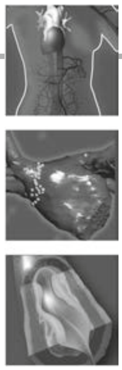

Treatment of inadvertent subintimal stenting during intervention of a coronary chronic total occlusion

We present a case of percutaneous coronary intervention of a chronic total occlusion of the right coronary artery. The lesion could not be crossed with a balloon after guidewire crossing, necessitating repeat crossing using a different pathway. Stent implantation resulted in ST-segment elevation due to inadvertent stent deployment into the subintimal space without distal outflow. A polymer-jacketed guidewire was used to enter the distal branches of the right coronary artery, restoring antegrade flow and resulting in resolution of ST-segment changes.

KEYWORDS: chronic total occlusion ■ complication ■ percutaneous coronary intervention

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A 58-year-old man with hypertension and hyperlipidemia presented with a non-ST elevation myocardial infarction. He underwent coronary angiography, which revealed significant stenosis of the mid-left anterior descending artery and a chronic total occlusion (CTO) of the proximal right coronary artery (RCA) filling distally via left to right collaterals. He underwent successful intervention of the mid-left anterior descending artery; however, 1 month later, due to persistent angina refractory to medical therapy, he was referred for elective percutaneous coronary intervention (PCI) of his RCA CTO.

Bilateral femoral arterial access was obtained with 45-cm long sheaths. The left main and RCAs were engaged with a 7 French Extra Backup 3.5 (Cordis, NJ, USA) and a Judkins Right 4 (Cordis) guide catheter, respectively. Diagnostic angiography demonstrated a CTO of the proximal RCA (Figure 1A) with filling of the distal RCA and the right posterior descending artery (Figure 1A) via collaterals from the left anterior descending artery. Unfractionated heparin was administered for anticoagulation. The lesion was crossed in the antegrade direction with a Pilot 200 wire (Abbott Vascular, IL, USA); however, we were unable to advance any equipment through the proximal RCA, despite using multiple 1.5-mm balloons, a 2.1 and 2.6 French Tornus catheter (Abbott Vascular; Figure 1B), a CrossBoss catheter (Bridgepoint Medical, MN, USA), a FineCross™ catheter (Terumo Medical, NJ, USA) and 0.9-mm laser catheter (Spectranetics, CO, USA). The Judkins Right 4 guide was subsequently exchanged over the 0.014-inch Pilot 200 wire for an AL1 guide for additional support, but we were still unable to advance any equipment through the proximal RCA.

We subsequently advanced a second Pilot 200 wire in a 'parallel wire' fashion antegradely through the CTO into the distal RCA (Figure 1C). With increased backup support from the AL1 guide and a second parallel wire, an intravascular ultrasonography catheter was able to be advanced further into the RCA. A contralateral injection (Figure 1D) suggested an intraluminal distal wire position. After predilation, four overlapping XIENCE V® stents (Abbott Vascular; 2.5 × 28, 2.5 × 28, 2.75 × 28 and 3 × 28 mm) were deployed from the distal to proximal RCA; however, post-stenting angiography revealed occlusion of the acute marginal branch, the posterior descending artery and the right posterolateral branch (Figure 1E), suggesting subintimal stent deployment. The patient developed chest pain and inferior ST-segment elevation.

The distal tip of a Pilot 200 guidewire was shaped into a 90° bend and the wire was aggressively advanced through each side branch, using a penetration technique, successfully entering the distal true lumen of all three vessels. After multiple sequential balloon dilations with 1.5- and 2.0-mm balloons, antegrade thrombolysis in myocardial infarction 3 flow was restored in all three vessels with resolution of the chest pain and electrocardiographic changes (Figure 1F). The patient had a periprocedural myocardial infarction with a peak creatine kinase-MB level of 41 ng/ml, but otherwise the patient had an uncomplicated recovery with resolution of his angina.

