ESC European Society of Cardiology

European Heart Journal - Case Reports (2021) **5**(11), 1–5
https://doi.org/10.1093/ehjcr/ytab448

CASE REPORT
Coronary heart disease

Bail-out intravascular lithotripsy for severe stent underexpansion during primary angioplasty: a case report

Niccolò Ciardetti , Francesca Ristalli , Giulia Nardi , and Carlo Di Mario *

Structural Interventional Cardiology, Department of Clinical and Experimental Medicine, Careggi University Hospital, Clinica Medica, Room 124, Largo Brambilla 3, 50134 Florence, Italy

Received 27 April 2021; first decision 3 June 2021; accepted 4 November 2021; online publish-ahead-of-print 11 November 2021

Background Intravascular lithotripsy is safe and effective for the treatment of *de novo* coronary artery calcifications. Its bail-out use in acute coronary syndrome and for underexpanded stents, although currently off-label, could be the best option when other conventional techniques fail.

Case summary A patient with an inferior ST-segment elevation myocardial infarction underwent a primary percutaneous coronary intervention. Stent underexpansion due to a heavily calcified lesion was refractory to high-pressure balloon dilatations. Complete stent expansion was achieved with intravascular lithotripsy, as evidenced by intravascular ultrasound, and no acute complications occurred.

Discussion Treatment strategies for stent underexpansion due to coronary artery calcifications are still debated. High-pressure non-compliant balloon dilatations are rarely sufficient to gain a complete stent expansion. Rotational and orbital atherectomy are contraindicated in presence of a thrombus. Given the possible risks of stent damages, intravascular lithotripsy is currently not indicated in acutely deployed stents but could be the best bail-out technique for otherwise undilatable stents due to severely calcified plaques.

Keywords Intravascular lithotripsy • Shockwave • Coronary artery calcification • Stent underexpansion • STEMI • Case report

ESC Curriculum 3.1 Coronary artery disease • 3.2 Acute coronary syndrome • 3.4 Coronary angiography

Learning points

- Intravascular lithotripsy could be an option for undilatable stents refractory to high-pressure balloon dilatations.
- Intravascular imaging should be used in cases of stent underexpansion to reveal the presence of calcified lesions and to guide the correct therapeutic approach.

Introduction

The presence of severe coronary artery calcifications in the setting of acute occlusion during ST-segment elevation myocardial infarction (STEMI) is a serious challenge. Coronary angiography underestimates the presence of calcium[1] and, since in the acute setting of an occlusive thrombus gentle pre-dilatation with undersized balloons or direct

* Corresponding author. Tel: +393486522399, Email: carlo.dimario@unifi.it
Handling Editor: Francesco Moroni
Peer-reviewers: Elad Asher and Lina Ya'quoub
Compliance Editor: Carlos Minguito Carazo
Supplementary Material Editor: Deepti Ranganathan

stenting is preferred to aggressive lesion preparation, it is not uncommon to realize that the implanted stent is grossly underexpanded and not responding to high-pressure dilatation with non-compliant (NC) balloons. Intravascular lithotripsy (IVL) has proven to be effective and safe in treating *de novo* calcified lesions,[2–4] and a recent retrospective study confirmed this finding also in the setting of STEMI patients.[5] This case report highlights its emerging role also in cases of undilatable stents refractory to other conventional techniques.

