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Wire externalisation techniques for retrograde percutaneous coronary interventions of chronic total occlusions

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Abbreviations

CTO chronic total occlusion
IVUS intravascular ultrasound
MC microcatheter
PCI percutaneous coronary intervention

Background

The current success rates of percutaneous coronary interventions (PCI) of chronic total occlusions (CTO) are reaching more than 90% by experienced CTO operators. This can be attributed mainly to the implementation of continuously improved interventional devices and strategies. The retrograde approach has contributed significantly to increase the success rate[1]. In most retrograde procedures wire externalisation represents an important final step after crossing the CTO lesion retrogradely during PCI. Based on our combined experience of >500 retrograde cases, this review article aims to illustrate and explain the different kinds of techniques of wire externalisation as well as important tips and tricks.

CONVENTIONAL WIRE EXTERNALISATION

Before starting the externalisation, the dedicated retrograde CTO wire has first to cross the occlusion and re-enter the correct lumen with the support of a microcatheter (MC) positioned 2-3 cm proximal to the wire tip. Then the retrograde CTO wire may be advanced and fed into the antegrade guiding catheter **(Figure 1A, Figure 1B)**.

Now the MC is advanced further over the conventional guidewire 2-5 cm into the antegrade guiding catheter **(Figure 1C)**. If the MC cannot be advanced into the guide because of a hard occlusion, tortuosity or friction, an antegrade trapping balloon (2.5-3.0 mm) should be placed into the distal guide and inflated at about 8 atm to trap and fix the retrograde wire. This will increase support and allows advancing the MC into the antegrade guide.

Now the retrograde CTO wire is pulled and replaced by the externalisation wire via the retrograde MC into the antegrade guiding catheter, finally exiting at the antegrade haemostatic valve.

Planning and preparing the procedure

Wire externalisation in retrograde PCI of CTOs means advancing the retrograde guidewire into and through the antegrade guiding catheter to serve as an antegrade route for balloon and stents.

Several parameters have to be taken into account prior to retrograde wiring: the length of the intracoronary loop depending on the length and tortuosity of the anatomic course of the collateral

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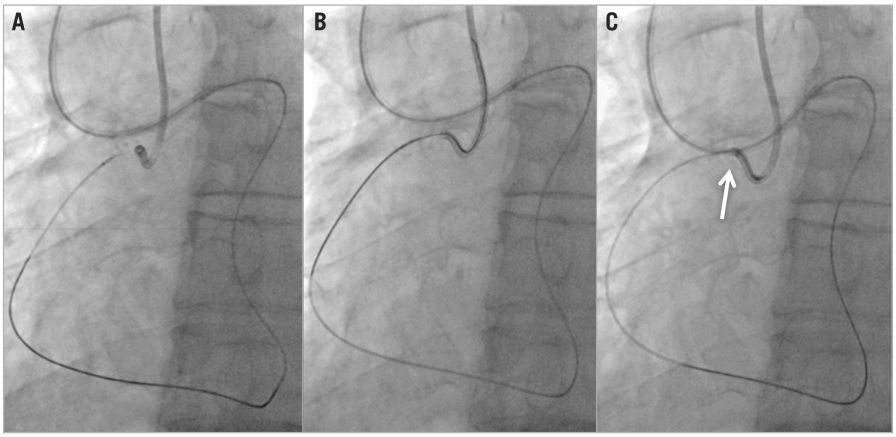

Figure 1. *Conventional wire externalisation. A retrograde MC is advanced towards the antegrade cap of the proximal CTO of the RCA (A). The retrograde guidewire engages the antegrade guiding catheter (B). The retrograde MC engages the antegrade guiding catheter (white arrow) (C). After retracting the retrograde guidewire the externalisation wire is advanced retrogradely via the externalisation route within the retrograde MC towards the antegrade guiding catheter (not shown).*

connection (CC), the diameter of the left ventricle and, last but not least, the patient's size.

Therefore, before starting the procedure, we recommend using shorter 90 cm guiding catheters, at least for the donor artery, and long retrograde (≥150 cm) MCs to start with for all retrograde CTO attempts in which wire externalisation is planned.

As in all retrograde procedures, it is important to measure the activated clotting time (>350 sec) every 30 mins during the procedure.

Anatomy - choosing collaterals

There are three potential retrograde pathways over which a retrograde wire can be externalised – a bypass graft, a septal channel or an epicardial. Vein grafts are generally very easy to pass and therefore a fast and elegant pathway for retrograde approach, although the CTO lesion in post-CABG patients is often more calcified and more difficult to cross. Septal collateral channels are most commonly used and are much safer during wire externalisation than epicardials, which are often fragile and tortuous and prone to rupture, if extensive sheer stress occurs during the externalisation process.

Application and techniques using microcatheters

In order to protect the collaterals from damage and to increase the manoeuvrability, the retrograde wire is always advanced together with a retrograde MC (e.g., Corsair [Asahi Intecc, Santa Ana, CA, USA]; Finecross® [Terumo Medical Corporation, Somerset, NJ, USA]; Turnpike [Vascular Solutions, Inc., Minneapolis, MN, USA]).

Sometimes the distance between the antegrade and retrograde guiding catheter may exceed the length of the microcatheter. In these circumstances, it may be impossible to exchange the wires safely. To overcome this hurdle, shorter guiding catheters (e.g., 90 cm) might be necessary to prevent such a gap between the MC and antegrade guide[2].

