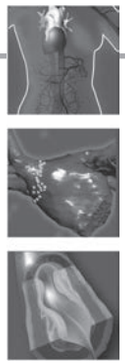

Chronic total occlusion percutaneous coronary intervention as mainstream therapy: are we at a tipping point?

"*This special focus issue on chronic total occlusions aims to define the current landscape...*"

KEYWORDS: chronic total occlusion ■ efficiency ■ outcomes ■ unmet need

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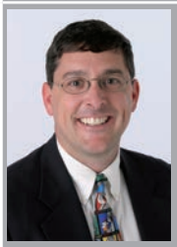

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Chronic total occlusions (CTOs) represent a spectrum in cardiovascular adaptation to ischemic heart disease. Their prevalence has been well described, with the impact on symptoms, prognosis and management becoming increasingly clear [1]. A mismatch seems to exist between their negative impact on quality of life and prognosis, and physician management strategies [2], which, in contrast to less occlusive disease, are more likely to be conservative and less likely to involve percutaneous revascularization.

Reasons for this apparent mismatch have previously included technical inability to durably revascularize patients (both surgically and percutaneously) and a lack of recognition of the beneficial effects of revascularization. To challenge these hypotheses require teachable, reproducible technical innovations in percutaneous revascularization and robust clinical data supporting this rationale.

This special focus issue on CTOs aims to define the current landscape from these perspectives, to summarize the current evidence base for CTO percutaneous coronary intervention (PCI), define the technical advances and describe procedure-related complications.

A potential limiting factor in CTO PCI uptake is the morbidity associated with obtaining a vascular access site. Larger guiding catheters are often required to facilitate use of techniques, such as 'anchor balloon', and to help with forward push when negotiating densely diseased arterial segments. This may mean the use of larger than standard (8 F compared with 6 F) femoral access with its attendant bleeding risks [3]. Niccoli *et al.* describe reasons why larger guiding catheters are desirable and discuss the reasons why access site may vary [4]. They also discuss the relative merits of transfemoral vs transradial access. The concept of passive versus active support catheters remains central to CTO PCI and methods of maximizing support from smaller guiding catheters are reviewed by Niccoli *et al.* The primary difference in compatibility of catheters between transfemoral access and transradial access is the size of the index access artery (radial vs femoral). The authors introduce the concept of internal vs external lumen diameter of equipment and explain how sheathless guide catheters may address this issue.

Despite the presence of CTO influencing a disproportionally higher referral rate for coronary artery bypass grafting (CABG), the durability of saphenous vein grafts to occluded vessel segments remains poor [5]. Karmpaliotis describes the very high prevalence of CTOs within post-CABG populations and aims to define the revascularization challenges presented [6,7]. This population is older, has more complex disease and higher levels of morbidity [8]. It is perhaps not surprising, therefore, that redo CABG remains an unattractive proposition; however, the percutaneous challenges are not small either. Compared with a non-CABG population, the disease burden is higher with longer occluded segments and greater levels of calcium evident. The impact of the technical innovations described in more detail later is therefore more evident. A higher incidence of procedures requiring subintimal dissection is seen, and while success rates described are lower, they illustrate that although good options exist for this challenging subset of patients, continuing procedural refinement is required [9].

Bagnall and Paranamana provide us with a summary of three recent papers [10]. The first describes an iteration in negotiating very durable, fibrotic or occluded vessel segments with the use of either rotational atherectomy or laser to successfully pass balloon resistant lesions [11]. The second article reinforces the messages delivered by the access site review within this edition of the journal by describing the beneficial impact

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of operator experience on transradial access for the treatment of CTO PCI [12].

The final article reviews the long-term follow-up of drug-eluting stents for the treatment of CTOs in a population where angiographic follow-up was mandated and a reassuringly low reocclusion rate was noted [13].

