Coronary chronic total occlusions (CTO) are common in contemporary practice with a prevalence of 1 in 5 cases at the time of diagnostic coronary angiography.\(^1\) A higher prevalence of 52% has been previously reported in a veteran population without prior coronary artery bypass undergoing coronary angiography.\(^2\) A CTO is defined as a 100% occlusion in a coronary artery with TIMI 0 flow (no antegrade flow beyond point of occlusion) of at least 3 months duration. Chronic coronary occlusions have generally been managed by medical therapy or surgical revascularization. Percutaneous coronary intervention (PCI) for CTO remains controversial as no randomized trial of CTO PCI versus medical therapy or coronary bypass has been performed to determine long-term survival after attempted CTO PCI. Due to the need for additional data for CTO PCI, appropriate use criteria (AUC) for percutaneous coronary intervention (PCI) downgrade the indications for PCI of CTO relative to non-CTO vessels. Critics of CTO revascularization generally perceive that symptoms are easily controlled with medications and CTO vessels have no impact on quality of life or survival. However, it is becoming increasingly evident that there are patients who continue to experience lifestyle limiting symptoms, despite optimal medical therapy for angina. In addition, observational data repeatedly suggest that a mortality benefit is provided by full revascularization.\(^3,6\) Greater recognition of the benefits of comprehensive revascularization for complex coronary artery disease (CAD) in conjunction with increasing success rates of CTO recanalization have together transformed CTO management into a vibrant new frontier in coronary artery disease therapies (Figure 1).

Consideration for CTO revascularization occurs in light of two important factors: 1) whether revascularization will provide the patient with quality of life benefit, improved survival, or both; and 2) which modality will provide the most durable result at the lowest up-front risk. The following review will attempt to provide a brief synopsis of data relevant to these factors and will highlight advances in technology that have made the emphasis on CTO PCI possible. We will review the data in the context of three broad questions: 1) Do CTOs contribute to ischemia despite collaterals filling the distal vessel? 2) Do CTOs cause symptoms? 3) Can CTOs be opened with high success and at an acceptable level of risk using percutaneous technology?

**Do CTOs contribute to ischemia despite collaterals filling the distal vessel?**

An elegant study to answer this question was performed by Sachdeva et al in which Fractional Flow Reserve (FFR) was performed of CTO vessels. FFR is a modality which measures pressure differences across a coronary stenosis to determine the likelihood that the stenosis impedes oxygen delivery to the myocardium. In this study, it was found that resting ischemia was present in 78% of CTO patients, and nearly every CTO crossed was hemodynamically significant despite collateral filling of the distal vessel.\(^7\) This is important as the field of CTO recanalization matures and becomes recognized by bodies formulating AUC criteria. The AUC criteria emphasize ischemic burden in selecting patients for whom benefit would be expected from revascularization. Data using nuclear imaging studies to quantify ischemia or at-risk myocardium suggest survival benefit from revascularization in patients with ≥10% ischemic myocardium.\(^8\) This has influenced contemporary CTO practice when selecting candidates for CTO recanalization.

**Potential Benefits of CTO Recanalization**

- Improve symptoms of angina and dyspnea
- Decrease need for coronary artery bypass surgery
- Decrease the need for anti-anginal medications
- Improve survival compared to that of patients with incomplete revascularization
- Improve left ventricular function
- Decrease substrate for arrhythmias
- Improve tolerance of future acute coronary syndrome events

**Figure 1**

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**Critics of CTO revascularization generally perceive that symptoms are easily controlled with medications and CTO vessels have no impact on quality of life or survival. However, it is becoming increasingly evident that there are patients who continue to experience lifestyle limiting symptoms, despite optimal medical therapy for angina.**
Do CTOs cause symptoms?
Observational studies suggest that classic anginal chest pain may be less prominent with CTOs than exertional shortness of breath. Physicians may underestimate symptoms in CTO patients and may underestimate the effect of those symptoms on quality of life (QOL). Several studies have reported significant improvement in QOL metrics following successful CTO recanalization. A recent multi-center prospective cohort study evaluated QOL at 1 year after one of four treatment options: medical therapy only, PCI to non-CTO, PCI to CTO, and coronary artery bypass graft (CABG). The medical therapy group had no improvement in QOL. The CTO revascularization groups (either PCI or CABG) had significant improvement in QOL metrics including angina frequency and disease perception scores.

Can CTOs be opened with high success and at an acceptable level of risk using percutaneous technology?
The answer to the question whether CTOs can be opened reliably by percutaneous techniques has evolved rapidly since January 2011. At that time, several high-volume North American CTO operators convened in Bellingham, Washington, to develop a consensus approach to CTO crossing. The “Hybrid CTO PCI algorithm” developed out of that meeting, and has placed a focus on teaching effective and efficient opening of CTO vessels. The hybrid algorithm emphasizes that anatomy dictates strategy in order to achieve CTO crossing with the least radiation and contrast exposure to the patient, and the least lab equipment utilization possible. In addition, the algorithm has emphasized comfort working in the sub-intimal space which was once considered a reason to abort a procedure. A CTO-specific system developed by BridgePoint Medical has embraced the sub-intimal space as a means to quickly and safely cross CTOs. This system includes a blunt tip catheter (CrossBoss™) and a specialized re-entry balloon (StingRay™) to perform antegrade dissection and re-entry of the CTO (Figure 2). In conjunction with an emphasis on efficiency, the hybrid algorithm for CTO recanalization has resulted in success rates for recanalization of approximately 90% compared to previous success rates of 70 to 75%. CTO operators are also performing the procedures safely. In a European registry of highly-experienced operators, the risk of major adverse events including death, stroke, and need for urgent CABG was less than 1%. The risk of a peri-procedural MI was 3.1%.

Summary
In counseling patients, consideration should be given to the potential for improved quality of life by decreasing angina class, decreasing the need for CABG, and decreasing the need for anti-anginal medications. There are also data to support improved left ventricular function with CTO recanalization, provided the territory is viable. As mentioned, recent data suggest a mortality benefit with complete revascularization, including percutaneous management of CTO. Also, CTO recanalization may decrease the substrate for arrhythmic events and protect against future ACS events. Prospective and randomized data will be available to better define the value of CTO PCI in the next few years. EURO-CTO (European Study on the Utilization of Revascularization vs Optimal Medical Therapy for the Treatment of Chronic Total Coronary Occlusions) is a multicenter trial to evaluate 1- and 3-year outcomes in patients randomized to revascularization or medical therapy. In addition, OPEN CTO (Outcomes, Patient health status, and Efficiency IN Chronic Total Occlusion hybrid procedures) is a North American registry at 10 sites enrolling 1,000 patients to evaluate the safety and impact on patient health status of CTO PCI.

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The VHVI Complex Coronary Revascularization and CTO program has been built to maximize success and value for patients and referring physicians. Our success rates for CTO recanalization are on par with national centers of excellence in complex CTO work (Figures 3A-D). A collaborative environment and a true “heart team approach” have been fostered to bring the best of PCI and coronary bypass for the benefit of patient outcomes.

References: