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Utility of adjunctive modalities in Coronary chronic total occlusion intervention

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ABSTRACT

Coronary chronic total occlusion (CTO) intervention remains one of the most challenging domains in interventional cardiology. Due to the technical challenges involved and potential procedural complications, CTO percutaneous coronary intervention (PCI) attempt and success rates remain less than standard PCI. However, the use of several adjunctive tools such as intravascular ultrasound, optical coherence tomography, rotational atherectomy, orbital atherectomy, excimer laser coronary atherectomy and percutaneous left ventricular assist device may contribute to improved CTO PCI success rates or provide better hemodynamic assessment of CTO lesion (i.e., using fractional flow reserve). In this review we present the current literature describing the utility and efficacy of these adjunctive modalities in CTO intervention.

Contents

1. Introduction

Coronary CTO, commonly seen in patients with chronic stable angina, is characterized by the presence of atherosclerotic plaque resulting in complete or near complete occlusion of coronary artery for greater than 3 months duration.[1,2] Although over time the myocardial territory supplied by CTO tends to form well developed collaterals from a donor artery, the potential for myocardial ischemia still persists. CTO treatment is primarily aimed at improving angina symptoms, inducible myocardial ischemia, left ventricular function, quality of life and possibly overall survival.[3,4,5] Often, a hard cap composed of dense fibrous tissue and calcium is present at both ends of CTO plaque with a soft portion in the middle, which makes guidewire crossing and subsequent balloon inflation more difficult.[6] The difficulty and complexity of recanalizing renders lower success rates for CTO PCI than PCI of subtotal stenosis. CTO PCI results in greater procedural cost due to incremental equipment use, increased radiation exposure to both operator and patient due to prolonged fluoroscopic and procedural times, and increased utilization of catheterization laboratory staff compared to less complex interventions.[1–5]

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For patients, undergoing complex CTO PCI increases the risk of coronary artery perforation, collateral vessel loss, higher radiation exposure and contrast induced nephropathy.[7] In addition, CTO PCI attempts are higher among high volume operators (>200 PCIs per year) compared to low or intermediate volume (<200 PCIs per year) operators.[4] Brilakis et al. using the data from National Cardiovascular Data Registry (NCDR) between July 2009 to March 2013 reported that CTO PCI represented only 3.8% of total 594,510 PCI cases for stable coronary artery disease.[8] In addition, patients undergoing CTO PCI had lower procedural success rates (59% vs 96%) and higher in-hospital major adverse cardiac event rates (MACE, 1.6% vs 0.8%) compared with non-CTO PCI patients. Thus, procedural complexity, economic disincentives, operator inexperience, failure of medical management, and potential risks associated with CTO PCI result in most cases referred for coronary artery bypass surgery. However, some studies have shown improved long-term survival rates for successful CTO PCI compared with failed CTO or non-CTO PCI,[9,10] thereby emphasizing the need for more aggressive CTO revascularization in the appropriate patient subset. In the midst of emergence of novel guidewires and CTO crossing tools,[11] advances in adjunctive imaging and debulking modalities in the era of drug eluting stents have contributed to increased CTO PCI success rates and have made percutaneous CTO intervention more amenable. In this review, we will describe such adjunctive modalities and the current literature evidence supporting their utility in CTO PCI.

1.1. Fractional flow reserve (FFR)

FFR, a measure of intracoronary physiology, is a lesion specific index used to determine the functional importance of coronary stenosis. FFR is the ratio of mean distal coronary pressure to mean aortic pressure in the setting of maximum hyperemia. FFR of $\leq$0.8 is currently recommended as a threshold for invasive determination of myocardial ischemia.[12,13] The information on myocardial ischemia obtained from FFR is more specific than myocardial perfusion studies, because every possible diseased artery could be analyzed individually using FFR. In FFR verses angiography for multivessel evaluation (FAME) study among patients with multivessel disease, FFR guided (Fig. 1) PCI resulted in reduced mortality and myocardial infarction rates compared with standard angiography guided PCI.[14] In addition, compared to non-FFR guided PCI,

