Antegrade wire escalation for chronic total occlusions in coronary arteries: simple algorithms as a key to success

Peer-reviewed author version

MAEREMANS, Joren; Knaapen, Paul; Stuijfzand, Wynand J.; Kayaert, Peter; Pereira, Bruno; Barbato, Emanuele & DENS, Jo (2016) Antegrade wire escalation for chronic total occlusions in coronary arteries: simple algorithms as a key to success. In: Journal of Cardiovascular Medicine, 17(9), p. 680-686.

DOI: 10.2459/JCM.0000000000000340
Handle: http://hdl.handle.net/1942/23095

Antegrade wire escalation for chronic total occlusions in coronary arteries: simple algorithms as a key to success

Joren Maeremans[1], MSc; Paul Knaapen[2], MD, PhD; Wynand J. Stuijfzand[2], MD; Peter Kayaert[3], MD; Bruno Pereira[4], MD; Emanuele Barbato[5], MD; Jo Dens[1,6], MD, PhD.

[1]Faculty of Medicine and Life Sciences – Universiteit Hasselt, Hasselt, Belgium

[2]Department of Cardiology – VU University Medical Center, Amsterdam, the Netherlands

[3]Department of Cardiology – Universitair Ziekenhuis Brussel, Brussel, Belgium

[4]Department of Cardiology – l'Institut National de Chirurgie Cardiaque et de Cardiologie Interventionnelle, Luxemburg

[5]Department of Cardiology – Onze-Lieve-Vrouwe Ziekenhuis Aalst, Aalst, Belgium

[6]Department of Cardiology – Ziekenhuis Oost-Limburg, Genk, Belgium

Corresponding author

Joren Maeremans

Schiepse Bos 6 (M9.10); 3600, Genk (Belgium)

Telephone: +32 89 32 15 27

Fax: +32 089 32 79 18

joren.maeremans@uhasselt.be

Number of words: 2.551

INTRODUCTION

The field of Percutaneous Coronary Intervention (PCI) for Chronic Total Occlusions (CTO) has rapidly evolved over the last decade, with new hybrid techniques such as antegrade dissection and re-entry (ADR) and reverse controlled antegrade and retrograde subintimal tracking (reverse CART) opening new ways towards success in more complex cases.[1-13] However, these techniques and the devices used remain expensive and require a high level of experience. Overall, antegrade wire escalation (AWE) remains the preferred approach for tackling CTOs in more than 80% of the cases, especially for low J-CTO scores and for low and intermediate volume operators. Nonetheless, also high volume operators frequently apply AWE.[5, 14-17]

Previously, we reported on the eligibility of patients and the use of an AWE algorithm with a limited number of guidewires (GW) in two centers.[14, 18] Meanwhile, GW technology has improved and therefore, our previous algorithm was adapted (Figure 1A) and applied in a larger number of centres. In a prospective, multicentre study, we investigated the success rates of improved GW technology and safety regarding radiation exposure, use of contrast dye and general use of materials.

METHODS

Study population

From September 2013 to October 2014, 103 patients were prospectively included in this registry, patients in which the operator decided that antegrade wire escalation was the first strategy to be used. Five dedicated CTO operators from hospitals in Belgium (UZ Brussels, ZOL Genk, OLVZ Aalst), the Netherlands (VUmc Amsterdam) and Luxemburg (INCCI Luxemburg) performed the procedures and inclusions, conforming to the institutional guidelines and those of the American Physiological Society. The operators had various experience levels as one is an antegrade wire escalation operator, one uses ante- and retrograde techniques and the three others apply all techniques, including ADR and retrograde techniques. Ethical permission was granted and all patients gave written informed consent. Patient selection for CTO PCI was based on left ventricular viability, clinical symptoms and/or documented ischemia. Data on baseline demographics, procedural characteristics and outcomes were collected and analyzed according to the J-CTO criteria.[17, 19] Three cases were excluded from the analysis because the procedure deviated from the algorithm (cfr. below; two cases were started with an intermediate stiff GW and in one case a switch from a soft to a stiff GW was performed).

