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Review article

Chronic total occlusions: What's new?

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Cardiovascular interventions is a fast-evolving specialty. New technologies and devices become available every year. Interventionists should be aware about current and future developments to be at best in providing patient care. Chronic total occlusion (CTO) is a challenging situation for a specialist, even for an experienced one, as the lesions require a special approach. The article contains the latest information regarding CTO treatment strategies and outcomes.

Chronic total occlusions are identified in 15–30% of all patients referred for coronary angiography and considered as 100% coronary lesion of more than 3 months evolution[1]. It is argued there are collaterals in the CTO situation, and optimal medical therapy is a good option. Unfortunately, collaterals provide 40% of antegrade blood flow at rest, and only 10% during stress[2]. Recent study of MA et al. using single photon emission computed tomography (SPECT) myocardial perfusion imaging (MPI) revealed CTO-related ischemia is an independent predictor for adverse events[3]. Systematic review and a meta-analysis of contemporary studies including 6,084 patients with a median of 12-months follow up showed that successful CTO PCI was associated with a lower incidence of MACE driven by lower all-cause mortality compared with failed CTO PCI at a median follow-up of 1 year[4]. According to a meta-analysis of 34 studies, CTO recanalization results in improvement of LVEF, reduction of adverse remodeling and an improvement of survival[5]. Study of Rha et al. demonstrated that successful CTO PCI with DESs was associated with a higher risk of repeat PCI for the target vessel, but showed a reduced incidence of death or MI[6]. Ten-year results of CTO recanalization provided by Park et at. showed late survival benefit after CTO PCI as a primary treatment strategy compared to optimal medical therapy. There was no difference during the first three years, but at the time interval between 3 and 10 years, relative reduction of cardiac deaths became apparent (Figure 1)[7].

There are no randomized trials regarding late CTO recanalization results, but available data clearly tells us PCI improves survival.

Three main algorithms for CTO procedures are presented in literature: EuroCTO (Figure 2, modified hybrid algorithm[8], Asia Pacific (Figure 3)[9] and North American (Figure 4)[10]. All approaches contain similar angiographic criteria regarding antegrade or retrograde initial recanalization strategy, Stingray System (Boston Scientific) use. Asia Pacific and EuroCTO algorithms contain more details, such as IVUS for proximal cap puncture, CrossBoss (Boston Scientific, Natick, Massachusetts) catheter use for in-stent CTO, criteria for knuckle-wiring and information on when to stop the procedure. The algorithms represent a useful toolset and guidance for all CTO operators.

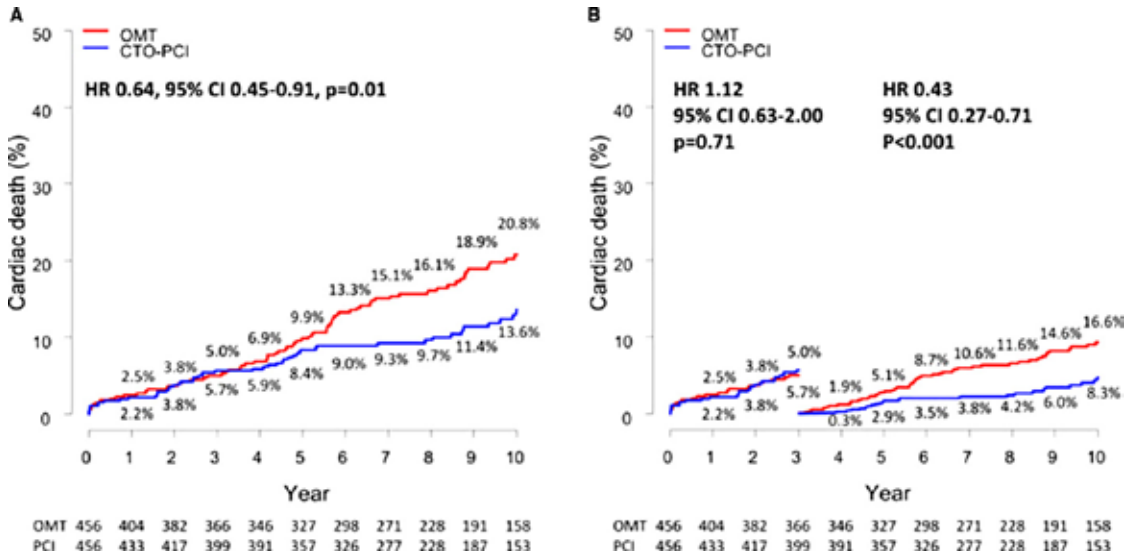

Figure 1. Kaplan-Meier event curves at 10 years and 3-year landmark analysis for cardiac death. **A,** 10-year cumulative event curves for cardiac death. **B,** Time-to-event curves with landmark analysis from 0 to 3 and 3 to 10 years for cardiac death. CTO indicates chronic total occlusion; HR, hazard ratio; OMT, optimal medical therapy; and PCI, percutaneous coronary intervention.

