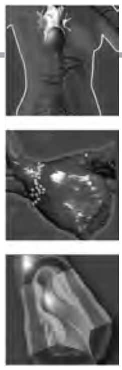

Treatment of calcific coronary stenosis with the use of excimer laser coronary atherectomy and rotational atherectomy

Rotational atherectomy is the technique of choice for severe coronary artery calcification to facilitate adequate stent deployment. However, rotational atherectomy use is dependent on the delivery of a dedicated guide wire, which is not always achievable. We describe a series of five patients with severely calcified coronary lesions that were successfully treated with the combination of excimer laser and rotational atherectomy when it was not possible to deliver a RotaWire™ and use rotational atherectomy alone.

KEYWORDS: atherectomy ▪ excimer laser ▪ percutaneous coronary intervention ▪ rotablation

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Noncrossable and nondilatable coronary lesions pose a major concern in percutaneous coronary intervention (PCI) often leading to technical failure, incomplete revascularization and complications. With the increasing age of the PCI population and the increasing complexity of cases undertaken in many centers, 'balloon failure' is now encountered more frequently. Such calcified stenosis, chronic total occlusions and noncompliant (NC) plaques often require the utilization of techniques other than balloon angioplasty in order to prepare the vessel for stenting. Adequate lesion debulking is particularly important in the drug-eluting stent (DES) era to permit better procedural success, target lesion revascularization and facilitate stent expansion and wall apposition, which in turn may lead to a reduction in late stent thrombosis [1].

The most commonly used device for heavily calcified coronary lesions and identified or perceived balloon failures is rotational atherectomy (RA). Indeed, the combined approach of RA–DES has a well-recognized favorable effect when dealing with heavily calcified lesions in both angiographic and clinical outcomes [2,3]. Practically, however, there are occasions when the dedicated RotaWire™ (Boston Scientific, MN, USA) cannot be advanced past the lesion either independently or via a microcatheter exchange system, rendering RA impossible.

Alternative techniques such as upsizing the guide catheter, use of a GuideLiner™ catheter (Vascular Solutions, MN, USA), use of a parallel wire or the anchor technique may assist passage of the balloon or microcatheter across the lesion but success is variable and often dependent on operator experience. The Tornus® penetration catheter (Asahi Intecc, Aichi, Japan) is a further developmental technique available that has demonstrated success in chronic total occlusions but has not been shown to be superior to RA in a small study [4,5]. In addition, whilst assisting with noncrossable lesions, these techniques are unlikely to be able to deal with nonballoon-expansible lesions and additional RA may still be required.

Excimer laser coronary atherectomy (ELCA) has an established role in the treatment of balloon failure caused by mild–moderate calcification, usually without the need for additional RA [6] with the advantage of being deliverable using the standard 0.014-inch guidewire. In lesions with more resistant calcification that can not be fully debulked with ELCA alone, a 'pilot hole' created by ELCA can be used to pass a RotaWire either independently or via a microcatheter exchange technique to permit subsequent RA and achieve procedural success. This combination of atherectomy techniques, which we have termed 'Raser', is demonstrated in the following five clinical cases.

Description of cases

■ Case 1

A 75-year-old diabetic male with angina pectoris attended for elective coronary angiography. This demonstrated a severe left anterior descending (LAD) lesion and a critical heavily calcified lesion in the proximal right coronary artery (RCA) with thrombolysis in myocardial infarction II flow and ECG ischemia during injection of the RCA. In view of the lesion severity he was admitted for elective revascularization options and after discussion chose PCI over coronary artery bypass graft surgery.

In light of the heavy calcification, we planned to use RA to debulk the lesion (Figure 1A). After transfemoral access a 7 Fr JR4 guide catheter was

