JACC: CARDIOVASCULAR INTERVENTIONS VOL. 11, NO. 14, 2018

PUBLISHED BY ELSEVIER

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Angiography Alone Versus Angiography Plus Optical Coherence Tomography to Guide Percutaneous Coronary Intervention

Outcomes From the Pan-London PCI Cohort

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ABSTRACT

OBJECTIVES This study aimed to determine the effect on long-term survival of using optical coherence tomography (OCT) during percutaneous coronary intervention (PCI).

BACKGROUND Angiographic guidance for PCI has substantial limitations. The superior spatial resolution of OCT could translate into meaningful clinical benefits, although limited data exist to date about their effect on clinical endpoints.

METHODS This was a cohort study based on the Pan-London (United Kingdom) PCI registry, which includes 123,764 patients who underwent PCI in National Health Service hospitals in London between 2005 and 2015. Patients undergoing primary PCI or pressure wire use were excluded leaving 87,166 patients in the study. The primary endpoint was all-cause mortality at a median of 4.8 years.

RESULTS OCT was used in 1,149 (1.3%) patients, intravascular ultrasound (IVUS) was used in 10,971 (12.6%) patients, and angiography alone in the remaining 75,046 patients. Overall OCT rates increased over time ($p < 0.0001$), with variation in rates between centers ($p = 0.002$). The mean stent length was shortest in the angiography-guided group, longer in the IVUS-guided group, and longest in the OCT-guided group. OCT-guided procedures were associated with greater procedural success rates and reduced in-hospital MACE rates. A significant difference in mortality was observed between patients who underwent OCT-guided PCI (7.7%) compared with patients who underwent either IVUS-guided (12.2%) or angiography-guided (15.7%; $p < 0.0001$) PCI, with differences seen for both elective ($p < 0.0001$) and acute coronary syndrome subgroups ($p = 0.0024$). Overall this difference persisted after multivariate Cox analysis (hazard ratio [HR]: 0.48; 95% confidence interval [CI]: 0.26 to 0.81; $p = 0.001$) and propensity matching (hazard ratio: 0.39; 95% CI: 0.21 to 0.77; $p = 0.0008$; OCT vs. angiography-alone cohort), with no difference in matched OCT and IVUS cohorts (HR: 0.88; 95% CI: 0.61 to 1.38; $p = 0.43$).

CONCLUSIONS In this large observational study, OCT-guided PCI was associated with improved procedural outcomes, in-hospital events, and long-term survival compared with standard angiography-guided PCI. (J Am Coll Cardiol Intv 2018;11:1313–21)

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ISSN 1936-8798/$36.00 https://doi.org/10.1016/j.jcin.2018.01.274

ABBREVIATIONS AND ACRONYMS

BCIS = British Cardiovascular Intervention Society

CI = confidence interval

HR = hazard ratio

IVUS = intravascular ultrasound

MACE = major adverse cardiac event(s)

MI = myocardial infarction

OCT = optical coherence tomography

PCI = percutaneous coronary intervention

Coronary angiography provides a 2-dimensional assessment of the arterial wall, and therefore it has substantial limitations in assessing luminal dimensions, vessel wall pathology, and results following percutaneous coronary intervention (PCI) (1). Optical coherence tomography (OCT) is an established intravascular imaging method that provides rapid acquisition of high-resolution images capable of assessing lumen dimensions and identifying thrombus, lipid, calcium, dissections, plaque prolapse, stent malapposition, and underexpansion (1,2). This superior spatial resolution of OCT could translate into meaningful clinical benefits and recent studies have suggested potential benefits using OCT guidance for PCI (3–6) with improved outcomes in the short term (7). However, to date no data exist about the effect of OCT on hard clinical endpoints in the long term.

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In the present study we report outcomes from a large cohort of consecutive patients undergoing PCI. The main aim of the study was to analyze the frequency of OCT use and determine the impact of OCT during PCI on long-term survival in a large contemporary cohort of patients.

METHODS

This was an observational cohort study of consecutive patients from the Pan-London (United Kingdom) PCI registry, which is a prospectively collected dataset that includes all patients treated by PCI in the 9 primary PCI centers within the London area, which covers a population of 8.2 million. The 9 tertiary cardiac centers in London are Barts Heart Centre (Barts Health NHS Trust), St George's Hospital (St George's Healthcare NHS Foundation Trust), King's College Hospital (King's College Hospital NHS Foundation Trust), Royal Brompton and Harefield Hospitals (Royal Brompton & Harefield NHS Foundation Trust), Hammersmith Hospital (Imperial College Healthcare NHS Foundation Trust), Guy's & St Thomas' Hospital (St Thomas' NHS Foundation Trust), Royal Free Hospital (Royal Free NHS Foundation Trust), and the Heart Hospital (UCL Hospitals NHS Foundation Trust). The registry included 123,764 patients who underwent PCI between January 1, 2005, and May 31, 2015. The anonymized databases of the 9 London centers who collect data based on the British Cardiac Intervention Society (BCIS) dataset were merged. The BCIS audit is part of a national mandatory audit that all UK PCI centers participate in.

