Successful Expansion of an Underexpanded Stent by Rotational Atherectomy

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Abstract

Keywords

- ▶ underexpanded stent
- ▶ in-stent restenosis
- ▶ rotational atherectomy
- ▶ stentablation

The current routine use of intracoronary stents in percutaneous coronary intervention (PCI) has significantly reduced rates of restenosis, compared with balloon angioplasty alone. On the contrary, small post-stenting luminal dimensions due to undilatable, heavily calcified plaques have repeatedly been shown to significantly increase the rates of in-stent restenosis. Rotational atherectomy of lesions is an alternative method to facilitate PCI and prevent underexpansion of stents, when balloon angioplasty fails to successfully dilate a lesion. Stentablation, using rotational atherectomy to expand underexpanded stents deployed in heavily calcified plaques, has also been reported. We report a case via the transradial approach of rotational-atherectomy-facilitated PCI of in-stent restenosis of a severely underexpanded stent due to a heavily calcified plaque. We review the literature and suggest rotational atherectomy may have a role in treating a refractory, severely underexpanded stent caused by a heavily calcified plaque through various proposed mechanisms.

Summary

Stentablation, using rotational atherectomy to expand underexpanded stents deployed in heavily calcified plaques, has been reported in few case reports. We report a case via the transradial approach of rotational-atherectomy-facilitated PCI of in-stent restenosis of a severely underexpanded stent due to a heavily calcified plaque, and review the literature.

Background

Currently, the use of intracoronary stenting and, more specifically, the routine use of drug-eluting stents have dramatically decreased the rates of coronary restenosis following percutaneous coronary intervention (PCI). Yet, small post-stenting luminal dimensions due to undilatable, heavily calcified plaque have repeatedly been shown to significantly increase the rates of in-stent restenosis as well as prove to be a factor in predisposing to subacute stent thrombosis. Heavily calcified lesions may limit optimal successful stent deployment, resulting in underexpansion of the stent. Rotational

atherectomy of these lesions is an alternative method to facilitate PCI and prevent underexpansion of stents, when routine balloon angioplasty fails to successfully dilate the lesion. The use of rotational atherectomy to ablate the metal struts of a stent has been reported previously and may be necessary in select situations.^{1–5} The use of rotational atherectomy has been described to open the ostia of jailed side branches of stented bifurcation lesions. The stent struts obstructing the side branch are consequently ablated.⁶ When stents are deployed in calcified, undilatable lesions, cases in which rotational atherectomy is used to ablate stent struts and the underlying calcific or fibrotic tissue have been reported.^{1–5} We report a case of rotational-atherectomy-facilitated PCI of in-stent restenosis of a severely underexpanded stent due to a heavily calcified plaque, via the transradial approach. We review the literature and suggest rotational atherectomy may have a role in treating a refractory, severely underexpanded stent caused by a heavily calcified plaque through various proposed mechanisms, without requiring total ablation of the stent.

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Fig. 1 Baseline coronary angiogram showed the mid-LAD 99% stenosis with heavily calcified plaque. LAD, left anterior descending artery.

Case

A 60-year-old man with a history of hypertension, diabetes mellitus, dyslipidemia, and tobacco use presented with a chief complaint of typical unstable angina pectoris, Canadian Classification System (CCS) class III. Physical exam findings and laboratory data were unremarkable. The electrocardiogram (ECG) showed sinus rhythm at 68 beats per minute, with left axis deviation, 1 mm ST elevations in the anterolateral leads and poor R wave progression in the precordial leads. Trans-thoracic echocardiogram (TTE) revealed anterior and apical wall hypokinesis. Given the anginal symptoms and significantly abnormal ECG and TTE, the patient was referred for cardiac catheterization.

Coronary angiography, via the transradial approach, revealed mild diffuse disease in the left main and right coronary

Fig. 2 Inflation of a compliant PTCA balloon within the lesion failed to successfully predilate the lesion. PTCA, percutaneous transluminal coronary angioplasty.

