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Original Article

Impact of Clinical and Angiographic Criteria on Procedural Outcomes and Target Lesion Revascularization After Percutaneous Coronary Intervention for Chronic Total Occlusion

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ABSTRACT

Background: Coronary chronic total occlusion (CTO) recanalization aims to improve myocardial perfusion in the corresponding ischemic territory. Successful CTO percutaneous coronary intervention (PCI) improves quality of life and left ventricular function.

Objectives: To investigate preprocedural predictors of successful antegrade CTO recanalization in two centers with limited resources and to evaluate procedural and midterm clinical outcomes after successful CTO recanalization.

Methods: This prospective study included 70 patients recruited from 2 centers with limited CTO PCI resources. The primary outcomes were procedural success rate, target lesion revascularization (TLR) at 1 year, and midterm success rate according to J-CTO scores. The secondary outcomes were major adverse cardiac events.

Results: J-CTO score variables were significant in predicting procedural success. A cutoff score of ≥2 was associated with procedural failure, with 100% sensitivity and 91% specificity, and may be used as a negative predictive factor when treating CTO lesions. A significant association was observed between the need for TLR, the presence of diabetes, and vessel angulation.

Conclusions: In resource-limited centers, use of an antegrade approach in patients with CTO lesions and lower J-CTO scores is expected to achieve higher midterm success rates compared with patients with higher J-CTO scores. ***(Iranian Heart Journal 2025; 26(4): 69-84)***

KEYWORDS: Coronary total occlusion; Major adverse cardiac events; Procedural success

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A coronary chronic total occlusion (CTO) is defined as a 100% occlusion with Thrombolysis in Myocardial Infarction (TIMI) grade 0 flow present for more than 3 months.[1,2] Coronary CTOs are relatively common, observed in approximately 15% to 25% of patients with coronary artery disease (CAD) undergoing coronary angiography.[3–7] A typical feature of a CTO is the presence of collaterals, which are found in approximately 90% of cases. [8] These collaterals can preserve myocardial function at rest but do not prevent ischemia during exercise due to a limited capacity to increase blood flow. [9] During recanalization, a collateral perfusion pressure of <40 mm Hg in the CTO territory can lead to underestimation of the distal vessel size. [10]

The presence of a well-developed collateral network is not protective against ischemic insults, as revascularization may provide a survival benefit over medical therapy even in this patient population. [11, 12] Viable myocardium subtended by a CTO is generally ischemic, regardless of the degree of collateralization. [13, 14] The goal of CTO recanalization is to improve myocardial perfusion in the corresponding ischemic territory. [15] This has two primary beneficial effects. First, successful CTO percutaneous coronary intervention (PCI) relieves ischemia, [16, 17] which is associated with reduced severity and frequency of angina and improved functional status and quality of life. [18] Second, an untreated CTO contributes to incomplete revascularization, [19] which has been associated with persistent left ventricular (LV) dysfunction. [20]

CTO recanalization facilitates complete revascularization, which may improve LV function. [21] CTOs possess an arrhythmic potential, with malignant ventricular arrhythmias occurring in up to 3% of patients with a CTO. [22] Scoring models provide a quantitative measure of procedural difficulty and the probability of recanalization success, thereby aiding clinical decision-making and enabling better case selection based on operator experience. [23]

The Japanese Chronic Total Occlusion (J-CTO) score is widely used. [24] While experienced operators can attempt even the most complex CTO PCIs with high success rates, operators early in their learning curve can select less complex cases (J-CTO score 0 or 1) and refer patients with more complex lesions (J-CTO score ≥2) to dedicated CTO centers. [24]

Objective

The objective of this study was to investigate the preprocedural predictors of successful antegrade CTO recanalization at two limited-resource centers and to evaluate the associated procedural and mid-term clinical outcomes.

METHODS

The study included 70 patients recruited for CTO revascularization from two centers with limited CTO PCI resources. Patients were divided into two groups:

- Group I: 39 patients with J-CTO scores <2
- Group II: 31 patients with J-CTO scores ≥2

All patients provided written informed consent, which included details of the expected benefits and potential risks of CTO revascularization. The Committees of Research and Medical Ethics approved the study (FMBSUREC/05072020/Mahmoud) on July 5, 2020, in accordance with the Declaration of Helsinki. Patient enrollment began in July 2020 and ended in July 2022.

