

REVIEW

Update on Chronic Total Occlusion Percutaneous Coronary Intervention

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Keywords

[Chronic Total Occlusion Percutaneous Coronary Intervention](#)

April 2023

ISSN 1557-2501

Index J INVASIVE CARDIOL 2023;35(4):E194-E204. Epub 2023 February 24.

Abstract

Background. Percutaneous coronary intervention (PCI) of chronic total occlusion (CTO) lesions can be challenging to perform. In the present review we summarize recent publications in this rapidly evolving area grouped according to indications, outcomes, technique, and complications.

J INVASIVE CARDIOL 2023;35(4):E194-E204. Epub 2023 February 24.

Key words: chronic total occlusion, percutaneous coronary intervention

Over the past year, important advances have been made in the field of chronic total occlusion (CTO) percutaneous coronary intervention (PCI). This manuscript reviews articles on CTO-PCI, published between November 2021 and November 2022, grouped according to indications, outcomes, technique, and complications.

Indications

The principal indication for CTO-PCI is to improve anginal symptoms.¹ A 7-component score named the OPEN-AP (OPEN-CTO Angina Prediction) score was developed using the Outcomes, Patient Health Status, and Efficiency in Chronic Total Occlusion Hybrid Procedures (OPEN-CTO) registry, to predict angina improvement and residual angina after CTO-PCI.² The 7 variables included in the OPEN-AP score were: (1) baseline angina frequency; (2) baseline nitroglycerin use; (3) Rose Dyspnea Scale score ≥ 2 (shortness of breath when walking with others); (4) Patient Health Questionnaire-8 score ≥ 10 ; (5) number of antianginal medications; (6) indication for PCI (symptom/ischemia reduction or not); and (7) the presence of multiple CTO lesions. The final model had a C index of 0.78. Patients with severe anginal symptoms at baseline and lower OPEN-AP scores were more likely to have symptom improvement during follow-up.

Can CTO-PCI positively impact the perfusion of myocardium not supplied by the occluded vessel? de Winter et al showed significant absolute increase in both the hyperemic myocardial blood flow (hMBF) (from 2.29 ± 0.67 mL/min/g to 2.48 ± 0.75 mL/min/g; $P < .01$) and the coronary flow reserve (CFR) (from 2.48 ± 0.76 to 2.74 ± 0.85) of the remote myocardium after CTO intervention in 164 patients 3 months after successful CTO-PCI.³ The increases in hMBF ($\beta = 0.58$; 95% confidence interval [CI], 0.48-0.67; $P < .01$) and CFR ($\beta = 0.54$; 95% CI, 0.44-0.64; $P < .01$) in the CTO territory were independently associated with the absolute increase in perfusion in remote myocardial regions.

A study of 212 patients demonstrated that extensive ischemia reduction post CTO-PCI was associated with lower rates of all-cause death and non-fatal myocardial infarction (MI) during a median follow-up of 2.8 years.⁴ Patients with left ventricular ejection fraction (LVEF) $\leq 55\%$ (but not those with LVEF $> 55\%$) had a better prognosis if perfusion defect reduction (hazard ratio [HR], 0.15; 95% CI,

0.03-0.69; $P=.001$) or hMBF increase (HR, 0.18; 95% CI, 0.04-0.82; $P=.03$) were achieved. Therefore, the effect of CTO revascularization may be more pronounced in patients with reduced LVEF compared with CTO patients with preserved LV function.

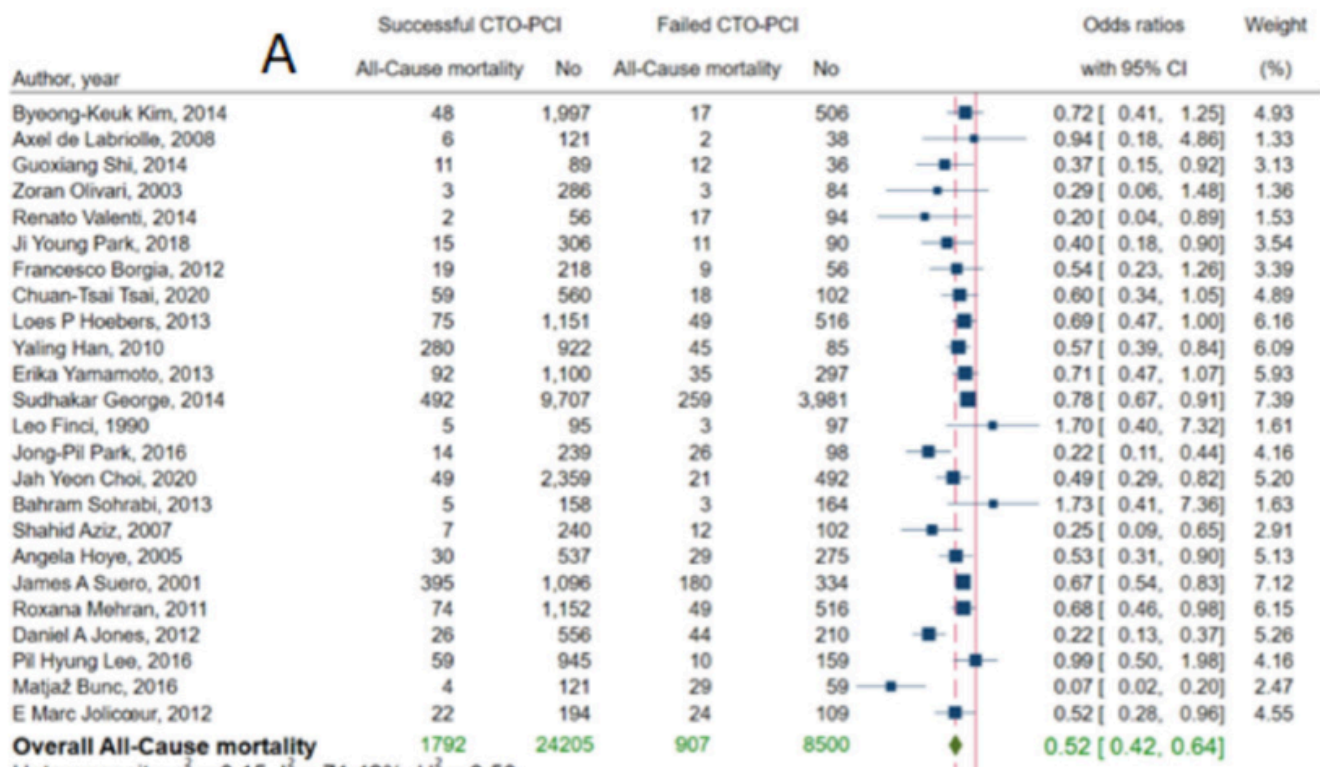
In a study of 622 patients with ischemic cardiomyopathy (ICM) and implantable cardioverter-defibrillators (ICDs),⁵ CTO patients who underwent PCI ($n = 113$), had fewer arrhythmic events (HR, 0.45; 95% CI, 0.29-0.71) and lower mortality (HR, 0.43; 95% CI, 0.22-0.85) compared with CTO patients who were treated medically ($n = 286$). Additionally, the long-term event rate of CTO-PCI patients was similar to that of ICM patients and ICD carriers without CTO ($n = 223$).

