Journal of Cardiovascular Disease Research

ISSN:0975 -3583,0976-2833 VOL 15, ISSUE 10, 2024

# Predictors of Successful Outcomes in Percutaneous Coronary Intervention in Chronic Total Occlusion

**Dharshan P[1], Praveen Velappan[2], Veena Felix[3], Lais Mohammed[4]**

**1 Senior Resident, Department of Cardiology, Government Medical College, Thiruvananthapuram**

**2 Associate Professor, Department of Cardiology, Government Medical College, Thiruvananthapuram**

**3 Assistant Professor, Department of Cardiology, Government Medical College, Thiruvananthapuram**

**4 Assistant Professor, Department of Cardiology, Government Medical College, Thiruvananthapuram**

**Corresponding Author:Name: Dharshan P**

**Designation: Senior Resident,Department: Department of Cardiology**

**Institute: Government Medical College, Thiruvananthapuram**

## Abstract

**Background:**Chronic total occlusion (CTO) remains a particularly challenging lesion subset for percutaneous coronary intervention (PCI). Over the past decade, there has been a significant increase in the number of PCI procedures performed for CTOs, driven by a deeper understanding of the anatomy and the development of advanced skills, along with the availability of specialized hardware. In this context, we aimed to study the predictors of successful outcomes of CTO PCI in a public sector hospital in Kerala.

**Objectives:**To assess the predictors of successful outcomes in patients undergoing PCI in Chronic Total Occlusion.

**Methods:**This was a single-centre non-randomized descriptive study on CTO PCI done at our centre.Detailed baseline clinical, angiographic and revascularization data were collected. Outcome of CTO PCI was also noted. All baseline parameters were analysed for predicting the outcome of CTO PCI.

**Results:**A total of 212 patients [Men 178(84%)] were treated with PCI forCTO. Out of these, 159 patients (75%) had successful PCI and was unsuccessful in53 patients (25%). Although predisposing factors like diabetes (60.4%),hypertension (61.8%), and dyslipidemia (58.5%) were observed in significantnumber of cases, there was no significant difference between the clinical andlaboratory characteristics among the two groups. The Left anterior coronary artery(LAD) was the target vessel in most of the patients (42%). The factors that aresignificantly associated with failure include Lesion length greater than 20 mm($p<0.001$), Lesions with calcification ($p<0.001$), Bend greater than 45 degrees($p=0.002$) and Distal vessel calcium.

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The prevalence of blunt stump, collaterals, and ostial lesions were similar betweenthe two groups. However, none of these factors were significant in determiningeither success or failure in the outcomes. The mean Japanese chronic total occlusion(J-CTO) score was 1.81 ± 0.9 (mean ± SD) and higher J-CTO Score was associatedwith higher failure rates.

**Conclusion**: The success rates for CTO PCI in this registry was about 75%. Our study also demonstrated that an occlusion length of greater than 20 mm, the presence of calcification, tortuosity, and distal vessel calcium were independently associated with poor procedural success in chronic total occlusion (CTO) percutaneous coronary intervention (PCI).

**Keywords:**Percutaneous coronary intervention, Chronic total occlusion.

**Introduction:**

Although Chronic Total Occlusion (CTO) is observed in up to 20% of patients undergoing diagnostic angiography and in up to 35% of those after an Acute Coronary Syndrome[1,2,3], the interventional treatment of coronary CTOs remains a challenging endeavour.With advancements in Percutaneous Coronary Intervention (PCI) techniques, the development of appropriate hardware, and improved operator skills, procedural success rates have increased from 50–60% to 75–90%. As a result, the procedure is now attempted more frequently.[2,3]

The clinical benefit of CTO revascularization remains a topic of debate. Several observational studies have demonstrated that successful CTO revascularization leads to improved cardiovascular outcomes. A meta-analysis by Hoebers et al.[4] demonstrated that successful CTO revascularization led to improvements in left ventricular ejection fraction and clinical outcomes. However, these findings were not entirely confirmed by the results of the EXPLORE and DECISION trials.[5,6]

The objective of the present study was to assess the factors contributing to success and failure in CTO-PCI procedures among Indian patients. The study aimed to determine the technical success rate and analyse the factors influencing successful outcomes.

**Material & methods**

Study design

This is a prospective study involving consecutive patients who underwent PCI for CTO of native coronary arteries between January 2023 and December 2023 at the Department of Cardiology in a tertiary care public sector hospital in South India.

Inclusion criteria

All patients aged 18 years and older undergoing PCI for CTO, whether as an elective or ad hoc procedure, who consented to participate in the study were included.

Exclusion criteria

Patients who did not provide informed consent, as well as those with preexisting severe renal, hepatic, pulmonary, or other serious systemic diseases, were excluded. Additionally, individuals presenting with acute coronary syndrome were also excluded from the study.

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Definitions

A Chronic Total occlusion is defined as a 100 percent stenosis of a coronaryartery with Thrombolysis In Myocardial Infarction (TIMI) 0 flow for more thanthree months (based on angiography or symptoms).

**Technical success** is defined as achievement of TIMI grade 2 or greater antegrade flow in all ≥2.5-mm distal branches with <30% residual stenosis of the target CTO lesion at procedure end.