Inclusion criteria:

Symptomatic patients with CTO lesions despite optimal medical therapy or asymptomatic patients with ischemic burden ≥10% of the LV mass. [17]

Exclusion criteria:

1. Patients with nonviable myocardium in the CTO territory, assessed by myocardial perfusion imaging
2. Patients with life expectancy <1 year
3. Patients with contraindications to dual antiplatelet therapy

Lesion success was defined as final diameter stenosis <30%, assessed by coronary angiography. Procedural success was defined as revascularization without myocardial infarction (MI) or target lesion revascularization (TLR) before hospital discharge.

Dual antiplatelet therapy was prescribed for 12 months after drug-eluting stent (DES) implantation.

All patients underwent scheduled follow-up angiography between 8 and 12 months after PCI. Echocardiography was also performed to assess contractility by ejection fraction (EF) and segmental wall motion.

The primary outcomes were procedural success rate, TLR at 1 year, and midterm success rate according to J-CTO scores. Midterm success rate was estimated by multiplying the lesion revascularization success rate by the TLR-free survival rate.

Procedural success rate was defined as the percentage of successful CTO cases with final diameter stenosis <30%, as assessed by coronary angiography. TLR-free survival rate was defined as the percentage of patients with a patent stent without in-stent restenosis on follow-up angiography.

The secondary outcomes were major adverse cardiac events (MACE), defined as a composite of all-cause death, MI, and need for repeat PCI or coronary artery bypass graft due to restenosis or occlusion of the target lesion. [17] MI was defined as an increase in creatine kinase–myocardial band level to ≥3-fold the upper limit of normal. Stent thrombosis was defined according to Academic Research Consortium criteria. [17]

All patients underwent clinical examination and history taking, followed by:

1. Resting ECG to detect ischemic changes and arrhythmia
2. Baseline laboratory investigations
3. Echocardiography within 24 hours before PCI and at 6 months, according to American Society of Echocardiography guideline recommendations. [17] LVEF was calculated using Simpson's modified biplane method. Regional LV wall motion score (WMS) was measured, and LV wall motion score index (WMSI) was calculated as the sum of all segment scores divided by the number of segments assessed. [17]
4. Myocardial perfusion imaging with 99mTc-sestamibi was performed to assess myocardial viability in asymptomatic patients and to evaluate ischemic burden. [17] CTO recanalization was indicated if ischemia was present in ≥10% of the LV mass. [17] Recanalization was performed only in patients with viable myocardium in the CTO territory associated with symptoms or ischemia. [17] Proof of viability was also required in cases of akinesia or dyskinesia of the CTO territory.
5. Coronary angiography was performed as an elective procedure.

Procedural setup: All patients received either clopidogrel (300 mg) or ticagrelor (180 mg) 24 hours before the procedure. CTO procedures were performed using 6F guide catheters, with a preference for bilateral access. Catheters providing a high degree of passive support were used, typically XB or extra backup curves for the left coronary artery and Amplatz Left for the right coronary artery.

Access site: The femoral approach was the preferred access route. The radial approach was used in cases of severe peripheral vascular disease, and bilateral femoral access was selected for contralateral injection. Diagnostic dual-catheter angiography was used to assess collateral filling, lesion length, and vessel course, with acquisition performed using a wide field of view. A bending of ≥1 or more bends of ≥45° within the occluded segment was documented. One point was awarded for each variable, and the points were summed to calculate a total J-CTO score for each lesion. [25–27]

The vessel segment beyond the distal cap but before the origin of a significant side branch is defined as the distal landing zone, which is the target for potential re-entry during antegrade dissection and re-entry. If the distal cap was located at or near a significant bifurcation, the risk of dissection extending across the branch and causing occlusion was increased, making antegrade dissection and re-entry a less favorable strategy. [28, 29]

Collaterals supplying the distal vessel facilitated visualization of the distal target during antegrade procedures. Patients were divided into two groups based on their J-CTO scores: the first group included patients with a J-CTO score of 0 or 1, and the second group included patients with a J-CTO score of ≥2. The appropriate revascularization strategy was then selected for each patient.

The procedure was initiated with the antegrade wiring escalation technique, which involves using a guidewire to penetrate the proximal cap and advance within the intraplaque space to reach the true distal lumen. In practice, the wire often passed in and out of the plaque vessel during this technique. A primary antegrade wiring strategy was considered appropriate, with a switch to an alternative approach if adequate progress was not achieved.