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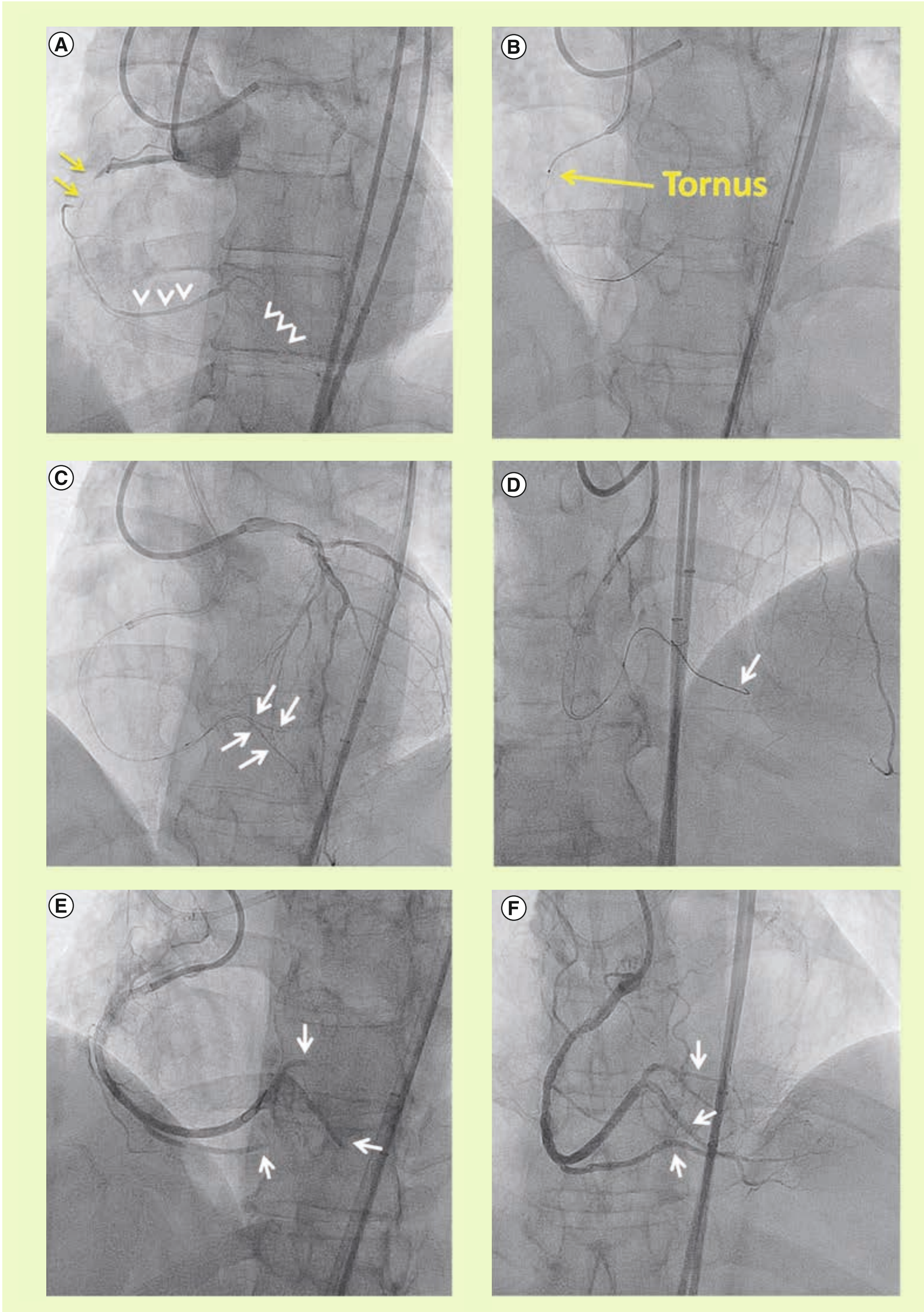

Figure 1. Percutaneous coronary intervention of the right coronary artery chronic total occlusion. (A) Coronary angiography demonstrating a chronic total occlusion of the mid-right coronary artery (arrows). The distal right coronary artery and the right posterior descending artery (arrowheads) were filling via collaterals from the left anterior descending artery. **(B)** The right coronary artery was crossed antegradely with a Pilot 200 wire (Abbott Vascular, IL, USA); however, no other catheter, such as the Tornus catheter (Abbott Vascular; arrow), could cross the occlusion. **(C)** Crossing of the right coronary artery occlusion with a second Pilot 200 wire (arrows). **(D)** Dual coronary injection suggesting intraluminal distal wire position (arrow). **(E)** Cessation of antegrade coronary flow in the acute marginal branch, right posterior descending artery and right posterolateral branch (arrows) after stenting of the right coronary artery. **(F)** After rewiring and balloon angioplasty of the acute marginal branch, right posterior descending artery and right posterolateral branch (arrows), antegrade coronary flow was restored in all three vessels.