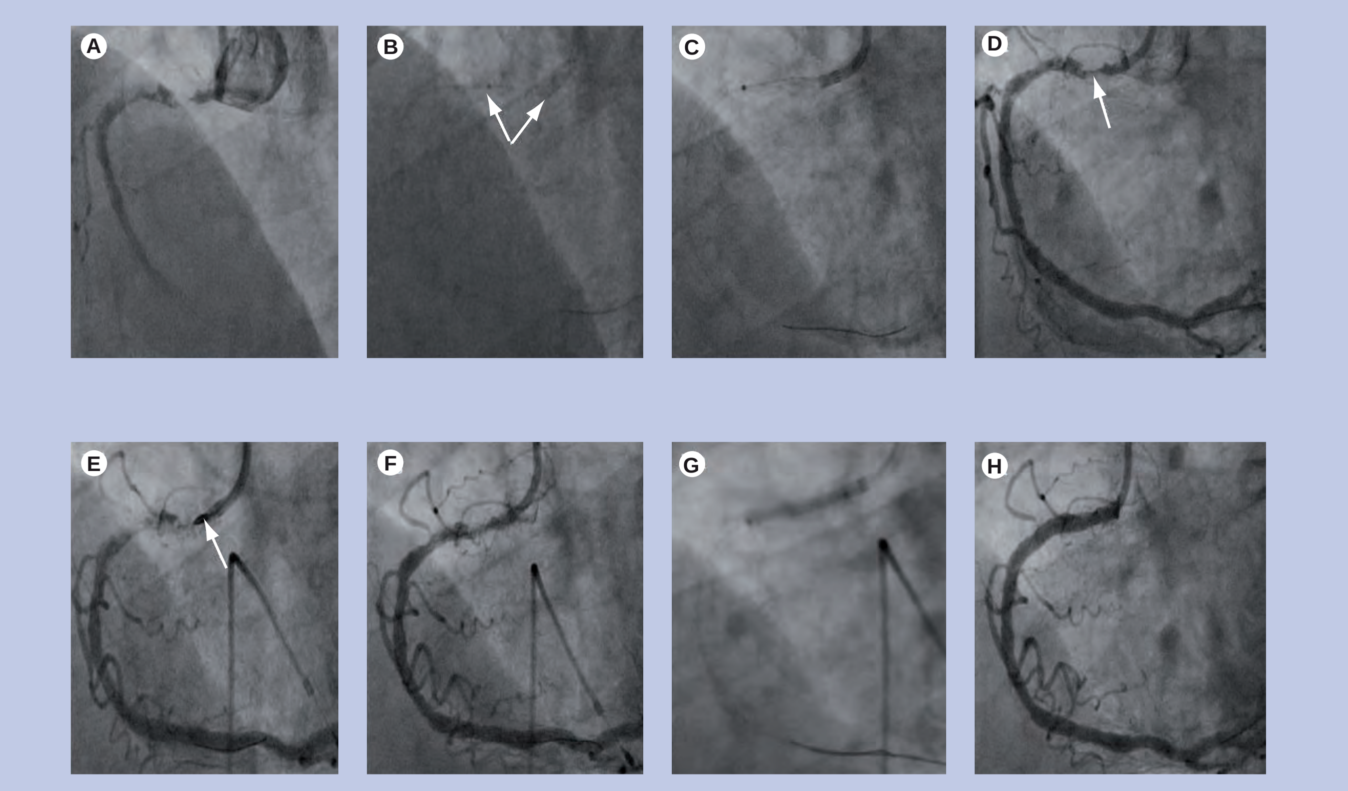

Figure 1. Left anterior oblique projections of the right coronary artery. (A) Severe proximal calcific stenosis with thrombolysis in myocardial infarction II flow. **(B)** Finecross® MG catheter would not traverse the proximal stenosis backing out the guide catheter (arrows). **(C)** 0.9-mm excimer laser coronary atherectomy catheter. **(D)** Visible channel through (arrow) the calcific lesion after utilizing a 0.9-mm excimer laser coronary atherectomy catheter. **(E)** 1.5 mm Rotablation Burr. **(F)** Post-1.5 mm Rotablation Burr demonstrating improved flow distally. **(G)** Full balloon expansion of a 3.0 × 20 mm Voyager™ NC balloon. **(H)** Final angiographic result.

positioned. A Hi-Torque Balance Middle Weight Universal™ (BMW) wire would not traverse the lesion and we used a Fielder XT (Asahi Intec, Abbott Vascular, Rangendingen, Germany) to wire the distal vessel. We attempted to exchange this for a RotaWire using a Finecross® MG catheter (Terumo Medical Corp., NJ, USA; 1.8 Fr), but this would not traverse the proximal stenosis backing out the guide catheter (Figure 1B). Therefore, we used a 0.9 mm ELCA (CVX-300®, Spectranetics, CO, USA) catheter, which created a visible channel through the lesion (Figure 1C), improved flow distally and enabled a Finecross MG catheter to traverse easily into the distal vessel for RotaWire exchange.

