Journal of the Society for Cardiovascular Angiography & Interventions 2 (2023) 100556

JSCAI

The official journal of the Society for Cardiovascular Angiography & Interventions

Original Research

Association Between Intracoronary Imaging During PCI and Clinical Outcomes in a Real-World US Medicare Population

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ABSTRACT

Background: Use of intravascular ultrasound (IVUS) or optical coherence tomography (OCT) during percutaneous coronary intervention (PCI) is endorsed by society guidelines, but US data on real-world outcomes are lacking.

Methods: Medicare claims data were identified for inpatient PCIs performed October 2015 to March 2020, with IVUS/OCT captured by ICD-10-PCS codes. Three-way propensity score matching (angio vs IVUS vs OCT) on baseline and procedural characteristics was performed. Major adverse cardiovascular events (MACE), a composite of death, myocardial infarction (MI), or repeat revascularization, was evaluated through 3 years, with a 30-day blanking window after index PCI to exclude staged procedures.

Results: Of the 502,821 PCI procedures, 463,201 (92%) were guided by angiography alone, with IVUS or OCT used in 37,908 (7.5%) and 1712 (0.3%), respectively. After propensity matching, compared with angiography, the risk of major adverse cardiovascular event was similar for IVUS (hazard ratio [HR], 0.97; 95% CI, 0.91-1.03; $P = .285$) but lower for OCT (HR, 0.85; 95% CI, 0.77-0.94; $P = .001$). A similar trend was observed in clinically relevant subgroups. Compared with angiography alone, the risk of MI or repeat revascularization was lower with OCT (HR, 0.86; 95% CI, 0.76-0.97; $P = .015$), and the risk of MI alone was lower with IVUS (HR, 0.90; 95% CI, 0.82-0.99; $P = .038$).

Conclusions: In a real-world US cohort, IVUS and OCT were used infrequently during PCI. Compared with angiography alone, use of intracoronary imaging during index PCI was associated with lower rates of clinical events through 3 years.

Introduction

The use of intravascular ultrasound (IVUS) during percutaneous coronary intervention (PCI) has demonstrated long-term clinical benefits in randomized clinical trials,[1–3] observational studies,[4,5] and meta-analyses.[6–8] Recent major society guidelines support intracoronary imaging use during PCI, particularly in left main or complex PCI,[9] and optical coherence tomography (OCT) is endorsed as an alternative imaging modality to IVUS in most settings.[10]

However, the rates of intracoronary imaging use during PCI in the US remain low,[11,12] and real-world data examining clinical outcomes after imaging–guided stent implantation are sparse. The objective of this study was to examine clinical outcomes among patients with Medicare who underwent inpatient PCI with versus without intravascular imaging using either IVUS or OCT.

Abbreviations: ACM, all-cause mortality; HR, hazard ratio; ICD, International Classification of Disease; IVUS, intravascular ultrasound; MI, myocardial infarction; OCT, optical coherence tomography; PCI, percutaneous coronary intervention.

Keywords: intracoronary imaging; intravascular ultrasound; myocardial infarction; optical coherence tomography; percutaneous coronary intervention; revascularization.

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https://doi.org/10.1016/j.jscai.2022.100556
Received 18 August 2022; Received in revised form 7 November 2022; Accepted 14 November 2022
Available online 5 December 2022

Methods

Study design and data source

This retrospective observational study used data from the Centers for Medicare and Medicaid Services, consisting of part A and B institutional claims for US fee-for-service (FFS) Medicare beneficiaries, and deidentified patient demographics (age, sex, and race), date of death if applicable, and Medicare insurance enrollment information. The study period was from October 1, 2015, through March 31, 2020, for the index PCI, and the latest clinical follow-up was through June 30, 2020. The dates of beneficiary Medicare enrollment and death were obtained from the 100% Master Beneficiary Summary File for the same period. This study used a deidentified database and, thus, was exempted from an institutional review board approval. Deidentified health information can be used as specified in the Health Insurance Portability and Accountability Act Privacy Rule, and therefore, informed consent was exempted.

Study population

US patients enrolled in FFS Medicare who underwent PCI in the inpatient setting during the study period were included. PCI and the corresponding use of intravascular imaging guidance with IVUS or OCT were identified using International Classification of Diseases (ICD)-10th edition, procedural codes (Supplemental Table S1). Patients with a diagnosis of cardiogenic shock or chronic total occlusion during the index hospitalization were excluded. Moreover, patients were excluded if they had been enrolled in FFS Medicare for <1 year before the index PCI, a period used to ascertain comorbidity data. Patient characteristics, such as age at the time of index procedure, sex, and race, were derived from Medicare enrollment data. Baseline comorbidities were identified based on primary and secondary diagnoses on inpatient or outpatient claims during the 1-year lookback period preceding the index PCI.

