Practical Use of Intravascular Imaging for Clinical Decision-Making During Drug-Eluting Stent Implantation

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Abstract

Percutaneous coronary intervention has evolved substantially from balloon angioplasty to contemporary drug-eluting stent implantation. Yet, even in the modern era, angiography remains an imperfect guide because it displays only the contrast-filled lumen and provides limited information about vessel size, plaque composition and distribution, or post-stenting findings. This gap has driven the growing use of intravascular imaging as a tool to translate coronary anatomy into procedural strategy in daily catheterization laboratories.

Intravascular ultrasound (IVUS) and optical coherence tomography (OCT) provide complementary perspectives during percutaneous coronary intervention. IVUS offers deep vessel-wall penetration and robust assessment of vessel dimensions, plaque burden, remodeling, and left main or ostial anatomy, whereas OCT provides near-histological resolution for evaluating lumen morphology, thrombus, calcium thickness, stent apposition, tissue protrusion, and edge injury. Contemporary randomized trials and meta-analyses support imaging-guided percutaneous coronary intervention over angiography guidance alone, particularly in complex lesions, although neither modality is universally superior. The practical value of imaging therefore depends on matching the modality to the clinical settings, lesion subset, and procedural constraints.

This state-of-the-art review summarizes current evidence and proposes a practical framework for intravascular imaging-guided drug-eluting stent implantation. We discuss how pre-intervention imaging informs lesion preparation, landing-zone selection, and stent sizing, and how post-intervention imaging identifies underexpansion, geographic miss, edge dissection, malapposition, and tissue protrusion. Specific attention is given to calcified lesions, acute coronary syndromes, bifurcation disease, left main disease, aorto-ostial lesions, intramural hematoma or spontaneous coronary artery dissection, and chronic kidney disease. A structured, lesion-specific approach to intravascular imaging may help refine procedural decision-making, support safer optimization, and improve the durability of drug-eluting stent implantation across diverse clinical settings.

Keywords: Intravascular imaging; Optical coherence tomography; Intravascular ultrasound; Drug-eluting stent implantation

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On September 16, 1977, Andreas Grüntzig performed the first percutaneous transluminal coronary angioplasty in Zurich, Switzerland, marking the beginning of the era of percutaneous coronary intervention (PCI)[1,2]. Since this milestone, the field has evolved from balloon angioplasty to bare-metal and drug-eluting stents, and PCI has become a standard treatment option for coronary artery disease. However, coronary angiography provides only a two-dimensional luminogram from a 3-dimensional structure and cannot adequately characterize lesion morphology, including plaque burden/composition, eccentricity, remodeling, and detect vessel size relevant to procedural planning and device selection[3,4]. Moreover, angiography-guided PCI may miss suboptimal stent deployment, including underexpansion, incomplete apposition, and edge dissection, which are better identified by intravascular imaging[5,6]. These limitations have driven the adoption of adjunctive intravascular imaging.

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What is already known about this topic?

Coronary angiography provides only limited information on vessel size, plaque morphology, calcium burden, and mechanisms of suboptimal stent deployment during DES implantation. Randomized trials and meta-analyses have shown that intravascular imaging-guided PCI with IVUS or OCT improves procedural optimization and clinical outcomes, particularly in complex coronary lesions.

What does this study add?

This review provides a practical, lesion-specific framework for using intravascular imaging during DES implantation. It summarizes how IVUS and OCT can guide modality selection, lesion preparation, stent sizing, landing-zone selection, and post-PCI optimization. It also highlights imaging-derived optimization targets, implementation barriers, and future directions, including artificial intelligence, physiology integration, and multimodality plaque-risk stratification.

Clinical outcomes in coronary artery disease and after PCI are influenced by factors beyond angiographic luminal stenosis[7]. Intravascular ultrasound (IVUS) emerged in the early 1970s and was first used in vivo in 1988; Optical coherence tomography (OCT) was introduced in 1991 and first applied to coronary imaging in the early 2000s[8-11]. Intravascular imaging informs lesion preparation and PCI optimization. Current United States[12] and European guidelines[13,14] support the use of IVUS or OCT for PCI guidance, particularly in selected patients and complex lesions, based on randomized trials showing improved procedural and clinical outcomes compared with angiography guidance alone. This state-of-the-art review summarizes the contemporary evidence for intravascular imaging-guided drug-eluting stent (DES) implantation and proposes a practical framework for modality selection, lesion preparation, stent sizing, and post-PCI optimization.

Clinical Outcomes: Evidence Supporting Intravascular Imaging-Guided PCI

Randomized trials and contemporary meta-analyses consistently support intravascular imaging-guided PCI over angiography-guided PCI alone (Table 1). In the updated network meta-analysis by Stone et al.[15], which included 22 randomized trials and 15,964 patients treated with drug-eluting stents, intravascular imaging guidance reduced the risk of target lesion failure by 29%, cardiac death by 45%, and all-cause mortality by 25%. Intravascular imaging guidance also reduced target-vessel myocardial infarction, target lesion revascularization, and stent thrombosis, with similar outcomes for IVUS and OCT. Benefit appears most consistent in complex lesions, with no clear difference between OCT and IVUS; in non-complex lesions, imaging improves procedural optimization, but routine use remains less certain. In a 2026 lesion-level network meta-analysis[16] of 17 randomized trials including 13,751 patients with complex coronary lesions, both OCT-guided PCI and IVUS-guided PCI were superior to angiography-guided PCI for the prevention of major adverse cardiovascular events (MACE), with consistent findings across chronic total occlusions, left main disease, bifurcation lesions, multivessel disease, and moderate-to-severe calcified lesions. Notably, no significant difference was observed between OCT and IVUS, suggesting clinically meaningful benefit with either modality in complex PCI (Table 1). The 5-year follow-up of RENOVATE-COMPLEX-PCI showed continued separation of the event curves in patients with complex coronary lesions, with the primary endpoint occurring in 10.5% of the imaging-guided group and 14.9% of the angiography-guided group (HR 0.68, 95% CI 0.51 to 0.91, p=0.009), supporting a sustained prognostic advantage of intravascular imaging guidance over time in complex coronary lesions[17]. Even in simple or non-complex lesions, intravascular imaging can improve procedural precision by refining lesion length and reference vessel assessment and by detecting suboptimal stent deployment not readily apparent on angiography. Nevertheless, routine use in low-risk lesions remains uncertain. In ILUMIEN III[18], OCT-guided PCI of non-complex lesions improved procedural optimization compared with angiography and achieved a minimum stent area (MSA) comparable to IVUS, but no significant difference in 12-month clinical outcomes was observed. Furthermore, in the IVUS-CHIP trial[19], routine IVUS guidance in complex high-risk PCI did not significantly reduce target-vessel failure compared with angiography-guided PCI. Similarly, the OPTIMAL trial[20] in unprotected left main disease showed no significant difference in patient-oriented clinical outcomes between IVUS-guided and angiography-guided PCI.

Technical Differences between IVUS and OCT

IVUS and OCT use different signal sources and provide different information (Table 2). IVUS uses ultrasound (~60 MHz) and typically provides axial resolution in the range of 80-100 μm. It offers deeper tissue penetration (4-8 mm) and more complete visualization of the vessel wall, including the external elastic membrane, thereby providing a more global assessment of vessel structure, compared to OCT. In contrast, OCT uses infrared light (1.3-μm wavelength) that provides 10 times higher resolution (10-20 μm) compared to IVUS. However, OCT has lower tissue penetration (1-2 mm). Because the OCT wavelength is shorter than the roughly 8-μm diameter of a red blood cell, the presence of blood causes signal backscattering, such that the vessel wall cannot be visualized without prior blood clearance. A lipid or necrotic core also attenuates the OCT light signal, limiting visualization of deeper structures.

OCT's higher resolution and blood clearance create a clearer lumen-plaque boundary, allowing accurate automated lumen measurement; IVUS may require greater operator interaction for precise delineation of lumen contours and may show somewhat lower reproducibility[21]. In the OPUS-CLASS study[22], OCT and IVUS correlated well for lumen measurements, but IVUS yielded systematically larger

Table 1. Summary of reports in PCI with imaging guidance

No.	Study, design, year	Sample size	Modality	Endpoint	Primary and clinical outcomes
1	Kim JS, et al.[83], Randomized, 2013	543	IVUS vs. angiography	1-year MACE (cardiovascular death, MI, target-vessel revascularization, or stent thrombosis)	In intention-to-treat analysis, 1-year MACE was 4.5% vs 7.3% (p=0.16); in per-protocol analysis, IVUS guidance was associated with lower MACE (4.0% vs 8.1%) and larger minimal lumen diameter.
2	de la Torre Hernández, et al.[84], Observational, 2014	1,670 (1,010 matched)	IVUS vs. angiography	Survival free of cardiac death, myocardial infarction, and target lesion revascularization at 3 years	At 3 years, survival free of cardiac death/MI/TLR was 88.7% vs 83.6% (p=0.04); definite/probable thrombosis was lower with IVUS (0.6% vs 2.2%); IVUS guidance independently predicted fewer major adverse events.
3	IVUS-XPL[85], Randomized, 2015	1,400	IVUS vs. angiography	1-year MACE (cardiac death, target lesion-related MI, ischemia-driven TLR)	MACE was lower with IVUS vs angiography (2.9% vs 5.8%), mainly driven by lower ischemia-driven TLR (2.5% vs 5.0%); cardiac death and target lesion-related MI were similar.
4	CTO-IVUS[86], Randomized, 2015	402	IVUS vs. angiography	Primary: cardiac death at 12 months; Secondary: MACE (cardiac death, MI, TVR)	Cardiac death did not differ significantly; MACE was lower with IVUS guidance (2.6% vs 7.1%), with lower cardiac death or MI.
5	AIR-CTO[87], Randomized, 2015	230	IVUS vs. angiography	Primary: in-stent late lumen loss at 1 year	In-stent late lumen loss was lower with IVUS (0.28±0.48 vs 0.46±0.68 mm), and in-true-lumen stent restenosis was lower (3.9% vs 13.7%); adverse clinical events were similar at 2 years.
6	ULTIMATE[47], Randomized, 2018	1,448	IVUS vs. angiography	Target-vessel failure at 12 months (cardiac death, target-vessel MI, clinically driven TVR)	TVF was lower with IVUS vs angiography (2.9% vs 5.4%); outcomes were best when all IVUS-defined optimal criteria were achieved.
7	IVUS-ACS[41], Randomized, 2024	3,505	IVUS vs. angiography	Target-vessel failure at 1 year (cardiac death, target-vessel MI, clinically driven TVR)	IVUS guidance lowered the 1-year composite outcome versus angiography guidance in ACS.
8	GUIDE-DES[88], Randomized, 2024	1,528	IVUS vs. angiography	Target lesion failure at 12 months (cardiac death, target-vessel MI, or ischemia-driven TLR)	Target lesion failure at 12 months was similar with QCA and IVUS guidance (3.81% vs 3.80%); there were no significant differences in stent edge dissection, perforation, or stent thrombosis.
9	IVUS-CHIP[19], Randomized, 2026	2,020	IVUS vs. angiography	Target-vessel failure (~18–24 months: cardiac death, target-vessel MI, clinically driven TVR)	No significant reduction in TVF with IVUS vs angiography (14% vs 11%); longer procedural time with similar complication rates.
10	OPTIMAL[20], Randomized, 2026	806	IVUS vs. angiography	Patient-oriented composite (death, MI, stroke, or revascularization)	No significant difference in outcomes between IVUS and angiography (34% vs 31%); individual components similar, with numerically higher stroke in IVUS group.
11	CLI-OPCI[65], Retrospective, 2012	670	OCT vs. angiography	1-year cardiac death or myocardial infarction	Compared with angiography alone, OCT-guided PCI was associated with lower 1-year cardiac death (1.2% vs 4.5%), cardiac death/MI (6.6% vs 13.0%), and cardiac death/MI/repeat revascularization (9.6% vs 14.8%).
12	OCTACS[89], Randomized, 2015	100	OCT vs. angiography	Percentage of uncovered struts at 6 months and dynamic malapposition pattern after PCI in NSTEMI	Percentage of uncovered struts at 6 months was significantly lower in the OCT group (4.3% vs. 9.0%, p<0.01); 6-month MACE occurred in 4% of the angiography group (1 cardiac death, 1 stent thrombosis) vs. 0% in the OCT group
13	DOCTORS[25], Randomized, 2016	240	OCT vs. angiography	Post-PCI fractional flow reserve	Post-PCI FFR was higher with OCT guidance (0.94 vs 0.92) without increases in procedural complications, type 4a MI, or acute kidney injury.
14	ILUMIEN IV[6], Randomized, 2023	2,487	OCT vs. angiography	Co-primary efficacy endpoints: minimum stent area after PCI and target-vessel failure at 2 years (cardiac death, target-vessel MI, ischemia-driven TVR)	OCT guidance produced a larger minimum stent area (5.72 vs 5.36 mm^2), but target-vessel failure at 2 years was similar (7.4% vs 8.2%); stent thrombosis was lower numerically (0.5% vs 1.4%).
15	OCTOBER[45], Randomized, 2023	1,201	OCT vs. angiography	2-year composite of cardiac death, target-lesion MI, or ischemia-driven target-lesion revascularization	OCT-guided PCI resulted in fewer major adverse cardiac events at 2 years than angiography-guided PCI in complex bifurcation lesions.
16	OCCUPI[90], Randomized, 2024	1,604	OCT vs. angiography	MACE at 1 year (cardiac death, MI, stent thrombosis, or ischemia-driven TVR)	The primary endpoint occurred less often with OCT guidance (5% vs 7%; HR 0.62); OCT-guided PCI reduced 1-year MACE without apparent excess stroke, bleeding, or contrast-induced nephropathy.