An analysis of the Prospective Global Registry for the Study of Chronic Total Occlusion Intervention (PROGRESS-CTO) compared primary to secondary retrograde approach for CTO lesion crossing.⁶ Patients in the primary retrograde group had better technical and procedural success rates compared with patients in the secondary retrograde group. The rates of in-hospital major adverse cardiac events were similar between the 2 groups.

Outcomes

Follow-up outcomes. The results of the 10-year follow-up of the Canadian Multicenter CTO Registry offer insights into the late clinical outcomes of CTO patients.⁷ Patients who underwent early (within 90 days) CTO revascularization (PCI or coronary artery bypass grafting [CABG]) had more favorable long-term outcomes, including all-cause mortality (22.7% [95% CI, 19.0-26.9] vs 36.6% [95% CI, 33.8-39.5]), subsequent revascularization (14.0% [95% CI, 11.0-17.4] vs 22.8% [95% CI, 20.4-25.3]), and acute coronary syndrome (ACS) hospitalization (10.0% [95% CI, 7.4-13.1] vs 16.6% [95% CI, 14.4-18.9]), compared with patients treated with medical therapy alone.

A meta-analysis of 58 publications on the outcomes of CTO-PCI⁸ divided published studies into 3 groups according to design. The first group included 33 observational studies of successful vs failed CTO-PCI and showed that successful CTO-PCI was associated with lower all-cause mortality (OR, 0.52; 95% CI, 0.42-0.64) (**Figure 1A**) and MACE rate (OR, 0.46; 95% CI, 0.37-0.58) during follow-up. The second group consisted of 19 studies that compared CTO-PCI vs no CTO-PCI and showed that CTO-PCI was associated with a lower all-cause mortality (OR, 0.38; 95% CI, 0.31-0.45) (**Figure 1B**) and MACE (OR, 0.57; 95% CI, 0.42-0.78) during follow-up. The third group included 6 randomized controlled trials (RCTs) comparing CTO-PCI vs no CTO-PCI and showed no significant difference in technical success and clinical outcomes between the 2 groups (**Figure 1C**). The latter finding could represent type II error given the limited RCTs performed to date, but observational studies are subject to selection bias.



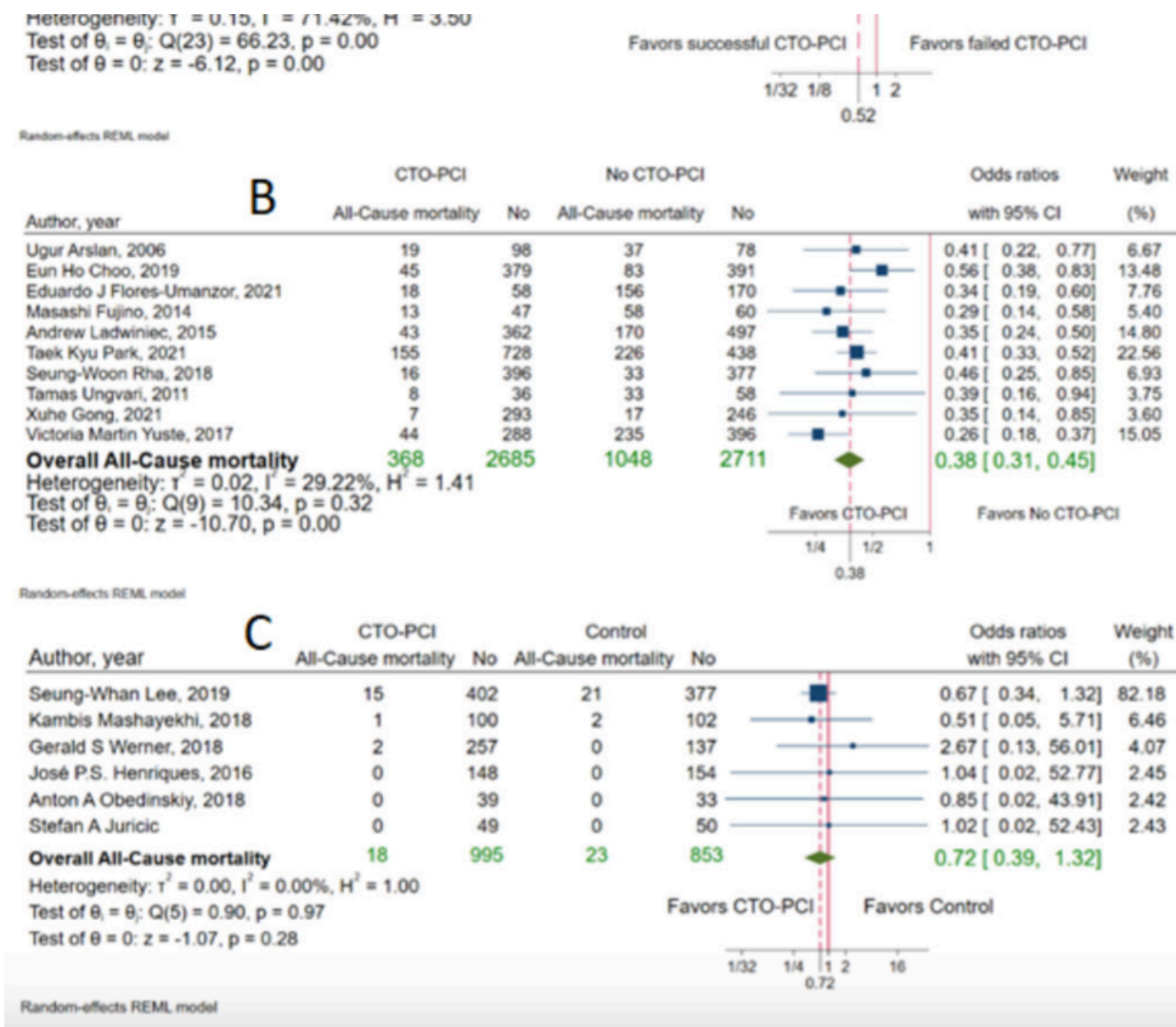


Figure 1. All-cause mortality after: (A) successful-failed CTO-PCI; (B) CTO-PCI vs no CTO-PCI (observational); (C) CTO-PCI vs no CTO PCI (randomized controlled trials). CTO = chronic total occlusion; PCI = percutaneous coronary intervention.

