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Review Article

A solution to improve the resolution: a comprehensive review of optical coherence tomography in coronary interventions

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ABSTRACT

Intracoronary imaging, specifically optical coherence tomography (OCT) and intravascular ultrasound (IVUS), has become critical for optimizing percutaneous coronary intervention (PCI). OCT offers higher resolution than IVUS, allowing detailed assessment of vessel structure, plaque characteristics, and stent deployment. This review synthesizes current evidence regarding the procedural safety, stent optimization efficacy, and clinical utility of OCT compared to IVUS and conventional angiography. A narrative review was conducted following SANRA guidelines, utilizing searches of PubMed/MEDLINE and Google Scholar for studies published from 2015 to 2025. Eligibility criteria included RCTs, cohort studies, systematic reviews, and meta-analyses comparing OCT, IVUS, and angiography in adult patients undergoing coronary interventions, focusing on procedural safety, stent optimization (expansion, apposition, restenosis), and plaque assessment. CT-guided PCI demonstrated a superior safety profile compared to angiography-guided PCI, with significantly lower rates of in-hospital major adverse cardiovascular events (MACE) and all-cause mortality. OCT's high resolution enabled superior detection of critical optimization parameters, including stent malposition, which was detected in 39% of lesions by OCT versus only 14% by IVUS. OCT provides unique diagnostic capability for ACS by precisely identifying high-risk plaque features, such as thin-cap fibroatheromas. In stable CAD, OCT changes the procedural strategy in up to 50% of cases by guiding lesion preparation and stent sizing OCT is a safe and highly effective imaging modality for guiding PCI. Its superior resolution provides distinct advantages over IVUS and angiography, particularly in quantifying stent apposition and characterizing vulnerable plaques. While IVUS offers greater penetration depth, the combined evidence supports the use of OCT as a first-line intracoronary imaging tool to improve clinical outcomes, justifying the push toward the integration of both modalities for comprehensive plaque assessment.

Keywords: Optical coherence tomography, Intravascular ultrasound, Percutaneous coronary intervention

INTRODUCTION

Optical coherence tomography (OCT) is a light-based intravascular imaging technique that helps interventionalists to investigate the structure or anatomy of the vessel close to a cellular level. It is performed in vivo with a level of resolution of (axial 10-20 um). It is ten times higher than other modalities like intravascular ultrasound (IVUS), but with a penetration depth limited to 1.5-2 mm.

In 1986, for the first time, implantation of coronary stenting was done in humans.[1] It has been a search since then to find ways to investigate coronary vessels from the inside in vivo. The first technique tried was angioscopy, which helped in understanding only the surface assessment of the vessels.[2] But the truly useful method was IVUS, which was developed in the 70s.[3] This was considered the gold standard for the vessel wall and stent imaging. Nevertheless, the resolution was ten times poorer than OCT, and the limitations were in stent assessments, especially stent tissue analysis.

In 1991, Huang et al reported the first clinical application of 2-dimensional OCT describing the significance of in both interventional cardiology and ophthalmology.[4] Currently, OCT is a modality that is highly utilised in routine clinical scenarios. It provides real-time data of intracoronary vessel imaging, which enables the description of the pathology. It precisely helps quantify the disease extent and severity, plaque characteristics,360-degree measurements, calcium deposits, presence of thrombus, helping accurately in sizing vessels. Also have good intra- and inter-observer correlation.[5]

There are two types: time domain OCT (first generation) helps in high-speed imaging by capturing multiple A scans sequentially over time to frame cross-sectional images, and frequency domain OCT (second generation), also known as Spectral or Fourier domain OCT, offering more sensitive and higher speed than time domain systems.[6]

