Vs Suboptimal Group

Variable	N of Patients With Events (Cumulative 3-Y Incidence)	Crude		*P* Value	Adjusted		*P* Value
		HR	95% CI		HR	95% CI	
TLR							
Optimal group	98 (5.7%)	1 (reference)	…	…	1 (reference)	…	…
Intermediate group	83 (5.8%)	1.02	0.76 to 1.36	0.91	0.97	0.72 to 1.31	0.85
Suboptimal group	43 (9.8%)	1.76	1.22 to 2.50	0.003	1.61	1.11 to 2.33	0.01
Clinically driven TLR							
Optimal group	72 (4.2%)	1 (reference)	…	…	1 (reference)	…	…
Intermediate group	64 (4.5%)	1.07	0.76 to 1.50	0.70	0.99	0.70 to 1.39	0.94
Suboptimal group	31 (7.1%)	1.72	1.11 to 2.59	0.01	1.49	0.97 to 2.31	0.07
TVR							
Optimal group	154 (9.0%)	1 (reference)	…	…	1 (reference)	…	…
Intermediate group	134 (9.4%)	1.05	0.83 to 1.32	0.7	1.01	0.80 to 1.28	0.91
Suboptimal group	51 (11.6%)	1.32	0.96 to 1.81	0.09	1.26	0.90 to 1.74	0.17
Clinically driven TVR							
Optimal group	114 (7.1%)	1 (reference)	…	…	1 (reference)	…	…
Intermediate group	103 (7.3%)	1.09	0.83 to 1.42	0.54	1.03	0.79 to 1.35	0.83
Suboptimal group	37 (8.5%)	1.29	0.88 to 1.84	0.19	1.16	0.79 to 1.70	0.46
All-cause death							
Optimal group	112 (6.4%)	1 (reference)	…	…	1 (reference)	…	…
Intermediate group	91 (6.3%)	0.98	0.74 to 1.29	0.86	0.89	0.67 to 1.19	0.44
Suboptimal group	34 (7.6%)	1.19	0.80 to 1.73	0.37	1.01	0.68 to 1.52	0.95
Myocardial infarction							
Optimal group	49 (2.8%)	1 (reference)	…	…	1 (reference)	…	…
Intermediate group	51 (3.5%)	1.25	0.85 to 1.86	0.26	1.06	0.71 to 1.58	0.12
Suboptimal group	24 (5.4%)	1.94	1.17 to 3.13	0.008	1.5	0.91 to 2.47	0.78
Definite/probable ST							
Optimal group	4 (0.2%)	1 (reference)	…	…	…	…	…
Intermediate group	4 (0.3%)	1.20	0.30 to 4.80	0.80	…	…	…
Suboptimal group	5 (1.2%)	4.91	1.32 to 18.3	0.02	…	…	…

Cumulative incidence was estimated by the Kaplan–Meier method. Multivariable adjustment was not performed for definite stent thrombosis because of the insufficient number of events. CI indicates confidence interval; HR, hazard ratio; MI, myocardial infarction; ST, stent thrombosis; TLR, target-lesion revascularization; TVR, target-vessel revascularization.

estimation. Use of online QCA for evaluating in-stent residual %DS might be an option in cases of angiography-guided PCI. Fourth, the angiographic residual stenosis could be a surrogate marker of restenosis and TLR. In an effort to explore the independent relation between the angiographic residual stenosis and TLR, we conducted an adjusted analysis with those factors such as hemodialysis, ISR, and total stent length ≥40 mm, which could influence both residual stenosis and TLR. Even after adjusting the confounders, a suboptimal angiographic result was independently associated with a higher risk for TLR. However, we did not include "heavy calcification" as a risk-adjusting variable, because heavy calcification was so closely correlated with high degree of residual stenosis.[9] It could be possible that stent implantation in heavily calcified lesions inevitably results in a suboptimal angiographic result even after all the efforts to optimize the angiographic result. However, in the subgroup analysis, the suboptimal angiographic result tended to be associated with higher risk for TLR regardless of the presence or absence of heavy calcification. There might be some room for improvement of luminal outcome, particularly in suboptimal lesions without heavy calcification. Finally, the present study did not include IVUS analysis, although IVUS was used in most of the patients. Therefore, information about plaque burden in the