A 1.5 mm burr was used to deliver 60 s of RA (Figure 1D) using the Rotablator® RA system (Boston Scientific). A BMW wire was passed to the distal vessel and lesion predilated with a 3.0 × 20 mm Voyager™ NC balloon (Abbott Vascular) that expanded easily (Figure 1E). Two overlapping Promus (Boston Scientific) stents (3.5 × 20 mm and 3.5 × 24 mm) were deployed back to the ostium and postdilated with a 4.0 × 20 mm Voyager NC balloon to achieve an excellent angiographic result (Figure 1F).

Case 2

A 72-year-old male with recent PCI to the LAD following an acute presentation attended for staged PCI for the RCA with ongoing limiting angina pectoris. The RCA was a large dominant vessel with a severe heavily calcified lesion in the mid-third.

The procedure was performed transradially with a 6 Fr Amplatz Left 1.0 guide catheter. A BMW guide wire was passed to the distal vessel with the intention of using a Finecross MG catheter in exchange for a RotaWire. However, the microcatheter would not cross the lesion and we felt it unlikely to be able to negotiate a RotaWire independently. Therefore, ELCA was performed (Table 1) with a 0.9 mm catheter to create a channel to permit easy passage of a RotaWire to the distal vessel. RA was performed with a 1.5 burr (90 s) to fully debulk the lesion. The RotaWire was exchanged for a BMW and after predilation with a 3.0 × 20 mm Voyager NC balloon, a 4.0 × 32 Promus Element (Boston Scientific) stent was delivered and postdilated with a 4.25 × 20 mm Voyager NC balloon with an excellent angiographic result (Figure 2A & B).

Table 1. Excimer laser coronary atherectomy details for each examined case.

	Case 1	Case 2	Case 3	Case 4	Case 5
ELCA guidewire	Fielder XT	BMW™	Fielder XT	Luge™	BMW™
Maximal fluence (mJ/mm^2)	80	80	80	80	80
Maximal repetition rate (Hz)	80	80	80	80	80
Total pulses	13,826	5472	10,500	12,800	1225
Case time (min)	90	91	115	160	129†
X-ray dose ($\mu Gy/m^2$)	6254	8719	9694	22,114	18,218†
Contrast (ml)	190	150	200	450	600†

†Case 5: note that the right coronary artery and left anterior descending artery were treated with percutaneous coronary intervention easily at the same sitting before attention was turned to the circumflex. This increased the case time, x-ray dose and amount of contrast used.
BMW: Balance Middle Weight Universal™; ELCA: Excimer laser coronary atherectomy.

■ Case 3

A 57-year-old male was admitted with an inferior non-STEMI (NSTEMI). Coronary angiography demonstrated an unobstructed left coronary system and a dominant, heavily calcified RCA with the most severe and calcific stenosis in the mid-vessel with further disease involving the ostium.

Following discussion with the patient regarding case complexity, he returned for PCI to the RCA. RA was anticipated and after transfemoral access a 7 Fr JR4 guide was positioned but a BMW wire would not cross the mid-course lesion. Instead, a Fielder XT wire was used to successfully negotiate the entire diseased segment with the intention of using a Finecross MG catheter in exchange for a RotaWire. However, the microcatheter would not pass beyond the proximal lesion. We therefore modified the lesion with ELCA using a 0.9 mm catheter to create an angiographically visible channel.

A Finecross catheter was then able to traverse the entire lesion and the Fielder XT was exchanged for the RotaWire. A 1.5 mm burr was used to debulk the disease (60 s). The RotaWire was then exchanged for a BMW wire and after predilation with Voyager NC balloons (3.0 × 20 mm and 3.5 × 20 mm); three overlapping Cypher (Cordis Europe, Roden, The Netherlands) stents (3.5 × 23, 3.5 × 33 and 3.5 × 23 mm) were deployed. The stents were postdilated with a 3.75 × 20 mm Voyager NC balloon, achieving an excellent angiographic result (Figure 3A & B).

