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ORIGINAL RESEARCH

Intravascular Imaging-Guided Percutaneous Coronary Intervention in Patients With End-Stage Renal Disease on Maintenance Dialysis

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ABSTRACT

BACKGROUND Patients with end-stage renal disease (ESRD) are at a higher risk of cardiovascular diseases. Intravascular imaging (IVI)-guided percutaneous coronary intervention (PCI) using optical coherence tomography (OCT) or intravascular ultrasound (IVUS) has been shown to result in better clinical outcomes than angiography guidance. Nevertheless, the clinical outcomes of IVI-guided PCI in ESRD patients remain uncertain.

OBJECTIVES This study aimed to compare the clinical outcomes of OCT- and IVUS-guided PCIs in ESRD patients and to report the trend of IVI-guided PCI in Taiwan.

METHODS Patients with ESRD on maintenance dialysis, who underwent OCT- or IVUS-guided PCI from 2015 to 2021, were compared by propensity-score matching. The primary outcome was composite cardiovascular outcomes, including coronary revascularization, cardiovascular death, and acute myocardial infarction.

RESULTS In 2021, IVI was used to guide PCIs in 27% (15,613 of 57,845) of general and 27.5% (1,754 of 6,387) of ESRD patients. Among 4,759 eligible ESRD patients, 443 and 4,316 patients underwent OCT- and IVUS-guided PCIs, respectively. After matching, the incidence of the primary outcome was comparable between the OCT and IVUS groups (42.1 [95% CI: 36.2-48.0] vs 47.6 [95% CI: 43.0-52.2] events per 100 person-years; HR: 0.88; 95% CI: 0.74-1.06). The results were similar for all components of the primary outcome and in subgroup analyses.

CONCLUSIONS The number of PCI- and IVI-guided procedures has progressively increased in the past decade in Taiwan in both the general and ESRD populations. Among ESRD patients on maintenance dialysis, the clinical outcomes were comparable between OCT- and IVUS-guided PCI. (JACC Asia. 2025;5:28–41) © 2025 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

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The authors attest they are in compliance with human studies committees and animal welfare regulations of the authors' institutions and Food and Drug Administration guidelines, including patient consent where appropriate. For more information, visit the Author Center.

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Coronary artery disease (CAD) is highly prevalent in patients with chronic kidney disease (CKD), and cardiovascular (CV) death is the leading cause of death in these patients.[1] CKD has also been shown to be a major independent risk factor for CV morbidity and mortality even after adjusting for other common CAD risk factors such as hypertension and diabetes, especially in patients with worsening glomerular filtration rate.[2-4] In 2021, 3.47 million all-cause deaths and 1.87 million CV deaths were attributable to CKD worldwide.[5] About one-third of end-stage renal disease (ESRD) patients starting dialysis have pre-existing CAD, and another one-third have significant occult CAD.[6] Furthermore, some nontraditional uremic-related factors may also increase the risk of nonatherosclerotic CV events, such as myocardial fibrosis, arrhythmias, or sudden cardiac death.[1,4,7,8]

Patients with ESRD often present with complex coronary anatomy, extensive and severe atherosclerosis, thinner fibrous cap, and larger calcification arc,[9-11] accompanied by a lower revascularization rate and higher risk of mortality even after coronary revascularization when compared with patients without ESRD.[12,13] Most randomized percutaneous coronary intervention (PCI) trials have either excluded ESRD patients or included too few to estimate the treatment benefits.[14] However, in a study of 1,460 renal transplant recipients, those who received PCI for obstructive CAD had similar outcomes compared with those without obstructive CAD, and had a significantly lower rate of death than those with medically managed obstructive CAD at 5 years after renal transplantation.[15] In our previous analysis, revascularization was also associated with a lower risk of mortality in 2,821 non-ST-segment elevation myocardial infarction (MI) patients with severe CKD, including those with ESRD.[16]

Intravascular imaging (IVI) tools such as optical coherence tomography (OCT) and intravascular ultrasound (IVUS) are useful modalities to optimize stent implantation and improve clinical outcomes.[17-22] However, previous studies have not been designed to compare the beneficial effects of IVI-guided PCI in CKD patients, and only substudies have analyzed the impact of IVI-guided PCI on these patients.[23,24] Furthermore, only a few randomized studies have compared the clinical impact of OCT- vs IVUS-guided PCI,[25-27] and no previous study has compared these 2 tools specifically in patients with CKD.

Therefore, the primary aim of this study was to compare the clinical outcomes of OCT- and IVUS-guided PCI in patients with ESRD on maintenance dialysis in a population-based nationwide cohort, including both hemodialysis and peritoneal dialysis. The secondary aim was to analyze the trend of IVI-guided PCI in Taiwan for the first time in the literature. Other specific IVI modalities, such as near-infrared spectroscopy and single hybrid imaging catheters, were not available in Taiwan during the study period and were thus not included in the present study.

ABBREVIATIONS AND ACRONYMS

ACS = acute coronary syndrome(s)

CAD = coronary artery disease

ESRD = end-stage renal disease

IVI = intravascular imaging

MACE = major adverse cardiovascular event(s)

