A case of covered stent failure in sealing up a coronary perforation potentially related to intravascular lithotripsy treatment: insights from optical coherence tomography

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Background
Intravascular lithotripsy (IVL) is a new modality in treatment of calcified coronary lesions which improves procedural outcomes. Coronary perforation is an extremely uncommon but potentially catastrophic complication of percutaneous coronary intervention (PCI) and IVL therapy.

Case summary
We report a case of an elective PCI to a calcified left anterior descending (LAD) and diagonal bifurcation lesion in a 65-year-old man. LAD was treated with two stents. Despite high pressure non-compliant balloon inflation, a focal area of under-expansion remained. IVL successfully treated the under-expansion but was complicated with a large coronary perforation. The perforation was successfully sealed with a PK-PAPYRUS covered stent sacrificing the diagonal branch. Patient remained stable until 3 hours later when he developed tamponade requiring urgent pericardial drainage. Repeat angiography demonstrated recanalization of the diagonal branch and ongoing contrast extravasation along its course. Optical coherence tomography intracoronary imaging was used to delineate the mechanism of ongoing bleeding. This demonstrated an interrupted elastic membrane of the covered stent, potentially caused by underlying fractured calcium. Therefore, a second overlying PAPYRUS stent was deployed which satisfactorily sealed the perforation.

Discussion
IVL is an emerging less invasive treatment for calcified coronary stenosis but could be associated with drastic complications. This case highlights the importance of awareness of IVL-related coronary perforation and the potential limitation of new generation thinner-wall covered stents. Intracoronary imaging plays an important role in identifying mechanisms of stent failure, tailoring treatment, and optimizing outcomes.

Keywords
Intravascular lithotripsy • Coronary perforation • Calcified coronary stenosis • Optical coherence tomography • Case report

ESC Curriculum
2.1 Imaging modalities • 3.2 Acute coronary syndrome • 3.4 Coronary angiography
Learning points

- Coronary perforation is a rare but potentially catastrophic complication of percutaneous coronary intervention (PCI) associated with treatment of severely calcified lesions and use of calcium modifying techniques such as high-pressure non-compliant balloon inflation and intravascular lithotripsy.
- New generation covered stents with thinner struts may have reduced effectiveness to seal coronary perforations in calcified lesions.
- Intracoronary imaging is a useful tool in identifying mechanisms of covered stent failure and optimizing PCI outcomes.

Introduction

Over the course of past 40 years, there has been significant improvement in percutaneous treatment of severely calcified coronary lesions. Traditional coronary calcium modifying techniques consist of (i) non-atherectomy techniques such as non-compliant (NC) balloons, ultra-high-pressure NC balloons, and cutting/scoring balloons and (ii) atherectomy techniques such as rotational/orbital atherectomy and Excimer Laser Coronary Atherectomy. These technologies have some limitations, and there remains a requirement for less invasive yet effective therapeutic modalities in recalcitrant calcified plaques.

Intravascular lithotripsy (IVL, Shockwave Medical, Inc.) is a novel therapeutic technique in treatment of calcified coronary stenosis. By transforming electrical energy into sonic waves, IVL selectively fractures calcium at low balloon inflation rate of 4 atm and leads to increased vessel compliance. Safety and efficacy of IVL were demonstrated in the DISRUPT-CAD III clinical trial, with high procedural success rate of 92.4%, low 30-day major adverse cardiac events at 7.8%, and no case of coronary perforation; however, a case of IVL induced coronary perforation was reported by Simsek et al. Despite being extremely rare, coronary perforation is a drastic complication of PCI, more likely to occur in complex anatomy, such as heavily calcified and tortuous vessels. In this report, we present an illustrative case of covered stent failure in sealing of coronary perforation following IVL therapy and unique insight from intracoronary optical coherent tomography (OCT).