Clinical and procedural characteristics, such as presence of ST-segment elevation myocardial infarction, non–ST-segment myocardial infarction, use of drug-eluting stents, bare-metal stents, balloon angioplasty, and fractional flow reserve (FFR), number of stents placed, number of vessels treated, and bifurcation lesion PCI were defined based on procedural and diagnostic codes recorded during the index admission (Supplemental Table S1). Complex PCI was defined as an index procedure that included at least 1 of the following conditions: ≥2 stents placed, ≥2 vessels treated, or intervention on a bifurcation as identified by ICD-10-Procedure Coding System codes. Patients with a diagnosis of ST-segment elevation myocardial infarction, non–ST-segment myocardial infarction, or unstable angina during the index PCI hospitalization were defined as having acute coronary syndrome; all others were defined as having stable coronary artery disease. To account for a potential relationship between hospital PCI volume and subsequent clinical outcomes, hospitals were divided into quartiles based on annual PCI volume, and this was included as a patient-level covariate. For all analyses, the study cohort was divided into 3 groups based on the imaging modality used: angiography only, IVUS, or OCT.

Outcomes

The main outcome of interest was major adverse cardiovascular events (MACE), defined as all-cause mortality (ACM), myocardial infarction (MI), or repeat revascularization (PCI or coronary artery bypass graft surgery). Because of coding, repeat revascularization could include PCI to either the culprit or a nonculprit vessel. Secondary outcomes included the composite of MI or repeat revascularization and the individual end points of ACM, MI, and repeat revascularization. Outcomes were assessed through 3 years after PCI. Given that ≤25% of staged PCIs occur >1 month after index PCI,[13] a 30-day blanking window after the index procedure was used to exclude potentially staged PCIs performed during this timeframe because claim codes cannot discriminate target vessel versus nontarget vessel revascularization. Patients were censored because of death or Medicare FFS disenrollment. In addition, patients without an outcome event were excluded at 3 years after the index procedure or at the end of follow-up (June 30, 2020), whichever occurred earlier.

Statistical analyses

Baseline characteristics among patients who underwent angiography-, IVUS-, or OCT-guided PCI were compared with analysis of variance or the Wilcoxon test as appropriate for continuous variables and the χ^2 test for categorical variables.

Propensity score matched analyses were performed to compare clinical outcomes among patients who underwent angiography-, IVUS-, or OCT-guided PCI. The corresponding analytical approach for propensity score matching analyses (Supplemental Appendix) involved 2 main steps. First, patients who underwent intravascular imaging–guided PCI (IVUS or OCT) were propensity-score matched 1:1 with patients who underwent angiography-guided PCI using a greedy matching algorithm using a caliper width of 0.20.[14] Robustness of the matching algorithm was evaluated by comparing standardized mean differences (SMDs) with a cutoff value of 0.1. Second, this cohort was used as a source population to generate a matched triplet cohort of angiography–IVUS–OCT-guided PCI using the *TriMatch package*.[15,16] To generate this matched triplet cohort, a 4:4:1 matching was performed with an optimal matching algorithm and a caliper width equal to 0.20 of the SD of the logit of the propensity score in the *TriMatch package*. The SMDs were estimated for all baseline covariates after triplet matching to assess the postmatching balance, with a cutoff value of 0.1 (Supplemental Figure S1).

After matching, event-free survival was estimated by the Kaplan–Meier method from the index PCI until 3 years after discharge, and differences between matched cohorts were compared using a univariate Cox proportional hazards model. The model was generated using a robust sandwich covariance matrix estimate and robust standard error estimates to consider the clustering of patients within hospitals.

Sensitivity analyses

We performed sensitivity analyses to assess the robustness of the primary results. First, in a subgroup analysis, the MACE outcome was compared in subgroups based on age, sex, baseline comorbidities, complex PCI, and annual hospital PCI volume quartiles. Second, we repeated the primary analysis using a 60-day blanking window to account for potential planned staged procedures beyond 30 days and with no blanking period. Third, we performed a series of falsification end point analyses,[17–19] in which end points not expected to be influenced by choice of intravascular imaging were tested to assess for residual bias. These falsification end points included markers of overall frailty and poor long-term prognosis: community-acquired pneumonia, diarrhea, cellulitis, deep vein thrombosis, intestinal obstruction, and osteomyelitis and were compared between patients who underwent angiography-, IVUS-, or OCT-guided PCI.

All analyses were performed by KK using R version 4.1.1 (R Foundation for Statistical Computing).

Results

The study population included 502,821 Medicare FFS beneficiaries who underwent inpatient PCI during the study period. In total, 463,201