Clinically, atherosclerotic plaque assessment, percutaneous coronary intervention (PCI) (percutaneous coronary intervention) guide and optimisation, stent struts coverage, apposition assessment and stent restenosis evaluation. In PCI, pre-intervention, plaque characterisation (lipid, calcium, fibrous cap, thickness, thrombus), intervention planning and stent sizing. In post-intervention stent strut malposition, intimal dissection, and prolapse (protrusion of tissue between stent struts extending inside a circular arc connecting adjacent struts) are seen. In the follow-up assessment, we examine stent strut coverage, neointimal formation, and characteristics of restenotic tissue. Multiple studies on OCT confirmed that delayed neointimal coverage following DES implantation versus bare metal stent placement.[7]

OCT is a promising intravascular imaging modality with several in-depth assessments that affect clinical outcomes in patients with coronary artery disease. PCI is the cornerstone of revascularisation for coronary artery disease (CAD). While conventional angiography remains the gold standard for procedural guidance, its inherent limitations, namely, its two-dimensional nature and inability to characterise plaque morphology or optimise stent placement precisely, have spurred the adoption of intracoronary imaging techniques. IVUS and, more recently, OCTs have emerged as critical adjunctive tools, offering detailed, cross-sectional views of the vessel wall and plaque composition.

IVUS provides superior penetration depth but is limited by lower resolution. In contrast, OCT offers a spatial resolution approximately ten times higher than IVUS, allowing for unparalleled visualization of both intraluminal and transmural coronary structures. The utilization of these advanced imaging modalities, particularly OCT, has been increasingly linked to improved procedural outcomes by facilitating precise lesion preparation, optimizing stent deployment, and identifying predictors of long-term adverse events.

This review synthesizes the current body of evidence focusing on three critical areas: the comparative procedural safety profile of OCT against IVUS and angiography; the role of OCT in achieving optimal stent implantation through quantitative and qualitative assessment, and the distinctive clinical utility of OCT in managing both acute coronary syndromes (ACS) and stable CAD.

METHODS

This narrative review was conducted in accordance with the SANRA (Scale for the Assessment of Narrative Review Articles) guidelines to ensure methodological rigour and transparency. The objective was to synthesise evidence regarding the role, applications, and outcomes of OCT in coronary interventions, with a specific focus on procedural guidance, stent optimisation, and plaque assessment.

Research question

The review was guided by a structured research question framed using the PICO framework.

Population: Adult patients (≥18 years) undergoing coronary interventions, including PCI and stent placement.

Intervention: Use of OCT for procedural guidance, stent optimisation, or plaque characterisation.

Comparison: Other intravascular imaging modalities, such as IVUS and coronary angiography.

Outcomes: Procedural outcomes (precision, safety, complications), stent-related parameters (expansion, malposition, restenosis), and plaque assessment metrics (characterisation accuracy, complication avoidance).

Study designs

Randomised controlled trials (RCTs), cohort studies, case-control studies, cross-sectional studies, systematic reviews, and meta-analyses.

Publications from January 2015 onwards. Articles published in English.

Inclusion criteria

Studies involving adult patients (≥18 years) with CAD, ACS, or related indications undergoing coronary interventions.

Studies evaluating OCT in: Procedural guidance during interventions. Stent optimisation (e.g., malposition, expansion, restenosis). Plaque assessment (e.g., characterisation, complication avoidance). Comparative studies assessing OCT against IVUS or angiography.

Exclusion criteria

Studies involving paediatric patients (<18 years) or non-human subjects; studies unrelated to coronary interventions (e.g., non-coronary vascular imaging); articles not directly evaluating OCT or failing to specify its application, editorials, letters, conference abstracts without full data, and case reports.

Information sources and search strategy

A comprehensive literature search was performed using PubMed/MEDLINE and Google Scholar. The search was limited to articles published between 2015 and 2025. The following combination of Medical Subject Headings (MeSH) and keywords was applied:

"Optical Coherence Tomography" OR "OCT" AND "Percutaneous Coronary Intervention" OR "PCI" AND "Stent Optimisation" OR "Plaque Characterisation" OR "Procedural Guidance" AND "Angiography" OR "Intravascular Ultrasound" OR "IVUS".

Reference lists of eligible articles and relevant reviews were also screened to identify additional studies.