Guidewire selection for the initial antegrade crossing was based on available equipment and lesion characteristics, following a simplified escalation scheme for antegrade wiring. A tapered, polymer-jacketed wire (e.g., Fielder XT) was used first in an attempt to track microchannels, which are sometimes invisible. This attempt was brief unless progress was achieved. If the initial wire failed to cross and the vessel course was well understood (particularly with short CTOs), a stiff, tapered guidewire was preferred. If the vessel course was unclear, a stiff, polymer-jacketed guidewire (e.g., Pilot 200) was selected for its increased likelihood of tracking the vessel architecture without exiting the vessel wall. For a heavily calcified proximal cap, a Confianza Pro 12 guidewire could be used initially to puncture the cap and facilitate entry into the occlusion. The guidewire tip was shaped to maximize the probability of successful crossing.

The guidewire was advanced through a microcatheter. Three guidewire handling techniques were used to cross the occlusion into the true distal lumen: sliding and drilling (used for both non-CTO and CTO lesions) and penetration (used primarily for CTO lesions).

1. Sliding: This technique, typically the first step, involved the forward movement of a polymer-jacketed guidewire to track microchannels within the CTO. The wire was advanced with gentle tip rotation and probing. If the wire failed to progress within a few minutes, the guidewire or technique was changed.
2. Drilling: This technique consisted of controlled clockwise and counterclockwise rotation of the guidewire, limited to approximately 90° in each direction.
3. Penetration: This technique involved the intentional, directed forward advancement of the guidewire, usually a stiff type (e.g., Confianza Pro 12). It was utilized for lesions with a calcified, hard-to-penetrate proximal cap and for traversing shorter occlusions when the vessel course was well understood.

There were three potential outcomes following guidewire advancement through the lesion:
a. Successful crossing into the true distal lumen.
b. Entry into the subintimal space.
c. Vessel perforation.

Guidewire location was ascertained drawing upon the following methods:

1. Contralateral injection: This was the optimal method when collaterals originated primarily from the contralateral coronary artery. The use of two orthogonal views was essential, except in very straightforward cases.
2. Tactile feedback: A sudden, spontaneous increase in the freedom of movement of the wire tip upon passing the distal cap provided an important clue that the distal true lumen had been entered.
3. Distal wiring with a workhorse guidewire: A microcatheter was advanced over the CTO crossing guidewire, which was then exchanged for a workhorse guidewire. Easy advancement of the workhorse wire into distal branches indicated a true lumen position.

After successful crossing, the microcatheter was advanced into the true distal lumen. The CTO-crossing guidewire was then removed and exchanged for a workhorse guidewire. Following microcatheter removal, standard balloon angioplasty and stenting were performed.
If the guidewire was positioned in the subintimal space, one of the following techniques was employed:

- **Directed re-entry:** A microcatheter was advanced into the subintimal space, and its tip was positioned adjacent to a well-visualized segment of the true distal lumen. Directed penetration was then used to achieve re-entry.
- Controlled subintimal tracking: Subintimal crossing and re-entry techniques were used to prevent uncontrolled extension of the subintimal dissection. This involved using a knuckle wire or dissection/re-entry catheter to cross subintimally to the distal true lumen, followed by wire-based re-entry techniques.
- Parallel-wire technique: When the initial guidewire entered the subintimal space (or a side branch), it was left in place as a marker. A second guidewire was then advanced parallel to the first wire until it successfully entered the true distal lumen. [12]

To achieve optimal stent expansion, noncompliant balloons were inflated at 20 atm or higher as needed, guided by the reference vessel size and confirmed by the degree of expansion using stent optimization technology (e.g., StentFiz). A follow-up visit was scheduled for between 9 and 12 months after PCI. Elective coronary angiography was subsequently performed for patients who were symptomatic or had any objective evidence of ischemia.

Statistical Analysis

Quantitative data are presented as mean (SD), and qualitative data are presented as numbers and percentages. SPSS, version 27, was used for all analyses. The χ^2 or Fisher exact test was employed to assess the association between two categorical variables. An independent *t*-test was used to examine the relationship between one quantitative variable and one qualitative variable. Following the EF and WMSI, a paired *t*-test was utilized in each category. Binary logistic regression was performed to analyze factors associated with success. A receiver operating characteristic (ROC) curve was used to determine the optimal JCTO score associated with success. Values of $P < 0.05$ were considered statistically significant.

