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EDITORIAL COMMENT

Beyond Angiography

Advancing Intravascular Imaging in PCI for Calcified Lesions

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Severely calcified coronary lesions represent one of the most challenging substrates in contemporary percutaneous coronary intervention (PCI). Their rigid, noncompliant nature impairs device delivery and optimal stent expansion, and increases the risk of dissection and perforation, making them a well-established predictor of adverse acute and long-term outcomes.[1] As the global population continues to age, and comorbidities become increasingly prevalent, the effective management of calcified lesions has never been more critical. Despite significant advances in coronary intervention technologies, severely calcified lesions continue to predict procedural failure.

Intravascular imaging (IVI) provides essential information on lesion length, vessel size, plaque distribution, and plaque composition—critical factors for appropriate device selection, sizing, and treatment strategy planning. Historically, IVI has evolved by demonstrating its benefit in improving PCI outcomes, particularly for complex lesions. However, current international guidelines—including the 2024 ESC Guidelines on chronic coronary syndromes—do not categorize severe calcification as a "complex lesion" for which IVI guidance is strongly recommended, unlike left main, bifurcation, or long lesions.[2] This is largely due to the paucity of prospective data specifically supporting IVI in this setting.

Calcium modification devices, such as orbital atherectomy (OA) or rotational atherectomy, have been developed to address the challenges of calcified lesions, but randomized trials have consistently failed to show significant clinical benefit in reducing target-vessel failure (TVF). The landmark ECLIPSE (Evaluation of Treatment Strategies for Severe CaLcIfic Coronary Arteries: Orbital Atherectomy vs. Conventional Angioplasty Technique Prior to Implantation of Drug-Eluting StEnts) trial compared OA with a balloon angioplasty (BA)-based strategy before drug-eluting stent implantation in patients with severely calcified lesions.[3] Unfortunately, OA did not demonstrate superiority over BA for minimal stent area or 1-year TVF. Possible explanations for these neutral results include suboptimal lesion selection, low event rates, variability in procedural technique, and the absence of standardized stent optimization strategies—most of which could potentially be addressed with IVI, such as intravascular ultrasound (IVUS) or optical coherence tomography (OCT). In this context, the present ECLIPSE substudy by Stone et al,[4] published in this issue of *JACC: Cardiovascular Interventions*, sets out to address a key clinical question: In patients with severely calcified coronary lesions undergoing PCI, does IVI-guidance improve procedural and long-term outcomes compared with angiography guidance alone? This analysis offers critical new insights into the potential role of IVI in this challenging subset. In this analysis, IVI—either OCT or IVUS—was associated with a 26% adjusted reduction in 1-year TVF, driven by lower rates of all-cause death, cardiac death, ischemia-driven revascularization, and stent thrombosis, after adjustment for baseline characteristics. Notably, this benefit was consistent regardless of lesion preparation strategy (OA or BA), challenging existing definitions of "complex lesions" and strongly support re-evaluating IVI's role in PCI for severely calcified lesions.

The potential mechanisms of IVI for improving PCI outcomes are likely multifactorial: precise quantification of calcium burden and morphology, informed lesion preparation, optimized device

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selection, and post-PCI assessment for stent expansion and apposition. Indeed, IVI-guided cases in ECLIPSE used more specialty balloons, postdilatation, more stents, and longer stent lengths; OA cases guided by IVI involved more atherectomy runs and longer total OA time—reflecting a more meticulous, tailored approach for each lesion. These refinements resulted in greater acute gain without higher complication rates. Although a direct causal link remains to be fully clarified, it is plausible that these imaging-informed strategies contributed substantially to the improved outcomes observed.

Another important consideration is that, in real-world practice, IVI is frequently employed, not only for lesion assessment and stent optimization, but also for selecting the most appropriate lesion preparation method. Because ECLIPSE randomized patients only with respect to OA vs BA, the present analysis cannot directly assess IVI's role in treatment selection. Nevertheless, the main trial demonstrated that angiography-based assessment of calcium severity alone was insufficient for selecting lesions likely to benefit from OA, as reflected by the neutral primary outcomes. Incorporating IVI-derived parameters—such as calcium arc, thickness, and depth—could enable more precise and effective lesion selection for OA, potentially enhancing safety and efficacy while also improving cost-effectiveness by avoiding unnecessary device use.

Furthermore, detailed post-PCI IVI analysis in severely calcified lesions could help define optimal imaging-based procedural endpoints—such as minimal stent area thresholds or acceptable residual calcium levels—that predict long-term success. Establishing these targets would allow operators to adopt a more proactive, IVI-guided approach when needed, with the ultimate goal of translating intraprocedural refinements into sustained improvements in patient outcomes. The results of the prespecified OCT substudy, once available, may further illuminate these optimal targets.

The exploratory comparison between OCT and IVUS in this substudy also deserves attention. OCT's superior resolution theoretically enables better characterization of calcium arc, thickness, and depth. However, compared with IVUS, OCT tends to be chosen more frequently in patients with fewer comorbidities and less complex lesions, given the need for contrast flushing to obtain optimal images. This selection bias likely contributes to the consistently better unadjusted outcomes seen with OCT in observational datasets.[5] In ECLIPSE, unadjusted analysis suggested a lower TVF rate with OCT than with IVUS, but this difference was attenuated and lost statistical significance after adjustment for baseline differences such as better renal function and smaller reference vessel diameter in the OCT group. These findings highlight the need for a dedicated, adequately powered randomized trial comparing OCT and IVUS specifically in severely calcified lesions.

In this sense, the ECLIPSE data underscore the inadequacy of angiography alone in fully defining the complexity of calcified lesions. Traditional angiography-based definitions may not reliably identify lesions that truly require calcium modification. It may be time to adopt a more refined framework of lesion complexity—one that incorporates IVI-based assessments of calcium burden and morphology.

Beyond this, the present study represents an important step toward answering a fundamental question: how does IVI improve PCI outcomes, and what specific imaging findings should serve as a true guide for procedural strategy in this challenging lesion subset? Importantly, IVI is not a magic wand that guarantees better outcomes simply by its use; its true value lies in the accurate interpretation of imaging findings and the deliberate translation of these insights into procedural decisions. Determining which imaging features matter most, and how they should guide lesion preparation, device selection, and stent optimization, will be key to designing more effective and reproducible PCI strategies for severely calcified lesions. The findings of this ECLIPSE subanalysis highlight the need to move beyond angiography and advance the role of IVI in PCI for calcified lesions. Future randomized trials should build on these insights to establish imaging-derived criteria for lesion selection, procedural strategy, and optimal endpoints—ultimately redefining standards of care for this most challenging disease subset.

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