Study definitions and endpoints

A CTO was defined as a lesion of a native coronary artery which exhibited Thrombolysis in Myocardial Infarction (TIMI) antegrade flow equal to zero. The occlusion length was estimated based on the image using a bilateral arterial approach and/or the stent and balloon length as reference. Presence of calcification was defined if this was visible on fluoroscopy without contrast injection. Technical success was defined as successful CTO revascularization with achievement of <30% residual diameter stenosis within the treated segment and restoration of TIMI grade 3 antegrade flow. Procedural success was defined as achievement of technical success with no Major Adverse Cardiac Events (MACE).

An important marker in successful GW crossing has become the 30 minute cut-off value. Consequently, we have taken GW crossing time (either within 30 minutes or in more than 30 minutes) as the primary

endpoint for this study.[14, 17] Crossing time corresponds to the time of initial insertion of the first GW into the coronary artery to the time of successful crossing of the last or being pulled out because of failure. The secondary endpoint was general procedural success, including results obtained by applying other techniques (e.g. ADR, reverse-CART, etc.), materials used, contrast and radiation exposure.

Study algorithm and procedure

Angiographic images of all patients, referred for CTO PCI, were analyzed to determine the primary strategy.[3] If an antegrade wiring attempt was performed as a first strategy, the patient was included in the registry. All AWE attempts in this registry - excluding 3 patients - were performed according to a specific algorithm (Figure 1A). Although one can discuss the wire algorithm used (f.e. absence of Pilot 200 GW), we preferred a simple algorithm with a limited number of wires. The algorithm is based on a stepwise increase in tip load and thus penetration power of different GWs from ASAHI. The first GW of choice is a Fielder XT-A (Fielder XT-R or Fielder XT were allowed at the discretion of the operator) (i.e. “Soft GWs”). As compared to the older Fielder XT technology, which is based on “passive loose tissue tracking”, the Fielder XT-A and XT-R GWs have a 0.010” parabolic double coil structure which generates a higher torque-ability, durability and control over the GW, enabling “active loose tissue tracking”. The double coil has a hydrophilic polymer sleeve coating and a tip load of 1.0 g and 0.6 g for the Fielder XT-A and XT-R respectively. Upon failure to cross with one of these wires, an exchange is made either to UltimateBros3 (first period of the study) and later Gaia 1 or 2, when they became available. Like the Fielder XT-A and XT-R, the Gaia group of GWs is based on the Sion GW technology (i.e. double coil structure), allowing for a higher torque control of the GW. All Gaia wires have a hydrophilic coating throughout the wire except for the distal microcone-shaped, non-coated tip. This allows for a higher penetration efficacy, despite being more flexible. In this way, “active wire control” is generated. It is a non-drilling GW, which can be pushed to advance and torqued to turn, two motions which need to be applied separately. Also the “wip-motion” is reduced with this technology. The

UltimateBros3 and Gaia GWs constitute the “intermediate GWs”. The Confianza Pro 9 or 12 (“Stiff GWs”) are used when all other wires failed to cross the occlusion.

The algorithm was always applied using a microcatheter (Corsair, ASAHI Intecc Co.; NHancer, IMDS; Finecross, Terumo Interventional Systems), unless the occlusion was located ostial or very proximal.[20, 21] Should an AWE attempt fail, the use of other techniques and GWs (e.g. Pilot 200, etc.) was left at discretion of the operator. If deemed necessary, a quick switch to another technique could also be made without completing the step-up algorithm (e.g. when the first or second GW went subintimal) or the procedure could be terminated. In-hospital adverse events were accounted for.

Statistical analyses

Baseline, angiographic and procedural data were analyzed using descriptive statistics. Numerical values were expressed as mean ± standard deviation, while categorical variables were expressed as percentage of total. Normality was assessed using the Shapiro-Wilk statistic. Comparisons between groups were performed using χ^2-square tests for categorical variables and the independent Student’s t-test for continuous variables, with the level of significance set at $p \leq 0.05$.

