











ORIGINAL RESEARCH

Procedural Characteristics of Intravascular Ultrasound–Guided Percutaneous Coronary Intervention and Their Clinical Implications

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BACKGROUND: Despite the clinical benefits to intravascular ultrasound (IVUS) guidance for percutaneous coronary intervention (PCI), most patients with coronary artery disease undergo angiography-guided PCI alone in the real-world setting. We sought to investigate the procedural characteristics of IVUS-guided PCI and their clinical outcomes, as compared with angiography-guided PCI.

METHODS AND RESULTS: This was a cohort study using patient-level data from the IVUS-XPL (Impact of Intravascular Ultrasound Guidance on the Outcomes of Xience Prime Stents in Long Lesions) and ULTIMATE (Intravascular Ultrasound Guided Drug Eluting Stents Implantation in All-Comers Coronary Lesions) clinical trials. A total of 2848 patients with 3872 native coronary lesions were included and procedural characteristics assessed by quantitative coronary angiography (QCA) were compared between IVUS and angiography guidance. Stent-to-reference vessel diameter ratio (ie, QCA stent sizing) was greater (1.11 ± 0.16 versus 1.07 ± 0.14 , $P<0.001$) and high-pressure postdilation was more frequently performed (83.7% versus 75.4%, $P<0.001$) with IVUS guidance, whereas residual stent edge dissections were more frequent in lesions treated with IVUS guidance (4.6% versus 0.7%, $P<0.001$). Given the dissection risk, optimal QCA stent sizing for IVUS guidance was a stent-to-QCA reference vessel diameter ratio ≥ 1.1 to <1.3 . Among 1424 patients (1969 lesions) treated with angiography guidance, QCA stent sizing <1.0 was observed in 651 (33.1%) lesions, while QCA stent sizing ≥ 1.1 to <1.3 was observed in only 526 (26.7%) lesions. Under angiography guidance, patients with both QCA stent sizing ≥ 1.1 to <1.3 and high-pressure postdilation (235 of 1424, 16.5%) had a lower risk of 3-year target lesion failure compared with others (hazard ratio, 0.532; 95% CI, 0.293–0.966 [$P=0.038$]).

CONCLUSIONS: IVUS-guided PCI resulted in larger QCA-assessed stent sizing and more frequent postdilation with high-pressure inflations. These procedures may further improve long-term clinical outcomes in patients undergoing PCI without IVUS.

REGISTRATION: URL: <https://www.clinicaltrials.gov>; Unique identifier: NCT01308281 (IVUS-XPL); NCT02215915 (ULTIMATE).

Key Words: coronary artery disease ■ percutaneous coronary intervention ■ ultrasound

Cumulative evidence has suggested that intravascular ultrasound (IVUS)–guided percutaneous coronary intervention (PCI) may improve clinical outcomes in patients with coronary artery disease

compared with angiography-guided PCI. The large-scale prospective ADAPT-DES (Assessment of Dual Antiplatelet Therapy With Drug-Eluting Stents) study reported that IVUS guidance compared with angiography

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CLINICAL PERSPECTIVE

What Is New?

- Intravascular ultrasound–guided percutaneous coronary intervention had the procedural characteristics of larger quantitative coronary angiography–assessed stent sizing and more frequent postdilation with high-pressure inflations.

What Are the Clinical Implications?

- These procedural characteristics associated with intravascular ultrasound–guided percutaneous coronary intervention may improve clinical outcomes compared with percutaneous coronary intervention without intravascular ultrasound.

Nonstandard Abbreviations and Acronyms

ADAPT-DES	Assessment of Dual Antiplatelet Therapy With Drug-Eluting Stents
DES	drug-eluting stent
IVUS-XPL	Impact of Intravascular Ultrasound Guidance on the Outcomes of Xience Prime Stents in Long Lesions
ULTIMATE	Intravascular Ultrasound Guided Drug Eluting Stents Implantation in All-Comers Coronary Lesions

guidance was associated with reduced 2-year rates of major adverse cardiac events, definite/probable stent thrombosis, and myocardial infarction (MI).¹ Similarly, 2 large randomized clinical trials—IVUS-XPL (Impact of Intravascular Ultrasound Guidance on the Outcomes of Xience Prime Stents in Long Lesions) and ULTIMATE (Intravascular Ultrasound Guided Drug Eluting Stents Implantation in All-Comers Coronary Lesions)—demonstrated that IVUS-guided drug-eluting stent (DES) implantation reduced the rate of major adverse cardiac events up to 3 to 5 years.^{2,3} However, the real-world use of IVUS guidance remains low despite its benefits.⁴ For example, IVUS was used in only 5.6% of all patients with PCI from the US Medicare cohort between 2009 and 2017.⁵ This phenomenon is possibly related to the willingness and education of physicians and the low reimbursement for IVUS use. As a result, and for all practical purposes, most patients with coronary artery disease undergo angiography-guided PCI. Thus, it is still an important to improve clinical outcomes in patients treated with angiography-guided PCI.

