Complications of chronic total occlusion percutaneous coronary intervention

J. Karacsonyi · E. Vemmou · I. D. Nikolakopoulos · I. Ungi · B. V. Rangan · E. S. Brilakis

Accepted: 30 September 2020 / Published online: 27 October 2020
© The Author(s) 2020

Abstract Chronic total occlusion percutaneous coronary interventions can be highly complex and are associated with an increased risk of complications, such as perforation, acute vessel closure (which can lead to rapid haemodynamic compromise if it involves the donor vessel), and equipment loss or entrapment. Awareness of the potential complications and meticulous attention to equipment position and patient monitoring can help minimise the risk of complications and allow prompt treatment should they occur.

Keywords Complication · Percutaneous coronary intervention · Chronic total occlusion

Introduction

Despite its clinical benefits [1, 2] chronic total occlusion (CTO) percutaneous coronary intervention (PCI) is associated with higher complication rates than PCI of non-occlusive lesions [3]. CTO PCI complications include death, acute myocardial infarction, stroke, the need for repeat PCI, emergency coronary artery bypass graft surgery, tamponade requiring pericardiotomy or surgery, acute vessel closure (which can be a catastrophic complication if it involves the CTO donor vessel), coronary dissection, aorto-ostial dissection, thrombus, embolisation of thrombus, plaque or air, side branch occlusion, spasm, pseudo-lesion formation, intramural haematoma, perforation, equipment entrapment/loss, hypotension, arrhythmias, vascular access complications and bleeding, contrast-induced acute kidney injury, and radiation skin injury [4]. The complications of CTO PCI can be classified as acute and long-term based on timing. CTO PCI complications can also be classified according to location into cardiac and non-cardiac complications. Cardiac complications can be further divided into coronary and non-coronary (Tab. 1). Each complication has a different mechanism and underlying causes. A score has been developed for estimating the risk of periprocedural complications using the following three parameters: patient age >65 years, +3 points; lesion length ≥23 mm, +2 points; and use of the retrograde approach, +1 point [5].

Donor vessel injury

Donor vessel injury requires immediate identification and management, as it can lead to extensive ischaemia and haemodynamic decompensation [6]. In a meta-analysis of retrograde CTO PCIs, donor vessel dissection occurred in 2% of treated CTOs (95% confidence interval: 0.9–4.5%) [7].

Donor vessel injury may be due to dissection caused by deep catheter engagement, for example during equipment withdrawal or during wire externalisation when the operator pulls the retrograde wire forcefully (Fig. 1). Flow in the donor vessel can also be compromised due to catheter or vessel thrombosis, which may be due to long procedures with decreasing activated clotting time (ACT), blood stasis, especially in diseased donor vessel and failure to regularly clear the guide catheter, particularly after trapping [6].

To prevent this complication paying close attention to the position of the guide catheters and to the...
Hier steht eine Anzeige.

Springer
Hier steht eine Anzeige.

(Springer)
Non-cardiac complications
- Radiation skin injury
- Contrast-related nephropathy
- Allergies
- Vascular access complication
- Thromboembolic complications
- Stroke

Medications 

...possibly the administration of intravenous antiplatelet... 

...treated by thrombectomy and post-removal of the externalised guidewire... 

...treated with stenting, ideally over the safety guidewire... 

...dissections... 

...required in the donor vessel... 

Table 1 Types of complications during chronic total occlusion (CTO) percutaneous coronary interventions (PCI)

| Acute complications of CTO PCI | Non-cardiac complications |
|--------------------------------|---------------------------|
| Cardiac complications         |                           |
| Coronary complications        |                           |
| Acute vessel closure           | Vascular access complication |
| Donor vessel injury            | Contrast-related nephropathy |
| Occlusion of collaterals       | Allergies                 |
| (Aorto)coronary dissection     | Radiation skin injury      |
| Dissection of distal vessel   | Thromboembolic complications |
| Side branch occlusion          | Stroke                     |
| Thrombus                       |                           |
| Spasm                          |                           |
| Pseudolesion formation         |                           |
| Subintimal stent deployment    |                           |
| Embolisation: – thrombus, – plaque, – air | |
| Perforation:                   |                           |
| Large vessel                   |                           |
| Collateral                     |                           |
| Distal vessel                  |                           |
| Equipment entrapment/loss      |                           |
| Non-coronary complications     |                           |
| Hypotension                    |                           |
| Myocardial infarction          |                           |
| Arrhythmias                    |                           |
| Death                          |                           |
| Intramural haematoma           |                           |
| Tamponade                      |                           |

Cardiac complications
- Perforation
- Equipment entrapment/loss

Table 1. Types of complications during chronic total occlusion (CTO) percutaneous coronary interventions (PCI).

