

Role of intravascular imaging and intravascular lithotripsy in the management of complex calcific coronary lesions: a case report

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Abstract—Heavily calcified coronary artery disease (CAD) represents one of the most technically demanding challenges in interventional cardiology, as calcium deposits limit appropriate lesion preparation and adequate stent expansion. We report the case of a 56-year-old male with double-vessel disease involving critical stenosis of the proximal left anterior descending artery (LAD) and mid-to-distal right coronary artery (RCA). Percutaneous coronary intervention (PCI) was performed under dual-modality intravascular imaging guidance using the Makoto near-infrared spectroscopy and intravascular ultrasound (NIRS-IVUS) system. Intravascular lithotripsy (IVL) was employed for calcium modification prior to drug-eluting stent (DES) deployment. NIRS-IVUS revealed circumferential calcium arcs up to 360° in the proximal LAD with concealed lipid-rich plaque (maxLCBI4mm = 788) and a mixed calcific-fibrotic lesion in the mid-RCA (maxLCBI4mm = 249). Following IVL and DES deployment, post-intervention imaging demonstrated a minimal stent area (MSA) of 5.6 mm² in the LAD and 3.6–5.3 mm² across RCA segments. This case underscores the complementary value of NIRS-IVUS imaging and IVL-assisted lesion preparation in achieving optimal stent outcomes in complex calcific coronary lesions. The detection of lipid-rich plaque concealed beneath calcium using NIRS provided clinical insights that IVUS alone could not offer.

Index Terms—intravascular ultrasound, near-infrared spectroscopy, intravascular lithotripsy, calcific coronary artery disease, percutaneous coronary intervention, drug-eluting stent

I. INTRODUCTION

Calcific coronary artery disease (CAD) constitutes a significant and growing challenge in interventional cardiology, particularly as the global burden of atherosclerosis continues to rise. Coronary calcification, resulting from the deposition of calcium phosphate crystals within the arterial wall and atherosclerotic plaque, is associated with reduced plaque compliance, impaired balloon expansion, and suboptimal stent deployment [1]. These mechanical limitations predispose patients to adverse outcomes including stent underexpansion, in-stent restenosis, and increased rates of major adverse cardiovascular events (MACE).

Conventional coronary angiography, while useful for delineating luminal obstruction, lacks the spatial resolution to characterize plaque morphology, calcium distribution, or lipid burden—information that is critical for procedural planning in complex lesions. Intravascular imaging modalities, particularly intravascular ultrasound (IVUS) and optical coherence tomography (OCT), have substantially improved the ability to visualize coronary plaque architecture and guide PCI [2]. More recently, the integration of near-infrared spectroscopy (NIRS) with IVUS has provided a dual-modality approach capable of simultaneously assessing plaque morphology and lipid core composition, enabling the identification of lipid-rich plaque (LRP) and associated patient-level risk of MACE [3].

The Makoto Intravascular Imaging System (Nipro, Osaka, Japan) is the only FDA-cleared combined NIRS-IVUS platform indicated for the detection of lipid core plaque (LCP) and risk stratification for MACE. The lipid core burden index (LCBI), and particularly the maxLCBI4mm (the maximum LCBI within any 4-mm segment), serves as a validated marker of vulnerable plaque, with values exceeding

400 associated with significantly elevated procedural and long-term cardiovascular risk [4].

Intravascular lithotripsy (IVL; Shockwave Medical, Santa Clara, CA, USA) has emerged as a novel, safe, and effective method for the modification of severely calcified coronary lesions. By delivering localized sonic pressure waves that selectively fracture intimal and medial calcium deposits, IVL enables more compliant lesion preparation and improves stent expansion compared with conventional balloon angioplasty or atherectomy alone [5, 6]. When combined with intravascular imaging, IVL-assisted PCI allows for a more tailored and evidence-based approach to complex calcific coronary disease.

Herein, we report the case of a 56-year-old male with double-vessel disease who underwent NIRS-IVUS-guided PCI with IVL and DES implantation for critical calcific stenoses in both the proximal LAD and the mid-to-distal RCA. We describe the procedural strategy, intravascular imaging findings, and post-intervention outcomes, and we discuss the broader implications of multimodality imaging-guided PCI in calcific coronary disease.

II. CASE PRESENTATION

A. Patient History and Clinical Examination

A 56-year-old male presented with a chief complaint of chest pain and palpitations of recent onset. There was no history of prior myocardial infarction or coronary revascularization. On clinical examination, the patient was hemodynamically stable with a heart rate of 80 beats per minute and a blood pressure of 130/80 mmHg. Respiratory examination revealed bilateral air entry without added sounds. Cardiovascular auscultation revealed normal first and second heart sounds (S1 and S2) without murmurs. The abdomen was soft with audible bowel sounds, and there was no focal neurological deficit. Baseline electrocardiography and laboratory investigations were performed as part of the initial workup.