Sample size

Using G. Power version 3.1 for Windows 10, the sample size was calculated using the chi-square test family to assess the difference between patients with a JCTO score of <2 and those with a JCTO score of ≥2 regarding procedural success (success vs failure). Assuming an effect size of 0.4, an alpha error of 0.05, and a power of 90% with one degree of freedom (2 × 2 table), we determined that 60 cases were needed, divided into two groups of 30 each. The non-centrality parameter (λ) was 13.02, and the critical χ^2 was 3.84. Accounting for an approximate 10% dropout rate, 33 patients were included in each group.

RESULTS

This prospective study included 70 patients (46 men and 24 women) recruited from Beni-Suef University Hospital and Beni-Suef Insurance Hospital from July 2020 through July 2022. The age of the study population ranged from 45 to 80 years. Patients presented with significant angina (class III-IV) or recent acceleration of previously chronic stable angina. Overall, 36 (51.4%) patients had a previous MI, and 34 (48.6%) did not.

Patients were divided into two groups:

Group I: 39 patients with a JCTO score of <2.

Group II: 31 patients with a JCTO score of ≥2 .

No significant differences were observed between the two groups regarding baseline characteristics, as shown in Table 1.

Seventeen patients had normal contractility (EF 52.5% ± 2.3%) with a calculated LV WMSI of 1.1 ± 0.1, and 53 patients had reduced contractility (EF 36% ± 5.1%) with a calculated LV WMSI of 1.4 ± 0.2 ($P < 0.001$).

Angiographic data of CTO lesions showed no significant difference between the two groups regarding the coronary vessel involved in the lesion (Table 2).

Lesion characteristics in both groups are presented in Table 3.

The guidewire was successfully passed in 90% of lesions, with differences in procedure time observed between the two groups (Table 4). Various guidewires used are shown in Figure 1.

Table 1. Baseline characteristics and risk factors of the studied groups

Characteristics	Group I J-CTO <2 (N. = 39)	Group II J-CTO ≥2 (N. = 31)	*P*
Age (mean±SD)	55.7 Y±4.976 Y	57.9 Y±6.4 Y	0.117
Sex Females Males	 14(35.9%) 25(64.1%)	 10(32.3%) 21(67.7%)	0.750
Comorbidities Diabetes mellitus Hypertension	 11(28.2%) 8(20.5%)	 10(32.3%) 8 (25. 8%)	 0.713 0.602
Smoking	6(15.4%)	5(16.1%)	0.932
Dyslipidemia	17 (43.6%)	13(41.9)	0.887
Family history of ischemic heart disease	18 (46.2%)	14(45.4)	0.947
More than 1 risk	22(56.4)	18(58.0)	0.893

J-CTO score: The Japanese Chronic Total Occlusion score

Table 2. Lesion characteristics of the studied patients

Characteristics	Group I J -CTO Score <2 (N. = 39)	Group II J-CTO Score ≥2 (N. = 31)	*P*
Site Left anterior descending artery Left circumflex coronary artery Left main-Left circumflex Right coronary artery	 22(56.4%) 5(12.8%) 0(0.0%) 12(30.8%)	 11(35.5%) 4(12.9%) 1(3.2%) 15(48.4%)	0.235

J-CTO score: The Japanese Chronic Total Occlusion score

Table 3. Lesion characteristics and CTO variables of the studied patients

Characteristics	Group I J -CTO Score <2 (N. = 39)	Group II J-CTO Score ≥2 (N. = 31)	*P*
The Stump of the Lesion Blunt Tapering	 13(33.3%) 26(66.7%)	 29(93.5%) 2(6.5%)	<0.001*
Length of the lesion <20 ≥20	 34(87.2%) 5(12.8%)	 8(25.8%) 23(74.2%)	<0.001*
Bending	0(0.0%)	5(16.1%)	0.014*
Calcification	10(25.6%)	16(51.6%)	0.025*

J-CTO score: The Japanese Chronic Total Occlusion score

Table 4. Time to pass the wire in both groups

	Group I J-CTO Score <2 (N. = 39)	Group II J-CTO Score ≥2 (N. = 31)	*P*
Time to pass wire (min) Mean ± SD	17.9±5.3 min	31±6.4 min	0.001*