STUDY DATABASE. The UK BCIS audit collects data from all hospitals in the United Kingdom that perform PCI, recording information about every procedure performed (8). PCI is defined as the use of any coronary device to approach, probe, or cross 1 or more coronary lesions, with the intention of performing a coronary intervention (8). The database is part of the suite of datasets collected under the auspices of the National Institute for Cardiovascular Outcomes Research and is compliant with UK data protection legislation. Data are collected prospectively at each hospital, electronically encrypted, and transferred online to a central database. Each patient entry offers details of the patient journey, including the method and timing of admission, inpatient investigations, results, treatment, and outcomes. Patients' survival data are obtained by linkage of patients' National Health Service numbers to the Office of National Statistics, which records live status and the date of death for all deceased patients. Patient and procedural details were recorded at the time of the procedure and during the admission into each center's local BCIS database. Anonymous datasets with linked mortality data from the Office of National Statistics were merged for analysis from the 9 centers.

STUDY POPULATION AND PROCEDURES. Patients undergoing elective or urgent PCI were included. Patients with acute ST-segment elevation myocardial infarction (MI) (n = 21,370) and patients undergoing pressure wire–guided PCI (n = 15,228) were excluded. Patient demographic characteristics, technical aspects of the PCI procedure, and adverse outcomes,

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Manuscript received December 13, 2017; revised manuscript received January 16, 2018, accepted January 30, 2018.

including complications up to the time of hospital discharge, were collected. Patients undergoing PCI were pre-treated with clopidogrel (300 to 600 mg) and aspirin (75 to 300 mg). The use of glycoprotein IIb or IIIa inhibitors was at the discretion of the interventional cardiologist. Coronary lesions were classified as left main stem, proximal left anterior descending, other left anterior descending, left circumflex artery, right coronary artery, or graft. The severity of luminal narrowing was graded as 0%, 1% to 49%, 50% to 74%, 75% to 94%, 95% to 99%, or 100%. Typically, patients were prescribed clopidogrel for 1 month (after implantation of a bare-metal stent) to 12 months (after implantation of drug-eluting stents or in patients with non-ST-segment elevation myocardial infarction) after PCI.

CLINICAL OUTCOMES. The primary clinical outcome was all-cause mortality at a median of 4.8 years (interquartile range: 2.2 to 6.4 years). Mortality data were obtained from the Office for National Statistics. Secondary outcomes were in-hospital major adverse cardiac event (MACE) defined as a composite of all-cause mortality, myocardial infarction (new ischemic pain with new ST-segment elevation and elevation of enzymes), whether treated with further revascularization therapy or not, stroke and reintervention PCI. Non-MACE complications included arterial complications, aortic dissection, coronary dissection (dissection defined as unintentional intimal disruption using the National Heart, Lung, and Blood Institute classification system for intimal tears) (9), and coronary perforation.

ETHICS. Data were collected as part of a mandatory national cardiac audit and all patient identifiable fields were removed before merging of the datasets and analysis. The local ethics committee advised that formal ethical approval was not required for this study.

STATISTICAL ANALYSIS. Clinical characteristics of patients were compared using the Pearson chi-square test for categorical variables, and for continuous variables an unpaired *t* test was used for 2-group comparisons and a 1-way analysis of variance was used for 3-group comparisons assuming a normal distribution. Non-normally distributed data were compared using nonparametric tests (Mann-Whitney and Kruskal-Wallis tests). We calculated Kaplan-Meier product limits for cumulative probability of reaching an endpoint and used the log-rank test for evidence of a statistically significant difference between the groups. Time was measured from the first admission for a procedure to outcome (all-cause mortality) with unadjusted figures reported for median follow-up (4.8 years). Cox regression analysis was used to estimate hazard ratios (HRs) in the entire population and fully adjusted models, based on covariates ($p < 0.05$) associated with the outcome.

