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Safe and predictable transcatheter removal of broken coronary guidewires: the 'knuckle-twister' technique: a case series report

Gregor Leibundgut [1]*, Alexandru Achim [2], and Lian Krivoshei[2]

[1]Department of Cardiology, University Hospital Basel, Petersgraben 4, Basel 4031, Switzerland; and [2]Department of Cardiology, Medizinische Universitätsklinik, Kantonsspital Baselland, Rheinstrasse 26, Liestal 4410, Switzerland

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Background Guidewire fracture and loss is a rare but well-known and feared complication of percutaneous coronary interventions. With the increasing number of complex coronary interventions and procedures for chronic total occlusions, operators face new challenges and boundaries, and the need for solutions to otherwise rare complications is increasing.

Case summary We have developed a simple and practical method for retrieving fractured and lost guidewires, called the 'knuckle-twister' technique. This article summarizes seven cases in which guidewires lost in the coronary vasculature have been successfully removed and describes this technique in detail. The goal was to gather different clinical scenarios: free wire lost *in situ*, wire jailed behind stent struts, wire in small branches, part of the wire protruding into the aorta, 'invisible' guidewire microfilaments/coils, etc.

Discussion The innovation of the knuckle-twister consists in folding a polymer-jacketed guidewire and transforming it into an open lasso that tightens when twisted. *In vitro*, its grip strength and pulling force was tested and exceeded 1.5 kg. Moreover, in all *in vivo* cases, the lost material could be efficiently and quite rapidly retrieved with this simple and highly reproducible technique.

Key clinical message Broken guidewires that were lost in the coronary vasculature can be safely retrieved with this novel and simple technique requiring no special safety equipment.

Keywords Case report • Broken guidewire • Guidewire loss • Guidewire retrieval • Guidewire entrapment • Guidewire fracture

ESC Curriculum 3.1 Coronary artery disease • 3.4 Coronary angiography

Learning points

- Learn the current retrieval techniques and algorithms for lost coronary guidewires.
- Learn the steps of the novel "knuckle-twister" technique.
- Learn its versatility and reproducibility in different clinical scenarios.

Introduction

Guidewire fracture and loss is an uncommon, yet feared complication of percutaneous coronary intervention (PCI).[1] Predisposing factors for such complications are chronic total occlusions (CTOs), bifurcation lesions, very tortuous and calcified vessels, as well as hydrophilic guidewires.[2,3] Procedures of complex high-risk and indicated PCIs, as well as interventions for CTOs, are increasing in number worldwide.[4] Percutaneous coronary intervention techniques have advanced significantly over time, but calcified lesions still represent a special challenge