J-CTO score: The Japanese Chronic Total Occlusion score

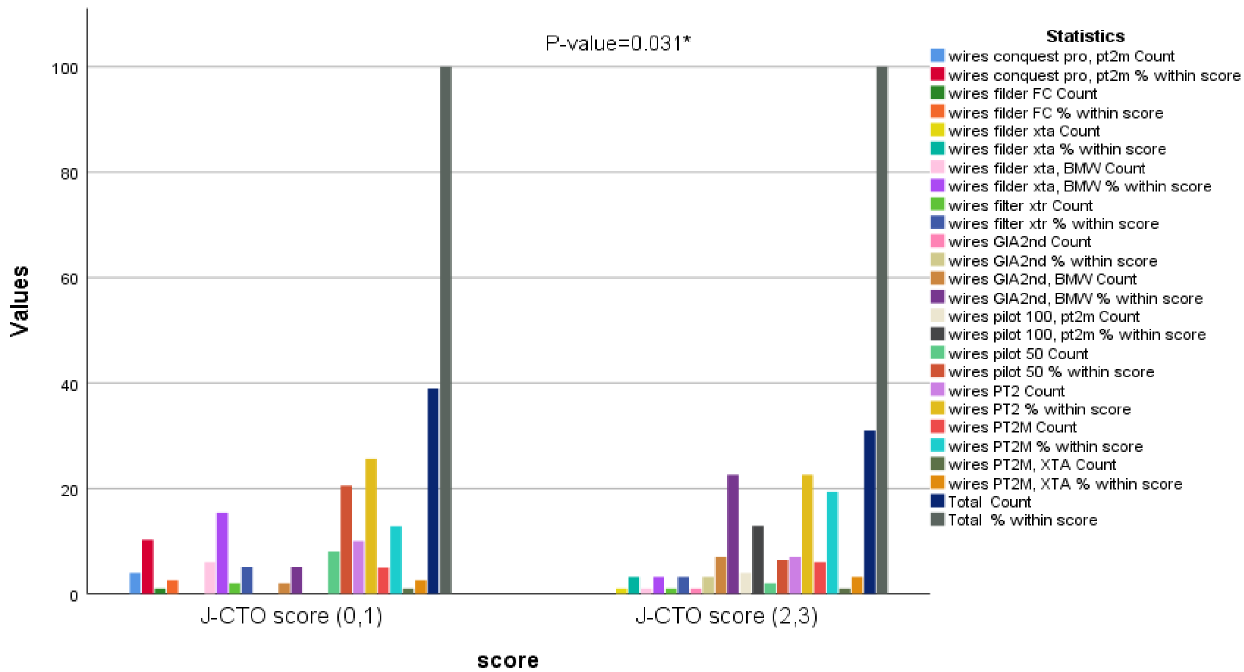

Figure 1. The image presents the different types of wires were used in the present study.

Our results showed the amount of dye used (Table 5). The primary outcome of the study, procedural success rate, is presented in Table 6. MACE or urgent need for TLR are shown in Table 7. The effect of risk factors on success rate in successful versus failed cases is presented in Table 8. Table 9 demonstrates no difference between the two groups regarding the coronary vessel involved in the CTO lesion and the success rate. The effect of J-CTO score variables on success rate is shown in Table 10; these variables were significant predictors of procedural success. A cutoff score of ≥2 was associated with procedural failure, with 100% sensitivity and 91% specificity, and may be used as a negative predictive factor when treating CTO lesions (Table 11, Figure 2).

Table 5. Amount of dye used in both groups

	Group I J-CTO Score <2 (N. = 39)	Group II J-CTO Score ≥2 (N. = 31)	*P*
Amount of dye used (mL)	194.8 mL ±25 mL	296.8mL ±14 mL	<0.001*

J-CTO score: The Japanese Chronic Total Occlusion score

Table 6. Outcomes of the study in the studied groups

Outcomes	Group I J-CTO Score <2 (N. = 39)	Group II J-CTO Score ≥2 (N. = 31)	*P*
Success Failure	39(100.0%) (0.0%)	24(77.4%) 7(22.6%)	0.002*

J-CTO score: The Japanese Chronic Total Occlusion score

Table 7. Outcomes of the study in the studied groups by MACE

Complications	Group I J-CTO Score < 2 (N. = 39)	Group II J-CTO Score ≥2 (N. = 31)	*P*
No MACE Unstable angina	38(97.4%) 1(2.6%)	31(100.0%) 0(0.0%)	0.369

J-CTO score: The Japanese Chronic Total Occlusion score, MACE: major adverse cardiac events

Table 8. Comparison of risk factors and sex on procedural success

Characteristics	Successful Cases (N. = 63)	Failed Cases (N. = 7)	*P*
Age (mean ±SD)	56.6±5.8	58.7±2.9	0.343
Sex Female Male	 19(30.1%) 44(69.9%)	 5(71.4%) 2(28.6%)	0.040*
Diabetes mellitus	20(31.7%)	1(14.3%)	0.665
Hypeternsion	13(20.6%)	3(42.9%)	0.346
Smoking	10(15.9%)	1(14.3%)	0.926

