Lost in circulation

Hristo Kirov MD | Sophio Tkebuchava MD | Gloria Faerber MD | Mahmoud Diab MD | Tim Sandhaus MD | Torsten Doenst MD, PhD

Department of Cardiothoracic Surgery, Jena University Hospital, Friedrich-Schiller-University of Jena, Jena, Germany

Correspondence
Torsten Doenst, MD, PhD, Department of Cardiothoracic Surgery, Friedrich-Schiller-University of Jena, Am Klinikum 1, 07747 Jena, Germany.
Email: doenst@med.uni-jena.de

Abstract

Background: Device complications in complex percutaneous coronary interventions are rare but potentially deadly. Surgical removal is often required. However, an evaluation of surgical therapy beyond case reports is practically not existent.

Methods: We prospectively followed all cases of retained guide wires and/or other devices referred to us for surgical removal between 2015 and 2019 and retrospectively searched our database for such cases between 2010 and 2014.

Results: From 2015 on, eight cases were referred for surgical removal from six different cardiology departments. In the 5 years before, there was not a single case. Six patients were operated emergently. Patients were 60.5 ± 5.42 years old, overweight (body mass index 30.1 ± 3.77) and except for one case (left ventricular-assist device) showed preserved ejection fraction (EF) (mean EF 57 ± 18.01). The retained devices were mostly located in the right coronary artery (50%), followed by the circumflex artery (37.5%) and diagonal branch (12.5%). The devices were remnants of guide wires (n = 4), balloon catheters (n = 3), and in one case a rotablator. Full sternotomy was performed in six patients and two received a left-sided minithoracotomy (n = 2). The operations were performed on-pump in five (62.5%) and off-pump in three patients. Complete extraction of the foreign bodies was possible in all patients. Two patients died; one in unrelated multiorgan failure and one due to retained-device-related right heart failure. The other patients survived and had uneventful postoperative courses.

Conclusions: Retained foreign bodies from cardiac interventions can be completely removed surgically using individualized approaches. There appears to be a trend toward a rising incidence of such interventional complications.

KEYWORDS

coronary intervention, guide wires, surgery

1 | INTRODUCTION

Since the introduction of coronary angioplasty by Andreas Grüentzig in 1977,1 percutaneous coronary interventions (PCI) has significantly developed and currently deals with a constantly expanding range of challenging lesion sets. Registry data confirm that over the last decades, the proportion of interventions on American College of Cardiology/American Heart Association (ACC/AHA) Type C lesions...
grew significantly (11% vs 30% for heavily calcified lesions). Currently, these complex lesions represent a significant proportion of PCI procedures performed. Therefore, it is well conceivable that this increase in complexity may also lead to a rise in complications including broken, entrapped, or left-in-place guide wires or rotablator devices.

The management of such rare complications is challenging. Three therapeutic options exist: conservative, interventional, or surgical treatment. As entrapped wire fragments and devices in the coronary vessels can cause complications, such as emboli, thrombosis, dissection, and rupture, a conservative strategy is possible only in a small number of cases (14.9%). Some of these potential complications can be managed interventionaly and different techniques have been described, but surgical removal, potentially combined with coronary bypass grafting, appears to remain the most common therapy. Despite these recognitions, the literature mainly contains single-case reports on surgical therapy and evaluation of a larger case series is practically not existent.

2 | METHODS

We prospectively followed all cases of retained guide wires and rotablator devices between January 2015 and December 2019, referred for surgical removal from five different cardiology departments. In addition, we searched our database for such cases between January 2010 and December 2014. The institutional ethics review committee approved the study protocol (reference number: 2020-1749 from 22 April 2020) and waived the need for written informed consent.

Statistical analysis was performed via SPSS Statistics 22 (IBM, Armonk, NY). Data are presented as mean ± standard deviation or percent of patients.

3 | RESULTS

Figure 1 shows an example of echocardiographic (panels a, c, and d), fluoroscopic (panels e and f) images of retained wires, as well as the wires themselves postextraction. While from 2015 on, eight cases with lost parts of cardiac interventions were referred, there was not a single case in the 5 years before.