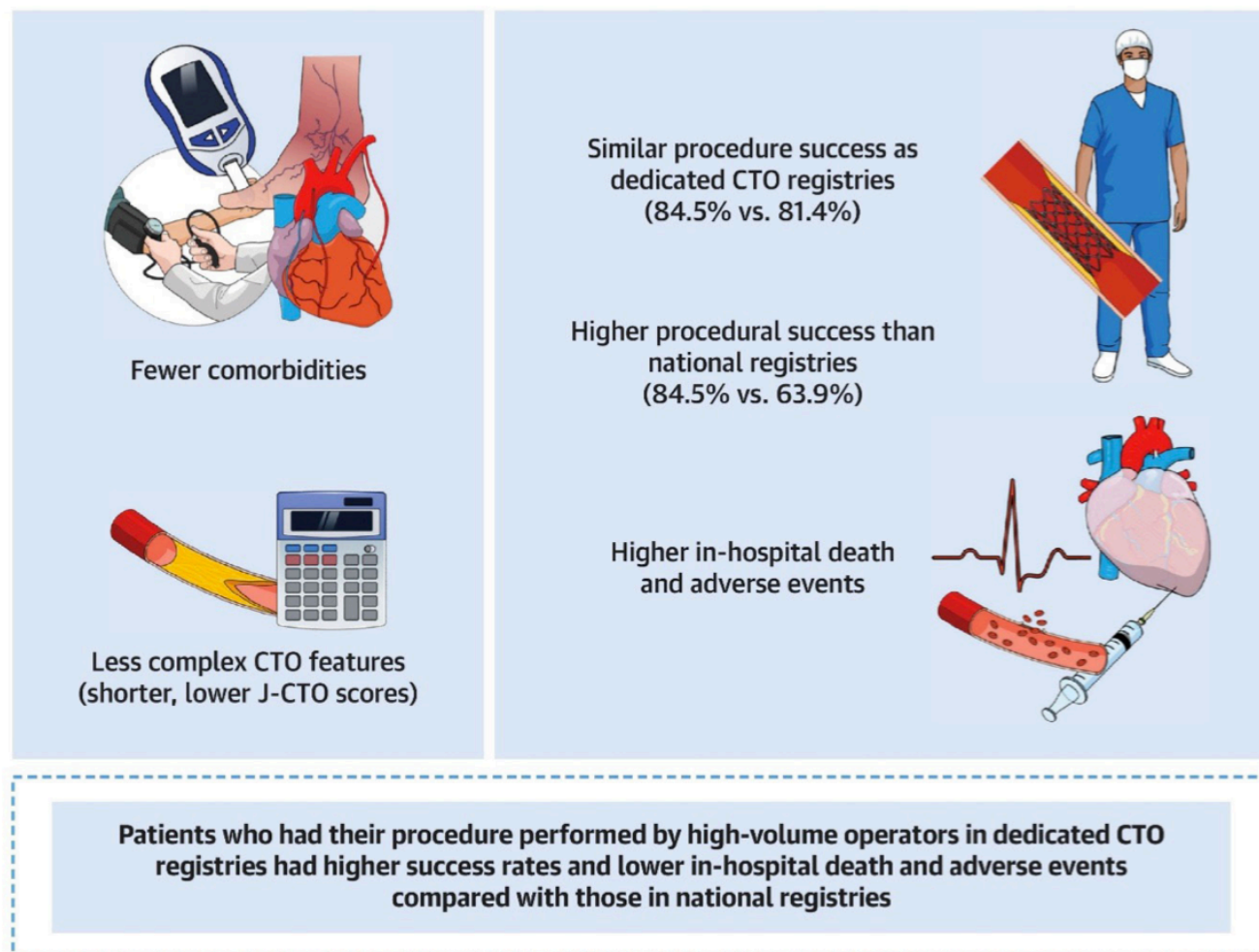
Megaly et al examined CTO-PCI follow-up outcomes between CTO-PCI registries and RCTs⁹ and showed that patients included in RCTs had lower risk profiles and less complex lesions compared with those in real-world registries. Specifically, RCT patients had fewer comorbidities, such as diabetes, hypertension, previous MI, and prior CABG, while their occlusion lengths were shorter (29.6 ± 19.7 mm vs 32.6 ± 23.0 mm, a relative difference of 9.2%) and their Japan–Chronic Total Occlusion (J-CTO) scores were lower (2.0 ± 1.1 vs 2.3 ± 1.2 , a relative difference of 13%) compared with patients enrolled in dedicated CTO registries (Figure 2).

CENTRAL ILLUSTRATION: Summary of the Study Results

Comparative Analysis of Chronic Total Occlusion Patients in Randomized Trials and Real-World Registries

6 RCTs (n = 1,047) vs. 10 dedicated CTO registries (n = 76,467), 5 national registries (n = 110,349)

RCT Patients Compared With Real-World Registries



Megaly M, et al. J Am Coll Cardiol Interv. 2022;15(14):1441.

Figure 2. Summary of the comparison between real-world registries and randomized controlled trials (RCTs) of chronic total occlusion (CTO) percutaneous coronary intervention. J-CTO = Japan Chronic Total Occlusion score. Image reproduced with permission from JACC Cardiovascular Interventions and Megaly et al.