PROPENSITY SCORE. A propensity score analysis was performed using a nonparsimonious logistic regression model, which compared: 1) OCT versus angiography alone; and 2) OCT-guided versus intravascular ultrasound (IVUS)-guided PCI (10). Variables included in the model including age, sex, diabetes mellitus, hypertension, hypercholesterolemia, previous coronary artery bypass grafting, previous PCI, previous MI, previous cerebrovascular accident, peripheral vascular disease, clinical presentation, multivessel disease, chronic renal failure, left ventricular ejection fraction, restenosis, access route, vessel treated, stent type (bare-metal stent or drug-eluting stent), presence of chronic total occlusion, segment length, diameter, and glycoprotein IIb or IIIa inhibitor use. A regression adjustment which incorporated the propensity score into a proportional hazard model as a covariate was then performed. The C-score was 0.84, indicating good discrimination.

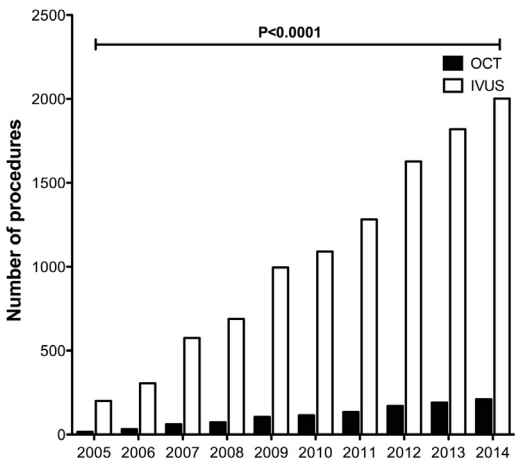
MATCHING. After ranking propensity score in an ascending order, a nearest-neighbor 1:1 matching algorithm was used with calipers of 0.2 SDs of the logit of the propensity score. Either each OCT and angiography-alone patient or OCT and IVUS patient were used in at most 1 matched pair to create a matched sample with similar distribution of baseline characteristics between observed groups. Based on the matched samples, the Cox proportional hazards model was used to determine the impact of OCT on mortality over follow-up. STATA version 10 (StataCorp, College Station, Texas) was used for propensity matching, with SPSS for Mac version 19.0 (IBM Corporation, Armonk, New York) used for all other analyses.

RESULTS

In total, 87,166 patients were included in the study. Overall OCT was used in 1,149 (1.3%) patients, IVUS was used in 10,971 (12.6%) patients, and angiography alone was used in the remaining 75,046 (86.1%) patients.

OCT NUMBER PER YEAR. Intravascular imaging rates increased over the study period, with significant increases seen in the use of both OCT ($p < 0.0001$) and IVUS ($p < 0.0001$) (**Figure 1**). Significant variations in the use of both devices were seen between centers ($p = 0.002$).

FIGURE 1 Number of OCT and IVUS Procedures Performed Over Time



An increasing number of optical coherence tomography (OCT) and intravascular ultrasound (IVUS) procedures performed over the study period ($p < 0.0001$).

BASELINE CHARACTERISTICS. Patients who had OCT- or IVUS-guided PCI were slightly younger than patients who had angiography-guided PCI ($p < 0.0001$). OCT-guided PCI was more common in elective patients, and those with a history of previous MI and PCI (Table 1).

ANATOMICAL AND PROCEDURAL CHARACTERISTICS. The distribution of target vessels was significantly different across the 3 groups. IVUS was more commonly used in left main stem PCI. Intravascular imaging was more commonly used in elective patients, and those with a history of diabetes, and previous revascularization (coronary artery bypass grafting, PCI). Both intracoronary imaging techniques were more commonly used if multivessel PCI was performed. The mean overall stent length was shortest in the angiography-guided group (21.0 ± 11.9 mm), longer in the IVUS-guided group (23.5 ± 13.5 mm), and longest in the OCT-guided group (25.8 ± 13.9 mm). OCT- and IVUS-guided procedures were associated with greater procedural success rates compared with angiography alone (Table 2).

TABLE 1 Baseline Characteristics According to the Angiography-Only, IVUS, and OCT Groups