* Corresponding author. Tel: +41 61 265 4444, Email: kardiologie@mac.com
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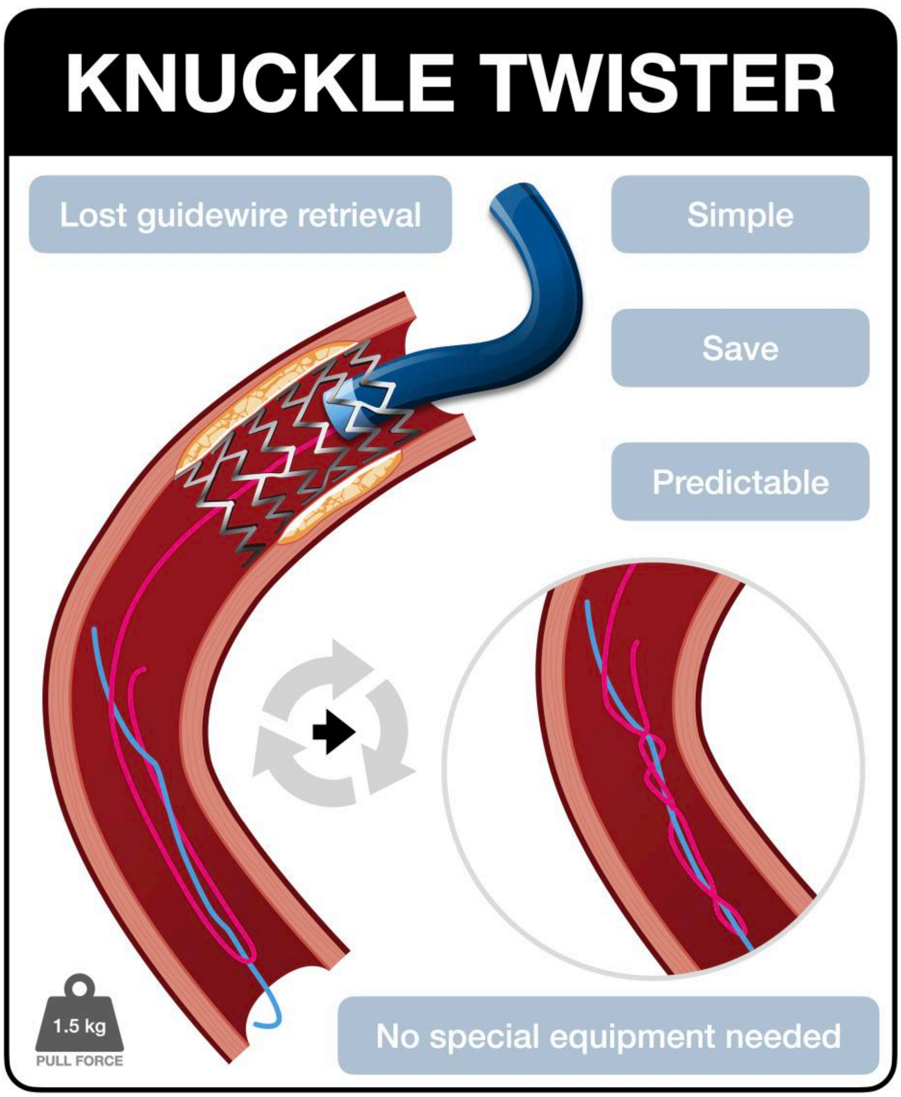
for the interventional cardiologist. Because these interventions usually comprise a difficult and complex coronary artery anatomy, complications are sometimes impossible to avoid.[5] Therefore, operators must be aware of their possibilities and management strategies. During stent rewiring or calcific CTO crossing, the guidewire might get entrapped and the operator could be faced with the scenario of pulling and subsequently losing an unpredictable fragment of the guidewire inside the coronary circulation and the aorta. In such situations, micro-snaring can be attempted, but this can be cumbersome if the fragment is not proximal, and successful capture depends on the correct alignment of the loop to the guidewire. The multiwire technique[6] is unpredictable and its grasping force is low. The alternative would be implantation of an additional stent that would fix the fragment to the vessel wall or open surgery, both of which are to be avoided.

We are introducing a novel technique for coronary guidewire loss expressively named 'knuckle-twister' and demonstrate its versatility in different *in vivo* scenarios as well as test its pulling force in-bench. The 'knuckle-twister' technique is a simple and practical method of retrieving a fractured and/or entrapped guidewire by folding a polymer-jacketed guidewire and transform it into an open lasso that closes and tightens when twisted. In the next section, we will describe seven cases in which the technique has been successfully implemented.

Summary figure



Case reports

All PCI cases presented below involve a fractured guidewire that was lost in a coronary artery and subsequently retrieved with the knuckle-twister technique. We briefly summarize the clinical scenario and focus in more detail on the specific failure mode and retrieval method for each case. Several representative videos show the live retrieval technique of the following cases described below (see Supplementary material online, *Videos S1–S4*).