Timeline

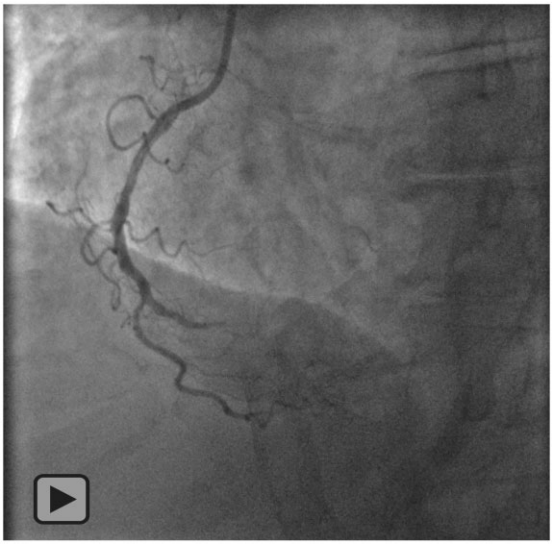
2000	Stent implantation on the second segment of right coronary artery for an inferior acute myocardial infarction
2001	Repeated angioplasty on the previous implanted stent for restenosis
13 April 2021	Sudden onset chest pain with out-of-hospital diagnosis of ST-segment elevation inferior myocardial infarction
	Emergency coronary angiography was carried out and an occlusion of the right coronary artery distally to the previous stent was found
	An Everolimus eluting stent was deployed and several high-pressure balloon dilatations failed to properly dilate the stent distally
	Intravascular ultrasound evidenced a heavily calcified lesion and intravascular lithotripsy was used effectively to correct the stent underexpansion
16 April 2021	The patient was discharged without any acute complications

Case presentation

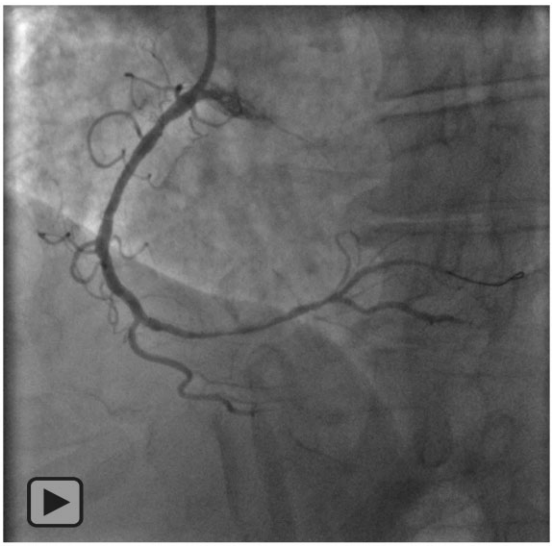
A 67-year-old man was directly transferred to the Catheterization Laboratory because of constrictive chest pain radiated to the jaw lasting for 5 hours with out-of-hospital evidence of ST-segment elevation inferior myocardial infarction. Physical examination was unremarkable and the patient showed no signs of heart failure (Killip Class I).

Besides hypertension and dyslipidaemia on medical treatment, his medical history included a previous inferior acute myocardial infarction 20 years before treated with stent implantation on the second segment of the right coronary artery (RCA) and subsequent percutaneous transluminal coronary angioplasty for restenosis after 9 months.

After 250 mg i.v. of acetylsalicylic acid and 5000 IU of unfractionated heparin, the right radial was instrumented with a 6 French (Fr) sheath and a Judkins left guiding catheter, and left coronary angiography was performed showing a diffusely ectatic left main and proximal left anterior descending coronary artery with multiple irregularities but no significant obstructive lesions. The RCA was engaged with a 6 Fr Judkins right guiding catheter and an occlusion of the third segment distal to the previously implanted stent was found (*Video 1*). No visible calcium was present angiographically. The occlusion was easily crossed with a Runthrough® NS Floppy guidewire (Terumo Medical Corporation, Somerset, New Jersey, USA). A 2.0 × 15 mm balloon expanded well at 14 Atmospheres (Atm), leading to restored anterograde flow, chest pain reduction, and ECG normalization. Angiography showed a long critical stenosis throughout the third segment of RCA (*Video 2*). Cangrelor administration was started and a 2.75 × 38 mm Everolimus eluting stent (Xience Sierra,



Video 1 Right coronary artery angiography showing an intrastent occlusion (TIMI 0 flow) at the beginning of the third segment.



Video 2 Right coronary angiography after crossing the occlusion and balloon dilatation showed long critical stenosis throughout the third segment.