	Angiography Only (n = 75,046)	IVUS (n = 10,971)	OCT (n = 1,149)	p Value
Age, yrs	65.21 ± 11.71	64.14 ± 12.01	62.73 ± 12.06	<0.0001
Male	55,979 (74.1)	7,819 (71.3)	794 (69.1)	0.530
Previous MI	23,599 (31.4)	3,297 (30.1)	470 (40.9)	<0.0001
Previous CABG	10,111 (13.4)	1,267 (12.0)	113 (10.8)	<0.0001
Previous PCI	20,566 (27.4)	3,791 (34.5)	522 (45.4)	<0.0001
Cardiogenic shock	798 (1.1)	128 (1.2)	4 (0.4)	0.039
Hypercholesterolemia	41,048 (45.3)	5,334 (48.6)	643 (55.9)	<0.0001
Diabetes mellitus	17,488 (12.1)	2,788 (26.5)	288 (27.5)	<0.0001
Hypertension	39,737 (52.6)	5,839 (53.2)	649 (56.5)	<0.0001
Smoking history	37,292 (49.3)	4,868 (44.4)	488 (42.5)	<0.0001
PVD	2,295 (3.2)	364 (3.4)	36 (3.2)	0.339
CKD (creatinine >200 μmol/l)	3,419 (4.5)	483 (4.6)	48 (4.2)	0.262
Presentation (stable angina)	43,144 (57.1)	5,911 (56.1)	662 (63.3)	<0.0001
Poor left ventricular function (LVEF <30%)	7,931 (10.5)	1,013 (9.2)	133 (11.6)	0.186

Values are mean ± SD or n (%).

CABG = coronary artery bypass grafting; CKD = chronic kidney disease; IVUS = intravascular ultrasound; LVEF = left ventricular ejection fraction; MI = myocardial infarction; OCT = optical coherence tomography; PCI = percutaneous coronary intervention; PVD = peripheral vascular disease.

CLINICAL OUTCOMES IN THE ENTIRE POPULATION.

In-hospital outcomes. Procedural complication rates were generally low and similar across the study groups ($p = 0.135$). There were significantly lower in-hospital MACE rates observed between the study groups, with both in-hospital mortality and recurrent MI rates higher in the angiography-guided group compared with IVUS- or OCT-guided groups (Table 3).

All-cause mortality. A significant unadjusted difference in mortality was observed between patients who underwent OCT-guided PCI (7.7%) compared with patients who underwent either IVUS- (12.2%) or angiography-guided (15.7%; $p < 0.0001$) PCI (Figure 2), with differences seen for both elective ($p < 0.0001$) and acute coronary syndrome subgroups ($p = 0.0024$) (Figure 3).

Cox analysis revealed both OCT and IVUS guidance were predictors of survival compared with angiography alone (OCT, HR: 0.40; 95% confidence interval [CI]: 0.18 to 0.84; $p < 0.0001$; IVUS, HR: 0.62; 95% CI: 0.48 to 0.81; $p < 0.0001$) and this difference was maintained with multiple adjustment with both modalities (OCT, HR: 0.48; 95% CI: 0.26 to 0.81; $p = 0.001$; IVUS: HR: 0.72; 95% CI: 0.32 to 0.93; $p = 0.012$). However, no adjusted difference in survival was seen when comparing OCT-guided and IVUS-guided procedures (HR: 0.85; 95% CI: 0.63 to 1.34; $p = 0.43$). The other variables showing independent association with mortality were age, chronic renal failure, severe systolic left ventricular impairment, and multivessel disease. Radial artery access and procedural success were also independently associated with survival.

The above Cox proportional hazards model was repeated with the year of procedure included as a categorical variable to allow for improvements in PCI technique and technology over the long study period. This confirmed the associations between OCT (HR: 0.49; 95% CI: 0.28 to 0.83; $p = 0.0004$) and

IVUS (HR: 0.75; 95% CI: 0.33 to 0.92; p = 0.001) with mortality, with no difference seen between the 2 imaging techniques (HR: 0.85; 95% CI: 0.62 to 1.26; p = 0.45).

CLINICAL OUTCOMES IN THE PROPENSITY-MATCHED POPULATION. Two propensity-matched cohorts were assessed; OCT- versus angiography-guided PCI (n = 2,268, 1,134 patients in each group) and OCT- versus IVUS-guided PCI (n = 2,250, 1,125 patients in each group). The baseline demographics and procedural variables were well balanced in each of the propensity-matched cohorts, with the minimal p value after matching comparing the variables between the 2 groups being p > 0.33 in all matched groups.

In-hospital MACE. In the propensity-matched cohort, OCT-guided PCI was associated with significantly reduced rates of in-hospital MACE compared with angiography alone (0.80% vs. 2.00%; p = 0.01), again driven by reduced rates of recurrent MI and all-cause mortality but not to IVUS-guided PCI (0.80% vs. 1.0%0; p = 0.84) (Table 4).