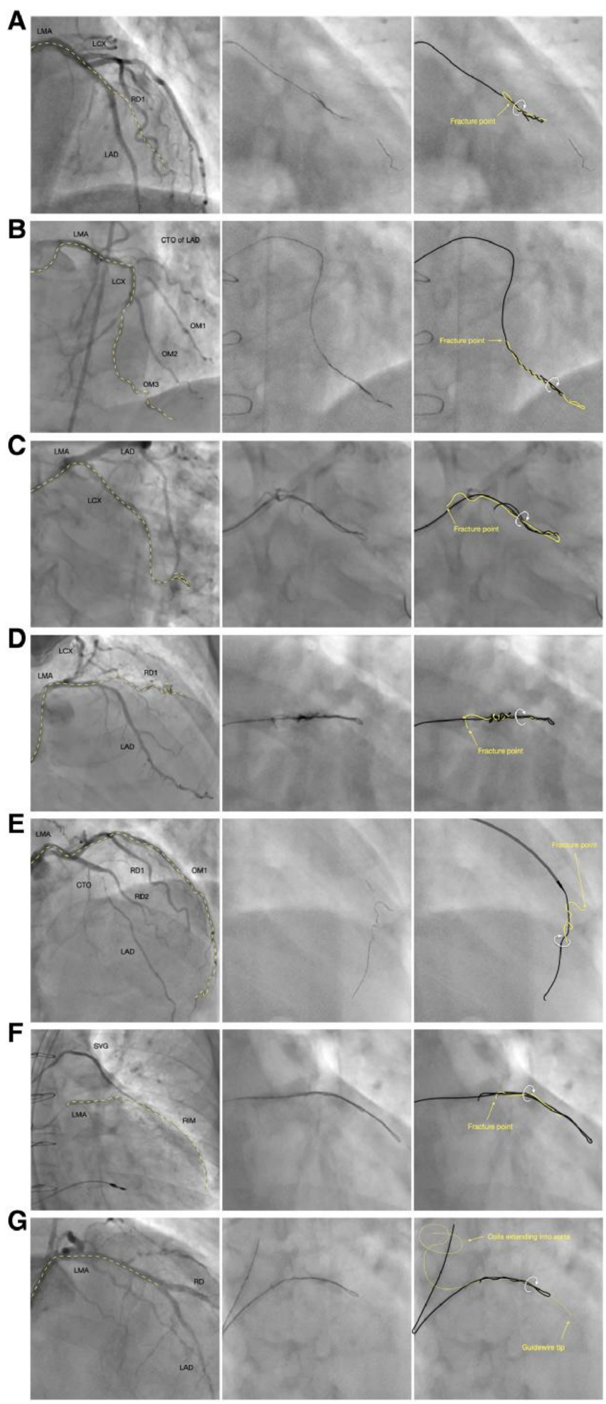


Figure 1 Cases 1–7. (*A*) Diagonal branch; (*B*) distal left circumflex artery; (*C*) proximal left circumflex artery; (*D*) first diagonal branch; (*E*) ipsilateral epicardial collateral; (*F*) retrograde wiring through a saphenous vein graft; (*G*) unravelling of guidewire coils. The left panel shows the coronary tree with the guidewire indicated by a dashed yellow line. The middle panel shows a magnification of the region of interest, with the Fielder XT-A forming the knuckle-twister loop. The right panel illustrates the knuckle-twister in black and the lost piece of the guidewire in yellow for improved visibility.

Case 1: diagonal branch

A 71-year-old male patient with a known history of dyslipidaemia was referred for coronary angiography due to crescendo angina and findings of ischaemia in the left anterior descending artery (LAD) territory in the cardiac positron emission tomography study. Angiography showed a CTO of the mid-LAD, immediately after the first diagonal branch (D1) take-off. The CTO was successfully recanalized by an antegrade parallel-wire technique. During final provisional stenting over D1, rewiring the side branch probably through a small stent cell and pushing a used 2.0 semi-compliant balloon through the metal struts resulted in kinking of the workhorse Sion Blue guidewire (Asahi Intecc, Aichi, Japan) in the D1. Pulling back the deformed guidewire after opening the struts led to complete entrapment and rupture at the level of the D1 ostium, with 4 cm of guidewire lost in the entire length of D1. A Fielder XT-A (Asahi Intecc, Aichi, Japan), with its end bent 360° backward ~3 cm from the tip, creating a large knuckle or an open lasso, was advanced into D1, with the loop facing forward. Rotating very fast in one direction, it began to loop and tighten around the lost guidewire. Without force, the entire ensemble was then successfully retracted 'en bloc' (*Figure 1A*). The bifurcation was restored with final kissing balloon inflation (KBI) and the proximal optimization technique, with a good angiographic result. The patient remained uneventful after 18 months.