Discussion

Our report demonstrates that: in cases of ‘balloon uncrossable’ CTOs, recrossing the lesion through a different pathway may allow balloon crossing and lesion dilation; confirmation of intraluminal wire position is of paramount importance prior to stenting to avoid inadvertent stenting of the subintimal space that can compromise antegrade flow; and in the case of inadvertent subintimal space stenting, using a stiff polymer-jacketed guidewire can facilitate crossing into the distal true lumen and restoration of antegrade coronary flow.

■ Crossing of the balloon-uncrossable CTO

The most common reason for CTO PCI failure is failure to cross the lesion with a guidewire [1]. The second most common reason is the inability to cross the lesion with a balloon after successful guidewire crossing (balloon uncrossable CTOs) [1,2]. Crossing of the balloon uncrossable CTO can be achieved using several techniques [2]. First, a small (1.25 or 1.5 mm) balloon is inserted as deep as possible into the CTO and inflated at high pressure. Long balloons are preferred as the highest profile segment of the balloon is the mid-shaft marker. If this fails, the balloon can be inflated again until it ruptures, which can modify the plaque and allow lesion crossing. If this fails, the Tornus catheter (Asahi Intecc, Japan) can be utilized. The Asahi Tornus device is a wire-braided microcatheter designed to penetrate otherwise difficult to cross CTO lesions by advancing using counterclockwise rotation. Second-line techniques include the use of strategies that increase guide catheter support, such as using a larger and more supportive shape guide catheter, using the Guideliner catheter (Vascular Solutions, MN, USA) [3] or various anchor balloon techniques [4]. Occasionally, a combination of techniques, such as Anchor-Tornus [5] or Guideliner-Tornus may be required. Third-line strategies include the use of rotational atherectomy or laser, or recrossing the lesion through a different path, as was ultimately done in our case.

■ Confirming intraluminal wire position

After antegrade CTO crossing, it is of paramount importance to confirm that the wire has entered the distal true lumen before proceeding with balloon dilation and stenting. This can be accomplished by dual injection, contrast injection through a microcatheter, using intravascular imaging and by observing the wire movement into distal branches. Dual injection is most commonly used and is crucial for nearly all CTO procedures, even when most collaterals are ipsilateral, as ipsilateral collaterals may become occluded during crossing attempts [6,7]. We recommend against using antegrade contrast injection through a microcatheter, because it carries the risk of subintimal space ‘staining’ and dissection propagation if the wire is not in the distal true lumen, which can then hinder subsequent true lumen re-entry attempts. Intravascular imaging is another option if the imaging catheter can cross the lesion. Intravascular ultrasonography is usually used [8], although optical coherence tomography has also been reported [9]. However, advancing the imaging catheter distally may be challenging. Moreover, the forceful contrast injection required for optical coherence tomography may propagate a subintimal dissection. Although distal side branch entry of the wire is suggestive of true lumen position [10], it may also be misleading as the wire can advance subintimally into side branches.

If the subintimal guidewire position is confirmed, entering the distal true lumen can be achieved using several strategies [11]: in the original subintimal tracking and re-entry (STAR) technique, the knuckled guidewire was advanced distally until it spontaneously entered into the distal true lumen [12]; in the more contemporary limited antegrade subintimal tracking (LAST) or mini-STAR [13] technique, the area of subintimal dissection is limited by re-entering the true lumen as close as possible to the distal cap without propagating the dissection into the distal part of the vessel; finally, the Stingray system (Bridgepoint Medical) has been specifically designed to facilitate distal true lumen crossing. The Stingray balloon is 2.5 mm in diameter and 10 mm in length and has a flat shape with two side exit ports: upon low-pressure inflation (2–4 atm) it orients one exit port automatically towards the true lumen. The Stingray wire is a stiff guidewire that has a 20-cm distal radiopaque segment and a 0.009-inch tapered tip with a 0.0035-inch distal taper. The Stingray guidewire is directed towards one of the two side ports of the Stingray balloon under fluoroscopic guidance to re-enter the distal true lumen [14,15].