ACS=acute coronary syndrome; CA=coronary angiography; CTO=chronic total occlusion; DES=drug-eluting stent; FFR=fractional flow reserve; HR=hazard ratio; ICA=invasive coronary angiography; IVI=intravascular imaging; IVUS=intravascular ultrasound; MACE=major adverse cardiac events; MI=myocardial infarction; MSA=minimum stent area; NSTEMI=non-ST-elevation myocardial infarction; OCT=optical coherence tomography; OFDI=optical frequency domain imaging; PCI=percutaneous coronary intervention; QCA=quantitative coronary angiography; RR=relative risk; TLR=target lesion revascularization; TVF=target-vessel failure; TVR=target-vessel revascularization

Because of heterogeneity in study design, comparator, imaging modality, lesion subset, endpoint definition, and follow-up duration, direct numerical pooling across all reports in this table was not performed. Published systematic reviews and network meta-analyses are included to provide quantitative context for the available randomized evidence.

Table 1. (continued)

No.	Study, design, year	Sample size	Modality	Endpoint	Primary and clinical outcomes
17	CALIPSO[91], Randomized, 2025	143	OCT vs. angiography	Primary endpoint: minimal stent area measured by OCT	Minimal stent area was larger with OCT guidance (median 6.5 vs 5.0 mm^2); periprocedural complications, contrast volume, and procedure duration were similar.
18	OPINION[27], Randomized, 2017	829	IVUS vs. OCT	Primary: target-vessel failure at 12 months; major secondary: angiographic binary restenosis at 8 months	OFDI was noninferior to IVUS for 1-year target-vessel failure (5.2% vs 4.9%); angiographic restenosis at 8 months was similar.
19	MISTIC-1[33], Randomized, 2020	109	IVUS vs. OCT	Primary endpoint: in-segment minimum lumen area at 8 months; secondary endpoint: device-oriented composite endpoint	At 8 months, in-segment minimum lumen area was 4.56±1.94 mm^2 with OFDI and 4.13±1.86 mm^2 with IVUS (noninferiority met); 3-year device-oriented composite endpoint rates were similar (7.4% vs 7.3%).
20	OCTIVUS[32], Randomized, 2023	2,008	IVUS vs. OCT	Primary endpoint: composite of cardiac death, target vessel-related MI, or ischemia-driven target-vessel revascularization at 1 year	At 1 year, the primary endpoint occurred in 2.5% with OCT and 3.1% with IVUS; OCT was noninferior to IVUS, and major procedural complications were lower with OCT (2.2% vs 3.7%).
21	OPINION ACS[34], Randomized, 2024	158	IVUS vs. OCT	In-stent minimum lumen area at 8 months	OFDI was noninferior to IVUS for 8-month in-stent minimum lumen area; proximal edge dissections and irregular protrusion were less frequent, while MACE was similar.
22	RENOVATE-COMPLEX-PCI[58], Randomized, 2023	1,639	IVI (IVUS or OCT) vs. angiography	Composite of cardiac death, target-vessel-related MI, or clinically driven TVR	At a median follow-up of 2.1 years, the primary endpoint occurred in 7.7% vs 12.3% (HR 0.64); there was no apparent between-group difference in procedure-related safety events.
23	ILUMIEN III[18], Randomized, 2016	450	IVUS vs. OCT vs. angiography	Primary efficacy endpoint: post-PCI minimum stent area measured by OCT; primary safety endpoint: procedural MACE	Median minimum stent area was 5.79 mm^2 (OCT), 5.89 mm^2 (IVUS), and 5.49 mm^2 (angiography). OCT was noninferior to IVUS for minimum stent area, and procedural MACE was infrequent across groups.
24	iSIGHT[92], Randomized, 2021	151	IVUS vs. OCT vs. angiography	Post-procedure stent expansion (ratio of MSA to the average reference lumen area) measured by post-PCI OCT	Stent expansion with OCT (98.01±16.14%) was noninferior to IVUS (91.69±15.75%, p<0.001) and superior to angiography (90.53±14.84%, p=0.041); long-term (median 2.5 years) MACE rates were low and similar across groups
25	Buccheri et al.[93], Systematic review/Bayesian network meta-analysis, 2017	17,882	IVUS/OCT vs. angiography; IVUS vs. OCT	Comparative clinical efficacy of angiography, IVUS-, and OCT-guided PCI	Compared with CA guidance, IVUS reduced all-cause death, MI, TLR, and stent thrombosis; both IVUS and OCT reduced MACE and cardiovascular death. No significant differences were found between IVUS and OCT.
26	Giacoppo et al.[94], Systematic review/network meta-analysis, 2024	15,489	IVUS vs. OCT vs. angiography	Coprimary outcomes: target lesion revascularization and myocardial infarction	IVUS was associated with lower target lesion revascularization than ICA; OCT significantly reduced stent thrombosis vs ICA only in the frequentist analysis; no significant differences in myocardial infarction were seen among strategies.
27	Stone et al.[15], Systematic review/network meta-analysis, 2024	15,964	IVI (IVUS or OCT) vs. angiography; IVUS vs. OCT	Primary endpoint: target lesion failure (cardiac death, target vessel-MI, or target lesion revascularisation)	Compared with angiography-guided PCI, intravascular imaging-guided PCI reduced target lesion failure (RR 0.71), cardiac death, target vessel-MI, TLR, stent thrombosis, all MI, and all-cause death; outcomes were similar between OCT and IVUS.

ACS=acute coronary syndrome; CA=coronary angiography; CTO=chronic total occlusion; DES=drug-eluting stent; FFR=fractional flow reserve; HR=hazard ratio; ICA=invasive coronary angiography; IVI=intravascular imaging; IVUS=intravascular ultrasound; MACE=major adverse cardiac events; MI=myocardial infarction; MSA=minimum stent area; NSTEMI=non-ST-elevation myocardial infarction; OCT=optical coherence tomography; OFDI=optical frequency domain imaging; PCI=percutaneous coronary intervention; QCA=quantitative coronary angiography; RR=relative risk; TLR=target lesion revascularization; TVF=target-vessel failure; TVR=target-vessel revascularization

Because of heterogeneity in study design, comparator, imaging modality, lesion subset, endpoint definition, and follow-up duration, direct numerical pooling across all reports in this table was not performed. Published systematic reviews and network meta-analyses are included to provide quantitative context for the available randomized evidence.

dimensions, with lesion-level differences affected by wire position, frame rate, and contour/stent interface definitions[23]. Imaging-related complications were rare and did not differ significantly. OCT-guided PCI required more contrast (17-70 mL more)[18,24-27], although blood clearance for OCT acquisition can also be achieved with saline or low-molecular-weight dextran with acceptable image quality[28,29].

Role of Near-Infrared Spectroscopy

Near-infrared spectroscopy (NIRS) is another intravascular imaging modality that provides complementary information on coronary plaque composition. Unlike IVUS and OCT, which mainly provide structural information for vessel sizing, lesion preparation, stent deployment, and post-PCI optimization, NIRS itself is primarily used to

Table 2. Properties of IVUS and OCT

Feature	IVUS	OCT
Representative devices (catheter)	Terumo: AltaView/AnteOwl WR Boston: OptiCross HD Philips: Refinity/Eagle Eye	Abbott: Dragonfly OpStar/Dragonfly OPTIS TERUMO: FastView
Source of image	Ultrasound (sound waves)	Near-infrared light (optical)
Minimum guide catheter size	5Fr compatible	6Fr recommended, 5Fr compatible
Axial resolution (μm)	22-100 μm (HD-IVUS: 22-40 μm)	10-20 μm
Maximum pullback length	~100-150 mm	54-75 mm (FastView: 150 mm)
Pullback speed	0.5-9 mm/second	18-36 mm/second (FastView:0-40 mm/second)
Blood issue	No blood clearance required Blood is semi-transparent to sound; minimal backscatter	Requires blood clearance Requires flushing with contrast, low-molecular-weight dextran or saline to visualize vessel wall

IVUS=intravascular ultrasound; OCT=optical coherence tomography

detect lipid-rich plaque and quantify lipid burden, commonly expressed as the lipid core burden index. In contemporary clinical practice, NIRS has most often been integrated with IVUS as NIRS-IVUS, combining lipid detection with assessment of plaque burden, vessel dimensions, and remodeling. Prospective natural-history studies[30] have shown that NIRS-IVUS can identify patients and non-culprit plaques at increased risk for future coronary events. NIRS can also be combined with OCT. Such NIRS-OCT or DeepOCT-NIRS systems are designed to integrate high-resolution plaque and stent morphology assessment with spectroscopic lipid detection. This hybrid approach may theoretically overcome some limitations of OCT alone, particularly its limited ability to quantify lipid content behind signal attenuation, while preserving detailed assessment of fibrous cap, thrombus, calcium, stent apposition, and edge complications. However, compared with IVUS and OCT, the clinical evidence supporting NIRS-guided procedural optimization during DES implantation remains less established. Therefore, in the present review, NIRS is considered a complementary modality for plaque-risk stratification rather than a primary tool for stent sizing or post-PCI optimization.

Clinical Application: Practical Use of Intravascular Imaging for PCI Guidance

A practical OCT-based framework for PCI guidance is the MLD-MAX algorithm[31] (Figure 1), which organizes image interpretation into pre- and post-intervention steps. Before stent implantation, OCT is used to define Morphology, Lesion Length, and vessel Diameter; after stent deployment, the imaging run is repeated to assess medial edge dissection, stent apposition, and stent expansion. Although this algorithm was developed for OCT-guided PCI, its core principles apply to both OCT and IVUS. Table 3 summarizes modality selection according to lesion characteristics. Randomized trials have shown comparable outcomes between OCT- and IVUS-guided PCI. In the OCTIVUS trial[32], which randomized 2,008 patients with significant coronary lesions, OCT-guided PCI was again noninferior to IVUS-guided PCI for the 1-year composite of cardiac death, target-vessel myocardial infarction, or ischemia-driven target-vessel revascularization (2.5% vs. 3.1%); contrast-induced nephropathy was similar, and major procedural complications were less frequent in the OCT arm, while imaging procedure-related complications were not observed. Similar findings were observed in other randomized studies such as MISTIC-1[33], OPINION[27], and OPINION ACS[34]. Taken together, these data indicate that neither modality is uniformly superior; rather, both OCT and IVUS can effectively guide PCI when used within a systematic imaging workflow.

Pre-Intervention Assessment and Lesion Preparation

Before PCI, intravascular imaging defines lesion morphology, landing zones, and device size, and helps determine whether additional lesion preparation is needed. In practice, imaging is typically performed after intracoronary nitroglycerin, with the catheter advanced distal to the target lesion and pullback acquired across the lesion to the coronary ostium. If the imaging catheter cannot cross, small-balloon (generally, ≤2 mm balloon) predilation or plaque modification may be required.