■ Case 4

A 61-year-old diabetic female with a BMI of 48 kg/m^2 was admitted with an inferior NSTEMI. Transradial coronary angiography demonstrated a large dominant RCA with a severely calcified mid-course stenosis.

A Runway™ guide was positioned and RA was anticipated but a RotaWire could not be passed into the distal vessel. A Luge™ wire was advanced across the lesion, but a 0.85 × 10 mm Nano (SIS Medical, Winterthur, Switzerland) balloon, the lowest profile over-the-wire balloon available in our catheter laboratory at the time, would not cross the lesion to allow exchange for a RotaWire.

A 0.9 mm Excimer laser catheter was advanced to the calcification and although this catheter did not fully cross the lesion, laser energy sufficiently modified the stenosis to permit a 2.0 × 10 mm Apex (Boston Scientific) NC balloon to predilate to 12 atm. However, no larger balloons would cross the diseased segment and it was necessary to perform RA as originally planned. A RotaWire now easily passed to the distal vessel and a 1.25 mm Burr was used to debulk the lesion (90 s). After predilation with a 3.5 × 20 mm NC balloon three overlapping Tsunami™ (3.5 × 18, 3.5 × 10 and 3.5 × 8 mm) bare metal stents (Terumo Corp.,

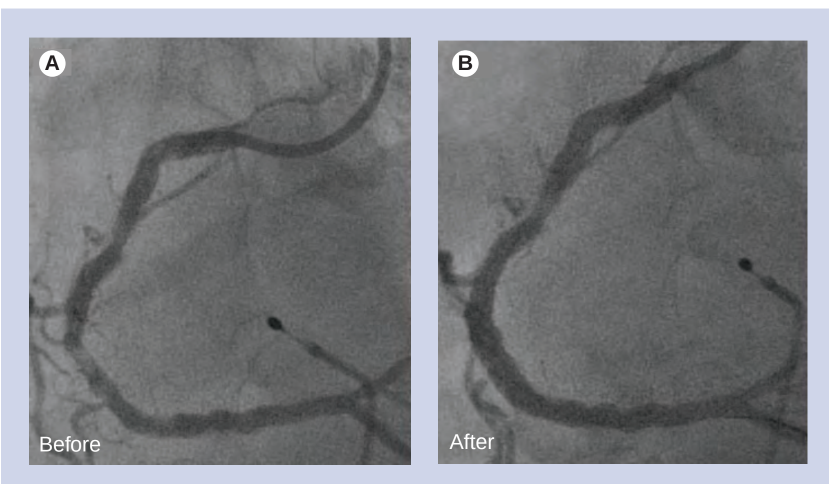

Figure 2. Left anterior oblique projections of the right coronary artery.
(A) Large dominant vessel with a severe heavily calcified lesion in the mid-third.
(B) Final angiographic result.

Figure 3. Left anterior oblique projections of the right coronary artery. **(A)** Dominant heavily calcified right coronary artery with severe and calcific stenosis in the mid-vessel with further disease involving the ostium. **(B)** Final angiographic result.

Tokyo, Japan) and one 3.5 × 15 mm Prokinetic™ bare-metal stent (Biotronik, Berlin, Germany) were deployed. A good angiographic result was achieved after postdilatation with a 4.5 × 10 mm Voyager NC balloon (Figure 4A & B).

■ Case 5

A 77-year-old diabetic male with ongoing limiting angina was electively admitted for PCI to the RCA and LAD, and RA to the circumflex artery in view of previous balloon failure. He had had previous intervention to his RCA and LAD with DESs but had focal restenosis. At the time of his last LAD intervention an attempt was made to treat the circumflex. However, after a BMW wire had successfully crossed the lesion no balloon could be advanced into the lesion.

Figure 4. Left anterior oblique projections of the right coronary artery. **(A)** Large dominant right coronary artery with a severely calcified mid-course stenosis. **(B)** Final angiographic result.

