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CORONARY ARTERY DISEASE

Original Studies

Impact of Intravascular Ultrasound-Guided Percutaneous Coronary Intervention on Long-Term Clinical Outcomes in a Real World Population

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Objectives: To compare long-term clinical outcomes between intravascular ultrasound (IVUS)-guided and angiography-guided percutaneous coronary intervention (PCI) in a large "real world" registry. Background: The impact of IVUS-guided PCI on clinical outcomes remains unclear. Methods: Between January 1998 and February 2006, 8,371 patients who underwent IVUS- (n = 4,627) or angiography- (n = 3,744) guided PCI were consecutively enrolled. Three-year clinical outcomes were compared after adjustment for inverse-probability-of-treatment weighting (IPTW) in the overall population and in separate populations according to stent type. Results: A crude analysis of the overall population showed that the 3-year mortality rate was significantly lower in the IVUS-guided group than in the angiography-guided group (96.4% ± 0.3% vs. 93.6% ± 0.4%, log-rank P < 0.001). When adjusted by IPTW, patients undergoing IVUS-guided PCI remained at lower risk of mortality (hazard ratio [HR] 0.627; 95% CI 0.50–0.79, P < 0.001). Similarly, in the drug-eluting stent (DES) population, the 3-year risk of mortality was significantly lower in patients undergoing IVUS-guided PCI (HR 0.46; 95% CI 0.33–0.66, P < 0.001). In contrast, IVUS-guided PCI did not reduce the risk of mortality in the bare metal stent population (HR 0.82; 95% CI 0.60–1.10, P = 0.185). However, the risks of myocardial infarction (HR 0.95; 95% CI 0.63–1.44, P = 0.810), target vessel revascularization (HR 1.00; 95% CI 0.86–1.15, P = 0.944), and stent thrombosis (HR 0.82; 95% CI 0.53–1.07, P = 0.109) were not associated with IVUS guidance. Conclusions: IVUS-guided PCI may reduce long-term mortality when compared with conventional angiography-guided PCI. This may encourage the routine use of IVUS for PCI in patients undergoing DES implantation.

Key words: ultrasound; coronary disease; stents

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INTRODUCTION

Intravascular ultrasound (IVUS) has provided valuable information on cross-sectional coronary vascular structure, with high spatial resolution. IVUS has therefore played a key role in contemporary stent-based percutaneous coronary interventions (PCI), in accurately assessing coronary anatomy, assisting in selection of treatment strategy, and defining optimal stenting outcomes [1–6]. Indeed, suboptimal stent deployment observed on IVUS examination has been found to predict restenosis or stent thrombosis in patients undergoing drug-eluting stent (DES) and bare metal stent (BMS) implantation [3,4,7–12]. In contrast, coronary angiography, despite being the standard tool for evaluating coronary arteries during PCI, is limited in its ability to characterize lesion length, size, and eccentricity because the technique can produce only two-dimensional silhouette images of the three-dimensional vascular lumen [13]. Therefore, PCI guided by IVUS may have advantages over PCI guided by coronary angiography, with respect to patient clinical outcomes.

However, the reports to compare the long-term clinical benefits of IVUS-and angiography-guided PCI in sizable unselected populations were limited. We therefore compared long-term clinical outcomes of IVUS- and angiography-guided PCI in a large "real world" patient registry. In addition, outcomes were further classified by stent type to evaluate the differential impact of IVUS in DES and BMS deployment.

METHODS

Study Population

Between January 1998 and February 2006, 8,371 consecutive patients who underwent PCI at two academic tertiary hospitals in Korea were enrolled. The study population was divided into those undergoing IVUS- or angiography-guided PCI. A procedure was considered to be IVUS-guided when IVUS examinations were performed during the procedure to guide optimal stent deployment. The remaining patients, who did not undergo IVUS examination during the index procedure, were classified as having undergone angiography-guided PCI. Written informed consent for the use of their data was obtained from all patients.

Procedures

All procedures were performed using standard interventional techniques. Guidance of IVUS was at the discretion of the operator, and IVUS images were obtained using an automatic pullback system using one of the two commercially available ultrasound systems: Atlantis S (Boston Scientific Corp/SCIMED, Minneapolis, MN) or Eagle Eye (Volcano Therapeutics, Rancho Cordova, CA). BMS placement was the default treatment for PCI between January 1998 and January 2003, whereas DES has been the default treatment for PCI since February 2003. The choice of a specific type of DES was at the discretion of each physician. Antiplatelet and periprocedural anticoagulation therapy followed standard regimens. Before or during the procedure, patients were given loading doses of aspirin (200 mg) and clopidogrel (300 or 600 mg) or ticlopidine (500 mg), if not already on a maintenance dose. Use of glycoprotein IIb/IIIa inhibitors was at the discretion of the surgeon. After each procedure, patients were maintained on aspirin (100–200 mg once daily) and clopidogrel (75 mg once daily) or ticlopidine (250 mg twice daily) for at least 6 months after DES and for at least 1 month after BMS implantation, with longer clopidogrel treatment being at the discretion of the physician.