B. Diagnostic Coronary Angiography

Diagnostic coronary angiography was performed via the right radial artery approach. The angiographic assessment revealed double-vessel disease with the following findings:

Left main coronary artery (LMCA): No significant obstruction.

Left anterior descending artery (LAD): Critical stenosis of approximately 99% in the proximal segment.

Left circumflex artery (LCx): Distal stenosis of 50–60%; minor plaque in the first and second obtuse marginal (OM1, OM2) branches.

Right coronary artery (RCA): Stenosis of 70–80% in the mid-to-distal segment; minor plaque in the posterior descending artery (PDA) and posterolateral branch (PLB).

In view of the critical LAD and hemodynamically significant RCA stenoses, a decision was made to proceed with NIRS-IVUS-guided PCI to optimize lesion assessment and interventional outcomes.

III. INTRAVASCULAR IMAGING FINDINGS

A. Pre-Intervention NIRS-IVUS: Left Anterior Descending Artery

The LMCA was engaged using a CLS 3.5 × 7F guiding catheter, and the LAD was wired with a BMW guidewire advanced distally. Pre-intervention NIRS-IVUS pullback was performed using the Makoto Intravascular Imaging System.

Pullback from the mid-LAD demonstrated a distal reference vessel diameter of 3.6 mm, a minimal lumen area (MLA) of 3.0 mm², and a maxLCBI4mm score of 788—indicating a substantial lipid core burden and a high-risk plaque phenotype. At the distal level, a circumferential calcium arc of approximately 160° was observed. Progressing proximally, the plaque transitioned to a fibrotic morphology with focal calcium deposits and a gradual increase in vessel caliber.

In the proximal LAD, calcium deposits were identified at the 3–4 o'clock and 10–11 o'clock positions. A segment with a 170° calcium arc was identified, followed by the origin of a diagonal side branch. Beyond this bifurcation point, a 360° circumferential calcium arc was detected. Crucially, NIRS imaging on the Makoto console identified a lipid-rich pool underlying this heavily calcified segment—a finding that would not have been detectable by IVUS alone. Mild plaque was also noted at the carina of the LMCA–LAD bifurcation.

The co-registered NIRS chemogram documented a maxLCBI4mm of 788 in the LAD, exceeding the validated threshold of 400 for high-risk plaque, thereby identifying this lesion as a vulnerable, lipid-rich calcified plaque warranting modified PCI strategy.

B. Pre-Intervention NIRS-IVUS: Right Coronary Artery

Pre-intervention NIRS-IVUS pullback from the distal RCA to the proximal segment revealed a distal reference vessel diameter of 3.2 mm, a proximal reference diameter of 4.2 mm, an MLA of 2.8 mm², and a maxLCBI4mm of 249. In the mid-segment, an 180° calcium arc associated with a discrete, high-grade stenosis was identified. A mixed fibrotic and lipid-rich plaque was observed in the remaining mid-RCA segments, while the proximal RCA appeared angiographically and intravascularly normal.

The maxLCBI4mm of 249 in the RCA, while below the high-risk threshold of 400, still indicated a moderate lipid burden and supported the use of imaging-guided lesion preparation to optimize stent outcomes.

IV. LESION PREPARATION AND STENT IMPLANTATION

A. Left Anterior Descending Artery Intervention

Following pre-dilatation of the LAD lesion with a 2.0 × 10 mm semicompliant balloon, IVL was performed using a 3.5 × 12 mm Shockwave balloon catheter to modify the circumferential calcium and improve vessel compliance. IVL delivers focused, high-energy sonic pressure waves that selectively disrupt superficial and deep calcific deposits without inducing significant barotrauma to the adjacent vessel wall [5]. Following successful calcium modification, a 3.0 × 28 mm zotarolimus-eluting stent (DES) was deployed from the proximal to the mid-LAD segment.

Post-intervention NIRS-IVUS pullback confirmed a minimal stent area (MSA) of 5.6 mm² with a reduction in the maxLCBI4mm to 486, indicating effective plaque modification and adequate stent expansion. Stent struts were uniformly apposed to the vessel wall, with no evidence of malapposition, edge dissection, or geographic miss.

B. Right Coronary Artery Intervention

The RCA lesion was pre-dilated using a 3.5 × 10 mm balloon catheter. Pre-intervention NIRS-IVUS findings guided subsequent IVL therapy using a 3.5 × 12 mm Shockwave balloon. A 3.0 × 48 mm drug-eluting stent was then deployed from the mid- to distal RCA.

Post-intervention NIRS-IVUS pullback demonstrated variable stent expansion across the RCA: MSA at 4.0 mm = 4.8 mm²; at 8.1 mm = 5.0 mm²; at 13.9 mm = 3.6 mm²; at 15.0 mm = 5.3 mm²; and at 26.3 mm = 8.8 mm². The relatively smaller MSA at 13.9 mm was attributed to a densely calcified, fibrotic segment with minimal residual lipid content, which mechanically resisted full stent expansion despite adequate IVL treatment—a recognized limitation of IVL in regions of concentric, lamellar calcium [7]. The maxLCBI4mm was reduced to 106, confirming effective plaque modification and reduction in lipid burden across the treated RCA segment.