A perspective on the role of device innovation, in the form of an interview, is provided by Chad Kugler, founder and primary inventor of the BridgePoint Medical system (MN, USA), which utilizes antegrade subintimal channels to track past the CTO and re-enter the distal true lumen. Kugler addresses the drivers for innovation in this area, the challenges involved in bringing a new technology to market and the remaining challenges the field faces [14].

Strange introduces and describes the principles behind subintimal tracking, outlining the differential tissue properties, which facilitate techniques that rely on the principles of blunt dissection to track past occluded vessel segments [15]. The rationale for prospective use of the subintimal space relies on the need for procedural efficiency, as well as an individual operator's inability to remain definitively within the intima, particularly within long or tortuous occluded segments. The principles behind the development of 'blunt' dissection techniques (such as controlled antegrade and retrograde subintimal tracking and reverse controlled antegrade and retrograde subintimal tracking) are described along with the technological developments that developed from rudimentary antegrade blunt dissection techniques (subintimal tracking and re-entry technique) to more controlled, predictable methods of true lumen re-entry with the use of the CrossBoss™ and Stingray™ (BridgePoint Medical) CTO crossing system.

Gallagher and Smith describe the integration of CTO crossing techniques into an algorithm-based method, which affords operators a framework for initial selection of strategy and a flow-based system for adapting to preprocedural challenges [16]. This system, referred to as 'hybrid', relies on the principles of procedural efficiency, introducing the concept of an algorithmic-based escalation of techniques to deal with challenging technical aspects of the procedure. The four technique-based foundation stones are discussed and placed within their context: those of antegrade wire escalation, antegrade dissection re-entry, retrograde wire escalation and retrograde dissection re-entry. It is further explained how 'failure' with any of these initial strategies should lead to a rapid switch to the next strategy indicated by the hybrid algorithm. Finally, the key angiographic factors influencing the choice of initial strategy are described, those of the nature of the proximal cap; the length of the CTO, the degree of disease distal to the CTO and the quality of the collateral circulation.

Procedure failure, although less common than previously, is still a subject worthy of consideration. Wilson *et al.* describe the common factors that lead to procedure failure, how to recognize these preprocedure, when to stop and how to address these procedure limiters in such a way that leads to a subsequent successful procedure [17].

Buller gives a fascinating perspective of the combined engineering and clinical challenges of developing a coronary guidewire, perhaps the most important tool in the treatment of CTOs [18]. He describes the differential properties required to address clinical challenges found with an occluded arterial segment and introduces the concept of task-specific wiring, subsequently describing the properties of the wires used to deal with challenges, such as penetrating the proximal cap, traversing the occluded segment, negotiating collateral channels and re-entering the 'true' lumen from a subintimal position.

Douglas *et al.* review the evidence base for CTO revascularization, addressing perceived limiters of CTO revascularization [19]. While the authors accept the relative paucity of randomized controlled studies, the larger number of registry-based studies showing a prognostic outcome for successful versus unsuccessful PCI were noted [20]. Studies examining at surrogate markers of an adverse outcome are also discussed and reviewed, improvements in quality of life [21]; left ventricular ejection fraction [22]; reduction in sudden cardiac death [23] and the concept of 'double jeopardy' (the inferior prognostic outlook of CTO patients with an acute coronary syndrome) [24] are discussed. The relationship between ischemic burden and adverse outcome throughout the spectrum of coronary artery disease exists as a rationale for revascularization in the context of an ischemic burden >10% in a symptomatic patient.

McEntegart and Spratt discuss and describe the role of planning in both designing an optimal CTO program and with specific reference to individual procedures [25]. The impact of successful team work is reviewed, with the need for attention to detail in the fields of radiation, anticoagulation and access site are reviewed and discussed.

Hanratty provides a timely review of the retrograde procedure [26], outlining its genesis [27] to its current role as a key component of CTO revascularization [28]. Hanratty provides a practical guide to a successful retrograde procedure, ranging from guide set up, through subintimal recanalization methods to externalization and working on an externalized wire.