The procedure was performed transfemorally and the RCA (6 Fr JR4) and LAD (extra back-up [EBU] 3.75) were treated easily before attention was turned to the circumflex. An attempt was made to deliver a RotaWire but it would not advance across the lesion. Instead, a BMW wire was successfully passed into the distal vessel. The lowest profile over-the-wire balloon available at the time was a Ryujin® (Terumo Corp.) 1.25 × 15 mm (2.2 Fr) and this would not cross. Therefore, ELCA was performed using a 0.9 mm catheter (Table 1). This modified the lesion sufficiently to pass a RotaWire into the distal vessel. RA was then performed using a 1.25 mm burr and the vessel was predilated with a 2.5 × 15 mm Maverick™ (Boston Scientific) balloons and a 2.0 × 10 mm Flextome® Cutting balloon® (Boston Scientific). Following this, two Prokinetic stents (2.25 × 15 mm and 2.5 × 20 mm) were deployed and postdilated with a 2.5 × 20 mm Mercury™ NC balloon (Abbott Vascular) with an excellent angiographic result (Figure 5A & B).

■ Case summary

These cases demonstrate the successful use of this device in complex calcified stenotic disease in conjunction with RA. These cases were performed in our unit over the last 3 years and have been presented in historical order with the most recent as the first case. From Table 1, there is a suggestion that x-ray fluoroscopy time and case duration have decreased with more experience and anticipation of the need for the combined technique.

We believe that this is the first reported case series using this combined strategy. We have coined the term Raser to describe this adjunctive technique.

Discussion

Rotational atherectomy is the technique of choice for severe coronary artery calcification to facilitate adequate stent deployment [6]. However, it can only be utilized if a 0.009-inch diameter stainless steel RotaWire can be advanced distal to the lesion and occasionally this is not possible. In these five cases, an excimer laser catheter, which requires only a standard 0.014-inch guidewire, was used to create a channel through the lesion to permit subsequent passage of a balloon or microcatheter and RotaWire to complete the revascularization procedure. ELCA is generally only indicated for mild–moderate calcified lesions [7], but we have demonstrated that ELCA can also be useful as an adjunct to facilitate RA in heavily calcified lesions.

Thermal injury caused by first-generation coronary lasers resulted in them being disregarded in PCI [8]. However, with contemporary excimer coronary laser technology complications owing to thermal injury have largely been resolved. A combination of pulsed-wave ablation with shallow tissue penetration depth (50 μm) owing to shorter wavelength of light (ultraviolet 308 nm) in conjunction with saline boluses during lasing now permit the safe use of this device for a variety of clinical indications.

Excimer laser coronary atherectomy utilizes three mechanisms to ablate tissue: photochemical, photothermal and photomechanical. The photochemical process dissolves molecular bonds, using pulsed energy with a very short pulse duration (135 ns), so that the energy dissipates in-between pulses. Photothermal energy from molecular vibration heats intracellular water to vaporize and rupture cells. Steam forms a vapor bubble that expands and collapses, dissolving tissue and clearing by-products away from the catheter tip – the photomechanical process. The particles generated are less than 5 μm and are absorbed by the reticuloendothelial system, as in RA.

The key principles for safe, successful coronary laser atherectomy include slow advancement of the catheter (0.5–1.0 mm/s) during laser activation and removal of contrast and blood at the laser–tissue interface before laser emission. The latter is mandatory as iodinated contrast and blood have a significant potentiating effect on the photothermal process, increasing the risk of localized thermal injury. This is avoided by clearing the manifold, line, Y connector and guide catheter using saline and repeat boluses of saline during lasing [9].

Excimer laser coronary atherectomy is currently indicated for the treatment of mild-to-moderate calcified lesions resistant to balloon inflation [7], saphenous venous grafts [10,11], in-stent restenosis and there is emerging evidence for the use of ELCA in acute STEMI to prevent distal embolization and no-reflow in thrombus laden lesions [12–14].

In the treatment of noncrossable lesions, ELCA may still be helpful, even if the catheter does not fully cross the lesion (as in Case 4) as the stenosis may be sufficiently modified to permit case completion. Similarly, in clinical practice with noncrossable and nondilatable lesions we have found ELCA to be extremely useful despite the catheter occasionally not crossing the lesion [15].

The main limitation of ELCA is the cost of both the laser console and catheters. However, the capital costs of the console can be partially offset by other indications such as the pacing lead extraction and the treatment of critical limb ischemia. The consumable costs remain high but are comparable with other atherectomy devices (e.g., RA, Tornus). We accept that there are alternative approaches to these complex cases other than Raser, which individual interventionists will tackle in their own way. While Raser is not a unique technique, it can facilitate safe and effective PCI for complex lesions, allowing relatively short case duration and low ionizing radiation doses.

