JACC: CARDIOVASCULAR INTERVENTIONS
VOL. 9, NO. 9, 2016

ISSN 1936-8798/$36.00
PUBLISHED BY ELSEVIER
http://dx.doi.org/10.1016/j.jcin.2016.02.006

EDITORIAL COMMENT

# Chronic Total Occlusion Percutaneous Coronary Intervention

## Bridging the Gap*

Emmanouil S. Brilakis, MD, PhD,[a] M. Nicholas Burke, MD[b]

Percutaneous coronary intervention (PCI) of chronic total occlusions (CTOs) can be challenging to perform because of traditionally low success and higher complication rates. A meta-analysis of 65 studies published between 2000 and 2011 reported 77% angiographic success and 3.1% risk for major adverse cardiac events (1). An analysis from the National Cardiovascular Data Registry of cases performed between 2009 and 2013 demonstrated that patients undergoing CTO PCI had lower procedural success (59% vs. 96%; $p < 0.001$) and a 2× higher risk for major adverse cardiac events (1.6% vs. 0.8%; $p < 0.001$) compared with those undergoing non-CTO PCI (2).

Several single- and multiple-operator registries have recently reported much better outcomes than those just quoted. Christopoulos et al. (3) reported 91% technical success and a 1.7% rate of major adverse cardiac events among 1,036 consecutive CTO PCIs performed using the hybrid approach between 2012 and 2015 at 11 U.S. centers. Kandzari et al. (4) reported 96.4% procedural success among 250 patients at 20 U.S. centers. Tsuchikane et al. reported a 97.8% success rate in 180 CTO PCIs performed by 2 expert operators in Japan (5). In this issue of *JACC: Cardiovascular Interventions*, Galassi et al. (6) report a 94.4% technical success rate among 662 CTO PCIs performed by a single, highly skilled operator between 2010 and 2014 in Europe.

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How can the gap between what is achieved at most centers and what is achieved at experienced centers be bridged? One answer is to increase the number of experienced, high-volume CTO operators. Higher CTO PCI volume equals higher success and lower complication rates (2,7); yet, 75% of operators performing CTO PCI in the United States do 10 or fewer such cases per year (2). Another answer is to select cases that have a higher likelihood of being successful even among less experienced operators. Three angiographic and clinical scores have been developed to date to assist with patient selection for CTO PCI.

The "grandfather" of CTO PCI clinical scores is the J-CTO (Multicenter CTO Registry in Japan) score, which was developed to predict successful guidewire crossing within the first 30 min (8). This was followed by the clinical and lesion-related (CL) score (9), the PROGRESS-CTO (Prospective Global Registry for the Study of Chronic Total Occlusion Intervention) score (10), and the ORA (ostial location, Rentrop grade <2, age ≥75 years) score (6) (**Table 1**), all of which were developed to predict procedural or technical success.

These scores share many similarities, but also have differences (**Table 1**). The ORA score is the most parsimonious (3 variables), whereas the CL score is the most expansive (6 variables). Some scores give equal weight to all included variables (J-CTO and PROGRESS-CTO), whereas others have differential weighting (CL and ORA). All scores contain

*Editorials published in *JACC: Cardiovascular Interventions* reflect the views of the authors and do not necessarily represent the views of *JACC: Cardiovascular Interventions* or the American College of Cardiology.

From the [a]VA North Texas Healthcare System and University of Texas Southwestern Medical Center at Dallas, Dallas, Texas; and the [b]Minneapolis Heart Institute and Foundation, Minneapolis, Minnesota. Dr. Brilakis has received consulting and speaking honoraria from Abbott Vascular, Asahi, Boston Scientific, Elsevier, Somahlution, St. Jude Medical, and Terumo; has received research support from InfraRedx and Boston Scientific; and his spouse is an employee of Medtronic. Dr. Burke has received consulting and speaking honoraria from Abbott Vascular and Boston Scientific.