Table 1 shows the demographic characteristic of the study population. Most patients were male. They were on average 60 years old, overweight (body mass index 30.1 ± 3.77) and except in one case (patient with left ventricular assist device [LVAD]) had preserved ejection fraction. Of the eight patients, six were operated emergently. In one case, a broken guide wire was an accidental finding during an LVAD implantation. Three of the eight patients were referred to our center for surgical extraction after elective PCI.

Table 2 shows the operative characteristics of the patients. The surgical approach was either through complete sternotomy (n = 6) or left-sided minithoracotomy (n = 2). Out of the eight cases, five were operated on-pump (62.5%) and three off-pump (37.5%). An aortotomy

![Figure 1](https://example.com/figure1.png)
was necessary in four patients to extract the wires. In six cases, additional bypass grafting was performed. One patient with a lost wire in a perforated right coronary artery developed right heart failure which was not reversible through extraction and bypass grafting. As a consequence, the implantation of a right ventricular assist device was required. Complete extraction of the foreign bodies was possible in all patients.

Table 3 shows the device-type and location in the coronary vessels. The broken devices were mostly located in the right coronary artery (50%), followed by the circumflex artery (37.5%), and diagonal branch (12.5%). In three cases, a vessel was perforated. The devices were mostly remnants of guide wires (n = 4); balloon catheters (n = 3), and in 1 case a rotablator. Interestingly, three out of the eight cases were secondary to chronic total occlusion (CTO) therapy. All cases of CTO in our group were located in the right coronary artery (RCA). Table 4 shows a description of each removed foreign body as well as its type and brand.

Two patients died due to multiorgan failure. One was related to the retained device. The implantation of the right heart assist device was not able to prevent the unfavorable outcome. The other patient was a marginal LVAD candidate who developed multiorgan dysfunction unrelated to the retained wire. The lost device here was an accidental finding. All other patients survived and had uneventful postoperative courses. The 1-year follow-up was uneventful for all survivors.

### DISCUSSION

We demonstrate, in this manuscript, that retained foreign bodies from cardiac interventions such as broken guide wires or rotablator was necessary in four patients to extract the wires. In six cases, additional bypass grafting was performed. One patient with a lost wire in a perforated right coronary artery developed right heart failure which was not reversible through extraction and bypass grafting. As a consequence, the implantation of a right ventricular assist device was required. Complete extraction of the foreign bodies was possible in all patients.

Table 3 shows the device-type and location in the coronary vessels. The broken devices were mostly located in the right coronary artery (50%), followed by the circumflex artery (37.5%), and diagonal branch (12.5%). In three cases, a vessel was perforated. The devices were mostly remnants of guide wires (n = 4); balloon catheters (n = 3), and in 1 case a rotablator. Interestingly, three out of the eight cases were secondary to chronic total occlusion (CTO) therapy. All cases of CTO in our group were located in the right coronary artery (RCA). Table 4 shows a description of each removed foreign body as well as its type and brand.

Two patients died due to multiorgan failure. One was related to the retained device. The implantation of the right heart assist device was not able to prevent the unfavorable outcome. The other patient was a marginal LVAD candidate who developed multiorgan dysfunction unrelated to the retained wire. The lost device here was an accidental finding. All other patients survived and had uneventful postoperative courses. The 1-year follow-up was uneventful for all survivors.

### DISCUSSION

We demonstrate, in this manuscript, that retained foreign bodies from cardiac interventions such as broken guide wires or rotablator

---

**TABLE 1** Demographic characteristics of the study population

|                          | Study population (n = 8) |
|--------------------------|--------------------------|
| Age, y                   | 60.5 ± 5.4               |
| Sex, male                | 75%                      |
| BMI, kg/m²               | 30.1 ± 3.77              |
| Diabetes mellitus        | 37.5%                    |
| Left ventricular EF (%)  | EF 57 ± 18               |
| Euroscore II             | 14.1 ± 14.76             |
| STS score                | 2.2 ± 2.01               |
| One-vessel CAD           | 12.5%                    |
| Two-vessel CAD           | 35.5%                    |
| Three-vessel CAD         | 50%                      |
| Emergency operation      | 75%                      |
| Elective PCI             | 37.5%                    |

Note: Values are mean ± standard deviation or percent of patients. Abbreviations: BMI, body mass index; CAD, coronary artery disease, EF, ejection fraction; PCI, percutaneous coronary intervention; STS, society of thoracic surgeons.