Calcified Lesion

Intravascular imaging is of practical value in calcified lesions, because the extent, distribution, and depth of calcium strongly influence the need

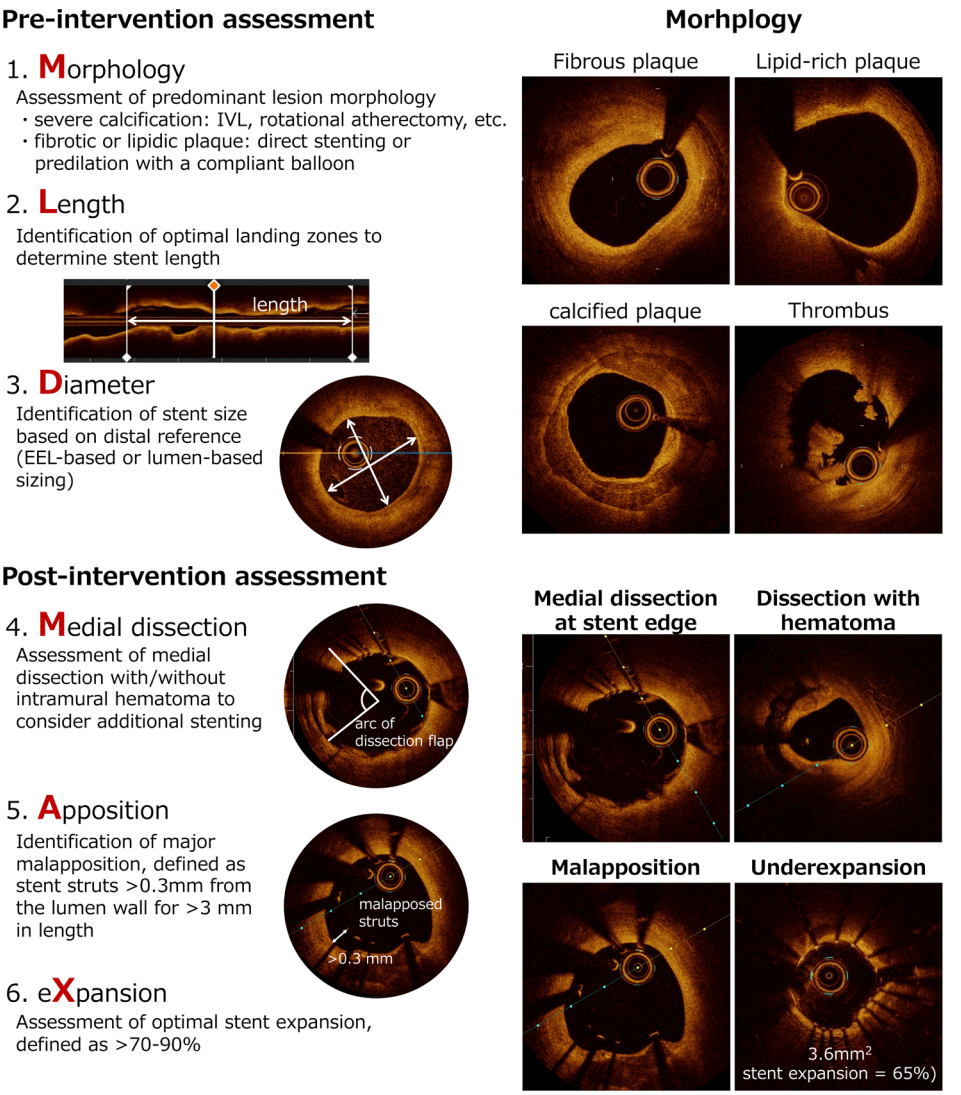

Figure 1. MLD-MAX algorithm. Panel A: Pre-intervention assessment: Pre-PCI OCT imaging "MLD." After pre-PCI imaging, the baseline OCT is used for procedural planning and strategizing. Panel B: Post-PCI OCT imaging "MAX." The post-PCI OCT is used to assess whether further optimization is required and, specifically, encompasses three further steps.

for plaque modification and the risk of subsequent stent underexpansion. This clinical relevance is now supported by outcome data: in the ECLIPSE trial, among 2,005 patients with severely calcified lesions, intravascular imaging-guided PCI was associated with a lower 1-year rate of target-vessel failure than angiography-guided PCI alone (9.3% vs. 13.2%, adjusted HR 0.74, 95% CI 0.56 to 0.97), with no significant difference between OCT- and IVUS-guided strategies[35]. Both IVUS and OCT calcium scores are summarized in Table 4. For lesion assessment, with IVUS, a calcium score assigns 1 point each for superficial calcium >270° over a length ≥5 mm, 360° superficial calcium, calcified nodule, and small vessel size (<3.5 mm), thereby integrating calcium burden and vessel geometry into a simple pre-PCI framework[36]. With OCT, the original score—often remembered as the "rule of 5s"[37]—identifies high-risk lesions by calcium angle >180°, thickness >0.5 mm, and length >5 mm; lesions with a score of 4 had substantially worse stent expansion than those with scores of 0-3. More recently, the revised OCT "rule of 3s"[38] refined prediction in severely calcified lesions by using 3 features: calcium >270° with length >3 mm, calcium angle of 360°, and minimum calcium thickness >0.3 mm. These imaging findings are increasingly used to

Table 3. Clinical benefits and practical considerations of IVUS and OCT according to specific coronary lesion subsets

Lesion subset	IVUS advantage	OCT advantage	Practical caveat
Left main coronary artery	IVUS has better tissue penetration and more reliable visualization of the external elastic lamina (EEL), supporting global vessel sizing, landing-zone selection, and stent optimization in large-caliber segments.	OCT has higher spatial resolution for detailed assessment of stent apposition, edge dissection, side-branch ostium, and stent deformation when image acquisition is feasible. There was no clear difference between OCT and IVUS in the LEMON study[95].	Both are useful for left main PCI guidance; however, IVUS is generally preferred because of its advantages and lack of need for contrast-mediated blood clearance. OCT is a reasonable alternative in selected distal left main lesions, particularly for bifurcation optimization and detailed post-stent assessment, when adequate image acquisition is feasible[14].
Aorto-ostial lesion	IVUS does not require contrast-mediated blood clearance and is less affected by guide catheter disengagement, making it more practical for true ostial and aorto-ostial assessment.	OCT may provide high-resolution assessment of superficial edge pathology if adequate clearance can be obtained.	IVUS is generally preferred for aorto-ostial lesions because OCT acquisition is often limited by guide catheter disengagement and incomplete blood clearance at the coronary ostium; although guide-extension–assisted OCT may be feasible in selected cases, IVUS is usually more practical for accurate ostial delineation, vessel sizing, and stent positioning.
Calcified lesion	IVUS can assess vessel dimensions, guide EEL-based stent sizing, and evaluate circumferential calcium burden and vessel remodeling, making it particularly useful when plaque preparation and stent sizing need to be guided by the vessel size rather than calcium thickness alone.	OCT has advantages for detailed calcium characterization, including calcium arc, thickness, and length, and for confirming calcium fracture after lesion preparation; OCT-derived calcium scoring identifies the risk for stent underexpansion and may help tailor calcium-modification strategies[37,38].	The two modalities are often complementary; IVUS is generally favored when EEL-based sizing and overall vessel architecture are the main procedural priorities, whereas OCT is favored when decisions hinge on calcium thickness, longitudinal extent, or confirmation of calcium fracture. Available clinical data do not show clear superiority of one intravascular modality over the other in this lesion subset.
ACS	IVUS is particularly useful when safe procedural guidance is needed in thrombotic lesions or in hemodynamically unstable patients, when contrast should be minimized, or when the primary objective is reliable stent sizing and post-PCI optimization rather than culprit lesion morphology identification.	OCT is particularly helpful when defining the culprit mechanism, such as plaque rupture, plaque erosion, calcified nodule, residual thrombus, or unexplained ACS/MINOCA presentations.	Modality selection is often determined by feasibility and clinical intent: OCT is more informative when lesion-level morphology is needed, whereas IVUS is often more practical in heavy thrombus burden, impaired flow, proximal/ostial culprit lesions, hemodynamic instability, or renal concern.
Intramural hematoma/SCAD	The strengths of IVUS are that it can be performed without blood clearance with contrast injection and that its deeper penetration permits complete assessment of the vessel wall up to the EEL, including through thrombus. However, its lower resolution may miss identifying small SCAD-related structures, including the intimal-medial membrane and focal fenestrations connecting the true and false lumens[96].	OCT allows detailed evaluation of the true lumen, including any associated thrombus, together with the size, morphology, and extent of the false lumen. It also delineates the relationship between the false lumen and side branches, and can identify fenestrations or a more typical entry tear between the true and false lumens. Careful interpretation is required to detect the characteristic crescentic semilunar false lumen and ensure a correct OCT diagnosis[96].	Intracoronary imaging in SCAD/intramural hematoma should be used selectively rather than routinely. Conservative management is preferred in many stable SCAD cases; if imaging is needed, OCT may provide greater diagnostic detail but can extend the false lumen or intramural hematoma because it requires contrast flushing, whereas IVUS is less likely to do so but may miss small intimal abnormalities because of its lower spatial resolution. Given the reported increased risk of iatrogenic dissection in SCAD patients, repeat OCT imaging should only be considered where clinically necessary.
Bifurcation lesion	IVUS was useful when bifurcation PCI is driven by concern for side-branch compromise or the need for repeated procedural reassessment, as IVUS can define plaque distribution associated with side-branch occlusion without the workflow constraints of OCT blood clearance and side-branch imaging. Left main lesions: see above.	OCT is helpful to assess side-branch optimization, including confirmation of distal cell rewiring, evaluation of side-branch ostial coverage, and detection of stent deformation or incomplete apposition. OCT-guided bifurcation PCI was associated with lower 2-year MACE than angiography guidance in OCTOBER[45].	Modality choice in bifurcation PCI should be driven by the procedural objective and lesion anatomy rather than by a universal hierarchy: IVUS is often preferred when proximal main-vessel optimization or left main bifurcation assessment is the dominant issue, whereas OCT is particularly useful when guidewire recrossing, side-branch ostial scaffolding, or post-stent geometry needs to be checked in detail; OCT may be less practical when blood clearance is difficult.
Renal dysfunction	IVUS is usually preferred when contrast minimization is a priority—such as in advanced CKD, prior contrast-associated kidney injury, or planned ultra-low/zero-contrast PCI—because of IVUS-based contrast-sparing workflows.	OCT can still be considered in selected stable patients when additional lesion- or stent-level detail is expected to change management, and adequate low-contrast flushing, low-molecular-weight dextran, or saline is feasible, although such strategies are not universally applicable.	In non-dialysis CKD, IVUS is generally preferred because standard OCT still requires flushing and may increase procedural complexity; OCT is therefore best reserved for selected cases in experienced centers using low- or no-contrast protocols.

ACS=acute coronary syndrome; CKD=chronic kidney disease; EEL=external elastic lamina; IVUS=intravascular ultrasound; MACE=major adverse cardiac events; MINOCA=myocardial infarction with non-obstructive coronary arteries; OCT=optical coherence tomography; PCI=percutaneous coronary intervention; SCAD=spontaneous coronary artery dissection

This table contrasts the clinical benefits of IVUS and OCT in selected lesion subsets. IVUS is generally advantageous when deep vessel-wall visualization, external elastic lamina-based sizing, or contrast minimization is clinically important, whereas OCT is advantageous when high-resolution assessment of plaque morphology, calcium thickness, stent apposition, edge dissection, or side-branch/stent geometry is expected to influence procedural decision-making.

guide device selection before stenting. Contemporary imaging-based consensus documents propose using IVUS or OCT to decide whether lesion modification with rotational atherectomy, orbital atherectomy, or intravascular lithotripsy is required[39,40].