Outcome Definitions and Data Collection

The primary endpoint of the study was all-cause mortality. The secondary endpoint was the cumulative incidence of major adverse cardiac events (MACE) including death from any cause, myocardial infarction (MI), target-vessel revascularization, (TVR), and stent thrombosis.

All deaths were considered to be cardiac origin unless a noncardiac origin was established clinically or at autopsy. MI was defined as creatinine kinase-MB levels >three-fold the upper limit of normal values, with or without electrocardiographic changes. TVR was defined as any repeat revascularization of a previously stented vessels. Stent thrombosis was assessed by Academic Research Consortium definitions, including all levels of certainty (definite, probable, or possible) [14].

Baseline clinical, angiographic, and procedural characteristics were prospectively collected using a standard case report form and entered into a dedicated database system. Clinical follow-up after PCI was recommended at 1 month, 6 months, and 1 year, and annually thereafter. To validate follow-up data, information on deaths was obtained from the National Registration System of the Ministry of Government Administration and Home Affairs in Korea, which employs a unique personal identification number for each patient. Similarly, information on rehospitalization for adverse clinical events was obtained from the Hospital Disease Code Registration System, which is merged (for reimbursement purposes) into the Health Insurance Review Agency of Korea. Outcomes of interest were centrally adjudicated by independent physicians.

TABLE I. Baseline Clinical, Angiographic, and Procedural Characteristics of the Overall Population

	IVUS guidance ($N = 4,627$)	Angiography guidance ($N = 3,744$)	P value
Age (years)	58.9 ± 10.1	61.8 ± 10.4	<0.001
Male gender	3,317 (71.7)	2,559 (68.3)	<0.001
Diabetes	1,043 (22.5)	953 (25.5)	0.002
Hypertension	2,014 (43.5)	1,769 (47.2)	0.001
Smoking	1,636 (35.4)	1,310 (35.0)	0.726
Hypercholesterolemia	1,305 (28.2)	1,108 (29.6)	0.163
Previous coronary angioplasty	440 (9.5)	292 (7.8)	0.006
Previous coronary artery bypass graft	53 (1.1)	80 (2.1)	<0.001
Renal failure (creatinine >2.0 mg dl^{-1})	105 (3.0)	164 (5.8)	<0.001
Acute coronary syndrome	2,839 (53.5)	2,468 (65.9)	<0.001
Left ventricular ejection fraction (%)	58.5 ± 9.6	57.0 ± 10.8	<0.001
Vessel treated			
Left anterior descending artery	2,723 (58.9)	1,866 (49.8)	<0.001
Left circumflex artery	568 (12.3)	805 (21.5)	<0.001
Right coronary artery	1,149 (24.8)	1,262 (33.7)	<0.001
Left main coronary artery	390 (8.4)	95 (2.5)	<0.001
Coronary graft	13 (0.3)	25 (0.7)	0.009
Lesion characteristics			
Bifurcation lesion	917 (19.8)	603 (16.1)	<0.001
Restenotic lesion	201 (4.3)	90 (2.4)	<0.001
Ostial lesion	523 (11.3)	174 (4.6)	<0.001
Chronic total occlusion	189 (4.1)	148 (4.0)	0.760
Procedural characteristics			
Stent type			<0.001
Drug-eluting stent	2,765 (59.8)	1,816 (48.5)	
Bare-metal stent	1,862 (40.2)	1,928 (51.5)	
Multivessel coronary angioplasty	1,309 (28.3)	1,251 (33.4)	<0.001
Direct stenting without pre-dilation	481 (10.4)	195 (5.2)	<0.001
Maximal balloon pressure, atm	14.1 ± 4.2	12.8 ± 3.8	<0.001
Maximal balloon size, mm	3.6 ± 0.6	3.3 ± 0.6	<0.001
Average stent diameter per patient (mm)	3.3 ± 0.5	3.1 ± 0.7	<0.001
Number of stents per patient	1.7 ± 1.0	1.6 ± 1.0	0.032
Total stent length per patient, mm	38.6 ± 27.9	36.7 ± 25.4	0.002
Medication used			
Statin	1,948 (42.1)	1,428 (38.1)	<0.001
Beta-blocker	3,532 (76.3)	2,734 (73.0)	<0.001
ACEI or ARB	1,182 (25.5)	1,088 (29.1)	<0.001

Data are means ± SDs or n (%).