Impact of patient characteristics. Three publications (2 retrospective studies and 1 meta-analysis) examined the impact of sex on the outcomes of CTO-PCI.¹⁰⁻¹² All 3 demonstrated higher procedural success in women. The 2 retrospective studies also showed higher procedural complication rates in women compared with men, while the meta-analysis did not find a significant difference in in-hospital and long-term (≥ 6 months) mortality between the 2 groups. Race was also assessed as a potential factor affecting patient outcomes in CTO-PCI and the results indicated that, while there was no difference in technical success between races, in-hospital MACE may be more frequent in Asians (4.2%) and Caucasians (2.2%), compared with Hispanics (1.4%) and Blacks (0.2%).¹³

Prior CABG. Prior CABG was associated with more complex lesion characteristics and comorbidities in 2 retrospective studies in patients undergoing CTO-PCI.^{14,15} Of 1662 patients in the Latin America (LATAM) CTO registry, 251 (15.1%) had prior CABG (**Figure 3**). Prior CABG patients had lower LVEF (52.8% vs 54.4%; $P=.042$) and higher J-CTO (2.46 vs 2.10; $P<.001$) and PROGRESS CTO (1.28 vs 0.91; $p < 0.001$) scores. Technical (78.8% vs 86.6%; $P=.002$) and procedural (77.2% vs 85.4%; $P=.001$) success was lower in prior CABG patients with no difference in in-hospital major adverse cardiac and cerebrovascular event (MACCE) rate between the 2 groups.¹⁴ Similarly, an analysis from the British Cardiovascular Intervention Society database showed lower procedural success and similar complication rates in patients with prior CABG compared with patients without prior CABG.¹⁵

Outcomes of CTO PCI in patients with prior-CABG: Insights from the LATAM CTO Registry

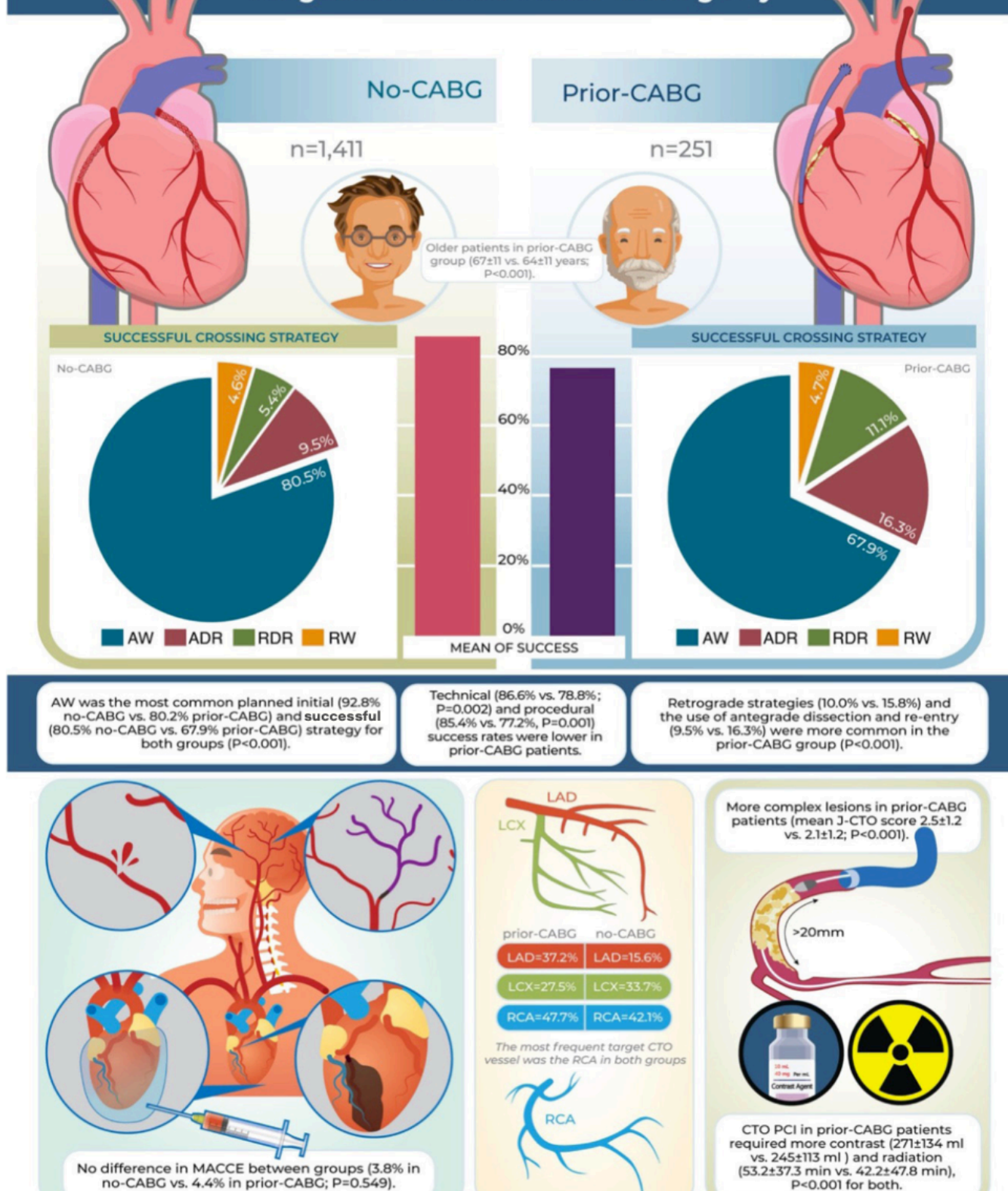


Figure 3. Summary of the comparison of no-CABG and prior-CABG chronic total occlusion (CTO) percutaneous coronary intervention (PCI) patients in the Latin America (LATAM) CTO registry. ADR = antegrade dissection and re-entry; AW = antegrade wiring; ADR = antegrade dissection and re-entry; CABG = coronary artery bypass grafting; LAD = left anterior descending; LCX = left circumflex; MACCE = major adverse cardiac and cardiovascular events; RCA = right coronary artery; RDR = retrograde dissection and re-entry; RW = retrograde wiring. Image reproduced with permission from Catheterization & Cardiovascular Interventions and Hernandez-

Allahwala et al¹⁶ showed that CTOs supplied by a grafted donor vessel were less likely to have robust collaterals (37% vs 83%; $P<.001$). Moreover, patients with previous CABG also had lower Rentrop ($P<.001$) and collateral connection ($P<.001$) grades compared with no prior CABG patients.