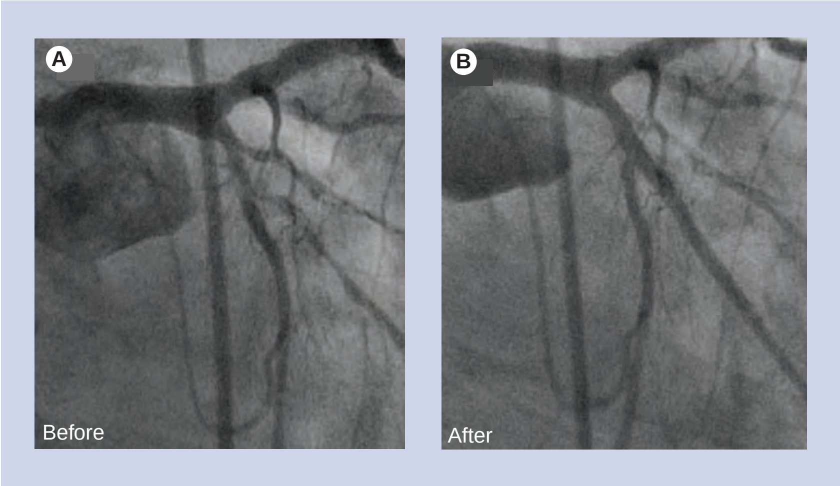

Figure 5. Postero-anterior caudal projections of the circumflex coronary artery. (A) Severe calcific disease. **(B)** Final angiographic result.

Conclusion

We have demonstrated that ELCA may be indicated as an adjunct to facilitate RA in heavily calcified lesions to permit successful PCI and negate the need to consider alternative coronary revascularization such as CABG. We have found this combination useful in five cases thus far and have coined the term Raser to describe this technique. If the strategy is anticipated at the start of the case then acceptable radiation exposure, case duration and contrast load can be determined with Raser. With further experience of this technique, these effects will likely be reduced further.

Future perspective

With both continuing changes in the demographics of the PCI population and increasing case complexity, the incidence of 'balloon failure' is likely to increase in coming years. Despite continuing advances in wire and balloon technology, the management of 'balloon failure' is likely to require adjunctive 'mechanical' solutions and we believe that Raser, as a simple and safe technique, may play a valuable role in these cases.

Executive summary

Background

- Noncrossable and nondilatable coronary lesions pose a major concern in percutaneous coronary intervention (PCI) often leading to technical failure, incomplete revascularization and complications.
- With the increasing age of the PCI population and the increasing complexity of cases undertaken in many centers, 'balloon failure' is now encountered more frequently.
- The technique of choice for heavily calcified coronary lesions is rotational atherectomy (RA).
- There are occasions when the dedicated RotaWire™ cannot be advanced past the lesion either independently or via a microcatheter exchange system rendering RA impossible.
- There are a number of strategies to deal with balloon failure other than RA but each has its own limitations.
- Excimer laser coronary atherectomy (ELCA) is recognized as a treatment strategy for balloon failure due to mild-to-moderate calcified lesions but it is generally not considered useful if calcification is very extensive. However, the combination of ELCA–RA has been used successfully in the cases discussed herein.

Case summary

- These cases demonstrate the successful use of this device in complex calcified stenotic disease in conjunction with RA.

Discussion

- Excimer laser coronary atherectomy–rotational atherectomy strategies are effective in cases of balloon failure when heavy calcification is present.
- An Excimer laser catheter was used to create a channel through the lesion to permit the subsequent passage of a balloon/microcatheter and RotaWire to complete the procedure.

Conclusion

- We have demonstrated that ELCA may be indicated as an adjunct to facilitate RA in heavily calcified lesions to permit successful PCI and negate the need to consider alternative coronary revascularization such as coronary artery bypass graft surgery.
- This technique may play a valuable role in the future with both continuing changes in the demographics of the PCI population and increasing case complexity.

Financial & competing interests disclosure

Suneel Talwar and Peter O'Kane are European Proctors for Spectranetics. The authors have no other relevant affiliations or financial involvement with any organization or entity with a financial interest in or financial conflict with the subject matter or materials discussed in the manuscript apart from those disclosed.

No writing assistance was utilized in the production of this manuscript.

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