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CMR Guidance for Recanalization of Coronary Chronic Total Occlusion

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ABSTRACT

OBJECTIVES This study explored whether cardiac magnetic resonance (CMR) could help select patients who could benefit from revascularization by identifying inducible myocardial ischemia and viability in the perfusion territory of the artery with chronic total occlusion (CTO).

BACKGROUND The benefit of revascularization using percutaneous coronary intervention (PCI) in CTO is controversial. CMR offers incomparable left ventricular (LV) systolic function assessment in addition to potent ischemic burden quantification and reliable myocardial viability analysis. Whether CMR guided CTO revascularization would be helpful to such patients has not yet been explored fully.

METHODS A prospective study of 50 consecutive CTO patients was conducted. Of 50 patients undergoing baseline stress CMR, 32 (64%) were selected for recanalization based on the presence of significant inducible perfusion deficit and myocardial viability within the CTO arterial territory. Patients were rescanned 3 months after successful CTO recanalization.

RESULTS At baseline, myocardial perfusion reserve (MPR) in the CTO territory was significantly reduced compared with the remote region (1.8 ± 0.72 vs. 2.2 ± 0.7; $p = 0.01$). MPR in the CTO region improved significantly after PCI (to 2.3 ± 0.9; $p = 0.02$ vs. baseline) with complete or near-complete resolution of CTO related perfusion defect in 90% of patients. Remote territory MPR was unchanged after PCI (2.5 ± 1.2; $p =$ NS vs. baseline). The LV ejection fraction increased from 63 ± 13% to 67 ± 12% ($p < 0.0001$) and end-systolic volume decreased from 65 ± 38 to 56 ± 38 ml ($p < 0.001$) 3 months after CTO PCI. Importantly, despite minimal post-procedural infarction due to distal embolization and side branch occlusion in 8 of 32 patients (25%), the total Seattle Angina Questionnaire score improved from a median of 54 (range 45 to 74) at baseline to 89 (range 77 to 98) after CTO recanalization ($p < 0.0001$).

CONCLUSIONS In this small group of patients showing CMR evidence of significant myocardial inducible perfusion defect and viability, CTO recanalization reduces ischemic burden, favors reverse remodeling, and ameliorates quality of life. (J Am Coll Cardiol Img 2016;9:547–56) © 2016 by the American College of Cardiology Foundation.

One or more arteries with chronic total occlusion (CTO) are identified in approximately one-third of diagnostic coronary angiograms in patients with known or suspected coronary artery disease (1,2). The benefits of PCI of a CTO are controversial for 3 main reasons: first, PCI of a CTO is technically challenging for the interventional cardiologist, with a lower success rate than achieved in other

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ABBREVIATIONS AND ACRONYMS

CMR = cardiac magnetic resonance

CTO = chronic total occlusion

EF = ejection fraction

ESV = end-systolic volume

LV = left ventricle/ventricular

LVEF = left ventricular ejection fraction

MI = myocardial infarction

MPR = myocardial perfusion reserve

PCI = percutaneous coronary intervention

SAQ = Seattle Angina Questionnaire

coronary lesions; second, OAT (Occluded Artery Trial) demonstrated a lack of benefit of PCI versus medical therapy in patients with an occluded infarct-related artery (3). However, these results cannot be widely applied to patients with CTO (occlusion duration of ≥3 months) because the OAT patient cohort presented with an occluded infarct-related coronary artery 3 to 28 days after acute myocardial infarction (MI), and PCI was not guided by the presence of residual myocardial viability and ischemia; third, the procedure can last several hours with significant radiation exposure, contrast dose, and cost. Selection criteria aimed at identifying patients who can benefit from PCI of CTO have not yet been proposed. Cardiac magnetic resonance (CMR) is a high-resolution noninvasive imaging technique that can assess regional and global left ventricular (LV) function, and detect the presence and the extent of infarction and ischemic burden (4). We therefore hypothesized that CMR could help in selecting patients suitable for CTO PCI.