All-cause mortality. OCT-guided PCI was associated with significantly reduced mortality rates over the follow-up period when compared with angiography alone (9.60% vs. 16.80%; p < 0.0001), but no difference was seen when OCT-guided PCI was compared with IVUS use (8.96% vs. 10.20%; p = 0.12). Applying Cox multivariate regression analysis to adjust for baseline clinical and procedural characteristics OCT-guided PCI was an independent predictor for mortality (HR: 0.39; 95% CI: 0.21 to 0.77; p = 0.0008) compared with angiography alone but not when compared with IVUS-guided PCI (HR: 0.88 CI: 0.61 to 1.38; p = 0.43).

INTRAVASCULAR IMAGING VERSUS ANGIOGRAPHY-GUIDED PCI IN THE ENTIRE POPULATION. Combining OCT and IVUS into a single intravascular imaging group and comparing to angiography-only guided PCI, similar baseline and procedural differences between groups were seen (Online Tables S1 and S2). Lower in-hospital MACE rates were seen between the groups (p = 0.0003), driven by lower rates of mortality and recurrent MI (Online Table S3). Over the follow-up period, a significant unadjusted difference in mortality was observed between patients who underwent intravascular imaging-guided PCI (12.3%) compared with patients who underwent angiography-guided PCI alone (15.8%; p < 0.0001) (Online Figure S1) with differences seen for both elective (p < 0.0001) and acute coronary syndrome subgroups (p < 0.0001).

TABLE 2 Procedural Characteristics According to the Angiography-Only, IVUS, and OCT Groups

	Angiography Only (n = 75,046)	IVUS (n = 10,539)	OCT (n = 1,149)	p Value
Access for PCI				
Radial	19,872 (26.3)	3,016 (28.6)	577 (55.2)	<0.0001
Diseased vessels				
Mean vessels	1.27 ± 0.59	1.30 ± 0.65	1.32 ± 0.62	<0.0001
Target vessel				<0.0001
Right coronary artery	26,846 (35.5)	3,225 (30.6)	263 (22.9)	
Left main coronary artery	3,061 (4.0)	1,104 (10.5)	38 (3.3)	
Left anterior descending	34,556 (45.7)	5,312 (48.4)	630 (54.8)	
Left circumflex coronary	20,389 (27.0)	2,595 (24.6)	236 (20.5)	
Saphenous vein graft	3,374 (4.5)	385 (3.7)	28 (2.7)	
Multivessel intervention	13,181 (17.4)	2,033 (19.3)	234 (22.4)	<0.0001
Stent diameter	3.20 ± 3.23	3.59 ± 3.46	3.48 ± 2.43	<0.0001
Length of stented segment	23.51 ± 13.64	25.01 ± 11.94	25.75 ± 13.87	<0.0001
DES	49,135 (65.0)	7,312 (69.3)	773 (73.9)	<0.0001
GP IIb/IIIa inhibitor	11,686 (15.5)	1,269 (12.0)	89 (8.5)	<0.0001
Procedural success	70,768 (94.3)	10,086 (95.7)	1,123 (97.7)	<0.0001

Values are n (%) or mean ± SD.

DES = drug-eluting stent(s); GP = glycoprotein; TIMI = Thrombolysis In Myocardial Infarction; other abbreviations as in Table 1.

Cox analysis revealed that intravascular imaging was a predictor of survival compared with angiography alone (HR: 0.55; 95% CI: 0.38 to 0.82; p < 0.0001), and this difference was maintained with multiple adjustment with both modalities (HR: 0.63; 95% CI: 0.33 to 0.84; p = 0.0001).

DISCUSSION

This large prospective, observational, multicenter registry analysis is the largest study to date comparing outcomes following OCT guidance versus IVUS or angiography alone for routine PCI. To our

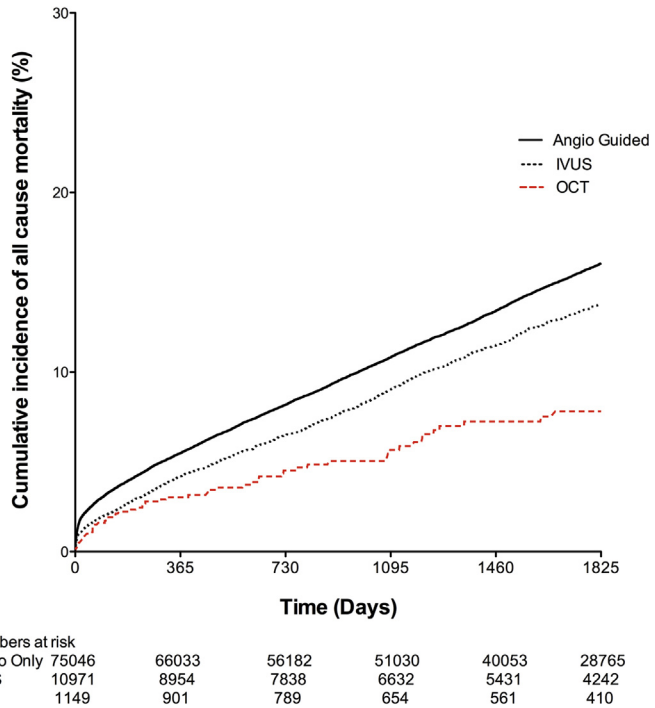
TABLE 3 In-Hospital Outcomes and Complications Post-PCI According to the Angiography-Only, IVUS, and OCT Groups