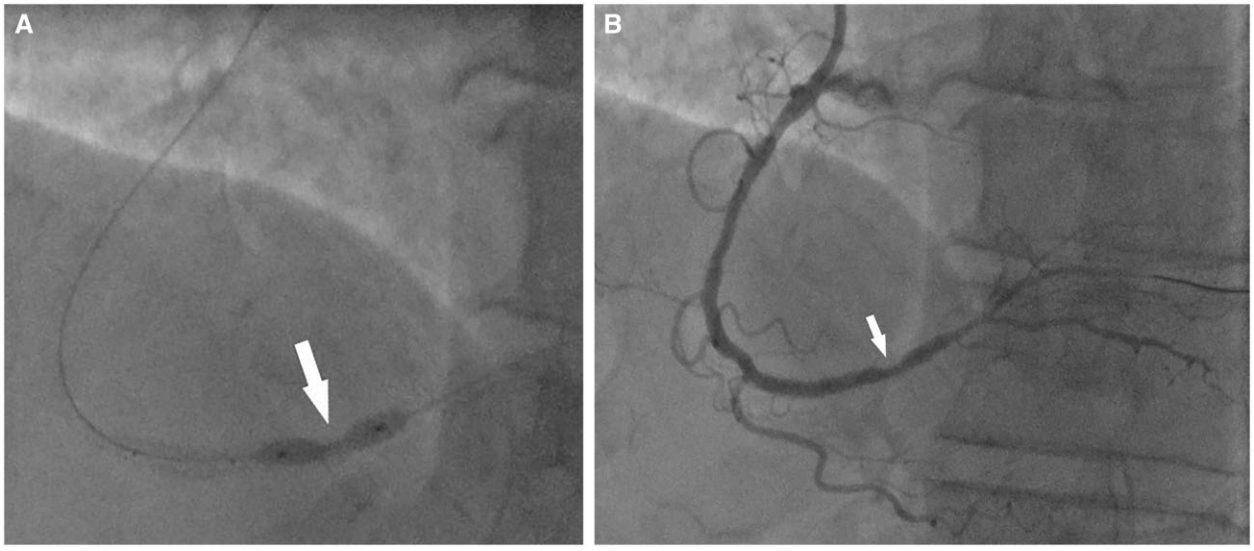


Figure 1 The focal area of stent underexpansion. (*A*) 'Dog-bone' distortion (arrow) of the balloon; (*B*) Angiography showing the focal area of stent underexpansion (arrow) after several balloon dilatations.