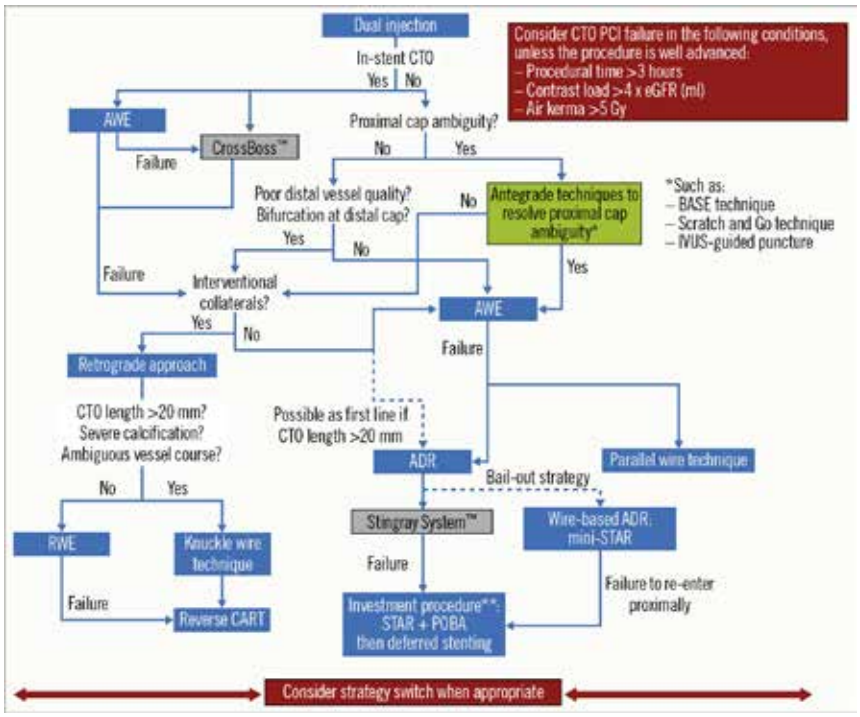

Figure 2. Modified hybrid algorithm for CTO PCI
ADR: antegrade dissection re-entry; AWE: antegrade wire escalation; BASE: balloon-assisted subintimal entry; CART: controlled antegrade retrograde tracking; CTO: chronic total occlusion; eGFR: estimated glomerular filtration rate; IVUS: intravascular ultrasound; PCI: percutaneous coronary intervention; POBA: plain old balloon angioplasty; RWE: retrograde wire escalation; STAR: subintimal tracking and re-entry.

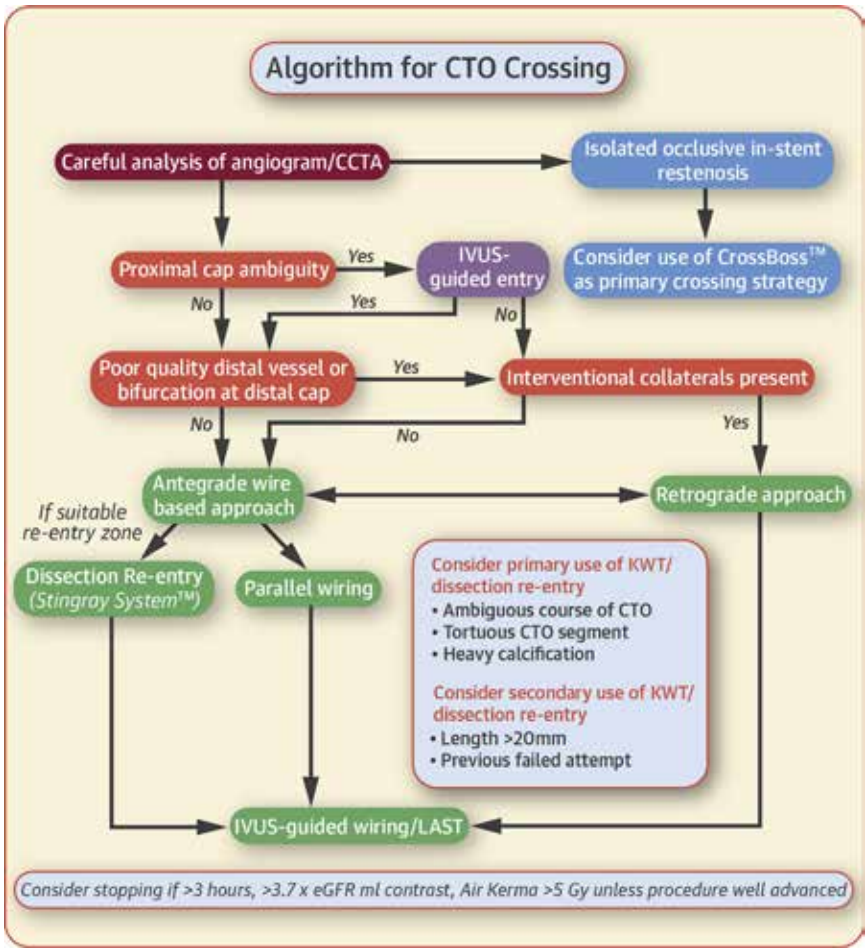

Figure 3. Asia-Pacific CTO club algorithm
eGFR - estimated glomerularfiltration rate; IVUS - intravascular ultrasound; KWT - knuckle wire technique; LAST - limited antegrade subintimaltracking;