Acute coronary syndrome (ACS)

Pre-intervention intravascular imaging serves not

Table 4. IVUS and OCT-derived calcium score

Scoring	Device	Lesions	Assessment points	Cut-off and clinical implication
IVUS calcium score	IVUS	Maximum superficial calcium angle >270° and angiographically visible calcium	1) Calcium angle >270° and length >5 mm (1 pt) 2) 360° of calcium (1 pt) 3) Calcified nodule (1 pt) 4) Vessel diameter <3.5 mm (1 pt)	Score ≥2: High risk of underexpansion; consider atherectomy
OCT-based calcium score "Rule of 5"	OCT	Any calcium	1) Max angle >180° (2 pts) 2) Max thickness >0.5 mm (1 pt) 3) Length>5 mm (1 pt)	Score 0-3: Good expansion Score 4: High risk of stent underexpansion
Revised OCT-based calcium score "Rule of 3"	OCT	Maximum superficial calcium angle >270° and angiographically visible calcium	1) Minimum calcium thickness >0.3 mm (1 pt) 2) 360° of calcium (1 pt) 3) Calcium angle >270° and length >3 mm (1 pt)	Score ≥2: Risk of stent underexpansion (Score 3 PPV: ~80%); consider calcium modification

IVUS=intravascular ultrasound; OCT=optical coherence tomography; PPV=positive predictive value

only to optimize PCI but also to clarify the underlying culprit characteristics, which may influence lesion preparation and even the overall treatment strategy. In the IVUS-ACS trial[41], which enrolled 3,505 patients with ACS, IVUS-guided PCI reduced the 1-year rate of target-vessel failure compared with angiography-guided PCI alone (4.0% vs. 7.3%, HR 0.55, 95% CI 0.41 to 0.74), mainly through lower rates of target-vessel myocardial infarction and repeat revascularization. When the key question is culprit morphology, OCT has a clear advantage because its spatial resolution allows in vivo differentiation among plaque rupture, plaque erosion, and calcified nodule (Figure 2). In OCT-based ACS studies, plaque erosion has been observed more often in younger patients and in non-ST-segment elevation ACS, whereas calcified nodule is less common and tends to occur in older patients. Importantly, OCT-based phenotyping may also alter whether immediate stenting is required: in the EROSION study[42], 92.5% of selected patients with ACS caused by plaque erosion who were treated with antithrombotic therapy without stenting remained free from major adverse cardiovascular events at 1 year. On the other hand, a calcified nodule may require more aggressive lesion preparation. Culprit morphology defined by OCT also has prognostic relevance. In the TACTICS registry[43], one-year major adverse cardiac events occurred most frequently in patients with calcified nodules (32.1%), followed by plaque rupture (12.4%) and plaque erosion (6.2%). Thus, both IVUS and OCT are useful in ACS for PCI optimization, but OCT is particularly valuable when culprit morphology may alter strategy.

Other Complex Lesions

In other complex lesion subsets, neither IVUS nor OCT is uniformly preferred, and the choice of modality should be tailored to lesion anatomy and the specific procedural question. Because OCT requires transient blood clearance, adequate visualization of aorto-ostial lesions is often difficult, whereas IVUS can generally assess these segments more reliably. Similarly, when a large intramural hematoma is present, including in spontaneous coronary artery dissection, the contrast injection required for OCT may propagate the dissection or enlarge the false lumen; in this setting, IVUS is often preferred because it does not require blood clearance and provides deeper visualization of the vessel wall. By contrast, bifurcation PCI is an area in which OCT has attracted particular interest, because 3-dimensional reconstruction can visualize jailed-strut configuration and guidewire recrossing and has been shown to reduce acute incomplete stent apposition compared with angiographic guidance in the OPTIMUM trial[44]. The potential clinical importance of these procedural advantages is supported by the OCTOBER trial[45], in which OCT-guided PCI for complex bifurcation lesions reduced 2-year major adverse cardiac events compared with angiography-guided PCI.

Stent Sizing with IVUS Guidance

Whereas the bare-metal stent era favored a "bigger-is-better" sizing strategy to maximize acute luminal gain, the DES era has moved toward anatomically appropriate, vessel-guided sizing with subsequent optimization of stent expansion. In the current routine practice, IVUS-guided stent or post-stent balloon sizing (Figure 3) is reference-based: 1) external elastic lamina (EEL) diameters of the proximal reference, distal reference, or lesion site, usually rounded down by (at least) 0.5 mm; or 2) reference lumen diameters. Both are typically larger than angiographic reference lumen diameter measures, especially in smaller vessels[46]. Moreover, in the ULTIMATE trial[47], stent diameter was calculated according to the lumen diameter of

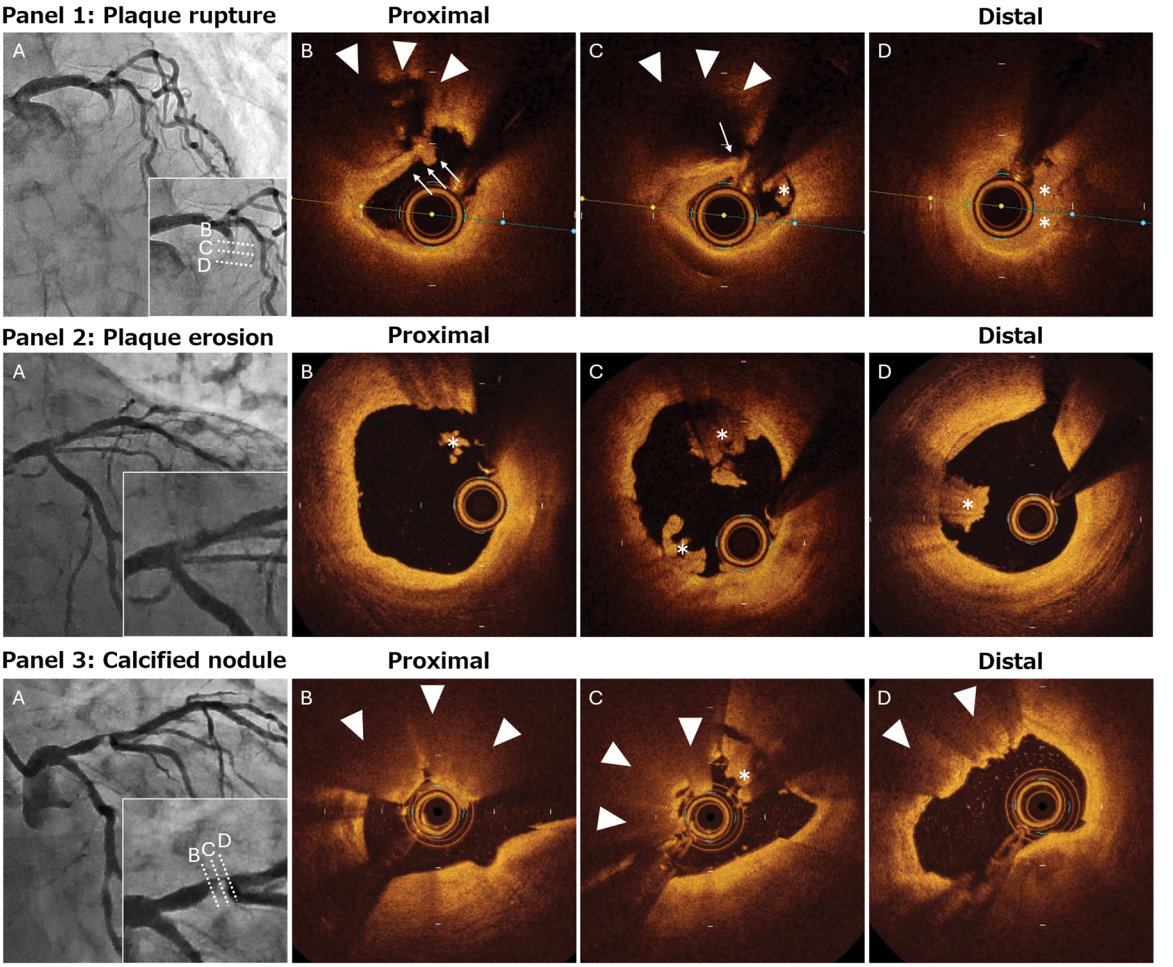

Figure 2. ACS culprit morphology by OCT. In each case, the coronary angiograms (image A) and optical coherence tomography (OCT) images (B-D) with thrombus (asterisk) are shown. Panel 1 is a case of plaque rupture: the white arrowheads indicate the rupture cavity, and the white arrow shows the disrupted fibrous cap. Panel 2 is a case with plaque erosion: the asterisk indicates thrombus without rupture on a smooth luminal surface. Panel 3 is a case with eruptive calcified nodule: the white arrowhead indicates calcified nodules with thrombus (asterisk). The surface of the nodule is irregular, with a disrupted fibrous cap (C).

the distal reference (ratio of 0.8 to media diameter or 1:1 to lumen diameter). When IVUS is used to determine stent length, the goal is not simply to cover the angiographic stenosis, but to place both stent edges in reference segments with the lowest possible plaque burden and an adequate lumen area, ideally with plaque burden <50% and at minimum <55% when feasible. Angiographically normal-appearing reference segments are often not truly normal on IVUS; plaque burden >50% was still present in 37% of proximal and 21% of distal angiographically normal reference segments after newer-generation DES implantation[48]. In addition, residual edge plaque burden was the independent predictor of 9-month angiographic edge restenosis[49]. In diffuse disease, where completely normal landing zones may not exist, IVUS can still help identify the least diseased proximal and distal segments and thereby minimize the risk of edge restenosis.

Stent Sizing with OCT Guidance

A representative case of OCT-guided stenting is shown in Figure 4. In the OCT workflow used in the ILUMIEN III and IV trials[6,18], vessel-based sizing is the following method (Figure 5): if the EEL can be visualized adequately (≥180°), the mean EEL diameter of the distal reference is used to determine the stent diameter and rounded down to the nearest available stent size, usually in 0.25-mm increments, to select stent diameter. For example, if the distal reference EEL measures 3.7×3.5 mm, the mean EEL is 3.6 mm, and thus a 3.5 mm stent diameter should be chosen. When the distal EEL cannot be delineated reliably,

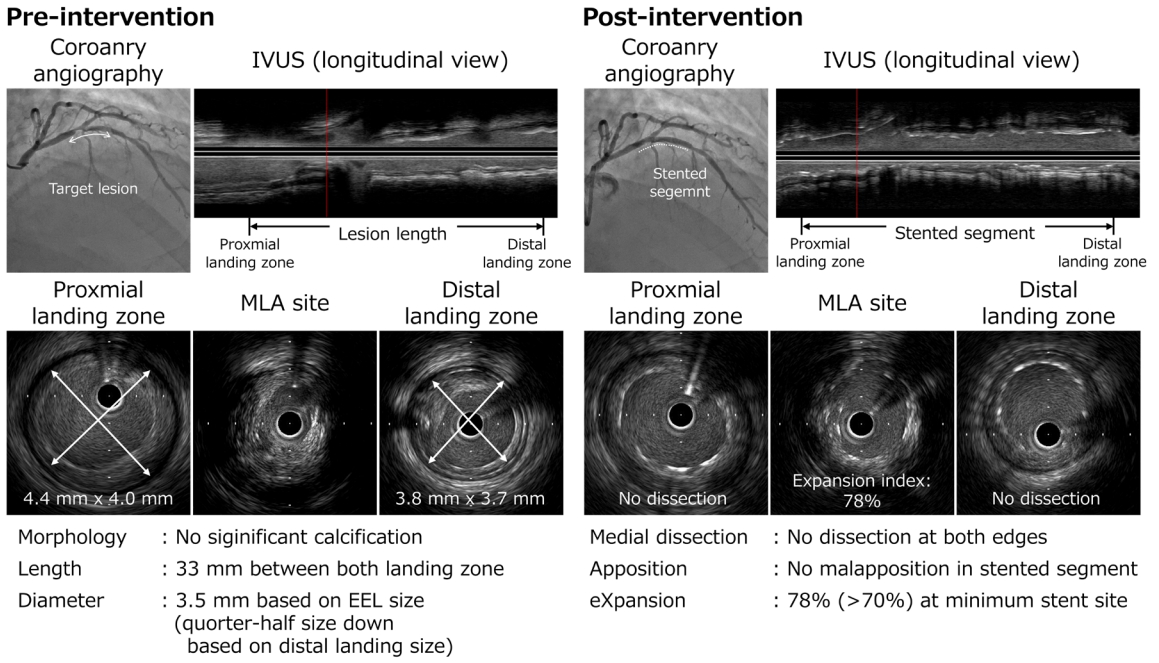

Figure 3. IVUS-guided PCI. The left panels show pre-intervention angiography and IVUS. Target lesion (white line) is a proximal-middle LAD lesion, separating the first diagonal and septal branch. IVUS shows attenuated plaque with no significant calcification. Lesion length is 33 mm and vessel size is 3.7-3.8 mm at the distal landing zone. The operator planned to deploy a 3.5×33 mm drug-eluting stent. The right panels show post-intervention angiography and IVUS. The dotted line shows the stented segment. No medial dissection is observed at either stent edge. IVUS shows no malapposed struts. Stent expansion is 78%, so the operator decided to perform additional post-dilation with a 3.5 mm non-compliant balloon to obtain optimal stent expansion.