Data extraction and synthesis

Eligible studies were reviewed in full text, and relevant data were extracted according to the predefined domains of interest.

Procedural guidance

Procedural guidance was stent optimisation and plaque assessment.

The findings were synthesised narratively, with emphasis on OCT's applications, comparative performance against IVUS and angiography, and clinical outcomes. Results were structured thematically around the three core domains of OCT use.

PROCEDURAL SAFETY OF OCT COMPARED TO IVUS AND ANGIOGRAPHY

Multiple studies have evaluated the safety profiles of different coronary imaging techniques used during PCI. These include IVUS, frequency domain optical coherence tomography (FD-OCT) and conventional angiography.

In a 2017 publication, a single-centre study published by J.N.S. and A.K. between 2008 and 2013, the safety profiles of FD-OCT and IVUS were compared in patients undergoing invasive imaging. Seven (0.6%) out of the 1,142 patients who underwent OCT-guided PCI developed complications compared to twelve (0.5%) out of 2,476 patients who underwent IVUS-guided.[8]

In a separate observational cohort study by Jones et al, clinical outcomes were compared between two propensity-matched cohorts: the first cohort of 2,268 patients (1,134 in each group) compared OCT-guided PCI and angiography-guided PCI. OCT-guided PCI was linked with decreased rate of in-hospital major adverse cardiovascular events (MACE), recurrent MI and all-cause mortality compared to angiography (0.80% vs 2.00%, p=0.01). In contrast, no differences were observed when OCT was compared to IVUS-guided PCI in a second cohort of 2,250 patients (1,125 in each group).[9]

In a 2015 prospective cohort study, 2(1.9%) out of 103 patients who underwent OCT-guided PCI experienced complications at baseline. One patient developed ventricular fibrillation, triggered by vessel flushing with contrast, while the other sustained a dissection at the proximal stent edge caused by the tip of the OCT imaging catheter. In contrast, no complications were observed in patients who underwent IVUS-guided PCI.[10]

In their 2023 prospective, randomised, single-blind trial, Ali ZA et al reported that procedural complications related to OCT imaging occurred in one patient from the OCT group and two patients from the angiography group, resulting in a total of 3 complications out of 2,484 (0.1%) patients.[11]

In 2023, a meta-analysis was carried out, which demonstrated that OCT-guided PCI was associated with lower MACE, cardiovascular death and higher contrast volume and was also associated with longer duration of PCI compared to angiography-guided coronary intervention.[12]

In another RCT in 2023, which had a sample size of 2008 patients with significant coronary artery disease, it demonstrated that the incidence of major procedural complications was lower in the OCT group twenty-two (2.2%) than in the IVUS group thirty-seven (3.7%). However, imaging procedure-related complications were not observed.[13]

A 2022 meta-analysis demonstrated that Major adverse cardiovascular events (MACE) were reported in 11 out of 14 studies. Angiography was associated with elevated odds of MACE as compared with IVUS (OR, 1.64; 95% CI, 1.30-2.07); however, OCT had comparable Odds of MACE with IVUS (OR, 1.31;95% CI, 0.81-2.11).[14]

A 2024 single-centre retrospective study demonstrated in their study that an OCT-guided PCI procedure in an acute myocardial infarction was associated with lower one-year MACE rates compared to IVUS-guided PCI.[15]

A 2024 meta-analysis review of randomised control trials demonstrated that OCT was associated with better clinical outcomes for PCI in complex lesions compared to angiography. OCT was also associated with reduced MACE, cardiac death, MI and stent thrombosis.[16]

These findings suggest that while OCT may offer distinct advantages over angiography in terms of reducing in-hospital complications and long-term mortality, its benefits over IVUS appear to be less pronounced, yet at least as safe, if not superior.