MOTHER-AND-CHILD CATHETER

After advancing the retrograde MC across the antegrade CTO cap, the dedicated CTO wire should be exchanged for a less traumatic guidewire, which is then advanced to enter the ostium of the antegrade guiding catheter **(Figure 1A, Figure 1B)**. This may sometimes become very challenging, either because the guiding is not aligned optimally, or because a curve or eccentric wire position does not allow feeding the wire tip into the orifice. In this situation or when the retrograde MC is unable to cross the CTO lesion due to hard tissue, friction or merely because it is too short, the antegrade guide might be extended using a "child" catheter (e.g., GuideLiner® [Vascular Solutions]; Guidezilla™ [Boston Scientific, Marlborough, MA, USA]; Guidion™ [IMDS, Roden, the Netherlands]), which shortens the intracoronary gap[3] and may also minimise the risk of retrograde dissection at the proximal part of the coronary artery **(Figure 2A, Figure 2B)**.

TIP-IN TECHNIQUE

Alternatively, the so-called "tip-in" technique can be useful, especially in situations with a difficult anatomy, such as proximal calcification and severe tortuosity[4]. An antegrade MC needs to be advanced towards the CTO as far as possible followed by retrograde intubation with the retrograde guidewire (i.e., "tip-in"). This can be performed at different levels of the coronary artery, for instance within the antegrade guiding catheter, within the CTO lesion or at the proximal CTO cap. Finally, the antegrade MC is advanced over this wire to the distal cap of the CTO and the procedure may be finalised antegradely **(Figure 3)**.

If retrograde advancement of the MC across the CTO appears impossible, one might try to advance the long externalisation wire directly into the antegrade guide along the channel that has been created by the CTO wire. Besides, the application of intravascular ultrasound (IVUS) guiding can be helpful for better navigation and control of the engagement of the stiff retrograde CTO wire

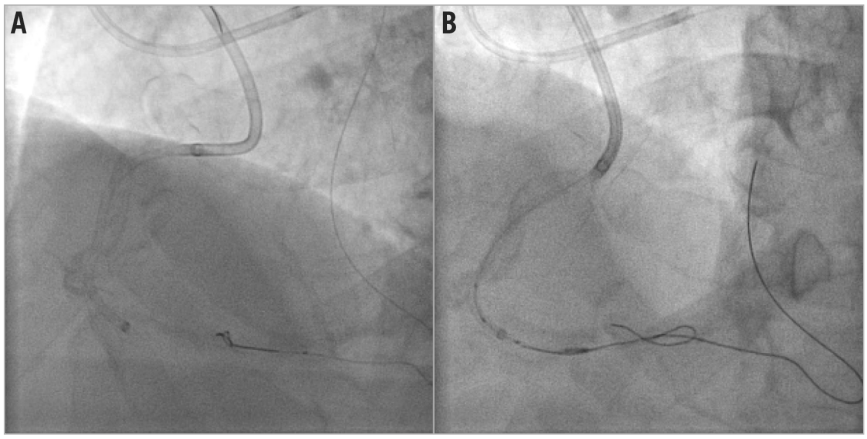

Figure 2. *Shortening the retrograde externalisation route. Insertion of an antegrade child catheter towards the proximal cap of the CTO (A). Antegrade IVUS guiding might facilitate the retrograde penetration of the guidewire from the true lumen to the subintimal space (B).*

with the antegrade guiding catheter **(Figure 4)** or mother-and-child catheter **(Figure 2B)**. The primary advantage of IVUS in this setting consists in avoiding subintimal haematoma and confirming the correct intraluminal pathway of the guidewire towards the guiding catheter.

TRAPPING BALLOON TECHNIQUE

Once the wire has entered the guide, the retrograde MC should be advanced over the conventional guidewire into the antegrade guiding catheter as well. Often, this manoeuvre is revealed to be technically challenging, because the intracoronary loop as well as the distance within the retrograde guiding catheter leads to an increasing instability and poor back-up. To counterbalance this instability, the retrograde wire, as mentioned earlier, can be entrapped within the proximal part of the occluded artery or in the antegrade guiding catheter by an antegrade balloon (i.e., trapping balloon technique) inflated at 8 atm (in detail: balloon diameter of 2.5 mm for 6-7 Fr guiding catheters; balloon diameter of 2.75-3.00 mm for 8 Fr guiding catheters). This stabilisation will allow a rapid and steady advancement of the retrograde MC into the antegrade guiding