Reduced LVEF and heart failure. Patients with low LVEF undergoing CTO-PCI have increased risk of complications. In an analysis of the PROGRESS-CTO registry, 7827 patients were divided into 3 groups based on LVEF ($\leq 35\%$, 36%-49%, and $\geq 50\%$) showing higher mortality in the lower LVEF group (1.1%, 0.4%, and 0.3%, respectively; $P=.001$), with no difference in technical success.¹⁷ In a similar analysis from the Japanese CTO-PCI Expert Registry, LVEF $\leq 35\%$ patients had higher in-hospital MACCE rates (3.4%, 1.7%, and 1.5%, respectively; $P=.001$) and no difference in technical success. In multivariable analysis, LVEF $\leq 35\%$ (OR, 1.58; 95% CI, 1.04-2.41) and New York Heart Association (NYHA) class ≥ 3 (OR, 2.01; 95% CI, 1.03-3.93) were associated with higher in-hospital MACCE.

In a study of 112,061 patients who underwent CTO-PCI, Albaeni et al¹⁸ showed that patients with heart failure with reduced EF (HFrEF) were more likely to experience in-hospital mortality (adjusted odds ratio [aOR], 1.73; 95% CI, 1.21-2.48) and acute renal failure (aOR, 2.68; 95% CI, 2.34-3.06) and more likely to require mechanical support (aOR, 2.76; 95% CI, 2.17-3.51) after CTO-PCI, compared with patients without heart failure. Patients with heart failure with preserved ejection fraction (HFpEF) had similar likelihood of mortality and need for mechanical support compared with patients without heart failure, but higher incidence of acute renal failure (aOR, 2.95; 95% CI, 2.29-3.81).

Reattempt CTO-PCI. Zhong et al examined 208 patients undergoing reattempt CTO-PCI.¹⁹ Subintimal plaque modification with successful guidewire crossing during the initial procedure (OR, 11.21; 95% CI, 1.31-96.16), referral to high-volume operators (OR, 2.38; 95% CI, 1.14-4.98), and a bidirectional approach (OR, 2.31; 95% CI, 1.12-4.79) were positively associated while the time interval for reattempt (OR, 0.85; 95% CI, 0.73-0.98 per 90-day increment) was negatively associated with technical success.

Operator experience. To investigate the effect of operator experience on the outcomes of CTO-PCI, Matsuno et al compared the outcomes of PCI in 2 different registries, one containing procedures performed by experienced operators and the other containing procedures performed by less experienced operators.²⁰ There was no difference in technical success or in-hospital MACE between the 2 registries, except for patients treated with a primary antegrade approach, in whom the technical success was slightly better (91.8% vs 89.5%; $P=.009$) in the experienced operator registry. In contrast, Karacsonyi et al showed higher technical success in cases performed by high-volume operators (>60 cases per year), but also higher incidence of MACE, which could potentially be explained by the higher lesion complexity of the cases performed by high-volume operators.²¹

Same-day discharge. Same-day discharge (SDD) may be possible after CTO-PCI. In the British Cardiovascular Intervention Society (BCIS) registry, use of SDD increased between 2007 and 2014 without change in 30-day mortality.²² SDD was more likely when radial access was used (OR, 1.94; 95% CI, 1.80-2.09).

Balloon undilatable lesions. The incidence of balloon undilatable lesions was high (8.5%) in the PROGRESS-CTO registry.²³ These lesions were associated with lower technical success (90.9% vs 93.8%; $P=.007$) and higher MACE (5.0% vs 1.3%; $P<.001$) compared with balloon dilatable lesions. In multivariable analysis, moderate/severe proximal vessel calcification had the strongest association with balloon undilatable lesions.

Intravascular lithotripsy (IVL) is a novel tool for treating heavily calcified lesions. In an analysis of 82 patients who underwent IVL, technical (94%) and procedural (90%) success rates were high, with low incidence of complications (2 Ellis class 2 perforations treated conservatively).²⁴ IVL has also been successfully used for extraplaque dilatation of a heavily calcified in-stent restenosis lesion.²⁵

Techniques

Arterial access. The radial artery has become the dominant access site for conventional PCI. While its use in CTO-PCI has been increasing over time, only 24% of patients had radial-only access in a large multicenter CTO registry.²⁶ Radial-only access was independently associated with fewer vascular access complications (OR, 0.45; 95% CI, 0.22-0.91) and similar technical success and MACE rates compared with femoral access.

The FORT CTO (Femoral or Radial Approach in the Treatment of Coronary Chronic Total Occlusion) trial randomized 610 patients undergoing CTO-PCI to radial vs femoral access (**Figure 4**).²⁷ Procedural success and MACE rates were similar in the 2 groups, but the incidence of access-site complications was lower in radial access patients (2% vs 6%; $P=.019$) without the need for a longer procedure,

contrast volume, or radiation dose.