ACC/AHA = American college of cardiology/American heart association classification; ACEI = angiotensin converting enzyme inhibitor; ARB = angiotensin II receptor blocker.

Statistics

Differences in baseline clinical, angiographic, and procedural characteristics between groups of patients undergoing IVUS- and angiography-guided PCI were compared using Student's t test for continuous variables and χ^2 or Fisher's exact test for categorical variables, as appropriate. To compare clinical follow-up data between the two groups and to reduce follow-up bias, clinical outcomes were censored at 3 years in both groups. Cumulative incidence rates were estimated by the Kaplan–Meier method and compared by the log-rank test.

To reduce the impact of treatment selection bias and potential confounding in an observational study, we rigorously adjusted significant differences in patient characteristics using propensity-score analysis and multivariable Cox's proportional hazards regression [15,16]. Propensity scores, indicating the predicted probability of receiving a specific treatment conditional on observed covariates, were estimated by multiple logistic-regression analysis. To create a propensity score, single imputation was used to fill incomplete baseline variables with the assumption that data omission was random [17]. All prespecified covariates were included in full nonparsimonious models for IVUS- versus angiography-guided PCI (Table I). Model discrimination was assessed using c statistics, and model calibration was evaluated with Hosmer-Lemeshow statistics. An individual propensity score was incorporated into the Cox's regression model as a covariate and type of PCI strategy (IVUS- vs. angiography-guided) to calculate a propensity-adjusted hazard ratio for the