**TABLE 2** Operative characteristics of the study population

| Patient | Surgical approach | Off/on-pump | Other procedure | Revascularization | Complications | Complete removal |
|---------|-------------------|-------------|-----------------|-------------------|---------------|-----------------|
| 1       | Sternotomy        | On-pump     | Aortotomy       | LIMA to LAD; SVG to PDA | No            | Yes             |
| 2       | Sternotomy        | On-pump     | LVAD; TVR, ASD-closure; aortotomy | No | No | Yes |
| 3       | Sternotomy        | Off-pump    | Yes             | LIMA to LAD, Radial artery to RIVP | No | No | Yes |
| 4       | Thoracotomy       | Off-pump    | No              | No                | No            | No              |
| 5       | Sternotomy        | On-pump     | Patch plastic (RD1) | No | No | Yes |
| 6       | Thoracotomy       | Off-pump    | No              | No                | No            | Yes             |
| 7       | Sternotomy        | On-pump     | Aortotomy       | LIMA to LAD       | No            | Yes             |
| 8       | Sternotomy        | On-pump     | Aortotomy; RVAD | SVG to PDA        | Yes           | Yes             |

Abbreviations: ASD, atrial septal defect; LAD, left anterior descending artery; LIMA, left internal mammary artery; LVAD, left ventricular assist device; PDA, posterior descending artery; RD1, first diagonal branch; RVAD, right ventricular assist device; SVG, saphenous vein graft; TVR, tricuspid valve reconstruction.

**TABLE 3** Device type and location

| Patient | Device type | Location | Vessel perforation |
|---------|-------------|----------|--------------------|
| 1       | Guide wire  | RCA      | No                 |
| 2       | Guide wire  | RCA      | No                 |
| 3       | Rotablator  | RCA      | No                 |
| 4       | Balloon catheter | RCX   | Yes                |
| 5       | Guide wire  | RD1      | No                 |
| 6       | Balloon catheter | RCX   | Yes                |
| 7       | Guide wire  | RCX      | No                 |
| 8       | Balloon catheter | RCA  | Yes                |

Abbreviations: RCA, right coronary artery; RCX, circumflex artery; RD1, first diagonal branch.
devices can be completely removed surgically using individualized approaches. There appears to be a trend toward a rising incidence of such interventional complications possibly reflective of the increased complexity of coronary interventions performed nowadays.

Broken and/or entrapped guide wires, balloons, or other devices are a rare complication of interventional procedures. The incidence of these complications has been reported with 0.1% to 0.2% and may even rise up to 0.2% to 0.4% in cases of rotational atherectomy.\(^9\)\(^-\)\(^{13}\) Currently, about 400 PCI procedures are performed per 100,000 people in Germany.\(^14\) This would calculate that between 300 and 600 such complications occur per year in Germany alone. In the United States (with currently 180 PCI per 100,000 per year,\(^15\) but four times the population) and the other European countries (with PCIs ranging from 94 to 675 per 100,000 per year,\(^14\)\(^-\)\(^{16}\)) many more PCIs are performed in total and therefore thousands of more broken or entrapped devices can be expected per year. However, the reports in the literature about these complications focus on conventional and interventional therapy\(^5\)\(^-\)\(^{7}\)\(^,\)\(^9\)\(^-\)\(^{17}\)\(^,\)\(^23\) and the surgical information is limited to case reports.\(^5\)\(^,\)\(^9\)\(^-\)\(^{24}\)\(^-\)\(^{26}\) The largest published case series so far has reported five such cases, combining them with four cases of stent dislocation.\(^27\) Thus, it appears as if there is a significant publication bias for these cases and our ability to assess true outcomes of surgery for these complications is currently very limited.