Table 5. Subgroup Analysis: Optimal Versus Suboptimal Group

	Optimal Group	Suboptimal Group			
	N of Patients With TLR (Cumulative Incidence)		Suboptimal Vs Optimal (Reference) Group		
	N=1760	N=452	Nonadjusted HR (95% CI)	*P* Value	Interaction *P* Value
Hemodialysis					
(+)	17/86 (22.0%)	8/33 (26.7%)	1.40 (0.57–3.14)	0.45	0.60
(−)	81/1674 (5.0%)	35/419 (8.6%)	1.76 (1.17–2.60)	0.007	
Total stent length					
≥40 mm	17/278 (6.3%)	21/158 (13.7%)	2.24 (1.19–4.31)	0.01	0.22
<40 mm	81/1481 (5.6%)	22/294 (7.8%)	1.39 (0.85–2.19)	0.18	
In-stent restenosis					
(+)	21/208 (10.3%)	12/55 (22.4%)	2.33 (1.11–4.65)	0.03	0.39
(−)	77/1552 (5.1%)	31/397 (8.1%)	1.61 (1.05–2.42)	0.03	
RVD					
≤2.75 mm	62/990 (5.9%)	27/254 (10.2%)	1.83 (1.15–2.84)	0.01	0.89
>2.75 mm	36/732 (5.6%)	16/188 (9.3%)	1.66 (0.90–2.94)	0.10	
Heavy calcification					
(+)	13/196 (7.1%)	10/88 (11.6%)	1.70 (0.72–3.86)	0.22	0.98
(−)	85/1564 (5.6%)	33/364 (9.4%)	1.72 (1.14–2.55)	0.01	
Stent type					
EES	63/973 (5.6%)	29/254 (9.5%)	1.73 (1.10–2.66)	0.02	0.90
BES	35/517 (5.9%)	14/112 (10.6%)	1.83 (0.95–3.32)	0.07	
Bifurcation treatment					
(+)	20/280 (6.2%)	12/119 (8.7%)	1.42 (0.68–2.87)	0.34	0.49
(−)	78/1210 (5.6%)	31/247 (10.4%)	1.90 (1.24–2.86)	0.004	

BES indicates biolimus-eluting stent; CI, confidence interval; EES, everolimus-eluting stent; HR, hazard ratio; RVD, reference vessel diameter; TLR, target-lesion revascularization.

stent edges was not taken into consideration, which could be an important determinant of both residual stenosis and late lumen loss.

Conclusions

The residual angiographic in-stent %DS ≥20% was associated with increased risk for TLR in patients treated with the new-generation DES.

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Disclosures

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Kansai Rosai Hospital: Masaaki Uematsu, Masaki Awata

Hyogo Prefectural Amagasaki Hospital: Yoshiki Takatsu, Ryoji Taniguchi

Hyogo College of Medicine Hospital: Motomaru Masutani

Tenri Hospital: Yoshihisa Nakagawa, Hirokazu Kondo

Nara Medical University Hospital: Shiro Uemura, Kenichi Ishigami

Japanese Red Cross Society Wakayama Medical Center: Takashi Tamura, Hiroki Sakamoto