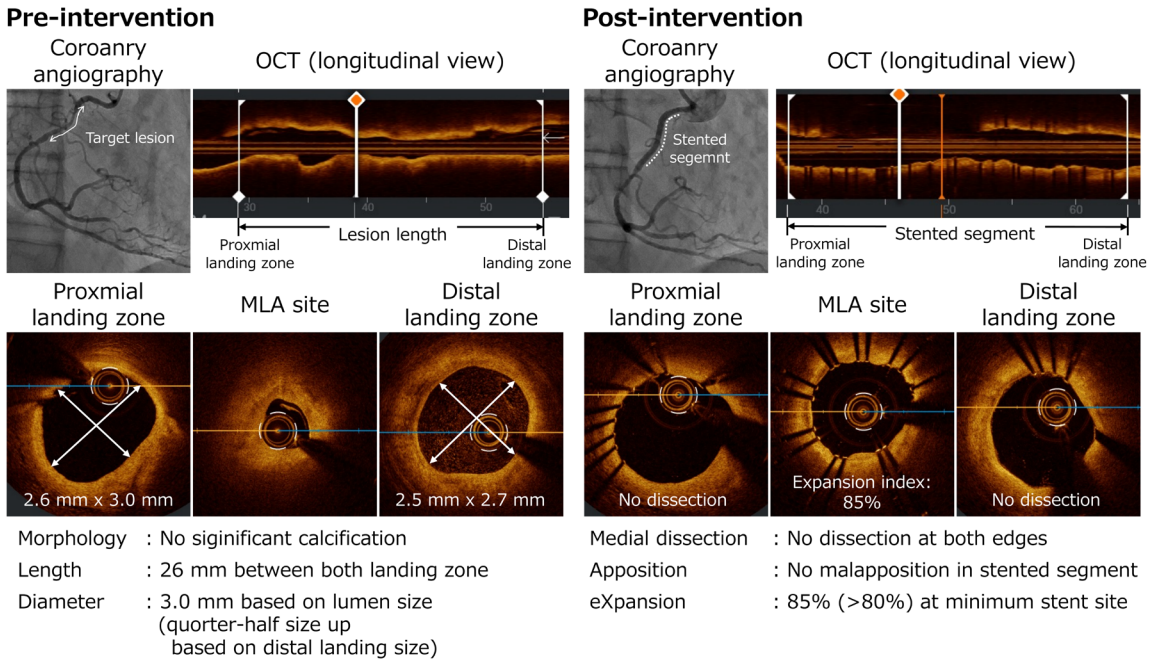

Figure 4. OCT-guided PCI. The left panels show pre-intervention angiography and OCT. The target lesion (white line) is a proximal-RCA lesion. OCT shows a fibrolipidic plaque without significant calcification. Lesion length is 26 mm and lumen size is 2.5-2.7 mm at the distal landing zone. The operator planned to deploy a 2.75×26 mm drug-eluting stent. The right panels show post-intervention angiography and OCT. The dotted line shows the stented segment. No medial dissection is observed at either stent edge. OCT shows no malapposed struts. Stent expansion is 85%. OCT shows optimal stenting.

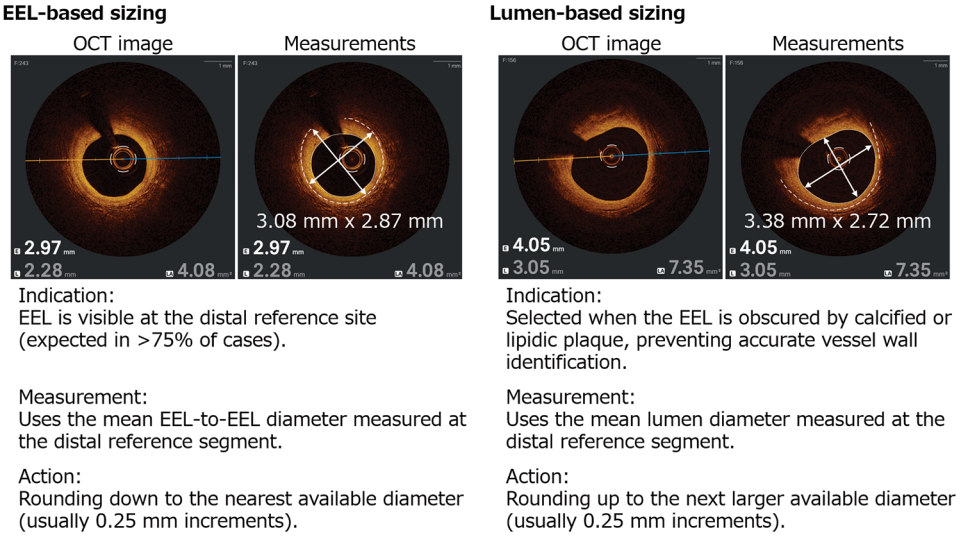

Figure 5. EEL- and lumen-based stent sizing. The left panels: EEL-based sizing is the preferred method when the external elastic lamina (EEL) is visible at the distal reference site, which is expected in over 75% of cases. The stent diameter is determined by measuring the mean EEL-to-EEL diameter and rounding down to the nearest available stent size (usually in 0.25 mm increments). This approach ensures the stent size is matched to the actual vessel wall dimensions. The right panels: Lumen-based sizing is used when the EEL is obscured by calcified or lipidic plaque, preventing a clear measurement of the vessel wall at the distal reference. The stent diameter is determined by measuring the mean lumen diameter and rounding up to the next larger available stent size. This method provides a safe alternative for sizing when the outer boundaries of the vessel are not identifiable.

OCT sizing falls back to a lumen-based strategy. In that setting, the mean distal lumen diameter is used and generally rounded up to the next available stent size (Figure 5). The proximal reference is then used mainly to guide post-dilatation balloon sizing rather than the nominal stent diameter itself. For example, if the distal reference lumen measures 2.9×2.8 mm, the mean lumen diameter is 2.85 mm, and thus a 3.0 mm stent diameter should be chosen. In the ILUMIEN III substudy[50], an EEL-guided stent sizing selected larger stent diameters than a lumen-guided approach, with potentially hazardous oversizing. In the OPINION imaging substudy[51], the lumen-based PCI with OCT guidance was associated with a trend toward a smaller MSA than that with IVUS guidance, but with fewer proximal stent-edge hematomas, resulting in a similar minimum lumen area at 8-month follow-up. Taken together, these findings support that contemporary OCT-guided stent sizing increasingly relies on either lumen-based sizing in an appropriate distal reference segment or sizing according to the actual distal vessel diameter when the EEL can be delineated adequately. To cover residual disease adjacent to the lesion, thus minimizing geographic miss, stent length is determined by the distance between the chosen distal and proximal landing zones, the healthiest practical reference segments (normal or at least fibrous or calcified segment) visible on the OCT pullback.

Postprocedure Assessment and Complications

Post-PCI intravascular imaging should confirm optimal stenting and identify acute complications, including edge dissection, stent malapposition, and tissue protrusion. In IVUS-guided PCI, the ULTIMATE criteria[47] remain the most widely used standardized benchmark: MSA >5.0 mm² or >90% of the distal reference lumen area, plaque burden <50% within 5 mm of either stent edge, and no edge dissection extending into the media for >3 mm. In OCT-guided PCI, the post-PCI component of the MLD-MAX algorithm[31] focuses on medial dissection, apposition, and expansion. Standardized optimization (Table 5) appears to matter clinically: in a recent RENOVATE-COMPLEX-PCI imaging analysis[52], inadequate absolute expansion together with residual underexpansion, major malapposition, or major dissection was associated with a higher risk of target lesion failure.

MSA and Stent Expansion

Post-PCI MSA is strongly associated with restenosis and stent thrombosis. An absolute IVUS criterion of achieving optimal stent expansion of

Table 5. Imaging-derived targets for post-PCI optimization with IVUS and OCT

Parameter	IVUS criterion	OCT criterion	Clinical relevance	Potential indication for further optimization
Minimal stent area (MSA)	In non-left main PCI, an MSA >5.0 mm^2 was used in ULTIMATE. MSA >5.0-5.5 mm^2, or MSA/distal reference lumen area >90%, was associated with improved long-term hard clinical outcomes[47,97].	No single universal OCT-derived absolute cutoff has been established. An MSA <4.5-5.0 mm^2 has been associated with adverse outcomes[54,55].	Smaller post-PCI stent area is consistently associated with restenosis and target lesion failure.	Additional optimization may be considered when MSA remains below the intended threshold or when focal underexpansion is identified.
Stent expansion	Relative stent expansion ≥80% of the mean reference area or ≥90% of the distal reference area has commonly been used; absolute MSA appears to provide stronger prognostic value than stent expansion[47,58,98].	A ≥90% of the reference lumen area has been used as the procedural optimization goal[6,18], whereas <70% identifies underexpansion[65,99], a ≥80% may be considered a pragmatic target for acceptable expansion	Inadequate expansion is a major determinant of stent failure and worse clinical outcomes.	Further post-dilatation may be considered when relative or absolute expansion remains suboptimal.
Geographic miss/ Residual edge disease	Landing zones should be selected to ensure complete lesion coverage and to avoid deploying stent edges on lipid-rich plaque, with a plaque burden <50-55% at both stent edges (typically within 5 mm of the stent edge)[48,100].	Complete lesion coverage should be achieved to avoid reference-segment disease, especially lipid plaque, at the stent margins; residual edge disease within 5 mm of the stent edge, defined as MLA <4.5 mm^2, may justify additional stent coverage or further optimization.	Geographic miss/residual disease at the stent edge contributes to edge restenosis and repeat revascularization.	Additional treatment may be considered when a more suitable landing zone can be achieved or when substantial residual disease (residual edge plaque burden ≥50%) is present at the edge.
Edge dissection	Large or extensive edge dissection involving the media with a length >3 mm, particularly when associated with lumen compromise or intramural hematoma, is generally regarded as unfavorable[47,100].	Major edge dissection has generally been defined by substantial circumferential extent and length (in ILUMIEN IV, ≥60° of vessel circumference and ≥3 mm in length), whereas CLI-OPCI II identified distal edge dissection with flap thickness >200 μm as a clinically relevant threshold[6,65].	Minor edge dissections are frequently clinically benign, whereas extensive dissections or those associated with intramural hematoma, residual lumen compromise, or impaired flow are more likely to be clinically relevant and have been linked to adverse outcomes.	Additional treatment may be considered for major dissection, lumen compromise, hematoma extension, or impaired flow.
Malapposition	No universal threshold has been established for post-PCI malapposition. Current consensus documents emphasize descriptive assessment of residual incomplete stent apposition, including its presence and extent (e.g., arc and/ or length)[67,100].	In OCT-guided PCI, extensive acute malapposition is defined as a maximal distance >0.4 mm and longitudinal extension >1 mm[67].	Acute malapposition is common after PCI, although its prognostic significance appears weaker than that of underexpansion or edge pathology.	Further optimization may be considered when malapposition is extensive.
Tissue protrusion/ thrombus	No widely accepted IVUS-based quantitative threshold is available in current consensus documents; in practice, attention should be directed to the presence, extent, morphology, and any associated flow impairment or concomitant underexpansion[67,100].	Smooth tissue protrusion is frequently observed after stenting, whereas larger (a maximum protrusion angle ≥180°), irregular, or thrombotic protrusion has been associated with less favorable outcomes, particularly in ACS[71-73].	Smooth protrusion with adequate stent expansion and preserved flow may often be managed conservatively. Large, irregular protrusion may be linked to adverse clinical outcomes.	Further optimization may be considered when protrusion is large, irregular, associated with lumen compromise or impaired flow, or accompanied by stent underexpansion, major malapposition, or substantial residual thrombus burden.

ACS=acute coronary syndrome; IVUS=intravascular ultrasound; OCT=optical coherence tomography; MLA=minimum lumen area; PCI=percutaneous coronary intervention

MSA >5.0-5.5 mm^2, or MSA/distal reference lumen area >90%, was associated with the most favorable clinical outcomes[53]. In the OCT guidance, previous analyses have consistently identified an MSA <4.5-5.0 mm^2 as a predictor of subsequent cardiac events[54,55]. However, these cutoffs do not define optimal stenting, and a larger MSA is still associated with less coronary artery restenosis until a plateau is reached at an MSA of ~8 mm^2. Moreover, for left main PCI optimization, the classic IVUS-derived "Kang rule" remains the main reference, with target MSAs of 5.0 mm^2 (ostium of left circumflex artery), 6.3 mm^2 (ostium of left anterior descending coronary artery [LAD]), 7.2 mm^2 (polygon of confluence [POC]), and 8.2 mm^2 (left main coronary artery [LM] above the POC)[56]. OPTIVUS criteria[57] simplified these thresholds to 5-6-7-8 mm^2, providing a practical framework for IVUS-guided LM stent optimization. Thus, in daily practice, achieving these segmental MSA targets remains a reasonable goal, particularly in distal LM bifurcation PCI.