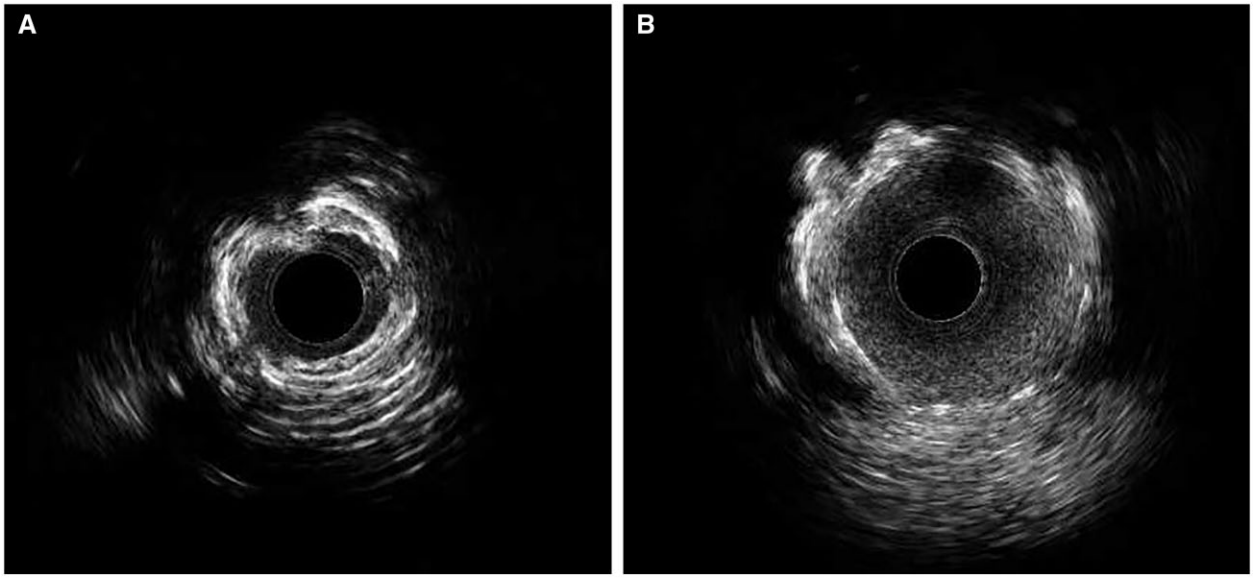


Figure 2 Intravascular ultrasound (IVUS) before and after intravascular lithotripsy. (*A* Intravascular ultrasound showing a heavily circumferential (360°) calcified plaque as the reason of stent underexpansion (minimum stent area 1.98 mm^2). (*B*) Intravascular ultrasound showing optimal stent expansion (minimum stent area 6.92 mm^2) after intravascular lithotripsy and 3.25 mm non-compliant balloon dilatation at 8 Atm.

Abbott, USA) was deployed with a short overlap with the previous stent proximally. Multiple post-dilatations with 3.00 × 12 mm and 2.75 × 6 mm NC balloons at high pressure (up to 24 Atm) failed to dilate the stent distally, where a focal underexpansion of the stent gave a typical image of 'dog-boning' to all balloons (*Figure 1*). Intravascular ultrasound (IVUS) (Opticross™ HD 60MHz, Boston Scientific, USA) was performed and a focal circumferential (360°) highly calcified lesion with a minimum stent area (MSA) of 1.98 mm^2 was found (*Figure 2A*, Supplementary material online, *Video S1*). After the second series of 10 pulses with a 3.00 × 12 mm IVL balloon (Shockwave Medical Inc., Santa Clara, CA, USA) the 'dog-bone' distortion of the balloon disappeared, with full expansion at 4 Atm and 6 Atm (*Figure 3*). Final stent post-dilatation with a Sapphire® II NC 3.25 × 8 mm balloon (OrbusNeich, Hong Kong, China) was done at