Case 2: obtuse marginal branch

A 73-year-old male patient, hypertensive, dyslipidaemic, former smoker, with a history of coronary artery bypass grafting (CABG) with the left internal mammary artery (LIMA) to the LAD and two saphenous vein grafts (SVGs) to the left circumflex artery (LCX) and distal right coronary artery (RCA), was referred for non-ST segment elevation myocardial infarction. Coronary angiography showed a CTO of the RCA and LAD, a 90% stenosis in the middle segment of the LCX, a patent SVG to distal RCA, and occluded SVG to the LCX. It was suspected that the occlusion of the SVG to the LCX may be acute, but given the large thrombus burden and poor prognosis of PCI in SVGs, it was decided to proceed with the native LCX CTO–PCI, starting with plaque debulking using orbital atherectomy (CSI, St Paul, Minneapolis, USA). After successful orbital atherectomy, the 0.014″ tip of the otherwise 0.012″ Viperwire (CSI) became entrapped in the extremely calcified lesion, broke while pulling back, and was finally lost in the distal obtuse marginal branch (OM3) (*Figure 1B*). A Fielder XT-A was folded into a large knuckle and twisted at the level of the lost wire in the same manner. The retrieval was successful on the first attempt, and PCI was continued with a good final angiographic result. The patient is uneventful after 12 months.

Case 3: left circumflex artery

A 76-year-old female patient with known multi-vessel disease and a history of PCI of the proximal RCA and proximal LAD 1 year prior to the current presentation was admitted again after a positive stress test. The coronary angiogram showed patent stents in the RCA and LAD and a new severely calcified stenosis in the mid-LCX (*Figure 1C*). After extensive preparations of lesions, stent advancement into the LCX was finally enabled in the tortuous anatomy by using a buddy-wire technique with a Sion Blue workhorse guidewire. Unfortunately, while pulling back the buddy-wire just before stent implantation, the buddy-wire became entangled with the stent, ruptured and remained inside the left main artery and proximal LAD. Taking advantage of the same 'knuckle-twister' technique, the lost guidewire fragment was safely retrieved from the coronary vasculature.

Case 4: diagonal branch after stenting

A 70-year-old male patient, diabetic, dyslipidaemic, with a positive family history for coronary artery disease complaining of typical angina at rest and anterior wall ischaemia detected during stress cardiac magnetic resonance testing was referred for coronary angiography. The angiogram confirmed a true bifurcation lesion at the level of LAD–D1. A two-stent technique was planned (DK-Culotte). The PCI was conducted using two normal workhorse wires (Sion Blue), unfortunately during rewiring through two layers of struts for the final KBI, the wire advanced with significant friction towards D1 and got entrapped when pulling back (*Figure 1D*). It should be mentioned that the first kissing did not expand fully the side-branch stent (D1), leaving it underexpanded and most probably contributing to the wire entrapment. The lost wire was successfully and safely retrieved using the 'knuckle-twister' technique, on first attempt. The procedure was finalized with a good angiographic result, and the patient remained uneventful at 1-year follow-up.

Case 5: ipsilateral epicardial collateral

A 70-year-old male patient, former smoker, dyslipidaemic, with a known history of two-vessels disease, prior RCA PCI, LAD CTO, and actual non-sustained VTs and angina CCS 2–3 received an indication for LAD CTO–PCI. The antegrade cap was ambiguous, exactly next to the D1 origin, and all wires were advanced antegradely in the subintimal space. Switching to a retrograde approach, wiring the very tortuous ipsilateral epicardial collateral to the LAD with a SUOH 03 guidewire (Asahi Intecc, Aichi, Japan) proved to be very difficult. The dedicated guidewire for such highly angulated vessels got entrapped in the tortuosity of the epicardial vessel and the coiled portion of the guidewire broke free and remained in the distal collateral (*Figure 1E*). The PCI was then again continued through the antegrade approach, this time using a dual lumen microcatheter placed at the LAD–D1 bifurcation and an antegrade dissection re-entry procedure was performed to reach the true lumen of the LAD. After recanalization, the lost tip of the SUOH 03 was extracted easily using the 'knuckle-twister', obtaining an overall optimal result, with a good clinical follow-up at 15 months.

Case 6: retrograde chronic total occlusion–percutaneous coronary intervention through a saphenous vein graft

A 77-year-old male patient, hypertensive, dyslipidaemic, with a history of CABG was admitted for an NSTEMI. The coronary angiography revealed two proximal CTOs of the native LAD and LCX, occlusion of all venous grafts [to LCX and ramus intermedius artery (RIM)], practically only the LIMA to the LAD and the native RCA being patent. The culprit lesion could not be established, therefore antegrade CTO–PCI of both RIM and LCX was attempted. After assiduous efforts, only wiring of the RIM was possible via a retrograde approach over the occluded SVG. Because the angle towards the proximal RIM was very acute at the site of the anastomosis, the polymer-jacketed guidewire needed to be spun extensively in order to advance retrograde into the occluded segment. As a consequence of the sharp bend and prolonged guidewire rotation the end of the guidewire broke at the site of the anastomosis on the RIM (*Figure 1F*). Using this lost guidewire as a marker wire, the anterograde passage of the occlusion was possible. After balloon dilatation, the guidewire was captured antegradely through the native coronary using the same 'knuckle-twister' technique. The LCX CTO was treated 2 months later, also retrogradely over the occluded SVG. The patient remained uneventful at 12 months.