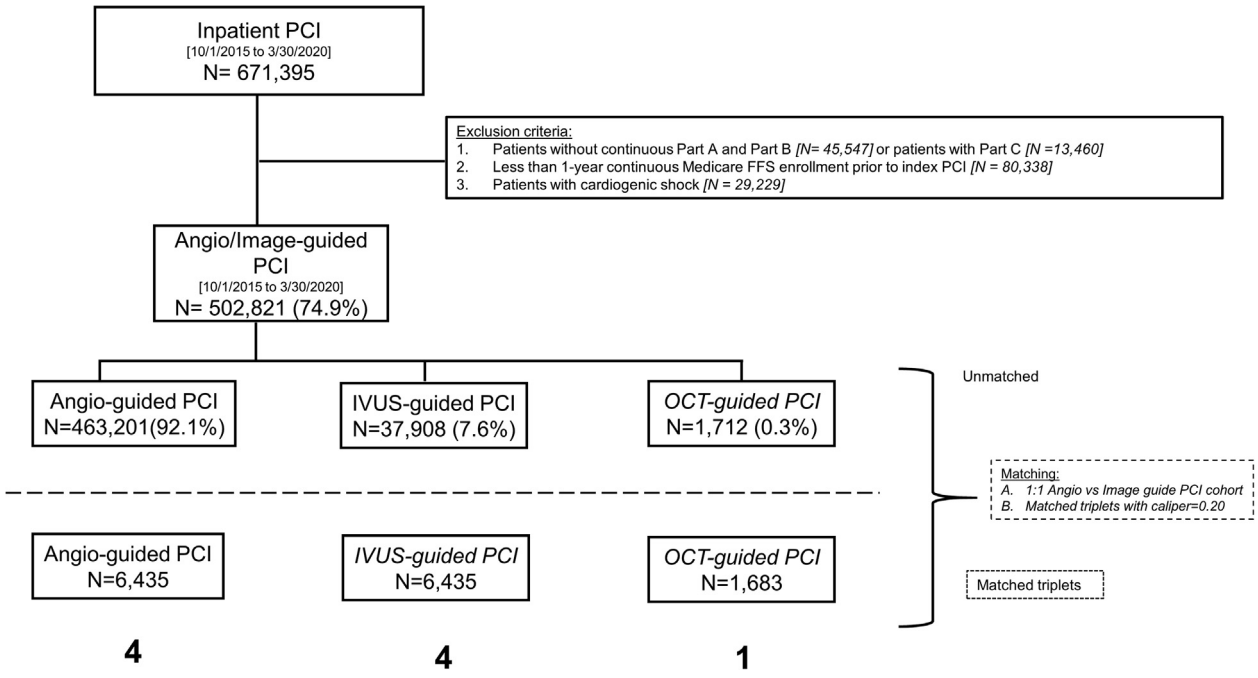


Figure 1.
Cohort diagram. FFS, fee-for-service; IVUS, intravascular ultrasound; MACE, major adverse cardiovascular events; OCT, optical coherence tomography; PCI, percutaneous coronary intervention.

(92%) PCI procedures were guided by angiography alone, with IVUS and OCT used in 37,908 (7.5%) and 1712 (0.3%) procedures, respectively (Figure 1). Baseline clinical and procedural characteristics are provided in Table 1. Compared with the angiography-guided PCI group, the IVUS group showed more frequent comorbidities, whereas the OCT group exhibited a lower prevalence of hypertension (90.3% vs 88.1%), renal disease (30.4% vs 23.8%), peripheral vascular disease (23.5% vs 20.5%), and obesity (23.9% vs 21.1%). Patients who received either IVUS- or OCT-guided PCI were more likely to experience a complex PCI procedure and to get FFR measurement performed. After 4:4:1 propensity matching, the angiography-, IVUS-, and OCT-guided PCI arms included 6435, 6435, and 1683 patients, respectively (Figure 1). Characteristics after matching were well-balanced across the 3 groups, with all SMDs of < 0.1 (Supplemental Figure S1).

Clinical outcomes in the propensity-matched cohort

Compared with angiography-guided PCI, the risk of MACE through 3 years was similar after IVUS-guided PCI (hazards ratio [HR], 0.97; 95% CI, 0.91-1.03; $P = .285$) but was lower after OCT-guided PCI (HR, 0.85; 95% CI, 0.77-0.94; $P = .001$) (Central Illustration). OCT use was associated with a lower risk of MACE than with IVUS use (HR, 0.88; 95% CI, 0.79-0.97; $P = .012$). Similar results were observed when comparing the incidence rate ratios (IRRs) for MACE (Table 2).

Regarding the composite of MI or repeat revascularization, the risk was similar after IVUS-guided PCI compared with angiography-only PCI (HR, 0.97; 95% CI, 0.90-1.04; $P = .391$) but was lower after OCT-guided PCI (HR, 0.86; 95% CI, 0.76-0.97; $P = .015$). The HR for MI or repeat revascularization for OCT compared with IVUS was 0.89 (95% CI, 0.78-1.00; $P = .058$) (Figure 2).

Individual end points evaluated included ACM, MI, and repeat revascularization. Compared with that after angiography-alone PCI, the risk of ACM was similar after IVUS-guided PCI (HR, 1.01; 95% CI, 0.92-1.10; $P = .828$) and lower after OCT-guided PCI (HR, 0.82; 95% CI, 0.71-0.95; $P < .01$). OCT use was associated with a lower risk of ACM compared with IVUS use (HR, 0.81; 95% CI, 0.70-0.94; $P = .006$) (Figure 2). The risk of MI was lower after IVUS-guided PCI compared with angiography-alone (HR, 0.90; 95% CI, 0.82-0.99; $P = .038$) and similar to OCT-guided PCI (HR, 0.87; 95% CI, 0.75-1.01; $P = .068$). Compared with angiography-alone, the risk of revascularization was similar after IVUS-guided PCI (HR, 0.96; 95% CI, 0.87-1.06; $P = .426$) and lower after OCT-guided PCI (HR, 0.77; 95% CI, 0.65-0.91; $P = .003$). Among patients who underwent either IVUS- or OCT-guided PCI, OCT was associated with a lower rate of revascularization compared with IVUS (IRR, 0.82; 95% CI, 0.70-0.96; $P = .011$) and a similar rate of MI (IRR, 0.98; 95% CI, 0.86-1.12; $P = .802$) (Table 2).