The risk of perforation can be minimised by meticulous attention to equipment during CTO crossing attempts. Guidewire position within the vessel ‘architecture’ should be confirmed before advancing microcatheters and other equipment. Coronary perforation may lead to cardiac tamponade, myocardial infarction, rapid haemodynamic collapse, and death.

The first step in managing a perforation is to inflate a balloon proximal to or at the perforation to stop bleeding into the pericardium (Fig. 3). Large vessel perforations are usually treated with covered stent implantation, although dissection/re-entry techniques have also been successfully used in some cases.

Distal vessel perforations are treated with embolisation, usually with fat or coils. Covered stents and/or coils can often be delivered through a single guide catheter, especially if 8-French guides...
Fig. 1  Example of donor vessel dissection during retrograde chronic total occlusion (CTO) percutaneous coronary intervention (PCI). PCI of a right coronary artery (RCA) CTO (a). After a failed antegrade crossing attempt, retrograde crossing was performed (b) and the retrograde guidewire was externalised (c). During RCA stenting over the externalised guidewire (d), the patient developed severe chest pain and hypotension due to proximal left anterior descending artery (LAD) dissection (d). The LAD was immediately stented (e) with restoration of antegrade flow and stabilisation of the patient (f, g). After removal of the entrapped retrograde guidewire and stenting of the RCA an excellent final angiographic result was achieved (h). Reproduced with permission from [6]. Online case with video is available on https://www.ctomanual.org/Case 22

Fig. 2  Types of coronary perforation based on location. Reproduced with permission from [33]

Types of coronary perforation

| Location                  | Image |
|---------------------------|-------|
| LAD dissection            | ![Image](https://www.ctomanual.org/Case 22) |
| LAD stent over second antegrade wire | ![Image](https://www.ctomanual.org/Case 22) |
| LAD flow restored         | ![Image](https://www.ctomanual.org/Case 22) |

Complications of chronic total occlusion percutaneous coronary intervention
are used [20]. Alternatively the dual guide catheter technique can be employed with one guide catheter used for delivering a balloon to achieve haemostasis and the second guide catheter for covered stent delivery. Availability of 0.014-inch coils can facilitate delivery through standard microcatheters, as larger 0.018-inch coils require larger microcatheters (such as the Progreat (Terumo, Tokyo, Japan) or Renegade (Boston Scientific, Marlborough, MA, USA)) or use of the Finecross microcatheter (Terumo). Storage of perforation management equipment (covered stents, coils, pericardiocentesis kit) in a CTO or complex PCI cart can expedite treatment [21].

**Side branch occlusion**

Occlusion of the side branches can develop, especially when subintimal dissection/re-entry strategies are applied in CTO PCI, and has been associated with a higher risk of post-PCI myocardial infarction [22, 23]. Extensive dissection/re-entry strategies, such as the subintimal tracking and re-entry (STAR) technique, are associated with high rates of restenosis and re-occlusion likely due to side branch occlusion and decreased outflow [24]. The extent of dissection should, therefore, be limited [23, 25]. Moreover, side branch wiring before stenting can help prevent occlusion and can be facilitated by use of dual lumen microcatheters, such as the Twin Pass (Teleflex, Wayne, PA, USA), Crusade (Kaneka, Tokyo, Japan), NHancer Rx (IMDS, Roden, The Netherlands) or Sasuke (Asahi Intecc Co., Seto, Japan). In some cases a retrograde crossing strategy can be applied to preserve side branches [6, 26]. Intravascular imaging, particularly intravascular ultrasound, can help to determine the mechanism of side branch loss and also facilitate re-opening [6].

**Equipment loss or entrapment**

This complication is rare but potentially could be life-threatening depending on the device and location of the entrapment or loss. Stents are the most commonly embolised devices with an estimated incidence of 0.32% [27]. Equipment delivery can be challenging during CTO PCI, especially through tortuosity and calcification [28]. Retrograde equipment delivery should be avoided [29] as well as excessive guidewire and microcatheter rotation and aggressive Rotablator burr advancement [30, 31]. Use of smaller burrs, advancement of the burr using a pecking motion and avoidance of sudden decelerations is advised [32]. Before attempting stent delivery the target lesion should be carefully prepared with balloon angioplasty and atherectomy if necessary. Checking the transmission of torque to the guidewire tip, and alternating clockwise and counter-clockwise microcatheter rotation, can help minimise the risk of equipment loss/entrapment.