Timeline

| Day 0       | Rescue percutaneous coronary intervention for failed thrombolysis of inferior myocardial ST segment myocardial infarction |
|-------------|---------------------------------------------------------------------------------------------------------------|
| 72 h        | Stage percutaneous coronary intervention of left anterior descending artery complicated with coronary perforation |
| 75 h        | Cardiac tamponade requiring urgent pericardial drainage; repeat coronary angiography, and second covered stent insertion |
| Day 6       | Clinically stable, no pericardial effusion, and mild left ventricular dysfunction on transthoracic echocardiography |
| 6 month     | Symptom free with mild left ventricular dysfunction on transthoracic Echocardiography |

Case presentation

A 65-year-old male was transferred from a regional hospital following resuscitated ventricular fibrillation cardiac arrest and unsuccessful thrombolysis of inferior ST elevation myocardial infarction (STEMI). On arrival to our centre, he had ongoing ST elevation in inferior ECG leads, had mild chest pain, and was haemodynamically stable. His cardiovascular examination was unremarkable. He underwent immediate rescue percutaneous coronary intervention (PCI) to right coronary artery. He was later referred for inpatient staged PCI of the left anterior descending artery (LAD).

He did not have any significant past medical history and was not on any regular medications. He was an ex-smoker and consumed two to four standard units of alcohol per day. Initial coronary angiography showed an acute occlusion of the proximal RCA and severe mid RCA stenosis (treated with PCI), anomalous left circumflex coronary artery arising from proximal RCA with no significant disease, and long segment of severe calcific disease in the proximal to mid LAD (Figure 1A; Supplementary material online, Video S1). His blood tests showed normal full blood count, renal function, and liver function results with high troponin-I levels. Post-PCI transthoracic echocardiography (TTE) showed left ventricular ejection (LVEF) of 45% with inferior wall akinesia, and no significant valvular pathologies.

The staged procedure was performed via the right radial artery with a 6-F Ikari-Left 3.5 (Terumo Interventional Systems) guiding catheter and standard angioplasty wires in LAD and diagonal branch. The LAD lesion was predilated and stented with two overlapping stents (Xience Sierra 3.0 × 23mm and 3.5 × 23mm, Abbott Cardiovascular). Despite high pressure (20 atm) post-dilatation with non-compliant balloons, significant focal stent under-expansion remained in mid LAD just distal to the diagonal bifurcation (Figure 1B). As the stent under-expansion was due to coronary calcification, IVL with a 3 × 12 mm balloon was performed achieving better stent expansion. Further high-pressure post-dilatation with a 3.0 NC-balloon resulted in an Ellis grade-III coronary perforation (Figure 1C; Supplementary material online, Video S2). Prolonged balloon inflation was unsuccessful to stop the extravasation, but it was successfully sealed with a PK-Papyrus (Biotronik) covered stent (3.0 × 20mm) sacrificing the diagonal branch (Figure 1D). At the end of the procedure, the patient was stable with minimal pericardial effusion and no clinical or echocardiographic features of cardiac tamponade.

Three hours later, the patient developed cardiac tamponade requiring urgent pericardial drainage. Repeat angiography demonstrated recanalization of the diagonal branch and ongoing contrast extravasation along its course (Figure 1E; Supplementary material online, Video S3). Further post-dilatation of the Papyrus covered stent failed to seal the perforation. Considered options were deployment of a second overlying covered stent or attempting to re-wire the diagonal to seal the perforation with coils. OCT was used to clarify the mechanism of bleeding. This demonstrated an interrupted elastic membrane of the Papyrus stent at the diagonal bifurcation, potentially caused by underlying fractured calcium (Figure 2; Supplementary material online, Video S4). A second overlying PK-PAPYRUS stent (3.5 × 15 mm) was deployed and satisfactorily sealed the perforation (Figure 1F; Supplementary material online, Video S5).

Following the procedure, he remained stable, and the pericardial drainage was removed after 24 hours. He was discharged on day 3 with no residual pericardial effusion on TTE, mild LV systolic dysfunction (LVEF 45%) with inferior wall akinesia. His 6-month follow up TTE was unchanged, and the patient was clinically well.
Covered stent failure in IVL-related coronary perforation

**Discussion**

Coronary artery calcification (CAC) remains a challenge despite significant advances in coronary angioplasty techniques and equipment. CAC is present in one third of patients with coronary artery disease (CAD) and predicts poor outcomes. Treatment of heavily calcified coronary lesions has been associated with increased procedural complications, and major adverse cardiac events.

Modifying CAC also has evolved in the course of time, and a number of devices have become available. IVL is an emerging modality in treatment of calcified coronary lesions with a novel therapeutic function which creates calcium fractures. It has several advantages compared with atherectomy techniques and can be potentially used as a bail-out treatment of significant stent under-expansion.