The present study sought to investigate, compare, and contrast the procedural characteristics of IVUS-guided versus angiography-guided PCI and to explore their clinical outcomes, especially among patients who underwent angiography-guided PCI using IVUS guidance–like parameters.

METHODS

Study Population

The data that support the findings of this study are available from the corresponding author on reasonable request. We used the pooled patient-level data from the IVUS-XPL and ULTIMATE trials,^{2,3,6,7} which investigated the clinical benefits of IVUS-guided PCI over angiography-guided PCI in patients with coronary artery disease. Briefly, in the IVUS-XPL trial, 1400 patients with long coronary lesions were randomly assigned to receive IVUS-guided versus angiography-guided everolimus-eluting stent implantation between 2010 and 2014 at 20 Korean centers.⁶ In the ULTIMATE trial, 1448 “all-comer” patients were randomly assigned to either IVUS-guided or angiography-guided DES implantation between 2014 and 2017 at 8 Chinese centers.⁷ The IVUS-XPL trial included patients with stent length ≥ 28 mm and excluded those with acute ST-segment–elevation MI within 48 hours, cardiogenic shock, left main disease, bifurcation lesion requiring 2-stent technique, chronic total occlusion, or in-stent restenosis.⁶ The ULTIMATE trial included all patients who required DES implantation and excluded those with chronic total occlusion not recanalized or severe calcification needing rotational atherectomy.⁷ Details of both trials have been previously reported.^{6,7} Each trial protocol was approved by the institutional review boards or ethics committees at each participating center, and all participants gave written informed consent. The present study included all 2848 patients from the IVUS-XPL and ULTIMATE trials.

For patients treated with angiography-guided PCI, stent diameter and length were determined by visual estimation.^{6,7} For patients treated with IVUS-guided PCI, stent diameter and length were determined by IVUS measurements.^{6,7} After PCI, aspirin 100 mg/d was prescribed indefinitely and clopidogrel 75 mg/d was prescribed for at least 6 months.^{6,7}

Quantitative Coronary Angiography

In the IVUS-XPL and ULTIMATE trials, comprehensive quantitative coronary angiography (QCA) analysis was performed in the independent core laboratory of each trial using offline software. After guiding catheter calibration, reference vessel

diameter and minimum lumen diameter were measured before and after PCI. The reference vessel diameter was an average of proximal and distal diameters, and diameter stenosis was calculated as follows: reference vessel diameter minus minimum lumen diameter divided by reference vessel diameter $\times 100$. Stent sizing was assessed by stent-to-reference vessel diameter ratio. The residual stent edge dissection was defined as an intraluminal linear filling defect or a persistent parietal radiopacity at the proximal or distal edge of the stent after PCI.⁸ The angiographic analysts in each of the core laboratories were blinded to patient data (including outcomes) and treatment assignments.

Clinical Outcomes

The definition for study end points were similar in the IVUS-XPL and ULTIMATE trials, with all clinical end points assessed by an independent committee.^{6,7} Follow-up for the study end points was censored as 3 years in the present analysis since only 3-year clinical outcomes were available in the ULTIMATE trial even though 5-year clinical outcomes were available in the IVUS-XPL trial.^{2,3} In the present study, target lesion failure was defined as a composite of cardiac death, target vessel-related MI, and clinically driven target lesion revascularization. All deaths were considered cardiac death unless a definite noncardiac cause could be established.^{6,7} Target lesion-related MI was defined as the presence of clinical symptoms, ECG changes, or abnormal findings on imaging studies with evidence of myocardial necrosis in the territory supplied by the coronary artery containing the lesion that was stented during the index procedure.^{6,7} Definite or probable stent thrombosis was defined according to Academic Research Consortium recommendations.^{6,7,9} Ischemia-driven target lesion revascularization was defined as ischemia or angina referable to the target lesion requiring repeat percutaneous intervention or bypass surgery.^{6,7}

Statistical Analysis

The present study was based on an intention-to-treat analysis to compare the procedural characteristics between IVUS-guided and angiography-guided PCI. Categorical variables were reported as number (percentage) and compared using chi-square test or Fisher exact test. Continuous variables were reported as mean \pm SD and compared using Student *t* test. Receiver operating characteristic curve analysis was performed to evaluate the cutoff value for the variable of stent-to-reference vessel diameter ratio. The best cutoff value was determined using the Youden index. The risk of residual stent edge dissection according to stent-to-reference vessel diameter ratio was assessed

using logistic regression. Cumulative incidences of clinical outcomes were calculated using Kaplan-Meier estimates. A Cox regression model including each trial as a random effect was used to compare clinical outcomes. Information on patients who were lost to follow-up were used as censored data in the survival analysis. For composite outcomes, each patient was assessed until the occurrence of the first event and considered only once for the survival analyses. All analyses were performed using SAS version 9.2 (SAS Institute Inc) or MedCalc (MedCalc Software). All tests were 2-sided, and a $P < 0.05$ was considered statistically significant.

