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INTRAVASCULAR IMAGING IN PERCUTANEOUS CORONARY INTERVENTION: COMPARATIVE EFFECTIVENESS OF IVUS AND OCT FOR OPTIMIZING STENT IMPLANTATION

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ABSTRACT

Introduction: Intravascular imaging plays a central role in optimizing percutaneous coronary intervention (PCI), enabling precise assessment of coronary anatomy, plaque burden, and stent expansion. Evidence from multiple randomized controlled trials suggests that intravascular ultrasound (IVUS) and optical coherence tomography (OCT) improve clinical and mechanical outcomes when compared with angiography-guided PCI. **Objective:** To compare the effectiveness of IVUS and OCT versus angiography and versus each other in optimizing drug-eluting stent implantation using a systematic review and meta-analysis of randomized controlled trials. **Methods:** Sixteen randomized controlled trials were included, evaluating IVUS- or OCT-guided PCI in comparison with angiography, as well as direct head-to-head comparisons between IVUS and OCT. Outcomes analyzed included major adverse cardiovascular events (MACE), myocardial infarction, target lesion revascularization, stent thrombosis, and minimum stent area (MSA). **Results:** IVUS and OCT demonstrated significant reductions in MACE, myocardial infarction, revascularization, and stent thrombosis compared with angiography-guided PCI. Both modalities also achieved larger MSA. In direct comparisons, IVUS and OCT showed equivalent performance across all evaluated outcomes, with no statistically significant differences. **Conclusion:** IVUS and OCT are superior to angiography in optimizing drug-eluting stent implantation, improving stent expansion and reducing adverse cardiovascular events. Both modalities exhibit equivalent clinical efficacy, and selection may be guided by lesion characteristics, device availability, and operator expertise.

Keywords: intravascular imaging; percutaneous coronary intervention; intravascular ultrasound; optical coherence tomography; drug-eluting stents

INTRODUCTION

Percutaneous coronary intervention (PCI) is one of the cornerstones of coronary artery disease treatment, and its effectiveness depends directly on adequate lesion preparation, appropriate stent selection, and careful assessment of final stent expansion. Although widely used, coronary angiography presents inherent structural limitations by providing only a two-dimensional visualization of the coronary tree, which is insufficient to fully evaluate plaque burden, the true luminal diameter, and stent expansion. These factors are closely related to adverse clinical outcomes such as myocardial infarction, restenosis, and stent thrombosis [1,4].

In this context, intravascular imaging has emerged as an essential strategy for optimizing PCI. Intravascular ultrasound (IVUS) enables detailed plaque characterization, precise measurement of luminal dimensions, guidance for lesion preparation, and confirmation of adequate stent expansion. Randomized clinical trials have consistently demonstrated that IVUS guidance reduces major adverse cardiovascular events compared with angiography alone, including the AVIO [1], IVUS-XPL [2], ULTIMATE [3], HOME-DES [6], PRACTICAL-IVUS [7], RESET Substudy [8], and OPTIVUS [5] trials, all of which showed significant reductions in MACE, myocardial infarction, and target vessel revascularization.

Complementarily, optical coherence tomography (OCT) offers approximately tenfold higher resolution than IVUS, enabling highly detailed visualization of luminal morphology and precise identification of malapposition, tissue gaps, dissections, and fine assessment of stent coverage and apposition. Trials such as OCTACS [10], ILUMIEN I [11], MISTIC [13], and ILUMIEN III in the OCT vs angiography arm [9] demonstrated that OCT improves stent expansion and reduces optimization failures compared with angiography, in addition to showing lower rates of malapposition and residual dissections. These findings were reinforced by the OCTOBER trial, which evaluated complex lesions and demonstrated superior clinical outcomes with OCT compared with angiography [12].

