Percutaneous coronary intervention of chronic total occlusions (CTOs) represents the most technically challenging procedure in contemporary interventional cardiology (1,2). Although large, definitive randomized trials are lacking, a growing body of evidence suggests that successful percutaneous CTO revascularization relieves symptoms, improves left ventricular systolic function, reduces the need for surgical coronary bypass, and in the context of complete coronary revascularization, improves survival (3–5). Yet, compared with patients with severely stenotic, but patent, vessels, patients with a CTO are more likely to be referred for coronary bypass surgery or medical therapy, and in a recently published Canadian registry, only 1 in 10 patients with a CTO underwent percutaneous coronary intervention (PCI) (6). Historically, the success rate of CTO PCI was in the range of 70% (6–8). This uncertainty regarding the likelihood of success, mixed with the fear of unacceptably high complication rates and prohibitive procedural costs, contribute to the reluctance to percutaneously revascularize CTOs.

The J-CTO (Japanese Multicenter CTO Registry) score (9) was originally developed to predict the likelihood of successful guidewire crossing within 30 min. Independent angiographic predictors of failure (each given 1 point) that made up the J-CTO score included prior failed attempt, angiographic evidence of heavy calcification, bending within the occluded segment, blunt proximal stump, and occlusion length >20 mm (9). CTOs were then graded as easy, intermediate, difficult, and very difficult (J-CTO scores of 0, 1, 2, and ≥3 respectively). Since then, the J-CTO score has been found to predict the overall likelihood of CTO PCI success. High J-CTO scores have been shown to correlate with lesion complexity (10), and may account for the paradox of stagnant CTO PCI success rate over time, which was due to intervening on increasingly complex CTOs (11).

In this issue of JACC: Cardiovascular Interventions, Opolski et al. (12) use coronary computed tomography angiography (CCTA) to improve on the J-CTO score. They report on a CCTA-derived scoring system in a cohort of 240 CTO PCI lesions from 4 European centers. They assigned 1 point for each independent predictor of successful guidewire crossing within 30 min. The points are then summed to yield the CT-RECTOR score. CTO lesions were categorized as easy (score 0), intermediate (score 1), difficult (score 2), and very difficult (score ≥3). In this study, independent predictors of failure derived from CCTA analysis included occlusion length >20 mm, multiple occlusions, blunt stump, bending, and severe calcification in the CTO segment. Clinical predictors of failure included a previously failed attempt at percutaneous
revascularization and duration of CTO > 12 month or unknown duration of occlusion. Using this score, the probability of successful guidewire crossing within 30 min for each group (from easy to very difficult) was 95%, 88%, 57%, and 22%, respectively. By combining CCTA and clinical characteristics, the area under the receiver-operating characteristic curve for the CT-RECTOR score was greater than that of the J-CTO score (0.83 vs. 0.71, \( p < 0.001 \)), suggesting superior discrimination between straightforward and complex CTO procedures.

There are several important considerations that are required before applying the CT-RECTOR score to contemporary CTO angioplasty, particularly if it will eventually be studied and evolve as a predictor of procedural success. With new technologies and techniques, success rates in expert centers consistently above 90% are possible with very acceptable complication rates (13,14). Of note in the U.S. series (14), with adoption of the “hybrid” approach (15), the use of CCTA is very limited. Therefore, the decision to revascularize a CTO is a clinical one, on the basis of symptoms, myocardial viability, and patient preference, and should not be on the basis of the ease or difficulty of the case. As such, the CT-RECTOR score is useful by identifying highly complex cases that should be avoided by operators early in their CTO PCI learning curve and rather referred to expert centers.

The study cohort had a modest success rate of only 62%, a very low percent of retrograde CTO PCI, and no cases of controlled antegrade dissection re-entry. In addition, the percent of prior coronary artery bypass graft surgery (CABG) was 17%, which is comparable to prior series from Europe (13) and Japan (16), but significantly lower than the U.S. series (14), reflecting revascularization patterns that are different across the world. Patients with prior CABG represent a particularly challenging population because of extent of disease, calcification, and distortion of anatomy (vessel tenting). Historically, the success rate in prior CABG was lower than in non-CABG patients (78.1% vs. 87.2%, \( p < 0.001 \)) (16), and only recently the success rates became comparable between CABG and non-CABG patients (87.5% vs. 92.5%, \( p = 0.07 \)) (14,17). Therefore, the applicability of the CT-RECTOR score to U.S. centers and operators that perform high-end CTO PCI is unclear.

It is important to note that in the present study, dual injection coronary angiography was performed in only two-thirds of cases. Consequently, the incremental value of CCTA, above angiographic scoring systems that systematically employ dual injection, may be exaggerated because of suboptimal baseline

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**FIGURE 1** Algorithm for Crossing CTOs

The algorithm starts with dual coronary injection (box 1) to allow assessment of several angiographic parameters (box 2) and allows 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. Reproduced with permission from Brilakis et al. (15).
angiography without contralateral coronary injection. Single-catheter angiography provides inadequate information. Dual injection is crucial for determining the lesion length, the size and location of the distal target vessel, evaluating whether there is a significant bifurcation at the distal cap, the presence, size, and tortuosity of collateral vessels, and for deciding on the optimal CTO PCI strategy (18). We recommend performing the dual injection angiogram at the time of the diagnostic procedure once a CTO is identified and strongly discourage ad hoc CTO PCI (19). This allows for a thorough pre-procedural planning. By implementing the “hybrid algorithm,” the operator who is familiar with all available CTO PCI techniques (antegrade wire escalation, antegrade dissection and re-entry, and retrograde wire escalation and dissection re-entry) can decide on the initial, as well as all the alternative strategies, in case the initial approach fails, that will provide the safest, most efficient, and most effective way to recanalize the CTO in a single procedure (Figure 1). It should be noted that CCTA has some advantages over the angiogram: it is more sensitive than the angiogram at detecting tortuosity in the occluded segment and calcification that may impact the treatment strategy. Future research on CCTA should focus on identifying additional anatomic characteristics that could assist in formulating a CTO PCI strategy in the context of comprehensive CTO PCI algorithm.

In 2014, a new benchmark for CTO success rates of above 90% has been established. Anatomy dictates how and who should perform the CTO PCI, not whether the CTO PCI should be attempted. Similarly, lesion complexity no longer dictates the feasibility of CTO PCI, but the strategy for successful CTO revascularization.

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