Table 9. Comparison between the site of chronic total occlusions and the procedural success

Characteristics	Successful Cases (N. = 63)	Failed Cases (N. = 7)	*P*
Site Left anterior descending Left circumflex coronary artery Left main-Left circumflex Right coronary artery	 28(44.4%) 8(12.7%) 1(1.6%) 26(41.2%)	 5(71.4%) 1(14.3%) 0(0.0%) 1(14.3%)	0.393

Table 10. Association between J-CTO score variables and procedural success

Characteristics	Successful Cases (N. = 63)	Failed Cases (N. =7)	*P*
Stump Blunt Tapering	 34(53.9%) 29(45.3%)	 7(100.0%) 0(0.0%)	0.021*
Length of the Lesion <20 ≥20	 42(66.7%) 21(33.3%)	 0(0.0%) 7(100.0%)	0.001*
Bending	3(4.7%)	2(28.6%)	0.073
Calcification	21(33.3%)	5(71.4%)	0.097

J-CTO score: The Japanese Chronic Total Occlusion score

Table 11. Cutoff, sensitivity, specificity, positive predictive value, and negative predictive value for predicting failure from J-CTO scores

Items	J-CTO Score
Cutoff	≥2
Area under the curve	0.953
Sensitivity	100%(85-100)
Specificity	91(82-95)
Positive predictive value	100(85-100)
Negative predictive value	90(80-92)

J-CTO score: The Japanese Chronic Total Occlusion score

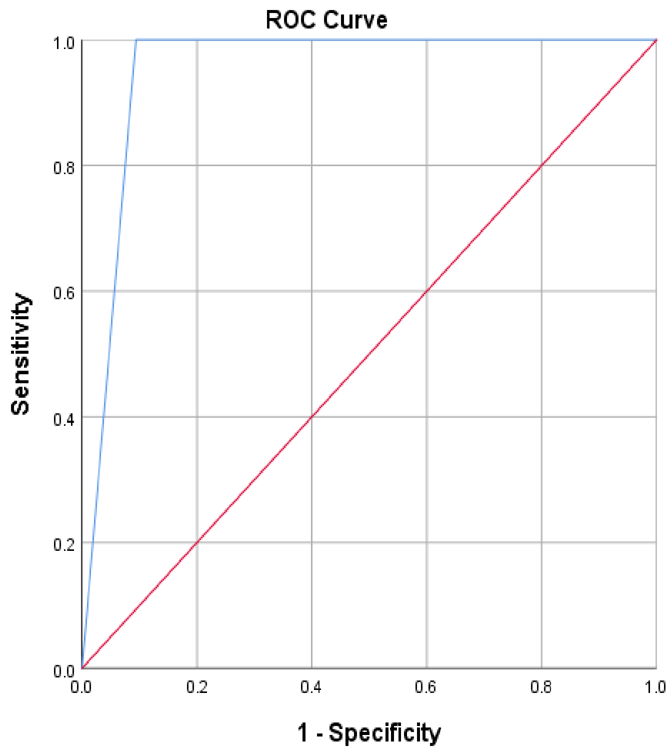

Figure 2. The image depicts the receiver operating characteristic curve for predicting procedural failure based on the J-CTO score.

J-CTO score: The Japanese Chronic Total Occlusion score

Table 12. Follow-up of all patients' EF (%) and LV WMSI

	Baseline EF%	EF% After 6 Months	*P*
Normal contractility N. =13	52%±2.2%	57%±1.7%	<0.001*
Impaired contractility N. =50	37%±5.2%	45%±2.5%	<0.001*
	Baseline LV WMSI	WMSI After 6 Months	
Normal contractility N. =13	1.1±0.1	1±0.1	0.017*
Impaired contractility N. =50	1.4±0.2	1.15±0.1	<0.001*

EF: ejection fraction, LV: left ventricle, WMSI: wall motion score index

Symptomatic patients included 1 patient (2.6%) in Group I and 3 patients (12.5%) in Group II, with an insignificant difference (*P = 0.193*). Table 12 presents follow-up LVEF and LV WMSI for all patients. Follow-up coronary angiography is shown in Table 13.