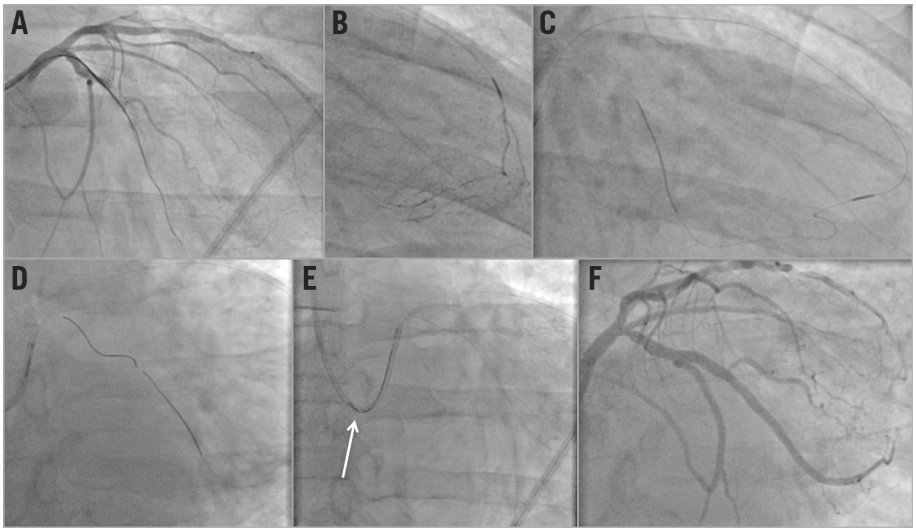

Figure 3. *"Tip-in" technique within a single 6 Fr guidewire. PCI of a CTO of the proximal CX with an antegrade failure using the "parallel wire" technique (A). An antegrade MC is advanced within a diagonal branch of the LAD and super-selective antegrade contrast injection over this MC shows a retrograde ipsilateral epimyocardial CC towards the distal CX (B). A retrograde SION wire (Asahi Intecc) is advanced without distal protection of an MC, because the retrograde MC could not follow within the tiny retrograde CC (C). An antegrade SION marker wire supports correct retrograde advancement of an exchanged retrograde Gaia First wire (Asahi Intecc) ("kissing wire" technique) (D). The retrograde Gaia First wire finally crosses the CTO and is "tipped in" the antegrade MC located within the antegrade guidewire (white arrow) (E). Panel F shows the final result after implantation of four DES (XIENCE® Pro 3.5/8 mm, 3.0/23 mm, 2.5/18 mm, 2.5/12 mm; Abbott Vascular, Santa Clara, CA, USA).*

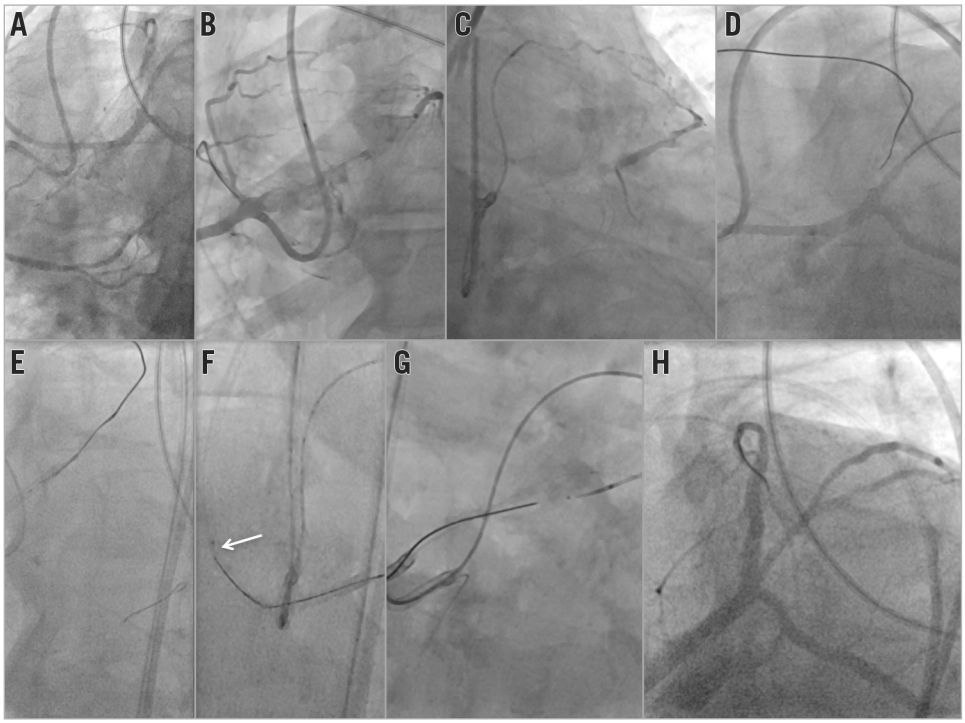

Figure 4. *"Tip-in" technique after passing a conus branch for retrograde access. Proximal CTO of the LAD with a blunt stump, a length of 25 mm and a J-CTO score of 2 (A). Contralateral CCs retrogradely filling the distal cap of the CTO originate from a conus branch of the RCA (B). A super-selective contrast injection over the MC located within the conus branch visualises the retrograde contralateral CCs (C). A SION wire is advanced retrogradely using contralateral CCs from the conus branch (D). An exchanged retrograde Confianza 12g (Asahi Intecc) penetrates the CTO from the distal cap controlled by antegrade IVUS (E). Panel F shows the "tip-in" of the retrograde Confianza 12g into the antegrade MC located in the antegrade EBU 3.5 guiding catheter. An antegrade MC is advanced simultaneously with retrograde pullback of the retrograde MC, both over the retrograde Confianza 12g, and the antegrade MC is advanced behind the distal CTO cap into the true lumen of the LAD (G). Final result after PCI with implantation of a DES (XIENCE 3.5×33 mm) (H).*

catheter. The trapping balloon of course needs to be deflated before the conventional wire is exchanged for the externalisation wire.

Upon friction within the MC, the inner lumen of the MC might be flushed with saline or with dedicated lubricant (Rotaglide™ Lubricant [Boston Scientific]; ViperSlide™ Lubricant [Cardiovascular Systems Inc., St. Paul, MN, USA]). Increasing the lubricity is especially helpful within the Corsair MC after multiple wire exchanges due to wire abrasion that may cause increased wire friction ("Corsair fatigue" phenomenon).

