Journal of the American Heart Association

ORIGINAL RESEARCH

Role of Intravascular Ultrasound-Guided Percutaneous Coronary Intervention in Optimizing Outcomes in Acute Myocardial Infarction

Yongcheol Kim, MD, PhD*; SungA Bae, MD, PhD*; Thomas W. Johnson, BSc, MBBS, MD; Nak-Hoon Son, PhD; Doo Sun Sim, MD, PhD; Young Joon Hong, MD, PhD; Sang Wook Kim, MD, PhD; Deok-Kyu Cho, MD; Jung-Sun Kim, MD, PhD; Byeong-Keuk Kim, MD, PhD; Donghoon Choi, MD, PhD; Myeong-Ki Hong, MD, PhD; Yangsoo Jang, MD, PhD; Myung Ho Jeong, MD, PhD; on behalf of the KAMIR-NIH (Korea Acute Myocardial Infarction Registry-National Institutes of Health) Investigators†

BACKGROUND: The role of intravascular ultrasound (IVUS)-guided percutaneous coronary intervention (PCI) is still unclear in patients with acute myocardial infarction acute myocardial infarction. This study aimed to evaluate the long-term impact of IVUS-guided PCI in patients with acute myocardial infarction.

METHODS AND RESULTS: Among a total of 13 104 patients with acute myocardial infarction, enrolled in the Korea Acute Myocardial Infarction Registry-National Institutes of Health, we selected patients who underwent PCI with second-generation drug-eluting stent implantation. The primary outcome was the risk of target lesion failure at 3 years. Among the study population, 1887 patients (21.0%) underwent IVUS-guidance, and 7120 patients (79.0%) underwent angiography-guidance for second-generation drug-eluting stent implantation. IVUS-guided PCI was associated with a significantly lower risk of target lesion failure at 3 years (4.8% versus 8.0%; hazard ratio [HR], 0.59; 95% CI, 0.47 to 0.73; $P<0.001$) compared with angiography-guided PCI. The difference was driven mainly by a lower risk of cardiac death and target vessel myocardial infarction. The results were consistent after confounder adjustment by multiple sensitivity analyses. Moreover, quartile analysis of volume of IVUS use showed that higher IVUS use was associated with a decreased risk of 3-year target lesion failure (adjusted HR, 0.58; 95% CI, 0.45 to 0.75; $P<0.001$ for quartile 1 versus 4; $P<0.001$ for trend comparison across all quartiles).

CONCLUSIONS: In patients with acute myocardial infarction who underwent PCI with second-generation drug-eluting stent implantation, the use of IVUS guidance was associated with a significant reduction in 3-year target lesion failure, mainly driven by hard end points, such as cardiac death and target vessel myocardial infarction.

Key Words: acute myocardial infarction ■ drug-eluting stent ■ intravascular ultrasound ■ percutaneous coronary intervention

Intravascular ultrasound (IVUS) provides detailed guidance of percutaneous coronary intervention (PCI) from pre-interventional lesion characterization, including plaque morphology, lesion length, and reference vessel diameter, to post-interventional IVUS to assess the stent result including minimal stent area and stent expansion.[1] As a result, IVUS-guided drug-eluting stent (DES) implantation has demonstrated

Correspondence to: Myung Ho Jeong, MD, PhD, principal investigator of the Korea Acute Myocardial Infarction Registry, Department of Cardiology, Chonnam National University Hospital, 42 Jebong-ro, Dong-gu, Gwangju 61469, Republic of Korea. E-mail: myungho@chollian.net

*Y. Kim and S. Bae contributed equally.

†A complete list of the KAMIR-NIH Investigators can be found in the Appendix at the end of the manuscript.

Supplemental Material for this article is available at https://www.ahajournals.org/doi/suppl/10.1161/JAHA.121.023481

For Sources of Funding and Disclosures, see page 12.

JAHA is available at: www.ahajournals.org/journal/jaha

CLINICAL PERSPECTIVE

What Is New?

- Patients with acute myocardial infarction in the intravascular ultrasound-guided percutaneous coronary intervention group showed a significantly lower risk of 3-year target lesion failure than those in the angiography-guided percutaneous coronary intervention group, which was consistently observed in multiple sensitivity analyses with confounder adjustment.
- Intravascular ultrasound guidance also demonstrated a significantly lower risk of cardiac death, all-cause death, target vessel myocardial infarction, and major adverse cardiovascular events at 3 years.
- Centers with higher usage of intravascular ultrasound-guided percutaneous coronary intervention demonstrated a reduction in 3-year target lesion failure.

What Are the Clinical Implications?

- Intravascular ultrasound-guidance for acute myocardial infarction percutaneous coronary intervention should be given greater consideration where the clinical and financial circumstances allow, to enhance long-term patient outcomes.

Nonstandard Abbreviations and Acronyms

TLF	target lesion failure
TV-MI	target vessel myocardial infarction

better clinical outcomes than angiography-guided DES implantation in several randomized trials.[2–5] Extended follow-up from randomized trials have shown that the 1-year clinical benefits of IVUS guidance remain consistent for up to 5 years.[6,7] Moreover, IVUS-guided PCI for complex coronary artery lesions and unprotected left main disease has demonstrated significantly lower mortality than angiography-guidance.[8,9] These findings strengthen the existing guideline recommended use of IVUS to optimize stent implantation in selected patients.[10]

In patients with acute myocardial infarction (AMI), the use of intravascular imaging modalities, including IVUS and optical coherence tomography, have been observed to increase gradually between 2012 to 2017.[11] However, the role of IVUS is still unclear in patients with AMI undergoing PCI in the current second-generation DES era as there are limited data on the clinical impact of IVUS-guided PCI in patients with AMI. Therefore, this study aimed to evaluate the long-term impact of IVUS-guided second-generation DES implantation in patients with AMI using a large-scale dedicated registry for AMI.

METHODS

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Study Protocols and Population Selection

We analyzed data from a nationwide, multicenter, prospective KAMIR-NIH (Korea Acute Myocardial Infarction-National Institutes of Health) registry. The 20 major cardiovascular centers were recruited between November 2011 and December 2015. The detailed study protocols have been published previously.[12] Trained study coordinators at each site collected the data using a web-based report form on the Internet-based Clinical Research and Trial management system. The follow-up of clinical outcomes was checked at 1, 6, 12, 24, and 36 months. The follow-up data were collected from the patients by attending physicians, and the web-based case report forms were completed. It has been supported by a grant from the Korea Centers for Disease Control and Prevention since November 2011 (Internet-based Clinical Research and Trial management system study No. C110016). The study protocols were approved by the ethics committees of each participating center, all complying with the principles of the Declaration of Helsinki (Institutional Review Board approval number: CNUH-2011-172). All patients provided informed consent to participate in the registry. The steering committee board of KAMIR-NIH determined the standardized definitions of all variables. The detailed clinical and diagnostic parameters of all subjects have been described previously.[12]

The selection of the study population is shown in Figure 1. Among a total of 13 104 patients enrolled in the KAMIR-NIH registry, we selected patients who underwent PCI with second-generation DES implantation. The exclusion criteria were cardiogenic shock, thrombolysis before PCI, no PCI or PCI without stenting, PCI with bare-metal stent or first-generation DES, fractional flow reserve or optical coherence tomography, missing data, and patients lost to follow-up. We defined lost to follow-up as when the patient was discharged alive but never visited the outpatient department. As a result, 9007 patients were selected for this analysis; these patients were then divided into those undergoing IVUS-guided PCI and those undergoing angiography-guided PCI.

Study Procedures

Patients diagnosed with AMI were treated according to contemporary guidelines.[13,14] Patients routinely

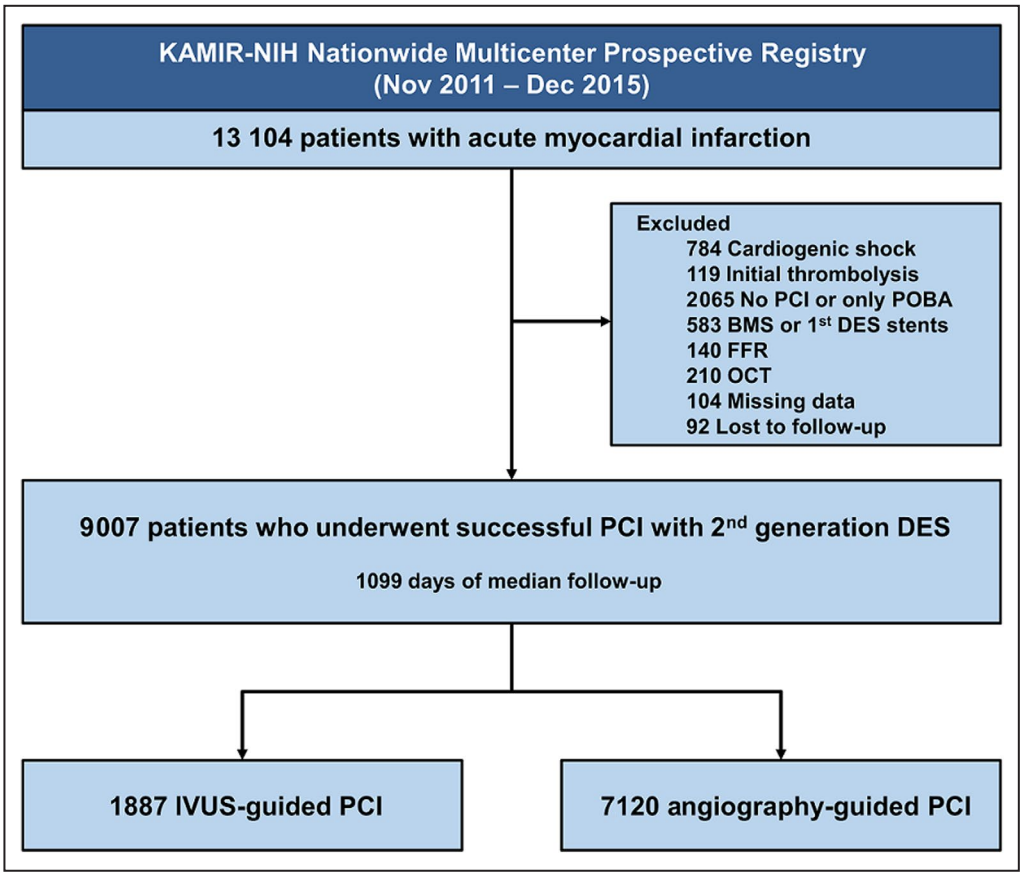


Figure 1. Study flowchart.
The study population was derived from the nationwide, multicenter, prospective KAMIR-NIH (Korea Acute Myocardial Infarction Registry-National Institutes of Health) registry. BMS indicates bare-metal stent; DES, drug-eluting stent; FFR, fractional flow reserve; IVUS, intravascular ultrasound; OCT, optical coherence tomography; PCI, percutaneous coronary intervention; and POBA, plain old balloon angioplasty.