**TABLE 1 Comparison of Currently Available Scores for Chronic Total Occlusion Percutaneous Coronary Intervention**

| | J-CTO Score | CL Score | PROGRESS-CTO Score | ORA Score |
|---|---|---|---|---|
| Number of variables | 5 | 6 | 4 | 3 |
| Number of cases | 494 | 1,657 | 781 | 1,073 |
| Overall success | 88.6% (guidewire crossing) | 72.5% (procedural success) | 92.9% (technical success) | 91.9% (technical success) |
| Clinical | | | | |
| Age ≥75 yrs | | | | + |
| Prior CABG surgery | | + | | |
| Prior MI | | + | | |
| Prior CTO PCI failure | + | | | |
| Angiographic | | | | |
| Blunt stump | + | + | +* | |
| Ostial location | | | | + |
| Severe calcification | + | + | | |
| Severe tortuosity | + | | + | |
| CTO length >20 mm | + | + | | |
| CTO target vessel | | + (non-LAD) | + (circumflex) | |
| Collateral vessels | | | + (interventional) | + (Rentrop grade <2) |

*Proximal cap ambiguity.

CABG = coronary artery bypass graft; CL = clinical and lesion-related score; CTO = chronic total occlusion; J-CTO = Multicenter CTO Registry in Japan; LAD = left anterior descending coronary artery; MI = myocardial infarction; ORA = ostial location, Rentrop grade <2, age ≥75 years; PCI = percutaneous coronary intervention; PROGRESS-CTO = Prospective Global Registry for the Study of Chronic Total Occlusion Intervention.

angiographic variables, and all except the PROGRESS-CTO score contain at least 1 clinical variable.

Every score contains a variable that describes the "entry" to the CTO (proximal cap). Three scores contain a variable characterizing the CTO morphology (calcification, tortuosity, length), and 2 scores contain a variable on collateral circulation, a key determinant of the feasibility of the retrograde approach (11). Finally, 2 scores contain a variable describing which vessel is occluded, with the left anterior descending coronary artery having the best and the circumflex coronary artery the worst success rates (12).

How should these scores be used to improve CTO PCI outcomes?

First, outcomes could be improved by providing a context for interpreting the angiogram. At least 15 min of focused angiographic review is critical to understand the characteristics of the target CTO and devise a procedural plan. Focus should be at the beginning of the CTO (clear or ambiguous proximal cap), the length and characteristics (tortuosity, calcification) of the occlusion, the vessel distal to the occlusion, and the presence and quality of collateral vessels (13). Calculating at least 1 CTO score could enhance the extent and depth of angiographic review.

Second, outcomes could be improved by assisting with case selection for CTO PCI. This is particularly important for less experienced operators, who could benefit from attempting simpler cases (lower scores) early on and either deferring or referring the more complex cases early during their CTO PCI experience. CTO scores may be less useful for highly experienced operators who can achieve high success rates even with the most complex cases: technical success in very difficult (J-CTO score ≥3) lesions was 89.9% in the PROGRESS-CTO registry (14).

Third, by helping plan the time and resources required for procedures, outcomes would improve. CTO PCI can be unpredictable, with some seemingly simple lesions turning out to be highly challenging to recanalize and vice versa. However, in general, more complex lesions are more likely to require longer periods of time and more frequent use of advanced crossing strategies, such as the retrograde approach and antegrade dissection and re-entry (14).

Additional work is needed to build on the excellent progress in CTO PCI score development. External and prospective validation will be critical to confirm the accuracy and applicability of each score among different patient, operator, and lesion populations. To date the only score that has undergone external validation is the J-CTO score, which showed good predictive capacity for technical success in 1 multicenter registry (14) but not in 2 single-operator registries (6,15). The effect of rapid and accelerating introduction of novel devices and techniques on CTO PCI will also need to be assessed.

CTO PCI is undergoing a transformative period of growth. Validation and implementation of dedicated scores can help bridge the gap between what can be and what is achieved in CTO PCI, providing our patients the successful outcomes they need and deserve.

**REPRINT REQUESTS AND CORRESPONDENCE:** Dr. Emmanouil S. Brilakis, VA North Texas Health Care System, 4500 S. Lancaster Road (111A), Dallas, Texas 75216. E-mail: esbrilakis@gmail.com.

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**KEY WORDS** chronic total occlusion, outcomes, percutaneous coronary intervention, score