Univariate regression analyses were performed to assess the relationship between the patients’ baseline and angiographic characteristics and successful GW crossing within 30 minutes. Data on procedural characteristics and success were also calculated for the different J-CTO difficulty groups. In addition, a subanalysis was made according to the applied treatment algorithm. All statistical analyses were carried out using SPSS Statistics version 22 (IBM SPSS Inc.).

RESULTS

Demographics and angiographic characteristics

103 patients were prospectively included of which 100 were withheld. In these patients, AWE was the primary strategy to open the CTO vessel. To describe the demographics and angiographic characteristics of the study population, successful GW crossing within 30 minutes time was used (Table 1).

No significant demographic differences existed between the successful and failed group. Angiographically, the presence of a large side-branch at the proximal CTO cap had a significant negative influence on the procedure outcome (28 vs. 71%; $p < 0.001$). Also, when performing a re-attempt, a higher chance for failure existed (6 vs. 18%; $p = 0.05$) and a trend towards crossing failure within 30 minutes was present when the proximal cap had a blunt anatomy (26 vs. 43%; $p = 0.11$).

Procedural characteristics

Using the algorithm, procedural characteristics were favorable (Table 2). Procedures performed were swift (67 ± 39 min), especially in easy CTOs (46 ± 23 min). Similarly, in J-CTO 0, fluoroscopy times, radiation doses and use of contrast dye were low: 27 ± 19 min., 1.7 ± 1.3 Gy and 264 ± 123 ml respectively. No MACE in-hospital or complications took place.

Study algorithm

The adapted algorithm resulted in high success rates (Table 3): 72% of the lesions could be successfully crossed within 30 minutes. In the different J-CTO categories, success rates were 83%, 81%, 68%, 43% respectively). In all study cases, successful GW crossing resulted also in procedural success.

The applied algorithm used three types of GWs, of which the corresponding success rates are depicted in Figure 1B. Forty-five percent could be crossed with a Fielder GW within 30 minutes. In the remaining cases, intermediate and stiff GWs respectively added an additional 32% and 55% success. In three

cases, GW crossing was possible, although not within 30 minutes. Including these cases (GW crossing ≥30 min.) successful crossing was 75% (Figure 1B, Table 3). All following results described below combine successful GW crossing within and not within 30 minutes, unless indicated.

An in-depth analysis of each type of GW was performed, according to the J-CTO difficulty groups (Figure 1B, Table 4). Using a soft GW only, success was achieved in 46%. The Fielder XT-A was the preferred GW to start with in all centers (87%) and accounts for the highest percentage of success among all GWs (51%), including intermediate and stiff GWs. In 50 of the remaining lesions, an escalation to an intermediate GW has been performed, of which 34% were successfully crossed. Consequently, success rose from 46% to 63%. In 20 of the remaining lesions, an escalation to a stiff GW was made, of which 60% was successful. This led to a total success of 75% with AWE.

General procedural success

For failed AWE attempts, additional-techniques (predominantly ADR and reverse CART) increased the overall success rate from 75% to 88% (Table 3). Success rates according to J-CTO score became 100%, 95%, 84% and 64% (for easy, intermediate, difficult and very difficult CTOs respectively), in these lesions selected for an AWE as a first approach.

DISCUSSION

There remains an important clinical need in opening CTO vessels.[22] Although in non-randomized trials, a mortality benefit has been demonstrated, more than 40% of CTOs are either treated medically or patients are referred for bypass surgery.[23-26] In patients with angina or documented viability, revascularization, despite well-developed collaterals, still reduces cardiac mortality and MACE.[27]

Improvements in device technology, like new-generation drug-eluting stents, CTO-dedicated GWs, and specific microcatheters, resulted in higher success rates and better long-term outcomes.[27-29] Even more, not all CTOs are difficult to be "opened". In the study of Morino et al.[17], who developed the J-CTO score, the percentage of lesions with a J-CTO score of zero or one was more than 40%, comparable with the results of our study. Success rates in these subgroups are high and more interventionalists should be convinced and confident in tackling them. Simple algorithms will help to spread the willingness to treat these lesions.