RESULTS

Procedural Characteristics of IVUS-Guided PCI

Among 1424 patients randomized to IVUS guidance, 22 patients (1.5%) underwent angiography guidance alone. Among 1424 patients randomized to angiography guidance, 38 patients (2.7%) underwent IVUS guidance. Table S1 shows baseline characteristics between patients randomized to IVUS-guided versus angiography-guided PCI. There were no significant differences between the 2 strategies. Table 1 shows lesional and procedural characteristics. Patients randomized to IVUS-guided PCI were treated with bigger stents and had larger stent-to-QCA reference vessel diameter ratios (1.11 \pm 0.16 versus 1.07 \pm 0.14, $P < 0.001$) compared with patients randomized to angiography-guided PCI. Patients randomized to IVUS-guided PCI also underwent postdilation with higher-pressure inflations more frequently (83.7% versus 75.4%, respectively; $P < 0.001$). Postintervention QCA minimum lumen diameter was larger in lesions treated with IVUS-guided PCI compared with angiography-guided PCI (2.6 \pm 0.5 mm versus 2.5 \pm 0.5 mm, $P < 0.001$). However, the frequency of residual stent edge dissection was more common in lesions with IVUS guidance compared with angiography guidance (4.6% versus 0.7%, $P < 0.001$).

Using receiver operating characteristics curve analysis, the stent-to-QCA reference vessel diameter ratio that best separated IVUS guidance from angiography guidance was >1.09 (area under the curve, 0.592; 95% CI, 0.576–0.608 [$P < 0.001$]) (Figure 1A). However, lesions with stent-to-QCA reference vessel diameter ratio ≥ 1.3 were associated with an increased risk of residual stent edge dissection, compared with those with stent-to-QCA reference vessel diameter ratio < 1.1 (Figure 1B) (odds ratio, 2.321; 95% CI, 1.290–4.176 [$P = 0.029$]). Therefore, optimal stent sizing to maximize the stent size, but avoid stent edge dissections, was a stent-to-QCA reference vessel diameter ratio ≥ 1.1 to < 1.3 .

Table 1. Lesional and Procedural Characteristics

Variables	IVUS guidance (n=1903)	Angiography guidance (n=1969)	P value
Treated vessels			0.171
Left main	95 (5.0)	87 (4.4)	
Left anterior descending artery	999 (52.5)	980 (49.8)	
Left circumflex artery	338 (17.8)	361 (18.3)	
Right coronary artery	471 (24.7)	541 (27.5)	
AHA/ACC lesion type B2/C	1533 (80.6)	1557 (79.1)	0.251
Preintervention QCA			
Reference vessel diameter, mm	2.8±0.5	2.8±0.5	0.389
Proximal	2.9±0.5	2.9±0.5	0.239
Distal	2.7±0.6	2.7±0.5	0.232
Minimum lumen diameter, mm	0.9±0.5	0.9±0.5	0.387
Lesion length, mm	33.5±17.7	33.2±17.1	0.537
Mean stent diameter, mm	3.1±0.4	3.0±0.4	<0.001
Stent-to-reference vessel diameter ratio	1.11±0.16	1.07±0.14	<0.001
Postdilation	1593 (83.7)	1485 (75.4)	<0.001
Balloon diameter, mm	3.6±0.7	3.5±0.6	<0.001
Balloon-to-stent diameter ratio	1.17±0.20	1.18±0.20	0.115
Inflation pressure, atm	18.3±4.2	17.9±4.1	0.011
No. of implanted stents	1.5±0.8	1.5±0.7	0.282
Total stent length, mm	42.7±22.8	41.4±21.7	0.061
Postintervention QCA			
Minimum lumen diameter, mm	2.6±0.5	2.5±0.5	<0.001
Diameter stenosis, %	13.0±9.5	13.4±9.1	0.168
Residual stent edge dissections	88 (4.6)	13 (0.7)	<0.001

Data are presented as mean±SD or number (percentage). ACC indicates American College of Cardiology; AHA, American Heart Association; IVUS, intravascular ultrasound; and QCA, quantitative coronary angiography.