Wire externalisation

Once the retrograde MC has entered the antegrade guiding catheter, the wire needs to be exchanged for a >330 cm long externalisation wire (e.g., RG3, 0.009 inch [Asahi Intecc]; ViperWire® [Cardiovascular Systems, Inc.]; R350 [Vascular Solutions]). This exchange wire will be advanced and pushed out of the antegrade Y-connector to serve as an antegrade rail **(Figure 5A)**. The externalisation wire is then easily advanced until it reaches the antegrade haemostatic valve. Instead of opening the haemostatic valve for wire externalisation, the externalisation wire can be manually engaged into an introducer needle inserted antegradely into the Y-connector of the haemostatic system **(Figure 5B, Figure 5C)**. During wire externalisation, it is crucial to maintain maximal stability of the whole externalisation system (i.e., retrograde guiding catheter – retrograde MC – antegrade guiding catheter), which can be achieved by keeping the trapping balloon inflated at the level of the MC within the antegrade guiding catheter. This also prevents unnecessary blood loss during disconnections of the haemostatic valve during manual wire movements.

We also recommend securing the retrograde tip of the externalisation wire with a torquer **(Figure 5D)** to prevent unintentional loss of the externalisation wire into the externalisation system. After successful wire externalisation, the retrograde guiding catheter should be removed from the coronary ostium to avoid wedging, deep intubation or possible iatrogenic ostial dissections[5]. Now the retrograde MC can be pulled back into the distal CTO vessel, where it still protects the CC from being cut by the "naked" wire. Final PCI with implantation of coronary stents will be performed antegradely over the externalised wire.

Snaring and CTOs at the aortocoronary ostium

Intubation of aortocoronary ostia is often impossible in patients with ostial CTOs. As a consequence, direct retrograde guidewire engagement cannot be performed. This requires guidewire engagement

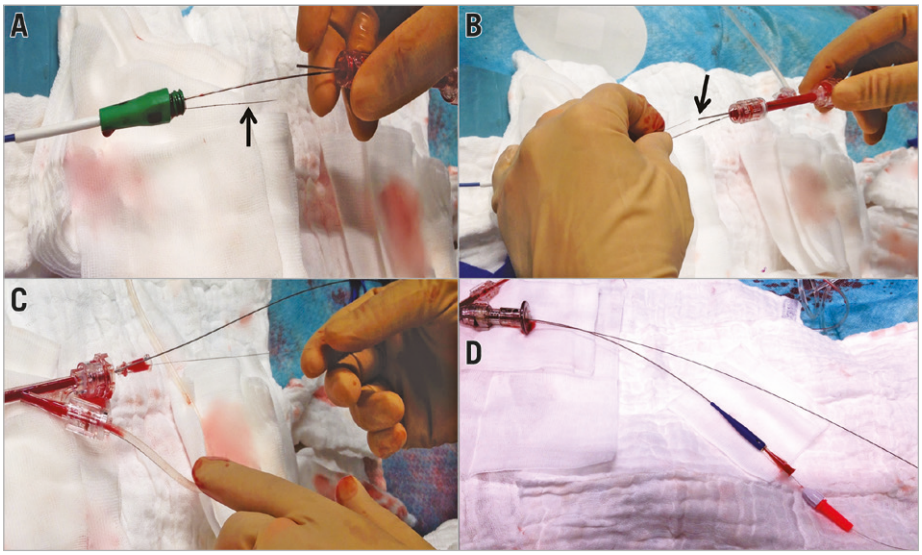

Figure 5. *Illustration of the wire externalisation process outside of the body. The RG3 externalisation wire is externalised through the antegrade guiding catheter (black arrow) (6 Fr) (A). The externalisation wire is engaged to the distal site of the introducer needle (black arrow) placed within the antegrade Y-connector (B). After adjustment of the Y-connector to the guidewire, externalisation can be performed safely (C). In order not to lose the retrograde ending of the externalisation wire, it should be fixed by the torquer in front of the retrograde Corsair MC (D).*

within the aortic root or ascending aorta by means of an antegrade coronary snare device **(Figure 6)**. Snare devices with large loops (i.e., diameter of 18-45 mm; e.g., EXPRO Elite™ Snare 35 mm [Vascular Solutions]) or even triple-interlaced snare devices are recommended. Alternatively, a modified "home-made" snare method[6] ("KAM snare") can be applied **(Figure 7)**. It consists of a wire loop trapped by an inflated balloon at the distal site of a child catheter (e.g., GuideLiner) **(Moving image 1)**. **Figure 8** and **Moving image 2** illustrate the application of the "KAM method" during a CTO intervention.

An almost reproducible manner is to snare the distal part of an externalised wire out of the brachiocephalic trunk. After successful snaring of the retrograde guidewire, the retrograde MC should be engaged to the antegrade guiding catheter. Now the retrograde wire can be removed and exchanged for an externalisation wire. Alternatively, a long retrograde wire can be retracted gently until it exits the extracorporeal haemostatic valve of the Y-connector. The tension during retraction needs to be very gentle to avoid strangulation with haemodynamic impairment as well as injury of CCs.

In situations in which the retrograde MC might not be externalised to the aortic root due to extensive calcification, a stiff CTO wire has to be snared out of the aortic root. Therefore, it is very important that the proximal part of the externalised wire is fixed outside of the retrograde MC with a torque in order to avoid losing the stiff externalised wire. Once the retrograde CTO wire is trapped by the snare, we recommend trying again to externalise the MC into the aortic root and repeating the snaring manoeuvre with a new long (>300 cm) floppy or externalisation wire such as the RG3 or R350. An alternative option is to puncture the cap by a long stiff CTO wire (e.g., 300 cm Confianza [Asahi Intecc]) out of the aortic root and to snare this one.