NHI = National Health Insurance

NHIRD = National Health Insurance Research Database

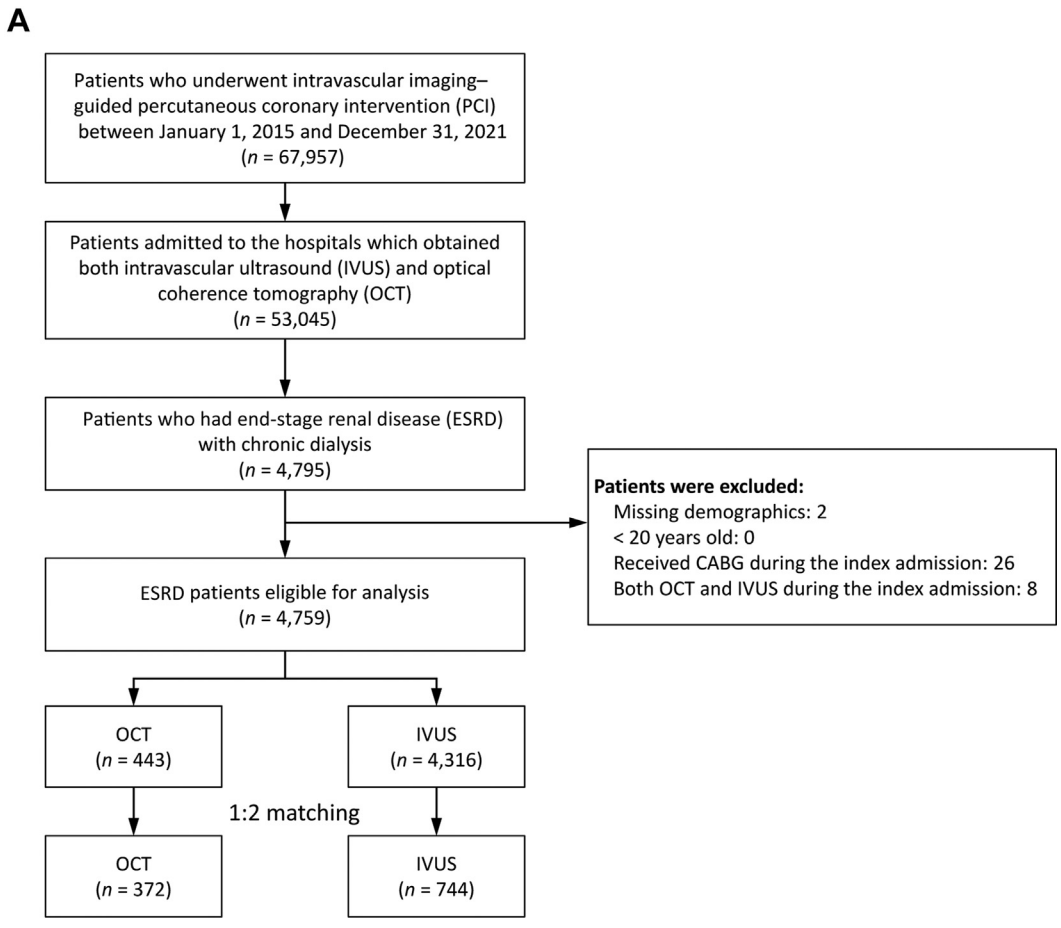
RA = rotational atherectomy

METHODS

DATA SOURCE. Data from the Taiwan National Health Insurance Research Database (NHIRD) of the National Health Insurance (NHI) program were utilized in this study. The mandatory NHI program was established in March 1995, and covers over 99% of the entire Taiwanese population. The NHIRD is maintained by the Health and Welfare Data Science Center of Taiwan, and it is updated annually with a time lag of about 2 years. The NHIRD contains all inpatient and outpatient registration files and claims data from the NHI, including comprehensive demographic data, established diagnoses, procedures, medications, and outpatient and hospitalization records. Before 2016, diseases were recorded according to International Classification of Diseases-9th Revision-Clinical Modification (ICD-9-CM) codes, and with both ICD-9-CM and ICD-10-CM codes thereafter. Linkage of data within various subdatabases of the NHIRD is accomplished through the use of deidentified civil identification numbers assigned to insured individuals. Details of the NHI and NHIRD have been published previously.[28-30] Before releasing information, the Bureau of NHI encrypts all personal identifiers and adheres to data processing regulations to ensure confidentiality. This study was approved by the Institutional Review Board of Chang Gung Memorial Hospital in Linkou (approval number: 202101250B1), and the need for informed consent was waived because of the retrospective study design and the use of anonymized clinical data.

STUDY COHORT AND DESIGN. Using the NHIRD, we identified patients with ESRD on maintenance dialysis who underwent IVI-guided PCI between January 1, 2015, and December 31, 2021, with or without coronary stenting (Figure 1A). Although IVUS has been reimbursed by the NHI program since 2009 for specific lesions, OCT was first reimbursed in 2014 under identical criteria. Therefore, the period of cohort inclusion started in 2015. In the NHI program, a catastrophic illness certificate is issued by the NHI Bureau to patients with major diseases, including ESRD with

FIGURE 1 The Study Design and Details of Intravascular Imaging-Guided PCI



(A) Flowchart of the inclusion and exclusion of the patients. (B) The number of general patients receiving different intravascular imaging modalities during percutaneous coronary intervention (PCI) and the proportion of intravascular imaging-guided PCI. (C) The number of annual end-stage renal disease (ESRD) patients on maintenance dialysis and the proportion of these patients who underwent PCI, and (D) the number of ESRD patients receiving different intravascular imaging modalities during PCI and the proportion of intravascular imaging-guided PCI. IVUS = intravascular ultrasound; OCT = optical coherence tomography.

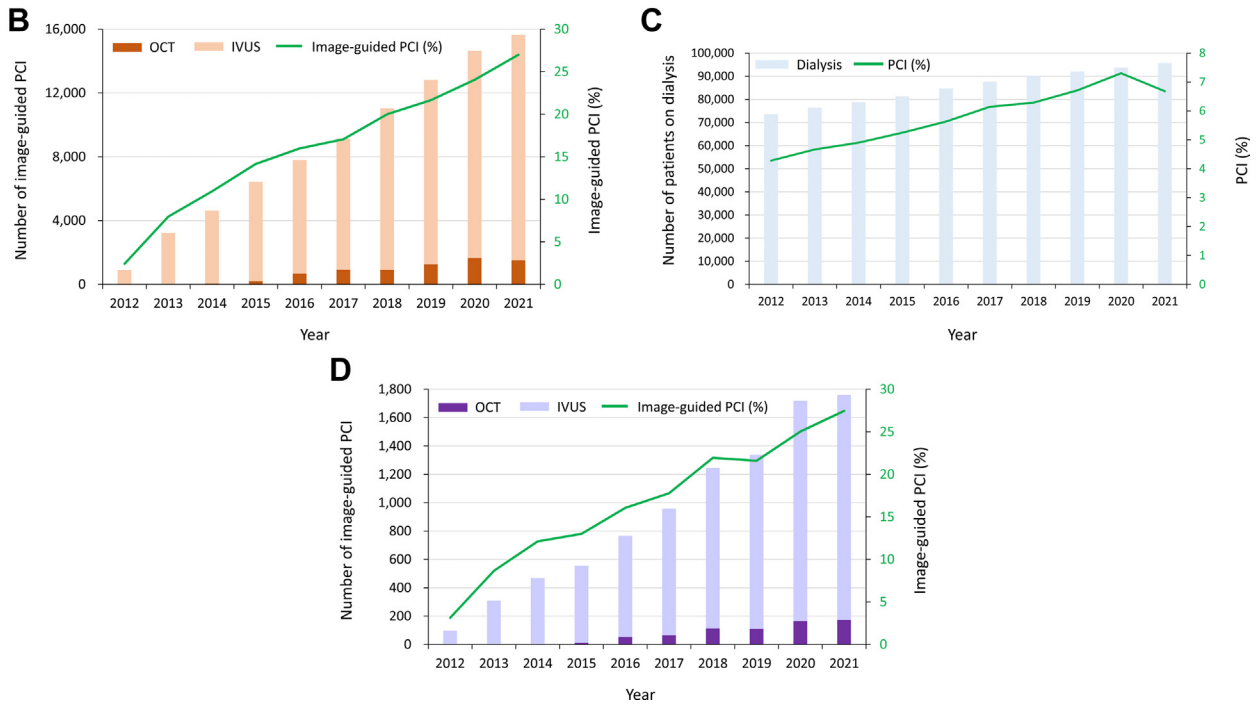
Continued on the next page

maintenance dialysis (ICD-9-CM: 585; ICD-10-CM: N18.5, N18.6). These dialytic patients were divided into OCT- and IVUS-guided PCI groups. To account for hospital effects, we only included patients admitted to hospitals that obtained both IVI modalities and matched OCT- to IVUS-guided PCI patients within the same hospital.[18] The use of IVI and the indication for imaging guidance were at the physician's discretion.

Patients younger than 20 years of age and those with missing demographic data (ie, age and sex) were excluded from the study. To avoid confounding effects of revascularization strategies other than PCI and both imaging modalities, patients who received coronary artery bypass grafting (CABG) or both OCT and IVUS during the same index admission were also excluded.

COVARIATE MEASUREMENTS. The following covariates were obtained from the NHIRD: age, sex, region of residence and its urbanization level, dialysis duration, dialysis modality, accreditation of the hospital, cumulative PCI volume of the hospital (grouping into quartiles), comorbidities (hypertension, diabetes, and 6 others), and historical events requiring hospitalization. Regarding PCI, we also obtained the number of implanted drug-eluting stents

FIGURE 1 Continued



(DES) and bare-metal stents before and during the index admission, number of intervened vessels during the index admission, clinical presentation as acute coronary syndrome (ACS) or chronic coronary syndrome (CCS), PCI complexity, and major in-hospital events (excluding in-hospital mortality) during the index admission. The NHIRD does not contain details of PCI procedures such as the intervened vessel, stenting location, chronic total occlusion, in-stent restenosis, bifurcation, or calcified lesions treated by rotational atherectomy (RA). We defined "complex PCI" as ≥2 vessels intervened or ≥3 stents implanted during the index admission, as reported in previous studies.[21,31] Historical events included previous PCI, CABG, coronary revascularization, image-guided PCI, cancer, and 5 other events requiring hospitalization.