Case 7: unravelling of the guidewire coils

A 70-year-old male patient presented with angina CCS 3 and a severe bifurcation lesion of the LAD and D1. A provisional one-stent approach was planned. During rewiring through the stent struts in the main branch into the diseased D1 with a Sion Blue guidewire, the wire was rotated vigorously in an attempt to reach the true lumen. Unfortunately, the wire advanced in the subintimal space, behind the freshly implanted stent and got entrapped. Unsuccessful attempts of controlled retraction were made using a microcatheter and post-dilating the stent. The operator ultimately forcefully pulled it back what resulted in fracture of the core wire and unravelling of the coils. After removal of the shaft of the guidewire and unfortunately also the guiding catheter, the coils extended from the LAD to the aorta and into the brachiocephalic trunk (*Figure 1G*). It should be mentioned that intraprocedural IVUS discovered the angiographically invisible unravelled thin coils of the guidewire extending into aorta and a calcific nodule at the level of entrapment—this in combination with the stent most likely contributing to the complication. With the introduction of a large knuckle from a Fielder XT-A and twisting around the invisible coils in the left main, retrieval of the extending coils was immediately successful. The patient has an uneventful outcome at 10 months.

The knuckle-twister technique

Figure 2 shows individual steps of the technique.

(1) Use a polymer-jacketed tapered guidewire (e.g. Fielder XT-A) for the retrieval wire.
(2) Form a knuckle of ∼3–6 cm of length, depending on the length of the vessel in which the wire is lost.
(3) Advance the knuckle into the coronary artery until it lays parallel to the lost wire.
(4) Alternatively, advance the retrieval wire slightly distal of the lost wire.
(5) Start drilling the retrieval wire.
(6) Pullback while continuously drilling until the wire becomes completely entangled with the lost wire.
(7) Retrieve the retrieval wire into the guiding catheter to remove the lost wire from the coronary vessel.
(8) The technique can be modified with the addition of a guide extension catheter to protect the proximal vessel or prevent further entanglement with a proximal stent.

Bench testing

Figure 3 illustrates the bench testing model.

A piece of a broken workhorse guidewire was placed in a silicone tube. A 6 cm long knuckle was formed from the tip of a Fielder XT-A and inserted into the silicone tube from the opposite side until the knuckle was parallel to the lost wire (*Figure 3A*). The Fielder XT-A was then rotated multiple times until it became twisted around the lost wire (*Figure 3B*). To determine the pulling force of the retrieval knuckle, we used a spring force gauge. The lost wire was held with a conventional torquer and attached to the gauge (*Figure 3C*). The retrieval wire was then pulled and the maximum pulling force was measured with the gauge. In repetitive tests with various broken wires