OCT IN STENT OPTIMIZATION

OCT is a newer imaging technology that provides cross-sectional views with a spatial resolution roughly ten times higher than IVUS. It uses near-infrared light to capture detailed intracoronary images.[17] OCT enables high-resolution imaging of both intraluminal and transmural coronary structures, allowing precise planning and assessment of treatment strategies before and after stent placement.[18]

The utilisation of OCT globally is limited, one of the major reasons being the lack of quantitative criteria for stent optimisation. The primary reason for the unclear quantitative criteria for stent optimisation is that interventional cardiologists prefer to use predetermined PCI endpoints, either based on their own practice experiences or local guidelines for OCT-guided PCI.[19] The success of intravascular stent implantation largely hinges on the stent's geometric design and its influence on blood flow dynamics. These stents are medical devices placed within arteries to reopen blocked vessels and restore normal circulation.[20] However, once implanted, the stent disrupts local blood flow and modifies shear stress on the arterial wall, potentially triggering harmful tissue reactions and raising the risk of complications.[21]

Evidence for OCT use in PCI primarily comes from observational registries, with only a few randomised trials, most targeting surrogate endpoints such as improved post-PCI fractional flow reserve (FFR) and lacking sufficient power to assess clinical outcomes.[22]

Like IVUS, OCT offers both quantitative and qualitative assessment of the vessel wall before PCI and allows precise evaluation of stent optimisation after the procedure. Overall, most studies identify five key parameters for OCT-guided stent optimisation: stent expansion, stent apposition, tissue protrusion (TP), edge dissection, and lesion coverage.[18]

Stent optimisation was achieved in roughly half of the patients undergoing imaging-guided PCI and correlated with improved clinical outcomes, with the benefit being more pronounced in OCT-guided procedures compared to IVUS-guided ones.[23]

Stent expansion

When at least one of the following OCT findings is present, it is considered suboptimal stent expansion. In-stent minimum lumen area <4.5 mm^2; reference lumen narrowing with lumen area <4.5 mm^2; stent edge dissection with a width ≥200 µm.[19]

Optimal stent deployment was defined as full apposition of the stent struts with no edge dissections, while adequate stent expansion was defined as achieving either a minimum stent area (MSA) greater than 5.0 mm^2 or more than 90% of the distal reference lumen area.[18] Stent under expansion is considered a bad prognostic factor, which can lead to worse short-term and long-term outcomes. OCT revealed stent under expansion in ⅓ RD patients with very late stent restenosis.[24]

OCT can help in the measurement of an indicator of stent under expansion. MSA refers to the smallest cross-sectional area inside a deployed stent within an artery. In studies involving non-left main coronary arteries, OCT revealed the optimal MSA to be >3.5 - >5.0 mm.[2] As MSA is more dependent on the vessel size, relative expansion can be used as a more realistic predictor for optimal stent optimisation.[19]

Although relative expansion of >80% or >90 % is the criterion for optimal stent expansion, given the circumstances in clinical practices, >70% expansion is considered as practically feasible and as optimal stent expansion.[19] According to the ILUMIEN III trial, MSA attained with OCT (5.79 mm2) was non-inferior to MSA attained by IVUS (5.89 mm2).[25]

OCT can also be used to detect stent edge dissection when the angiography shows unclear findings like haziness, filling defects, etc. Meanwhile, OCT imaging with injection of contrast can be a hazard too, because of an increase in intracoronary pressure (9±2 mmHg in systole), which will further lead to expansion of stent edge dissection. Whereas few studies consider the increase in intracoronary pressure due to contrast injection as small and insignificant, and consider OCT as a safe imaging technique for assessment of suspected dissections/injuries of coronary vessels as long as they are not near the catheter tip.[14] Whenever signs of pressure waveform damping are noted or for catheter-induced or very proximal dissections, it is better to opt for intravascular ultrasound than OCT as imaging technique.[26] Studies reported that when the dissection length is >2 mm, the dissection angle is >60˚, and when media/adventitia is involved, these are the indicators of target lesion failure.[19]

IN-STENT RESTENOSIS

OCT became an essential tool for exploring various mechanisms leading to in-stent restenosis. According to a study using OCT, the incidence of in-stent restenosis is 15-20% for bare metal stents and 5-10% for drug-eluting stents. According to the French PCI registry, use of OCT for analysing restenosis is limited to only 1.9% of cases.[24] Evidence suggests that both OCT-guided and IVUS-guided PCIs have similar efficacy in decreasing restenosis rates[25-27] and OCT guidance is non-inferior to IVUS.[28]

STENT MALAPPOSITION

According to the latest European Association of Percutaneous Cardiovascular Interventions consensus definitions, it is considered to be a significantly malapposed strut when the distance between the strut surface and the lumen is≥400 µm in post-PCI OCT analysis.