OUTCOME DEFINITIONS. The primary outcome was the composite of major adverse cardiovascular events (MACE), including PCI, CABG, CV death, and acute MI. The identification of revascularization procedures relied on the Taiwan NHI reimbursement codes extracted from the inpatient claims data, which included target and nontarget lesions, and clinically driven and nonclinically driven procedures after the index admission during the follow-up period. The occurrences of acute MI were established based on the principal diagnosis recorded in the inpatient claims data, referring to spontaneous MI developed after the index admission during the follow-up period, with these diagnoses having been validated previously.[32,33] The secondary outcomes were components of the primary outcome, in-hospital mortality, all-cause mortality, and ischemic stroke. Details regarding the location, date, and cause of death were acquired by linking data to the Taiwan Death Registry database, which is also maintained by the Health and Welfare Data Science Center of Taiwan. CV death was defined according to the standardized criteria outlined by the U.S. Food and Drug Administration for CV and stroke endpoint events in clinical trials. Patients were followed up from the discharge day of the index admission until the date of outcome occurrence, death, or the end of the study (December 31, 2021), whichever occurred first.

STATISTICAL ANALYSIS. To mitigate potential confounding arising from selection bias and hospital effects when comparing outcomes between the study groups (OCT vs IVUS), we created a propensity score-matched cohort to pair patients receiving OCT with those undergoing IVUS within the same hospital. The propensity score was computed using a multivariable

TABLE 1 Demographic and Clinical Characteristics of Patients on Maintenance Dialysis Receiving OCT vs IVUS

		Before Matching			After Matching		
	Total (N = 4,759)	OCT (n = 443)	IVUS (n = 4,316)	STD	OCT (n = 372)	IVUS (n = 744)	STD
Demographics							
Age, y	66.4 ± 10.8	65.9 ± 11.1	66.5 ± 10.8	0.05	66.1 ± 11.0	66.4 ± 11.2	0.03
Male	3,082 (64.8)	287 (64.8)	2,795 (64.8)	0.00	235 (63.2)	487 (65.5)	0.05
Region of the residence							
North	2,088 (43.9)	180 (40.6)	1,908 (44.2)	0.07	152 (40.9)	304 (40.9)	0.00
Central	786 (16.5)	60 (13.5)	726 (16.8)	0.09	38 (10.2)	76 (10.2)	0.00
South	1,745 (36.7)	193 (43.6)	1,552 (36.0)	-0.16	173 (46.5)	346 (46.5)	0.00
East or outlying Islands	140 (2.9)	10 (2.3)	130 (3.0)	0.05	9 (2.4)	18 (2.4)	0.00
Urbanization level of the residence							
1, least urbanized	403 (8.5)	55 (12.4)	348 (8.1)	-0.14	50 (13.4)	100 (13.4)	0.00
2	2,233 (46.9)	278 (62.8)	1,955 (45.3)	-0.36	220 (59.1)	440 (59.1)	0.00
3, most urbanized	2,123 (44.6)	110 (24.8)	2,013 (46.6)	0.47	102 (27.4)	204 (27.4)	0.00
Dialysis duration, y	5.6 ± 5.4	5.7 ± 5.5	5.5 ± 5.3	-0.04	5.6 ± 5.5	5.6 ± 5.5	0.00
Dialysis modality							
Hemodialysis	4,387 (92.2)	411 (92.8)	3,976 (92.1)	0.02	347 (93.3)	695 (93.4)	−0.01
Peritoneal dialysis	372 (7.8)	32 (7.2)	340 (7.9)	0.02	25 (6.7)	49 (6.6)	−0.01
Accreditation of the hospital							
Medical center	3,608 (75.8)	326 (73.6)	3,282 (76.0)	0.06	290 (78.0)	580 (78.0)	0.00
Regional hospital	1,065 (22.4)	114 (25.7)	951 (22.0)	-0.09	82 (22.0)	164 (22.0)	0.00
District hospital	86 (1.8)	3 (0.7)	83 (1.9)	0.11	(0.0)	(0.0)	NA
Cumulative hospital volume of PCI (quartile)							
<5,805	1,139 (23.9)	119 (26.9)	1,020 (23.6)	-0.07	85 (22.8)	170 (22.8)	0.00
5,805-9,536	1,320 (27.7)	161 (36.3)	1,159 (26.9)	-0.21	135 (36.3)	270 (36.3)	0.00
9,537-11,125	1,164 (24.5)	127 (28.7)	1,037 (24.0)	-0.11	118 (31.7)	236 (31.7)	0.00
≥11,126	1,136 (23.9)	36 (8.1)	1,100 (25.5)	0.48	34 (9.1)	68 (9.1)	0.00
Comorbidity							
Hypertension	4,490 (94.3)	415 (93.7)	4,075 (94.4)	0.03	352 (94.6)	691 (92.9)	−0.07
Diabetes mellitus	3,629 (76.3)	340 (76.7)	3,289 (76.2)	-0.01	283 (76.1)	568 (76.3)	0.01
Dyslipidemia	2,475 (52.0)	244 (55.1)	2,231 (51.7)	-0.07	203 (54.6)	405 (54.4)	0.00
Atrial fibrillation	684 (14.4)	61 (13.8)	623 (14.4)	0.02	49 (13.2)	114 (15.3)	0.06
Gout	891 (18.7)	87 (19.6)	804 (18.6)	-0.03	66 (17.7)	164 (22.0)	0.11
Chronic obstructive pulmonary disease	423 (8.9)	39 (8.8)	384 (8.9)	0.00	30 (8.1)	68 (9.1)	0.04
Peripheral artery disease	1,216 (25.6)	119 (26.9)	1,097 (25.4)	-0.03	95 (25.5)	196 (26.3)	0.02
History of event							
Cancer	539 (11.3)	49 (11.1)	490 (11.4)	0.01	46 (12.4)	95 (12.8)	0.01
Myocardial infarction	2,372 (49.8)	217 (49.0)	2,155 (49.9)	0.02	184 (49.5)	347 (46.6)	−0.06
Heart failure hospitalization	2,674 (56.2)	241 (54.4)	2,433 (56.4)	0.04	207 (55.6)	404 (54.3)	−0.03
Ischemic stroke	1,042 (21.9)	87 (19.6)	955 (22.1)	0.06	75 (20.2)	149 (20.0)	0.00
Gastrointestinal bleeding	2,114 (44.4)	196 (44.2)	1,918 (44.4)	0.00	162 (43.5)	338 (45.4)	0.04
Major bleeding	1,759 (37.0)	181 (40.9)	1,578 (36.6)	-0.09	150 (40.3)	300 (40.3)	0.00
Percutaneous coronary intervention	2,293 (48.2)	221 (49.9)	2,072 (48.0)	-0.04	179 (48.1)	337 (45.3)	−0.06
Coronary artery bypass grafting	335 (7.0)	18 (4.1)	317 (7.3)	0.14	17 (4.6)	37 (5.0)	0.02
Coronary revascularization	2,420 (50.9)	226 (51.0)	2,194 (50.8)	0.00	184 (49.5)	349 (46.9)	−0.05
Image-guide PCI	187 (3.9)	14 (3.2)	173 (4.0)	0.05	12 (3.2)	23 (3.1)	−0.01
Previous number of DES implanted							
1	576 (12.1)	57 (12.9)	519 (12.0)	-0.03	46 (12.4)	88 (11.8)	−0.02
2	382 (8.0)	41 (9.3)	341 (7.9)	-0.05	30 (8.1)	63 (8.5)	0.01
≥3	395 (8.3)	43 (9.7)	352 (8.2)	-0.05	32 (8.6)	59 (7.9)	−0.02