Sensitivity and falsification end point analyses

Regarding the primary MACE comparison, findings were similar across key clinical subgroups, including those based on age, sex, comorbidities, and hospital PCI volume (Figure 3). Moreover, findings were similar across subgroups for the ACM comparison (Supplemental Figure S2). There was no significant change in the primary MACE comparison when the blanking window was extended to 60 days (Supplemental Figure S3A) or when no blanking window was applied (Supplemental Figure S3B).

Finally, in the falsification end point analyses, there was no significant association between PCI-guidance category (angiography, IVUS, or OCT) and incident community-acquired pneumonia, acute diarrhea, cellulitis, deep vein thrombosis, intestinal obstruction, or osteomyelitis (Supplemental Figure S4).

Discussion

The principal findings of this study evaluating clinical outcomes among 502,821 US Medicare beneficiaries who underwent PCI were as follows: (1) intracoronary imaging was used in less than 10% of PCI procedures; and (2) use of intracoronary imaging during PCI was associated with lower rates of clinical events through 3 years compared with angiography use alone.

Table 1. Baseline characteristics of study cohort before and after matching.

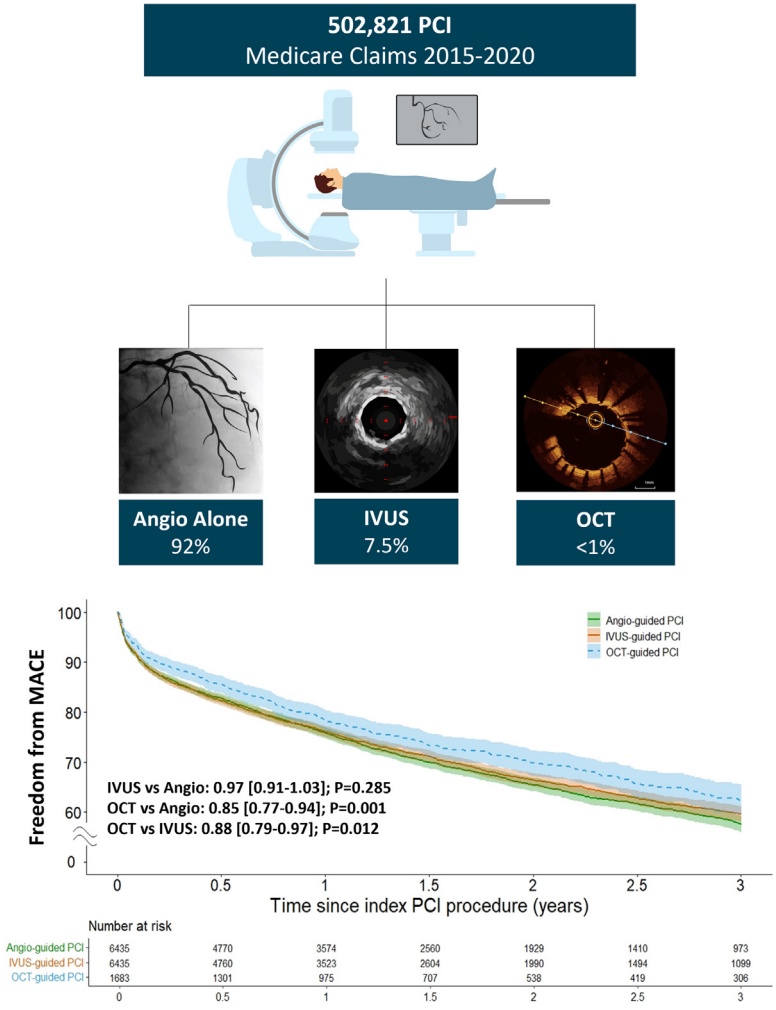
	Before matching				After matching			
	Angiography-guided (n = 463,201)	IVUS-guided (n = 37,908)	OCT-guided (n = 1712)	*P*	Angiography-guided (n = 6435)	IVUS-guided (n = 6435)	OCT-guided (n = 1683)	*P*
Age, y	73 (67-80)	73 (68-80)	72 (67-79)	.155	73 (67-79)	73 (68-79)	72 (68-79)	.484
Male sex	280,573 (60.6)	23,367 (61.6)	1030 (60.2)	<.001	3819 (59.3)	3884 (60.4)	1019 (60.5)	.435
Race				<.001				<.001
White	399,823 (86.3)	32,474 (85.7)	1477 (86.3)		5845 (90.8)	5778 (89.8)	1461 (86.8)	
Black	35,072 (7.6)	2773 (7.3)	115 (6.7)		351 (5.5)	361 (5.6)	111 (6.6)	
Other	6101 (1.3)	587 (1.5)	32 (1.9)		57 (0.9)	87 (1.4)	28 (1.7)	
Asian	6348 (1.4)	549 (1.4)	19 (1.1)		33 (0.5)	26 (0.4)	18 (1.1)	
Hispanic	7129 (1.5)	592 (1.6)	25 (1.5)		49 (0.8)	65 (1)	24 (1.4)	
North American Native	3198 (0.7)	433 (1.1)	14 (0.8)		27 (0.4)	32 (0.5)	14 (0.8)	
Unknown	5530 (1.2)	500 (1.3)	30 (1.8)		73 (1.1)	86 (1.3)	27 (1.6)	
Hypertension	418,399 (90.3)	34,410 (90.8)	1508 (88.1)	<.001	5723 (88.9)	5665 (88)	1488 (88.4)	.276
Diabetes	207,750 (44.9)	16,763 (44.2)	667 (39)	<.001	2449 (38.1)	2458 (38.2)	660 (39.2)	.679
Cerebrovascular disease	394,246 (85.1)	31,604 (83.4)	1493 (87.2)	<.001	736 (11.4)	740 (11.5)	218 (13)	.202
Renal disease	140,586 (30.4)	12,394 (32.7)	407 (23.8)	<.001	1462 (22.7)	1506 (23.4)	406 (24.1)	.409