received antiplatelet agents including 300 mg of aspirin and a $P2Y_{12}$ inhibitor (clopidogrel 300-600 mg, ticagrelor 180 mg, or prasugrel 60 mg) before the procedure, followed by daily aspirin (100 mg) and $P2Y_{12}$ inhibitors (clopidogrel 75 mg once, ticagrelor 90 mg twice, or prasugrel 10 mg once daily). Angiographic data were obtained visually by operators at the investigative site. All procedures were performed with standard interventional techniques. The decision to use IVUS during PCI was made at the discretion of the operator. Similarly, the choice of stent, interventional strategy (for example, use of thrombus aspiration), and therapeutics (such as the use of glycoprotein IIb/IIIa inhibitors) was left to the treating physician.

Study Outcomes

The primary outcome was target lesion failure (TLF) at 3 years after index procedure, defined as the composite of cardiac death, target vessel myocardial infarction (TV-MI), and ischemia driven target lesion revascularization. All-cause death was regarded as cardiac death unless a definite non-cardiac cause could be identified. TV-MI was defined as a myocardial infarction (MI) with evidence of myocardial necrosis in the vascular territory of a previously treated target vessel. Target lesion revascularization was considered ischemia-driven if any revascularization, including PCI or bypass surgery, of the target lesion was undertaken in the presence of ≥50% angiographic diameter stenosis associated with symptoms of ischemia or a positive functional study, or a ≥70% angiographic diameter stenosis without ischemic symptoms or positive functional study. Secondary outcomes included individual components of TLF, definite or probable stent thrombosis, which was defined according to the Academic Research Consortium definitions,[15] and major adverse cardiovascular events, which comprised a composite of death from any cause, any MI, and any revascularization.

Statistical Analysis

Continuous variables were analyzed with descriptive methods depending on their distribution, corroborated by the Shapiro-Wilk test. Variables with a normal distribution were described with mean values and standard

deviation. Otherwise, median and interquartile ranges were used. Taking into consideration the normality of each quantitative variable, an analysis with independent 2-sample *t*-tests or Mann-Whitney tests was performed. Discrete variables were described through frequencies and percentages. Depending on the number of events, Chi-square or Fisher's exact test was performed. The trend analyses in IVUS use were measured by Cochrane-Armitage test. Cumulative incidence of clinical events at 3 years were calculated based on Kaplan–Meier curve, and comparison of clinical outcomes between the IVUS-guided PCI and angiography-guided PCI groups was performed with the log-rank test.

As differences in baseline characteristics could significantly affect outcomes, sensitivity analyses were performed to adjust for confounding factors. First, a multivariable Cox regression model was used for each of the above cut-offs, with the following covariates: age ≥65 years as elderly, Killip class 3 as acute pulmonary edema, hypertension, diabetes, prior revascularization (PCI or coronary artery bypass graft), previous history of cerebrovascular accident, estimated glomerular filtration rate ≤60 mL/min per 1.73 m^2 as chronic kidney disease, left ventricular ejection fraction ≤50% as left ventricle dysfunction, left main disease, multivessel disease, procedural factors (trans-radial approach, glycoprotein IIb/IIIa inhibitor, thrombus aspiration, stent type, stent diameter ≥3 mm, stent length ≥35 mm, stent number ≥2). Second, we performed propensity score-matched cohort between the groups. Propensity scores (PS) were obtained from logistic regression with a significantly difference between the 2 groups (age, sex, clinical presentation, hypertension, previous history of cerebrovascular accident, left ventricular ejection fraction, troponin I, dual antiplatelet therapy, $P2Y_{12}$ inhibitor, renin-angiotensin system inhibitor, beta-blocker, statin, number of vessel disease, multivessel disease, culprit vessel, trans-radial approach, glycoprotein IIb/IIIa inhibitor, thrombus aspiration, stent type, stent diameter, stent length, stent number). We employed nearest-neighbor matching using a caliper size of 0.2 multiplied by the standard deviation for linearly transformed propensity scores (logit transformation).[16] Third, for the numerical difference between the 2 groups (IVUS-guided n=1887 versus angiography-guided n=7120), inverse probability weighting adjustment was performed. the inverse of PS of all variables was assessed by the proportional hazards regression model. The values after inverse probability weighting adjustment were within ±10% across all matched covariates, demonstrating successful balance between the comparative groups (Figure S1). To investigate the difference in primary outcome by quartiles of IVUS-guided PCI volume, Kaplan–Meier curves and multivariable Cox regression model of TLF at 3 years by quartile of institutional volume of IVUS use was performed. In addition, comparisons of the primary outcome between IVUS-guided PCI and angiography-guided PCI groups according to the exploratory subgroups of interest were followed, and the interaction between treatment effect and these covariates was assessed with a Cox regression model.

All statistical analyses were performed in the R version 3.6.3 software (R Foundation for Statistical Computing, Vienna, Austria) using "*survival*", "*MatchIt*", "*WeightIt*" packages.

RESULTS

Baseline Characteristics

Among the study population, 1887 patients (21.0%) underwent IVUS-guidance and 7120 (79.0%) underwent angiography-guidance for second-generation DES implantation, respectively. IVUS-guided PCI in patients with AMI increased from 15.0% in 2011 to 25.7% in 2015, and this tendency was also observed in both the ST-segment–elevation myocardial infarction (STEMI) and non-STEMI groups (all *P* for trend <0.001) (Figure S2). Moreover, the use of IVUS guidance showed a wide discrepancy, from 0.8% to 86.4%, by the institute (Table S1).

The mean age of the total study population was 63.3±12.2 years, and 4541 patients (50.4%) presented with STEMI. The baseline clinical, lesion, and procedural characteristics of the 2 groups are summarized in Tables 1 and 2. Patients undergoing IVUS-guided PCI were younger and more likely to be men. Further, the IVUS-guided PCI group had a lower prevalence of patients with STEMI and history of hypertension, and higher left ventricular ejection fraction than the angiography-guided PCI group. Regarding lesion and procedural characteristics, the IVUS-guided PCI group had higher rates of multivessel disease, left main disease, and trans-radial approach than the angiography-guided PCI group. In terms of stent type, second-generation everolimus, sirolimus, and zotarolimus-eluting stents were used more in the IVUS-guidance group. A significantly larger stent diameter (≥3 mm), longer stent length (≥35 mm), and more multiple stent implantation (≥2 stents) were observed in the IVUS-guided PCI group. The trends of medication use in both groups are summarized in Table S2. After PS-matching, the standardized differences between the groups were <10.0% for all variables, indicating appropriate matching. No significant differences existed in the baseline characteristics between the groups in the PS-matched population.

Clinical Outcomes According to PCI strategy

Figures 2 and 3 and Table 3 present a comparison of clinical outcomes between the IVUS-guided PCI and angiography-guided PCI groups. The median

Table 1. Baseline Clinical Characteristics of Study Population

	Crude population			PS-matched cohort			
	IVUS-guided (n=1887)	Angiography-guided (n=7120)	*P* value	IVUS-guided (n=1852)	Angiography-guided (n=1852)	*P* value	SMD (%)
Demographics, n (%)							
Age, y, mean (SD)	62.4 (12.2)	63.6 (12.4)	<0.001	62.4±12.2	62.8±12.5	0.317	2.0
Men	1487 (78.8)	5290 (74.3)	<0.001	1459 (78.8)	1465 (79.1)	0.840	0.8
BMI, median (IQR)	24.1 (22.0–26.1)	23.9 (22.0–25.9)	0.130	24.1 (22.0–26.1)	24.0 (22.2–26.2)	0.292	2.4
Killip class 3	112 (5.9)	518 (7.3)	0.048	111 (6.0)	115 (6.2)	0.837	0.9
Clinical presentation, n (%)			<0.001			0.792	1.0
STEMI	838 (44.4)	3703 (52.0)		826 (44.6)	835 (45.1)		
NSTEMI	1049 (55.6)	3417 (48.0)		1026 (55.4)	1017 (54.9)		
Cardiovascular risk factors, n (%)							
Hypertension	864 (45.7)	3625 (50.9)	<0.001	852 (46.0)	843 (45.5)	0.792	1.0
Diabetes	487 (25.8)	1984 (27.9)	0.080	476 (25.7)	466 (25.2)	0.734	1.2
Dyslipidemia	223 (11.8)	829 (11.6)	0.865	221 (11.9)	249 (13.4)	0.183	4.5
Current smoker	796 (42.2)	2829 (39.7)	0.057	780 (42.1)	788 (42.5)	0.816	0.9
Previous history of MI	112 (5.9)	405 (5.7)	0.723	108 (5.8)	85 (4.6)	0.104	5.6
Prior revascularization	75 (4.0)	300 (4.2)	0.691	74 (4.0)	84 (4.5)	0.464	2.7
Previous history of CVA	94 (5.0)	445 (6.2)	0.044	92 (5.0)	109 (5.9)	0.246	4.1
LVEF, median (IQR)	53.7 (47.0–60.0)	52.4 (46.0–59.0)	<0.001	53.1 (47.0–60.0)	53.4 (46.0–60.0)	0.697	2.4
eGFR, median (IQR)	88.4 (70.6–105.9)	87.4 (67.8–106.3)	0.265	88.4 (70.3–105.9)	88.4 (69.0–107.0)	0.923	1.5
Peak cardiac enzyme levels, median (IQR)							
Troponin I, ng/mL	18.9 (3.1–36.6)	21.2 (3.9–61.8)	<0.001	19.1 (3.1–36.8)	14.0 (2.7–43.5)	0.974	1.2
CK-MB, ng/mL	55.2 (11.6–181.8)	56.9 (9.6–174.9)	0.261	56.5 (11.8–182.9)	56.3 (8.2–174.9)	0.051	9.6
Medication at discharge, n (%)							
DAPT	1873 (99.3)	7098 (99.7)	0.014	1842 (99.5)	1842 (99.5)	1.000	0
Aspirin	1886 (99.9)	7112 (99.9)	0.695*	1851 (99.9)	1851 (99.9)	1.000*	0
P2Y12 inhibitor	1874 (99.3)	7105 (99.8)	0.002	1843 (99.5)	1843 (99.5)	1.000	0
Clopidogrel	1146 (60.7)	4506 (63.3)		1125 (60.7)	1121 (60.5)		
Ticagrelor	574 (30.4)	1653 (23.2)		565 (30.5)	579 (31.3)		
Prasugrel	154 (8.2)	946 (13.3)		153 (8.3)	143 (7.7)		
RAS inhibitor	1512 (80.1)	5855 (82.2)	0.038	1490 (80.5)	1496 (80.8)	0.835	0.8
Beta-blocker	1570 (83.2)	6132 (86.1)	0.002	1539 (83.1)	1546 (83.5)	0.792	1.0
Statin	1819 (96.4)	6677 (93.8)	<0.001	1784 (96.3)	1782 (96.2)	0.931	0.6