	Angiography Only (n = 75,046)	IVUS (n = 10,539)	OCT (n = 1,149)	p Value
In-hospital MACE	1,351 (1.8)	147 (1.4)	15 (1.3)	0.016
Death	492 (0.7)	42 (0.4)	4 (0.3)	0.010
Q-wave MI	495 (0.7)	53 (0.5)	3 (0.2)	0.046
Reintervention PCI	251 (0.3)	32 (0.3)	4 (0.4)	0.689
CVA	50 (0.1)	9 (0.09)	2 (0.2)	0.325
Emergency CABG	67 (0.1)	11 (0.1)	2 (0.2)	0.655
Procedural complications	1,654 (2.2)	263 (2.5)	29 (2.4)	0.136
Side-branch occlusion	303 (0.4)	52 (0.5)	4 (0.3)	
Coronary perforation	150 (0.2)	63 (0.6)	4 (0.3)	
Slow/no reflow	300 (0.4)	21 (0.2)	3 (0.2)	

Values are n (%).

CVA = cerebrovascular accident; MACE = major adverse cardiac event(s); other abbreviations as in Table 1.

FIGURE 2 Kaplan-Meier Curve Comparing All-Cause Mortality Between OCT-Guided, IVUS-Guided, and Angiography-Alone Procedures



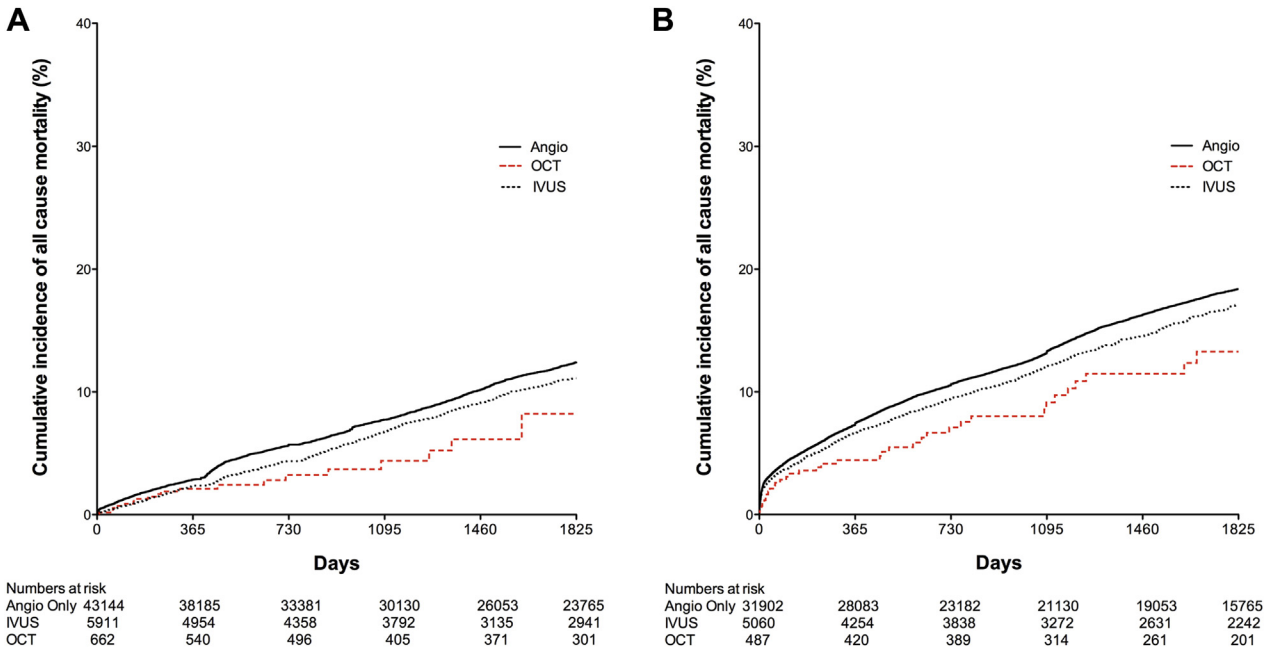
A significant unadjusted difference in mortality was observed between patients who underwent OCT-guided percutaneous coronary intervention compared with patients who underwent either IVUS- or angiography-guided percutaneous coronary intervention ($p < 0.0001$). Abbreviations as in Figure 1.