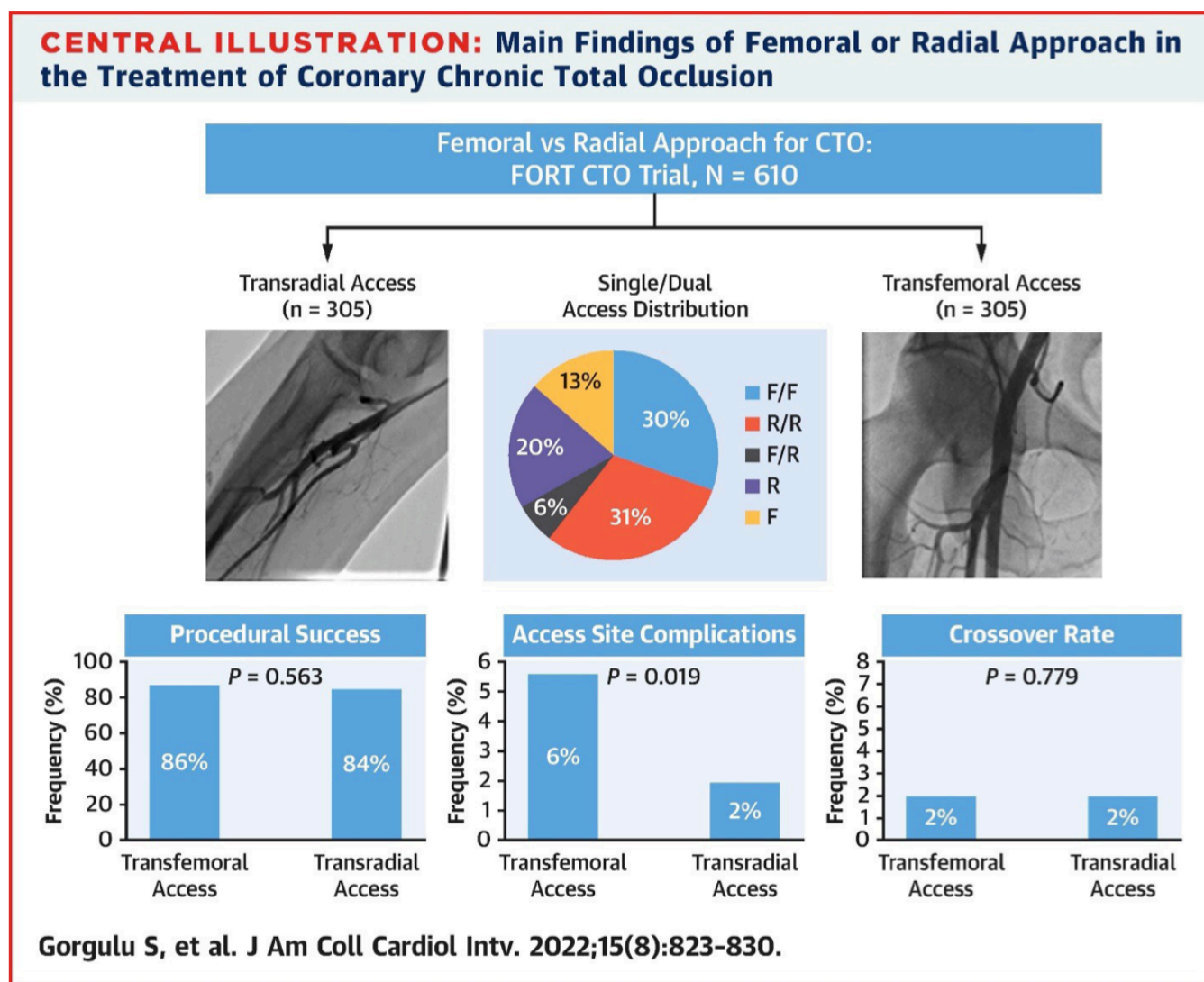


Figure 4. Main findings of femoral or radial approach in the treatment of coronary chronic total occlusion (CTO). F = femoral; F/F = femoral/femoral; F/R = femoral/radial; FORT CTO = Femoral or Radial Approach in the Treatment of Coronary; CTO = chronic total occlusion; R = radial; R/R = radial/radial. Image reproduced with permission from JACC Cardiovascular Interventions and Gorgulu et al.

Antegrade techniques. The safety and feasibility of the antegrade fenestration and re-entry (AFR) technique using a dedicated dual-guidewire balloon (DGB) was evaluated in a study of 14 patients with high J-CTO scores (3.1 ± 0.9).²⁸ Success was high with DGB-AFR alone (71%) and increased with use of rescue antegrade dissection and re-entry (86%). There were no periprocedural complications.

Two novel techniques were described by Megaly et al, the side power knuckle technique and the antegrade-antegrade dissection re-entry (AADR) technique.²⁹ The side power knuckle technique can be used to obtain access into a flush occlusion of a large side branch. To achieve that, a 1:1 balloon is inflated in the main vessel to help advance a non-tapered, stiff, polymer-jacketed wire into the occluded side branch (or a side branch lost during antegrade dissection and re-entry). The AADR technique is a modification of the antegrade dissection and re-entry technique and the extended reverse controlled antegrade and retrograde dissection re-entry technique (reverse CART), which can be used to treat a bypassed vessel CTO when the bypass conduit is patent. A 1:1 balloon advanced through the bypass conduit is inflated to help antegrade puncture and wire crossing into the distal true lumen.

Proximal cap crossing. A randomized controlled double-blinded trial examined intralesional collagenase delivery as a means of facilitating guidewire crossing.³⁰ Successful guidewire crossing was not significantly higher in the collagenase group (74% vs 63%; $P = .52$) although success was higher when a soft-tip guidewire was used (0% in placebo group, 17% in 900 μ g collagenase group, and

29% in 1200 μ g collagenase group; $P=.03$). A novel technique was proposed by Karacsonyi et al for microcatheter uncrossable proximal cap, named “guide-extension Carlino,” in which the lesion is treated by injecting contrast through a guide catheter extension wedged against the proximal cap.³¹

Retrograde crossing. In both the European CTO (ERCTO) Club Registry (82.6% primary retrograde cases) and the PROGRESS-CTO registry (only primary retrograde cases),^{32,33} the most significant factor associated with success in retrograde CTO-PCI was the presence of interventional collaterals. The ERCTO study identified 4 additional parameters, namely, lesion calcification, distal vessel opacification, proximal target-vessel tortuosity, and operator volume, that can be used, along with the Werner collateral classification, to formulate a nomogram and predict the probability of success with the retrograde technique.

The predominant technique for retrograde CTO crossing is reverse CART, which can be further subclassified into conventional, contemporary, and extended reverse CART.³⁴ Xu et al showed that contemporary reverse CART was associated with shorter procedure times (181.7 minutes vs 189.8 minutes; $P=.04$) and numerically fewer target-vessel perforations (0.6% vs 3.6%; $P=.06$) and major side-branch occlusions (1.2% vs 5.0%; $P=.05$).³⁵

Simsek et al showed that epicardial collateral crossing success rates increased from 5%-10% to 76% in 2021, with no change in MACE.³⁶

Ostial CTOs. In the Japanese CTO-PCI Expert registry, the prevalence of ostial occlusions was 3.6%. Both aorto-ostial and non-aorto-ostial CTOs were associated with lower technical success rates (85% [aorto-ostial] vs 86% [non-aorto-ostial] vs 91% [non-ostial]; $P<.01$ and $P<.01$), and higher incidence of cardiac tamponade (7% [aorto-ostial] vs 6% [non-aorto-ostial] vs 3% [non-ostial]; $P<.01$ and $P<.05$) and contrast-induced acute kidney injury (8% [aorto-ostial] vs 8% [non-aorto-ostial] vs 4% [non-ostial]; $P<.01$ and $P<.01$) compared with non-ostial CTOs.³⁷ Garbo et al described a novel bailout technique for aorto-ostial lesions, termed “power flush,” which was successfully used for 3 aorto-ostial CTO cases.³⁸ In this technique, a guide catheter is used to forcefully inject contrast directly to the aortic wall at the level of the coronary ostium to gain access to the extra-plaque space that facilitates vessel revascularization. In 1 of the cases, a further iteration of the power flush technique was used, termed “nick and flush,” in which preliminary nicking of the aortic wall with a penetrative wire was done before power flush.