Stent underexpansion is also common in both early stent thrombosis and in-stent restenosis. Stent expansion ≥80% of the mean reference area has commonly been used in IVUS-guided PCI[58]. However, stent expansion is not defined in a single way. In the ADAPT-DES IVUS substudy[59], 10 different expansion indices were examined, including absolute MSA and several normalized ratios using distal reference, average reference, or vessel area, and only the ratio of MSA to vessel area at the MSA

site independently predicted lesion-specific 2-year clinically driven target-lesion revascularization or definite stent thrombosis. In the widely used OCT platform, Ultreon™ 2.0 software (Abbott, Abbott Park, IL, USA), automatic post-PCI stent expansion assessment commonly relies on a tapered reference (or dual-reference) approach. Thus, although expansion should generally reach at least 80% to 90% of the relevant reference area, the measured expansion index depends on which reference is used[47,59].

Geographic Miss and Edge Dissection

Geographic miss refers to failure to fully cover the diseased or pre-ballooned segment with the stent, so that the landing zone is placed on residual plaque or untreated edge disease[60]. In IVUS studies, residual plaque burden at the reference segment has predicted edge restenosis, with a threshold around 50% to 55% after newer-generation DES implantation[48]. OCT studies have reached similar results: the independent predictors of binary angiographic stent edge restenosis at 9-12 months were lipidic plaque (optimal cutoff was a lipid arc ≥185°) and minimal lumen area (optimal cutoff was 4.1 mm²) in the stent edge segment[61].

Edge dissection is an important post-PCI finding, but its clinical significance depends on depth, length, circumferential extent, and the residual lumen rather than on its mere presence. The ULTIMATE criteria[47] recommend confirming the absence of edge dissection extending into the media for >3 mm by using IVUS. IVUS-detected residual edge dissection has been associated with subsequent target lesion revascularization, particularly when the effective lumen area within the dissection is small, around 5.0 mm² or less[62]. OCT is more sensitive than IVUS for detecting post-stent edge injury, and in ILUMIEN III, untreated edge dissections were seen more often after IVUS-guided or angiography-guided PCI than after OCT-guided PCI[18,63]. However, this should not be interpreted as meaning that every OCT-detected dissection is clinically important. In serial OCT follow-up of 22 edge dissections, most angiographically silent, non-flow-limiting edge dissections healed spontaneously, and no target lesion revascularization was observed at 1 year[64]. What appears to matter most is the morphology of the residual edge dissection. In the CLI-OPCI II study, a distal edge dissection >200 μm together with residual edge narrowing with a minimal lumen area <4.5 mm² predicted later adverse events[65]. Consistent with this, a contemporary analysis from ILUMIEN IV and other studies suggests that OCT-detected stent edge dissection is associated with a higher risk of major adverse cardiovascular events[55,66]. Small, non-flow-limiting edge dissections can often be observed, whereas large (dissection flap ≥60°), deep (media-involving), extend longitudinally for several millimeters, lumen-compromising dissections, or those with intramural hematoma may require additional stenting, because true-lumen compromise in this setting may precipitate acute vessel closure.

Malapposition

There is no single universal definition of clinically relevant post-stent malapposition. When the same lesions were evaluated by both IVUS and OCT, OCT can detect acute malapposition more. By IVUS, incomplete stent apposition is generally defined qualitatively as separation of at least 1 stent strut from the vessel wall, outside a side-branch ostium, with blood speckle visible behind the strut, whereas by OCT it is defined quantitatively according to the strut-to-vessel wall distance relative to strut thickness and axial resolution; accordingly, the diagnostic threshold varies by stent platform. Current expert consensus suggests that extensive acute malapposition with a maximal distance >0.4 mm and longitudinal extension >1 mm should be avoided or corrected whenever feasible[67]. In OCT studies, however, these thresholds were not associated with excess 5-year adverse events[68]. By contrast, more extensive malapposition burden appears to be clinically relevant: total malapposition volume ≥7.0 mm³ predicted major safety events, suggesting that volumetric extent may be more informative than distance alone[69].

Tissue Protrusion

Tissue protrusion, or plaque/thrombus prolapse through the stent struts, is a frequent post-PCI imaging finding, particularly in thrombotic or otherwise unstable lesions. However, IVUS-detected tissue protrusion was not associated with excess 2-year major adverse cardiac events; indeed, lesions with tissue protrusion had larger final luminal dimensions and less clinically driven target-lesion revascularization, suggesting that protrusion itself is not uniformly detrimental when accompanied by adequate stent expansion[70]. By contrast, OCT-defined irregular protrusion has been consistently linked to worse outcomes. Irregular protrusion was a predictor of 1-year device-oriented clinical events, largely driven by repeat revascularization[71]. Similarly, in the CLI-OPCI ACS substudy, residual intrastent plaque/thrombus protrusion predicted device-oriented cardiovascular events in ACS patients after PCI[72]. More recently,

among STEMI lesions with OCT-detected irregular protrusion, a maximum protrusion angle ≥180° was associated with a markedly higher 1-year event rate than smaller protrusions (12.5% vs 1.5%)[73].

Barriers to Implementation and Future Directions

Despite growing randomized evidence and current guideline recommendations, routine use of intravascular imaging in PCI remains limited by practical barriers, including added cost, longer procedure time, and the need for expertise in image acquisition and interpretation[74]. Recent health-economic analyses nevertheless suggest that IVUS-guided PCI may be cost-effective over time by reducing repeat revascularization and other adverse events[75,76]. Use of intravascular imaging also varies markedly by region. Despite the recommendations of current guidelines, real-world adoption of intravascular imaging in PCI has also varied markedly by region. Intravascular imaging was used in 10% of PCI in the United States[74], versus approximately 84% for IVUS-guided PCI in Japan[77] and 11.3% to 14.5% in Thailand[78], depending on adjunctive-use criteria. These differences likely reflect not only the evidence base, but also reimbursement, local training patterns, and operator preference. Several emerging technologies may help overcome these barriers. Artificial intelligence-based analysis could shorten interpretation time, reduce operator dependence, and improve measurement standardization[79]. Integration of intravascular imaging with coronary physiology may further refine PCI decision-making by combining information on lesion function with plaque morphology and procedural optimization[80]. Another important future direction is preventive PCI for non-flow-limiting vulnerable plaque. In the PREVENT trial, imaging-guided preventive PCI reduced the 2-year primary endpoint compared with optimal medical therapy alone in patients with vulnerable plaques and non-ischemic fractional flow reserve[81]. At the same time, the absolute event rate of vulnerable plaques progressing to myocardial infarction remains relatively low, and prior natural-history studies have shown that plaque morphology alone is often insufficient to identify the lesions that will actually cause future events[30,82]. Therefore, the next challenge is not only to detect vulnerable plaque, but also to improve the precision with which lesions truly destined to cause ACS can be identified. In this context, NIRS-IVUS and emerging NIRS-OCT systems may provide complementary information by combining structural plaque assessment with lipid-rich plaque detection. Such multimodality imaging may help refine plaque-risk stratification, although whether NIRS-guided treatment decisions improve clinical outcomes remains to be established.

Conclusion

Intravascular imaging has moved PCI guidance beyond angiography alone by allowing more accurate assessment of lesion morphology, vessel size, stent expansion, and procedure-related complications. Randomized trials have shown that both IVUS- and OCT-guided PCI improve procedural optimization and reduce adverse cardiovascular events compared with angiography-guided PCI, particularly in complex lesions. These findings are now reflected in contemporary guidelines, which support the use of intravascular imaging in selected patients and lesion subsets during PCI. Although IVUS and OCT offer different strengths, both can improve outcomes when used in a structured manner. Broader adoption and future advances in automation, physiology integration, and plaque-risk stratification may further expand the role of imaging-guided PCI.

Author Contributions

YS conceived the review, performed the literature review, drafted the manuscript, and approved the final version.

Clinical Trial Registration

Not applicable. This manuscript is a state-of-the-art review and does not report a clinical trial.

Conflicts of Interest

The author declares no conflict of interest

Data Availability Statement

Not applicable. No datasets were generated or analyzed in the present article.

Ethics Approval and Consent to Participate

Not applicable. This article is a review and does not involve human participants, human data, or animal experiments.

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Use of Artificial Intelligence

During the preparation of this manuscript, the

author used ChatGPT for language editing. The author reviewed and edited all content and takes full responsibility for the final manuscript.

References

1. Gruntzig A. Transluminal dilatation of coronary-artery stenosis. Lancet 1978;1:263. doi: 10.1016/s0140-6736(78)90500-7.
2. Grüntzig AR, Senning A, Siegenthaler WE. Nonoperative dilatation of coronary-artery stenosis: Percutaneous transluminal coronary angioplasty. N Engl J Med 1979;301:61-8.
3. Mintz GS, Popma JJ, Pichard AD, Kent KM, Satler LF, Chuang YC, et al. Limitations of angiography in the assessment of plaque distribution in coronary artery disease: A systematic study of target lesion eccentricity in 1446 lesions. Circulation 1996;93:924-31.
4. Mézquita AJV, Biavati F, Falk V, Alkadhi H, Hajhosseiny R, Maurovich-Horvat P, et al. Clinical quantitative coronary artery stenosis and coronary atherosclerosis imaging: A consensus statement from the quantitative cardiovascular imaging study group. Nat Rev Cardiol 2023;20:696-714.
5. Wijns W, Shite J, Jones MR, Lee SW, Price MJ, Fabbiocchi F, et al. Optical coherence tomography imaging during percutaneous coronary intervention impacts physician decision-making: ILUMIEN I study. Eur Heart J 2015;36:3346-55.
6. Ali ZA, Landmesser U, Maehara A, Matsumura M, Shlofmitz RA, Guagliumi G, et al. Optical coherence tomography-guided versus angiography-guided PCI. N Engl J Med 2023;389:1466-76.
7. van Zandvoort LJC, Masdjedi K, Witberg K, Ligthart J, Tovar Forero MN, Diletti R, et al Explanation of postprocedural fractional flow reserve below 0.85. Circ Cardiovasc Interv 2019;12:e007030. doi: 10.1161/CIRCINTERVENTIONS.118.007030.
8. Tearney GJ, Waxman S, Shishkov M, Vakoc BJ, Suter MJ, Freilich MI, et al. Three-dimensional coronary artery microscopy by intracoronary optical frequency domain imaging. JACC Cardiovasc Imaging 2008;1:752-61.
9. Yock PG, Linker DT, Angelsen BA. Two-dimensional intravascular ultrasound: Technical development and initial clinical experience. J Am Soc Echocardiogr 1989;2:296-304.
10. Huang D, Swanson EA, Lin CP, Schuman JS, Stinson WG, Chang W, et al. Optical coherence tomography. Science 1991;254:1178-81.
11. Bom N, Lancée CT, Van Egmond FC. An ultrasonic intracardiac scanner. Ultrasonics 1972;10:72-6.
12. Lawton JS, Tamis-Holland JE, Bangalore S, Bates ER, Beckie TM, Bischoff JM, et al. 2021 ACC/AHA/SCAI guideline for coronary artery revascularization: A report of the American College of Cardiology/American Heart Association Joint Committee on clinical practice guidelines. J Am Coll Cardiol 2022;79:e21-129.
13. Byrne RA, Rossello X, Coughlan JJ, Barbato E, Berry C, Chieffo A, et al. 2023 ESC guidelines for the management of acute coronary syndromes. Eur Heart J 2023;44:3720-826.
14. Vrints C, Andreotti F, Koskinas KC, Rossello X, Adamo M, Ainslie J, et al. 2024 ESC guidelines for the management of chronic coronary syndromes. Eur Heart J 2024;45:3415-537.
15. Stone GW, Christiansen EH, Ali ZA, Andreasen LN, Maehara A, Ahmad Y, et al. Intravascular imaging-guided coronary drug-eluting stent implantation: An updated network meta-analysis. Lancet 2024;403:824-37.
16. Carvalho PEP, Antunes VLJ, Bittar de Pontes V, Gomes WF, Polachini Assunes Goncalves B, Caixeta A, et al. IVUS, OCT, or angiography as guidance for PCI in complex coronary artery lesions: Network meta-analysis of randomized controlled trials. JACC Cardiovasc Interv 2026;19:31-43.
17. Lee JM, Kim O, Song YB, Lee JY, Lee SJ, Lee SY, et al. Intravascular imaging- vs angiography-guided complex PCI: 5-year outcomes from a randomized trial. J Am Coll Cardiol 2026;87:2099-113.
18. Ali ZA, Maehara A, Généreux P, Shlofmitz RA, Fabbiocchi F, Nazif TM, et al. Optical coherence tomography compared with intravascular ultrasound and with angiography to guide coronary stent implantation (ILUMIEN III: OPTIMIZE PCI): A randomised controlled trial. Lancet 2016;388:2618-28.
19. Diletti R, Daemen J, Faurie B, Barbierato M, Tchétché D, Hovasse T, et al. Intravascular ultrasound-guided or angiography-guided complex high-risk PCI. N Engl J Med 2026;394:2200-11.
20. Testa L, De la Torre Hernandez JM, De Maria GL, Jones DA, Piñon-Esteban P, Campo G, et al. IVUS-guided versus angiography-guided PCI in unprotected left main coronary disease. N Engl J Med 2026;394:2189-99.
21. Gerbaud E, Weisz G, Tanaka A, Kashiwagi M, Shimizu T, Wang L, et al. Multi-laboratory inter-institute reproducibility study of IVOCT and IVUS assessments using published consensus document definitions. Eur Heart J Cardiovasc Imaging 2016;17:756-64.
22. Kubo T, Akasaka T, Shite J, Suzuki T, Uemura S, Yu B, et al. OCT compared with IVUS in a coronary lesion assessment: the OPUS-CLASS study. JACC Cardiovasc Imaging 2013;6:1095-104.
23. Sawada T, Shite J, Negi N, Shinke T, Tanino Y, Ogasawara D, et al. Factors that influence measurements and accurate evaluation of stent apposition by optical coherence tomography. Assessment using a phantom model. Circ J 2009;73:1841-7.
24. Prati F, Di Vito L, Biondi-Zoccai G, Occhipinti M, La Manna A, Tamburino C, et al. Angiography alone versus angiography plus optical coherence tomography to guide decision-making during percutaneous coronary intervention: The Centro per la Lotta Contro l'Infarto-Optimisation of Percutaneous Coronary Intervention (CLI-OPCI) study. EuroIntervention 2012;8:823-9.