IVUS-Guided Like Procedures in Patients Randomized to Angiography-Guided PCI

The frequency of stent sizing as assessed by stent-to-QCA reference vessel diameter ratio is presented in Figure 2. The frequency of stent sizing was different between IVUS guidance and angiography guidance ($P<0.001$). A total of 1424 patients with 1969 lesions were randomized to angiography-guided PCI. Stent sizing <1.0 was observed in 651 (33.1%) lesions, ≥ 1.0 to <1.1 was observed in 696 (35.3%) lesions, and ≥ 1.1 to <1.3 was observed in 526 (26.7%) lesions. The cumulative incidence of target lesion failure at 3 years, grouped by optimal stent sizing ≥ 1.1 to <1.3 and use of high-pressure postdilation, is shown in Figure 3. Neither stent sizing ≥ 1.1 to <1.3 alone nor high-pressure postdilation alone was related to target lesion failure. However, the risk of target lesion failure decreased when both stent sizing ≥ 1.1 to <1.3 and high-pressure postdilation were performed in all stented lesions (hazard ratio, 0.532; 95% CI, 0.293–0.966 [$P=0.038$]).

Baseline characteristics and procedural results according to IVUS-guided like procedures (stent sizing

≥ 1.1 to <1.3 followed by high-pressure postdilation) in patients randomized to angiography guidance is shown in Table S2. The frequency of multivessel disease and multivessel PCI was lower in patients with IVUS-guided like procedures. Post-PCI, residual diameter stenosis was smaller in patients with IVUS-guided like procedures, and the frequency of residual stent edge dissection was not different (0.9% versus 0.9%, respectively; $P=1.0$). The reduced risk of target lesion failure among patients with IVUS-guided like procedures was mainly driven by a decrease in the need for target lesion revascularization (Table 2), and it was consistent even after adjusting for the presence of multivessel disease, treated vessels, number of treated lesions, number of implanted stents, and reference vessel diameter (adjusted hazard ratio, 0.506; 95% CI, 0.274–0.932 [$P=0.029$]).

Among a total of 2848 patients, 93 patients died during the 3-year follow-up. Among 2755 available patients, 2636 patients (95.7%) completed the clinical follow-up at 3 years. Figure 4 represented time-to-event curves for target lesion failure at 3 years between IVUS

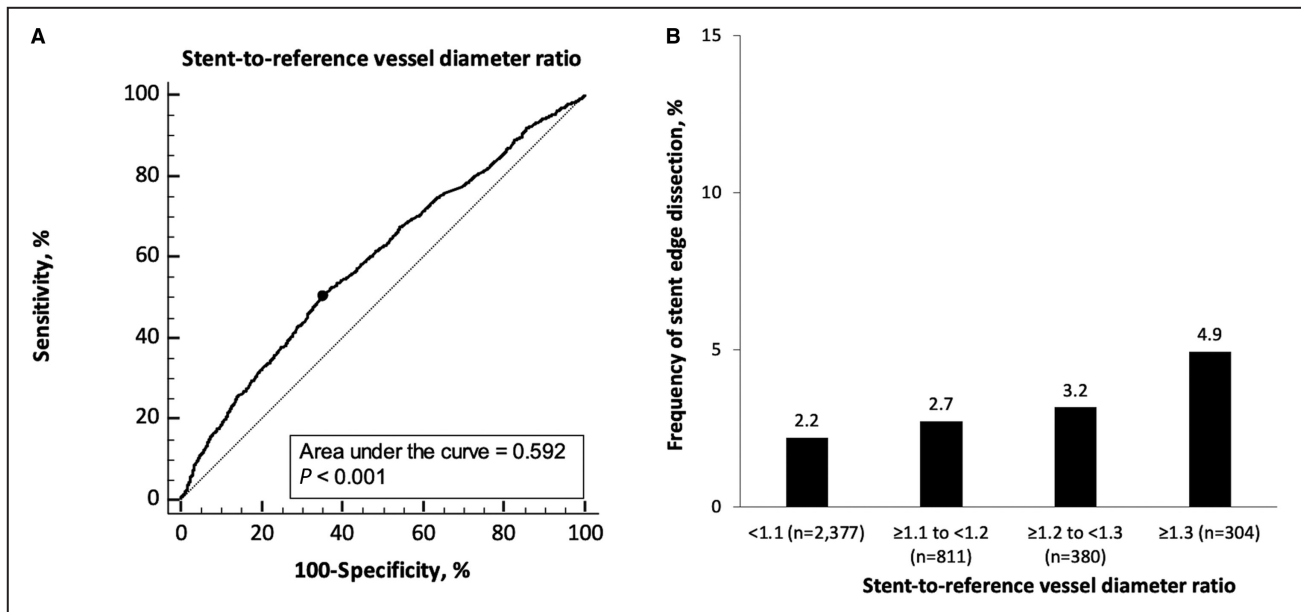


Figure 1. Optimal selection of stent size for intravascular ultrasound-guided like percutaneous coronary intervention. (A) Receiver operating characteristic curve analysis, and (B) frequency of residual stent edge dissection.

guidance versus angiography guidance in all patients, as well as in patients randomized to the angiography-guided group, but with versus without IVUS-guided like procedures.