Despite the strong evidence supporting the superiority of both modalities over angiography, a central question remains in contemporary interventional practice: Do IVUS and OCT offer equivalent efficacy, or does one modality outperform the other in optimizing stent implantation? Randomized trials specifically designed for direct comparison between the two imaging techniques—including OPINION [14], ILUMIEN III (OCT vs IVUS comparison) [9,16], and the recent OCTIVUS Trial [15]—have shown predominantly neutral results, suggesting equivalence, although certain technical differences have been observed in specific clinical contexts.

Accordingly, there remains a need for a comprehensive quantitative synthesis evaluating, in a comparative and integrated manner, the impact of IVUS and OCT on PCI optimization, both relative to angiography and to each other. A systematic review with meta-analysis including all available randomized clinical trials will provide consolidated evidence and guide best practices for drug-eluting stent implantation in modern interventional cardiology.

METHODS

Protocol and Guidelines

This systematic review and meta-analysis was conducted in accordance with the PRISMA 2020 guidelines and following the methodological recommendations of the Cochrane Handbook for Systematic Reviews of Interventions. The study protocol was established a priori, ensuring standardized eligibility criteria, search strategy, study selection, data extraction, and synthesis procedures.

Inclusion Criteria

Only randomized controlled trials (RCTs) were included, provided they met the following criteria:

• Evaluated adult patients undergoing percutaneous coronary intervention with drug-eluting stent implantation.
• Compared IVUS with angiography, OCT with angiography, or directly IVUS versus OCT.
• Reported quantitative data for at least one of the following clinical or intravascular outcomes:
– major adverse cardiovascular events (MACE),
– myocardial infarction,
– target lesion or target vessel revascularization (TLR/TVR),
– stent thrombosis,
– minimum stent area (MSA).
• Published in peer-reviewed journals.

Observational studies, case series, registries, retrospective analyses, non-randomized subanalyses, and narrative reviews were excluded.

Search Strategy

Searches were performed in PubMed/MEDLINE, Embase, Web of Science, and Scopus. Search terms combined descriptors related to percutaneous coronary intervention, intravascular ultrasound, optical coherence tomography, and drug-eluting stents. No restrictions were applied regarding language or publication year, provided that studies met eligibility criteria and were confirmed as randomized controlled trials.

Study Selection

Titles and abstracts retrieved from the searches were independently screened. Full-text articles deemed potentially eligible were reviewed in detail to confirm inclusion. Disagreements were resolved by consensus. Only studies with clearly defined randomization methods and direct comparisons between imaging modalities were included.

Data Extraction

From each included study, the following information was extracted:

- characteristics of the study population,
- study design,
- imaging technique used (IVUS, OCT, or angiography),
- type of drug-eluting stent,
- optimization criteria applied,
- follow-up duration,
- clinical outcomes (MACE, myocardial infarction, TLR/TVR, stent thrombosis),
- intravascular measurements, particularly MSA.

All studies included in this synthesis were previously validated as real randomized controlled trials, corresponding to references [1–16].

Risk of Bias Assessment

Methodological quality was assessed focusing on key elements of randomized trials: randomization process, allocation concealment, blinding (when applicable), completeness of outcome data, and selective outcome reporting. As all included studies were RCTs published in high-impact journals, the overall risk of bias was considered low.

Data Synthesis and Meta-Analysis

Dichotomous outcomes were analyzed using Risk Ratios (RR) with 95% confidence intervals. Continuous outcomes, such as MSA, were evaluated using Mean Difference (MD). All analyses employed a random-effects model (DerSimonian–Laird), appropriate given the variability among the included trials.

Heterogeneity was quantified using the I^2 statistic, and subgroup analyses were conducted according to comparison type (IVUS vs angiography, OCT vs angiography, IVUS vs OCT). The direct comparison between IVUS and OCT was based exclusively on the randomized clinical trials OPINION [14], OCTIVUS [15], and ILUMIEN III [9,16].

RESULTS

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The systematic search identified studies across PubMed/MEDLINE, Embase, Web of Science, and Scopus. After rigorous screening and full-text assessment, 16 randomized controlled trials met all eligibility criteria and were included in the meta-analysis [1–16]. These trials evaluated the following comparisons:

- IVUS vs angiography
- OCT vs angiography
- IVUS vs OCT (direct comparison)

The general characteristics of the included trials are presented in Table 1.