25. Meneveau N, Souteyrand G, Motreff P, Caussin C, Amabile N, Ohlmann P, et al. Optical coherence tomography to optimize results of percutaneous coronary intervention in patients with non-ST-elevation acute coronary syndrome: Results of the multicenter, randomized DOCTORS study (Does Optical Coherence Tomography Optimize Results of Stenting). Circulation 2016;134:906-17.
26. Habara M, Nasu K, Terashima M, Kaneda H, Yokota D, Ko E, et al. Impact of frequency-domain optical coherence tomography guidance for optimal coronary stent implantation in comparison with intravascular ultrasound guidance. Circ Cardiovasc Interv 2012;5:193-201.
27. Kubo T, Shinke T, Okamura T, Hibi K, Nakazawa G, Morino Y, et al. Optical frequency domain imaging vs. intravascular ultrasound in percutaneous coronary intervention (OPINION trial): One-year angiographic and clinical results. Eur Heart J 2017;38:3139-47.
28. Kurogi K, Ishii M, Sakamoto K, Komaki S, Kusaka H, Yamamoto N, et al. Optical coherence tomography-guided percutaneous coronary intervention with low-molecular-weight dextran- effect on renal function. Circ J 2020;84:917-25.
29. Kimura M, Takeda T, Tsujino Y, Matsumoto Y, Yamaji M, Sakaguchi T, et al. Assessing the efficacy of saline flush in frequency-domain optical coherence tomography for intracoronary imaging. Heart Vessels 2024;39:310-8.
30. Erlinge D, Maehara A, Ben-Yehuda O, Bøtker HE, Maeng M, Kjøller-Hansen L, et al. Identification of vulnerable plaques and patients by intracoronary near-infrared spectroscopy and ultrasound (PROSPECT II): A prospective natural history study. Lancet 2021;397:985-95.
31. Shlofmitz E, Croce K, Bezerra H, Sheth T, Chehab B, West NEJ, et al. The MLD MAX OCT algorithm: An imaging-based workflow for percutaneous coronary intervention. Catheter Cardiovasc Interv 2022;100 Suppl 1:S7-13.
32. Kang DY, Ahn JM, Yun SC, Hur SH, Cho YK, Lee CH, et al. Optical coherence tomography-guided or intravascular ultrasound-guided percutaneous coronary intervention: The OCTIVUS randomized clinical trial. Circulation 2023;148:1195-206.
33. Muramatsu T, Ozaki Y, Nanasato M, Ishikawa M, Nagasaka R, Ohota M, et al. Comparison between optical frequency domain imaging and intravascular ultrasound for percutaneous coronary intervention guidance in biolimus A9-eluting stent implantation: A randomized MISTIC-1 non-inferiority trial. Circ Cardiovasc Interv 2020;13:e009314. doi: 10.1161/CIRCINTERVENTIONS.120.009314.
34. Otake H, Kubo T, Hibi K, Natsumeda M, Ishida M, Kataoka T, et al. Optical frequency domain imaging-guided versus intravascular ultrasound-guided percutaneous coronary intervention for acute coronary syndromes: The OPINION ACS randomised trial. EuroIntervention 2024;20:e1086-97.
35. Stone GW, Genereux P, Maehara A, Lewis BE, Shlofmitz RA, Dohad S, et al. Intravascular imaging vs angiography guidance for PCI of severely calcified lesions: The ECLIPSE trial. JACC Cardiovasc Interv 2025;18:2338-51.
36. Zhang M, Matsumura M, Usui E, Noguchi M, Fujimura T, Fall KN, et al. Intravascular ultrasound-derived calcium score to predict stent expansion in severely calcified lesions. Circ Cardiovasc Interv 2021;14:e010296. doi: 10.1161/CIRCINTERVENTIONS.120.010296.
37. Fujino A, Mintz GS, Matsumura M, Lee T, Kim SY, Hoshino M, et al. A new optical coherence tomography-based calcium scoring system to predict stent underexpansion. EuroIntervention 2018;13:e2182-9.
38. Sato T, Matsumura M, Yamamoto K, Sugizaki Y, Shlofmitz E, Moses JW, et al. A revised optical coherence tomography-derived calcium score to predict stent underexpansion in severely calcified lesions. JACC Cardiovasc Interv 2025;18:622-33.
39. Ikari Y, Saito S, Nakamura S, Shibata Y, Yamazaki S, Tanaka Y, et al. Device indication for calcified coronary lesions based on coronary imaging findings. Cardiovasc Interv Ther 2023;38:163-5.
40. Riley RF, Patel MP, Abbott JD, Bangalore S, Brilakis ES, Croce KJ, et al. SCAI expert consensus statement on the management of calcified coronary lesions. J Soc Cardiovasc Angiogr Interv 2024;3:101259. doi: 10.1016/j.jscai.2023.101259.
41. Li X, Ge Z, Kan J, Anjum M, Xie P, Chen X, et al. Intravascular ultrasound-guided versus angiography-guided percutaneous coronary intervention in acute coronary syndromes (IVUS-ACS): A two-stage, multicentre, randomised trial. Lancet 2024;403:1855-65.
42. Xing L, Yamamoto E, Sugiyama T, Jia H, Ma L, Hu S, et al. EROSION study (effective anti-thrombotic therapy without stenting: intravascular optical coherence tomography-based management in plaque erosion): A 1-year follow-up report. Circ Cardiovasc Interv 2017;10:e005860. doi: 10.1161/CIRCINTERVENTIONS.117.005860.
43. Kondo S, Mizukami T, Kobayashi N, Wakabayashi K, Mori H, Yamamoto MH, et al. Diagnosis and prognostic value of the underlying cause of acute coronary syndrome in optical coherence tomography-guided emergency percutaneous coronary intervention. J Am Heart Assoc 2023;12:e030412. doi: 10.1161/JAHA.123.030412.
44. Onuma Y, Kogame N, Sotomi Y, Miyazaki Y, Asano T, Takahashi K, et al. A randomized trial evaluating online 3-dimensional optical frequency domain imaging-guided percutaneous coronary intervention in bifurcation lesions. Circ Cardiovasc Interv 2020;13:e009183. doi: 10.1161/CIRCINTERVENTIONS.120.009183.
45. Holm NR, Andreasen LD, Neghabat O, Laanmets P, Kumsars I, Bennett J, et al. OCT or angiography

guidance for PCI in complex bifurcation lesions. N Engl J Med 2023;389:1477-87.
46. Maehara A, Matsumura M, Ali ZA, Mintz GS, Stone GW. IVUS-guided versus OCT-guided coronary stent implantation: A critical appraisal. JACC Cardiovasc Imaging 2017;10:1487-503.
47. Zhang J, Gao X, Kan J, Ge Z, Han L, Lu S, et al. Intravascular ultrasound versus angiography-guided drug-eluting stent implantation: The ULTIMATE trial. J Am Coll Cardiol 2018;72:3126-37.
48. Kang SJ, Cho YR, Park GM, Ahn JM, Kim WJ, Lee JY, et al. Intravascular ultrasound predictors for edge restenosis after newer generation drug-eluting stent implantation. Am J Cardiol 2013;111:1408-14.
49. Liu J, Maehara A, Mintz GS, Weissman NJ, Yu A, Wang H, et al. An integrated TAXUS IV, V, and VI intravascular ultrasound analysis of the predictors of edge restenosis after bare metal or paclitaxel-eluting stents. Am J Cardiol 2009;103:501-6.
50. Shlofmitz E, Jeremias A, Parviz Y, Karimi Galougahi K, Redfors B, Petrossian G, et al. External elastic lamina vs. luminal diameter measurement for determining stent diameter by optical coherence tomography: An ILUMIEN III substudy. Eur Heart J Cardiovasc Imaging 2021;22:753-9.
51. Otake H, Kubo T, Takahashi H, Shinke T, Okamura T, Hibi K, et al. Optical frequency domain imaging versus intravascular ultrasound in percutaneous coronary intervention (OPINION Trial): Results from the OPINION imaging study. JACC Cardiovasc Imaging 2018;11:111-23.
52. Lee JM, Lee SY, Kwon W, Lee SJ, Lee JY, Lee SH, et al. Intravascular imaging predictors associated with cardiovascular events after complex PCIs. Circ Cardiovasc Interv 2025;18:e014920. doi: 10.1161/CIRCINTERVENTIONS.124.014920.
53. Lee YJ, Zhang JJ, Mintz GS, Hong SJ, Ahn CM, Kim JS, et al. Impact of intravascular ultrasound-guided optimal stent expansion on 3-year hard clinical outcomes. Circ Cardiovasc Interv 2021;14:e011124. doi: 10.1161/CIRCINTERVENTIONS.121.011124.
54. Romagnoli E, Burzotta F, Vergallo R, Gatto L, Biondi-Zoccai G, Ramazzotti V, et al. Clinical impact of OCT-derived suboptimal stent implantation parameters and definitions. Eur Heart J Cardiovasc Imaging 2023;25:48-57.
55. Landmesser U, Ali ZA, Maehara A, Matsumura M, Shlofmitz RA, Guagliumi G, et al. Optical coherence tomography predictors of clinical outcomes after stent implantation: The ILUMIEN IV trial. Eur Heart J 2024;45:4630-43.
56. Kang SJ, Ahn JM, Song H, Kim WJ, Lee JY, Park DW, et al. Comprehensive intravascular ultrasound assessment of stent area and its impact on restenosis and adverse cardiac events in 403 patients with unprotected left main disease. Circ Cardiovasc Interv 2011;4:562-9.
57. Nishikawa R, Shiomi H, Yamamoto K, Morimoto T, Miyazawa A, Ando K, et al. Optimal intravascular ultrasound-guided percutaneous coronary intervention in patients with left main coronary artery disease: The OPTIVUS-complex PCI study LMCA cohort. Am J Cardiol 2026;259:202-11.
58. Lee JM, Choi KH, Song YB, Lee JY, Lee SJ, Lee SY, et al. Intravascular imaging-guided or angiography-guided complex PCI. N Engl J Med 2023;388:1668-79.
59. Fujimura T, Matsumura M, Witzenbichler B, Metzger DC, Rinaldi MJ, Duffy PL, et al. Stent expansion indexes to predict clinical outcomes: An IVUS substudy from ADAPT-DES. JACC Cardiovasc Interv 2021;14:1639-50.
60. Abouelnour A, Gori T. Intravascular imaging in coronary stent restenosis: Prevention, characterization, and management. Front Cardiovasc Med 2022;9:843734. doi: 10.3389/fcvm.2022.843734.
61. Ino Y, Kubo T, Matsuo Y, Yamaguchi T, Shiono Y, Shimamura K, et al. Optical coherence tomography predictors for edge restenosis after everolimus-eluting stent implantation. Circ Cardiovasc Interv 2016;9:e004231. doi: 10.1161/CIRCINTERVENTIONS.116.004231.
62. Kobayashi N, Mintz GS, Witzenbichler B, Metzger DC, Rinaldi MJ, Duffy PL, et al. Prevalence, features, and prognostic importance of edge dissection after drug-eluting stent implantation: An ADAPT-DES intravascular ultrasound substudy. Circ Cardiovasc Interv 2016;9:e003553. doi: 10.1161/CIRCINTERVENTIONS.115.003553.
63. Ali ZA, Karimi Galougahi K, Maehara A, Shlofmitz RA, Fabbiocchi F, Guagliumi G, et al. Outcomes of optical coherence tomography compared with intravascular ultrasound and with angiography to guide coronary stent implantation: One-year results from the ILUMIEN III: OPTIMIZE PCI trial. EuroIntervention 2021;16:1085-91.
64. Radu MD, Räber L, Heo J, Gogas BD, Jørgensen E, Kelbæk H, et al. Natural history of optical coherence tomography-detected non-flow-limiting edge dissections following drug-eluting stent implantation. EuroIntervention 2014;9:1085-94.
65. Prati F, Romagnoli E, Burzotta F, Limbruno U, Gatto L, La Manna A, et al. Clinical impact of OCT findings during PCI: The CLI-OPCI II study. JACC Cardiovasc Imaging 2015;8:1297-305.
66. Jinnouchi H, Sakakura K, Yanase T, Ugata Y, Tsukui T, Taniguchi Y, et al. Impact of stent edge dissection detected by optical coherence tomography after current-generation drug-eluting stent implantation. PLoS One 2021;16:e0259693. doi: 10.1371/journal.pone.0259693.
67. Räber L, Mintz GS, Koskinas KC, Johnson TW, Holm NR, Onuma Y, et al. Clinical use of intracoronary imaging. Part 1: guidance and optimization of coronary interventions. An expert consensus document of the European Association of Percutaneous Cardiovascular Interventions. Eur Heart J 2018;39:3281-300.
68. Lee SY, Im E, Hong SJ, Ahn CM, Kim JS, Kim BK, et al. Severe acute stent malapposition after drug-eluting stent