Table 14 summarizes the need for TLR in both groups, and TLR according to J-CTO score is shown in Table 15. Table 16 demonstrates a significant association between the need for TLR, the presence of diabetes, and vessel angulation.

Table 13. Scheduled follow-up angiography

	Group I J-CTO Score <2 (N. =39)	J-CTO Score ≥ 2 (N. =24)	*P*
No significant in-stent restenosis Significant in-stent restenosis	3(7.7%) 1(2.6%)	5(20.8%) 4(16.7%)	0.187 0.044

J-CTO score: The Japanese Chronic Total Occlusion score

Table 14. Target lesion revascularization

	Group I J-CTO<2 (N. =39)	Group II J-CTO Score ≥2 (N. =24)	*P*
Target lesion revascularization	1(2.6%)	4(16.7%)	0.044

J-CTO score: The Japanese Chronic Total Occlusion score

Table 15. Comparison between low and high J-CTO scores regarding procedural outcomes

J-CTO Scores	Lesion Success Rate	TLR-Free Survival Rate	The Net Midterm Survival Rate
Group I <2	100%	97.4%	97.4%
Group II ≥2	77.4%	83.3%	64.4%
P	0.002*	0.046	0.001

J-CTO score: The Japanese Chronic Total Occlusion score

Table 16. Comparison between patients with normal follow-up coronary angiography and patients with significant lesions needing target lesion revascularization regarding different risk factors

Characteristics	Normal Controlled Coronary Angiography (N. =58)	Significant Lesion (N. =5)	*P*
Age (mean±SD)	56.6±6.0	55.2±5.3	0.595
Sex Female Male	20(34.5%) 38(65.5%)	0(0.0%) 5(100.0%)	0.112
Diabetes mellitus	19(32.8%)	4(80.0%)	0.035*
Hypetension	14(24.1%)	2(40.0%)	0.434
Smoking	9(15.5%)	0(0.0%)	0.341
Stump Blunt Tapering	30(51.7%) 28(48.3%)	4(80.0%) 1(20.0%)	0.224
Length of the lesion <20 ≥20	33(56.9%) 25(43.1%)	5(100.0%) 0(0.0%)	0.059
Bending	2(3.4%)	2(40.0%)	0.029*
Calcification	20(34.5%)	2(40.0%)	0.804

DISCUSSION

The primary reason most physicians have relatively low application rates of CTO PCI may be uncertainty regarding the procedure's success rate in resource-limited centers. Access to indices that predict potential CTO treatment success on a lesion-by-lesion basis may alleviate this uncertainty. To establish a scoring method for determining difficulty in guidewire crossing through CTO lesions, study lesions were selected from the J-CTO (Multicenter CTO Registry of Japan) registry cohort. [30]

In our two-center study, the overall success rate of coronary CTO PCI was 90%, with 100% success in Group I cases with J-CTO score <2 and 77.4% in Group II patients with J-CTO ≥2 lesions. These results are consistent with Han et al., [31] who reported an overall CTO success rate of 88.9%. Success was higher in easy and intermediate J-CTO lesions (score <2) compared with difficult and very difficult lesions (J-CTO score ≥2).

Guidewire crossing time differed significantly between groups, with a longer time required for lesions with J-CTO score ≥2 (31 ± 6.4 min) compared with lesions with J-CTO score <2 (17.9 ± 5.3 min; *P* = 0.001).
These findings are consistent with Pershad et al., [32] who reported that guidewire success rates declined in proportion to lesion difficulty. Tanaka et al. [171] found that lesion success rates by J-CTO score were approximately 97%, 92%, 87%, and 74% for scores of 0, 1, 2, and ≥3, respectively.

In our study, female patients were associated with a higher procedural failure rate compared with male patients. Pershad et al. [32] recently reported a sex-stratified analysis from the OPEN-CTO registry, showing similar procedural success in both sexes. This difference may reflect referral bias, with only women with lower J-CTO scores being referred for CTO PCI.

Criteria favoring procedural success by the antegrade approach in our study included lesions with a tapered end, lesions <20 mm in length, and lesions angulated <45°. Conversely, criteria associated with procedural failure were blunt proximal cap (*P* = 0.021) and lesion length >20 mm (*P* = 0.001). These findings were partially consistent with Han et al., [31] who reported that PCI success declined with longer duration of occlusion, presence of bridging collaterals, greater occlusion length, moderate to severe calcification or tortuosity, and ostial or distal location of CTO lesions.