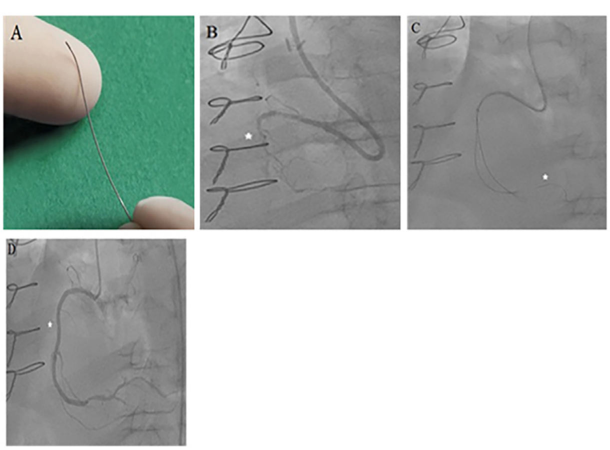

Fig. 1. Device and case images of coronary fractional flow reserve measurement (FFR). A. FloWire Doppler Guide Wire for FFR measurement (Image provided courtesy of Volcano Corporation, San Diego, CA); B. Case image demonstrating a proximal right coronary artery (RCA) chronic total occlusion (CTO) (*); C. pre-intervention FFR wire positioning in the distal RCA (*) through a Corsair catheter after crossing the CTO with pre-FFR of 0.45; D. and final post-intervention image of revascularized RCA CTO (*) for post-FFR of 0.85.

FFR guided PCI resulted in fewer stents and procedural contrast volume use, similar health related quality of life and significant decrease in 2-year major adverse cardiac events.[15] Although FFR use has been increasingly recommended, especially in multivessel PCI, its utility in CTO evaluation is not well-known. Often, the presence of collaterals from the donor artery in the CTO myocardial territory renders operators less inclined towards the need for CTO revascularization. Sachdeva et al., in a study of 100 patients (50 each in CTO and non-CTO groups), reported that in symptomatic patients with CTO, FFR use helps identify ischemic zones within the CTO territory even in the presence of well-developed coronary collaterals and regional ventricular dysfunction. The severity of ischemia was greater in CTO territory compared with non-CTO regions, and 78% of patients with CTO had ischemia at rest, i.e., FFR $\leq$ 0.8. Pre-PCI FFR was lower in the CTO group compared with non-CTO group (0.45 ± 0.15 vs 0.58 ± 0.17), but was similar post-PCI. Post-PCI, the FFR in the CTO ischemic zone reverted back to normal. Interestingly, the rate of all-cause mortality, target lesion revascularization and angina were similar among CTO-PCI and non-CTO PCI groups.[16] Varghese et al., in a prospective study of 50 CTO lesions with well-developed collaterals, demonstrated significant improvement in FFR post-PCI. The pre-PCI FFR (median 0.54, range 0.27–0.83) normalized in most cases post-PCI (median 0.9, range 0.61–1.12).[17] These findings suggest that in patients with complex coronary lesions, using FFR could help identify ischemia in the CTO territory which could be normalized post-PCI. Furthermore, the above findings also suggest that the mere presence of robust collaterals and absence of wall motion abnormality alone do not indicate absence of ischemia in the corresponding CTO territory.

The CTO myocardial territory is dependent on the donor artery blood flow for tissue perfusion. In multivessel disease involving the donor artery, using FFR may help determine the need for donor artery revascularization. In patients with CTO and intermediate donor artery stenosis, FFR in the donor artery is frequently abnormal and reverts to normal after successful CTO PCI.[18] Therefore, recanalizing CTO and resultant normal FFR in the donor artery would obviate the need for donor artery PCI or multivessel bypass surgery.[19] However, the change in donor vessel FFR after CTO PCI may be related to lesion severity in the donor vessel, and any improvement in very low pre-PCI FFR associated with severe stenotic lesions may not be enough to cross the $\leq$ 0.8 treatment threshold.[20] FFR, therefore, remains a useful tool in the setting of multivessel disease with concomitant CTO to evaluate donor artery lesion physiology and determine the need for donor artery and even CTO lesion revascularization.

1.2. Intra-vascular ultrasound (IVUS)

IVUS has been a valuable adjunct to coronary angiography due to its ability to provide direct high resolution (100–150 μm) view of vessel wall and to precisely allow measurements of lumen area, plaque size and composition.[12,21,22] In non-CTO interventions, IVUS use during stent placement has been associated with lower rates of restenosis, repeat revascularization and major adverse cardiac events.[21,23] IVUS is particularly useful in complex interventions involving ostial and bifurcation lesions and segments with multiple overlapping vessels and branch points[21−−23]. Contrary to conventional angiography, IVUS provides a cross-sectional assessment of CTO plaque morphology, size and distribution, and provides real time images of the exact location of guidewire within the atherosclerotic plaque to help discriminate the true lumen from a false lumen.[12,21,22] In addition, IVUS can identify intramural hematomas resulting from guidewire penetration in the medial space during recanalization.[24]

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