Our study is so far the largest case series describing the surgical therapy of this interventional complication and to the best of our knowledge, the first prospective one. We observed an increase of the incidence of such patients referred to our department during the last years, while the general number of the other procedures performed remained stable. Our patients were referred from six different cardiology departments and were all performed by different interventional cardiologists, therefore likely excluding a specific human influence as a possible cause. Other authors have also noted that despite technical improvements in the quality of the wires, the incidence of this complication has not decreased over the last decades and may become even higher.\(^25\)

Our data show that having an individualized approach is important when surgically treating patients with wire, balloon, or device entrapment. The main challenges, except extracting the wire have been caused by vessel perforation, potentially combined with blood loss, and/or pericardial tamponade. Another main challenge has been the management of acute ischemia as a result of vessel occlusion or aborted PCI in cases of myocardial infarction. An important risk factor that needs to be taken into consideration is the duration and the location of myocardial ischemia. In case of suspected acute ischemia, off-pump revascularization has been associated with reduced early mortality and morbidity compared with on-pump.\(^28\) We, therefore, chose an off-pump revascularization strategy whenever possible. However, catheter remnants protruded into the aorta in 50% of the cases and a cardioplegic arrest combined with aortotomy was needed to extract them.

An important procedural aspect here is the fact that protruding wires in the aorta are not easily identifiable fluoroscopically. The protrusion can often not be seen in the fluoroscopic images from the cath-lab and in most cases only the tip of the catheter may be identified (Figure 1, panels e and f). However, the wires protruding from the coronary ostium into the aorta can be easily identified using echocardiography (Figure 1, panels a, c, and d). Therefore, in all cases of suspected broken and entrapped wires and devices, transoesophageal echocardiography seems to be the diagnostic tool of choice, which best helps in choosing the right operative strategy (on- vs off-pump; aortotomy vs aorta no-touch technique).

Although the attempt to remove entrapped wire remnants from the coronary circulation is the preferable option, our case where the wire was an accidental finding during an LVAD implantation proves that surgical therapy is not always necessary and such remnants may remain undetected without causing complications. However, conservative treatment of such patients with systemic anticoagulation and antiplatelet agents appears more appropriate for occluded or smaller distal vessels and early surgical referral may be indicated if

| Patient | Length, cm | Shape | Remnant type and brand |
|---------|------------|-------|------------------------|
| 1       | 50         | Curved | ASAHI Gaia second PTCA guide wire (ASAHI INTECC CO, Seto-shi, Japan) |
| 2       | 7          | P-shaped remnant | BMW guide wire; (Abbott Vascular, Santa Clara, CA) |
| 3       | 8          | L-shaped remnant with 1.5-mm head | 1.5 Burr Catheter (Boston Scientific, Marlborough, MA) |
| 4       | Not measured | Straight | Balloon catheter, brand unknown |
| 5       | >20        | Straight | BMW guide wire; (Abbott Vascular, Santa Clara, CA) |
| 6       | Not measured | Straight | Balloon catheter, brand unknown |
| 7       | >20        | Curved | BMW 0.014 Universal 190-cm guide wire, (Abbott Vascular, Santa Clara, CA) |
| 8       | 17         | Curved | NC 5.0 balloon catheter, brand unknown |

Note: “Length” describes the dimension of the piece retained in the patients. Abbreviations: BMW, balance middleweight; PTCA, percutaneous transluminal coronary angioplasty.
ischemic events are encountered.\textsuperscript{5,17} Currently, there are no guidelines regarding the optimal management or choice of antiplatelet/anticoagulation regimen for such patients.\textsuperscript{17} Case reports for cases both with and without antiplatelet/anticoagulation regimen have been published.\textsuperscript{17,18,29} The endovascular management remains another important treatment option with a number of different interventional techniques described: snare loop, double or triple wire technique, deep-guide catheter wedge, and balloon inflation techniques or stenting against the vessel wall.\textsuperscript{5,6,12,30,31} Currently, there is no sufficient data of the use of extracorporeal mechanical circulatory support during endovascular management, but its use in cases of hemodynamic instability appears plausible in patients with contraindications for surgery.