OCT provides 10x higher resolution compared to IVUS.[20] OCT detected stent malapposition in 39% of lesions, whereas IVUS could detect it in only 14% of lesions.[29]

A final in-stent MLA below 4.5 mm², distal stent edge dissection (>200 µm in thickness or >60° and >3 mm in length), and reference edge narrowing with a RLA below 4.5 mm² were the strongest predictors of device-oriented clinical events (DoCE).[22]

A network meta-analysis comparing outcomes of OCT-guided PCI, IVUS-guided PCI, and angiography-guided PCI suggested that OCT-guided and IVUS-guided PCIs have better outcomes than angiography-guided PCI. Both OCT-guided and IVUS-guided PCIs have similar outcomes.[25-28] Evaluation of benefit for OCT guided PCIs, P-score of Major adverse cardiovascular events -MACEs (0.973), MI p-score (0.823), cardiac death p-score (0.921). With IVUS, all-cause death P-score (0.792), Target lesion revascularisation TLR (p-score 0.865), stent thrombosis (p-score 0.930).[30]

OCT IN ACUTE CORONARY SYNDROMES

OCT plays a pivotal role in acute coronary syndromes (ACS) by identifying high-risk plaques, such as thin-cap fibroatheromas (TCFAs), which are prone to rupture and subsequent thrombosis. TCFAs are characterised by a thin fibrous cap (<65 µm) overlying a lipid-rich necrotic core, and their detection is critical for risk stratification. A study by Hong et al (2022) demonstrated that combining OCT-based lipid-to-cap ratio (LCR) with optical flow ratio (OFR) could stratify ACS patients into groups with up to a 43-fold increased risk of adverse cardiovascular events. This underscores OCT's ability to not only diagnose ACS but also predict future events.[31]

Clinical implications

Risk stratification: OCT identifies high-risk plaques that may require aggressive lipid-lowering therapy or targeted interventions.[12]

Procedural guidance: OCT ensures optimal stent expansion and apposition, reducing the risk of stent thrombosis and periprocedural myocardial infarction (PMI).[12]

Plaque modification: OCT assesses the success of plaque modification techniques, such as atherectomy, in complex lesions.[12]

The DOCTORS study (2016) demonstrated that OCT-guided PCI significantly improved post-procedure FFR compared to angiography-guided PCI, without increasing procedural complications.[32] Furthermore, a 2023 meta-analysis by Wulandari et al revealed that OCT-guided PCI reduced MACE by 48% and cardiovascular mortality by 53%, despite requiring higher contrast volumes and longer procedure times.[12]

OCT IN STABLE CAD AND PROCEDURAL GUIDANCE

In stable CAD, OCT provides detailed plaque characterisation, enabling personalised treatment strategies. Key features such as fibrous cap thickness, calcific deposits, and lipid composition are visualised with high precision, allowing for the identification of vulnerable plaques that may not be apparent on angiography.[33]

Enhanced plaque characterisation

TCFA identification: OCT differentiates TCFAs from thick-cap fibroatheromas (ThCFAs) and non-lipid plaques, offering prognostic insights into their likelihood of rupture.[34]

Stent optimisation: OCT-guided PCI results in a larger MSA and improved intra-stent flow areas compared to angiography-guided PCI, reducing the risk of restenosis and stent thrombosis.[35]

Residual complications: OCT detects stent malapposition and underexpansion, ensuring superior procedural outcomes.[36]