Avoiding complications

"PING-PONG" AND "SINGLE-GUIDING" TECHNIQUES

The retrograde approach via ipsilateral CCs may sometimes be very challenging, mainly because collaterals are mostly very fragile epimyocardial CCs[7] and 7 Fr guides are often too narrow to host the antegrade and retrograde devices[8]. To overcome the lack of space, the "ping-pong" technique using two guiding catheters **(Figure 9)** may facilitate wire manipulation tremendously[9]. However, excessive shear stress due to alternating ostial intubation at the coronary ostium as well as simultaneous ostial intubation of both guiding catheters should be avoided.

As an alternative, a "single-guiding technique" using only one single 8 Fr guiding catheter might offer sufficient space for both the antegrade and retrograde guidewires and devices **(Figure 10)**. However, the trapping balloon technique described above cannot be used in a single guide strategy.

REMOVAL OF THE EXTERNALISED GUIDEWIRE AND MICROCATHETER

The externalised guidewire will be removed retrogradely after the PCI has been completed. To avoid any strangulation or vessel injury, the retrograde guiding catheter needs to be slightly disengaged from the retrograde coronary ostium throughout the PCI procedure **(Figure 10)**. Any forceful manipulation of the externalised system involves the risk of guide catheter penetration and serious aortocoronary dissection.

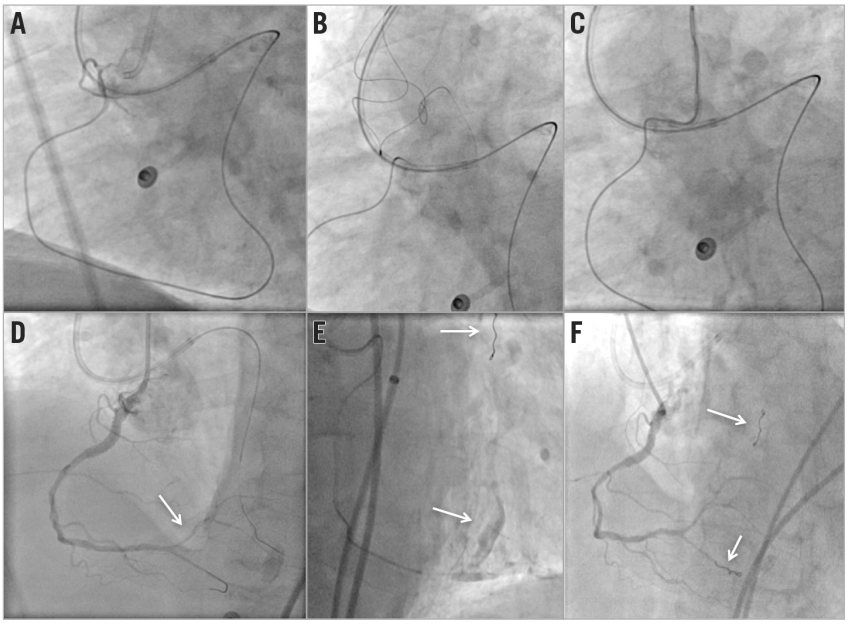

Figure 6. *Snaring the CTO wire in an aorto-ostial CTO lesion. Angiography visualisation of a massively calcified aorto-ostial CTO of the RCA by super-selective contrast injection over the retrograde Corsair MC (A). After retrograde penetration of the CTO with a Confianza 12g, snaring with an EXPRO Elite Snare (Vascular Solutions) (size: 35 mm) is performed within the aortic root (B). The snared retrograde Confianza 12g guidewire had to be pulled back into the antegrade aortic guiding catheter by increasing tractive effort endangering haemodynamics by possibly strangulating the heart (C). After wire externalisation, the ostium of the RCA is treated by PCI/DES implantation. Then, the retrograde Corsair MC protecting contralateral CCs was carefully removed. However, final angiography revealed a huge perforation of intraseptal CCs (white arrow) at the insertion point of the RCA (D). Panels E and F illustrate the implantation of intracoronary coils into a septal CC of the LAD and into the distal branch of the PDA (white arrows).*