Our results are also partially aligned with Maiello et al., [33] who analyzed 27 clinical, morphologic, and procedural variables as potential predictors of successful outcomes. Success rates were significantly influenced by:
(a) Duration of occlusion: 89% if ≤1 month, 87% if 1–3 months, 45% if >3 months, and 60% for CTOs of unknown age; (b) Morphology of occlusion: 83% in tapered lesions and 51% in abrupt lesions; (c) Length of occlusion: 71% in lesions <15 mm and 60% in lesions >15 mm; (d) Bridging collaterals: 29% if present and 67% if absent.

The introduction of new strategies, such as the parallel wire technique, has recently improved procedural success rates. [34, 35] In our study, only 1 patient (1.4%) experienced a complication, consisting of a small right coronary artery perforation with mild pericardial effusion, which resolved spontaneously without resulting in MACE. This finding is consistent with Ellis et al., [36] who reported an incidence of coronary perforation of <1%.

Follow-up echocardiography demonstrated improvement compared with baseline, consistent with Galassi et al., [37] who reported increased LVEF 6 months after successful CTO PCI in patients with low and mid-range LVEF. This improvement is likely attributable to reduced adverse LV remodeling.

Our study also found significant improvement in segmental wall motion indices on follow-up echocardiography compared with baseline. These results align with the EXPLORE CMR study, which showed that revascularization of dysfunctional myocardium supplied by the CTO led to greater recovery of regional LV function from baseline to 4-month follow-up compared with no revascularization of the CTO territory. [38]

In our study, the incidence of TLR was 2.6% for J-CTO <2 and 16.7% for J-CTO ≥2, with a significant difference (P = 0.044). This finding aligns with Abe et al., [39] who reported that high J-CTO score lesions (J-CTO ≥2) independently correlated with increased TLR risk.

Our results are also consistent with Misuru et al., [39] who reported midterm success rates according to J-CTO score of 0, 1, 2, and ≥3 as 91.9%, 81.9%, 72.1%, and 63.7%, respectively.

We found a significant association between the need for TLR and the presence of diabetes mellitus (DM) and vessel angulation, attributable to significant in-stent restenosis. This finding is consistent with Mashaly et al., [40] who reported that DM in patients with CTO was associated with higher rates of TLR and MACE. The authors also reported that, among patients undergoing PCI with DES for CTO lesions, MACE was more common in the DM group. Possible mechanisms include increased intimal hyperplasia after PCI and elevated levels of fibrinogen, factor VII, and plasminogen activator inhibitors.

CONCLUSIONS

At the two limited-resource centers in this study, lesions with lower J-CTO scores were associated with a high rate of procedural antegrade success, shorter guidewire manipulation time, and an increased TLR–free survival rate compared with lesions with higher J-CTO scores, resulting in a higher net midterm success rate. Lesions with a high J-CTO score remain challenging. Calcification and an occlusion length of 20 mm or more were the primary factors affecting the procedure and TLR of a CTO lesion treated with a DES. To reduce the TLR rate for these complex lesions, we should consider different PCI strategies for CTO.

Study Limitations

First, the decision to perform follow-up angiography was based on patient symptoms and was not performed routinely for all patients, which may have increased the observed TLR rate. Second, a longer follow-up period beyond 1 year is needed to assess net long-term success.

Recommendations

Tertiary centers with limited resources in developing countries could develop unique scoring systems, based on the established J-CTO score, to select patients with CTO who have a high likelihood of successful antegrade revascularization with an optimal cost-benefit ratio.

Declarations

Ethics Approval and Consent to Participate

Written informed consent was obtained from all patients after they were informed of the expected benefits and potential risks of the chronic total occlusion revascularization technique. The study was approved by the Committees of Research and Medical Ethics at Beni-Suef University (approval FMBSUREC/05072020/Mahmoud, July 5, 2020) in accordance with the Declaration of Helsinki.

Consent for Publication

Not applicable.

Availability of Data and Material

The data sets used and analyzed during the current study are available from the corresponding author on reasonable request.

Conflict of Interest

The authors declare no competing interests.

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Clinical Trial Number

Not applicable.

Author Contributions

Y.A.: Enrolled the patients, performed the intervention and noninvasive tests, and revised the manuscript. M.M.: Managed patient follow-up and contributed to writing the manuscript. K.A.: Performed the intervention, interpreted the data, and contributed to the manuscript. O.A.: Enrolled the patients, performed the intervention and noninvasive tests, analyzed and interpreted the data, and wrote the manuscript. All authors read and approved the final manuscript.

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