Wakayama Medical University Hospital: Takashi Akasaka, Hironori Kitabata

Tottori University Hospital: Masahiko Kato, Yoshiyuki Furuse

Matsue Red Cross Hospital: Kinya Shirota, 1 Asao Mimura

The Sakakibara Heart Institute of Okayama: Keizou Yamamoto, Hiroyuki Takinami

Kurashiki Central Hospital: Kazushige Kadota, Hiroyuki Tanaka

Kawasaki Medical School Hospital: Hiroyuki Okura, Yoji Neishi

Okayama University Hospital: Hiroshi Ito, Yoshiki Hata

Hiroshima City Hospital: Masaharu Ishihara, Kazuoki Dai

Fukuyama Cardiovascular Hospital: Seiichi Haruta, Hideo Takebayashi

Tsuchiya General Hospital: Mamoru Toyofuku

Chikamori Hospital: Kazuya Kawai, Shuichi Seki

University Of Occupational And Environmental Health Japan: Shinjo Sonoda, Yoshitaka Muraoka

Kurume University Hospital: Takafumi Ueno, Seiji Kanaya

Kokura Memorial Hospital: Masashi Iwabuchi, Shinichi Shirai

Kouseikai Hospital: Yoshihiro Iwasaki

Saiseikai Kumamoto Hospital: Koichi Nakao

Kumamoto Rousai Hospital: Toshiyuki Matsumura, Sei Nakata

Miyazaki Medical Association Hospital: Yoshisato Shibata, Nehiro Kuriyama

Kagoshima Medical Center: Hitoshi Nakashima, Yasuhisa Iriki

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Caress Sapporo Tokeidai Memorial Hospital: Kazushi Urasawa, Ryoji Koshida

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Hokkaido Junkanki Hospital: Daisuke Hotta, Masaru Yamaki

Teine Keijinkai Hospital: Mitsugu Hirokami

Cardio-vascular Center Hokkaido Ohno Hospital: Takehiro Yamashita, Masato Nagashima

Caress Sapporo Hokko Memorial Hospital: Yoichi Nozaki

Hokkaido Social Insurance Hospital: Keiichi Igarashi, Jungo Furuya

Aomori Prefectural Central Hospital: Fuminobu Yoshimachi, Dai Miura, Yoshihisa Aida, Yukinori Sakamoto

Iwate Prefectural Central Hospital: Akihiro Nakamura, Shigefumi Fukui

Iwate Medical University Hospital: Tetsuya Fusazaki

Tohoku Kousei Nenkin Hospital: Yoshiaki Katahira, Takao Nakano

Sendai Open Hospital: Atsushi Kato, Toru Takii

Iwaki Kyoritsu General Hospital: Yoshito Yamamoto, Tomohiro Tada

Fukushima Medical University Hospital: Yasuchika Takeishi, Kazuhiko Nakazato

Saiseikai Kurihashi Hospital: Yoshimi Ota, Atsushi Honda

Saitama Cardiovascular and Respiratory Center: Tetsuya Ishikawa, Takuro Fujii

Dokkyo Medical University Koshigaya Hospital: Takaaki Komatsu

New Tokyo Hospital: Sunao Nakamura, Naoyuki Kurita

Juntendo University Hospital: Hiroyuki Daida, Katsumi Miyauchi

Sakakibara Memorial Hospital: Itaru Takamisawa

NTT Medical Center Tokyo: Masao Yamasaki

The Cardiovascular Institute Hospital: Junji Yajima, Shingo Tanaka, Ryuichi Funada

Mitsui Memorial Hospital: Kengo Tanabe, Yoshifumi Nakajima

Tokyo Medical University Hospital: Nobuhiro Tanaka, Masashi Ogawa

Teikyo University Hospital: Ken Kozuma, Nobuaki Suzuki

Tokyo Women's Medical University Hospital: Nobuhisa Hagiwara, Fumiaki Mori

Juntendo University Nerima Hospital: Masataka Sumiyoshi, Kenji Inoue, Shinya Okazaki