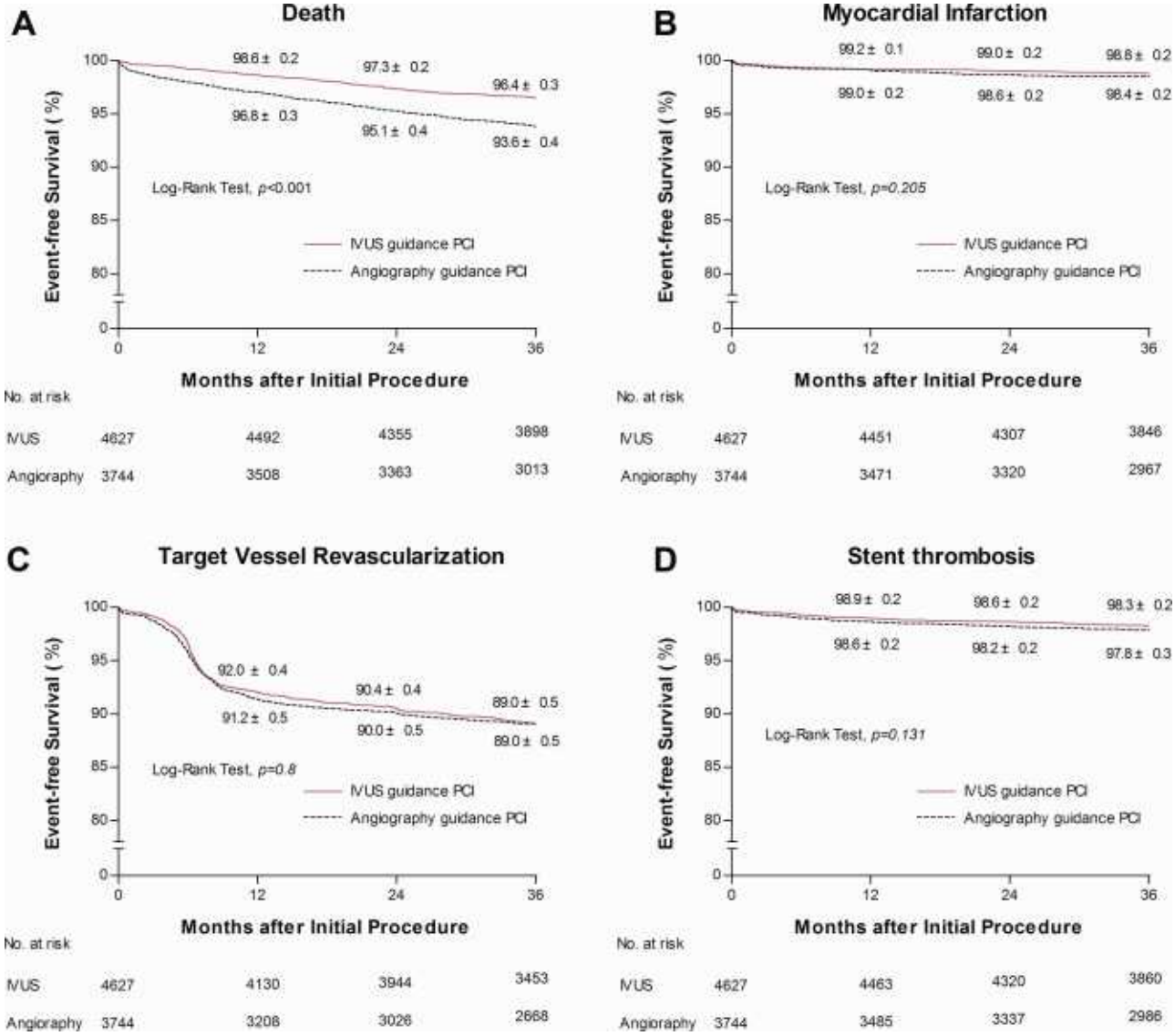

Fig. 1. Kaplan–Meier event-free 3-year survival curves for death, myocardial infarction, target-vessel revascularization, and stent thrombosis in the overall population following IVUS- or angiography-guided PCI. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

overall population (*C* statistic = 0.74, Hosmer-Lemeshow statistic $P = 0.21$), the DES population (*C* statistic = 0.75, Hosmer-Lemeshow statistic $P = 0.41$) and the BMS population (*C* statistic = 0.74, Hosmer-Lemeshow statistic $P = 0.22$). We also applied adjustment, using weighted Cox's proportional-hazards regression models using inverse-probability-of-treatment weighting (IPTW) method [18–20]. By this technique, weights for patients undergoing angiography-guided PCI were the inverse of (1—propensity score), and weights for patients undergoing IVUS-guided PCI were the inverse of the propensity score.

All reported *P* values are two-sided, and values of $P < 0.05$ were considered statistically significant. SAS software version 9.1 (SAS Institute, Cary, NC) was used for all statistical analyses.

RESULTS

Patient Characteristics

A total of 8,371 patients were included; of these, 4,627 (55.3%) underwent IVUS-guided PCI and 3,744 (44.7%) underwent angiography-guided PCI. The baseline clinical, angiographic, and procedural characteristics of the two groups are presented in Table I. Patients undergoing IVUS-guided PCI had a higher prevalence of male gender; previous PCI; left main coronary artery, bifurcation, restenotic, and ostial lesions; longer