The occurrence of coronary perforation is more frequent in complex coronary interventions and usually requires covered stent insertion if extravasation persists. Surprisingly in our case, repeat emergency coronary angiography demonstrated delayed and ongoing contrast extravasation along the course of the diagonal branch. The most likely explanation was an under-expanded or under-sized covered stent resulting in recanalization of diagonal branch or geographical miss with the covered stent not covering the region of perforation around the diagonal bifurcation. Other possibilities were late propagation of coronary wall tear proximal to the covered stent edge and distal wire perforation; however, on reviewing the final images of the initial angioplasty procedure, we observed no evidence to support this. We attempted to advance an angioplasty wire into the diagonal and were unsuccessful. In addition, subsequent intracoronary imaging confirmed a well-expanded covered tent covering the region of the diagonal ostium.

We proceeded with OCT intracoronary imaging to delineate the mechanism of ongoing bleeding and tailor our intervention based on the findings. OCT revealed that ongoing bleeding was possibly due to a localized interruption in the PK-PAPYRUS elastic membrane. In the context of our case, this could have occurred due to implantation of covered stent in a severely calcified lesion which was modified/fractured with IVL therapy. Post-dilatation of the covered stent with a non-compliant balloon against the fractured calcium edges could possibly have damaged the elastic membrane. It is also possible the covered stent elastic membrane could have been damaged during stent manufacturing or advancing the stent through the guide catheter and stented proximal segment of LAD.

This case describes a potential mechanism of covered stent failure in the treatment of coronary perforation within calcified lesions. This case

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**Figure 1** Intravascular lithotripsy related coronary perforation and treatment with covered stent. (A) Pre-percutaneous coronary intervention angiography with severe mid left anterior descending stenosis; (B) residual waste with high-pressure non-compliant balloon inflation in under-expanded stent; (C) coronary perforation at the bifurcation; (D) initial sealing with first PAPYRUS stent; (E) delayed recanalization of diagonal branch with contrast extravasation; (F) successful treatment with second PAPYRUS stent.
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of coronary perforation was not thought directly related to the IVL device, and perforation occurred following use of non-compliant balloon inflation after IVL therapy. IVL was used in an ‘off-label’ manner to rectify stent under-expansion, and IVL did partially improve stent under-expansion in this case. Use of IVL in stent under-expansion has been reported but not formally investigated.

**Conclusion**

Coronary perforation is an uncommon but potentially catastrophic complication of PCI, especially in complex calcified lesions and use of calcium modifying techniques. IVL is an emerging less invasive treatment for calcified coronary stenosis; however, interventional cardiologists must be familiar with potential complications and their management. The new generation ultra-thin covered stents are more deliverable but potentially less effective in sealing perforations. Intracoronary imaging plays a crucial role in determining mechanism of device failure, tailoring treatment, and optimizing outcomes.

**Lead author biography**

Ata Doost graduated from Shahid Beheshti University of Medical Sciences, Tehran, Iran in 2008. He was awarded Fellowship of Royal Australian College of Physicians in Adult Cardiology in 2019. Following that, he started Clinical Fellowship in Interventional Cardiology at Fiona Stanley Hospital, in Perth Western Australian till August 2021. Dr Doost is now Clinical Fellow in Structural Interventional Cardiology at the King’s College Hospital, London, United Kingdom.

**Supplementary material**

Supplementary material is available at [European Heart Journal – Case Reports](https://doi.org/10.1093/ehjcr/llab119) online.

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**Figure 2** Optical coherent tomography imaging of initial PAPYRUS covered stent. (A) 2D cross-sectional view distal to perforation demonstrating well-expanded and apposed stent struts with lumen diameter 3.18 × 3.55 mm; (B) 2D cross-sectional view proximal to perforation demonstrating well expanded and apposed stent struts with lumen diameter 3.4 × 3.34 mm; (C) 2D cross-sectional view demonstrating calcium fracture behind the stent struts; (D) disrupted PK-PAPYRUS elastic membrane (asterisk) with signal poor areas within vessel wall representing contrast extravasation; (E) 3D intra-luminal fly-through demonstrating disrupted PK-PAPYRUS elastic membrane (arrow); (F) longitudinal optical coherent tomography image demonstrating the location of coronary perforation (arrow).
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Slide sets: A fully edited slide set detailing this case and suitable for local presentation is available online as Supplementary data.

Consent: The authors confirm that written consent for the submission and publication of this case, including images, has been obtained from the patient in line with COPE guidance.

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