Should equipment loss or entrapment occur, the first decision is whether to attempt retrieval or deploy/crush the equipment against the vessel wall. For stent loss in coronary segments that are unlikely to be significantly affected by the stenting, deployment is often the preferred strategy, as stent retrieval attempts may result in distal stent embolisation or target vessel injury [27]. If crushing is the best option intravascular imaging should be performed to ensure an optimal PCI result [6]. If retrieval is attempted, various snares, most commonly three-loop snares, are most often used.

**Conclusions**

CTO PCI can lead to potentially life-threatening complications. Awareness of such complications, meticulous using techniques to minimise risk, using and
prompt recognition and treatment can optimise CTO PCI outcomes.

**Conflict of interest** J. Karacsonyi, E. Vemmonu, I.D. Nikolakopoulos, I. Ungi and B.V. Rangan declare that they have no competing interests. E. S. Brilakis has received consulting/speaker honoraria from Abbott Vascular, the American Heart Association (associate editor of *Circulation*), Amgen, Biotronik, Boston Scientific, the Cardiovascular Innovations Foundation (Board of Directors), ControlRad, CSI, Ehis, Elsevier, GE Healthcare, InfraRedx, Medtronic, Siemens, and Teleflex, as well as research support from Regeneron and Siemens. He is a shareholder of MHI Ventures.

**Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/.

**References**

1. Garcia S, Abdullah S, Banerjee S, Brilakis ES. Chronic total occlusions: patient selection and overview of advanced techniques. Curr Cardiol Rep. 2013;15:334.

2. Safley DM, Grantham JA, Hatch J, Jones PG, Spertus JA. Quality of life benefits of percutaneous coronary intervention for chronic occlusions. Catheter Cardiovasc Interv. 2014;84:629–34.

3. Brilakis ES, Banerjee S, Karmpaliotis D, Lombardi WL, Tsi T, Shunk KA, et al. Procedural outcomes of chronic total occlusion percutaneous coronary intervention: a report from the NCDR (national cardiovascular data registry). JACC Cardiovasc Interv. 2015;8:245–53.

4. Rigger J, Hanaraty CG, Walsh SJ. Erratum to: common and uncommon CTO complications. Int J Cardiol. 2019;14:48.

5. Danek BA, Karatasakis A, Karmpaliotis D, Alaswad K, Yeh RW, Jaffer FA, et al. Development and validation of a scoring system for predicting periprocedural complications during percutaneous coronary interventions of chronic total occlusions: the prospective global registry for the study of chronic total occlusion intervention (PROGRESS CTO) complications score. J Am Heart Assoc. 2016;5:e04272. https://doi.org/10.1161/JAHA.116.004272.

6. Brilakis ES. Manual of chronic total occlusion interventions, a step-by-step approach. 2nd ed. London: Elsevier; 2018.

7. ElSabagh A, Patel VG, Jeroudi OM, Michael TT, Alomar ME, Mogabgab O, et al. Angiographic success and procedural complications in patients undergoing retrograde percutaneous coronary chronic total occlusion interventions: a weighted meta-analysis of 3,482 patients from 26 studies. Int J Cardiol. 2014;174:243–8.

8. Patel SM, Menon RV, Burke MN, Jaffer FA, Yeh RW, Vo M, et al. Current perspectives and practices on chronic total occlusion percutaneous coronary interventions. J Invasive Cardiol. 2018;30:43–50.

9. Azzalini L, Poletti E, Ayoub M, Ojeda S, Zivelonghi C, La Manna A, et al. Coronary artery perforation during chronic total occlusion percutaneous coronary intervention: epidemiology, mechanisms, management, and outcomes. EuroIntervention. 2019;15:e804–e11.

10. Danek BA, Karatasakis A, Taji P, Sandoval Y, Karmpaliotis D, Alaswad K, et al. Incidence, treatment, and outcomes of coronary perforation during chronic total occlusion percutaneous coronary intervention. Am J Cardiol. 2017;120:1285–92.

11. Hirai T, Nicholson WJ, Sapontis J, Salisbury AC, Marso SP, Lombardi W, et al. A detailed analysis of perforations during chronic total occlusion angioplasty. Interv Cardiol. 2019;12:1902–12.

12. Taji P, Xenogiannis I, Gargoufas D, Karmpaliotis D, Alaswad K, Jaffer FA, et al. Contemporary outcomes of the retrograde approach to chronic total occlusion interventions: insights from an international CTO registry. EuroIntervention. 2019; https://doi.org/10.4244/EIJ-D-19-00441.

13. Ellis SG, Ajluni S, Arnold AZ, Popma JJ, Bittl JA, Eigler NL, et al. Increased coronary perforation in the new device era. Incidence, classification, management, and outcome. Circulation. 1994;90:2725–30.