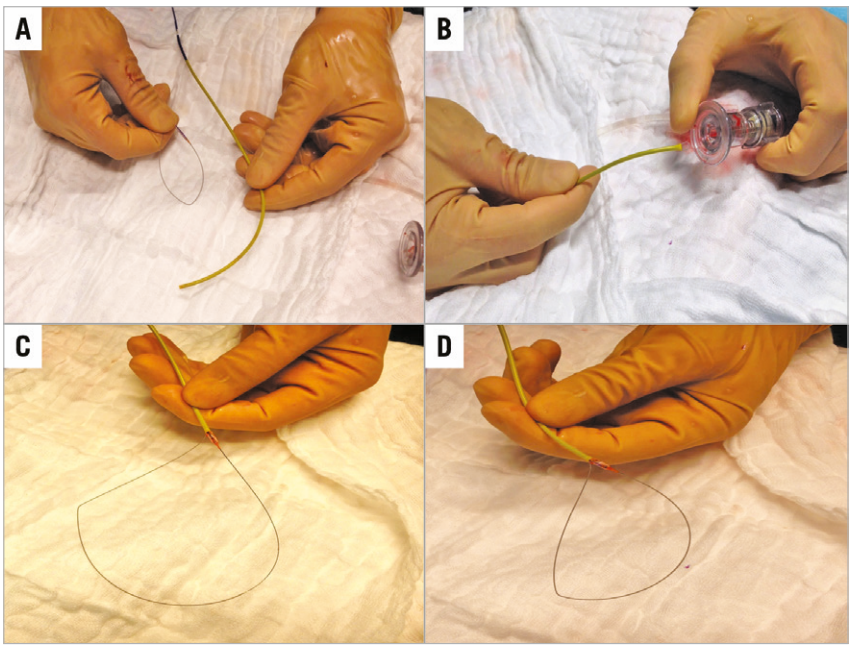

Figure 7. *Modified home-made snare. The "KAM snare" consists of a guidewire inserted within the monorail barrel of a conventional PTCA balloon. The distal end of the guidewire is then shaped as a loop (A). The looped guidewire with the railed balloon is introduced into a child catheter at the proximal entry site. Hence, the balloon entraps the distal returning end of the guidewire loop within the child catheter (e.g., GuideLiner) (B). The "KAM snare" is inserted into the proximal site of the Y-connector (B). Pulling or pushing the exterior proximal end of the guidewire either increases or decreases the diameter of the "KAM snare" (C & D).*

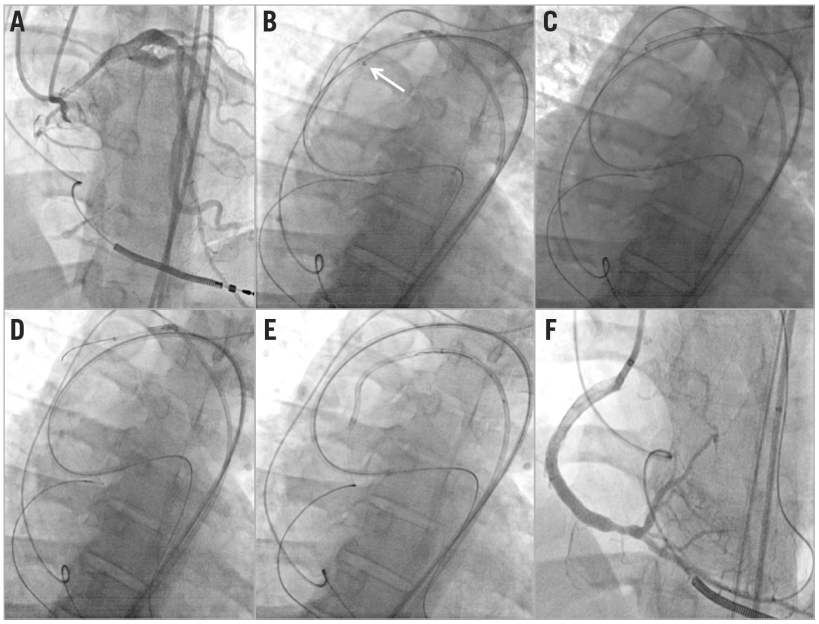

Figure 8. *Application of the "KAM snare". CTO intervention of a long proximal CTO of the RCA (A). Panel B shows the "KAM snare" within the retrograde guidewire located in the aortic arch (white arrow). The retrograde guidewire is snared within the aortic arch (C & D). Pulling back the child catheter of the "KAM snare" reveals two advantages: (1) the antegrade guiding catheter can accurately intubate the ostium of the RCA, while (2) the retrograde MC can be introduced safely into the antegrade guiding catheter over the retrograde guidewire (E). Panel F shows the final result after PCI with implantation of 71 mm of drug-eluting stents over the externalisation wire.*

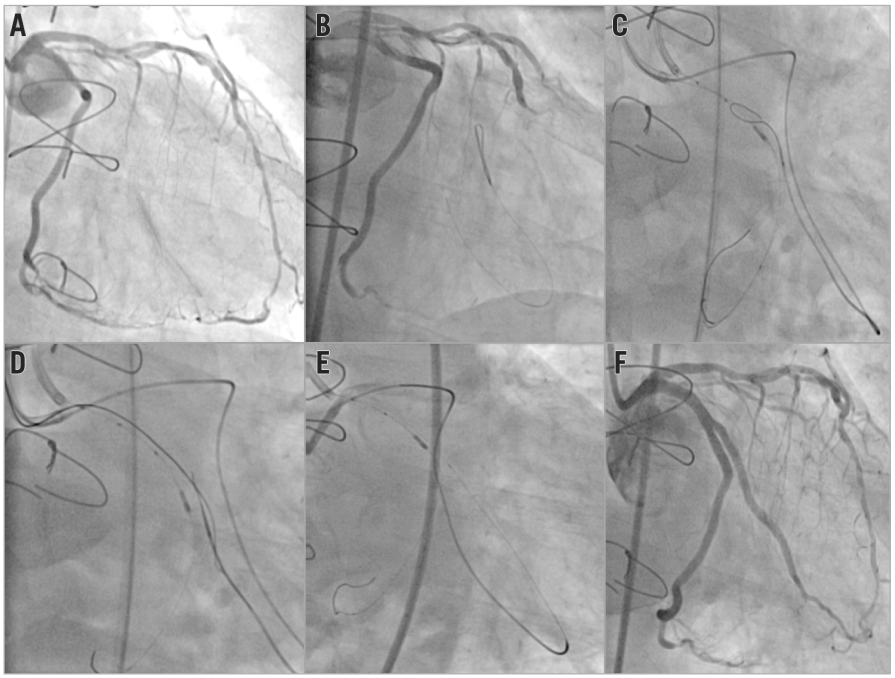

Figure 9. *"Ping-pong" technique for ipsilateral approach. CTO of the marginal branch of the CX with ipsilateral retrograde septal CCs from the LAD (A). Panel B shows the retrograde SION black guidewire (Asahi Intecc) within the marginal branch. First attempts of penetrating the proximal CTO cap failed with a Pilot 200 (Asahi Intecc) and Confianza 12g guidewires. A second guiding catheter was inserted and engaged at the ostium of the left main trunk ("ping-pong" technique). IVUS imaging showed a subintimal position of the distal end of the retrograde guidewire (C). The CTO was then punctured antegradely with a Confianza 12g controlled by IVUS guidance (D). After advancing the antegrade MC beyond the CTO over the guidewire, a "rendezvous" manoeuvre was performed by intubating the antegrade guidewire into the retrograde Corsair MC (E). Panel F shows the final result after PCI with DES implantation at the CX/RM bifurcation according to a mini-crush technique with final kissing.*