Values are presented as mean (SD), median (interquartile range) or n (%).

BMI indicates body mass index; CK-MB, creatine kinase-myocardial band; CVA, cerebrovascular accident; DAPT, dual antiplatelet therapy; eGFR, estimated glomerular filtration rate; IQR, interquartile range; IVUS, intravascular ultrasound; LVEF, left ventricular ejection fraction; MI, myocardial infarction; NSTEMI, non-ST-segment–elevation myocardial infarction; PCI, percutaneous coronary intervention; PS, propensity score; RAS, renin-angiotensin system; SMD, standard mean difference; and STEMI, ST-segment–elevation myocardial infarction.

*Fisher Exact Test.

follow-up duration was 1099 days (interquartile range, 1058 to 1130 days). The risk of 3-year TLF was significantly lower in the IVUS-guided group than in the angiography-guided group (4.8% versus 8.0%; hazard ratio [HR], 0.59; 95% CI, 0.47 to 0.73; *P*<0.001), mainly driven by a significantly lower risk of cardiac death and TV-MI in the IVUS-guided group (Figures 2 and 3). Similarly, all-cause death and major adverse cardiovascular events were also significantly lower in the IVUS-guided group. However, there was no significant difference in the risk of any revascularization and ischemia driven target lesion revascularization. Multiple sensitivity analyses using multivariable Cox regression, PS matching, and inverse probability

Table 2. Lesion and Procedural Characteristics of Study Population

	Crude population			PS-matched cohort			
	IVUS-guided (n=1887)	Angiography-guided (n=7120)	*P* value	IVUS-guided (n=1852)	Angiography-guided (n=1852)	*P* value	SMD (%)
Lesion characteristics, n (%)							
No. of vessel disease			0.018			0.612	3.3
One-vessel disease	901 (47.7)	3652 (51.3)		890 (48.1)	893 (48.2)		
Two-vessel disease	600 (31.8)	2154 (30.3)		585 (31.6)	562 (30.3)		
Three-vessel disease	386 (20.5)	1314 (18.5)		377 (20.4)	397 (21.4)		
Multivessel disease	986 (52.3)	3468 (48.7)	0.007	962 (51.9)	959 (51.8)	0.948	0.3
Culprit vessel			<0.001			0.794	3.3
LM	196 (10.4)	216 (3.0)		171 (9.2)	161 (8.7)		
LAD	924 (49.0)	3319 (46.6)		922 (49.8)	945 (51.0)		
LCX	284 (15.1)	1212 (17.0)		279 (15.1)	285 (15.4)		
RCA	483 (25.6)	2373 (33.3)		480 (25.9)	461 (24.9)		
ACC/AHA B2/C lesion	1615 (85.6)	6198 (87.1)	0.103	1587 (85.7)	1606 (86.7)	0.391	3.0
Procedural characteristics, n (%)							
Trans-radial approach	832 (44.1)	2628 (36.9)	<0.001	815 (44.0)	797 (43.0)	0.573	2.0
Glycoprotein IIb/IIIa inhibitor	372 (19.7)	995 (14.0)	<0.001	352 (19.0)	342 (18.5)	0.705	1.4
Thrombus aspiration	422 (22.4)	1762 (24.7)	0.034	413 (22.3)	417 (22.5)	0.906	0.5
Stent type			<0.001			0.936	3.0
Biolimus	305 (16.2)	1452 (20.4)		301 (16.3)	299 (16.1)		
Everolimus	1023 (54.2)	3692 (51.9)		1006 (54.3)	1015 (54.8)		
Novolimus	9 (0.5)	88 (1.2)		9 (0.5)	8 (0.4)		
Sirolimus	78 (4.1)	224 (3.1)		77 (4.2)	67 (3.6)		
Zotarolimus	472 (25.0)	1664 (23.4)		459 (24.8)	463 (25.0)		
Successful PCI	1877 (99.5)	7083 (99.5)	0.155*	1820 (100)	1849 (100)	1.000	0
Stent diameter ≥3 mm	1395 (73.9)	4926 (69.2)	<0.001	1371 (74.0)	1322 (71.4)	0.077	5.9
Stent length ≥35 mm	589 (31.2)	1796 (25.2)	<0.001	576 (31.1)	579 (31.3)	0.943	0.3
Stent number ≥2	767 (40.6)	2354 (33.1)	<0.001	745 (40.2)	748 (40.4)	0.947	0.3

Values are presented as mean (SD) or n (%).

ACC indicates American College of Cardiology; AHA, American Heart Association; DES, drug-eluting stent; IVUS, intravascular ultrasound; LAD, left anterior descending artery; LCX, left circumflex artery; LM, left main; PCI, percutaneous coronary intervention; PS, propensity score; RCA, right coronary artery; SMD, standard mean difference; and TIMI, thrombolysis in myocardial infarction.

*Fisher Exact Test.

weighting adjustment consistently demonstrated significantly lower risk of all-cause death, cardiac death, TV-MI, TLF, and major adverse cardiovascular events in the IVUS-guided PCI group compared with the angiography-guided PCI group. Regarding the risk of definite or probable ST, the unadjusted rate was significantly lower in the IVUS-guided PCI group than in the angiography-guided PCI group (0.4% versus 0.8%; *P*<0.040), although there was no statistically significant difference between groups after multiple sensitivity analyses.

Clinical Outcomes by Volume of IVUS Use

We analyzed the enrolled 20 centers by quartiles of IVUS-guided PCI volume among patients with AMI who underwent PCI with second-generation DES implantation. Institutional usage of IVUS-guidance ranged from

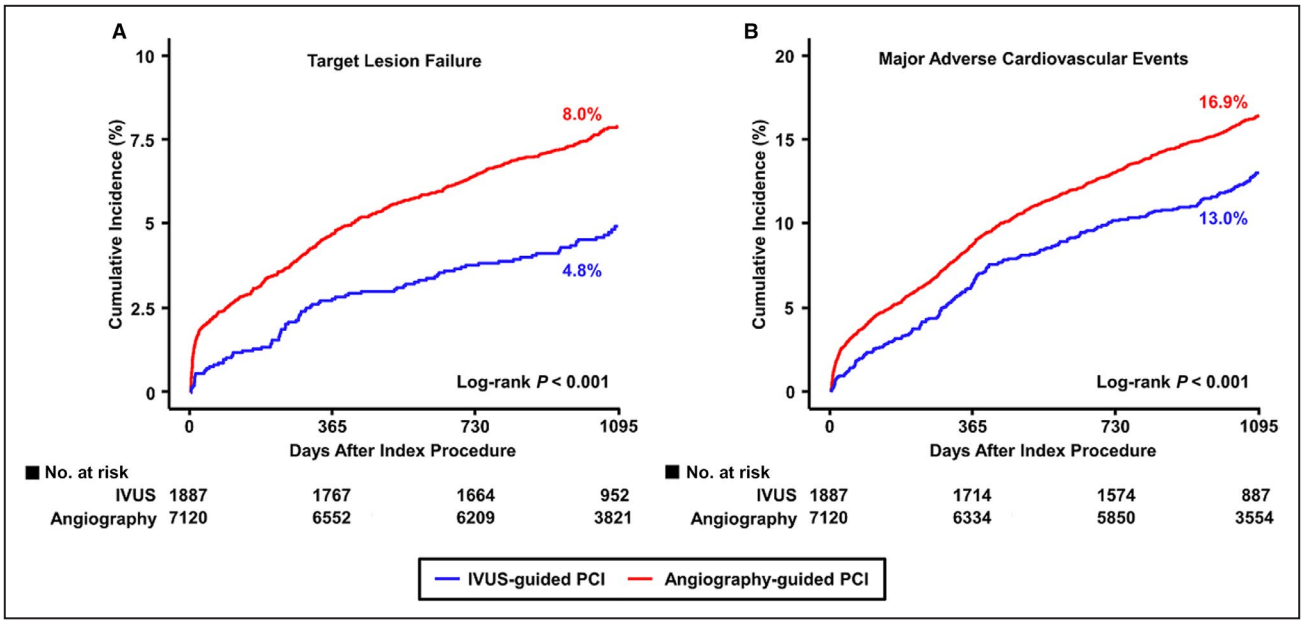


Figure 2. Cumulative incidence of clinical outcomes.
Kaplan–Meier curves are shown for comparison of the rates of (**A**) target lesion failure and (**B**) MACEs between IVUS-guided vs angiography-guided second-generation drug-eluting stent implantation among patients with acute myocardial infarction. IVUS indicates intravascular ultrasound; MACE, major adverse cardiovascular events; and PCI, percutaneous coronary intervention.