Peripheral vascular disease	108,937 (23.5)	9783 (25.8)	351 (20.5)	<.001	1253 (19.5)	1242 (19.3)	345 (20.5)	.540
Obesity	110,904 (23.9)	9558 (25.2)	362 (21.1)	<.001	1340 (20.8)	1316 (20.5)	361 (21.4)	.647
Index year				<.001				.308
2015-Q4	26,926 (5.8)	1689 (4.5)	53 (3.1)		205 (3.2)	179 (2.8)	53 (3.1)	
2016	109,470 (23.6)	7063 (18.6)	324 (18.9)		1138 (17.7)	1259 (19.6)	321 (19.1)	
2017	107,129 (23.1)	7699 (20.3)	306 (17.9)		1235 (19.2)	1163 (18.1)	305 (18.1)	
2018	101,135 (21.8)	8454 (22.3)	346 (20.2)		1329 (20.7)	1294 (20.1)	344 (20.4)	
2019	97,579 (21.1)	10,291 (27.1)	554 (32.4)		2055 (31.9)	2043 (31.7)	536 (31.8)	
2020-Q1	20,962 (4.5)	2712 (7.2)	129 (7.5)		473 (7.4)	497 (7.7)	124 (7.4)	
Dyslipidemia	378,756 (81.8)	31,743 (83.7)	1415 (82.7)	<.001	5350 (83.1)	5368 (83.4)	1392 (82.7)	.769
Smoking	254,905 (55)	21,493 (56.7)	984 (57.5)	<.001	3650 (56.7)	3616 (56.2)	968 (57.5)	.593
History of CAD	434,828 (93.9)	36,472 (96.2)	1652 (96.5)	<.001	6193 (96.2)	6201 (96.4)	1623 (96.4)	.898
Previous MI	97,049 (21)	8506 (22.4)	342 (20)	<.001	1235 (19.2)	1260 (19.6)	338 (20.1)	.680
Previous CABG	87,266 (18.8)	6065 (16)	187 (10.9)	<.001	676 (10.5)	640 (9.9)	187 (11.1)	.309
Previous PCI	128,818 (27.8)	10,656 (28.1)	447 (26.1)	<.001	1605 (24.9)	1572 (24.4)	441 (26.2)	.318
Clinical presentation								
STEMI	117,963 (25.5)	7602 (20.1)	325 (19)	<.001	1267 (19.7)	1272 (19.8)	322 (19.1)	.841
NSTEACS	210,664 (45.5)	16,643 (43.9)	684 (40)	<.001	2602 (40.4)	2593 (40.3)	681 (40.5)	.984
Procedural characteristics								
FFR measured	20,991 (4.5)	3235 (8.5)	180 (10.5)	<.001	606 (9.4)	591 (9.2)	171 (10.2)	.473
PCI procedure				<.001				.318
Angioplasty	21,726 (4.7)	981 (2.6)	29 (1.7)		100 (1.6)	123 (1.9)	29 (1.7)	
BMS	37,335 (8.1)	1950 (5.1)	49 (2.9)		184 (2.9)	212 (3.3)	49 (2.9)	
DES	404,140 (87.2)	34,977 (92.3)	1634 (95.4)		6151 (95.6)	6100 (94.8)	1605 (95.4)	
Complex PCI	171,987 (37.1)	18,829 (49.7)	854 (49.9)	<.001	3173 (49.3)	3230 (50.2)	842 (50)	.590
PCI volume quartile				<.001				<.001
1	14,357 (3.1)	827 (2.2)	20 (1.2)		59 (0.9)	64 (1)	20 (1.2)	
2	60,880 (13.1)	4344 (11.5)	79 (4.6)		298 (4.6)	325 (5.1)	79 (4.7)	
3	119,485 (25.8)	9714 (25.6)	189 (11)		973 (15.1)	1006 (15.6)	188 (11.2)	
4	268,479 (58)	23,023 (60.7)	1424 (83.2)		5105 (79.3)	5040 (78.3)	1396 (82.9)	

Values are presented as mean (range) or n (%).
BMS, bare-metal stent; CAD, coronary artery disease; CABG, coronary artery bypass grafting; DES, drug-eluting stent; FFR, fractional flow reserve; MI, myocardial infarction; NSTEACS, non–ST-elevation acute coronary syndrome; PCI, percutaneous coronary intervention; STEMI, ST-elevation myocardial infarction.