Another important finding in our study is that the broken devices were mostly located in the right coronary artery (50% of the patients), as were all cases of CTO. Studies of coronary calcification using computed tomography angiography have shown that the coronary artery calcium score (surrogate marker for atherosclerotic plaque burden) is often higher in the RCA, especially when severe stenoses were present (1344 for the RCA vs 361 for the left anterior descending and 475 for the circumflex artery).\textsuperscript{32} Therefore, it is well conceivable to propose that the rate of mechanical complications might be a consequence of the above-mentioned difference and therefore presumably takes place in the RCA. However, our study is limited by the small number of cases, although it reflects the largest series currently available.

5 CONCLUSION

We demonstrate in this study that retained foreign bodies from cardiac interventions such as broken guide wires or rotablator devices can be completely removed surgically using individualized approaches. Most of the entrapped devices are located in the RCA. Furthermore, we demonstrate that there appears to be trend toward a rising incidence of these complications possibly reflective of the increased complexity of coronary interventions performed nowadays.

CONFLICT OF INTERESTS

The authors declare that there are no conflict of interests.

AUTHOR CONTRIBUTIONS

HK gathered the data, applied for approval from the ethics committee, analyzed the results, and wrote the manuscript with the help of TD. ST helped in analyzing the study results and revising the manuscript. GF, TS, and MD performed the operative procedures and helped in revising the manuscript. TD analyzed the study results, took part in writing and correcting the manuscript, and provided active support through all parts of the study process. All authors approved the final manuscript.