3.7% in quartile 1% to 71.0% in quartile 4. Conversely, mean institutional volumes of AMI cases decreased from 625 in quartile 1 to 275 in quartile 4 (Table S1). Kaplan-Meier curves of TLF at 3 years by quartile of institutional IVUS use and the association of quartile of IVUS use and TLF at 3 years are presented in Figure 4. Greater institutional IVUS use was associated with a decreased risk of 3-year TLF (adjusted HR, 0.58; 95% CI, 0.45 to 0.75; P<0.001 for quartile 1 versus quartile 4; P<0.001 for trend comparison across all quartiles).

Subgroup Analysis

Figure 5 presents a forest plot showing the prognostic impact of IVUS-guided PCI on the TLF among the various subgroups. The significantly lower risk of TLF in the IVUS-guided PCI group than in the angiography-guided PCI group was consistent across all subgroups except in patients aged <65 years.

DISCUSSION

In the present study, we compared the 3-year clinical outcomes between IVUS-guided and angiography-guided second-generation DES implantations in patients with AMI using data from a nationwide, multicenter, prospective registry. The main findings of the current study were as follows: (1) patients with AMI in the IVUS-guided PCI group showed a significantly lower risk of 3-year TLF than those in the angiography-guided PCI group, which was consistently observed in multiple sensitivity analyses with confounder adjustment (Figure 4); (2) IVUS guidance also demonstrated a significantly lower risk of cardiac death, all-cause death, TV-MI, and major adverse cardiovascular events at 3 years; (3) centers with higher usage of IVUS-guided PCI demonstrated a reduction in 3-year TLF (Figure 4); and (4) a significantly lower risk of 3-year TLF in the IVUS-guided PCI group compared with the angiography-guided PCI group was consistent across various subgroups.

Recently several studies have reported that IVUS-guided PCI was associated with improved clinical outcomes compared with angiography-guided PCI.[4–9] In the 2 randomized trials including extended 3- and 5-year follow-up, the clinical benefits of IVUS-guidance were driven mainly by a reduced risk of revascularization and not the hard end points of death and MI.[6,7] In contrast to previous studies, we have observed that patients undergoing IVUS-guided PCI had a significantly lower risk of the primary outcome, TLF at 3 years, mainly driven by a lower risk of cardiac death and TV-MI compared with those in the angiography-guided PCI group. Moreover, all-cause death was less with IVUS-guided PCI. These findings support the observations of previous real-world registries and meta-analyses that IVUS guidance could improve hard end points, such as mortality and MI, for DES implantation compared with angiography.[8,9,17,18] However, it is important to acknowledge that these previous studies included a greater diversity of patients, whereas our study has focused on the impact of IVUS guidance from a population derived from a dedicated prospective registry for AMI. It is important to consider why an IVUS-guided

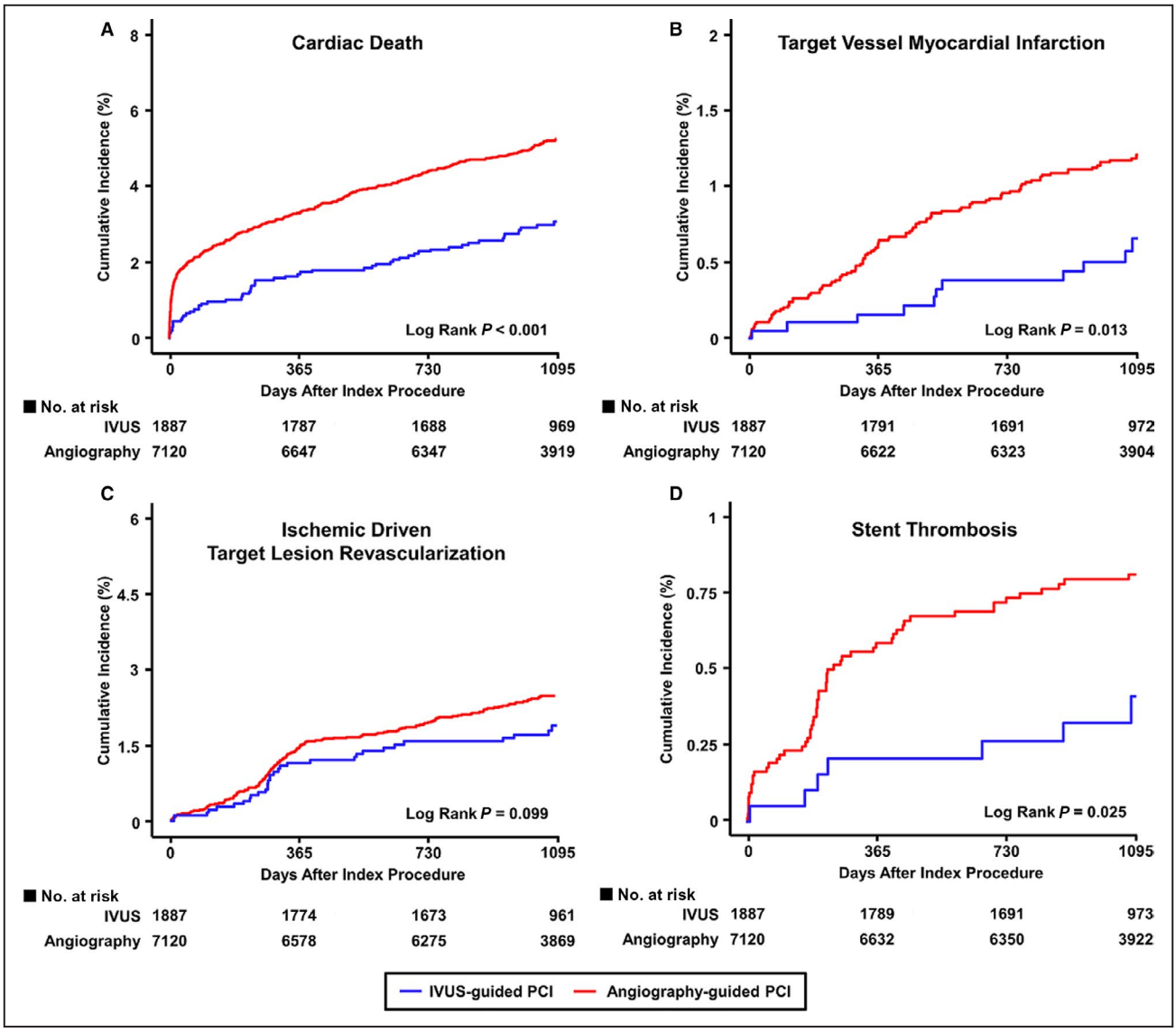


Figure 3. Cumulative incidence of individual clinical outcomes.
Kaplan–Meier curves are shown for the comparison of the rates of (**A**) cardiac death, (**B**) target vessel myocardial infarction, (**C**) ischemic driven target lesion revascularization, and (**D**) stent thrombosis between groups. IVUS indicates intravascular ultrasound; and PCI, percutaneous coronary intervention.

approach to PCI in AMI may provide superior outcomes to angiography-guided intervention. Delineation of disease, with particular recognition of lipidic plaque burden <50% defining stent landing zones, modification of calcific lesions and accurate assessment of vessel size, often effected by associated spasm and high luminal thrombus load in the AMI setting, enables optimal stent selection. Often post-stenting optimization is challenged by conflicting concerns about the acute risk of no reflow/distal embolization with high pressure post-dilatation versus the long-term impact on outcome with persisting stent under-expansion. IVUS provides an accurate assessment of the acute stent result, quantifying stent expansion and identifying tissue protrusion, persisting thrombus and stent edge problems.

Studies evaluating the clinical impact of IVUS-guidance in patients with AMI are limited, a previous KAMIR study showed no significant difference in the incidence of all-cause death at 1 year between IVUS- and angiography-guided PCI after matching; however, it is likely that inclusion of patients who underwent PCI with balloon angioplasty or stent implantation, including bare-metal stents and first-generation DES, plus a limited follow-up of 1 year impacted on the findings.[19] Consequently, our new analysis of an extended KAMIR data set has focused upon patients with AMI receiving contemporary second generation DES with 3-year follow-up.

