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CLINICAL RESEARCH

CORONARY

Noninvasive Discrimination of Coronary Chronic Total Occlusion and Subtotal Occlusion by Coronary Computed Tomography Angiography

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ABSTRACT

OBJECTIVES The aim of this study was to investigate whether noninvasive discrimination of chronic total occlusion (CTO), a complete interruption of coronary artery flow, and subtotal occlusion (STO), a functional total occlusion, is feasible using coronary computed tomography angiography (CTA).

BACKGROUND CTO and STO may be different in pathophysiology and clinical treatment strategy.

METHODS We included 486 consecutive patients (median age 63 years, 82% male) who showed a total of 553 completely occluded coronary arteries in coronary CTA. The length of occlusion, side branches, shape of proximal stump, and collateral vessels were measured as anatomical findings. Transluminal attenuation gradient, which reflects intraluminal contrast kinetics and functional extent of collateral flow, was measured as a physiological surrogate. All patients were followed by invasive coronary angiography.

RESULTS Coronary arteries with CTO showed longer occlusion length (cutoff ≥15 mm), higher distal transluminal attenuation gradient (cutoff ≥−0.9 Hounsfield units [HU]/10 mm), more frequent side branches, blunted stump, cross-sectional calcification ≥50%, and collateral vessels compared with arteries with STO ($p < 0.001$, all). The combination of these findings could distinguish CTO from STO (c-statistics = 0.88 [95% confidence interval: 0.94 to 0.90], sensitivity 83%, specificity 77%, positive predictive value 55%, negative predictive value 93%; $p < 0.001$). Percutaneous coronary intervention (PCI) was attempted in 342 arteries and was successful in 279 arteries (82%). The computed tomography findings could predict the unsuccessful PCI (c-statistics = 0.70 [95% confidence interval: 0.65 to 0.75], sensitivity 63%, specificity 73%, positive predictive value 91%, negative predictive value 31%; $p < 0.001$).

CONCLUSIONS Noninvasive coronary CTA could discern CTO from STO, and also could predict the success of attempted PCI. (J Am Coll Cardiol Intv 2015;8:1143–53) © 2015 by the American College of Cardiology Foundation.

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ABBREVIATIONS AND ACRONYMS

CAG = coronary angiography

CTA = computed tomography angiography

CTO = chronic total occlusion

ECG = electrocardiography

PCI = percutaneous coronary intervention

STO = subtotal occlusion

TAG = transluminal attenuation gradient

Chronic total occlusion (CTO), a complete interruption of coronary arterial flow caused by plaque obstructing arterial lumen, is not uncommon and is found in 18% to 31% of invasive coronary angiography (CAG) cases (1,2). CTO is known to be frequently accompanied by microchannels smaller than the spatial resolution of angiography, which corresponds to less than complete luminal occlusion histologically (3). Therefore, CTO and subtotal occlusion (STO), which is a "functional" total occlusion or a slow contrast penetration through the occluded segment, are not distinguished strictly in clinical practice (4–6).

Discrimination of CTO from STO before cardiac catheterization is of clinical value because percutaneous coronary intervention (PCI) is attempted less frequently for CTO lesions and has a higher rate of unsuccessful procedures and late restenosis compared with non-CTO lesions (7,8). However, noninvasive discrimination of CTO from STO remains a challenge, because both show complete interruption of contrast-enhanced arterial lumen in anatomical imaging tests and myocardial ischemia in functional imaging tests (9–11).

The pathogenesis of CTO is presumed to be thrombotic occlusion in the context of nonfatal myocardial infarction (MI) followed by progression of organized thrombus filling up to the ostium of side branches. Organized thrombus is replaced by collagen-rich fibrous tissue or calcification. Collateral vessel develops to supply myocardium subtended by occluded vessels (12–14). The angiographic characteristics of CTO would be summarized by the long totally occluded segment between adjacent side branches, blunt proximal stump, and collateral vessels flowing into the distal segment or side branches (**Figure 1**).

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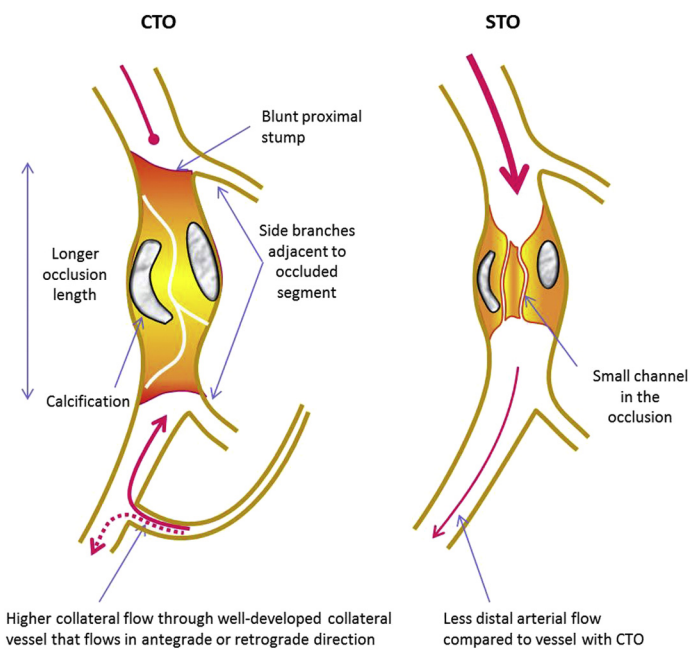
We reasoned that these anatomical and physiological findings can be identified by coronary computed tomography angiography (CTA), a noninvasive modality that enables investigation of both the arterial lumen and the obstructive plaque. It would be helpful to the decision of the revascularization strategy and the prediction of PCI procedural success. We investigated anatomical and physiological findings in the coronary CTA of patients with totally occluded coronary arteries and compared it with the invasive CAG and the result of PCI.

FIGURE 1 The Anatomical and Physiological Differences Between CTO and STO



Intracoronary thrombotic occlusion in the context of nonfatal myocardial infarction is followed by progression of organized thrombi, which is replaced later with proteoglycan and fibrous tissue. Collateral vessel develops and flows into the distal artery or side branch. Blunt proximal stump is formed by the progression of tissue extending up to the side branch ostium. Therefore, chronic total occlusion (CTO) is typically characterized by a long, totally occluded segment between adjacent side branches, blunt proximal stump, and collateral vessels flowing into the distal vessel or side branch. The **white line** in the CTO plaque denotes microchannels or loose connective tissue, which are not visible by computed tomographic angiography. STO = subtotal occlusion.

METHODS

PATIENTS. From June 2006 to November 2013, we consecutively screened 578 patients who showed at least 1 totally occluded coronary artery by clinically indicated coronary CTA and were validated by subsequent diagnostic CAG within 12 weeks (median 14 days). Patients with recent MI within 90 days by the computed tomography acquisition time were not enrolled, nor were those with uncompensated heart failure, left main disease, creatinine ≥2.0 mg/dl, or estimated glomerular filtration rate ≤30 ml/min. Patients with an occlusion in the small branch, vasospastic angina, and poor image quality were excluded. Patients who underwent bypass surgery or PCI for occluded arteries were also excluded due to the potential confounding on the coronary flow physiology. The remaining 486 patients comprised the study cohort (**Figure 2**). Our prior studies enrolled