artery. The left circumflex artery had a moderately obstructive 70% stenosis in the mid-portion, which was successfully stented. The left anterior descending artery (LAD) had a heavily calcified, proximal 90% stenosis as well as a mid-99% stenosis with Thrombolysis in myocardial infarction (TIMI) flow grade 2 (**Fig. 1**). For the PCI of the LAD, the left main was engaged transradially with a 6F EBU 3.5 guiding catheter (Medtronic Inc., Minneapolis, MN). An intravenous heparin bolus was administered and periodic activated clotting times were obtained and maintained at 250 to 300 seconds. The patient was also given oral aspirin (325 mg) and clopidogrel (600 mg) loading doses. A 0.014" Runthrough guidewire (Terumo Medical Company, Tokyo, Japan) was used to cross the lesions. Then a compliant Maverick 2.5 × 12 mm balloon (Boston Scientific Corp., Natick, MA) was used and inflated to 10 atm to predilate both the proximal and mid-LAD lesions (**Fig. 2**). Although the proximal LAD lesion was successfully dilated, the heavily calcified mid-LAD lesion remained undilatable despite balloon angioplasty, while the flow significantly improved to TIMI 3 flow. Rotational atherectomy was performed successfully with 1.25-mm Burr. After rotational atherectomy, a Taxus 2.5 × 12 mm drug-eluting stent (Boston Scientific Corp.) was deployed at 14 atm (**Fig. 3**). However, the stent was underexpanded (**Fig. 4**) and multiple balloon inflations with a Quantum Non-Compliant 3.0 × 8 mm balloon (Boston Scientific Corp.), at pressures as high as 30 atm of pressure failed to dilate the lesion. The patient was discharged home on optimal medical therapy with close clinical follow-up. After 6 months, he re-presented with unstable angina and repeat coronary angiogram, via the transradial approach, revealed the mid-LAD had a 99% in-stent restenosis lesion, again with TIMI 2 flow. A bivalrudin bolus and continuous infusion was administered. A compliant Maverick 2.5 × 12 mm balloon was inflated to 10 atm to predilate the lesion and improve blood flow to TIMI 3. However, the lesion remained undilatable at the underexpanded stent portion. Rotational atherectomy with 1.25-mm burr was initially attempted and the ablation was started at the proximal edge of the stent (**Fig. 5**). However, despite multiple runs of rotational atherectomy and using speeds of 200,000 rpm, the burr would not advance through the proximal edge of the stent. Nevertheless, at this point after rotational atherectomy, a Quantum Maverick Non-Compliant 3.0 × 12 mm balloon was inflated to 14 atm within the stent (**Fig. 6**), with evidence of full expansion of the balloon and full expansion of the stent (**Fig. 7**). The patient did well clinically and was discharged from the hospital without symptoms. At the point of 2 years of clinical follow-up, he remains angina free.

Discussion

In rigid, heavily calcified lesions, stent underexpansion is frequently observed. Stent underexpansion can increase risks of in-stent restenosis and also predispose patients to stent thrombosis. These can lead to adverse cardiac events including acute coronary syndromes, myocardial infarction, and

Fig. 3 The stent was deployed in the mid-LAD lesion but remained underexpanded despite inflation with a noncompliant PTCA balloon even at high pressures as high as 30 atm. atm, atmospheres; LAD, left anterior descending artery; PTCA, percutaneous transluminal coronary angioplasty.

death. Therefore, stent underexpansion should always be avoided, thus making heavily calcified lesions still a challenging hurdle to overcome despite current advances in the modern stent era. Rotational atherectomy of lesions is an alternative method to facilitate PCI and prevent underexpansion of stents, when routine balloon angioplasty fails to successfully dilate the lesion.^{1–5} High-speed rotational atherectomy preferentially cuts hard plaque, increasing plaque compliance, thereby rendering the lesion more amenable to balloon dilatation.² Therefore, to facilitate stent expansion in heavily calcified lesions, rotational atherectomy prior to stent implantation is often required.²

Kobayashi et al reported a case in which a stent was implanted in a heavily calcified “napkin-ring” lesion resulting in marked stent underexpansion.² When in-stent restenosis developed, intravascular ultrasound revealed the predominant cause of the stenosis was the underexpanded stent within a calcified band. When high-pressure balloon angioplasty failed to dilate the lesion, ablation of the stent struts using stentablation was performed. Rotational atherectomy

Fig. 4 The stent remained underexpanded at the heavily calcified mid-LAD lesion. LAD, left anterior descending artery.