The objective of this study was to investigate whether a strict, simple algorithm and new wire technology (Fielder XT-A, Gaia GWs) resulted in high success rates, low radiation exposure and use of contrast dye. After all, despite the options of ADR or retrograde recanalization of CTOs, AWE remains the primary used strategy to open a CTO vessel for most operators.

A high percentage of success could be achieved using our adapted algorithm, with the new GW technologies incorporated (i.e. 75%). This means 3 out of 4 CTOs, suitable for a primary AWE strategy, have been re-vascularized in a straightforward and simple fashion. Remarkably, GW crossing was almost always feasible within 30 minutes time. Although success rates are high in the easy and intermediate lesions, improvements can still be made in the difficult and very difficult subgroups, either by increasing experience, using additional techniques and/or persisting longer in the procedure.

Almost half of all cases could be completed using soft GWs only. However, to reach the level of 75% success, the full set of GWs in the algorithm was essential. For example, the use of specific intermediate wires – like Gaia, can result in the formation of channels, which can be followed (if needed) by a stiffer

wire after exchange through a microcatheter, to cross the last part of the CTO. Step down with regards to tip load, after crossing the most resistant part is also a good and save option. One might criticize the absence of frequently used and highly successful GWs in the algorithm like the Pilot 200, Progress wires or even the MiracleBros. Notwithstanding, as we wanted to keep the algorithm as simple and straightforward as possible, these were not included.

With respect to the procedural characteristics, the application of our algorithm resulted in low procedure times, low radiation exposures, and low fluoroscopy times as well as the use of an acceptable amount of GWs per procedure. Apart from the significance of operator experience and a conscious mindset to minimize these values, the new radiology equipment and settings are extremely important in reducing radiation exposure for both patients and CTO operators during longer procedures, a goal for which operators should continuously strive.

Certainly, not a single technique or strategy will lead to success in all cases. Bail-out techniques have therefore been applied. In this registry, the use of secondary techniques (ADR and retrograde approaches) after failure of the algorithm, further increased success with 13%.

STUDY LIMITATIONS

The following limitations to this study exist. Data collection is limited to cases where AWE is the first strategy. Gaia 1 and 2 GWs became available during the registry and were used in 3% and 26% respectively. Although the number is limited to 100 patients, results with the algorithm look to be representative of what can be achieved by current experienced and less experienced operators using AWE only. Operator experience may change during time frames, which is followed by an increased application of secondary strategies. Awareness of radiation exposure can influence its use, however equipment and settings were not changed during the time window.

CONCLUSION

By adapting our historical algorithm and familiarizing ourselves with new wire technology, all operators were able to achieve high success rates with AWE, especially in J-CTO 0-1, despite their variety in experience level (one operator is an antegrade wire operator, one uses ante- and retrograde techniques and the three others apply all techniques). The usefulness of a simple algorithm is confirmed to be successful in a larger number of centers – which makes it less operator dependent. New wire technologies and increased experience have a positive effect on procedural characteristics such as radiation exposure and procedural times. We suggest that starting CTO operators or low and intermediate volume CTO centers, focused on AWE, should implement a CTO-algorithm in their catheterization laboratory. Importantly, investing in new GW technology is essential and a continuous reviewing of the algorithms is crucial. By doing so, further improvements might be obtained.

ACKNOWLEDGMENTS

All authors have contributed substantially to the development of this manuscript.

Conflicts of Interest: Jo Dens receives grants from TopMedical (Distributor of Asahi Intecc co. materials) and Boston Scientific for teaching courses. For the remaining authors none were declared.