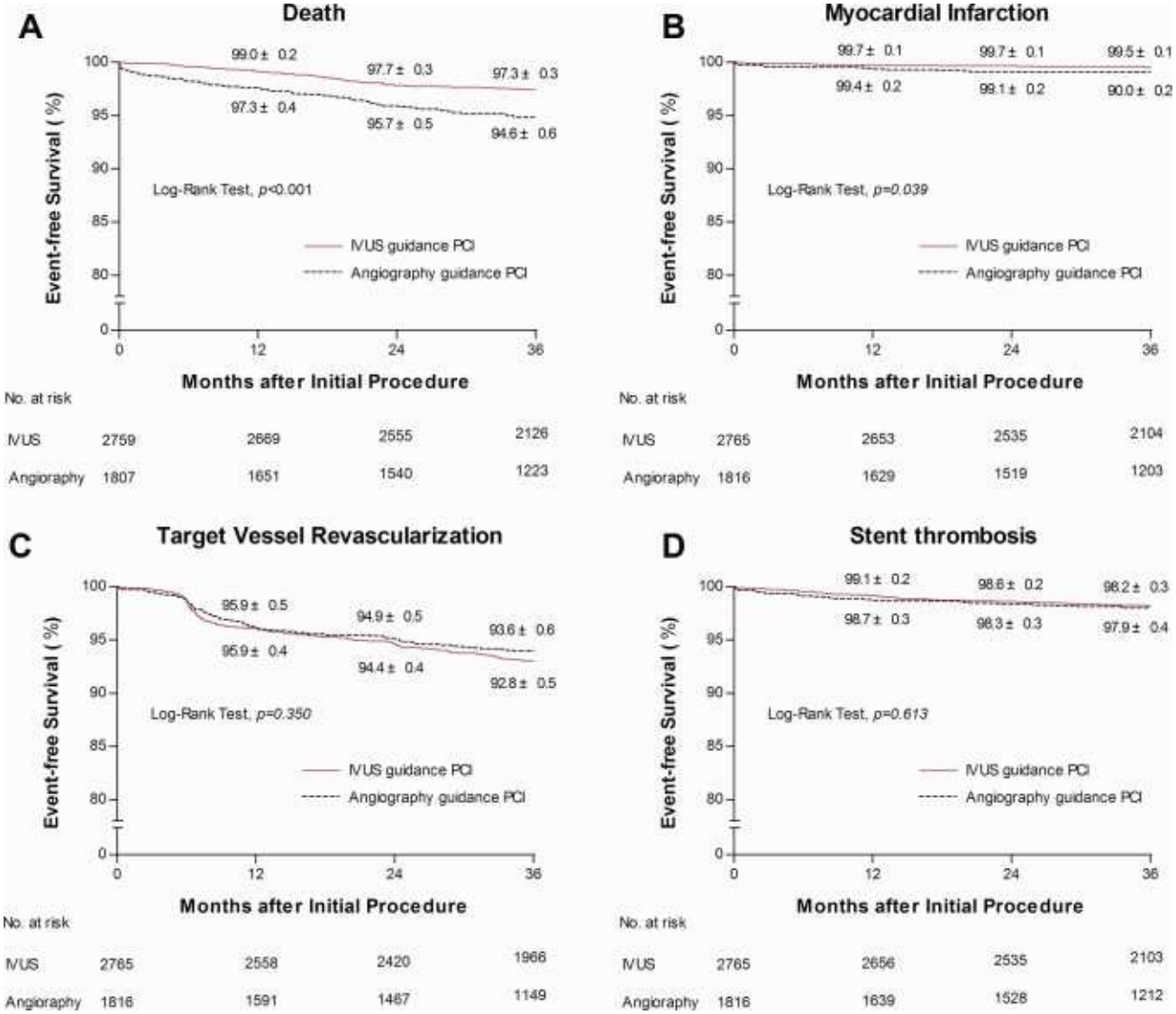

Fig. 2. Kaplan–Meier event-free 3-year survival curves for death, myocardial infarction, target-vessel revascularization, and stent thrombosis in the DES population following IVUS- or angiography-guided PCI. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

stent length; and greater numbers of stents. In contrast, patients undergoing angiography-guided PCI were older; had a lower left ventricular ejection fraction; and a higher prevalence of diabetes, renal failure, acute coronary syndrome, and multivessel disease. DES implantation was more frequent in patients undergoing IVUS-guided PCI.

Clinical Outcomes

Unadjusted incidence of events. Figure 1 shows the unadjusted event-free survival curves in the overall population. The 3-year cumulative survival rate was significantly higher in patients undergoing IVUS-guided PCI (96.4% ± 0.3% vs. 93.6% ± 0.4%, log-rank $P < 0.001$). However, the 3-year survival rates without MI (98.8% ± 0.2% vs. 98.4% ± 0.2%, log-rank $P = 0.205$), TVR (89.0% ± 0.5% vs. 89.0% ± 0.5%, log-rank $P = 0.8$), or ST (98.3% ± 0.2% vs. 97.8% ± 0.3%, log-rank $P = 0.131$) were similar in the two groups. The 3-year cumulative survival rates without adverse outcomes in the DES and BMS populations are shown in Figs. 2 and 3.

Adjusted hazards. Table II summarizes the crude and adjusted hazards of adverse outcomes in patients undergoing IVUS- and angiography-guided PCI. When adjusted by IPTW, patients undergoing IVUS-guided PCI were at a significantly lower risk of mortality than