knowledge our report is the largest study, including >85,000 patients, which provides convincing evidence that OCT guidance during PCI improves short- and long-term outcomes, as it is associated with a lower incidence of in hospital MACE—driven mainly by a reduced incidence of MI—and reduced mortality at long-term follow-up in the entire population, and in a propensity-matching analysis that accounted for the differences in the baseline demographics and lesion characteristics between the different study groups.

Several previous studies have demonstrated that OCT imaging allows detailed assessment of luminal and vessel walls and that stent underexpansion, thrombus protrusion, edge dissection, and residual plaque at the edges of the stent detected by OCT are known predictors of cardiovascular events (5,11-14). The ILLUMIEN I (Observation Study to Assess the Additive Role of OCT to FFR and Angiography in Optimizing the Outcome in Patients Undergoing PCI for Both Stable and Acute Ischemic Syndromes) study showed that OCT imaging detected unsatisfactory results in most patients who had successful angiography-guided PCI (5,15) with these interventions appearing to improve the post-PCI FFR as demonstrated in the DOCTORS (Does Optical Coherence Tomography Optimize Results of Stenting) study (from 0.92 ± 0.05 to 0.95 ± 0.04; $p < 0.005$) (4). Despite the wealth of structural and procedural information provided by these studies, there are little data on outcomes. The CLI-OPCI (Centro per la Lotta contro l'Infarto-Optimisation of Percutaneous Coronary Intervention) study of 670 retrospectively matched patients (7) showed that at 1-year of follow-up, the OCT group had lower cardiac mortality ($p = 0.01$), lower combined rate of cardiac mortality or MI ($p = 0.006$), and a lower rate of the composite primary endpoint of cardiac death, MI, or repeat revascularization ($p = 0.044$), compared with angiography-only guided procedures, differences that persisted after accounting for patients' baseline characteristics. However, limitations of this study, including the small patient numbers, high event rates in the angiography-guided group (especially mortality: 6.90% at 1 year), and the absence of differences in the clinical endpoint of target lesion revascularization (3.30% vs. 3.30%; $p = 1.000$) where OCT guidance is anticipated to provide prognostic benefit raised concerns about the findings of this analysis.

Similar to the previous registry, meta-analyses and randomized control studies we found that IVUS-guided PCI is also associated with a lower incidence of mortality than angiography-guided PCI (16-20). This benefit has been attributed to the optimal procedural results in the IVUS group, as IVUS guidance can be used to optimize stent apposition and is associated with both a larger minimum luminal diameter and a greater reduction in percentage diameter stenosis, which appear to be associated with better clinical outcomes post-PCI (17). The first study that compared IVUS with OCT demonstrated that IVUS guidance was associated with larger minimum (7.1 ± 2.1 mm^2 vs. 6.1 ± 2.2 mm^2) and mean stent area (7.5 ± 2.5 mm^2 vs. 8.7 ± 2.4mm^2) than OCT guidance ($p < 0.05$), a result that was attributed to the fact that IVUS imaging overestimates luminal dimensions comparing to OCT (21-23). However, the more recent ILUMIEN II (A Retrospective Evaluation of Stent Expansion with OCT Guidance vs. IVUS Guidance) and III (Optical Coherence Tomography [OCT] Compared to Intravascular Ultrasound [IVUS] and Angiography to Guide Coronary Stent Implantation: a Multi-center Randomized Trial in PCI) studies have shown no significant difference in the stent expansion index between these modalities, whereas the ILUMIEN III study also demonstrated no statistically

FIGURE 3 Kaplan-Meier Curve Comparing All-Cause Mortality Between Groups Based on Stable or ACS Presentation



(A) Elective percutaneous coronary intervention procedures ($p < 0.0001$) and **(B)** patients presenting with acute coronary syndrome (ACS) ($p = 0.0024$). Abbreviations as in Figure 1.

significant different minimum stent areas in IVUS-, OCT-, and angiography-guided groups (5.89 mm^2 vs. 5.79 mm^2 vs. 5.49 mm^2) (6). In the latter study, strut malapposition was higher in the IVUS (21%) and angiography groups (31%) compared with OCT (11%), suggesting that OCT guidance is likely to be associated with better procedural results (6). Nevertheless, in both the ILLUMIEN II and III studies strict criteria were introduced to guide PCI in the OCT (but not for IVUS), which might have introduced bias in the reported results, and may be difficult to compare our study to this, as information regarding the timing of OCT use (before or after PCI) and how it changed management is lacking. However, studies of OCT use (24) in all-comers have demonstrated that irrespective of timing or technique the use of OCT changes practice with use of adjunctive techniques, procedural planning, stent optimization, or treatment of complications (25). A recently published meta-analysis supports this fact, with results very similar to our own, suggesting that OCT use may improve outcomes (25).