Itabashi Chuo Medical Center: Hiroshi Ohta

Saiseikai Yokohama-City Eastern Hospital: Toshiya Muramatsu, Hiroshi Ishimori

Kanto Rosai Hospital: Atsuo Namiki

Yokohama Rosai Hospital: Kenichi Kato, Kazuhiko Yumoto

Tokai University Hospital: Nobuhiko Ogata, Shou Torii

Yokohama City University Medical Center: Kazuo Kimura, Kiyoshi Hibi

Kitasato University Hospital: Taiki Tojo, Takao Shimohama

Kanazawa Cardiovascular Hospital: Masanobu Namura, Yuki Horita

University of Fukui Hospital: Jong-Dae Lee, Hiroyasu Uzui, Akira Nakano

Fukui Cardiovascular Center: Sumio Mizuno, Katsushi Misawa

Ogaki Municipal Hospital: Hiroaki Mukawa, Yohei Shibata

Juntendo University Shizuoka Hospital: Satoru Suwa

Shizuoka General Hospital: Osamu Doi, Hideaki Moriwaki

Okamura Memorial Hospital: Yasuhiro Tarutani

Seirei Hamamatsu General Hospital: Hisayuki Okada

Hamamatsu Medical Center: Masakazu Kobayashi, Terumori Sato, Yohei Takayama

Aichi Medical University Hospital: Hiroaki Takashima, Takayuki Ito

Tosei General Hospital: Masayoshi Ajioka, Yosuke Murase

Toyota Memorial Hospital: Hisashi Umeda, Kazutaka Hayashi

Fujita Health University Hospital: Yukio Ozaki, Hiroyuki Naruse

Japanese Red Cross Nagoya Daini Hospital: Haruo Hirayama, Yasushi Tatematsu

Chubu Rosai Hospital: Tetsuya Amano, Tomohiro Yoshida

Nagai Hospital: Kozo Hoshino

Mie University Hospital: Takashi Tanigawa

Mie Heart Center: Hideo Nishikawa, Hiroyuki Suzuki

Yokkaichi Social Insurance Hospital: Masaki Kawamura, Takashi Yamanaka

Koto Memorial Hospital: Teruki Takeda

Shiga University of Medical Science Hospital: Takashi Yamamoto

Kyoto University Hospital: Takeshi Kimura, Masahiro Natsuaki

Mitsubishi Kyoto Hospital: Shinji Miki, Tetsu Mizoguchi

National Hospital Organization Kyoto Medical Center: Masaharu Akao, Mitsuru Abe

Kyoto Second Red Cross Hospital: Hiroshi Fujita

Osaka University Hospital: Shinsuke Nanto, Masahiro Kumada

Sakurabashi Watanabe Hospital: Kenji Fujii

Osaka City General Hospital: Akira Itoh

Osaka Saiseikai Noe Hospital: Shunsuke Take, Yoshihiro Kato, Shiho Koyama

Osaka City University Hospital: Takao Hasegawa, Tomokazu Iguchi

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Kobe City Medical Center General Hospital: Natsuhiko Ehara

Kobe University Hospital: Toshihiro Shinke, Takumi Inoue, Junya Shite

Kansai Rosai Hospital: Masaki Awata

Hyogo Prefectural Amagasaki Hospital: Yoshiki Takatsu, Ryoji Taniguchi

Hyogo College of Medicine Hospital: Motomaru Masutani

Tenri Hospital: Yoshihisa Nakagawa, Toshihiro Tamura

Japanese Red Cross Society Wakayama Medical Center: Takashi Tamura, Yuichi Kawase

Wakayama Medical University Hospital: Takashi Akasaka, Yasushi Ino, Hironori Kitabata