ORCID

Torsten Doenst \texttt{http://orcid.org/0000-0002-6411-909X}

REFERENCES

1. Tomberli B, Mattesini A, Baldereschi GI, Di Mario C. A brief history of coronary artery stents. Rev Esp Cardiol (Engl Ed). 2018;71(5):312-319.
2. Venkitachalam L, Kip KE, Selzer F, et al. Twenty-year evolution of percutaneous coronary intervention and its impact on clinical outcomes: a report from the National Heart, Lung, and Blood Institute–sponsored, multicenter 1985–1986 PTCA and 1997–2006 dynamic registries. Circul, Cardiovasc Interven. 2009;2(1):6-13.
3. Neumann F-J, Sousa-Uva M, Ahlsson A, et al. 2018 ESC/EACTS guidelines on myocardial revascularization. Eur Heart J. 2019;40(2):87-165.
4. Doenst T, Bargenda S, Kirov H, et al. Cardiac surgery 2018 reviewed. Clin Res Cardiol. 2019;108:974-989.
5. Al-Moghairi AM, Al-Amri HS. Management of retained intervention guide-wire: a literature review. Curr Cardiol Rev. 2015;9(3):260-266.
6. Collins N, Horlick E, Dzavik V. Triple wire technique for removal of fractured angioplasty guidewire. J Invas Cardiol. 2007;19(8):E230-E234.
7. Cho Y-H, Park S, Kim J-S, et al. Rescuing an entrapped guidewire using a Tornus® catheter. Circ J. 2007;71(8):1326-1327.
8. Demircan S, Yazici M, Durna K, Yasar E. Intracoronary guidewire embol: a unique complication and retrieval of the wire. Cardiovasc Revasc Med. 2008;9(4):278-280.
9. Giannini F, Candido L, Mitomo S, et al. A practical approach to the management of complications during percutaneous coronary intervention. JACC: Cardiovasc Interven. 2018;11(18):1797-1810.
10. Hartzler GO, Rutherford BD, McConahay DR. Retained percutaneous transluminal coronary angioplasty equipment components and their management. Am J Cardiol. 1987;60(16):1260-1264.
11. Steffenino G, Meier B, Finci L, et al. Acute complications of elective coronary angioplasty: a review of 300 consecutive procedures. Heart. 1998;92(2):151-158.
12. Woodfield SL, Lopez A, Heuser RR. Fracture of coronary guidewire outcomes of patients undergoing coronary revascularization in the United States, 2003-2016. JAMA Netw Open. 2020;3(2):e1921326.
13. Sulimov DS, Abdel-Rahman S, Kirov H, et al. Trends in characteristics and outcomes of patients undergoing coronary revascularization and its impact on clinical outcomes of patients undergoing coronary revascularization in the United States, 2003-2016. JAMA Netw Open. 2020;3(2):e1921326.
14. Alkhouri M, Alqahtani F, Kalra A, et al. Trends in characteristics and outcomes of patients undergoing coronary revascularization in the United States, 2003-2016. JAMA Netw Open. 2020;3(2):e1921326.
15. Kim LK, Feldman DN, Swaminathan RV, et al. Rate of percutaneous coronary intervention and its impact on clinical outcomes of patients undergoing coronary revascularization in the United States, 2003-2016. JAMA Netw Open. 2020;3(2):e1921326.
16. Kim LK, Feldman DN, Swaminathan RV, et al. Rate of percutaneous coronary intervention and its impact on clinical outcomes of patients undergoing coronary revascularization in the United States, 2003-2016. JAMA Netw Open. 2020;3(2):e1921326.
17. Khan SM, Ho DW, Dinaram T, Lazar JM, Marmur JD. Conservative management of broken guidewire. SAGE Open Med Case Rep. 2014;2:5. https://doi.org/10.1177/2050313X14554478.
18. Kim T-J, Kim J-K, Park B-M, et al. Fatal subacute stent thrombosis induced by guidewire fracture with retained filaments in the coronary artery. Korean Circ J. 2013;43(1):761-765.
19. Danek BA, Karatasakis A, Brilakis ES. Consequences and treatment of guidewire entrapment and fracture during percutaneous coronary intervention. Cardiovasc Revasc Med. 2016;17(2):129-133.
20. Salazar CH, Tirado G, McInerney A, Franco IN-C, Raiders of the lost wire. Eur Med J. 2019;7. https://doi.org/10.33590/emjcardiol/18-00120.
21. Corballis N, Sulfi S, Ryding A. Optical coherence tomographic study of a chronically retained coronary guidewire. Case Rep Cardiol. 2018;2018:9210764.
22. Chu CY, Lin TH, Su HM, Voon WC, Lai WT, Sheu SH. Management of a retained coronary guidewire fragment during percutaneous transluminal coronary angioplasty: a case report. Kaohsiung J Med Sci. 2009;25(3):151-155.
23. Datta G. Broken guidewire–a tale of three cases. Indian Heart J. 2015;67:549-552.
24. Modi A, Zorinas A, Vohra HA, Kaarne M. Delayed surgical retrieval of retained guidewire following percutaneous coronary intervention. J Card Surg. 2011;26(1):46-48.
25. Singh D, Darbari A. Retrieval of trapped and broken guide wire with immediate rescue off-pump coronary bypass surgery. Interact Cardiovasc Thorac Surg. 2014;19(3):529-531.
26. Park S-H, Rha S-W, Her K. Retrograde guidewire fracture complicated with pericardial tamponade in chronic total occlusive coronary lesion. Int J Cardiovasc Imaging. 2015;31(7):1293-1294.
27. Alexiou K, Kappert U, Knaut M, Matschke K, Tugtekin SM. Entrapped coronary catheter remnants and stents: must they be surgically removed? Tex Heart Inst J. 2006;33(2):139.
28. Fattouch K, Guccione F, Dioguardi P, et al. Off-pump versus on-pump myocardial revascularization in patients with ST-segment elevation myocardial infarction: a randomized trial. J Thorac Cardiovasc Surg. 2009;137(3):650-657.
29. Pourmoghaddas M, Fard OH. Retained jailed wire: a case report and literature review. ARYA Atheroscler. 2011;7(3):129.
30. Savas V, Schreiber T, O’Neill W. Percutaneous extraction of fractured guidewire from distal right coronary artery. Cathet Cardiovasc Diagn. 1991;22(2):124-126.
31. Kilic H, Akdemir R, Bicer A. Rupture of guide wire during percutaneous transluminal coronary angioplasty, a case report. Int J Cardiol. 2008;128(3):e113-e114.
32. Liu YC, Sun Z, Tsay P-K, et al. Significance of coronary calcification for prediction of coronary artery disease and cardiac events based on 64-slice coronary computed tomography angiography. BioMed Res Int. 2013:2013:472347.

How to cite this article: Kirov H, Tkebuchava S, Faerber G, Diab M, Sandhaus T, Doenst T. Lost in circulation. J Card Surg. 2020;35:1885-1890. https://doi.org/10.1111/jocs.14821