The only study to date that has directly compared procedural outcomes following IVUS and OCT-guided PCI is the OPINION (Optical frequency domain imaging vs. intravascular ultrasound in percutaneous coronary intervention) study, which randomized 817 patients (1:1) to IVUS- or OCT-guided PCI. The authors reported no difference in the combined endpoint of cardiac death, target vessel-related MI, and target vessel revascularization at 12 months (5.2% in the OCT-guided group and 4.9% in the IVUS-guided group; $p = 0.0042$ for non-inferiority) (26). However, the event rate in this study was lower than the 9% event rate assumed in the power calculation, and thus it might have been underpowered in detecting differences in the

TABLE 4 In-Hospital Outcomes Post-PCI According to Propensity-Matched Groups

	Angiography Only (n = 1,134)	OCT (n = 1,134)	p Value (Angiography vs. OCT)	IVUS (n = 1,125)	p Value OCT vs. IVUS
In-hospital MACE	23 (2.0)	9 (0.8)	0.013	11 (1.0)	0.838
Death	8 (0.7)	3 (0.3)	0.049	4 (0.4)	0.705
Q-wave MI	9 (0.8)	2 (0.2)	0.034	3 (0.3)	0.654
Reintervention PCI	4 (0.3)	2 (0.2)	0.654	2 (0.2)	0.617
CVA	1 (0.1)	1 (0.1)	0.479	1 (0.1)	0.479
Emergency CABG	1 (0.1)	1 (0.1)	0.479	1 (0.1)	0.479

Values are n (%).
Abbreviations as in Tables 1 and 3.

outcomes between the 2 studied groups. In our analysis we demonstrated, in a large number of patients, that there is no difference in the in-hospital MACE and long-term mortality between the IVUS and OCT guidance groups. The findings of our study provides for the first time an answer to the debate about the role of invasive imaging in guiding PCI, showing that both IVUS and OCT outperform standalone angiography (Online Appendix) and are equally effective in improving outcomes (27).

STUDY LIMITATIONS. This was an observational study, associated with the inherent biases of the study design; however, differences in baseline and clinical characteristics were adjusted in a multivariate analysis and a propensity analysis was performed to further account for confounding. We report all-cause mortality, and we did not provide information about target lesion-related endpoints (i.e., target vessel MI or revascularization) that would enable us to accurately assess the prognostic implication of IVUS and OCT imaging. However, the better in-hospital MACE rate and in particular the lower incidence of MI noted in the OCT- and IVUS-guided groups indicates that intravascular imaging is likely to improve the long-term prognosis by reducing the lesion-related MACE rate. Finally, the decision or not to use IVUS or OCT imaging to guide treatment and the response to IVUS and OCT images were left to the discretion of the operators, as there were no pre-specified recommendations for optimizing stent deployment. This might have introduced bias, but also reflects the current clinical practice, as there was a wide variation between studies and no established OCT or IVUS criteria for optimal stent deployment (4,6,28).

CONCLUSIONS

In this large observational study, OCT-guided PCI was associated with improved in-hospital MACE rate and long-term survival compared with standard angiography-guided PCI and similar outcomes when compared with IVUS-guided PCI. Further research is required to identify the group of patients and lesion types in which OCT guidance during PCI is associated with net prognostic benefit.

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PERSPECTIVES

WHAT IS KNOWN? OCT has superior spatial resolution compared with angiography; however, to date no data exist about the effect of OCT on hard clinical endpoints after PCI.

WHAT IS NEW? OCT-guided PCI was associated with improved procedural outcomes, in-hospital events, and long-term survival compared with standard angiography-guided PCI.

WHAT IS NEXT? Further research is required to identify the group of patients and lesion types in which OCT guidance during PCI is associated with net prognostic benefit.

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KEY WORDS intravascular ultrasound, optical coherence tomography, percutaneous coronary intervention

APPENDIX For an expanded Results section as well as supplemental tables and figure, please see the online version of this paper.