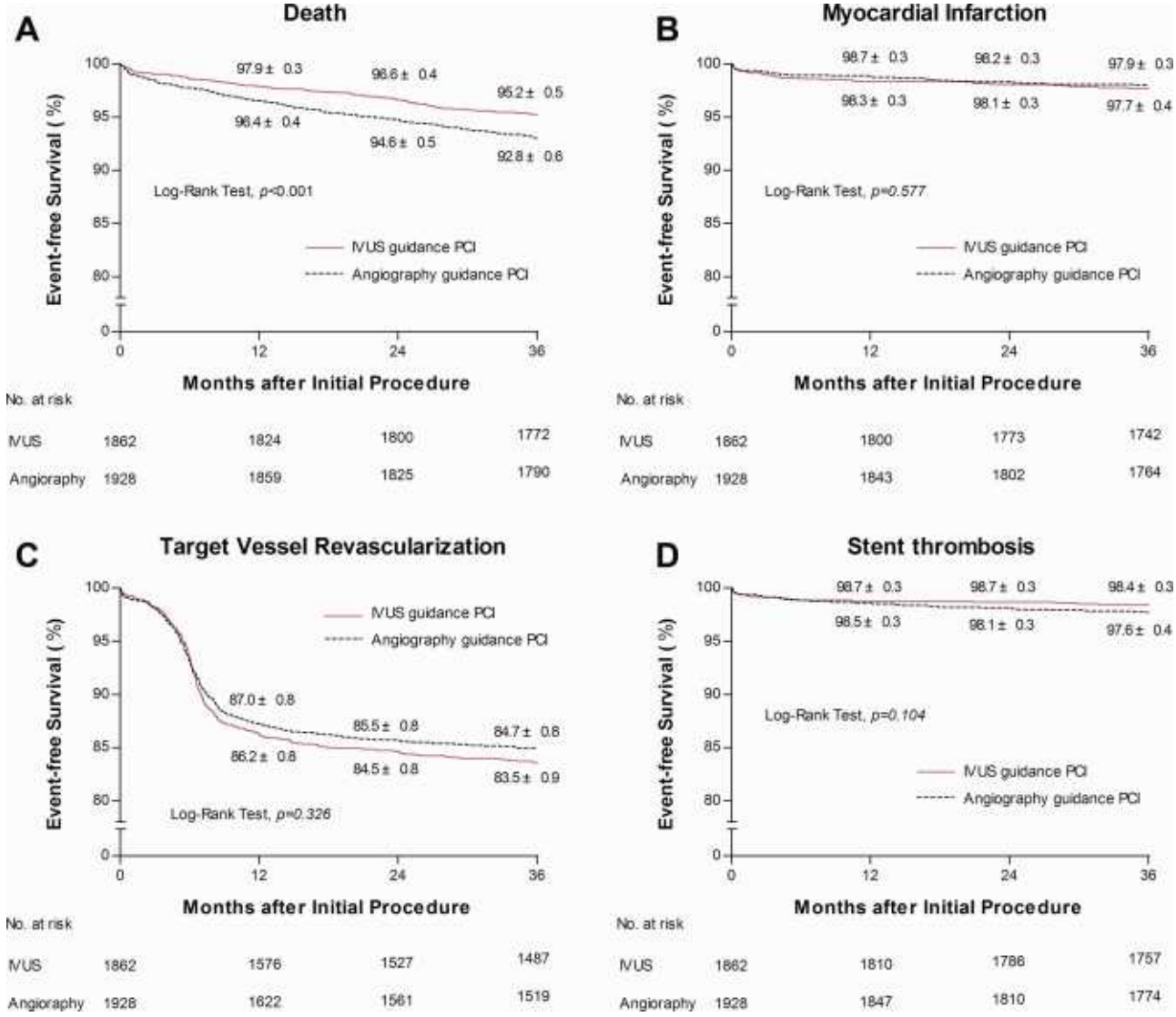

Fig. 3. Kaplan–Meier event-free 3-year survival curves for death, myocardial infarction, target-vessel revascularization, and stent thrombosis in the BMS population following IVUS- or angiography-guided PCI. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

were patients undergoing angiography-guided PCI (hazard ratio [HR] 0.63; 95% CI 0.50–0.79, $P < 0.001$). In addition, the adjusted hazards ratio using either the multivariate Cox's model, propensity score-adjusted, or IPTW method, showed the same results. Similarly, in the DES population, IVUS-guided PCI was associated with significantly lower risks of mortality and MACE. However, in the BMS population, no difference in mortality or MACE between the two groups was observed. In addition, there was no significant difference in individually adjusted hazards of MI, TVR, or ST in the overall population, the DES population, or the BMS population.

Independent predictors of mortality. To determine independent predictors of mortality, we performed multivariable Cox's proportional hazards regression with backward stepwise methods. In the overall population, IVUS guided PCI, age, renal failure, and left ventricular ejection fraction were identified as independent predictors of mortality (Table III).

DISCUSSION

We have shown here that IVUS-guided PCI may reduce the risk of long-term mortality when compared with angiography-guided PCI in a large observational cohort. Furthermore, when subanalyzed by stent type, the reduced risk of mortality was apparent in the DES population undergoing IVUS-guided PCI. However, the

TABLE II. Crude and Adjusted Hazard Ratios of Clinical Outcomes for IVUS-Guided PCI Compared With Angiography-Guided PCI