The low rate of intracoronary imaging use during PCI in this cohort is worth noting. Despite randomized trial data showing improved long-term outcomes with IVUS guidance during PCI[1–3] and endorsement of intracoronary imaging use by major US society guidelines,[9] IVUS was used in <8% of PCI's and OCT in <1% in this cohort. Although it is generally acknowledged that uptake of intracoronary imaging in the US has lagged behind other geographic regions, the contemporary rate of IVUS or OCT use in the US is not fully known, and data from multiple sources are needed. For example, the CathPCI registry, which is typically regarded as the most definitive data source on this topic, records use of IVUS or OCT during a PCI only if a minimal luminal area before PCI is documented.[20] Given that state-of-the-art use of intravascular imaging modalities to optimize PCI does not rely on minimal luminal area, the approach to data capture in the CathPCI registry has potential to be inaccurate and is not reflective of modern practice. Conversely, the Medicare data set used in this study reflects whether an IVUS or OCT catheter was billed for. However, these billing data also cannot capture how the imaging data were acquired or used but do provide a distinct perspective on the utilization of these tools, compared with existing data sources.

The reasons for low uptake of imaging–guided PCI in the United States are likely multifactorial, with financial, training, and cultural barriers, with perceived effects on procedural time and contrast use contributing.[21] Moreover, data from other sources, such as the National Inpatient Sample, have demonstrated low rates of IVUS and OCT use in the United States[11,12] and stand in stark contrast to contemporary practice other countries, such as Japan, where registry data have shown IVUS use in >80% of PCIs.[22]

Moreover, we observed differential use of intracoronary imaging relative to patient comorbidities and hospital PCI volume. Operators used IVUS more commonly in patients with a greater burden of comorbidities, whereas OCT was used more frequently in patients with fewer concurrent conditions. Both IVUS and OCT were used at higher rates in complex PCI and in conjunction with physiologic assessment with FFR and were used most frequently at high-volume PCI centers. These findings show that intracoronary imaging is used infrequently and



Central Illustration.
Incidence curves for the MACE composite outcome for patients with angiography-, IVUS-, or OCT-guided PCI in the propensity-matched cohort. IVUS, intravascular ultrasound; MACE, major adverse cardiovascular events; OCT, optical coherence tomography; PCI, percutaneous coronary intervention.

unevenly in the current US practice, pointing to a major focus for quality improvement moving forward.

Despite these noted population differences, propensity score matching resulted in balanced cohorts regarding the measured baseline variables. Among these paired groups, intracoronary imaging use during PCI was associated with lower rates of subsequent clinical events through 3 years. This association was particularly robust for OCT, which was associated with lower rates of the composite MACE end point compared with that for angiography alone, in addition to ACM and the composite of MI or repeat revascularization. Moreover, these findings were consistent across strata of hospital PCI volume.

There was no significant association between IVUS use and MACE at 3 years, warranting consideration given randomized trial data showing long-term benefit with IVUS-guided PCI.[1–3] Of note, these results are in contrast to a recent observational study that found lower rates of clinical outcomes associated with IVUS use,[5] although importantly the difference in mortality rates was seen only after 3 years, which is beyond the timeframe of this study. Furthermore, although the absence of an association in this study may simply reflect residual confounding based on case selection for IVUS use in real-world practice, the benefits of IVUS have been demonstrated in trials among experienced operators and specific lesion types. The absence of a statistically significant

Table 2. Incidence rate ratios for each end point

	IVUS vs Angiography	OCT vs Angiography	OCT vs IVUS
	Incidence rate ratio (95% CI); Angiography as reference, *P*	Incidence rate ratio (95% CI); Angiography as reference, *P*	Incidence rate ratio (95% CI); IVUS as reference, *P*
MACE	0.99 (0.94-1.04), .635	0.86 (0.79-0.94), .001	0.88 (0.80-0.95), .002
All-cause mortality	1.00 (0.92-1.10), .847	0.82 (0.71-0.95), .008	0.81 (0.70-0.94), .005
Myocardial infarction	0.91 (0.84-0.99), .023	0.89 (0.79-1.02), .088	0.98 (0.86-1.12), .802
Revascularization (PCI or CABG)	1.00 (0.91-1.10), 1.000	0.82 (0.70-0.96), .011	0.82 (0.70-0.96), 011

CABG, coronary artery bypass grafting; IVUS, intravascular ultrasound; MACE, major adverse cardiovascular events; OCT, optical coherence tomography; PCI, percutaneous coronary intervention.

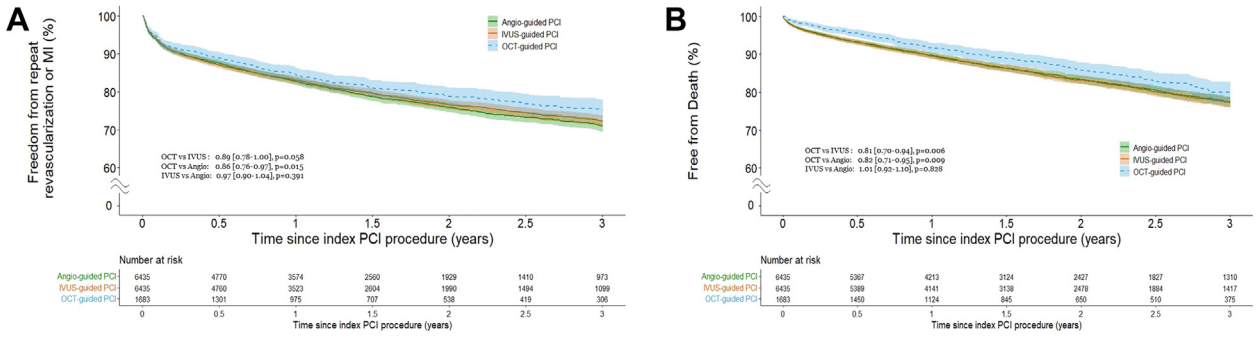


Figure 2.
Incidence curves. (**A**) The combined end points of revascularization or MI. (**B**) All-cause mortality for patients with angiography-, IVUS-, or OCT-guided PCI in the propensity-matched cohort. IVUS, intravascular ultrasound; MACE, major adverse cardiovascular events; OCT, optical coherence tomography; PCI, percutaneous coronary intervention.