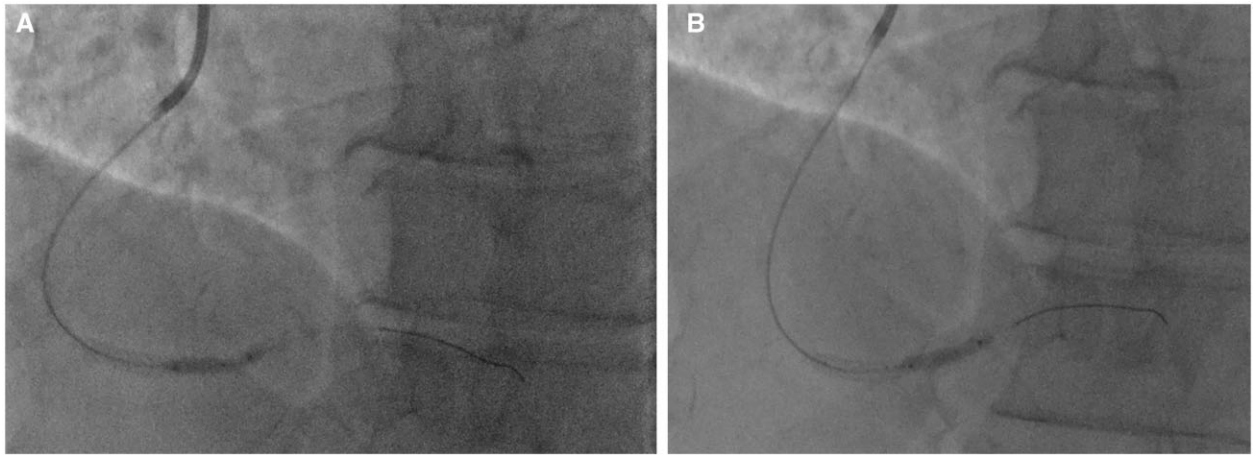


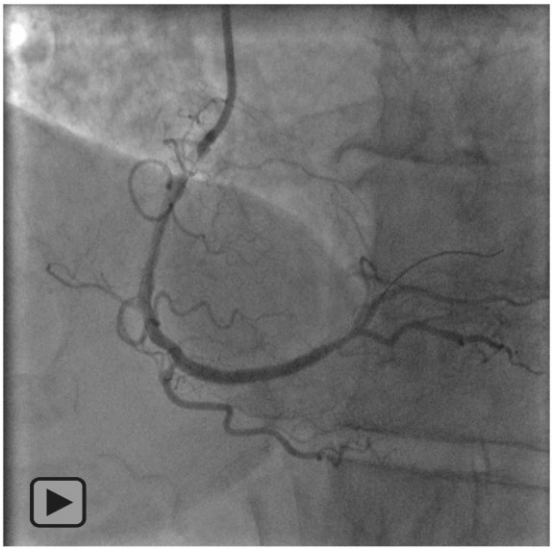
Figure 3 Intravascular lithotripsy (IVL) balloon. (*A*) Shockwave intravascular lithotripsy 3.00 mm balloon at first releasing pulses; (*B*) Shockwave intravascular lithotripsy 3.00 mm balloon after 20 pulses: 'dog-bone' distortion disappeared.

8 Atm distally and up to 24 Atm proximally across the overlapping stent struts. Angiography showed an excellent result (*Video 3*) and IVUS confirmed the complete stent expansion (MSA 6.92 mm^2, residual stenosis 0%, TIMI 3 flow) (*Figure 2B*, Supplementary material online, *Video S2*). At the end of the procedure ticagrelor 180 mg was administered and cangrelor was stopped after 2 h. The patient was transferred to the cardiology unit where the echocardiogram showed inferior wall hypokinesia with normal left ventricular ejection fraction. High sensibility troponin T peak was 1693 pg/mL (URL 14 pg/mL). After 72 h the patient was discharged and started a cardiac rehabilitation program as an outpatient. On follow-up visit 2 months later, the patient was asymptomatic and no complications occurred.

Discussion

Prospective, multicentre registries have shown successful stent delivery and low rates of adverse events using IVL in long highly calcified lesions.[2–4] These registries excluded patients with acute myocardial infarction or possible thrombus in the target vessel, but IVL could be the best option in this acute setting when highly calcified lesions do not expand and rotational or orbital atherectomy are contraindicated in the presence of thrombus.

In contrast to stable patients, where intravascular imaging is essential both pre- and post-stenting, especially in calcified lesions in order to characterize the type of calcification (calcium arc, thickness, length) and to guide a better lesion preparation, intravascular imaging prior to stenting in acute coronary syndromes is recommended only in complex or ambiguous cases, e.g. when calcium is evident on angiography or to better understand the reason of a stent failure.[6] In our case, the culprit lesion was clear, and anterograde flow was restored after balloon angioplasty with a small balloon, which well expanded at 14 Atm. Since calcium was not visible angiographically, we deployed the stent without further balloon pre-dilatation and dog-boning was evident only after stent deployment, not allowing a better preparation of the calcific plaque.



Video 3 Final angiography showing excellent result.

Rotational atherectomy is contraindicated before stent deployment in the presence of intravascular thrombus and becomes even more risky and cumbersome after the stent has been implanted. Intravascular lithotripsy could represent the best option to treat underexpanded stent in highly calcified lesions, but its use is currently off-label due to the possible damage to polymer coating and microfractures of metallic struts, as shown in bench tests.[7]

The calcium fragmented by IVL remains *in situ*, compared to what happen with atherectomy, where calcium and metallic microparticles may embolize distally, causing microvascular plugging, slow-flow, no-reflow, and periprocedural myocardial infarction.[8] Very few cases are reported on effective IVL use in cases of undilatable stent acutely

deployed in a STEMI patient.[5,9–11] This case is proof of the IVL usefulness in this setting, with the ability to fragment circumferential and deep calcifications beyond the stent and without complications. If data on safety will be confirmed in larger samples and with longer follow-ups, IVL would definitely become the best option for heavily calcified occluded arteries in acute coronary syndromes.