DISCUSSION

In this study, pooling the patient-level data from the 2 largest randomized trials of IVUS versus angiography DES implantation, larger stent sizing and more frequent postdilation with high-pressure inflation were

the procedural characteristics of IVUS-guided PCI, whereas residual stent edge dissection was a procedural complication. To avoid a stent edge dissection, the optimal stent sizing was a stent-to-reference vessel diameter ratio ≥ 1.1 to < 1.3 , as assessed by quantitative coronary angiography. Among patients undergoing angiography-guided PCI, the stent sizing based on visual estimation varied widely, resulting in not infrequent use of undersized stents. In patients randomized to angiography-guided PCI, those treated with optimal QCA stent sizing followed by high-pressure postdilation of all of the stented lesions had a low risk of target

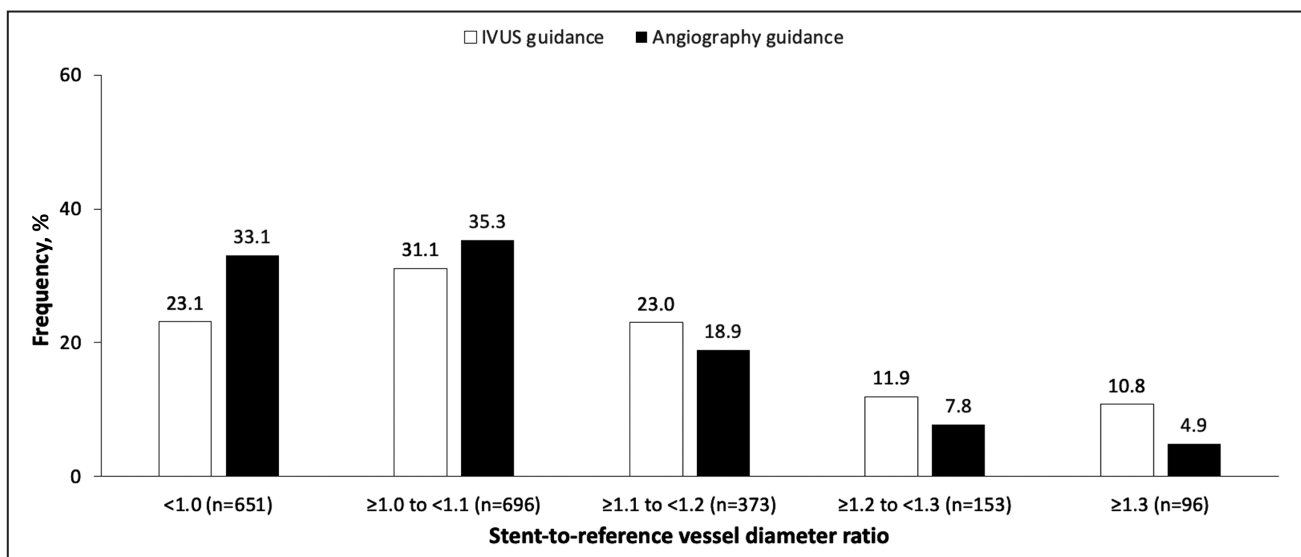


Figure 2. Frequency of stent sizing, as assessed by stent-to-reference vessel diameter ratio. IVUS indicates intravascular ultrasound.