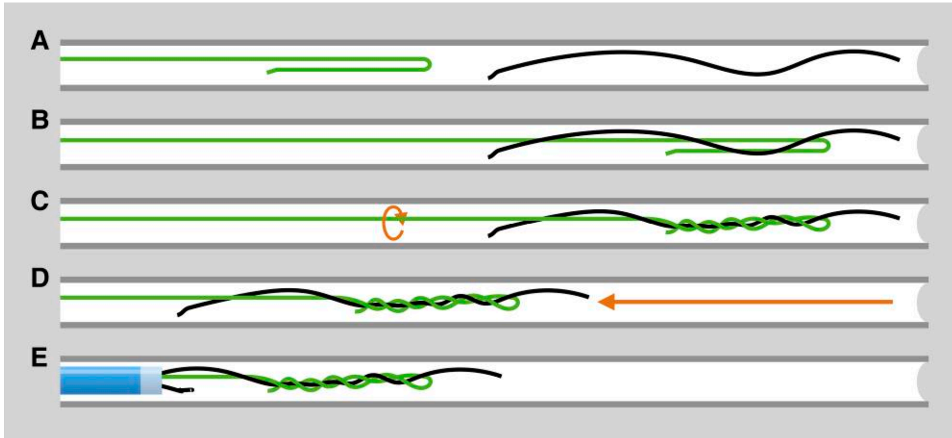


Figure 2 The knuckle-twister step-by-step. (*A*) To retrieve a broken piece of guidewire lost in a coronary artery (black wire) advance, a polymer-jacketed tapered-tip guidewire (green wire) with a knuckle of ∼5–6 cm length was used. (*B*) Parallel and overlap with the broken wire. (*C*) Twist around. (*D*) Retrieve. (*E*) Pieces of the broken and sometimes also the retrieval wire can fold while retrieving into the guide catheter.

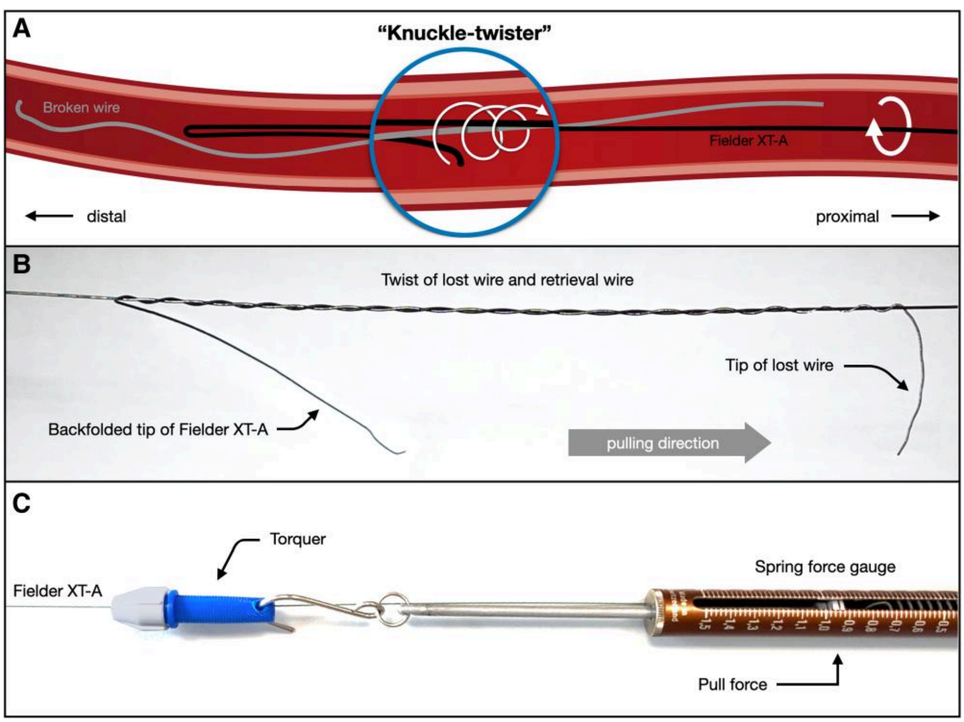


Figure 3 Illustration and bench model.

and several Fielder XT-A retrieval wires, a consistent pulling force of over 1.5 kg could be found.

Discussion

Factors that increase the risk of guidewire fracture include (i) extensive calcifications; (ii) tortuous anatomy; (iii) sharp or retroflex angulation of the main vessel or side branch; (iv) long jailed wire segment; (v) location of a bend in the guidewire (core wire vs. coiled tip); and (vi) jailing wires between two stent-layers.[7–9] There are several algorithmic approaches for dealing with guidewire entrapment and fracture. In the case of a lost fragment, it can either be left *in situ* and/or covered with a stent, but retrieval should be the preferred approach. Different solutions exist for retrieval using snares or the multiple guidewires technique,[6,10] but all are unpredictable and sometimes cumbersome. An individualized patient approach is advised if the percutaneous retrieval methods are not successful, as surgery may be indicated depending on the length of the free wire in aorta.[11]

The length of the protruding wire may be better visualized on CT if fluoroscopy is not conclusive.[11]

There is limited information available about the clinical outcomes of retained guidewire fragments. The most common adverse effects are accelerated restenosis, thrombosis, and perforation.[11,12] The most feared aspect is when the guidewire comes apart and filaments from it remain unseen in the coronary arteries. The thrombogenic risk depends on the amount of filament and their position in the vessel. There are cases in the literature where they became endothelialized without any long-term any hazard,[13] as well as cases of fatal acute thrombosis.[14] The guidewire as a whole lost in the vessel may be left in place ('conservative approach') in smaller vessels/smaller territories but at the cost of a prolonged dual antiplatelet regimen. Also, it is indicated to be eliminated from the circulation by excessive stenting, therefore the ideal solution remains its extraction at the baseline procedure.