Understanding the potential range of complications is an important first step in reducing their frequency to a minimum. Patel *et al.* describe the incidence of CTO-related complications detailing the most frequent, as well as the most potentially harmful of those complications [29]. A full range of coronary and extracoronary complications are described, including coronary and collateral perforation; donor vessel dissection, catheter thrombus and equipment entrapment. An algorithm for identifying and treating complications has been developed.

Finally, Sapontis and Hill describe the use of adjunctive imaging techniques to both optimize preprocedure planning and per-procedural outcomes [30]. This ranges from the use of echocardiography, coronary CT and MRI to aid patient selection through intravascular ultrasound to resolve procedure-related issues to optical coherence tomography in follow-up.

This special focus issue of *Interventional Cardiology*, therefore, provides a complete overview of the CTO space as it currently stands. We would like to thank all the authors for their work and expertise, we hope that you will enjoy reading this material and seek to employ the invaluable advice contained within to improve patient welfare.

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References

1 Christofferson RD, Lehmann KG, Martin GV, Every N, Caldwell JH, Kapadia SR. Effect of chronic total coronary occlusion on treatment strategy. *Am. J. Cardiol.* 95(9), 1088–1091 (2005).

2 Abbott JD, Kip KE, Vlachos HA *et al.* Recent trends in the percutaneous treatment of chronic total coronary occlusions. *Am. J. Cardiol.* 97(12), 1691–1696 (2006).

3 Agostoni P, Biondi-Zoccai GG, de Benedictis ML *et al.* Radial versus femoral approach for percutaneous coronary diagnostic and interventional procedures; systematic overview and meta-analysis of randomized trials. *J. Am. Coll. Cardiol.* 44(2), 349–356 (2004).

4 Niccoli G, De Vita MR, Montone RA, Burzotta F, Trani C. Access route for coronary chronic total occlusion: femoral or radial approach? *Interv. Cardiol.* 5(5), 485–488 (2013).

5 Widimsky P, Zbynek S, Stros P *et al.* One-year coronary bypass graft patency. A randomized comparison between off-pump and on-pump surgery. Angiographic results of the PRAGUE-4 trial. *Circulation* 110, 3418–3423 (2004).

6 Karmpaliotis D. Does prior coronary artery bypass grafting affect percutaneous chronic total occlusion revascularization? *Interv. Cardiol.* 5(5), 489–492 (2013).

7 Fefer P, Knudtson ML, Cheema AN *et al.* Current perspectives on coronary chronic total occlusions: the Canadian Multicenter Chronic Total Occlusions Registry. *J. Am. Coll. Cardiol.* 59, 991–997 (2012).

8 Teramoto T, Ito T, Tsuchikane E *et al.* Prior coronary artery bypass grafting diminishes the initial success rate of percutaneous coronary intervention in chronic total occlusion of a native coronary artery. *J. Am. Coll. Cardiol.* 59(13), E104 (2012).

9 Tesfaldet TM, Karmpaliotis D, Brilakis ES *et al.* Impact of prior coronary artery bypass graft surgery on chronic total occlusion revascularisation: insights from a multicentre US registry. *Heart* doi:10.1136/heartjnl-2013-303763 (2013) (Epub ahead of print).

10 Bagnall A, Paranamana R. Research highlights: highlights from the latest articles in chronic total occlusion percutaneous coronary intervention. *Interv. Cardiol.* 5(5), 499–502 (2013).

11 Fernandez JP, Hobson AR, McKenzie D *et al.* Beyond the balloon: excimer coronary laser atherectomy used alone or in combination with rotational atherectomy in the treatment of chronic total occlusions, noncrossable and nonexpansible coronary lesions. *EuroIntervention* 9(2), 243–250 (2013).

12 Burzotta F, Trani C, Tommasino A *et al.* Impact of operator experience and wiring technique on procedural efficacy of transradial percutaneous chronic total occlusion recanalization performed by dedicated radialists. *Cardiol. J.* doi:10.5603/CJ.a0063 (2013) (Epub ahead of print).