association between IVUS use and favorable outcomes in this data set may partly reflect a need for broader education and training on use of intracoronary imaging to optimize PCI. A recent survey found that <10% of graduating interventional cardiology fellows reported independence in use of all physiology and intracoronary imaging modalities, including only 15% reporting independence in use of IVUS.[23]

Regarding the favorable associations between OCT use and cardiovascular outcomes, these findings are encouraging for a

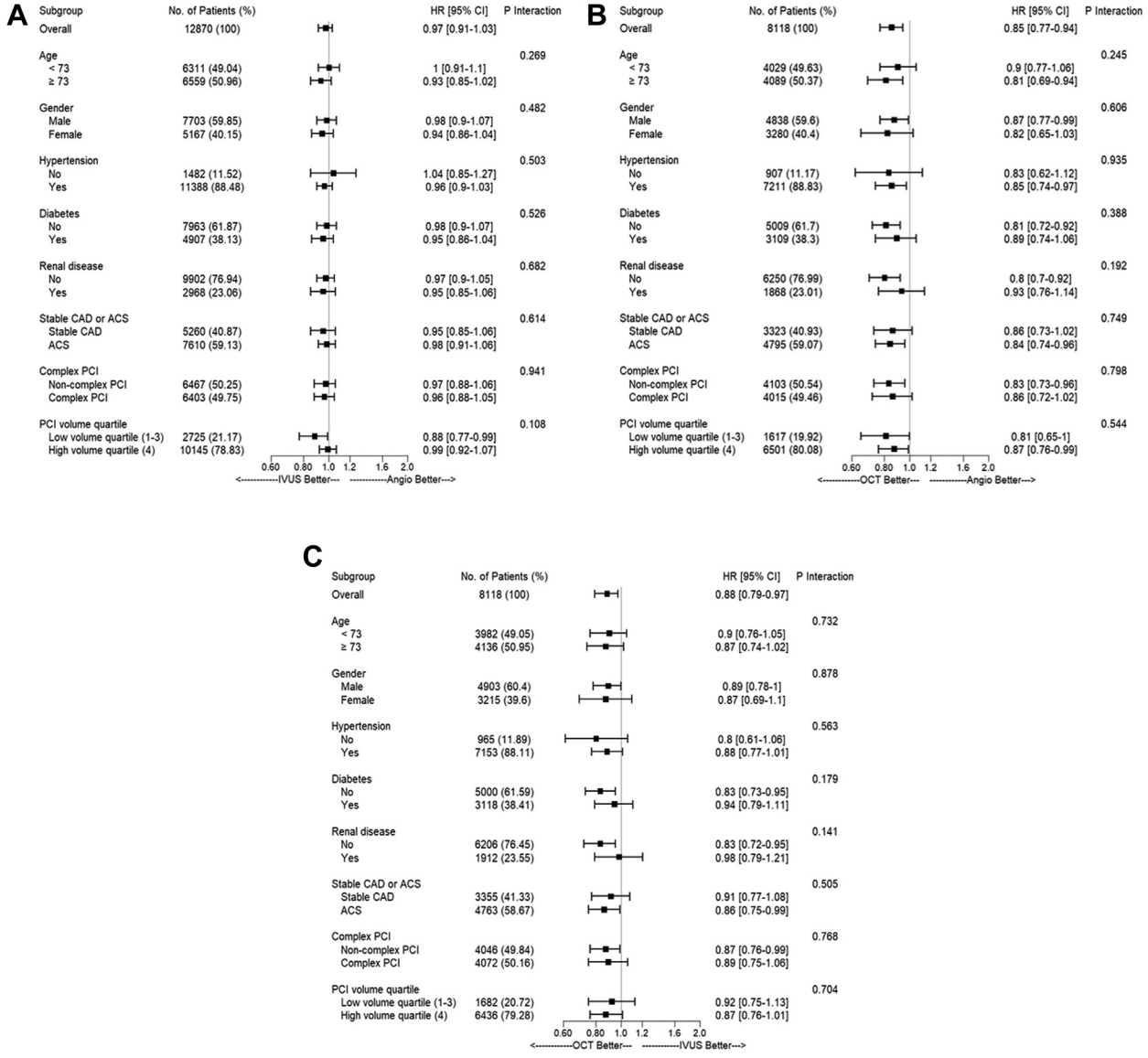


Figure 3.
Subgroup analyses for the MACE end point. (**A**) IVUS vs angiography, (**B**) OCT vs angiography, and (**C**) OCT vs IVUS. IVUS, intravascular ultrasound; MACE, major adverse cardiovascular events; OCT, optical coherence tomography; PCI, percutaneous coronary intervention.