■ Distal vessel rescue after subintimal stenting

Once stents have been inadvertedly deployed in the subintimal space without connection to the distal true lumen, the patient may remain asymptomatic [16,17] or may develop ST-segment elevation due to side branch loss, as in our case. Various techniques can be used to regain access into the distal true lumen. First, antegrade crossing can be attempted: in our case we were able to advance a stiff, polymer-jacketed guidewire (Pilot 200) into each of the occluded branches (acute marginal branch, posterior descending artery and right posterolateral branch). Balloon angioplasty allowed the restoration of antegrade flow in each of these branches. An alternative option is to use a dedicated re-entry system, such as the Stingray wire and balloon (Bridgepoint Medical) [14,15] or the Venture catheter (St Jude Medical, MN, USA) [18,19]; however, difficulty may be encountered in advancing the catheter past the stented segment. Third, retrograde crossing into the true lumen can be attempted, especially in the presence of large and nontortuous collateral vessels [7]. These same techniques can also be employed to re-enter the true lumen in cases of inadvertent diagnostic or guide catheter dissection during vessel engagement [20].

Apart from subintimal stenting, antegrade flow can be slow after CTO PCI because of distal edge dissection, distal embolization, vasoconstriction and competitive flow from collaterals. Edge dissections are detected in 1.7% of cases by angiography versus 9.2% of cases by intravascular ultrasonography [21]. Approximately half of the dissections occur in the proximal and the distal edge [22]. CTO lesions can be complex and calcified, increasing the risk for edge dissection [21], and this possibility must be considered if thrombolysis in myocardial infarction flow is reduced after stenting. No reflow and distal embolization usually occurs in patients with acute coronary syndromes or saphenous vein graft stenting, but can at times occur after CTO PCI due to embolization of atheromas, platelet–fibrin complexes, cholesterol crystals and macrophages [23,24]. Vasospasm is always a possibility after CTO PCI, especially when the distal vessel is of small caliber and diffusely diseased, but usually resolves after nitroglycerin administration. Finally, in some cases with well-developed collateral circulation, contralateral blood flow remains brisk after stenting, competing with antegrade flow, but this can be elucidated with more forceful antegrade injections.

Conclusion

In summary, inadvertent subintimal space stenting during CTO PCI can be salvaged using a stiff, polymer-jacketed guidewire to gain entry into the distal true lumen. Routine application of preventive strategies and awareness of potential treatment options can minimize the occurrence and the consequences of this CTO PCI complication.

Future perspective

Failure to cross is the most common cause of CTO PCI failure. Ensuring that the coronary guidewire enters into the distal true lumen is of paramount importance to prevent inadvertent subintimal stenting. Careful review of coronary angiography using dual injection is currently the main method of ensuring distal true lumen guidewire location, but novel equipment and techniques are constantly being developed to facilitate this task and make CTO PCI safer and more effective.

Informed consent disclosure

The authors state that they have obtained verbal and written informed consent from the patient for the inclusion of their medical and treatment history within this case report.

Financial & competing interests disclosure

S Banerjee has received research grants from Gilead and Boston Scientific; has received consultant/speaker honoraria from Covidien and Medtronic; and has ownership in MDCARE Global and intellectual property in HygeiaTel. E Brialkis has received speaker honoraria from St Jude Medical, Terumo and Bridgepoint Medical and a research grant from Guerbet; his spouse in an employee of Medtronic. 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

Executive summary

Chronic total occlusion guidewire crossing

- Successful chronic total occlusion guidewire crossing to the distal lumen remains the most common reason for chronic total occlusion percutaneous coronary intervention failure.
- Failure to dilate the lesion after successful guidewire crossing is the second most common reason for chronic total occlusion percutaneous coronary intervention failure.

Confirming intraluminal wire position

- Intraluminal wire position can be confirmed using contralateral injection, microcatheter contrast injection, intravascular ultrasonography or observation of wire movement into distal branches.

Distal vessel rescue

- Distal vessel jailing after inadvertent subintimal stenting or dissection can be treated using stiff polymer-jacketed wiring of the distal true lumen, dedicated re-entry devices or retrograde crossing into the true lumen.

or materials discussed in the manuscript apart from those disclosed.

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