13 Isaaz K, Mayaud N, Gerbay A *et al.* Long-term clinical outcome and routine angiographic follow-up after successful recanalization of complex coronary true chronic total occlusion with along stent length: a single-centre experience. *J. Invasive Cardiol.* 25(7), 323–329 (2013).

14 Kugler C. Taming coronary chronic total occlusions. *Interv. Cardiol.* 5(5), 503–507 (2013).

15 Strange JW. The use of subintimal pathways to facilitate chronic total occlusion procedural success. *Interv. Cardiol.* 5(5), 509–513 (2013).

16 Gallagher S, Smith EJ. Hybrid algorithm for chronic total occlusion percutaneous coronary intervention. *Interv. Cardiol.* 5(5), 515–519 (2013).

17 Wilson WM, Bagnall A, Spratt JC. In case of procedure failure: facilitating future success. *Interv. Cardiol.* 5(5), 521–531 (2013).

18 Buller CE. Coronary guidewires for chronic total occlusion procedures: function and design. *Interv. Cardiol.* 5(5), 533–540 (2013).

19 Douglas H, Johnston NG, Bagnall AJ, Walsh SJ. Current evidence base for chronic total occlusion revascularization. *Interv. Cardiol.* 5(5), 541–548 (2013).

20 Joyal D, Afilalo J, Rinfret S. Effectiveness of recanalization of chronic total occlusions: a systematic review and meta-analysis. *Am. Heart J.* 160(1), 179–187 (2010).

21 Grantham JA, Jones PG, Cannon L, Spertus JA. Quantifying the early health status benefits of successful chronic total occlusion recanalization: results from the FlowCardia's Approach to Chronic Total Occlusion Recanalization (FACTOR) trial. *Circ. Cardiovasc. Qual. Outcomes* 3(3), 284–290 (2010).

22 Chung CM, Nakamura S, Tanaka K *et al.* Effect of recanalization of chronic total occlusions on global and regional left ventricular function in patients with or without previous myocardial infarction. *Catheter. Cardiovasc. Interv.* 60(3), 368–374 (2003).

23 Godino C, Bassanelli G, Economou FI *et al.* Predictors of cardiac death in patients with coronary chronic total occlusion not revascularized by PCI. *Int. J. Cardiol.* doi:10.1016/j.ijcard.2012.12.044 (2013) (Epub ahead of print).

24 Bataille Y, Dery JP, Larose E *et al.* Incidence and clinical impact of concurrent chronic total occlusion according to gender in ST-elevation myocardial infarction. *Catheter. Cardiovasc. Interv.* 82(1), 19–26 (2012).

25 McEntegart M, Spratt JC. Procedure planning for chronic total occlusion percutaneous coronary intervention. *Interv. Cardiol.* 5(5), 549–557 (2013).

26 Hanratty CG. The retrograde approach: a practical guide for maximizing procedural success. *Interv. Cardiol.* 5(5), 559–566 (2013).

27 Kahn JK, Hartzler GO. Retrograde coronary angioplasty of isolated arterial segments through saphenous vein bypass grafts. *Catheter. Cardiovasc. Diagn.* 20, 88–93 (1990).

28 Brilakis ES, Banerjee S, Lombardi WL. Retrograde recanalization of native coronary artery chronic occlusions via acutely occluded vein grafts. *Catheter. Cardiovasc. Interv.* 75, 109–113 (2010).

29 Patel VG, Brayton KM, Tamayo A *et al.* Angiographic success and procedural complications in patients undergoing percutaneous coronary chronic total occlusion interventions: a weighted meta-analysis of 18,061 patients from 65 studies. *JACC Cardiovasc. Interv.* 6(2), 128–136 (2013).

30 Sapontis J, Hill J. The role of adjunctive imaging in chronic total occlusions. *Interv. Cardiol.* 5(5), 577–589 (2013).