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METHODS

STUDY DESIGN AND POPULATION. This single-center, prospective study included patients with a CTO considered suitable for recanalization after coronary angiography. CTO was defined as the presence of Thrombolysis In Myocardial Infarction (TIMI) flow grade 0 within the occluded artery with an estimated occlusion duration of ≥3 months, as suggested in the EuroCTO Club consensus document (5). CMR was performed 1 month before intervention and 3 months after recanalization. The CMR criteria for proceeding to revascularization were: 1) a majority of the segments in the CTO territory had <75% transmural extent of infarction by late gadolinium enhancement (LGE); and 2) an inducible perfusion defect was present in the CTO territory. Myocardial segments were assigned to coronary arteries as described in the American Heart Association (AHA) 17 segment model, with 7 segments for the left anterior descending artery, 5 for the right coronary artery, and 5 for the left circumflex artery (6). If the left circumflex artery was dominant, 2 inferior segments were reassigned from the right coronary artery to the left circumflex artery. Of the 52 patients initially recruited, 32 completed the study. The patient flow in the study is summarized in **Figure 1**. Exclusion criteria were: 1) significant other cardiac disease; 2) estimated glomerular filtration rate of <30 ml/min; 3) contraindications to CMR (e.g., claustrophobia, pacemaker, implantable cardioverter defibrillator, cerebral clips); and 4) contraindication to adenosine (e.g., severe asthma, greater than first-degree heart block). All participants gave written informed consent and the study was approved by the local ethics committee.

CARDIAC MAGNETIC RESONANCE. Image acquisition. CMR was performed in a 1.5-T scanner (Avanto, Siemens, Erlangen, Germany) with a dedicated cardiac 8-channel phased array receiver surface coil. Cine images were obtained with a steady-state free-precession sequence in 2 long-axis and multiple contiguous short-axis views encompassing the LV from base to apex. Typical image parameters were: echo time, 1.6 ms; repetition time, 3.2 ms; time per cine frame, 51 ms; α, 60°; matrix, 256 × 256; slice thickness, 8 mm; and gap, 2 mm. First-pass stress perfusion imaging was performed using a 3-slice (basal, mid-cavity, and apical views) hybrid-EPI sequence with T-SENSE (repetition time, 5.8 ms; inversion time, 110 to 140 ms; field of view, 360 × 270 mm; voxel size, 2.8 × 2.8 × 10 mm) over 50 consecutive cardiac cycles. The images were acquired after 4 min of 140 μg/kg/min adenosine infusion and after the injection of 0.1 mmol/kg of gadopentetic acid. LGE images were acquired 10 to 15 min after gadolinium injection in long- and short-axis planes, using a segmented inversion recovery gradient echo sequence (repetition time, 600 ms; echo time, 3.8 ms; α, 25°, slice thickness, 8 mm; gap, 2 mm; typical pixel size, 1.7 × 1.4 mm) (7). The inversion time was progressively optimized and adjusted to adequately null normal myocardium (typical values 320 to 440 ms). Cine and LGE images were acquired at the same long and short axis slice position. Finally, first-pass rest perfusion images were acquired >20 min after stress perfusion imaging.

Image analysis. Image analysis was performed by an experienced operator blinded to the clinical and angiographic data, using semiautomated software (CMRtools, Cardiovascular Imaging Solutions, London, United Kingdom). Quantitative LV volumes, left ventricular ejection fraction (LVEF), and LV mass were calculated from the short axis views excluding the papillary muscles. The images were assessed according to the AHA/American College of Cardiology 17-segment model (8). For each segment, wall motion was scored as 0 (normal), 1 (mildly hypokinetic), 2 (severely hypokinetic), 3 (akinetic), or 4 (dyskinetic). Infarcted myocardial mass was calculated from the LGE images. Myocardial regions were considered infarcted if the signal intensity was >5 standard deviations above that of the remote myocardium (8). Myocardial perfusion reserve (MPR) was calculated in all CTO and remote myocardial territories as