V. DISCUSSION

This case illustrates the clinical value of multimodality intravascular imaging in guiding complex, calcific PCI, particularly through the complementary use of IVUS and NIRS to characterize plaque morphology and lipid composition prior to and following intervention.

Coronary calcification is a well-established predictor of suboptimal PCI outcomes. Calcium deposits—particularly those that are circumferential, deep, or extensive—impair balloon compliance, limit stent expansion, and increase the risk of underdeployment and in-stent restenosis [1]. While IVUS remains the established standard for measuring vessel dimensions, assessing plaque burden, and detecting calcification arcs, it cannot characterize the lipid composition of coronary plaques. NIRS addresses this limitation by detecting the near-infrared absorption spectra of cholesterol-rich lipid cores, thereby enabling identification of high-risk, vulnerable plaque morphologies [8].

In the present case, the NIRS-IVUS pullback of the LAD identified a lipid-rich plaque (maxLCBI4mm = 788) concealed beneath a heavily calcified circumferential arc—a configuration that would have been undetectable by IVUS alone. The PROSPECT II trial and other large-scale NIRS studies have demonstrated that a maxLCBI4mm \geq 400 is independently associated with a two- to four-fold increase in the risk of non-culprit MACE [3, 9]. This finding, in combination with the significant calcium burden, supported the use of IVL as the preferred lesion modification strategy over conventional cutting balloon or rotational atherectomy.

IVL represents a paradigm shift in the management of severely calcified coronary lesions. Unlike rotational or orbital atherectomy, which ablate superficial calcium through mechanical friction, IVL generates sonic pressure waves that propagate through the vessel wall to fracture deep, concentric calcium deposits without preferentially damaging the media or adventitia [6]. The Disrupt CAD III trial demonstrated high procedural success rates and a low rate of serious adverse events with coronary IVL, establishing its safety and efficacy as a frontline strategy for calcific lesion preparation [5].

In this case, IVL facilitated favorable stent expansion in both vessels, as evidenced by the acceptable MSA values achieved on post-intervention IVUS. The reduced LCBI4mm scores following stent implantation reflect the physical disruption and redistribution of lipid-rich plaque material—a finding consistent with observations from other IVL and NIRS-IVUS studies [7]. The localized stent under-expansion at the 13.9 mm segment of the RCA underscores the continued challenge of achieving uniform stent expansion in the most severely calcified coronary segments, even with contemporary lesion modification tools.

From a safety and technical standpoint, the imaging-guided approach allowed for precise stent sizing and positioning, reducing the risk of geographic miss, edge dissection, and unrecognized malapposition. These findings are consistent with the growing body of evidence supporting IVUS-guided PCI as superior to angiography-guided PCI in terms of stent expansion, target lesion revascularization, and MACE at follow-up [10]. The additional NIRS dimension provides incremental value by identifying high-risk lipid core lesions that may benefit from modified stenting strategies.

VI. CONCLUSION

This case report highlights the synergistic value of NIRS-IVUS imaging and IVL-assisted calcium modification in the management of complex calcific coronary artery disease. The detection of concealed lipid-rich plaque beneath circumferential calcium using NIRS provided critical diagnostic information that was not available from IVUS or angiography alone, directly influencing the interventional strategy and contributing to favorable procedural outcomes. Post-intervention imaging confirmed adequate stent expansion and reduced lipid burden in both treated vessels.

As the prevalence of calcific CAD continues to increase—particularly among older and diabetic populations—the integration of multimodality intravascular imaging with advanced lesion modification techniques represents an important advance in optimizing PCI safety and long-term efficacy. Further prospective studies are warranted to assess the impact of NIRS-guided procedural decision-making on clinical endpoints, including MACE and target lesion revascularization, in this challenging patient population.

. CLINICAL LEARNING POINTS

The following key insights emerge from this case:

1. NIRS-IVUS imaging enables the detection of lipid-rich plaque concealed beneath calcified coronary segments—a finding with important implications for procedural risk stratification and intervention planning.
2. A maxLCBI4mm \geq 400 identifies patients and lesions at increased risk of MACE and should prompt consideration of modified stenting strategies, including distal embolic protection and aggressive lesion preparation.
3. IVL is an effective and safe modality for modifying deep and circumferential coronary calcium, facilitating improved stent expansion compared with conventional balloon techniques.
4. Densely calcified, lipid-poor segments may resist full stent expansion despite IVL, and under-expansion at such sites should be anticipated and closely monitored by post-intervention imaging.
5. Integration of multimodality intravascular imaging with contemporary lesion modification techniques optimizes stent apposition, expansion, and long-term clinical outcomes in calcific coronary disease.

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