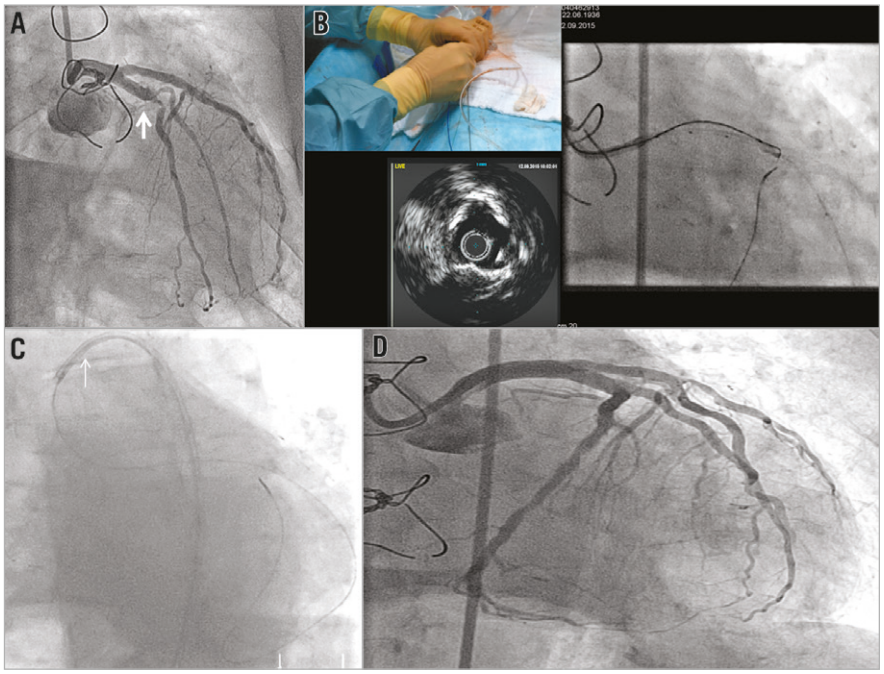

Figure 10. *Disengagement of an 8 Fr guiding catheter after ipsilateral externalisation. Short calcified CTO of the CX in a trifurcation (first and second marginal branch with an in-stent restenosis of the stent placed in the second marginal branch) (A, white arrow). Panel B shows an IVUS controlled puncture of the antegrade CTO cap with a Confianza 12g supported by a Corsair MC, towards a retrograde Turnpike MC (Vascular Solutions). All devices were placed in an 8 Fr EBU 4.0 catheter (Launcher 90 cm; Medtronic, Dublin, Ireland). After successful wire externalisation, the guiding catheter is retracted into the aortic root (white arrow). Now the Turnpike MC can be pulled back without any risk of aortocoronary dissection (C). Final result after culotte stenting of the CX/MB bifurcation with XIENCE DES (D).*

Before the externalisation wire is pulled back, it is very important to leave the externalised guidewire within the collateral vessel and to perform an angiogram to determine potential collateral injury before removing the retrograde guidewire from the collateral vessel. Occasionally, extensive friction may occur when the wire is pulled back, which again may cause strangulation or CC damage. In this case, a second antegrade protection MC can be advanced towards the tip of the retrograde MC to ease antegrade retrieval of the externalised wire ("MC kissing" technique) **(Figure 11)**.

ALTERNATIVE EXTERNALISATION TECHNIQUES

In patients with tiny epimyocardial CCs engaged with the retrograde wire and MC, we have to anticipate an increased risk of perforation due to shear stress during retrograde wire externalisation. Under these circumstances, the "tip-in" or "rendezvous" technique may be safer than conventional externalisation techniques[4,10].

The "rendezvous" technique describes the advancement of an antegrade guidewire into the retrograde MC positioned within the antegrade guiding catheter[10]. The antegrade guidewire will be inserted into the retrograde MC and advanced further through and beyond the CTO to the distal end of the coronary artery. Although the "rendezvous" technique was described originally to be performed within the antegrade guiding catheter, this manoeuvre can also be modified and performed at any site of the coronary

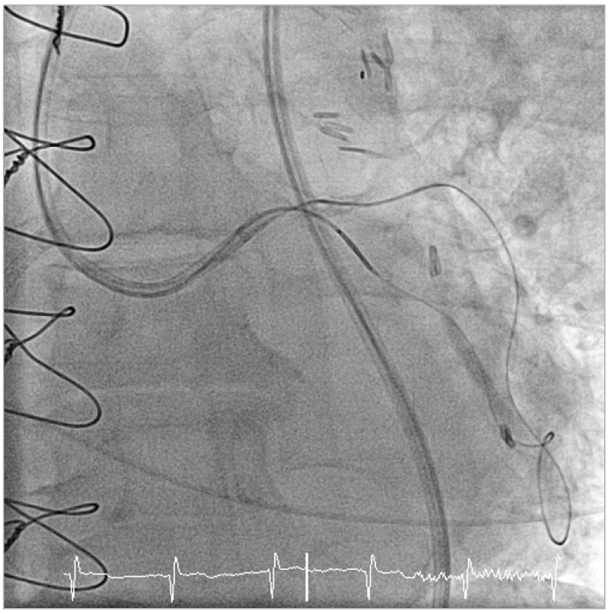

Figure 11. *"MC kissing" technique. A retrograde Turnpike LP MC (Vascular Solutions) was retracted with an additional antegrade push by an antegrade Corsair MC moving forward over the externalised wire towards the tip of the retrograde MC. The manoeuvre was used because of extensive friction of the ipsilateral externalised wire, while trying to remove this wire to prevent damage to the epimyocardial CC.*