Continued on the next page

TABLE 1 Continued

	Total (N = 4,759)	Before Matching			After Matching		
		OCT (n = 443)	IVUS (n = 4,316)	STD	OCT (n = 372)	IVUS (n = 744)	STD
Previous number of BMS implanted							
1	546 (11.5)	55 (12.4)	491 (11.4)	-0.03	45 (12.1)	67 (9.0)	−0.10
2	336 (7.1)	24 (5.4)	312 (7.2)	0.07	20 (5.4)	44 (5.9)	0.02
≥3	432 (9.1)	37 (8.4)	395 (9.2)	0.03	28 (7.5)	55 (7.4)	−0.01
Number of intervened vessels during the index admission							
1	2,535 (53.3)	274 (61.9)	2,261 (52.4)	-0.19	227 (61.0)	451 (60.6)	−0.01
2	1,877 (39.4)	144 (32.5)	1,733 (40.2)	0.16	123 (33.1)	245 (32.9)	0.00
3	347 (7.3)	25 (5.6)	322 (7.5)	0.07	22 (5.9)	48 (6.5)	0.02
Number of stents implanted per patient during the index admission							
1	1,495 (31.4)	171 (38.6)	1,324 (30.7)	-0.17	142 (38.2)	269 (36.2)	−0.04
2	1,096 (23.0)	82 (18.5)	1,014 (23.5)	0.12	71 (19.1)	150 (20.2)	0.03
≥3	1,111 (23.3)	57 (12.9)	1,054 (24.4)	0.30	51 (13.7)	95 (12.8)	−0.03
Number of BMS implanted during the index admission							
1	778 (16.3)	55 (12.4)	723 (16.8)	0.12	42 (11.3)	76 (10.2)	−0.03
2	396 (8.3)	25 (5.6)	371 (8.6)	0.12	22 (5.9)	34 (4.6)	−0.06
≥3	226 (4.7)	11 (2.5)	215 (5.0)	0.13	10 (2.7)	14 (1.9)	−0.05
Number of DES implanted during the index admission							
1	1,696 (35.6)	164 (37.0)	1,532 (35.5)	-0.03	140 (37.6)	275 (37.0)	−0.01
2	1,081 (22.7)	79 (17.8)	1,002 (23.2)	0.13	70 (18.8)	141 (19.0)	0.00
≥3	526 (11.1)	26 (5.9)	500 (11.6)	0.20	23 (6.2)	55 (7.4)	0.05
Presentation							
Chronic coronary syndrome	3,261 (68.5)	320 (72.2)	2,941 (68.1)	-0.09	266 (71.5)	542 (72.8)	0.03
Acute coronary syndrome	1,498 (31.5)	123 (27.8)	1,375 (31.9)	0.09	106 (28.5)	202 (27.2)	−0.03
Complex PCI of the index procedure	2,531 (53.2)	189 (42.7)	2,342 (54.3)	0.23	163 (43.8)	325 (43.7)	0.00
In-hospital events							
Aspiration catheter used	116 (2.4)	15 (3.4)	101 (2.3)	-0.06	11 (3.0)	21 (2.8)	−0.01
Cardiogenic shock with MCS	301 (6.3)	18 (4.1)	283 (6.6)	0.11	15 (4.0)	36 (4.8)	0.04
Endotracheal intubation	337 (7.1)	29 (6.5)	308 (7.1)	0.02	26 (7.0)	52 (7.0)	0.00
Intensive care unit admission	2,410 (50.6)	248 (56.0)	2,162 (50.1)	-0.12	199 (53.5)	452 (60.8)	0.15
Hospital stay, d	11.1 ± 17.5	10.7 ± 18.8	11.2 ± 17.3	0.03	11.1 ± 20.1	11.2 ± 19.3	0.01
Follow up, y	2.0 ± 1.6	1.8 ± 1.5	2.0 ± 1.7	0.09	1.9 ± 1.5	1.7 ± 1.5	−0.08

Values are mean ± SD or n (%).

BMS = bare-metal stent(s); DES = drug eluting stent(s); IVUS = intravascular ultrasound; MCS = mechanical circulation support; OCT = optical coherence tomography; PCI = percutaneous coronary intervention; STD = standardized difference.

logistic regression model, incorporating all covariates listed in Table 1 as explanatory variables. The follow-up duration was excluded from the propensity score calculation and was substituted with the admission date to equalize the follow-up duration in both groups. The matching algorithm used was greedy nearest neighbor with a caliper of 0.2. Because there were approximately 10 times more IVUS patients than OCT patients, each patient in the OCT group was matched to 2 counterparts in the IVUS group within the same hospital. The balance of baseline characteristics between study groups was evaluated using the standardized difference, with absolute values <0.2 considered indicative of nonsubstantial differences.

In-hospital mortality between groups was compared using logistic regression analysis. The risk of outcomes, including fatal events (ie, MACE, CV mortality, and all-cause mortality) between groups was compared using a Cox proportional hazard model. The incidence of other outcomes between groups was compared using the Fine and Gray sub-distribution hazard model, in which all-cause death was considered a competing risk. The outcomes between patients in the OCT and IVUS groups within the same matched pair may be correlated. To

address this potential outcome dependency within the same match pair, we used a robust sandwich-type variance estimator in the regression analyses mentioned in the previous text. The possible between-institution heterogeneity was additionally accounted for using the shared frailty approach in the survival regression models. The assumption of proportional hazards was tested by evaluating the Schoenfeld partial residuals and including an interaction term between study groups and natural logarithm of follow-up time. Sensitivity analysis using overlap weighting based on propensity score was conducted to assess the robustness of the primary analysis derived from matching. Subgroup analysis of MACE was performed by adding an interaction term(s) between study groups and the subgroup variable. The selected subgroup variables were dialysis duration (<5 years vs ≥5 years), dialysis modality, hospital accreditation (center vs noncenter), cumulative PCI volume of the hospital (< median vs ≥ median), diabetes, previous MI, previous coronary revascularization, complexity of PCI, and presentation (CCS vs ACS). The selection of subgroup variables was post hoc rather than prespecified. Statistical analyses were performed using SAS (version 9.4, SAS Institute). A 2-sided *P* value <0.05 was considered significant.

RESULTS

EPIDEMIOLOGY INFORMATION. The population of Taiwan has remained stable over the past decade at around 23 to 24 million,[34] while the total number of PCI procedures increased from 37,153 in 2012 to 57,845 in 2021 (Supplemental Table 1). Additionally, the number of IVI-guided PCIs rose from 2.4% (898 of 37,153) in 2012 to 27% (15,613 of 57,845) in 2021, including 4.1% (1,508 of 57,845) under OCT guidance and 24.4% (14,141 of 57,845) under IVUS guidance (**Figure 1B**). In 2012, a total of 73,572 patients with ESRD were on maintenance dialysis compared to 95,633 in 2021, with PCI procedures among these patients increasing from 3,151 in 2012 (4.3%, 3,151 of 73,572) to 6,387 (6.7%, 6,387 of 95,633) in 2021 (**Figure 1C**). The percentages of IVI-guided PCIs in these patients mirrored those in the general PCI population, increasing from 3.1% (99 of 3,151) in 2012 to 27.5% (1,754 of 6,387) in 2021, including 5.5% (172 of 6,387) under OCT guidance and 24.8% (1,587/6,387) under IVUS guidance (**Figure 1D**).