In this article, we describe a novel, simple, and predictable method for retrieving either fractured or entrapped guidewires. We have safely demonstrated this technique in several scenarios, including tortuous calcified lesions, in a side branch after bifurcation stenting, in an epicardial collateral during retrograde CTO–PCI, in the occluded segment in retrograde CTO–PCI, and of an unravelled coil extending into the aorta after brakeage of the guidewire tip core. The 'knuckle-twister' technique involves the use of a tapered-tip polymer-jacketed guidewire (Fielder XT-A, Asahi Intecc) which is of central importance. The tapering of the core wire towards the tip results in a more flexible wire and facilitates the formation of the long and less traumatic knuckle. In comparison non-tapered wires create stronger knuckles that could damage or dissect the vessel while advancing them to the lost wire fragment. The polymer jacket allows for better trackability through tortuous vessels and calcifications than a non-polymeric one. The polymer jacket also protects the coils from damage and being unravelled or breakage. In addition, the composite core construction of this guidewire provides excellent tip durability and torque performance.

In all seven cases described above, we could successfully retrieve the fractured and lost part of the guidewire from the coronary artery. To the best of our knowledge, this technique has not been described before. Another retrieval method of fractured or entrapped wires was previously described and includes the usage of three guidewires simultaneously.[6,15] Here the guidewires are advanced as distally as possible past the fractured wire and then rotated around to form one unit of entangled wires that can then be withdrawn. In contrast, our method uses only one additional guidewire with a long knuckle that forms an open loop that eventually closes and tightens around the lost wire. While the method with three parallel wires leaves the loop open and can therefore loose the wire fragment during pullback our method acts like an open snare (knuckle) that closes around the lost fragment while twisting the knuckle. The entanglement between the two wires becomes extremely tight and strong.

Our case series proves the utility of the 'knuckle-twister' technique in various clinical and anatomical scenarios. Once twisted around, the lost guidewire is safely caught in a closed loop with a pulling force that is high enough to extract all sorts of entrapped guidewire fragments from the coronaries. The technique is simple, predictable, and does not involve the use of a snare or any other retrieval tool. Finally, the bench test confirms the outstanding capacity of its grip.

In two cases, the first knuckle-twister broke off as well and we had to retrieve the two wires with a new knuckle-twister. Both cases were successful on the second attempt.

Although we have successfully used this technique in seven actual cases with different anatomies and guidewires, limitations of this method may exist. These include lost guidewires entangled behind stent struts (jailed wires), small fractured pieces of guidewires lost or stuck within the body of a CTO, and guidewires lost in very small septal or epicardial branches not accessible for a knuckled wire. However, in most of such cases actual retrieval is not necessary.

The technique has not been tested for lost stents and other equipment left behind in the coronaries. Stents retrieved by this method may fold over or get entrapped, dissect the coronary artery or become entangled with other more proximal stents during removal.

Conclusion

Guidewire fracture and entrapment or loss in the coronary vasculature is a rare complication but can occur during complex coronary interventions. The 'knuckle-twister' technique is a simple, effective, and predictable retrieval method that does not require special safety equipment.

Lead author biography

Gregor Leibundgut is head of the catheterization laboratories and director of CTO & complex PCI program at the University Hospital Basel, Switzerland. Dr Leibundgut has a strong interest in clinical education and lectures internationally on interventional devices and strategies in complex coronary procedures. He is a proctor for CTO–PCI and has performed many live cases during international meetings. He is a course director for the annual Swiss CTO&CHIP Summit. His research interests have centred on oxidized phospholipids on lipoprotein(a) and plasminogen, and the mechanical properties of coronary stents, with more than 80 publications in peer-reviewed journals.

Supplementary material

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

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Ethics approval: This material is the authors' own original work, which has not been previously published elsewhere.

Data availability

The numerical data and all images used to support the findings of this case series report are included within this article.

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