14. Brilakis ES, Karmpaliotis D, Patel V, Banerjee S. Complications of chronic total occlusion angioplasty. Interv Cardiol Clin. 2012;1:373–89.

15. Xenogiannis I, Brilakis ES. Advances in the treatment of coronary perforations. Catheter Cardiovasc Interv. 2019;93:921–2.

16. Taji P, Xenogiannis I, Chavez I, Gossi M, Mooney M, Poulose A, et al. Expecting the unexpected: preventing and managing the consequences of coronary perforations. Expert Rev Cardiovasc Ther. 2018;16:805–14.

17. Shaukat A, Taji P, Sandoval Y, Stanberry L, Garberich R, Burke MN, et al. Incidence, predictors, management and outcomes of coronary perforations. Catheter Cardiovasc Interv. 2019;93:48–56.

18. Giannini F, Candilio L, Mitomo S, Ruparelia N, Chieffo A, Baldetti L, et al. A Practical approach to the management of complications during percutaneous coronary intervention. JACC Cardiovasc Interv. 2018;11:1797–810.

19. Xenogiannis I, Taji P, Burke MN, Brilakis ES. An alternative treatment strategy for large vessel coronary perforations. Catheter Cardiovasc Interv. 2019;93:635–8.

20. Sandoval Y, Lobo AS, Brilakis ES. Covered stent implantation through a single 8-french guide catheter for the management of a distal coronary perforation. Catheter Cardiovasc Interv. 2017;90:584–8.

21. Brilakis ES, Mashayekhi K, Tsukhikane E, Rafeh NA, Alaswad K, Araya M, et al. Guiding principles for chronic total occlusion percutaneous coronary intervention. Circulation. 2019;140:420–33.

22. Michael TT, Papayannis AC, Banerjee S, Brilakis ES. Subintimal dissection/reentry strategies in coronary chronic total occlusion interventions. Circ Cardiovasc Interv. 2012;5:729–38.

23. Nguyen-Trong PK, Rangan BV, Karatasakis A, Danek BA, Christakopoulos GE, Martinez-Parachini JR, et al. Predictors and outcomes of side-branch occlusion in coronary chronic total occlusion interventions. J Invasive Cardiol. 2016;28:168–73.

24. Rinfret S, Ribeiro HB, Nguyen CM, Nombela-Franco L, Urena M, Rodes-Cabau J. Dissection and re-entry techniques and longer-term outcomes following successful percutaneous coronary intervention of chronic total occlusion. Am J Cardiol. 2014;114:1354–60.
25. Wosik J, Shorrock D, Christopoulos G, Kotsia A, Rangan BV, Roesle M, et al. Systematic review of the bridgepoint system for crossing coronary and peripheral chronic total occlusions. J Invasive Cardiol. 2015;27:269–76.
26. Kotsia A, Christopoulos G, Brilakis ES. Use of the retrograde approach for preserving the distal bifurcation after antegrade crossing of a right coronary artery chronic total occlusion. J Invasive Cardiol. 2014;26:E48–9.
27. Brilakis ES, Best PJ, Elesber AA, Barsness GW, Lennon RJ, Holmes DR Jr., et al. Incidence, retrieval methods, and outcomes of stent loss during percutaneous coronary intervention: a large single-center experience. Catheter Cardiovasc Interv. 2005;66:333–40.
28. Iturbe JM, Abdel-Karim AR, Papayannis A, Mahmood A, Rangan BV, Banerjee S, et al. Frequency, treatment, and consequences of device loss and entrapment in contemporary percutaneous coronary interventions. J Invasive Cardiol. 2012;24:215–21.
29. Sianos G, Papafaklis MI. Septal wire entrapment during re- canalisation of a chronic total occlusion with the retrograde approach. Hellenic J Cardiol. 2011;52:79–83.
30. Grise MA, Yeager MJ, Teirstein PS. A case of an entrapped rotational atherectomy burr. Catheter Cardiovasc Interv. 2002;57:31–3.
31. Sulimov DS, Abdel-Wahab M, Toelg R, Kassner G, Geist V, Richardt G. Stuck rotablator: the nightmare of rotational atherectomy. EuroIntervention. 2013;9:251–8.
32. Gupta T, Weinreich M, Greenberg M, Colombo A, Latib A. Rotational atherectomy: a contemporary appraisal. Interv Cardiol. 2019;14:182–9.
33. Brilakis ES. Manual of percutaneous coronary interventions: a step by step approach. 1st ed. London: Elsevier; 2020.