In a large database from the United States, including 1 484 080 patients with PCI, spanning 2004 to 2014, IVUS guidance was used in only 4.8% of cases,

Table 3. Comparison of 3-Year Clinical Outcomes

	IVUS-guided PCI (n=1887)	Angiography-guided PCI (n=7120)	Unadjusted		Adjusted*		PS-matched		IPW-adjusted	
			HR (95% CI)	*P* value	HR (95% CI)	*P* value	HR (95% CI)	*P* value	HR (95% CI)	*P* value
Target lesion failure†	90 (4.8)	571 (8.0)	0.59 (0.47–0.73)	<0.001	0.61 (0.49–0.77)	<0.001	0.64 (0.49–0.84)	0.001	0.64 (0.49–0.83)	0.001
All-cause death	98 (5.2)	612 (8.6)	0.60 (0.48–0.74)	<0.001	0.66 (0.53–0.82)	<0.001	0.64 (0.50–0.83)	0.001	0.68 (0.53–0.88)	0.003
Cardiac death	58 (3.1)	389 (5.5)	0.56 (0.42–0.73)	<0.001	0.62 (0.47–0.83)	0.001	0.63 (0.45–0.88)	0.006	0.65 (0.47–0.91)	0.012
Any MI	45 (2.4)	210 (2.9)	0.79 (0.57–1.09)	0.158	0.78 (0.56–1.08)	0.136	0.75 (0.50–1.12)	0.156	0.77 (0.52–1.14)	0.195
TV-MI	11 (0.6)	89 (1.2)	0.46 (0.25–0.86)	0.015	0.47 (0.25–0.88)	0.019	0.40 (1.19–0.82)	0.013	0.47 (0.23–0.97)	0.040
Any revascularization	147 (7.8)	578 (8.1)	0.95 (0.79–1.13)	0.550	0.90 (0.75–1.09)	0.289	0.93 (0.74–1.17)	0.523	0.92 (0.73–1.15)	0.471
ID-TLR	31 (1.6)	159 (2.2)	0.72 (0.49–1.07)	0.101	0.66 (0.44–0.98)	0.039	0.80 (0.49–1.29)	0.365	0.69 (0.44–1.09)	0.112
Definite/probable ST	7 (0.4)	62 (0.8)	0.42 (0.19–0.92)	0.030	0.42 (0.19–0.94)	0.034	0.49 (0.20–1.22)	0.127	0.44 (0.18–1.06)	0.067
MACE‡	245 (13.0)	1200 (16.9)	0.76 (0.66–0.87)	<0.001	0.76 (0.66–0.87)	<0.001	0.79 (0.66–0.93)	0.005	0.78 (0.66–0.92)	0.003

Values are presented as n (%) unless otherwise indicated.

HR, hazard ratio; ID-TLR, ischemic driven target lesion revascularization; IPW, inverse probability weighting; IVUS, intravascular ultrasound; MACE, major adverse cardiovascular event; MI, myocardial infarction; PCI, percutaneous coronary intervention; PS, propensity score; ST, stent thrombosis; and TV-MI, target vessel myocardial infarction.

*Adjusted variable: age ≥65 years, Killip class 3, hypertension, diabetes, prior revascularization, previous history of cerebrovascular accident, estimated glomerular filtration rate ≤60 mL/min per 1.73 m^2, left ventricular ejection fraction ≤50%, multivessel disease, left main disease, trans-radial approach, glycoprotein IIb/IIIa inhibitor, thrombus aspiration, stent type, stent diameter ≥3 mm, stent length ≥35 mm, stent number ≥2.

†A Target lesion failure: a composite of cardiac death, target vessel myocardial infarction, or target lesion revascularization.

‡A composite of all-cause death, any recurrent myocardial infarction, or any revascularization.

increasing from 1% in 2004 to 6% in 2014.[20] Another contemporary Medicare cohort in the United States, IVUS used in 5.6% of 1 877 177 PCI case and IVUS-guided PCI increased from 3.0% in 2009 to 6.9% in 2017.[21] Furthermore, those 2 studies showed significant hospital-level variation in IVUS use. Similar rates of IVUS use have been reported in the most recent analysis of the United Kingdom National PCI audit for 2018 to 2019.[22] In the current study, IVUS use in patients with AMI progressively increased during the study period, and a striking diversity in the frequency of IVUS guidance by center was observed ranging from 0.8% to 86.4%. Regarding the variation in the IVUS use proportions in patients with AMI, it might be explained by several factors. First, there are no positive data on the role of IVUS-guided PCI in the setting of AMI and recent expert consensus document suggest that the intracoronary imaging including IVUS guidance should be considered in patients with acute coronary syndrome with ambiguous angiographic lesions to determine disease etiology.[23] Second, patients circumstance of financial support for IVUS use is different, depending on regional health care system restrictions. Third, operators, especially in high volume PCI centers, may have additional time pressures that limit adoption of IVUS in a busy catheterization lab schedule. In the present study, quartile analysis by the institutional volume of IVUS use showed an inverse relationship with volume of AMI PCI, with quartile 1 reporting the highest volume of PCI and quartile 4 the lowest (Table S1). However, after adjustment by patient characteristics between groups, quartile 4 was significantly associated with a reduction in TLF at 3 years compared with quartile 1- and 3-year TLF decreased from quartile 1 to 4. Our quartile analysis suggests that IVUS-guided PCI in patients with AMI should be considered where circumstances allow, to enhance long-term outcomes. As a result, large, randomized trials about IVUS- and angiography-guided PCI in patients with AMI are needed to support the role of IVUS although long-term benefits of IVUS-guided PCI were observed in the current large-sized observational dedicated AMI registry.

In the subgroup analysis, the benefit of IVUS guidance was consistent across various subgroups including patients with AMI presenting with or without ST-elevation. Interestingly, the use of IVUS guidance did not show a reduction in TLF at 3 years in patients with left main stem (LMS) disease among patients with AMI. In contrast, 2 recent meta-analyses have demonstrated that IVUS guidance was associated with better clinical outcomes in patients with LMS disease.[24,25] More recently, a large cohort from the British Cardiovascular Intervention Society showed that intravascular imaging-guided LMS PCI, predominantly IVUS, associated with a reduction in mortality compared with angiography guidance.[9] In our study, only

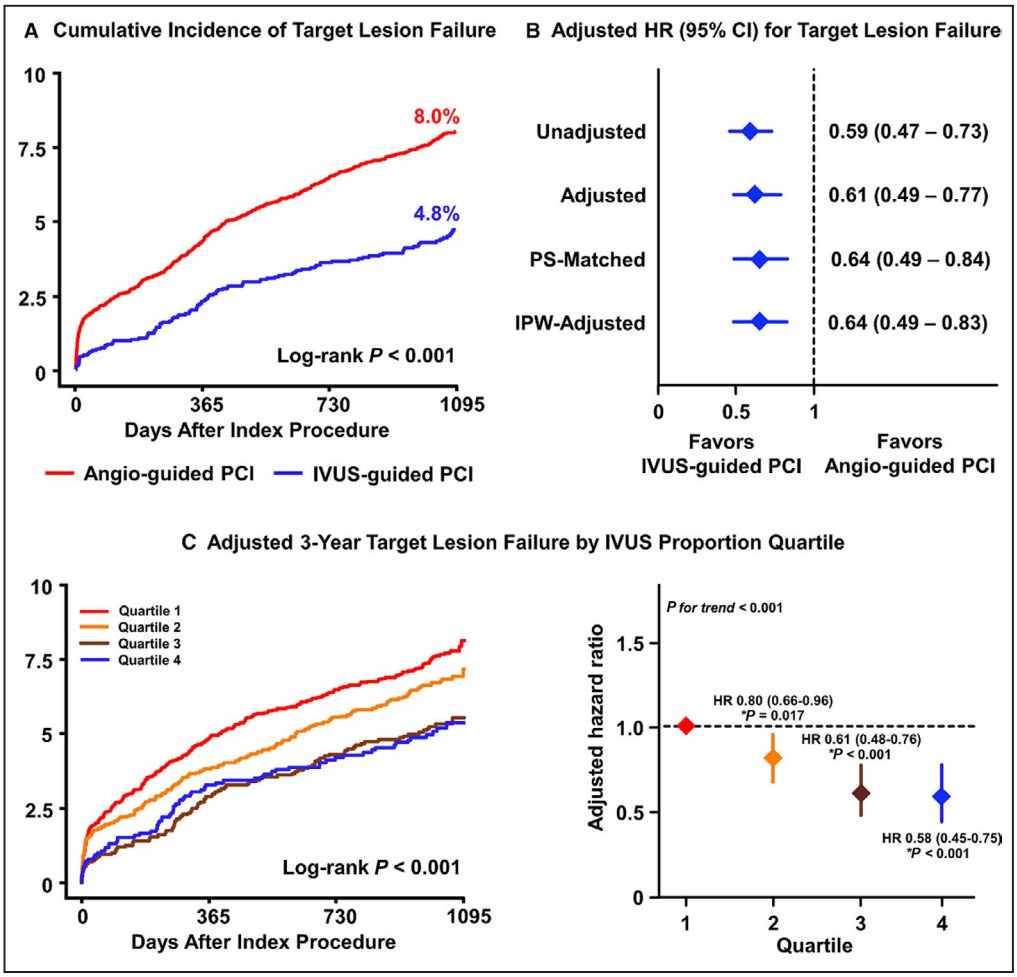


Figure 4. Long-term clinical impact of IVUS-guided PCI in patients with acute myocardial infarction.

The current study evaluated the long-term clinical impact of IVUS-guided PCI for patients with acute myocardial infarction in the current second-generation drug-eluting stent era, using a dedicated nationwide registry for acute myocardial infarction. In the setting of acute myocardial infarction, IVUS-guided PCI was associated with a significant reduction in 3-year target lesion failure (TLF) (**A**) and this result was consistently observed in multiple sensitivity analyses with confounder adjustment (**B**). Kaplan–Meier curves of adjusted TLF at 3 years by quartile of institutional volume of IVUS use (**C**, Left panel) and graph on IVUS use rates and risk of 3-year TLF (**C**, Right panel) showed that quartile 4 significantly associated with a reduction in adjusted TLF at 3 years compared with quartile 1, and adjusted the risk of 3-year TLF gradually decreased from quartile 1 to 4. HR indicates hazard ratio; IPW, inverse probability weighting; IVUS, intravascular ultrasound; PCI, percutaneous coronary intervention; and PS, propensity score. **P* for comparison vs quartile 1. Diamonds indicate the value of adjusted hazard ratio; and dashed line the reference line for 1 (standard adjusted hazard ratio).

416 patients with LMS disease (196 in IVUS group and 220 in angiography group) were included among a total of 504 patients in the KAMIR-NIH registry (excluded 88 patients). Therefore, further studies are needed to determine the benefits of IVUS-guided LMS PCI in patients with AMI.