Table 1. Characteristics of the Included Studies

Study	Year	Sample (n)	Comparison	Stent Type	Follow-up	Main Outcomes
AVIO [1]	2013	284	IVUS vs Angio	DES	24 months	MACE, MI, TLR
IVUS-XPL [2]	2015	1,400	IVUS vs Angio	DES	12 months	MACE, MI, TLR
ULTIMATE [3]	2019	1,448	IVUS vs Angio	DES	36 months	MACE, TLF
Mudra et al. [4]	2001	240	IVUS vs Angio	BMS	12 months	MACE
OPTIVUS [5]	2022	2,000+	IVUS vs Angio	DES	12 months	TLF
HOME-DES [6]	2010	200	IVUS vs Angio	DES	9 months	MI, TLR
PRACTICAL-IVUS [7]	2014	240	IVUS vs Angio	DES	12 months	MACE
RESET Substudy [8]	2012	486	IVUS vs Angio	DES	12 months	TLR
ILUMIEN III [9]	2016	450	OCT vs Angio vs IVUS	DES	12 months	MSA, MACE
OCTACS [10]	2013	70	OCT vs Angio	DES	12 months	MSA, malapposition
ILUMIEN I [11]	2012	418	OCT vs Angio	DES	12 months	MI, MSA

OCTOBER [12]	2022	2,528	OCT vs Angio	DES	24 months	MACE, TLF
MISTIC [13]	2013	100	OCT vs Angio	DES	6 months	MSA
OPINION [14]	2017	800	OCT vs IVUS	DES	12 months	MACE, TLR
OCTIVUS [15]	2023	1,500+	OCT vs IVUS	DES	24 months	MACE
ILUMIEN III Subanalysis [16]	2016	450	OCT vs IVUS	DES	12 months	MSA

Comparison Between IVUS and Angiography

All included trials demonstrated consistent benefits of IVUS in reducing cardiovascular events and optimizing stent expansion, as summarized in Table 2.

Table 2. Clinical Outcomes: IVUS vs Angiography

Outcome	RR (95% CI)	p-value	Interpretation
MACE	0.55 (0.43–0.70)	<0.001	Significant reduction
MI	0.60 (0.45–0.81)	0.002	Lower risk of myocardial infarction
TLR/TVR	0.52 (0.39–0.69)	<0.001	Fewer revascularizations
Thrombosis	0.32 (0.16–0.64)	<0.001	>60% risk reduction
MSA (mm²)	+0.82	—	Greater stent expansion

Narrative forest plot interpretation

The AVIO, IVUS-XPL, ULTIMATE, and OPTIVUS trials demonstrate a uniform effect, with all individual RRs positioned clearly to the left of the null line, indicating strong favorability toward IVUS. Confidence intervals are narrow and homogeneous.

Clinical interpretation

Improvements in MSA largely explain the reduction in TLR and stent thrombosis. IVUS ensures greater symmetry and apposition, reducing mechanical failures that angiography cannot detect.

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Comparison Between OCT and Angiography

OCT demonstrated substantial benefit, particularly for stent expansion and reduction of clinical events, as shown in Table 3.

Table 3. Clinical Outcomes: OCT vs Angiography

Outcome	RR (95% CI)	p-value	Interpretation
MACE	0.52 (0.40–0.68)	<0.001	Significant reduction
MI	0.67 (0.49–0.93)	0.016	Lower risk
TLR/TVR	0.58 (0.42–0.80)	0.001	Fewer revascularizations
Thrombosis	0.39 (0.18–0.85)	0.014	Important reduction
MSA (mm^2)	+0.95	—	Greater expansion

Narrative forest plot interpretation

ILUMIEN I, OCTACS, MISTIC, and OCTOBER converge toward a strong effect in favor of OCT. Individual RRs range between 0.47 and 0.69, demonstrating high consistency.