Lead author biography

He was born in 1993. He graduated with top marks and honours at the University of Siena Medical School. He is a Cardiology fellow with a special interest in Interventional Cardiology at Careggi University Hospital of Florence, where he is attending the Catheterization Laboratory directed by Professor Carlo Di Mario.

Supplementary material

Supplementary material is available at *European Heart Journal—Case Reports* online.

Slide sets: A fully edited slide set detailing these cases and suitable for local presentation is available online as Supplementary data.

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

Conflict of interest: Carlo Di Mario is the recipient of institutional research grants from AMGEN, Abbott Vascular, Behring, Boston Scientific, Chiesi Pharmaceuticals, Daiichi-Sankyo, Edwards Lifescience, Medtronic, Shockwave Medical, Volcano Philips. The other auhtors have no conflicts of interest to report.

Funding: None declared.

References

1. Mattesini A, Di Mario C. Calcium: a predictor of interventional treatment failure across all fields of cardiovascular medicine. *Int J Cardiol* 2017;**231**:97–98.
2. Brinton TJ, Ali ZA, Hill JM, Meredith IT, Maehara A, Illindala U et al. Feasibility of shockwave coronary intravascular lithotripsy for the treatment of calcified coronary stenoses: first description. *Circulation* 2019;**139**:834–836.
3. Ali ZA, Nef H, Escaned J, Werner N, Banning AP, Hill JM et al. Safety and effectiveness of coronary intravascular lithotripsy for treatment of severely calcified coronary stenoses: the disrupt CAD II study. *Circ Cardiovasc Interv* 2019;**12**:e008434.
4. Hill JM, Kereiakes DJ, Shlofmitz RA, Klein AJ, Riley RF, Price MJ et al. Intravascular lithotripsy for treatment of severely calcified coronary artery disease: the disrupt CAD III study. *J Am Coll Cardiol* 2020;**76**:2635–2646.
5. Cosgrove C, Hanratty CG, Hill JM, Mahadevan K, Mailey J, McEntegart M et al. Intravascular lithotripsy for treatment of calcific coronary lesions in ST elevation myocardial infarction. *Catheter Cardiovasc Interv* 2021;1–7. https://doi.org/10.1002/ccd.29801.
6. Johnson TW, Räber L, di Mario C, Bourantas C, Jia H, Mattesini A et al. Clinical use of intracoronary imaging. Part 2: Acute coronary syndromes, ambiguous coronary angiography findings, and guiding interventional decision-making: an expert consensus document of the European Association of Percutaneous Cardiovascular Interventions. *Eur Heart J* 2019;**40**:2566–2584.
7. Alawami M, Thirunavukarasu S, Ahmed J, El-Omar M. Intravascular lithotripsy to treat an underexpanded coronary stent: 4-month angiographic and OCT follow-up. *Catheter Cardiovasc Interv* 2020;**96**:1251–1257.
8. Mattesini A, Nardi G, Martellini A, Sorini Dini C, Hamiti B, Stolcova M et al. Intravascular imaging to guide lithotripsy in concentric and eccentric calcific coronary lesions. *Cardiovasc Revasc Med* 2020;**21**:1099–1105.
9. Ielasi A, Moscarella E, Testa L, Gioffrè G, Morabito G, Cortese B et al. IntravaScular Lithotripsy for the Management of UndILatable Coronary StEnt: The SMILE Registry. *Cardiovasc Revasc Med* 2020;**21**:1555–1559.
10. Aksoy A, Salazar C, Becher MU et al. Intravascular lithotripsy in calcified coronary lesions: a prospective, observational, multicenter registry. *Circ Cardiovasc Interv* 2019;**12**:e008154.
11. Moretti A, Schiariti M, De Luca A, Griffo S, Greco C. Coronary stents underexpansion successfully treated with shockwave lithoplasty. *Cardiovasc Revasc Med* 2020;**21**:149–151.