PATIENT INCLUSION. A total of 67,957 patients who underwent IVI-guided PCI were identified from the NHIRD from January 1, 2015, to December 31, 2021, of whom 53,045 were admitted to hospitals that obtained both OCT and IVUS modalities. Among these patients, 4,795 had ESRD and were on maintenance dialysis. After excluding 36 patients according to the exclusion criteria, the remaining 4,759 were eligible for further analysis, including 443 patients in the OCT group and 4,316 patients in the IVUS group. After 1:2 matching, 1,116 patients were enrolled, including 372 patients in the OCT-guided PCI group and 744 patients in the IVUS-guided PCI group (**Figure 1A**).

BASELINE CHARACTERISTICS. The average age of the study population was 66.4 years, and 64.8% (3,082 of 4,759) were men (**Table 1**). The average dialysis duration was 5.6 years; most patients were undergoing maintenance hemodialysis (92.2%; 4,387 of 4,759), and 75.8% (3,608 of 4,759) of the entire cohort were treated at medical centers. Hypertension was present in 94.3% (4,490 of 4,759) of the patients, 76.3% (3,629 of 4,759) had diabetes, and over one-half (52%; 2,475 of 4,759) were diagnosed with dyslipidemia. Previous CV event rates were high, including 49.8% (2,372 of 4,759) with MI, 56.2% (2,674 of 4,759) with heart failure, 21.9% (1,042 of 4,759) with ischemic stroke, 48.2% (2,293 of 4,759) with previous PCI, and 7% (335 of 4,759) with previous CABG, but only 3.9% (187 of 4,759) received IVI-guided PCI before enrollment. Because more than one-half of these patients did not undergo PCI before enrollment, more than 70% of the study cohort did not receive either DES or bare-metal stent implantation before the index admission.

During the index admission, 1, 2, and 3 vessels were intervened in 53.3% (2,535 of 4,759), 39.4% (1,877 of 4,759), and 7.3% (347 of 4,759) of the study population, respectively. Additionally, 31.4% (1,495 of 4,759), 23% (1,096 of 4,759), and 23.3% (1,111 of 4,759) of them received 1, 2, and 3 or more coronary stents, respectively, with the majority being DES. Overall, 31.5% (1,498 of 4,759) of the patients presented with ACS, and 53.2% (2,531 of 4,759) of the index procedures were defined as complex PCI. The average hospital stay was 11.1 days, and 50.6% (2,410 of 4,759) of the patients received intensive care during the index admission. The mean follow-up period was 2.0 years before matching, and all variables were well balanced after propensity score matching (absolute standardized difference values <0.2) between the 2 groups (**Table 1**).

CLINICAL OUTCOMES. The incidence of the primary outcome was 42.1 (95% CI: 36.2-48.0) events per 100 person-years in the OCT group and 47.6 (95% CI: 43.0-52.2) events per 100 person-years in the IVUS

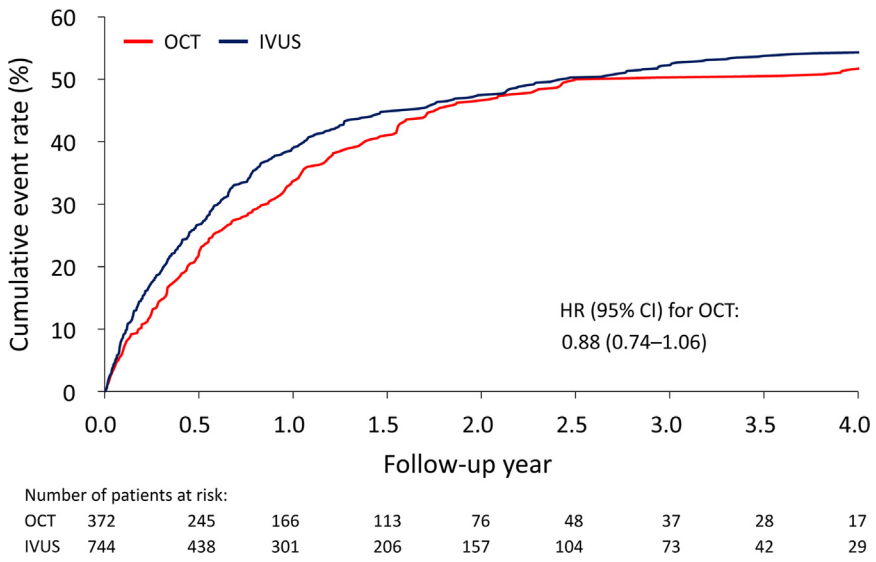
TABLE 2 Outcomes of Patients on Chronic Dialysis Who Received OCT vs IVUS in the Matched Cohort

	OCT (n = 372)		IVUS (n = 744)			
	No. of Events (%)	Incidence (95% CI)[a]	No. of Events (%)	Incidence (95% CI)[a]	OR/HR/SHR for OCT (95% CI)	*P* Value
Primary outcome: MACE[b,c]	194 (52.2)	42.1 (36.2–48.0)	411 (55.2)	47.6 (43.0–52.2)	0.88 (0.74–1.06)	0.178
Component of MACE						
PCI[d]	125 (33.6)	25.9 (21.4–30.5)	263 (35.3)	29.5 (26.0–33.1)	0.91 (0.73–1.13)	0.388
CABG[d]	15 (4.0)	22.4 (11.1–33.8)	27 (3.6)	21.5 (13.4–29.6)	1.10 (0.59–2.05)	0.770
Revascularization[d]	128 (34.4)	26.9 (22.3–31.6)	274 (36.8)	31.2 (27.5–34.9)	0.89 (0.72–1.10)	0.287
Cardiovascular death[b]	89 (23.9)	12.9 (10.2–15.5)	209 (28.1)	16.2 (14.0–18.4)	0.80 (0.63–1.03)	0.081
Acute myocardial infarction[d]	71 (19.1)	11.4 (87.6–14.1)	134 (18.0)	11.9 (98.4–13.9)	1.03 (0.77–1.37)	0.857
Secondary outcomes						
In-hospital mortality[e]	17 (4.6)	NA	37 (5.0)	NA	0.92 (0.51–1.65)	0.767
All-cause mortality[b]	133 (35.8)	19.2 (15.9–22.5)	305 (41.0)	23.6 (21.0–26.3)	0.82 (0.66–1.01)	0.056
Ischemic stroke[d]	21 (5.6)	31.6 (18.1–45.2)	25 (3.4)	19.9 (12.1–27.7)	1.68 (0.94–3.00)	0.081

[a]Number of events per 100 person-years. [b]HRs. [c]Coronary revascularization, cardiovascular death, or acute myocardial infarction. [d]Subdistribution HR (sHR). [e]OR.
CABG = coronary artery bypass grafting; MACE = major adverse cardiovascular event(s); NA = not applicable; other abbreviations as in Table 1.