	Crude		Multivariate adjusted[a]		Propensity score adjusted		IPTW	
	Hazard ratio (95% CI)	*P* value	Hazard ratio (95% CI)	*P* value	Hazard ratio (95% CI)	*P* value	Hazard ratio (95% CI)	*P* value
Overall Population								
Death	0.55 (0.45–0.68)	<0.001	0.70 (0.57–0.87)	0.001	0.61 (0.44–0.84)	0.002	0.63 (0.50–0.79)	<0.001
Myocardial infarction	0.79 (0.54–1.14)	0.21	1.14 (0.78–1.66)	0.51	1.01 (0.67–1.51)	0.97	0.95 (0.63–1.44)	0.81
TVR	0.98 (0.86–1.12)	0.80	1.08 (0.93–1.24)	0.31	1.04 (0.90–1.21)	0.57	1.00 (0.86–1.15)	0.94
MACE	0.84 (0.75–0.94)	0.003	0.92 (0.82–1.05)	0.20	0.92 (0.81–1.04)	0.17	0.86 (0.76–0.98)	0.026
Stent thrombosis	0.79 (0.58–1.08)	0.132	0.81 (0.59–1.12)	0.204	0.78 (0.56–1.10)	0.159	0.75 (0.53–1.07)	0.109
DES population								
Death	0.49 (0.36–0.67)	<0.001	0.55 (0.40–0.76)	<0.001	0.49 (0.35–0.70)	<0.001	0.46 (0.33–0.66)	<0.001
Myocardial infarction	0.48 (0.23–0.98)	0.043	0.55 (0.26–1.14)	0.105	0.50 (0.22–1.10)	0.085	0.49 (0.22–1.08)	0.075
TVR	1.15 (0.90–1.47)	0.250	1.02 (0.80–1.30)	0.893	0.99 (0.76–1.28)	0.914	0.90 (0.68–1.18)	0.429
MACE	0.85 (0.70–1.01)	0.071	0.79 (0.66–0.96)	0.017	0.76 (0.62–0.93)	0.007	0.70 (0.57–0.86)	0.001
Stent thrombosis	0.89 (0.58–1.38)	0.613	0.79 (0.50–1.26)	0.324	0.72 (0.44–1.16)	0.177	0.73 (0.45–1.18)	0.197
BMS population								
Death	0.67 (0.51–0.87)	0.003	0.79 (0.59–1.05)	0.102	0.86 (0.64–1.15)	0.308	0.82 (0.60–1.10)	0.185
Myocardial infarction	1.13 (0.73–1.75)	0.577	1.27 (0.81–1.98)	0.305	1.36 (0.85–2.20)	0.201	1.25 (0.78–2.03)	0.357
TVR	1.08 (0.92–1.27)	0.326	1.14 (0.96–1.35)	0.148	1.11 (0.93–1.32)	0.27	1.09 (0.91–1.30)	0.359
MACE	0.93 (0.80–1.08)	0.354	1.10 (0.94–1.29)	0.229	1.07 (0.90–1.26)	0.449	1.02 (0.87–1.21)	0.777
Stent thrombosis	0.68 (0.43–1.09)	0.106	0.74 (0.46–1.18)	0.202	0.85 (0.51–1.41)	0.533	0.76 (0.46–1.27)	0.297

CI = confidence interval; IPTW = weighted Cox's proportional-hazards regression model using inverse-probability-of-treatment weighting; IVUS = intravascular ultrasound; MACE = major adverse cardiac event; PCI = percutaneous coronary intervention; TVR = target-vessel revascularization.
[a]Adjusted for all variables listed in Table I.

3-year risks of MI, TVR, and stent thrombosis were not modified by the use of IVUS-guided PCI.

Contrary to a role as a clinical research tool in interventional cardiology [21–23], the clinical benefits of routine IVUS-guided PCI remain unclear. Some patients undergoing BMS implantation have shown favorable clinical outcomes after use of IVUS-guided PCI [5,7,24], whereas other studies did not find such outcomes [25–27]. However, only a few studies appearing to date have addressed the influence of IVUS-guided DES implantation on clinical outcomes [28,29]. Several cited studies had relatively small study populations and short-term ($\leq$1 year) follow-up. Conversely, the present study included a large number of patients and longer follow-up duration, thus more closely representing long-term clinical outcomes in a "real-world" population.

The most important finding of our study was that IVUS-guided PCI may reduce long-term mortality, compared with angiography-guided PCI. These findings extend our previous results [28] on a subset of patients undergoing left main coronary artery stenting, to a more general population. The IVUS substudy from the MAIN-COMPARE registry showed that the risk of 3-year mortality was about 60% lower when IVUS rather than angiography guidance was employed in a propensity-matched population. However, the more complex baseline clinical characteristics of the angiography-guided PCI group may be responsible for the higher observed mortality rate, compared with the IVUS-guided PCI group. The survival benefits of IVUS-guided PCI were consistently observed, however, even after rigorous adjustment for unbalanced patient characteristics between groups, using a multivariate Cox's model, propensity score-adjusted methods, and IPTW. IVUS-guided PCI, compared with angiography-guided