Study Limitations

First, the study has an inherent limitation on non-randomized, observational registry data, which might have resulted in selection bias. However, various sensitivity analyses, including PS-matching and inverse probability weighting methods, were conducted to adjust for the measured or unmeasured confounders of different baseline characteristics. Second, there were no detailed procedural data such as whether post-dilation has been performed and the maximum balloon pressure, total procedure time, total radiation dose, amount of contrast volume, and occurrence of contrast-induced nephropathy. Furthermore, the timing of IVUS use and detailed IVUS data, including minimal stent area and the presence of dissection

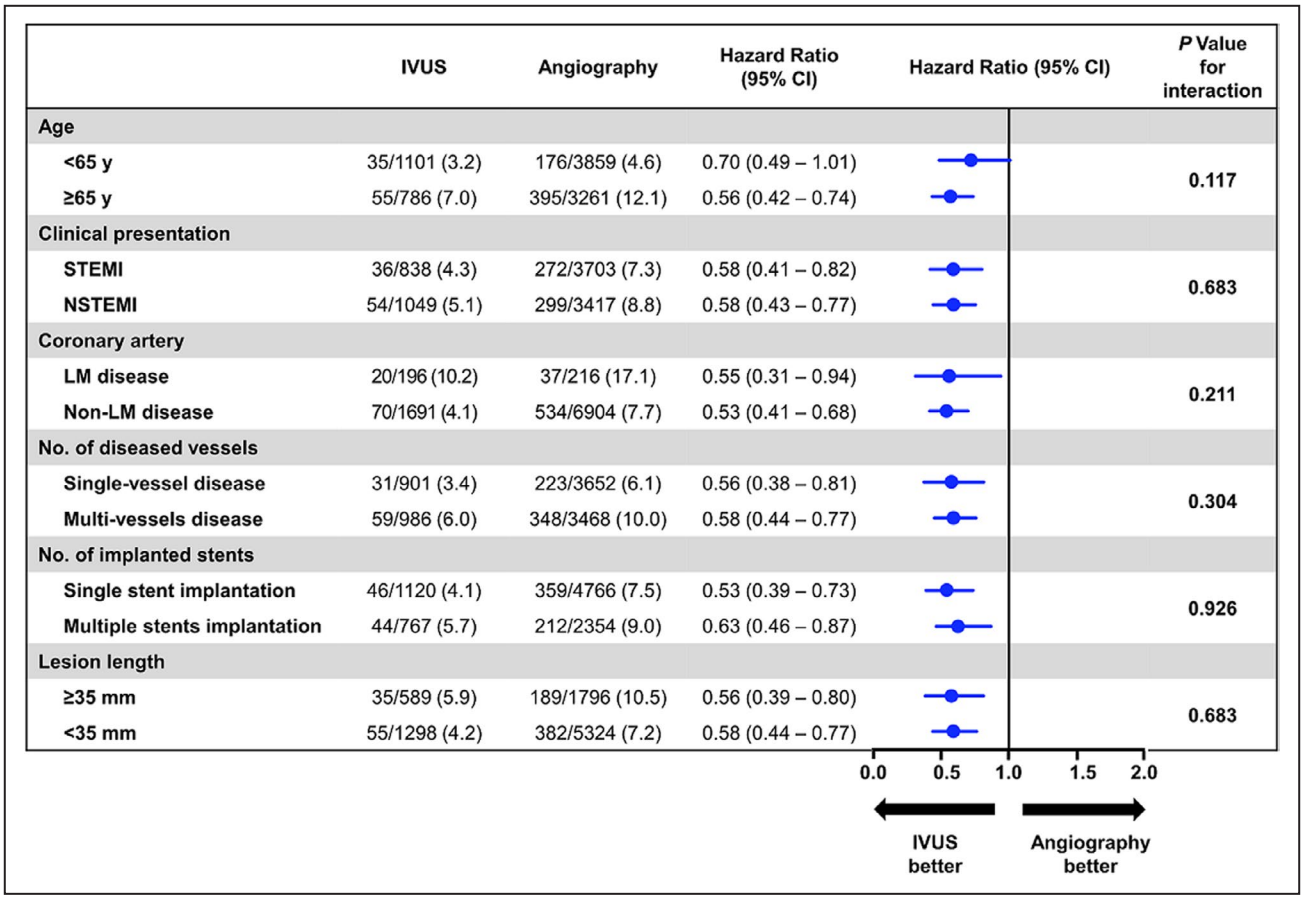


Figure 5. Exploratory subgroup analysis in 3-year target lesion failure by intravascular ultrasound use.
IVUS indicates intravascular ultrasound; LM, left main; NSTEMI, non-ST-segment–elevation myocardial infarction; and STEMI, ST-segment–elevation myocardial infarction. Blue lines indicate range of 95% CI; and circles the value of hazard ratio.

and malapposition, were not recorded during the procedure. The use of IVUS at physician discretion and without dedicated criteria for PCI guidance and stent optimization is likely to underestimate the beneficial effects observed with IVUS use. Similarly, the use of IVUS is not possible in all subgroups of patients, as demonstrated by the advanced age, greater frequency of STEMI and reduced EF observed in the angiography group. Third, all types of second-generation DESs were included in our study, although the clinical outcomes were significantly different according to the specific DES types in patients with AMI.[26]

CONCLUSIONS

In this nationwide multicenter registry, IVUS guidance was associated with a lower risk of TLF at 3 years, mainly driven by hard end points including cardiac death and TV-MI, among patients with AMI undergoing second-generation DES implantation compared with those undergoing angiography-guidance. Moreover, quartile analysis of volume of IVUS use showed that higher IVUS use was associated with a decreased risk of 3-year TLF. These results suggest an important role for IVUS-guided PCI in the treatment of patients with AMI to enhance long-term outcomes.

APPENDIX

Investigators of KAMIR-NIH (Korea Acute Myocardial Infarction Registry-National Institutes of Health)

Myung Ho Jeong (Principle Investigator), Chonnam National University Hospital, Gwangju, Korea. Young Jo Kim, Yeungnam University Medical Center, Daegu, Korea. Chong Jin Kim, Kyunghee University Hospital at Gangdong, Seoul, Korea. Myeong Chan Cho, Chungbuk National University Hospital, Cheongju, Korea. Hyo-Soo Kim, Seoul National University Hospital, Seoul, Korea. Hyeon-Cheol Gwon, Samsung Medical Center, Seoul, Korea. Ki Bae Seung, Seoul St. Mary's Hospital, Seoul, Korea. Dong Joo Oh, Korea University Guro Hospital, Seoul, Korea. Shung Chull Chae, Kyungpook National University Hospital, Daegu, Korea. Kwang Soo Cha, Pusan National University Hospital, Busan, Korea.

Junghan Yoon, Wonju Severance Christian Hospital, Wonju, Korea. Jei-Keon Chae, Chonbuk National University Hospital, Jeonju, Korea. Seung Jae Joo, Jeju National University Hospital, Jeju, Korea. Dong-Ju Choi, Seoul National University Bundang Hospital, Bundang, Korea. Seung-Ho Hur, Keimyung University Dongsan Medical Center, Daegu, Korea. In Whan Seong, Chungnam National University Hospital, Daejeon, Korea. Doo Il Kim, Inje University Haeundae Paik Hospital, Busan, Korea. Seok Kyu Oh, Wonkwang University Hospital, Iksan, Korea. Tae Hoon Ahn, Gachon University Gil Medical Center, Incheon, Korea. Jin-Yong Hwang, Gyeongsang National University Hospital, Jinju, Korea.

ARTICLE INFORMATION

Received August 2, 2021; accepted January 18, 2022.

Affiliations

Yonsei University College of Medicine and Cardiovascular Center, Yongin Severance Hospital, Yongin, Korea (Y.K., S.B., D.-K.C., D.C.); Bristol Heart Institute, Bristol, United Kingdom (T.W.J.); Division of Biostatistics, Yongin Severance Hospital, Yonsei University College of Medicine, Yongin, Korea (N.-H.S.); Chonnam National University Hospital, Gwnagju, Korea (D.S.S., Y.J.H., M.H.J.); Chung-Ang University Hospital, Seoul, Korea (S.W.K.); Severance Cardiovascular Hospital, Yonsei University Health System, Seoul, Korea (J.-S.K., B.-K.K., M.-K.H., Y.J.); and Department of Cardiology, CHA Bundang Medical Centre, CHA University, Seongnam, Korea (Y.J.).

Acknowledgments

The authors would like to thank the clinical investigators of the Korea Acute Myocardial Infarction Registry.

Sources of Funding

This study was supported by grant from a faculty research grant of Yonsei University College of Medicine (6-2020-0161) and research seed money grant of Internal Medicine in Yongin Severance Hospital.Disclosures
Dr Johnson has received consultancy & speaker fees from Boston Scientific. The remaining authors have no disclosures to report.