Fig. 5 Rotational atherectomy using 1.25-mm burr was performed at the proximal edge of the underexpanded stent but could not be advanced further through the stent.

with slow advancement and a stepped burr approach allowed ablation of both the stent struts and the underlying calcified plaque, allowing subsequent balloon dilatation at relatively low pressures.²

Rotational atherectomy may also facilitate in-stent scaffolding of previously underexpanded stents. Medina et al reported two cases of underexpanded stents despite pretreatment with rotational atherectomy and post-dilatation with high-pressure balloon inflations up to 25 atm.³ Rotational atherectomy was performed to erode the metal and the wall

Fig. 6 After rotational atherectomy, the noncompliant PTCA balloon fully dilated the lesion successfully at only 14 atm pressure. atm, atmospheres; PTCA, percutaneous transluminal coronary angioplasty.

Fig. 7 The final coronary angiogram showed the now fully expanded LAD stent. LAD, left anterior descending artery.

that was causing the persistent constriction. Stepped burrs were used and allowed balloon dilatation to successfully break the calcified plaques and fully expand the lesions. In-stent stenting was performed in both cases to scaffold the entire target segments, leading to angiographically optimal results.³

Mokabberi and Blankenship reported a case of successful stentablation of a rotational-atherectomy-facilitated stent expansion of an underexpanded stent in the setting of an inferior ST elevation myocardial infarction in the presence of heavy thrombus burden and intracoronary dissection, which are traditionally contraindications to the use of rotational atherectomy.¹

As suggested by Sunew et al,⁴ in cases of undilatable, underexpanded stents due to rigid, heavily calcified lesions, the options are limited when high-pressure balloon inflations with shorter, noncompliant balloons fail to successfully expand the stents. The options include modalities such as rotational atherectomy, excimer laser, and cutting balloons.⁴ Current cardiovascular excimer lasers contain a xenon-chloride dimer. Absorption of laser energy by blood and contrast leads to fast vapor bubble expansion and implosion intraluminally, causing explosive dilation and invagination of adjacent arterial wall after each excimer laser pulse.⁴ Although reported results show procedural success in 84 to 92% of cases with excimer laser, limited availability of this technology in most cardiac catheterization laboratories has limited its widespread use.⁴

In our own case reported here, we present a case of unstable angina due to in-stent restenosis at the site of a severely underexpanded stent implanted 6 months prior. The cause of the stent underexpansion was a rigid, heavily calcified plaque that was pretreated with balloon angioplasty and rotational atherectomy. To treat the severe in-stent restenosis caused by the underexpanded stent at the heavily calcified plaque, we performed balloon angioplasty but failed to successfully dilate the lesion. Then rotational atherectomy was performed but only at the proximal edge of the stent because it could not be passed further through the stent. Still,

after rotational atherectomy, balloon angioplasty successfully dilated the lesion at relatively low pressures and led to full stent expansion. The proposed mechanism of this successful facilitation of dilating the underexpanded stent by rotational atherectomy is multifactorial. One mechanism is likely stentablation or erosion of metal and fibrocalcific tissue at least at the proximal edge of the stent, allowing successful balloon dilation and full expansion. Another mechanism suggested by Feldman and Reisman is the well-known fact that rotational atherectomy causes heat generation in native vessel lesions.^{7,8} The contribution of thermal injury and heat generation to the stent struts and lesion may itself increase plaque compliance and make the underexpanded stent portion and lesion amenable to balloon dilatation. Finally, Ho et al conducted an electron microscopic study to investigate the mechanism by which rotational atherectomy facilitates underexpanded stent erosion.⁵ He suggests high-speed blunt impact and the compressive effect of the rotablator against the hard lesion may both be effective.

The most important lesson is not to deploy a stent in a calcified lesion that cannot be adequately predilated. Furthermore, when rotational atherectomy is performed prior to stenting, a larger sized burr should be considered when optimal dilation is not achieved with the initial burr size. However, after a stent has been deployed in a heavily calcified lesion and remains underexpanded despite high-pressure balloon inflations, rotational atherectomy may have a role in facilitating dilation of the underexpanded stent. Furthermore, to our knowledge, ours is the first case reported using this technique successfully via the transradial approach.

Conclusion

Incomplete stent expansion is a common problem in heavily calcified lesions, which can lead to significant restenosis. Rotational atherectomy, via the transfemoral or transradial approach, may have a role in facilitating successful dilatation of the underexpanded stent through multiple proposed mechanisms.

Conflict of Interest

None of the authors have any conflicts of interest, affiliations, grants, funds, or interests to disclose relevant to the subject matter or materials discussed in this work.

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