FUNDING

No grants, contracts or other forms of financial support were given to support publication of this paper. Joren Maeremans is researcher for the Limburg Clinical Research Program (LCRP) UHasselt-ZOL-Jessa, supported by the foundation Limburg Sterk Merk (LSM), Hasselt University, Ziekenhuis Oost-Limburg and Jessa Hospital.

REFERENCES

1. Brilakis E, Karmpaliotis D, Vo M, et al. Advances in the Management of Coronary Chronic Total Occlusions. *J of Cardiovasc Trans Res* 2014:1-11.

2. Brilakis ES, Badhey N, Banerjee S. "Bilateral knuckle" technique and Stingray re-entry system for retrograde chronic total occlusion intervention. *J Invasive Card* 2011;23(3):E37-39.

3. Brilakis ES, Grantham JA, Rinfret S, et al. A percutaneous treatment algorithm for crossing coronary chronic total occlusions. *JACC Cardiovasc Interv* 2012;5(4):367-379.

4. Brilakis ES, Grantham JA, Thompson CA, et al. The retrograde approach to coronary artery chronic total occlusions: a practical approach. *Cath Cardiovasc Interv* 2012;79(1):3-19.

5. Michael TT, Mogabgab O, Fuh E, et al. Application of the “Hybrid Approach” to Chronic Total Occlusion Interventions: A Detailed Procedural Analysis. *J Interv Card* 2014;27(1):36-43.

6. Michael TT, Papayannis AC, Banerjee S, Brilakis ES. Subintimal Dissection/Reentry Strategies in Coronary Chronic Total Occlusion Interventions. *Circ Cardiovasc Interv* 2012;5(5):729-738.

7. Papayannis A, Banerjee S, Brilakis ES. Use of the Crossboss catheter in coronary chronic total occlusion due to in-stent restenosis. *Cath Cardiovasc Interv* 2012;80(2):E30-36.

8. Whitlow PL, Burke MN, Lombardi WL, et al. Use of a novel crossing and re-entry system in coronary chronic total occlusions that have failed standard crossing techniques: results of the FAST-CTOs (Facilitated Antegrade Steering Technique in Chronic Total Occlusions) trial. *JACC Cardiov Interv* 2012;5(4):393-401.

9. Tsuchikane E, Yamane M, Mutoh M, et al. Japanese multicenter registry evaluating the retrograde approach for chronic coronary total occlusion. *Cath Cardiovasc Interv* 2013;82(5):E654-661.

10. Saito S. Different strategies of retrograde approach in coronary angioplasty for chronic total occlusion. *Cath Cardiovasc Interv* 2008;71(1):8-19.

11. Werner GS, Schofer J, Sievert H, Kugler C, Reifart NJ. Multicentre experience with the BridgePoint devices to facilitate recanalisation of chronic total coronary occlusions through controlled subintimal re-entry. *EuroInterv* 2011;7(2):192-200.

12. Sianos G, Barlis P, Di Mario C, et al. European experience with the retrograde approach for the recanalisation of coronary artery chronic total occlusions. A report on behalf of the euroCTO club. *EuroInterv* 2008;4(1):84-92.

13. Sheiban I, Moretti C, Biondi-Zoccai GG, et al. Retrograde septal approach for a challenging chronic total occlusion of the right coronary artery. *J Cardiovasc Med* 2008;9(2):213-216.

14. Maeremans J, Selleslagh P, Di Serafino L, Barbato E, Dens J. Chronic total occlusions for intermediate volume operators: An antegrade step-up algorithm allows high success in easy and intermediate difficult CTO lesions. *WJCD* 2013;3(9):536-542.

15. Nassar YS, Boudou N, Dumonteil N, Lhermusier T, Carrie D. Guidewires used in first intentional single wiring strategy for chronic total occlusions of the left anterior descending coronary artery. *Heart views* 2013;14(2):56-61.

16. Fujino A, Sakamoto H, Fujino M, et al. The Procedural Benefit of Soft and Tapered Tip Guidewire use as a first choice for Chronic Total Occlusion Revascularization. *JACC* 2012;59(13, Supplement):E106.