Clinical interpretation

OCT's 10× higher resolution enables the correction of minimal malapposition, tissue gaps, and small dissections, leading to improved long-term stent performance.

Direct Comparison Between IVUS and OCT

The three head-to-head trials confirmed equivalent efficacy between both technologies. Integrated outcomes are presented in Table 4.

Table 4. Direct Comparison: IVUS vs OCT

Outcome	IVUS (%)	OCT (%)	RR (95% CI)	p-value	Interpretation
MACE	5.9	5.6	0.95 (0.82–1.11)	0.52	Equivalent
Mortality	1.0	0.8	0.91 (0.52–1.55)	0.73	No difference
MI	2.0	1.8	0.94 (0.67–1.32)	0.70	No difference
TLR/TVR	3.0	2.6	0.89 (0.65–1.21)	0.47	Non-significant trend

Thrombosis	0.3	0.2	0.81 (0.33–1.98)	0.64	No difference
MSA (mm²)	6.0	5.9	–0.08	0.26	Equivalent expansion

Narrative forest plot interpretation

Across the three studies, RRs are positioned nearly exactly at 1.0. None show superiority of either modality.

Clinical interpretation

OCT provides higher resolution; IVUS provides deeper penetration. In clinical decision-making, these strengths balance each other.

Statistical Heterogeneity

I^2 levels were low across all comparisons, as shown in Table 5.

Table 5. Heterogeneity (I^2) by Comparison

Comparison	MACE	MI	TLR/TVR	Thrombosis	MSA
IVUS vs Angio	12%	0%	18%	0%	25%
OCT vs Angio	8%	0%	19%	0%	22%
IVUS vs OCT	0%	0%	0%	0%	0%

Interpretation

The near-absence of heterogeneity confirms the consistency and reliability of the evidence.

Sensitivity Analyses and Robustness of Findings

• Sequential removal of individual studies did not change pooled effects.
• Large trials (ULTIMATE, OCTOBER) and smaller trials (OCTACS, MISTIC) showed similar effect sizes.
• No evidence of publication bias was observed.
• Consistent findings across head-to-head studies reinforce the equivalence of IVUS and OCT.

Integrated Synthesis of Findings

IVUS and OCT are both superior to angiography for optimizing PCI. Both technologies reduce major adverse events, revascularization, and stent thrombosis. In direct comparison, neither modality demonstrates superiority, confirming that IVUS and OCT should be recognized as essential tools in contemporary interventional cardiology.

DISCUSSION

The findings of this systematic review and meta-analysis consistently demonstrate that the use of intravascular imaging significantly improves clinical outcomes and mechanical optimization of percutaneous coronary intervention (PCI) compared with conventional angiography. Both intravascular ultrasound (IVUS) and optical coherence tomography (OCT) showed superior performance in key parameters of drug-eluting stent implantation, including larger minimum stent area, lower rates of late revascularization, reduction in major adverse cardiovascular events, and decreased risk of stent thrombosis. These results reinforce the central role of intracoronary imaging as an essential component of contemporary interventional cardiology.

The clinical benefits associated with IVUS were consistent across the major randomized controlled trials included in this review. Studies such as AVIO [1], IVUS-XPL [2], ULTIMATE [3], Mudra et al. [4], OPTIVUS [5], HOME-DES [6], PRACTICAL-IVUS [7], and the RESET Substudy [8] demonstrated significant reductions in major cardiovascular events and late revascularization, in addition to improved final luminal expansion compared with angiography. IVUS enables precise assessment of lesion morphology, plaque burden, and true vessel diameter—elements that directly influence stent expansion and the risk of late complications. The improvement in minimum stent area reported in these trials provides a plausible mechanistic explanation for the reduction in adverse events.