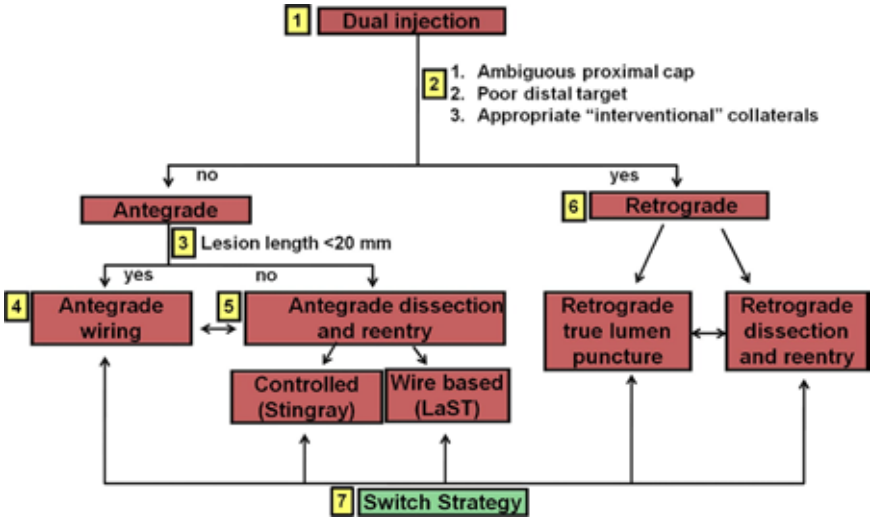

Figure 4. North American CTO algorithm
The algorithm starts with dual coronary injection (box 1) to allow assessment of several angiographic parameters (box 2) and allow selection of a primary antegrade (boxes 3 to 5) or primary retrograde (box 6) strategy. Strategy changes are made (box 7), depending on the progress of the case. CTO = chronic total occlusion; LaST = limited antegrade subintimal tracking.

Certainly, operator experience plays a key role in CTO interventions, but success also depends on tools and devices:

- Stingray LP (Boston Scientific), CTO re-entry system that helps to enter true lumen.
- CrossBoss (Boston Scientific), coronary CTO crossing catheter for subintimal space and true lumen;
- SUOH03 (ASAHI Intecc), an ultra-ow tipload guidewire (0.3 gf) for collateral tortuosities;
- Gaia Next (ASAHI Intecc), preshaped, cone-tipped CTO-dedicated guidewires family (Gaia Next 1, 2 gf tipload; Gaia Next 2, 4 gf tipload; Gaia Next 3, 6gf tipload);
- Judo Sentai (Boston Scientific), 0.008" tapered guidewires family (Judo 1, soft intraluminal crossing wire for antegrade microchannels, 1 gf tipload; Judo 3, intraluminal crossing wire for fibro-calcific lesions, 3 gf tipload; Judo 6, penetration wire with excellent steerability in tight lesions, 6 gf tipload).

Atherectomy is also a useful option, according to analysis of the PROGRESS-CTO registry: currently it is performed in approximately 3% of CTO PCI cases and associated with similar technical and procedural success and overall major cardiac events rates, but higher risk of donor vessel injury and tamponade[11]. When it comes to techniques, both subintimal and intraplaque recanalization approaches to CTO are associated with comparable mid-term angiographic results[12]. Modified STRAW is a novel technique presented by Vo, Minh N., et al. describes microcatheter use to decompress proximal hematoma and facilitate wire re-entry with a stingray (Boston Scientific)[13]. Antegrade fenestration and reentry (AFR) technique described by Carlino, Mauro, et al. causes extraplaque disruption of the vessel with 1:1-sized balloon catheter in the CTO body. The technique creates tears of the media, and aids soft wire to reach true lumen distally[14]. Using drug-coated balloon catheters after subintimal plaque modification in failed coronary CTO intervention and delayed (30 days to several months) repeat attempt with deferred stenting is another novel technique in complex cases[15]. Moreover, moderate-severe calcification is frequently found in CTOs. Intravascular lithotripsy could also improve outcomes along with atherectomy techniques[16]. Another valuable option for calcified lesions preparation and recoil decrease is super-high pressure balloon dilatation (SIS Medical)[17].

In conclusion, a CTO is a complex situation for an interventionist. Occluded arteries cause impact on quality of life and survival. Current technologies and operator experience significantly increased procedure success rate. We have a great toolbox nowadays, but needless to say, novel techniques and devices are required to improve outcomes, i.e., dedicated guidewires, microcatheters. There is always room for improvement. It would be nice to have new CTO guidelines consolidating available data that will help operators to take right decisions, making CTO procedures safer and widely used.

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