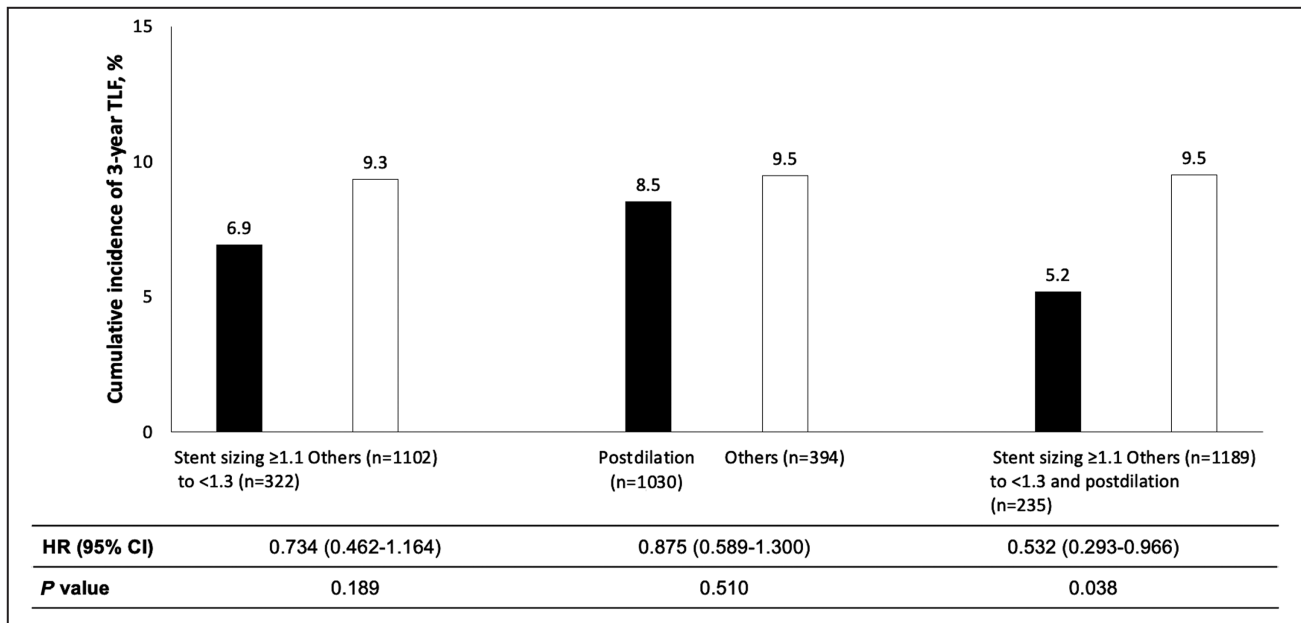


Figure 3. Cumulative incidence of target lesion failure (TLF) at 3 years in patients undergoing angiography guidance, according to stent sizing ≥ 1.1 to < 1.3 and postdilation. HR indicates hazard ratio.

lesion failure during 3-year follow-up that was comparable to IVUS guidance.

IVUS-guided recommendations of stent size have been based on either: (1) external elastic lamina diameters of proximal reference, distal reference, or lesion, usually rounded down by (at least) 0.5 mm; or (2) reference lumen diameters often rounded up to the next stent size.¹⁰ Both strategies generate vessel size measurements that are typically larger than angiographic reference lumen diameter measures,¹⁰ consistent with the current results that larger stents were used when patients were treated with IVUS guidance versus angiography guidance. High-pressure postdilation was performed more often in the IVUS guidance group to achieve optimal stent expansion recommended by the protocols of the IVUS-XPL and ULTIMATE trials, indicating that the selection of a larger stent size alone was

not enough to meet the protocol criteria. Conversely, the stent edge dissection occurred more frequently in IVUS guidance; this was the cost of larger stent sizing and more frequent postdilation with high-pressure inflation. Accordingly, optimal stent size should be determined considering these tradeoffs.

Currently recommended stent sizing in daily practice and in most study protocols is between 1.0 and 1.1 compared with visually estimated angiographic reference vessel size. However, clinical evidence about optimal selection of stent size on coronary angiography seems to be lacking. The present analysis favors stent sizing ≥ 1.1 measured by QCA, supporting the concept of the so-called bigger-is-better strategy for stent implantation. The fear that larger stents may cause more injury and accelerated neointimal hyperplasia was disproved in a large study by Kitahara et al¹¹ that included

Table 2. Three-Year Clinical Outcomes According to Intravascular Ultrasound-Guided Like Procedures in Patients Randomized to Angiography-Guided PCI

Variables	Stent sizing ≥ 1.1 to < 1.3 and postdilation (n=235)	Others (n=1189)	HR (95% CI)	P value
Target lesion failure	12 (5.2%)	109 (9.5%)	0.532 (0.293–0.966)	0.038
Cardiac death	2 (0.9%)	26 (2.3%)	0.353 (0.084–1.492)	0.157
Target vessel-related MI	3 (1.3%)	7 (0.6%)	2.084 (0.538–8.069)	0.288
Clinically driven target lesion revascularization	9 (3.9%)	81 (7.2%)	0.537 (0.270–1.070)	0.077
Definite/probable stent thrombosis	2 (0.9%)	8 (0.7%)	1.118 (0.236–5.290)	0.888
Death	3 (1.3%)	45 (3.9%)	0.309 (0.096–0.995)	0.049
Cardiac death or target vessel-related MI	4 (1.7%)	32 (2.8%)	0.578 (0.204–1.639)	0.303

Data are presented as number (Kaplan-Meier estimated event rate). HR indicates hazard ratio; and MI, myocardial infarction.