Imaging. Coronary computed tomography angiography (CCTA) can help resolve proximal cap ambiguity, identify significant calcium and accurately estimate lesion length. In a study of 7304 CTO-PCI patients, 375 of whom underwent preprocedural CCTA, preprocedural CCTA was not associated with technical success or MACE, even after adjusting for potential confounders.³⁹ Another study determined that the quantitative characteristics derived from CCTA, including the percentages of dense calcium, fibrous tissue, and necrotic tissue, were independently associated with successful guidewire crossing in ≤ 30 minutes and procedural success.⁴⁰ In a study of 137 patients with 141 CTO lesions who underwent preprocedural CCTA, the CCTA-derived J-Calc-CTO score showed a higher predictive value of 30-minute wire crossing than the J-CTO score in the derivation (c-statistics, 0.836 vs 0.670; $P>.01$) and validation groups (c-statistics, 0.879 vs 0.767; $P>.01$).⁴¹

Chugh et al performed a meta-analysis of IVUS-guided vs angiography-guided CTO-PCI⁴² showing lower risk of stent thrombosis ($P=.02$; $I^2=0\%$), shorter procedure time ($P<.001$; $I^2=88\%$), shorter fluoroscopy time ($P<.001$; $I^2=63\%$), and less contrast volume use ($P<.001$; $I^2=59\%$) in the IVUS-guided group. Additionally, IVUS-guided cases had shorter total stent length ($P<.001$; $I^2=39\%$) and total number of stents ($P<.001$; $I^2=72\%$).

Other techniques. Dual-lumen microcatheters (DLMCs) are important tools for CTO-PCI, particularly in lesions with large bifurcations at the proximal or the distal cap, as well as for enabling parallel wiring and antegrade dissection and re-entry. A EuroCTO consensus document was published, which describes the available DLMC and the cases in which they can be applied.⁴³ Currently available DLMCs include the following: Twin-Pass (Teleflex Medical); the Twin-Pass Torque (Teleflex Medical); the FineDuo/Crusade (Terumo/Kaneka); the NHancer Rx (IMDS); the ReCross (IMDS); and the Sasuke (Asahi Intecc). DLMC can facilitate: wiring of a major side branch near the proximal CTO cap; the parallel-wire technique; distal re-entry, access of side branch at the distal occlusion cap; selective engagement of angulated collaterals; using the reverse wire technique; and retrograde crossing and retrograde puncture of the distal CTO cap.

A novel technique was described for treating CTOs involving bifurcations, named double-barrel crush stenting, which uses simultaneous deployment of the main vessel and side-branch stents to prevent dissection flaps from separating the 2 lumens.⁴⁴

Balloon occlusion with a small balloon was used successfully in 2 CTO-PCI cases to prevent subintimal hematoma formation.⁴⁵ In this technique, a small balloon is advanced along the microcatheter in the proximal CTO vessel and inflated to stop antegrade blood flow. The dilated balloon prevents subintimal hematoma, but also provides anchor support for antegrade wire crossing.

Complications

Coronary perforation. In an analysis of 10,454 cases from the PROGRESS-CTO registry, the incidence of coronary perforation was 4.9%. Coronary perforation was associated with more complex lesions and lower technical (66% vs 87%; $P<.001$) and procedural (55% vs 87%; $P<.001$) success rates, and a higher incidence of in-hospital MACE (18% vs 1.3%; $P<.001$).⁴⁶ A study of the LATAM CTO registry identified 4 independent predictors of perforation during CTO-PCI, including maximum activated clotting time ($P<.01$), Multicenter CTO Registry in Japan score ≥ 2 ($P=.05$), antegrade knuckle wire ($P=.04$), and right coronary artery CTO-PCI ($P=.05$).⁴⁷ Furthermore, coronary artery perforation was associated with higher incidence of bleeding and ischemic events at 6 months ($P=.004$) and 1 year ($P<.01$). Miura et al showed that among 8760 patients, those who had a perforation ($n = 333$; 3.8%) had longer guidewire manipulation times compared with the non-perforation group (101.0 min vs 54.9 min; $P<.001$).⁴⁸ In all 3 studies, perforations were more common with retrograde crossing.

In patients with prior CABG, coronary artery perforation can lead to loculated effusions that can be hard to treat and may require CT-guided drainage or surgery. O'Sullivan et al described an 86-year-old man with prior CABG, who experienced delayed extracardiac hematoma after CTO-PCI and was treated conservatively, since percutaneous drainage was not possible due to the location of the effusion.⁴⁹ The patient developed pulmonary edema 12 hours later, which was successfully treated with 40 mg of intravenous furosemide.

Complication scores. Simsek et al developed the PROGRESS-CTO Complication score for estimating the risk of MACE (c-statistic, 0.74; 95% CI, 0.70-0.78) (**Figure 5**), mortality (c-statistic, 0.80; 95% CI, 0.73-0.86), pericardiocentesis (c-statistic, 0.78; 95% CI, 0.72-0.83), and acute MI (c-statistic, 0.72; 95% CI, 0.62-0.82).⁵⁰ Two scores were developed to estimate the risk of perforation during CTO-PCI. The OPEN-CLEAN score includes the following parameters: prior CABG (+1); occlusion length (20 to 60 mm [+1] ≥ 60 mm [+2]); LVEF $<50\%$ (+1); heavy calcification (+1); and age (50 to 70 years [+1], ≥ 70 years [+2]) (c-statistic, 0.75).⁵¹ The PROGRESS-CTO Perforation score includes the following parameters: age ≥ 65 years (+1); moderate/severe calcification (+1); blunt/no stump (+1); antegrade dissection and re-entry (+1); and retrograde approach (+2) (c-statistic, 0.74).⁵² The parameters of the different complication scores can be seen on **Table 1**.