implantation: Effects on long-term clinical outcomes. J Am Heart Assoc 2019;8:e012800. doi: 10.1161/JAHA.119.012800.
69. Kim BG, Kachel M, Kim JS, Guagliumi G, Kim C, Kim IS, et al. Clinical implications of poststent optical coherence tomographic findings: Severe malapposition and cardiac events. JACC Cardiovasc Imaging 2022;15:126-37.
70. Qiu F, Mintz GS, Witzenbichler B, Metzger DC, Rinaldi MJ, Duffy PL, et al. Prevalence and clinical impact of tissue protrusion after stent implantation: An ADAPT-DES intravascular ultrasound substudy. JACC Cardiovasc Interv 2016;9:1499-507.
71. Soeda T, Uemura S, Park SJ, Jang Y, Lee S, Cho JM, et al. Incidence and clinical significance of poststent optical coherence tomography findings: One-year follow-up study from a multicenter registry. Circulation 2015;132:1020-9.
72. Prati F, Romagnoli E, Gatto L, La Manna A, Burzotta F, Limbruno U, et al. Clinical impact of suboptimal stenting and residual intrastent plaque/thrombus protrusion in patients with acute coronary syndrome: The CLI-OPCI ACS substudy (Centro per la Lotta Contro L'Infarto-Optimization of Percutaneous Coronary Intervention in Acute Coronary Syndrome). Circ Cardiovasc Interv 2016;9:e003726. doi: 10.1161/CIRCINTERVENTIONS.115.003726.
73. Kyodo A, Soeda T, Okamura A, Iwai S, Sakagami A, Nogi K, et al. Clinical impact of irregular protrusion angle after coronary stenting at culprit lesions with ST-elevation myocardial infarction- An intravascular optical coherence tomography study. Circ Rep 2021;3:431-9.
74. Fazel R, Yeh RW, Cohen DJ, Rao SV, Li S, Song Y, et al. Intravascular imaging during percutaneous coronary intervention: Temporal trends and clinical outcomes in the USA. Eur Heart J 2023;44:3845-55.
75. Hong D, Lee J, Lee H, Cho J, Guallar E, Choi KH, et al. Cost-effectiveness of intravascular imaging-guided complex PCI: prespecified analysis of RENOVATE-COMPLEX-PCI trial. Circ Cardiovasc Qual Outcomes 2024;17:e010230. doi: 10.1161/CIRCOUTCOMES.123.010230.
76. Sharp ASP, Kinnaird T, Curzen N, Ayyub R, Alfonso JE, Mamas MA, et al. Cost-effectiveness of intravascular ultrasound-guided percutaneous intervention in patients with acute coronary syndromes: A UK perspective. Eur Heart J Qual Care Clin Outcomes 2024;10:677-88.
77. Kuno T, Miyamoto Y, Numasawa Y, Ueda I, Suzuki M, Noma S, et al. Enhancing coronary intervention outcomes using intravascular ultrasound: Analysis of long-term benefits in a Japanese multicenter registry. J Soc Cardiovasc Angiogr Interv 2023;3:101190. doi: 10.1016/j.jscai.2023.101190.
78. Suwannasom P, Chichareon P, Roongsangmanoon W, Thongtanomkul A, Wongpen A, Muenkaew M, et al. Impact of the adjunctive use criteria for intravascular ultrasound-guided percutaneous coronary intervention and clinical outcomes. Sci Rep 2023;13:711. doi: 10.1038/s41598-022-27250-3.
79. Matsumura M, Mintz GS, Dohi T, Li W, Shang A, Fall K, et al. Accuracy of IVUS-based machine learning segmentation assessment of coronary artery dimensions and balloon sizing. JACC Adv 2023;2:100564. doi: 10.1016/j.jacadv.2023.100564.
80. van Zandvoort LJC, Ali Z, Kern M, van Mieghem NM, Mintz GS, Daemen J. Improving PCI outcomes using postprocedural physiology and intravascular imaging. JACC Cardiovasc Interv 2021;14:2415-30.
81. Park SJ, Ahn JM, Kang DY, Yun SC, Ahn YK, Kim WJ, et al. Preventive percutaneous coronary intervention versus optimal medical therapy alone for the treatment of vulnerable atherosclerotic coronary plaques (PREVENT): A multicentre, open-label, randomised controlled trial. Lancet 2024;403:1753-65.
82. Stone GW, Maehara A, Lansky AJ, de Bruyne B, Cristea E, Mintz GS, et al. A prospective natural-history study of coronary atherosclerosis. N Engl J Med 2011;364:226-35.
83. Kim JS, Kang TS, Mintz GS, Park BE, Shin DH, Kim BK, et al. Randomized comparison of clinical outcomes between intravascular ultrasound and angiography-guided drug-eluting stent implantation for long coronary artery stenoses. JACC Cardiovasc Interv 2013;6:369-76.
84. de la Torre Hernandez JM, Baz Alonso JA, Gómez Hospital JA, Alfonso Manterola F, Garcia Camarero T, Gimeno de Carlos F, et al. Clinical impact of intravascular ultrasound guidance in drug-eluting stent implantation for unprotected left main coronary disease: Pooled analysis at the patient-level of 4 registries. JACC Cardiovasc Interv 2014;7:244-54.
85. Hong SJ, Kim BK, Shin DH, Nam CM, Kim JS, Ko YG, et al. Effect of intravascular ultrasound-guided vs angiography-guided everolimus-eluting stent implantation: The IVUS-XPL randomized clinical trial. JAMA 2015;314:2155-63.
86. Kim BK, Shin DH, Hong MK, Park HS, Rha SW, Mintz GS, et al. Clinical impact of intravascular ultrasound-guided chronic total occlusion intervention with zotarolimus-eluting versus biolimus-eluting stent implantation: Randomized study. Circ Cardiovasc Interv 2015;8:e002592. doi: 10.1161/CIRCINTERVENTIONS.115.002592.
87. Tian NL, Gami SK, Ye F, Zhang JJ, Liu ZZ, Lin S, et al. Angiographic and clinical comparisons of intravascular ultrasound- versus angiography-guided drug-eluting stent implantation for patients with chronic total occlusion lesions: two-year results from a randomised AIR-CTO study. EuroIntervention 2015;10:1409-17.
88. Lee PH, Hong SJ, Kim HS, Yoon YW, Lee JY, Oh SJ, et al. Quantitative coronary angiography vs intravascular ultrasonography to guide drug-eluting stent implantation: A randomized clinical trial. JAMA Cardiol 2024;9:428-35.
89. Antonsen L, Thayssen P, Maehara A, Hansen HS, Junker A, Veien KT, et al. Optical coherence tomography guided

percutaneous coronary intervention with Nobori stent implantation in patients with non-ST-segment-elevation myocardial infarction (OCTACS) trial: Difference in strut coverage and dynamic malapposition patterns at 6 months. Circ Cardiovasc Interv 2015;8:e002446. doi: 10.1161/CIRCINTERVENTIONS.114.002446.
90. Hong SJ, Lee SJ, Lee SH, Lee JY, Cho DK, Kim JW, et al. Optical coherence tomography-guided versus angiography-guided percutaneous coronary intervention for patients with complex lesions (OCCUPI): An investigator-initiated, multicentre, randomised, open-label, superiority trial in South Korea. Lancet 2024;404:1029-39.
91. Amabile N, Rangé G, Landolff Q, Bressollette E, Meneveau N, Lattuca B, et al. OCT vs angiography for guidance of percutaneous coronary intervention of calcified lesions: The CALIPSO randomized clinical trial. JAMA Cardiol 2025;10:666-75.
92. Chamié D, Costa JR Jr, Damiani LP, Siqueira D, Braga S, Costa R, et al. Optical coherence tomography versus intravascular ultrasound and angiography to guide percutaneous coronary interventions: The iSIGHT randomized trial. Circ Cardiovasc Interv 2021;14:e009452. doi: 10.1161/CIRCINTERVENTIONS.120.009452.
93. Buccheri S, Franchina G, Romano S, Puglisi S, Venuti G, D'Arrigo P, et al. Clinical outcomes following intravascular imaging-guided versus coronary angiography-guided percutaneous coronary intervention with stent implantation: A systematic review and Bayesian network meta-analysis of 31 studies and 17,882 patients. JACC Cardiovasc Interv 2017;10:2488-98.
94. Giacoppo D, Laudani C, Occhipinti G, Spagnolo M, Greco A, Rochira C, et al. Coronary angiography, intravascular ultrasound, and optical coherence tomography for guiding of percutaneous coronary intervention: A systematic review and network meta-analysis. Circulation 2024;149:1065-86.
95. Amabile N, Rangé G, Souteyrand G, Godin M, Boussaada MM, Meneveau N, et al. Optical coherence tomography to guide percutaneous coronary intervention of the left main coronary artery: The LEMON study. EuroIntervention 2021;17:e124-31.
96. Adlam D, Alfonso F, Maas A, Vrints C. European society of cardiology, acute cardiovascular care association, SCAD study group: A position paper on spontaneous coronary artery dissection. Eur Heart J 2018;39:3353-68.
97. Gao XF, Ge Z, Kong XQ, Kan J, Han L, Lu S, et al. 3-year outcomes of the ULTIMATE trial comparing intravascular ultrasound versus angiography-guided drug-eluting stent implantation. JACC Cardiovasc Interv 2021;14:247-57.
98. Lee SH, Jin X, Lee YJ, Kan J, Ge Z, Lee SJ, et al. Validation of intravascular ultrasound-defined optimal stent expansion criteria for favorable 1-year clinical outcomes. JACC Cardiovasc Interv 2025;18:2197-205.
99. Yonetsu T, Mizukami T, Yamamoto MH, Shishido K, Saito S, Kobayashi N, et al. Optical coherence tomography-guided stent optimization and clinical outcomes in all-comer patients with ST-elevation myocardial infarction. Eur Heart J Cardiovasc Imaging 2026;27:721-32.
100. Saito Y, Kobayashi Y, Fujii K, Sonoda S, Tsujita K, Hibi K, et al. CVIT 2025 clinical expert consensus document on intravascular ultrasound. Cardiovasc Interv Ther 2025;40:211-25.