TABLE III. Independent Predictors of Mortality

	Hazard ratio (95% CI)	*P* value
Overall population		
IVUS guided PCI	0.49 (0.34–0.71)	<0.01
Age (year)	1.03 (1.02–1.05)	<0.01
Renal failure	3.2 (1.78–5.6)	<0.01
LV EF, (%)	0.98 (0.96–1.00)	0.03
DES population		
IVUS guided PCI	0.52 (0.37–0.73)	<0.01
Age (year)	1.04 (1.02–1.05)	<0.01
Renal failure	2.8 (1.76–4.51)	<0.01
LV EF, (%)	0.98 (0.97–1.00)	0.02
Bifurcation lesion	1.71 (1.08–2.70)	0.02
Multivessel PCI	1.78 (1.21–2.63)	<0.01
BMS population		
Age (year)	1.05 (1.03–1.07)	<0.01
Renal failure	3.34 (2.02–5.53)	<0.01
LV EF (%)	0.97 (0.96–0.98)	<0.01
LM lesion	1.85 (1.07–3.20)	0.03
Ostial lesion	1.89 (1.25–2.85)	<0.01

CI = confidence interval; IVUS = intravascular ultrasound; LVEF = left ventricular ejection fraction; LM = left main; PCI = percutaneous coronary intervention.

PCI, may allow optimal stent deployment, including a larger acute lumen gain, adequate stent apposition, and full lesion coverage, with avoidance of the unnecessary use of coronary stents during the index procedure, resulting in clinical benefits [11,12,30]. Earlier identification by IVUS of procedure-related complications, such as stent edge dissection, and subsequent treatment thereof, may be another contributing factor.

The advent of DESs, which markedly reduce the rate of in-stent restenosis, may reduce the clinical utility of IVUS. However, contemporary PCI with DES is not totally free from in-stent restenosis and a need for subsequent repeat revascularization therapy [10,29]. Furthermore, the reduced risk of in-stent restenosis is offset by concerns about stent thrombosis in patients undergoing DES stenting [31–37]. In addition, physicians have encountered complex lesions more often, have identified a need for complicated procedures, and treat more high-risk patients, in the DES era [38,39]. Therefore, the value of clinical application of IVUS in daily practice should not be underestimated in patients undergoing DES implantation. A recent report showed that IVUS-guided DES implantation significantly reduced the incidence of definite stent thrombosis at 30 days and 12 months in 884 propensity-matched patients [29]. In the present study, the incidence of stent thrombosis was 1.7% in the IVUS-guided PCI group and 2.1% in the angiography-guided PCI group, although the difference did not reach statistical significance. In addition, subanalysis of our patients by stent type showed that only the DES population significantly benefited from IVUS-guided PCI, in terms of long-term survival. Therefore, when considering the safety aspect of PCI procedures, routine IVUS guidance may be of importance during DES stenting.

We observed no difference between IVUS- and angiography-guided PCI in long-term target vessel revascularization rate. This result was unexpected, and is somewhat inconsistent with those of previous studies [5,7,24]. Although the reason is unclear, the 3-year rate of repeat revascularization was quite low. Additionally, because the two academic tertiary hospitals involved the present study had extensive experience with IVUS-guided PCI, angiography-guided PCI in these hospitals has already been optimized using insight gained from use of IVUS, including the integration into routine practice of high-pressure optimization employing non-compliant balloons to prevent underexpansion of stents. Therefore, dedicated angiography-guided stent implantation may compensate for the gap in the need for repeat revascularization between the two strategies.

This study had several limitations. First, the work was non-randomized, and the observational design is inherently limited by a possible risk of selection bias. We therefore applied vigorous statistical adjustment as described, although the numbers and accuracies of the variables evaluated were limited, and unmeasured confounders may have influenced the outcomes. Second, the criteria for selection of IVUS guidance and optimizing stent deployment were not standardized, being at the discretion of attending physician. Third, no quantitative IVUS or angiographic measurements were obtained, and, therefore, the impact of these parameters on long-term clinical outcomes was not evaluated. Finally, the two participating centers are high-volume tertiary hospitals that have adopted IVUS as a routine PCI procedure. Therefore, it may be difficult to generalize the results of this study to hospitals with limited experience of IVUS examination. Furthermore, the cost of the ultrasound catheter, the additional time required to perform serial IVUS examination, and the availability of appropriately trained personnel capable of accurately acquiring and interpreting images, are very relevant factors [40]. Because of these limitations, the results of the present study should be regard as hypothesis-generating but certainly not definitive. Future randomized clinical trials of sufficiently large sample size, and the use of prespecified protocols, are needed to evaluate the efficacy of IVUS-guided PCI in DES implantation.

CONCLUSIONS

Using a large "real-world" registry, we demonstrated that IVUS-guided PCI significantly reduced long-term mortality, particularly in patients undergoing DES implantation, when compared with angiography-guided PCI. This finding may encourage the routine use of IVUS examination during the performance of DES implantation.

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