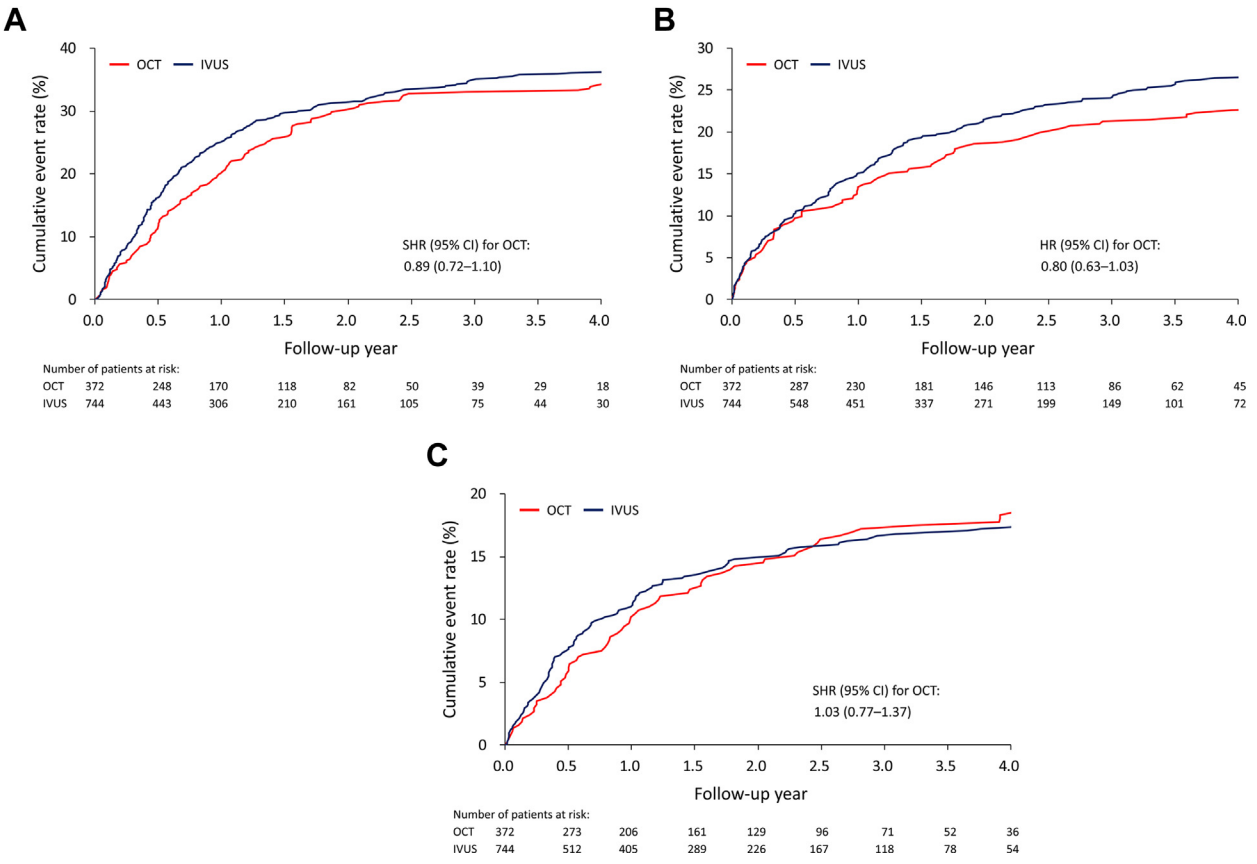
group (Table 2). The risk of MACE did not significantly differ between the study groups (HR: 0.88; 95% CI: 0.74-1.06) (Figure 2). Sensitivity analysis using overlap weighting showed consistent results with the primary analysis based on matching (HR: 0.86; 95% CI: 0.71-1.05) (Supplemental Table 2). Regarding each component of the primary outcome, the incidences of revascularization, CV death, and acute MI were not significantly different between the 2 groups (Figures 3A to 3C). The risks of in-hospital and all-cause mortality were also not significantly different between the 2 groups (OR: 0.92; 95% CI: 0.51-1.65; and HR: 0.82; 95% CI: 0.66-1.01, respectively) (Table 2). The clinical outcomes of the entire cohort are listed in Supplemental Table 3. Furthermore, the tests for the proportional hazards assumption were not statistically significant using either the Schoenfeld partial residuals approach or the time-dependent covariate approach (data not shown).

FIGURE 2 The Primary Outcome of the ESRD Patients Underwent Intravascular Imaging-Guided PCI



The cumulative event rate of composite cardiovascular outcome between OCT- and IVUS-guided PCI in the propensity score-matched ESRD cohort. Abbreviations as in Figure 1.

FIGURE 3 The Secondary Outcomes of the ESRD Patients Underwent Intravascular Imaging-Guided PCI



The cumulative event rate of secondary outcomes between OCT- and IVUS-guided PCI in the propensity score-matched ESRD cohort. (A) Coronary revascularization. (B) Cardiovascular death. (C) Acute myocardial infarction. SHR = subdistribution HR; other abbreviations as in Figure 1.

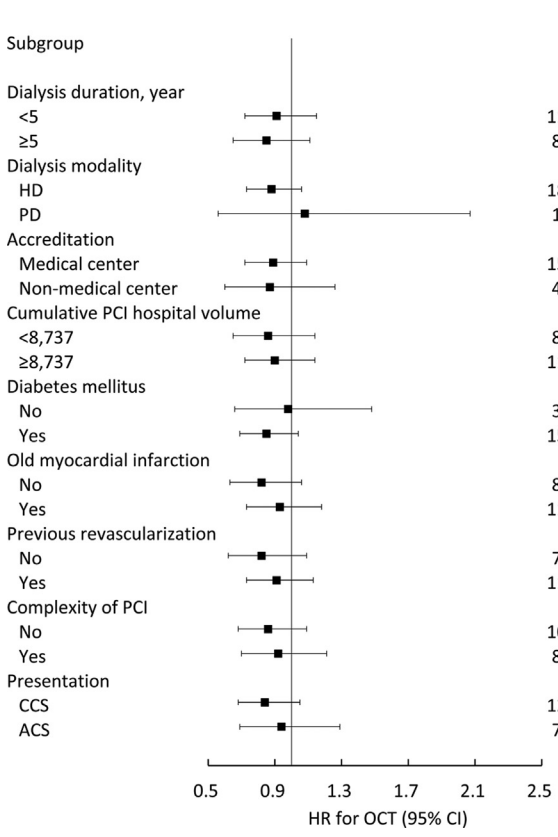
SUBGROUP ANALYSES. We further analyzed the primary composite outcome in different subgroups between the OCT- and IVUS-guided PCI groups. Compared with the IVUS-guided group, the incidence of the primary outcome did not differ in the OCT-guided group regarding dialysis duration, dialysis modality, hospital accreditation, PCI volume, patients with diabetes, old MI, previous PCI, complex PCI during the index admission, or ACS presentation (all P for interaction >0.05) (Figure 4).

DISCUSSION

This contemporary, large-scale, population-based, nationwide cohort study is the first to compare the clinical outcomes between OCT- and IVUS-guided PCI in patients with ESRD on maintenance dialysis. We found that the incidence of MACE, including PCI, CABG, CV death, and acute MI, was not different between the OCT- and IVUS-guided groups, even in different subgroup analyses. Additionally, this study is also the first to report the trend of the total number of PCI procedures and IVI-guided PCI procedures in both the general population and ESRD patients in Taiwan, which increased from 2.4% and 3.1% in 2012 to 27% and 27.5% in 2021, respectively (Central Illustration).