Supplemental Material

Tables S1–S2
Figures S1–S2

REFERENCES

1. Mintz GS, Guagliumi G. Intravascular imaging in coronary artery disease. *Lancet*. 2017;390:793–809. doi: 10.1016/S0140-6736(17)31957-8
2. Kim JS, Kang TS, Mintz GS, Park BE, Shin DH, Kim BK, Ko YG, Choi D, Jang Y, Hong MK. Randomized comparison of clinical outcomes between intravascular ultrasound and angiography-guided drug-eluting stent implantation for long coronary artery stenoses. *J Am Coll Cardiol Interv*. 2013;6:369–376. doi: 10.1016/j.jcin.2012.11.009
3. Kim BK, Shin DH, Hong MK, Park HS, Rha SW, Mintz GS, Kim JS, Kim JS, Lee SJ, Kim HY, et al. Clinical impact of intravascular ultrasound-guided chronic total occlusion intervention with zotarolimus-eluting versus biolimus-eluting stent implantation: randomized study. *Circ Cardiovasc Interv*. 2015;8:e002592. doi: 10.1161/CIRCINTERVENTIONS.115.002592
4. Hong SJ, Kim BK, Shin DH, Nam CM, Kim JS, Ko YG, Choi D, Kang TS, Kang WC, Her AY, et al. Effect of intravascular ultrasound-guided vs angiography-guided everolimus-eluting stent implantation: the IVUS-XPL randomized clinical trial. *JAMA*. 2015;314:2155–2163. doi: 10.1001/jama.2015.15454
5. Zhang J, Gao X, Kan J, Ge Z, Han L, Lu S, Tian N, Lin S, Lu Q, Wu X, et al. Intravascular ultrasound versus angiography-guided drug-eluting stent implantation: the ULTIMATE trial. *J Am Coll Cardiol*. 2018;72:3126–3137.
6. Hong SJ, Mintz GS, Ahn CM, Kim JS, Kim BK, Ko YG, Kang TS, Kang WC, Kim YH, Hur SH, et al. Effect of intravascular ultrasound-guided drug-eluting stent implantation: 5-year follow-up of the IVUS-XPL randomized Trial. *J Am Coll Cardiol Interv*. 2020;13:62–71. doi: 10.1016/j.jcin.2019.09.033
7. Gao XF, Ge Z, Kong XQ, Kan J, Han L, Lu S, Tian NL, Lin S, Lu QH, Wang XY, et al. Three-year outcomes of the ULTIMATE trial comparing intravascular ultrasound versus angiography-guided drug-eluting stent implantation. *J Am Coll Cardiol Interv*. 2021;14:247–257.
8. Choi KH, Song YB, Lee JM, Lee SY, Park TK, Yang JH, Choi JH, Choi SH, Gwon HC, Hahn JY. Impact of intravascular ultrasound-guided percutaneous coronary intervention on long-term clinical outcomes in patients undergoing complex procedures. *J Am Coll Cardiol Interv*. 2019;12:607–620.
9. Kinnaird T, Johnson T, Anderson R, Gallagher S, Sirker A, Ludman P, de Belder M, Copt S, Oldroyd K, Banning A, et al. Intravascular imaging and 12-month mortality after unprotected left main stem PCI: an analysis from the British Cardiovascular Intervention Society Database. *J Am Coll Cardiol Interv*. 2020;13:346–357.
10. Neumann F-J, Sousa-Uva M, Ahlsson A, Alfonso F, Banning AP, Benedetto U, Byrne RA, Collet J-P, Falk V, Head SJ, et al. 2018 ESC/EACTS Guidelines on myocardial revascularization. *Eur Heart J*. 2019;40:87–165. doi: 10.1093/eurheartj/ehy394
11. Kim Y, Johnson TW, Akasaka T, Jeong MH. The role of optical coherence tomography in the setting of acute myocardial infarction. *J Cardiol*. 2018;72:186–192. doi: 10.1016/j.jjcc.2018.03.004
12. Kim JH, Chae SC, Oh DJ, Kim HS, Kim YJ, Ahn Y, Cho MC, Kim CJ, Yoon JH, Park HY, et al. Multicenter cohort study of acute myocardial infarction in Korea- interim analysis of the Korea Acute Myocardial Infarction Registry-National Institutes of Health Registry. *Circ J*. 2016;80:1427–1436.
13. Steg PG, James SK, Atar D, Badano LP, Lundqvist CB, Borger MA, Di Mario C, Dickstein K, Ducrocq G, Fernandez-Aviles F, et al. ESC Guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation. *Eur Heart J*. 2012;33:2569–2619. doi: 10.1093/eurheartj/ehs215
14. O'Gara PT, Kushner FG, Ascheim DD, Casey DE, Chung MK, de Lemos JA, Ettinger SM, Fang JC, Fesmire FM, Franklin BA, et al. 2013 ACCF/AHA guideline for the management of ST-elevation myocardial infarction: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. *Circulation*. 2013;127:e362–425. doi: 10.1161/CIR.0b013e3182742cf6
15. Cutlip DE, Windecker S, Mehran R, Boam A, Cohen DJ, van Es G-A, Gabriel Steg P, Morel MA, Mauri L, Vranckx P, et al. Clinical end points in coronary stent trials: a case for standardized definitions. *Circulation*. 2007;115:2344–2351. doi: 10.1161/CIRCULATIONAHA.106.685313
16. Ho D, Imai K, King G, Stuart EA. MatchIt: nonparametric preprocessing for parametric causal inference. *J Stat Softw*. 2011;42:1–28.
17. Darmoch F, Alraies MC, Al-Khadra Y, Moussa Pacha H, Pinto DS, Osborn EA. Intravascular ultrasound imaging-guided versus coronary angiography-guided percutaneous coronary intervention: a systematic review and meta-analysis. *J Am Heart Assoc*. 2020;9:e013678. doi: 10.1161/JAHA.119.013678
18. Elgendy IY, Mahmoud AN, Elgendy AY, Mintz GS. Intravascular ultrasound-guidance is associated with lower cardiovascular mortality and myocardial infarction for drug-eluting stent implantation- insights from an updated meta-analysis of randomized trials. *Circ J*. 2019;83:1410–1413.
19. Ahmed K, Jeong MH, Chakraborty R, Ahn Y, Sim DS, Park K, Hong YJ, Kim JH, Cho KH, Kim MC, et al. Role of intravascular ultrasound in patients with acute myocardial infarction undergoing percutaneous coronary intervention. *Am J Cardiol*. 2011;108:8–14. doi: 10.1016/j.amjcard.2011.02.339
20. Smilowitz NR, Mohananey D, Razzouk L, Weisz G, Slater JN. Impact and trends of intravascular imaging in diagnostic coronary angiography and percutaneous coronary intervention in inpatients in the United States. *Catheter Cardiovasc Interv*. 2018;92:E410–E415. doi: 10.1002/ccd.27673
21. Mentias A, Sarrazin MV, Saad M, Panaich S, Kapadia S, Horwitz PA, Girotra S. Long-term outcomes of coronary stenting with and without use of intravascular ultrasound. *JACC Cardiovasc Interv*. 2020;13:1880–1890. doi: 10.1016/j.jcin.2020.04.052
22. British Cardiovascular Intervention Society. BCIS Audit Report 2018-19. Available at: https://www.bcis.org.uk/wp-content/uploads/2021/01/BCIS-Audit-2018-19-data-ALL-4-5-2020-for-web.pdf. Accessed April 25, 2019

23. Johnson TW, Räber L, di Mario C, Bourantas C, Jia H, Mattesini A, Gonzalo N, de la Torre Hernandez JM, Prati F, Koskinas K, et al. Clinical use of intracoronary imaging. Part 2: acute coronary syndromes, ambiguous coronary angiography findings, and guiding interventional decision-making: an expert consensus document of the European Association of Percutaneous Cardiovascular Interventions. *Eur Heart J*. 2019;40:2566–2584. doi: 10.1093/eurheartj/ehz332
24. Ye Y, Yang M, Zhang S, Zeng Y. Percutaneous coronary intervention in left main coronary artery disease with or without intravascular ultrasound: a meta-analysis. *PLoS One*. 2017;12:e0179756. doi: 10.1371/journal.pone.0179756
25. Wang Y, Mintz GS, Gu Z, Qi Y, Wang Y, Liu M, Wu X. Meta-analysis and systematic review of intravascular ultrasound versus angiography-guided drug eluting stent implantation in left main coronary disease in 4592 patients. *BMC Cardiovasc Disord*. 2018;18:115. doi: 10.1186/s12872-018-0843-z
26. Choe JC, Cha KS, Lee JG, Kim J, Shin JY, Ahn J, Park JS, Lee HW, Oh J-H, Choi JH, et al. Long-term outcomes of biodegradable versus second-generation durable polymer drug-eluting stent implantations for myocardial infarction. *J Am Coll Cardiol Interv*. 2020;13:97–111. doi: 10.1016/j.jcin.2019.08.020

SUPPLEMENTAL MATERIAL

Table S1. Percentage of IVUS Use by KAMIR-NIH Participating Site.

Hospital code	IVUS use (%)	IVUS (n)	Angiography (n)	Total patients (n)	Quartile	IVUS rates (%)	Quartile Average Case Volume (n)
A	0.8	2	243	245			
B	2.0	5	242	247			
C	3.4	20	572	592	**Q1**	**3.7**	**625**
D	3.7	4	105	109			
E	4.4	86	1848	1934			
F	6.5	57	815	872			
G	7.4	11	137	148			
H	11.3	83	653	736	**Q2**	**11.2**	**566**
I	13.6	72	459	531			
J	17.5	95	449	544			
K	17.9	93	428	521			
L	25.7	112	323	435			
M	29.7	105	248	353	**Q3**	**28.4**	**335**
L	33.3	27	54	81			

O	48.8	138	145	283			
P	57.2	174	130	304	**Q4**	**71.0**	**275**
Q	57.9	186	135	321			
R	68.8	86	39	125			
S	80.8	143	34	177			
T	86.4	388	61	449			