potential long-term clinical benefit in real-world practice with OCT guidance during PCI and are consistent with another recent observational analysis[4] but may be subject to residual confounding. In the ILUMIEN III trial, OCT guidance resulted in a similar minimum stent area compared with IVUS guidance but with fewer untreated complications, with potential implications for future events such as malapposition or edge dissection.[24] This latter observation may be related to the higher resolution provided by OCT. Regarding the similar rates of MI after OCT- vs IVUS-guided PCI observed in this study, use of either modality tends to result in longer total stent length than that in angiography-alone PCI,[1,24] perhaps covering vulnerable plaque at stent edges not seen on angiography. The upcoming results of the OPTIMAL PCI (OPtical Coherence Tomography (OCT) Guided Coronary Stent IMplantation Compared to Angiography: a Multicenter Randomized TriaL in PCI) randomized trial comparing OCT- with angiography-guided PCI[25] should be considered together with these observational data and other observational cohorts,[4,5] in the totality of clinical evidence.

Several important limitations must be considered. First, despite propensity score matching, sensitivity analyses, and the falsification analysis, a causal relationship underlying the observed associations cannot be assumed. Baseline clinical and procedural differences exist among patients undergoing angiography-, IVUS-, and OCT-guided PCI, and propensity score matching cannot consider unmeasured confounding variables. Second, although use of IVUS or OCT was captured by administrative codes, the technical application of these modalities during the procedures is not known. In addition, although, according to inpatient procedure coding guidance, an imaging procedure should be billed for only if the catheter successfully crossed the lesion, billing data do not capture whether the imaging was performed before or after PCI (or both) or how the imaging was interpreted by the operator. As noted, randomized trials with IVUS and OCT[1–3,25] have defined prescriptive imaging criteria for PCI optimization; whether similar techniques were used during procedures in this data set cannot be discerned. Third, to distinguish between different imaging technologies (IVUS vs OCT) used during the index procedure, this data set was limited to inpatient procedures among Medicare beneficiaries and cannot necessarily be generalized to other settings. Finally, the end points studied in this study, although clinically meaningful, are limited to those available in administrative claim data and do not include other important outcomes, such as angina relief, medication burden, financial effect, or patient quality of life.

Conclusion

In summary, among 502,821 US Medicare beneficiaries who underwent PCI, IVUS and OCT were used infrequently. Compared with angiography use, the use of intracoronary imaging during index PCI was associated with lower rates of clinical events through 3 years.

Declaration of competing interests

Dr Bergmark receives grant support through institution from Pfizer, Ionis, AstraZeneca, Abbott Vascular, Philips; receives consulting/personal fees from Abiomed, SpectraWAVE, Endovascular Engineering, CSI, Philips, Abbott Vascular, Servier, Daiichi-Sankyo, Janssen, and Quark; and is a member of the TIMI Study Group, which has received institutional grant support through the Brigham and Women's Hospital from Abbott, Amgen, Anthos Therapeutics, AstraZeneca, Bayer HealthCare Pharmaceuticals, Daiichi-Sankyo, Eisai, Intarcia, MedImmune, Merck, Novartis, Pfizer, Quark Pharmaceuticals, Regeneron Pharmaceuticals, Roche, Siemens Healthcare Diagnostics, The Medicines Company, and Zora Biosciences. Dr Osborn receives research grant support from NIH/NHLBI (K08 HL130465); sponsored research from Dyad Medical, NuPulseCV, and Opsens; and consulting/personal fees from Abbott Vascular, Canon, Opsens, and Philips; is a scientific advisory board member of Dyad Medical; and holds equity in this company. Dr Ali receives grants from NIH/NHLBI, Abbott, Philips, Boston Scientific, Abiomed, Opsens, Acist Medical, Medtronic, Cardiovascular Systems; personal from Boston Scientific, Abiomed, Amgen, and Astra Zeneca; and equity from Shockwave Medical. Dr Gupta receives payment from the Arnold & Porter Law Firm for work related to the Sanofi clopidogrel litigation and from the Ben C. Martin Law Firm for work related to the Cook Celect IVC filter litigation; receives consulting fees from Edwards LifeSciences; and holds equity in Heartbeat Health, a telecardiology healthcare platform. Drs Koli, Prillinger, West, and Hasegawa are employees of and holds stock in Abbott. Dr Croce receives grant support from Abbott, Takeda, Teleflex, and CSI; receives honoraria from Abbott, Biotronik, Philips, Abiomed, CSI, Takeda, and Cordis; and is a major stock shareholder in Dyad Medical. Dr Secemsky receives research grants to BIDMC: NIH/NHLBI K23HL150290, Food and Drug Administration, Harvard Medical School's Shore Faculty Development Award, AstraZeneca, BD, Boston Scientific, Cook, CSI, Laminate Medical, Medtronic and Philips and consulting/speaking fees from Abbott, Bayer, BD, Boston Scientific, Cook, CSI, Endovascular Engineering, Inari, Janssen, Medtronic, Philips, and VentureMed.

Funding sources

This study was funded by Abbott.

Ethics statement and patient consent

This research was performed in accordance with the relevant ethical guidelines. As noted in the Methods section, this study used a deidentified database and was, therefore, exempted from obtaining informed consent.

Supplementary material

To access the supplementary material accompanying this article, visit the online version of the *Journal of the Society for Cardiovascular Angiography & Interventions* at 10.1016/j.jscai.2022.100556.

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