Tottori University Hospital: Masahiko Kato, Yoshiyuki Furuse

Matsue Red Cross Hospital: Kinya Shirota

The Sakakibara Heart Institute of Okayama: Atsushi Hirohata, Eiki Hirose

Kurashiki Central Hospital: Kazushige Kadota, Seiji Habara

Kawasaki Medical School Hospital: Hiroyuki Okura, Yoji Neishi

Hiroshima City Hospital: Masaharu Ishihara, Yasuharu Nakama

Fukuyama Cardiovascular Hospital: Hideo Takebayashi, Kenji Goto

Tsuchiya General Hospital: Nobuo Shiode, Masaya Otsuka, Mamoru Toyofuku

Iwakuni Clinical Center: Satoru Sakuragi

Chikamori Hospital: Kazuya Kawai, Shuichi Seki

University of Occupational and Environmental Health Japan: Shinjo Sonoda

Fukuoka Wajiro Hospital: Taro Saito, Yoritaka Otsuka

Kurume University Hospital: Takafumi Ueno, Yoshiaki Mitsutake

Kokura Memorial Hospital: Masashi Iwabuchi, Shinichi Shirai

Kouseikai Hospital: Yoshihiro Iwasaki

Saiseikai Kumamoto Hospital: Koichi Nakao, Shinzo Miyamoto

National Hospital Organization Kumamoto Medical Center: Kazuteru Fujimoto

Kumamoto Rousai Hospital: Toshiyuki Matsumura, Takuo Tsurugi

Miyazaki Medical Association Hospital: Yoshisato Shibata, Nehiro Kuriyama

Tenyokai Central Hospital: Hiroshi Yamaguchi, Junichiro Takaoka

National Hospital Organization Kagoshima Medical Center: Hitoshi Nakashima, Tetsuro Kataoka

Bell Land General Hospital: Toru Kataoka

Table S1. Angiographic findings in the angiographic follow-up substudy.

Variables	Optimal group N=270	Intermediate group N=206	Suboptimal group N=51	P value
Before index procedure				
Lesion length, mm	12.5(8.9-19.3)(N=255)	17.7(11.9-25.5) (N=199)	19.3(13.1-28.6) (N=47)	<.0001
Reference vessel diameter, mm	2.6±0.5	2.7±0.6	2.7±0.7	0.41
*<=2.75mm	169(63%)	122(59%)	33(65%)	0.67
Minimum lumen diameter, mm	0.80(0.53-1.06)	0.83(0.54-1.04)	0.83(0.60-1.11)	0.94
Diameter stenosis, %	68(57-79)	68(59-79)	69(59-77)	0.88
After index procedure				
Minimum lumen diameter, mm				
In-stent	2.60±0.44	2.43±0.41	2.20±0.42	<.0001
In-segment	2.06±0.54	2.12±0.2	2.00±0.48	0.25
Diameter stenosis, %				
In-stent	5(1-7)	13(11-16)	23(21-24)	<.0001
In-segment	18(11-28)	19(14-26)	24(21-31)	0.0008
Acute gain, mm				
In-stent	1.7(1.4-2.1)	1.6(1.3-1.9)	1.3(1.1-1.6)	<.0001
In-segment	1.2(0.9-1.6)	1.3(1.0-1.6)	1.2(0.9-1.5)	0.36
Follow-up				
Minimum lumen diameter, mm				
In-stent	2.40±0.49 (N=269)	2.35±0.49	2.04±0.62	<.0001
In-segment	2.04±0.53 (N=269)	2.04±0.57	1.88±0.59	0.14
Diameter stenosis, %				
In-stent	11.2±11.6 (N=269)	15.2±9.6	26.2±20.7	<.0001
In-segment	22.3±14.3 (N=269)	24.3±15.4	31.0±19.8	0.001
Late loss, mm				
In-stent	0.20±0.35 (N=269)	0.09±0.3	0.16±0.52	0.002
In-segment	0.03±0.43 (N=269)	0.08±0.37	0.13±0.52	0.22
In-stent restenosis	15/270 (5.6%)	16/206 (7.8%)	5/51(9.8%)	0.44
Late acquired PSS	7/270 (2.6%)	5/206 (2.4%)	1/51 (2.0%)	0.96
Stent fracture	1/270 (0.4%)	3/206 (1.5%)	1/51 (2.0%)	0.34

PSS=peri-stent contrast staining.