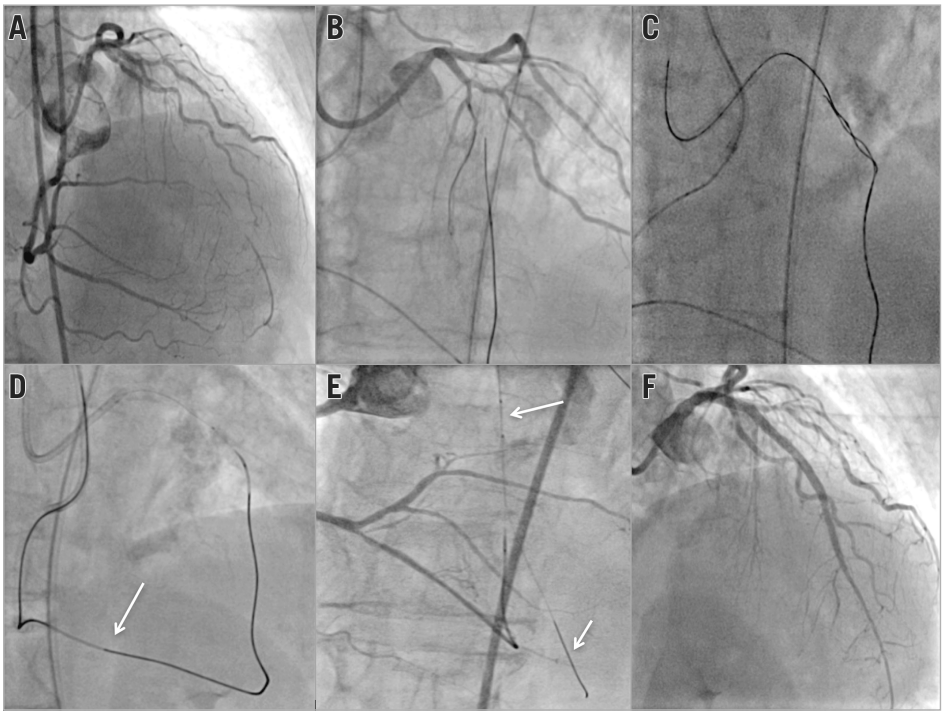

Figure 12. *"Rendezvous" technique. Long CTO of the LAD (A) with contralateral CCs from the RCA. A SION black guidewire is advanced retrogradely within a Corsair MC using septal CCs from the PDA towards the LAD. A SION blue guidewire (Asahi Intecc) is advanced antegradely into the second septal branch of the LAD at the proximal cap of the LAD CTO (B). Panel C shows the "kissing wire" technique with an antegrade Gaia Second (Asahi Intecc) and a retrograde Ultimate 3g guidewire (Asahi Intecc). Panel D - "rendezvous" technique: the antegrade Gaia Second supported by an antegrade Finecross MC intubates the tip of the retrograde Corsair MC (white arrow). Thereafter, a double lumen Crusade MC (Kaneka Medix Corp., Osaka, Japan) is advanced antegradely to the mid LAD including a second antegrade SION black guidewire. The SION black guidewire is then advanced into the distal LAD (E, two white arrows). Panel F shows the final result after PCI with implantation of DES.*

artery, always provided that optimal alignment of the retrograde and antegrade MCs can be achieved **(Figure 12)**. Once the antegrade guidewire is advanced across the CTO, the retrograde MC is pulled, followed by advancement of the antegrade MC. Finally, the antegrade guidewire may be exchanged for a soft-tipped conventional guidewire to finalise the procedure.

When the retrograde wire has already entered the antegrade guiding catheter and the retrograde MC is stuck in the vessel, a "tip-in" technique can be performed easily to avoid shear stress during externalisation[4]. To achieve this, the retrograde wire intubates the antegrade MC in the guiding catheter. Then the antegrade MC is advanced distally to the CTO lesion **(Figure 4)**. For this manoeuvre it is useful to increase the back-up of the MC by an additional antegrade supportive wire within the MC.

Conclusions

This review article summarises the crucial steps and bail-out techniques of wire externalisation during retrograde PCI of CTOs. Important tips are provided - how to avoid possible complications such as strangulation of the heart with haemodynamic impairment, injury of CCs due to increasing shear stress caused by guidewires and MCs within the intracoronary loop, aorto-ostial dissections and dissections of the donor coronary artery. A stepwise description of wire externalisation in retrograde CTO-PCI is outlined, addressing both the beginner and the experienced CTO operator.

Conflict of interest statement

The authors have no conflicts of interest to declare.

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Supplementary data

Moving image 1. Modified home-made snare: the "KAM snare".
Moving image 2. Application of the "KAM snare".

The supplementary data are published online at: http://www.pcronline.com/eurointervention/127th_issue/237