CENTRAL ILLUSTRATION: The PROGRESS-CTO In-Hospital MACE Risk Score

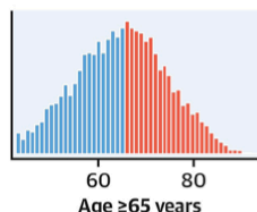


10,487 CTO PCIs performed at
40 centers in 7 countries
between 2012-2022

In-hospital MACE 2.05%

Technical success 86.3%

AUC: 0.74



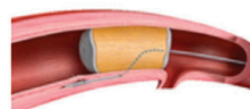
Age ≥65 years
+1 point



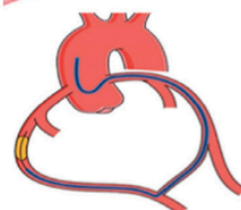
Moderate-to-severe
calcification
+1 point
Blunt stump
+1 point



Female
+2 points



Antegrade
dissection and
re-entry
+1 point



or

Retrograde
+2 points

Simsek B, et al. J Am Coll Cardiol Interv. 2022;15(14):1413-1422.

Figure 5. The PROGRESS-CTO In-hospital MACE score. AUC = area under the receiver-operating characteristic curve; CTO = chronic total occlusion; MACE = major adverse cardiovascular event(s); PCI = percutaneous coronary intervention; PROGRESS-CTO = Prospective Global Registry for the Study of Chronic Total Occlusion Intervention Image reproduced with permission from JACC Cardiovascular Interventions and Simsek et al.

TABLE 1. Overview of complication scores for chronic total occlusion percutaneous coronary intervention.						
	PROGRESS-CTO MACE	PROGRESS-CTO Mortality	PROGRESS-CTO Pericardiocentesis	PROGRESS-CTO Acute MI	OPEN-CLEAN	PROGRESS-CTO Perforation
Age (years)	≥65 (+1)	≥65 (+1)	≥65 (+1)	—	50 to 70 (+1) ≥70 (+2)	≥65 (+1)
Atrial fibrillation	—	—	—	yes (+1)	—	—
Calcification	moderate / severe (+1)	moderate / severe (+1)	moderate / severe (+1)	—	severe (+1)	moderate/ severe (+1)
Crossing strategy	ADR (+1) retrograde (+2)	ADR (+1) retrograde (+1)	ADR (+1) retrograde (+2)	—	—	ADR (+1) retrograde (+2)
Gender	female (+2)	—	female (+1)	—	—	—
LVEF	—	≤45% (+1)	—	—	<50% (+1)	—
Occlusion length (mm)	—	—	—	—	20 to 60 (+1) ≥60 (+2)	—
Prior CABG	—	—	—	yes (+1)	yes (+1)	—
Stump	blunt (+1)	—	—	blunt (+1)	—	blunt (+1)
ADR = Antegrade dissection and re-entry; CABG = coronary artery bypass graft; LVEF = Left ventricular ejection fraction; MACE = major adverse cardiac events; MI = myocardial infarction.						

Table 1. Overview of complication scores for chronic total occlusion percutaneous coronary intervention.

Specialized equipment. In a contemporary prospective multicenter trial of 163 patients who underwent CTO-PCI using specialized guidewires and microcatheters,⁵³ successful guidewire crossing was achieved in 89% of patients and procedural success in 73% of patients. However, the rates of perforation (12.3%) and in-hospital MACE (19%) were high, indicating that the risk of CTO-PCI is still higher than conventional PCI.

Radiation. Werner et al compared radiation dose in 3 groups of patients with different radiation protocols.⁵⁴ Group 1 used the standard available protocol at that time (2011-2013), with focus on low fluoroscopic radiation, group 2 used a modified protocol aiming to reduce the fluoroscopy exposure, and group 3 used a protocol with further modifications aimed at reducing cineangiographic exposure. Air Kerma (AK) radiation dose decreased from group 1 (2619 mGy; interquartile range [IQR], 1653-4574), to group 2 (2178 mGy; IQR, 1332-3500; $P<.001$), and even further in group 3 (746 mGy; IQR: 480-1225; $P<.001$). The results were not affected by patient weight or by the crossing strategy used.

Subintimal shift. Two cases of a rare cause of side-branch occlusion during bifurcation CTO-PCI, called “subintimal shift,” were presented by Azzalini et al.⁵⁵ Subintimal shift involves extension of a dissection plane and compression of the side-branch ostium when balloon inflation or stent deployment is attempted after extraplaque tracking occurs in the proximity of a bifurcation. In both cases, IVUS played a significant role for preventing or diagnosing subintimal shift. Utilizing an upfront 2-stent initial strategy is key for successfully managing such lesions.

Conclusion

In summary, great advancements were made on our understanding and our approach to CTO-PCI during the past year. Implementation of the recent study findings to everyday clinical practice could improve the outcomes of the patients who need this often complex procedure.

Affiliations and Disclosures

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Disclosures: The authors have completed and returned the ICMJE Form for Disclosure of Potential Conflicts of Interest. Dr Alaswad has been a consultant and speaker for Boston Scientific, Abbott Cardiovascular, Teleflex, and CSI. Dr Basir reports grant support from Abiomed, Chiesi, and Zoll; consultant fees/honoraria from Abbott Vascular, Abiomed, Boston Scientific, Cardiovascular Systems, Inc, Chiesi, Seranas, and Zoll. Dr Davies reports speaking honoraria from Abiomed, Asahi Intecc, Boston Scientific, Medtronic, Siemens Healthineers, and Shockwave; serves on advisory boards for Abiomed, Boston Scientific, and Medtronic. Dr Choi serves on the Medtronic advisory board. Dr Khatri reports personal honoraria for proctoring and speaking from Abbott Vascular, Medtronic, Terumo, Shockwave, and Boston Scientific. Dr Nicholson has been a proctor for and on the speakers' bureau and advisory boards for Abbott Vascular, Boston Scientific, and Asahi Intecc; and reports intellectual property with Vascular Solutions. Dr Rinfret reports income from Abbott Vascular, Abiomed, Boston Scientific, and SoundBite Medical and has been a consultant for Teleflex. Dr Jaber reports fees from Medtronic and proctoring fees from Abbott. Dr Burke reports consulting fees and speaker honoraria from Abbott Vascular and Boston Scientific. Dr Brilakis reports consulting/speaker honoraria from Abbott Vascular, American Heart Association (associate editor, *Circulation*), Amgen, Asahi Intecc, Biotronik, Boston Scientific, Cardiovascular Innovations Foundation (Board of Directors), CSI, Elsevier, GE Healthcare, IMDS, Medtronic, Siemens, and Teleflex; research support: Boston Scientific, GE Healthcare; owner, Hippocrates LLC; shareholder in MHI Ventures, Cleerly Health, and Stallion Medical. The remaining authors report no conflicts of interest regarding the content herein.

Manuscript accepted January 18, 2023.

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