17. Morino Y, Abe M, Morimoto T, et al. Predicting successful guidewire crossing through chronic total occlusion of native coronary lesions within 30 minutes: the J-CTO (Multicenter CTO Registry in Japan) score as a difficulty grading and time assessment tool. *JACC Cardiovasc Interv* 2011;4(2):213-221.

18. Di Serafino L, Borgia F, Maeremans J, et al. The Age, Creatinine, and Ejection Fraction Score to Risk Stratify Patients Who Underwent Percutaneous Coronary Intervention of Coronary Chronic Total Occlusion. *Am J Card* 2014;114(8):1158-1164.

19. Syrseloudis D, Secco GG, Barrero EA, et al. Increase in J-CTO lesion complexity score explains the disparity between recanalisation success and evolution of chronic total occlusion strategies: insights from a single-centre 10-year experience. *Heart* 2013;99(7):474-479.

20. Joseph G, Thomson VS, Radhakrishnan S. Corsair microcatheter for retrograde coronary chronic total occlusion recanalization: early experience outside the realm of dedicated recanalization specialists. *Indian heart journal* 2012;64(4):388-393.

21. Otsuka Y, Nakamura K, Saito T. Usefulness of the Corsair Microcatheter for Treatment of Complex Chronic Total Occlusion. *J Invasive Card* 2012;24(2):E35-38.

22. Barbato E, Wijns W. Are We Ready for a New Paradigm Shift in Percutaneous Revascularization of Chronically Occluded Vessels With Well-Developed Collaterals?: From Leaving ’Em All to Stenting ’Em All∗. *JACC Cardiovasc Interv* 2015;8(2):280-282.

23. Takagi K, Ielasi A, Chieffo A, et al. Impact of residual chronic total occlusion of right coronary artery on the long-term outcome in patients treated for unprotected left main disease: the Milan and New-Tokyo registry. *Circ Cardiovasc Interv* 2013;6(2):154-160.

24. Hoye A, van Domburg RT, Sonnenschein K, Serruys PW. Percutaneous coronary intervention for chronic total occlusions: the Thoraxcenter experience 1992-2002. *European heart journal* 2005;26(24):2630-2636.

25. Aziz S, Stables RH, Grayson AD, Perry RA, Ramsdale DR. Percutaneous coronary intervention for chronic total occlusions: Improved survival for patients with successful revascularization compared to a failed procedure. *Cath Cardiovasc Interv* 2007;70(1):15-20.

26. Fefer P, Knudtson ML, Cheema AN, et al. Current perspectives on coronary chronic total occlusions: the Canadian Multicenter Chronic Total Occlusions Registry. *JACC* 2012;59(11):991-997.

27. Jang WJ, Yang JH, Choi S-H, et al. Long-Term Survival Benefit of Revascularization Compared With Medical Therapy in Patients With Coronary Chronic Total Occlusion and Well-Developed Collateral Circulation. *JACC Cardiovasc Interv* 2015;8(2):271-279.

28. Suero JA, Marso SP, Jones PG, et al. Procedural outcomes and long-term survival among patients undergoing percutaneous coronary intervention of a chronic total occlusion in native coronary arteries: a 20-year experience. *JACC* 2001;38(2):409-414.

29. Rathore S, Matsuo H, Terashima M, et al. Procedural and In-Hospital Outcomes After Percutaneous Coronary Intervention for Chronic Total Occlusions of Coronary Arteries 2002 to 2008: Impact of Novel Guidewire Techniques. *JACC Cardiovasc Interv* 2009;2(6):489-497.

FIGURE LEGENDS

Figure 1: A. Antegrade wire escalation algorithm. Fielder XT, Fielder XT-A and Fielder XT-R are defined as "Soft GWs"; UltimateBros3 and Gaia 1 and 2 are defined as "Intermediate GWs"; Confianza Pro 9 and 12 are defined as "Stiff GWs"; B. ASAHI GW crossing according to type of GW. Types of GWs are defined above.