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EDITORIAL COMMENT

Coronary Computed Tomographic Angiography Can Predict Chronic Total Occlusion Recanalization Success

Where Do We Go From Here?*

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The management of patients with chronic total coronary occlusions (CTO) is challenging. The presence of a CTO is prognostically relevant and successful revascularization improves left ventricular function and outcome if the subtended myocardium is viable (1-3). Bypass surgery for a single coronary artery is usually not performed, but interventional treatment of chronic occlusions is technically challenging—whereas specialized centers may achieve success rates around 90% (4-6), broader scale registries report success ranges as low as 59% (7). If interventional recanalization fails, this is associated with poor acute and long-term prognosis (4-6).

Imaging is relevant to define the best management strategy for patients who have chronic coronary artery occlusions (8,9). Viability of the subtended myocardium can and should be determined by stress echocardiography, single-photon emission computed tomography, positron-emission tomography, or cardiac magnetic resonance before attempting CTO recanalization or before deciding whether a chronically occluded vessel should be included in a multivessel revascularization strategy. Furthermore, imaging can be used to predict the likelihood of success if recanalization of a CTO is attempted by catheter techniques. Several coronary angiographic characteristics predict failure. They include an adverse morphology of the proximal occlusion site ("blunt stump"), visible calcification, length of the occluded segment, and the degree of tortuosity. Together with the presence of a previously failed revascularization attempt, these parameters have been combined into the "J-CTO score" (the letter "J" standing for Japan, which harbors particular expertise regarding CTO recanalization), and the score has been shown to correlate with the likelihood to achieve recanalization, and also with the likelihood to achieve "30-minute wire crossing" (10-12). The latter is an outcome measure that is frequently used in CTO studies for 2 reasons. First of all, passage of a wire across the occlusion into the correct distal lumen is the crucial step that determines overall success—once a wire is correctly placed, the remaining steps to open the artery and place stents are usually relatively straightforward. Second, whether an attempt to open an occluded artery with catheter techniques is successful or not is substantially influenced not only by skill, but also by determination of the operator and the 30-min crossing time somewhat levels the aspect of how fiercely (and patiently) the operator pursues success.

Coronary computed tomography angiography (CTA) has a unique ability to visualize not only the patent, but also the occluded portions of the target artery and the use of coronary CTA to predict CTO success and failure has therefore been evaluated by many research groups. The first such paper was published by Mollet et al. (13) as early as 2005 and current knowledge has recently been summarized in a review article by Opolski et al. (14). In general, very similar parameters as those contained in the angiographic J-CTO score have been evaluated by most authors and several papers have used computed tomography (CT)-based scores that emulated or closely approximated the angiographic J-CTO score (15-18).

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In this issue of *iJACC*, Fujino et al. (19), from an experienced CTO group in Japan, publish their experience with CT-based determination of the J-CTO score and its ability to predict both 30-min wire crossing and eventual successful revascularization in a large cohort of 205 patients with 218 chronic total occlusions (19). The novelty aspect of their work is the direct comparison of the CT-based J-CTO score to the angiographic J-CTO score in a large series of patients. The authors are to be complemented for presenting a very clearly structured, executed, and described research study. The authors included exactly the same parameters in the CT-based CTO score that constitute the angiography-based "J-CTO Score" (a blunt proximal stump, calcification, tortuosity with at least one bend >45°, an occlusion length >20 mm, and a previously failed percutaneous coronary intervention attempt). The resulting scores were not identical for both methods: in 45% of all patients they were the same, whereas the CT score was lower than the angiographic score in 25% and higher than the angiography-based score in 30% of cases. Interestingly, the authors showed that CT was significantly superior to angiography to predict the likelihood both of 30-min wire crossing and of final recanalization success.

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Several details of the reported study merit mentioning: 1) the overall success rate was high (more than 80%), but with a median J-CTO score of 1, the sample included quite a high number of relatively noncomplex CTO lesions; 2) average occlusion length was significantly shorter in CT than in invasive angiography (11.7 mm vs. 15.0 mm), but because both were <20 mm, the contribution of occlusion length to the J-CTO score was the same for both methods; and 3) the most important detail concerns the classification of "calcium." In angiography, any visible calcium contributed to the J-CTO score while in CT, calcium was coded as "positive" if it covered >50% of the overall vessel-cross-section in any segment of the occlusion. All the same, given the poor sensitivity of angiography to identify calcium deposits, calcification was coded "positive" by CT in 27% of cases as opposed to 12% of cases in angiography. Together with lesion length, calcium was the most important item to predict recanalization success so that the analysis of calcium may be of particular importance when analyzing CT before an attempted CTO recanalization. Potentially, further refinements may be possible by varying the definition of positive calcium in CT—for example, a completely calcified cross-section may be an even stronger predictor of recanalization failure than coverage of 50% of the vessel area.

The ability of CT to predict revascularization success is "nice to have," but where do we go from here? It seems fair to state that what we currently know does not constitute a "game changer" in the field of CTO recanalization. While CT is routinely used in many centers before CTO recanalization is attempted, it is unknown whether a relevant number of CTO procedures are cancelled because of a "hostile CTA" (in fact, given the prognostic importance of CTO lesions, it is unlikely). To fully exploit the level of anatomic detail CT can provide, CTA results should be factored into the decision-making process in a more complex way, and the scientific community should develop, evaluate and validate such strategies. As an example, CT may additionally provide information on the size of the perfused territory distal to an occlusion and the degree of benefit that can be obtained by reopening an occluded artery. Also, it is conceivable that CT may influence the technical approach a CTO operator will choose in a number of ways—the selection of wires, the time point of switching from an antegrade to a retrograde approach (e.g., rather quickly in the presence of a severely calcified entry), the optimal angiographic angulation for orthogonal visualization of the occluded segment, and others. Some more or less direct attempts to evaluate how CT may more deeply influence CTO revascularization strategy have already been made. As examples, Sugaya et al. (20) showed that CT can identify coronary collaterals that are suitable for the retrograde approach, whereas image fusion of CT and angiography have been proposed both by Ghoshhajra et al. (21) and Opolski et al. (22). In a study by Rolf et al. (23), it has in fact been shown that CTO recanalization success rate was higher in 25 patients who underwent the procedure with an available CT angiogram (88%) as opposed to 25 patients without available CT (24%; $p = 0.03$), but cohorts were consecutive and patients were propensity matched rather than randomized, so that the results need to be interpreted with a substantial amount of caution.

Yet, the tremendous ability of CT to provide a high amount of unique information—beyond the mere estimate of how likely the intervention will be successful—should be explored in appropriately designed outcome trials (24). This includes the way in which CT can and should influence technical strategy, as well as the question of whether performing coronary CTA—which comes at the cost of

radiation exposure and iodinated contrast injection—influences the outcome in patients with chronic total occlusions. Given the results of trials such as that presented here by Fujino et al. (19) and many others published recently, it is likely that coronary CTA will meaningfully contribute to the management of patients with chronic coronary occlusions. However, definite proof is missing and the imaging and interventional communities should join forces to provide the necessary data.

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