Compared with patients with normal renal function, CKD patients are more likely to have larger coronary plaque burden, with the plaque comprising a higher percentage of necrotic core and dense calcium.[9] In addition, patients who progress to ESRD and require maintenance dialysis have been shown to have a thinner fibrous cap, higher prevalence of

FIGURE 4 **Subgroup Analyses of the Primary Outcome**



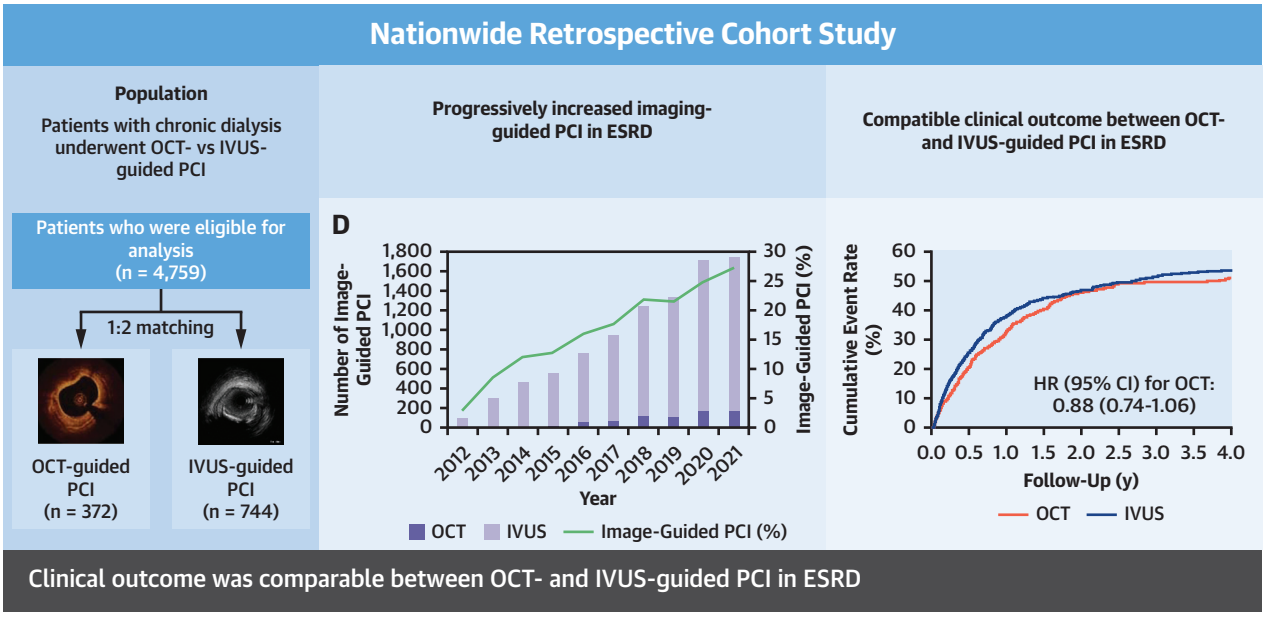
Subgroup	Number of events (%) OCT	Number of events (%) IUVS	HR (95% CI) for OCT	*P* for interaction
Dialysis duration, year				0.697
<5	111 (50.9)	238 (53.7)	0.91 (0.72–1.15)	
≥5	83 (53.9)	173 (57.5)	0.85 (0.65–1.11)	
Dialysis modality				0.538
HD	181 (52.2)	379 (54.5)	0.88 (0.73–1.06)	
PD	13 (52.0)	32 (65.3)	1.08 (0.56–2.07)	
Accreditation				0.918
Medical center	152 (52.4)	317 (54.7)	0.89 (0.72–1.09)	
Non-medical center	42 (51.2)	94 (57.3)	0.87 (0.60–1.26)	
Cumulative PCI hospital volume				0.785
<8,737	81 (50.3)	183 (56.8)	0.86 (0.65–1.14)	
≥8,737	113 (53.6)	228 (54.0)	0.90 (0.72–1.14)	
Diabetes mellitus				0.515
No	37 (41.6)	78 (44.3)	0.98 (0.66–1.48)	
Yes	157 (55.5)	333 (58.6)	0.85 (0.69–1.04)	
Old myocardial infarction				0.489
No	83 (44.2)	198 (49.9)	0.82 (0.63–1.06)	
Yes	111 (60.3)	213 (61.4)	0.93 (0.73–1.18)	
Previous revascularization				0.570
No	78 (41.5)	189 (47.9)	0.82 (0.62–1.09)	
Yes	116 (63.0)	222 (63.6)	0.91 (0.73–1.13)	
Complexity of PCI				0.704
No	107 (51.2)	217 (51.8)	0.86 (0.68–1.09)	
Yes	87 (53.4)	194 (59.7)	0.92 (0.70–1.21)	
Presentation				0.566
CCS	124 (46.6)	281 (51.9)	0.84 (0.68–1.05)	
ACS	70 (66.0)	130 (64.4)	0.94 (0.69–1.29)	

Data are shown as the number of primary outcomes in the ESRD patients receiving different imaging modalities in that subgroup. ACS = acute coronary syndrome(s); CCS = chronic coronary syndrome(s); HD = hemodialysis; PD = peritoneal dialysis.

plaque rupture, calcium nodules, and larger calcification arc than patients without ESRD,[10,11] which makes PCI more challenging for such patients. Moreover, the severity of coronary artery calcification has been positively correlated with dialysis duration.[35] Even after PCI with contemporary DES implantation, the incidence of target lesion failure in ESRD patients has been reported to be significantly higher than in patients without ESRD, especially in those with coronary calcium nodules,[23,24,36] which may impede adequate stent expansion and also increase stent eccentricity.[37] Furthermore, the increased risk of CAD and relatively poor CV outcomes in ESRD patients are not only caused by traditional factors but also by uremic-associated risk factors such as inflammation, anemia, oxidative stress, intradialytic hypotension, high ultrafiltration rates, inadequate control of volume overload, insufficient dialytic clearance of uremia molecules, and calcium-phosphate disorders.[1,6] In our cohort, the incidences of all-cause death and CV death and the rate of repeat revascularization were much higher than in the general population.

Although coronary angiography is the standard procedure to evaluate the severity of CAD and guide PCI, it has several inherent limitations. IVI modalities can provide tomographic or cross-sectional images of the coronary arteries, including not only the lumen but also vessel wall, plaque composition, and distribution.[38] By using near-infrared light instead of ultrasound to create images, OCT enables the rapid acquisition of high-resolution images during PCI. In addition, the light can penetrate calcified plaque to precisely evaluate its thickness and distribution, although the penetration depth is limited.[39] Blood clearance by rapid contrast injection is required for optimal OCT imaging quality, which may require 10 to 15 mL for each pull back and careful attention during imaging acquisition, such as contrast puffing, catheter intubation, and flushing-pull back coordination.

CENTRAL ILLUSTRATION **Comparison of Optical Coherence Tomography- and Intravascular Ultrasound-Guided Percutaneous Coronary Intervention in End-Stage Renal Disease**



Lin C-P, et al. JACC Asia. 2025;5(1):28–41.

The number and percentage of intravascular imaging-guided percutaneous coronary intervention (PCI) in end-stage renal disease (ESRD) patients on maintenance dialysis has progressively increased in the past decade, and the clinical outcome between optical coherence tomography (OCT)- and intravascular ultrasound (IVUS)-guided PCI was comparable in this population.