CLINICAL IMPACT

Studies have shown that OCT changes procedural strategy in approximately 50% of cases, primarily by optimising stent deployment and lesion preparation. For example, OCT-guided atherectomy and embolic protection devices reduce distal embolisation and mechanical injury, particularly in high-risk plaques.[32]

While angiography remains the gold standard for coronary imaging, OCT offers superior resolution for assessing plaque morphology and stent placement. Compared to IVUS, OCT provides higher resolution but has limited penetration depth, making it less effective for evaluating deeper plaque components.[37] Furthermore, it identifies high-risk features (e.g., TCFAs, macrophage infiltration) that angiography cannot detect, leading to better risk stratification and procedural outcomes.[34]

OCT also excels in visualising endoluminal structures, while IVUS provides deeper tissue penetration. The combined use of OCT and IVUS leverages their complementary strengths for comprehensive plaque characterisation.[38-39] The ILUMIEN IV trial (2024) demonstrated that OCT-guided PCI improved clinical outcomes, including larger MSA and reduced MACE, compared to angiography-guided PCI.[6] However, the October trial (2023) found no significant difference in outcomes for bifurcation lesions, highlighting the need for further research in specific lesion subsets.[40]

The integration of OCT and IVUS offers a synergistic approach to plaque characterisation. OCT's high resolution complements IVUS's deeper penetration, enabling precise assessment of plaque cap thickness and stress/strain indices, which are critical for evaluating plaque vulnerability.[38,39]

Combined OCT and IVUS data have been used to develop biomechanical models that predict plaque progression with exceptional accuracy.[9,10] The development of combined IVUS-OCT catheters promises to enhance our understanding of CAD and improve correlation with pathological specimens.[12] Diagnostic discordance and the influence of macrophages and calcifications on imaging outcomes remain challenges that must be addressed to fully harness the potential of these technologies.[41]

DISCUSSION

The compiled evidence strongly supports the procedural safety and clinical superiority of intracoronary imaging, specifically OCT, over conventional angiography in the context of PCI.

The primary finding is that OCT-guided PCI is associated with lower rates of in-hospital and long-term MACE, mortality, and recurrent MI compared to angiography-guided PCI. This superiority is largely attributable to the precise, high-resolution imaging that facilitates better stent implantation. The procedural safety profile of OCT, while sometimes associated with minor, imaging-specific events (e.g. contrast-induced vasospasm or minor catheter-tip dissection), is demonstrably high and at least non-inferior to IVUS.

The controversy surrounding the potential for contrast injection during OCT to expand stent edge dissection must be viewed in the context of the overall procedural data. Despite the theoretical risk of a minor increase in intracoronary pressure, the vast majority of studies confirm that OCT is a safe technique for assessing vessel injury, and major imaging-related complications remain extremely rare (0.1% in one large trial).

OCT's key strength lies in its exceptional resolution, which enables highly accurate detection of key predictors of adverse events, such as stent malapposition and small edge dissections. The fact that OCT detected stent malapposition nearly three times more frequently than IVUS suggests a potential for superior optimization in these specific parameters. This high resolution is also fundamental to characterizing high-risk plaque features like TCFA cap thickness, which is impossible with IVUS.

However, the limited penetration depth of OCT remains a constraint, particularly in highly calcified or large-vessel lesions, where IVUS still provides superior assessment of the external elastic lamina and total plaque burden. The recognition of these complementary strengths has spurred the development of combined IVUS-OCT catheters, suggesting a future where a synergistic approach might offer the most comprehensive plaque characterization.

CONCLUSION

The current evidence affirms that OCT is a safe and effective imaging modality that provides distinct advantages over angiography and is comparable to IVUS, particularly in optimizing stent expansion and apposition. While OCT-guided PCI is non-inferior to IVUS and superior to angiography for overall clinical outcomes, the integration of both OCT and IVUS is poised to enhance our understanding of CAD pathology and refine procedural guidance. Future large-scale, randomized trials will continue to solidify the distinct clinical benefits of OCT in specific complex lesion subsets and potentially lead to the adoption of combined-modality guidance as the new standard of care.

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