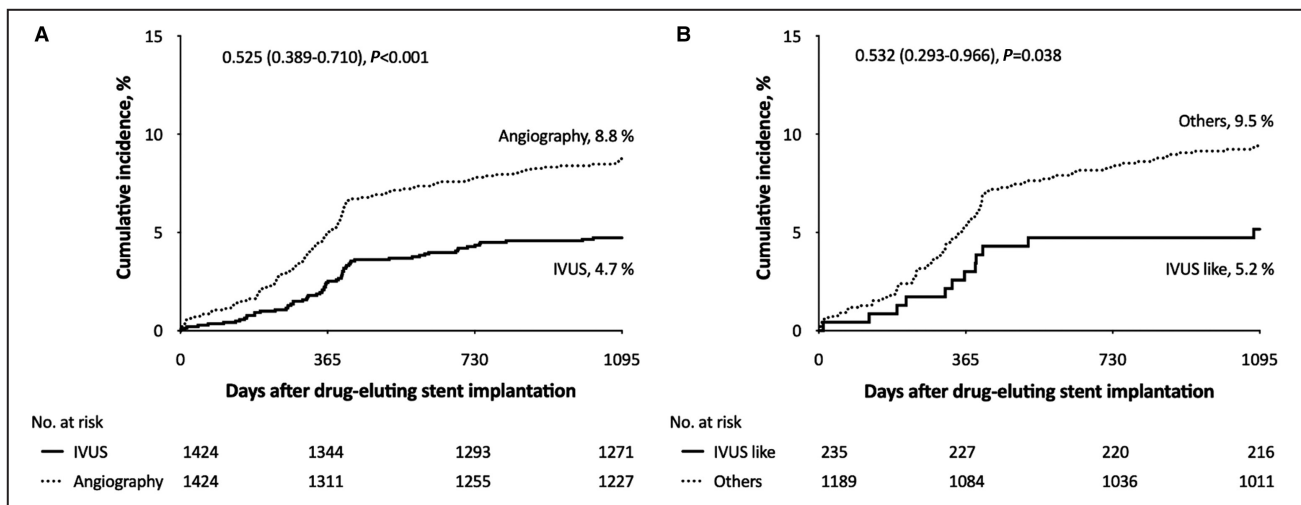


Figure 4. Time-to-event curves for target lesion failure at 3 years

(A) Intravascular ultrasound (IVUS) guidance vs angiography guidance in all patients, and (B) IVUS-guided like procedures (stent sizing ≥ 1.1 to < 1.3 and high-pressure postdilation) vs others in patients undergoing angiography guidance. Hazard ratios (95% CIs) are presented.

2931 lesions treated with DES; stent oversizing was associated with less restenosis and stent thrombosis at 1-year follow-up. The present study suggests an upper limit of optimal stent sizing (< 1.3) to avoid dissections.

A study by Zhang et al¹² showed that postdilation was associated with an increased risk of death/MI among patients presenting with an acute MI. However, a study by Pasceri et al¹³ demonstrated that routine postdilation resulted in an improved post-PCI minimum lumen diameter. In a study by Karjalainen et al,¹⁴ postdilation was associated with a reduction in nonfatal MI at long-term follow-up. In the present study, neither the stent sizing ≥ 1.1 to < 1.3 alone nor high-pressure postdilation alone was related to the occurrence of target lesion failure. Instead, procedures in which all lesions were treated with both stent sizing ≥ 1.1 to < 1.3 and high-pressure postdilation were associated with a subsequent reduction in target lesion failure, thereby defining “IVUS-guided like PCI” in patients treated with angiography guidance alone. Recently, a large DES registry also showed that patients who underwent DES implantation using IVUS-guided predilation, IVUS-guided stent sizing, and IVUS-guided postdilation were at a lower risk of 3-year cardiac events compared with those who did not.¹⁵

An unexpected finding in the current analysis was that one third of lesions treated with angiography-guided PCI used a stent sizing < 1.0 . Moreover, stent sizing < 1.1 was identified in 68.4%. Given the prescription of 1.1 versus reference vessel diameter in patients randomized to angiography guidance in the ULTIMATE trial, it seems obvious that operator bias widely affected stent sizing using visual estimation of vessel size alone. Previously, studies from Nallamothu et al¹⁶ and Zhang

et al¹⁷ demonstrated that the visual estimation was not accurate for assessing the severity of coronary lesions. In addition to these studies, the present results raise the issue of inaccuracy of visual estimation for stent sizing. Online QCA is widely available although rarely used. Notably, the accurate measurement is of paramount importance given the limitations of QCA such as vessel foreshortening and out-of-plane magnification.

Our study has several limitations. QCA did not evaluate the appropriateness of lesion preparation because of the heterogeneity within study protocols. The area under the receiver operating characteristic curve that identified the stent size that separated IVUS from angiographic guidance was poor (0.592). Thus, IVUS-guided like procedures do not represent all of the features of IVUS guidance. The benefits of IVUS guidance may be greater especially in high-risk patients or complex lesions. We could not evaluate the feasibility of online QCA-based PCI because the present study was a retrospective analysis using pooled data. Blinded IVUS was not performed in patients randomized to angiography guidance. The study results may not be generalizable to patients in other geographic regions or demographic subgroups because the present study analyzed patients from East Asia. The clinical events rarely occurred among patients with IVUS-guided like procedures. Finally, our study does not imply that IVUS-guided like procedures are comparable to IVUS-guided PCI because it did not evaluate outcomes between the 2 strategies. The study results should be considered hypothesis-generating given the current limitations of angiography guidance.