Caution should be exercised in CKD patients to prevent the risk of contrast-induced nephropathy after OCT-guided PCI, but it is not a major concern in ESRD patients who are already on maintenance dialysis. In comparison, IVUS imaging is based on ultrasound waves with deeper tissue penetration. However, it is not possible to evaluate calcium thickness with IVUS because the ultrasound waves are totally reflected by the leading edge of dense calcified plaque, creating an acoustic shadow behind. Nevertheless, blood clearance is not necessary during IVUS pull back, and because it is relatively easier for image acquisition than OCT, operators can frequently image lesions without much contemplation. Moreover, the availability of IVUS is much higher than OCT globally, and consequently, the frequency of IVUS-guided PCI is 20 times higher than that for OCT-guided PCI.[40,41] The ILUMIEN III (Optical Coherence Tomography Compared with Intravascular Ultrasound and with Angiography to Guide Coronary Stent Implantation) trial compared the clinical benefits of OCT-, IVUS-, and angiography-guided coronary stent implantation and demonstrated a similar minimum stent area between OCT- and IVUS-guided procedures.[25] In addition, the OPINION (Optical Frequency Domain Imaging vs. Intravascular Ultrasound in Percutaneous Coronary Intervention) trial showed a comparable incidence of target vessel failure at 12 months between optical frequency domain imaging and IVUS-guided PCI.[27] In the latest OCTIVUS (Optical Coherence Tomography versus Intravascular Ultrasound-Guided Percutaneous Coronary Intervention) randomized trial, OCT-guided PCI was found to be noninferior to IVUS-guided PCI with respect to the incidence of MACE at 1 year, but only 2% (n = 46) of the study cohort had ESRD and were receiving dialysis.[26] In the present study, we demonstrated comparable clinical outcomes between these 2 imaging modalities to facilitate PCI in 1,116 ESRD patients. However, the OCT group had a numerically lower incidence of coronary revascularization and acute MI compared with the IVUS group up to 1.5 years, and the incidence of CV death started to diverge after 6 months in the current cohort. This phenomenon may imply that lesions treated with OCT guidance might be simpler than those treated with IVUS

guidance or that there is a potential beneficial effect of OCT guidance in this population, which requires further prospective and longer-term studies to clarify. The frequency of IVUS-guided PCI (24.4%) was approximately 6 times higher than that for OCT-guided PCI (4.1%) in the general population, with a similar ratio in patients with ESRD on maintenance dialysis. Although there was significant imbalance in the number of patients underwent OCT and IVUS in the present study, which may imply that most operators had more experience with IVUS, we only included patients admitted to hospitals that obtained both IVUS and OCT modalities to mitigate such bias.

Even though previous studies and guidelines have recommended using IVI to guide complex PCI such as left main coronary artery disease,[19,21,22,42,43] several factors may limit the clinical use of IVI, including high cost, prolonged procedure time, reimbursement issues, and lack of training on the use and interpretation of these modalities.[44] Nevertheless, the use of IVI-guided PCI has progressively increased in recent years caused by accumulating training, experience and clinical evidence worldwide. In a real-world multicenter registry in Japan including 13,994 consecutive patients who underwent PCI from 2008 to 2014, IVUS was used in 9,814 patients (84.8%).[45] In addition, a Korean PCI registry reported that IVUS was used in 27.5% of patients in 2016,[46] and an observational study in the United Kingdom including 10,574 consecutive PCI patients reported that the usage of IVUS-guided PCI was 4.3%.[47] Further, in a German study of 30,814 coronary angiography examinations, 16.2% of 10,995 PCI procedures were under IVUS guidance,[48] and a Thai PCI registry reported that IVUS-guided PCI was performed in 14.5% of patients.[49] Similarly, IVI-guided PCI was performed in 11.6% of patients in a nationwide Spanish registry in 2020,[50] and IVI was used in 10.5% of PCI procedures among Medicare beneficiaries in the United States, which was an increase from 9.5% in 2013 to 15.4% in 2019.[51]

The usage of IVI-guided PCI in Taiwan is limited to specific lesions. The specific reimbursement criteria for both OCT and IVUS in the NHI program are the same: 1) left main coronary artery lesion or ostial lesion of major branches such as the left anterior descending artery, left circumflex artery, or right coronary artery; 2) chronic total occlusion lesions; 3) in-stent restenosis lesions; 4) stenotic lesion >35 or <5 mm; 5) visible intimal dissection or filling defect by angiography after PCI; 6) severe calcified lesion planned for RA; and 7) lesion planned for directional coronary atherectomy. The usage of IVI-guided PCI in Taiwan has significantly increased by 10-fold in the past decade in both the general and ESRD patient populations, and we believe this trend will continue because of ongoing training, education, and financial support. Meanwhile, it is not reasonable to compare IVI- to angiography-guided PCI using the NHIRD because of the restrictive reimbursement criteria for the usage of IVI modalities during PCI. The complexity and difficulty of PCI in patients for whom IVI-guided PCI is reimbursed by the NHI should be higher than in the general PCI population.

STUDY LIMITATIONS. First, although robust statistical adjustments were made for all variables in the NHIRD such as age, sex, hospital effects, dialysis duration, number of stents implanted, and comorbidities, other unrecognized or unmeasurable confounders not contained in the NHIRD may have affected the results, such as body weight, smoking, family history, blood sugar and lipid levels, urine output, stent/vessel size, lesion characteristics, stenting location, strategies, the usage of RA, and acute PCI results. Further prospective and randomized studies are warranted to validate our results. Second, we were unable to determine whether a repeated PCI procedure was performed in the initially treated lesion or the objective criteria for revascularization indication. As a result, it was challenging to differentiate patients undergoing nonclinically driven staged procedures or experiencing clinically driven disease progression in previously untreated lesions from those with target lesion failure. Third, the beneficial effects of IVI-guided PCI largely depend on the operators' experience and technique. We could only evaluate the outcomes of PCI using these 2 imaging modalities in the present study, but not the quality of image interpretation, decision-making process, or the achievement of stent optimization under IVI guidance. Moreover, the use of IVI modalities and the indication for imaging guidance were at the physician's discretion according to personal preference, and the additional time required to perform repetitive imaging procedures may have confounded the results. Fourth, the disease diagnoses and outcomes defined in the present study were based on ICD-9-CM or ICD-10-CM codes, which may be subject to misdiagnosis and coding errors.

However, the accuracy of CV disease diagnoses in the NHIRD has been validated previously, with a positive predictive value of 0.88 and percentage of consistency in comorbidity diagnoses of 95.9%.[32] Meanwhile, we could not evaluate PCI procedures and the usage of IVI modalities not covered by the NHI program, but this situation should be extremely rare in Taiwan. We believe that the present study accurately represents the real-world trend of the number of PCI procedures and the percentage of IVI-guided PCI procedures in both general and ESRD patients in Taiwan. Finally, retrospective design and relative short follow-up duration are limitations of the current study. Further prospective studies with longer follow-up period are warranted to validate our study results.

CONCLUSIONS

The number of PCI procedures and the percentage of IVI-guided procedures have progressively increased in Taiwan, both in the general population and among ESRD patients. Among the ESRD patients on maintenance dialysis who underwent PCI, the clinical outcomes between OCT- and IVUS-guided PCI were not different with respect to a composite of coronary revascularization, CV death, and acute MI.

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KEY WORDS end-stage renal disease, intravascular ultrasound, optical coherence tomography, percutaneous coronary intervention

APPENDIX For supplemental tables, please see the online version of this paper