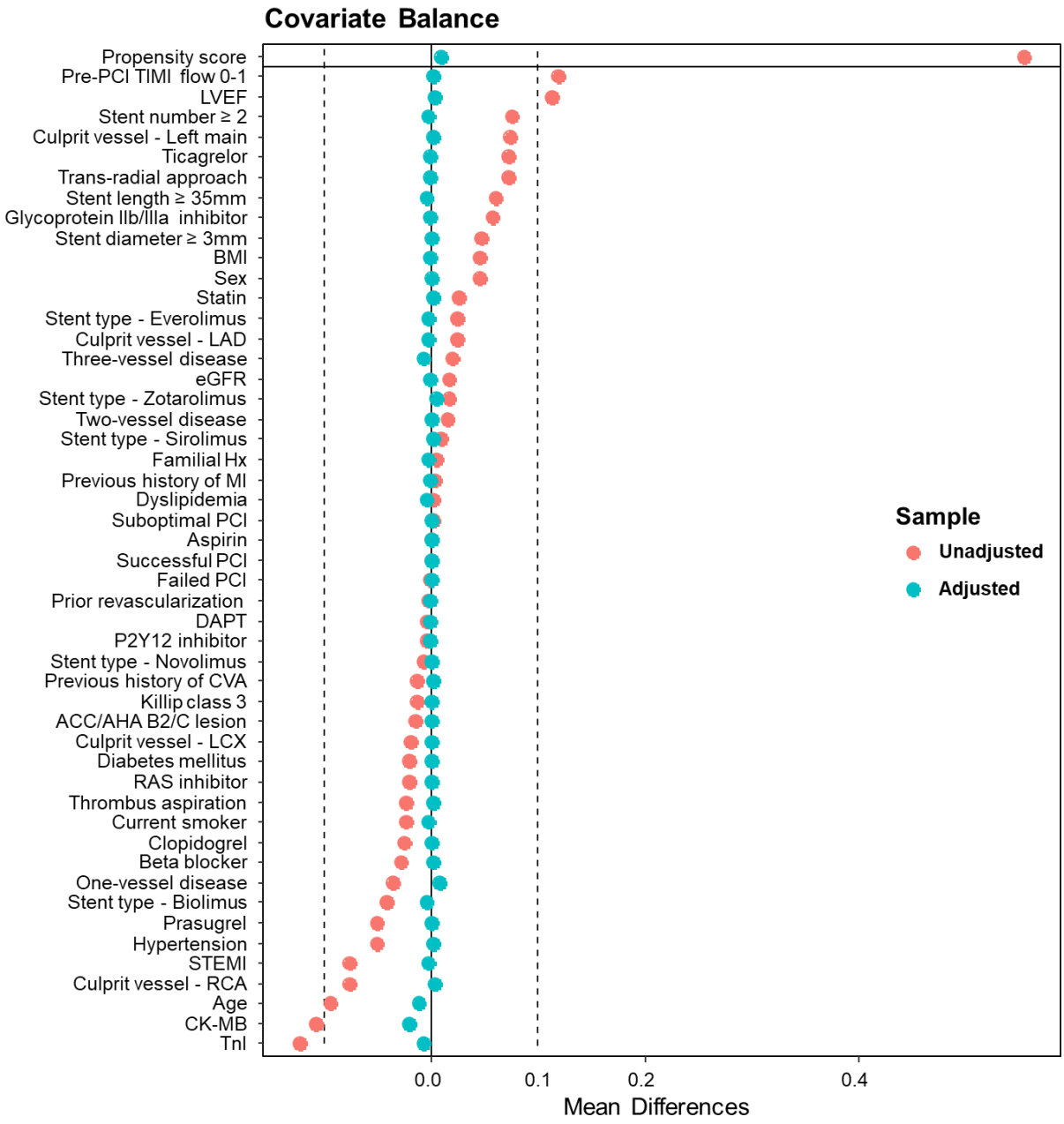
IVUS indicates intravascular ultrasound; KAMIR-NIH, Korea Acute Myocardial Infarction-National Institutes of Health

Table S2. Medication Use.

	At discharge		At 1 year		At 2 years		At 3 years	
	IVUS (N = 1887)	Angiography (N = 7120)	IVUS (N = 1770)	Angiography (N = 6536)	IVUS (N = 1646)	Angiography (N = 6137)	IVUS (N = 1536)	Angiography (N = 5863)
Antiplatelet agent								
Aspirin	1872 (99.2)	7026 (98.7)	1580 (89.3)	5952 (91.1)	1291 (78.4)	5095 (83.0)	1120 (72.9)	4585 (78.2)
Clopidogrel	1225 (64.9)	4855 (68.2)	1206 (68.1)	4471 (68.4)	1024 (62.2)	3836 (62.5)	930 (60.5)	3484 (59.4)
Potent $P2Y_{12}$ inhibitor	641 (34.0)	2163 (30.4)	187 (10.6)	740 (11.3)	75 (4.6)	326 (5.3)	49 (3.2)	239 (4.1)
Prasugrel	151 (8.0)	812 (11.4)	49 (2.8)	404 (6.2)	27 (1.6)	186 (3.0)	18 (1.2)	132 (2.3)
Ticagrelor	490 (26.0)	1351 (19.0)	138 (7.8)	336 (5.1)	48 (2.9)	140 (2.3)	31 (2.0)	107 (1.8)
Dual therapy	1,857 (98.4)	6990 (98.2)	1212 (68.5)	4711 (72.1)	770 (46.8)	3277 (53.4)	598 (38.9)	2612 (44.6)
Anticoagulant agent	36 (1.9)	175 (2.5)	26 (1.5)	139 (2.1)	24 (1.5)	147 (2.4)	28 (1.8)	149 (2.5)
Beta-blocker	1,570 (83.2)	6,132 (86.1)	1294 (73.3)	5307 (81.4)	1154 (70.1)	4770 (77.7)	1050 (68.4)	4444 (75.8)
Calcium channel blocker	135 (7.2)	396 (5.6)	253 (14.2)	876 (13.4)	295 (17.9)	1015 (16.5)	322 (21.0)	1090 (18.6)
RAS inhibitor	1512 (80.1)	5855 (82.2)	1244 (70.5)	4965 (76.1)	1143 (69.4)	4500 (73.3)	1062 (69.1)	4252 (72.5)
Statin	1820 (96.4)	6677 (93.8)	1691 (95.8)	6078 (93.2)	1563 (95.0)	5695 (92.8)	1472 (95.8)	5480 (93.5)

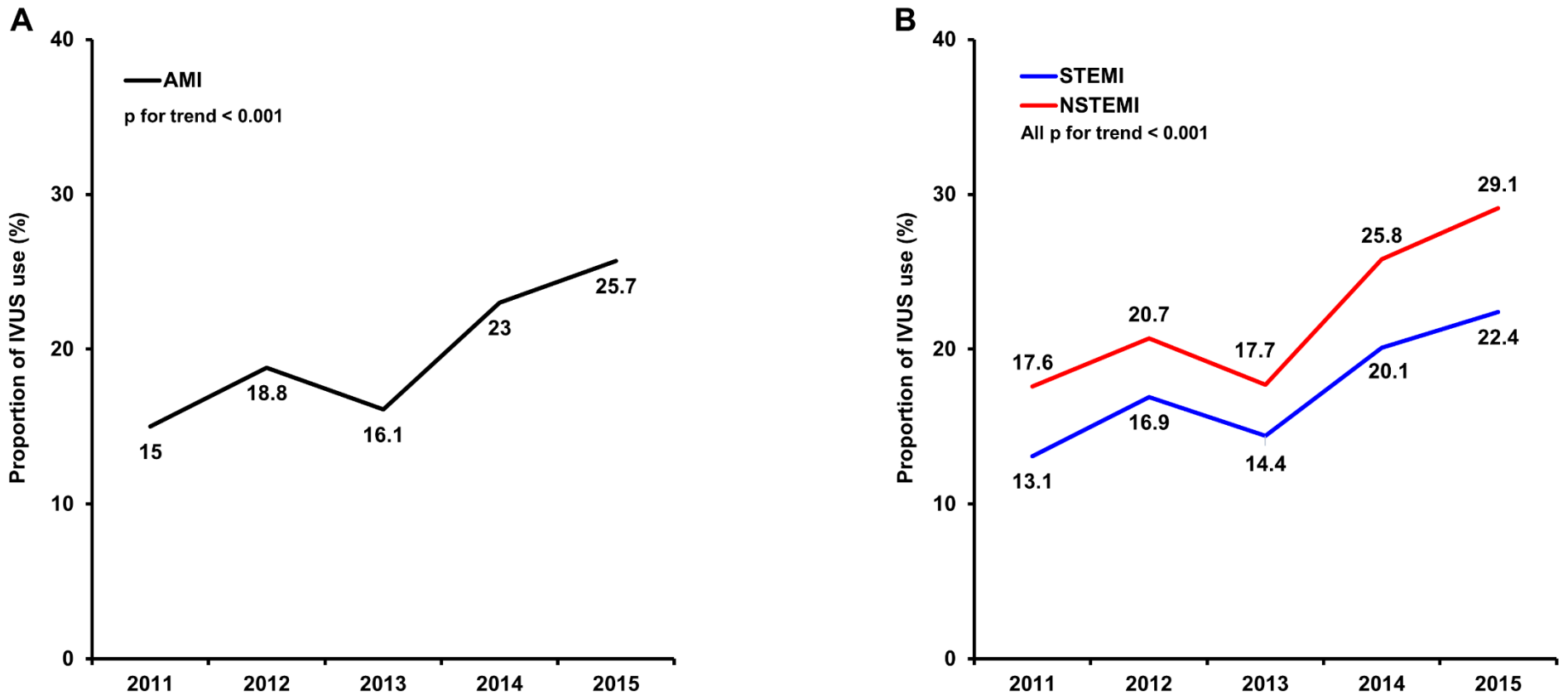
Values are presented as n (%). IVUS indicates intravascular ultrasound; RAS, renin-angiotensin system.

Figure S1. Covariate Balance between IVUS-Guided and Angiography-Guided PCI–IPW.



ACC/AHA indicates American College of Cardiology/American Heart Association; BMI, body mass index; CK-MB, creatine kinase-myocardial band; CVA, cerebrovascular accident; DAPT, dual antiplatelet therapy; DM, diabetes mellitus; eGFR, estimated glomerular filtration rate; HTN, hypertension; IPW, inverse probability weighting; IVUS, intravascular ultrasound; LAD, left anterior descending artery; LCX, left circumflex artery; LVEF, left ventricle ejection fraction; MI, myocardial infarction; PCI, percutaneous coronary intervention; RCA, right coronary artery; STEMI, ST-elevation myocardial infarction; TIMI, Thrombolysis in Myocardial Infarction.

Figure S2. Trends of IVUS-Guided PCI with Second-Generation DES Implantation in Patients with AMI (A) and STEMI and NSTEMI (B) from 2011 and 2015.



AMI indicates acute myocardial infarction; DES, drug-eluting stent; IVUS, intravascular ultrasound; NSTEMI, non-ST-elevation myocardial infarction ; PCI, percutaneous coronary intervention; STEMI, ST-elevation myocardial infarction.