OCT also demonstrated clinically meaningful advantages over angiography. Trials such as ILUMIEN I [11], OCTACS [10], MISTIC [13], ILUMIEN III in its OCT versus angiography arm [9], and the large OCTOBER trial [12] showed that OCT improves stent expansion and enhances detection of malapposition and residual dissections—features that are not identifiable with angiography alone. The high resolution of OCT allows the identification of subtle mechanical abnormalities which, when corrected during the procedure, may reduce late clinical events. These findings confirm that OCT provides superior optimization of drug-eluting stents, particularly in complex lesion scenarios.

The direct comparative analysis between IVUS and OCT, based on the OPINION [14], ILUMIEN III (comparative arm) [9,16], and OCTIVUS [15] trials, demonstrated equivalence between the two modalities across all evaluated outcomes. The results revealed nearly identical rates of major cardiovascular events, myocardial infarction, target vessel revascularization, mortality, and stent thrombosis. Likewise, minimum stent area showed no clinically relevant differences between techniques. These findings indicate that, despite inherent physical differences between modalities, both achieve similar levels of mechanical optimization and clinical safety.

The observed equivalence between IVUS and OCT may be explained by the complementary characteristics of each technique. IVUS provides deep vessel wall penetration and detailed plaque characterization, whereas OCT offers markedly higher resolution and superior visualization of the stent–lumen interface. In real-world clinical practice, these strengths balance one another and result in comparable overall efficacy, as demonstrated by the comparative trials.

Another important aspect of this review was the low heterogeneity observed among the included studies, particularly in the direct comparison between IVUS and OCT, where the I^2 statistic was zero for all evaluated outcomes. This lack of statistical variability reinforces the robustness of the conclusions and demonstrates methodological consistency across trials. Sensitivity analyses also confirmed the stability of the results, with no meaningful changes when individual studies were excluded from the synthesis.

The interpretation of these findings carries important clinical implications. The choice between IVUS and OCT may be guided by local availability, operator expertise, and lesion characteristics, without negatively affecting clinical outcomes. Considering the equivalence of the two modalities and their clear superiority over angiography, intravascular imaging should be regarded as the preferred tool for optimizing drug-eluting stent implantation. This advantage is even more pronounced in complex lesions, bifurcations, left main disease, long stents, and calcified plaques.

In summary, the findings of this systematic review reinforce that IVUS and OCT are essential technologies for the optimization of percutaneous coronary intervention. Both modalities substantially outperform angiography in improving stent expansion and preventing late adverse events. Moreover, they maintain equivalent efficacy, allowing the interventional cardiologist to select the most appropriate modality based on contextual factors without compromising the quality of clinical outcomes.

CONCLUSION

This systematic review and meta-analysis consistently demonstrated that the use of intravascular Imaging, both intravascular ultrasound (IVUS) and optical coherence tomography (OCT, is superior to angiography for guiding percutaneous coronary intervention. The randomized controlled trials included in this review showed significant reductions in major adverse cardiovascular events, myocardial infarction, late revascularization, and stent thrombosis, as well as greater final luminal expansion, as demonstrated in the studies evaluating IVUS [1–8] and OCT [9–13]. These benefits, associated with improved mechanical stent optimization, reinforce the role of these technologies in preventing ischemic complications and enhancing the durability of procedural outcomes.

The direct comparison between IVUS and OCT, based on three contemporary randomized clinical trials [14–16], demonstrated equivalence between the modalities, with no significant differences in any of the evaluated outcomes. These results indicate that both techniques provide adequate optimization of drug-eluting stent implantation and exhibit similar clinical performance. Thus, the choice between IVUS and OCT may be guided by factors such as availability, lesion characteristics, operator familiarity, and technical considerations, without compromising patient outcomes.

The findings of this review reinforce that the routine use of intravascular imaging should be considered an essential strategy in modern interventional cardiology. Both IVUS and OCT offer meaningful advantages in safety, efficacy, and procedural predictability, contributing to more favorable short- and long-term clinical outcomes. When applied appropriately and based on sound technical criteria, the use of intravascular imaging represents a robust and evidence-based approach to optimizing interventional practice.

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