Larger stent sizing and more common postdilation with high-pressure inflation were procedural

characteristics of IVUS-guided PCI. Given the high frequency of stent undersizing by visual estimation in patients treated with angiography-guided PCI, optimal stent sizing using QCA and routine high-pressure postdilation may further improve long-term clinical outcomes among patients undergoing angiography-guided PCI.

ARTICLE INFORMATION

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Supplemental Material

Tables S1–S2

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SUPPLEMENTAL MATERIAL

Table S1. Clinical characteristics

Variables	IVUS guidance (n=1,424)	Angiography guidance (n=1,424)	p
From IVUS-XPL	700 (49.2)	700 (49.2)	
Age, years	64.4±10.1	64.9±9.7	0.165
Male sex	1,018 (71.5)	1,011 (71.0)	0.772
Hypertension	966 (67.8)	965 (67.8)	0.968
Diabetes mellitus	467 (32.8)	482 (33.9)	0.551
Dyslipidemia	860 (60.4)	858 (60.3)	0.939
Current smoker	408 (28.7)	409 (28.7)	0.967
Prior myocardial infarction	101 (7.1)	115 (8.1)	0.322
Prior percutaneous coronary intervention	202 (14.2)	213 (15.0)	0.559
Left ventricular ejection fraction, %	62.0±9.0	61.4±9.8	0.124
Clinical diagnosis			0.100
Stable angina	513 (36.0)	513 (36.0)	
Unstable angina	730 (51.3)	692 (48.6)	
Acute myocardial infarction	181 (12.7)	219 (15.4)	
Angiographic diagnosis			0.122
One	573 (40.2)	520 (36.5)	
Two	489 (34.3)	515 (36.2)	
Three	362 (25.5)	389 (27.3)	
Dual-antiplatelet therapy at 3 years	353 (24.8)	384 (27.0)	0.185
Follow-up duration, days	1,041.9±205.7	1,040.3±211.4	0.831
Target lesion failure at 3 years	65 (4.7)	121 (8.8)	<0.001

Data are presented as mean ± standard deviation, number (percentage), or number (Kaplan-Meier estimated event rate).

IVUS, intravascular ultrasound.

Table S2. Baseline characteristics and procedural results according to intravascular ultrasound-guided like procedures in patients randomized to angiography guided-PCI

Variables	Stent sizing ≥ 1.1 to < 1.3 and post-dilation (n=235)	Others (n=1,189)	p
Age, years	64.8 \pm 10.0	64.9 \pm 9.6	0.921
Male sex	164 (69.8)	847 (71.2)	0.655
Hypertension	157 (66.8)	808 (68.0)	0.731
Diabetes mellitus	83 (35.3)	399 (33.6)	0.602
Dyslipidemia	137 (58.3)	721 (60.6)	0.503
Current smoker	70 (29.8)	339 (28.5)	0.693
Prior myocardial infarction	19 (8.1)	96 (8.1)	0.995
Prior percutaneous coronary intervention	38 (17.2)	175 (14.7)	0.569
Left ventricular ejection fraction, %	61.2 \pm 9.8	61.4 \pm 9.9	0.727
Clinical diagnosis			0.785
Stable angina	84 (35.7)	429 (36.1)	
Unstable angina	118 (50.2)	574 (48.3)	
Acute myocardial infarction	33 (14.1)	286 (15.6)	
Angiographic diagnosis			0.004
One	108 (46.0)	412 (34.7)	
Two	71 (30.2)	444 (37.3)	
Three	56 (23.8)	333 (28.0)	
Multi-vessel disease	127 (54.0)	777 (65.4)	0.001
Dual-antiplatelet therapy at 3 years	66 (28.1)	318 (26.8)	0.672
Treated vessels			
Left main	16 (6.8)	71 (6.0)	0.624
Left anterior descending artery	162 (68.9)	784 (65.9)	0.374
Left circumflex artery	33 (14.0)	322 (27.1)	<0.001

Right coronary artery	63 (26.8)	433 (36.4)	0.005
Any AHA/ACC lesion type B2/C	198 (84.3)	985 (82.8)	0.598
Number of treated lesions	1.2±0.4	1.4±0.6	<0.001
Number of implanted stents	1.9±1.3	2.1±1.3	0.033
Pre-intervention QCA			
Smallest reference vessel diameter, mm	2.6±0.4	2.8±0.5	<0.001
Minimum lumen diameter, mm	0.8±0.5	0.8±0.5	0.308
Post-intervention QCA			
Minimum lumen diameter, mm	2.4±0.4	2.5±0.5	0.104
Largest diameter stenosis, %	12.9±8.5	15.2±9.4	<0.001
<20%	200 (85.1)	895 (75.3)	0.001
Residual stent edge dissections	2 (0.9)	11 (0.9)	1.000

Data are presented as mean ± standard deviation or number (percentage).

ACC, American College of Cardiology; AHA, American Heart Association; QCA, quantitative coronary angiography.