**Procedure**

The operators performed the PCI procedure according to their practice at that time.Routinely start most cases with antegrade wire escalation and if we enter thesubintimal space (dissection), we move to antegrade dissection re-entry (ADR) if thedistal vessel is suitable for this approach and there is low risk of side branchcompromise. In patients who have good interventional collaterals, we wouldconsider retrograde approach.Baseline characteristics procedural and angiographic characteristics were recorded. All patients were pretreated with aspirin and a P2Y12 receptor antagonist such as clopidogrel, prasugrel or ticagrelor before the procedure.

**Statistical analysis**

Statistical analysis of the data was performed using SPSS20.0(IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp). Continuous variables were presented as mean, standard deviations (inter-quartile range and median if not normally distributed) and were compared using Student unpaired t-test. Categorical variables were presented as counts and percentages and compared with the chi-square test when appropriate (expected frequency >5). A p-value of <0.05 was considered significant. A p value <0.05 will be considered statistically significant.

**Results**

A total of 212 lesions in 212 patients (178 men; mean age: 58.41±9.52 years) were treated with PCI for CTO.Out of these, 159 patients (75%) had successful PCI and was unsuccessful in 53 patients (25%).The baseline demographic and clinical characteristics of the patients with successful and unsuccessful CTO PCI are given in **Table 1.**Although predisposing factors like diabetes (60.4%), hypertension (61.8%), and prior coronary artery disease (62.7%) was observed in significant no. of cases, there was no significant difference between the clinical and laboratory characteristics among the two groups.

Majority of the patients had multivessel disease (73%) and the left coronary artery (LAD) was the target vessel in most of the patients (42%).Complete lesion characteristics for both the groups are summarised in **Table 2.**Most patients (36.8%) presented with JCTOscore2 and higher J-CTOscorewasassociatedwithhigher failure rates (p <0.001).The very important factorsdeciding failure wasLesion length greater than 20 mm (p<0.001), Lesions with calcification (p<0.001), Bend greater than 45 degrees(p=0.002) and Distal vessel calcium(p=0.012).The prevalence of blunt stump, collaterals, and ostial lesions was similar

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between the two groups. However, none of these factors were significant in determining either success or failure in the outcomes.

Out of a total sample of 212 individuals, 106 (50%) used the radial access route, 63(29.7%) used the femoral access route, and 43 (20.3%) used a dual injection approach.This indicates that radial access was the most commonly used method, followed by femoral access and dual injection.191 (90.1%) had their CTO crossed on the first attempt, 14 (8.5%) on the second attempt, and 3 (1.4%) required more than two attempts. The vast majority, 209 patients (98.6%), underwent an antegrade guidewire approach, while a minority of 3 patients (1.4%) were treated using a retrograde approach.Complete details of the angiographic and procedural characteristics for the two groups are given in **Table 3 and Table 4.**

There was no significant difference in procedural time (p=0.953) or fluoroscopy time (p=0.982) between the success and failure groups. However, the amount of contrast used (p=0.062) and the number of wires used to cross the CTO (p=0.095) were higher in the unsuccessful CTO PCI group, though these differences were not statistically significant. Guidewire success was achieved in 192 patients (90.5%). Of these, 151 patients (78.6%) underwent PCI with stenting, and 15 patients (7.0%) underwent plain old balloon angioplasty (POBA). In 26 patients (13.5%), the procedure was classified as an unsuccessful CTO attempt because even the lowest profile balloons or microcatheters could not be advanced across the lesion, or the procedure was abandoned due to complications. Among the 15 patients who underwent POBA, technical success was achieved in only 8, while the remaining 7 were classified as unsuccessful CTO attempts.

As shown in **Table 5,** in almost half of the patients 88 (45.8%), the lesion was successfully crossed with a maximum of two wires. As shown in **Table 6,** the most frequently used wires that successfully crossed the lesion were Fielder XT in 50 patients (23.5%), GAIA 2 in 42 patients (19.8%), CROSS IT 100 in 23 patients (10.8%), GAIA 1 in 17 patients (8%), CROSS IT 200 in 12 patients (5.6%), PROGRESS 80 in 12 patients (5.6%), and PROGRESS 120 in 11 patients (5.1%). In the remaining 21.6% of patients, other wires were successful in crossing the lesion.

## Discussion

The aim of the present study was to identify factors affecting the outcomes ofpercutaneous coronary intervention (PCI) for chronic total occlusion (CTO) lesions.The overall success rate of CTO PCI in the study was 75%, which is highly promising considering that the average JCTO score for all attempted cases was 1.81 ± 0.90. This score falls between intermediate and difficult levels, indicating that the success rate is notable given the complexity of the cases.Prior Indian studies have reported CTO PCI success rates ranging from 68% to 87%.[7,8,9]For example, the study by Goel et al., one of the largest datasets with 632patients over a 9-year period, reported an overall success rate of 74.7%. The averageJ-CTO score in Goel et al.'s study was 1.5, which is similar to the 1.81 ± 0.90observed in our study.Additionally, data from a high-volume centre in South India reported an even higherCTO PCI success rate of 87% in a selected population,[10] with an average J-CTO score of 1.78 ± 0.12, but this study used the retrograde technique in about 10% of cases, compared

ISSN:0975 -3583,0976-2833 VOL 15, ISSUE 10, 2024

to just 1.4% in our study. The limited use of the retrograde technique in our study may have contributed to the slightly lower overall success rate observed.

The most important factor for the success of a CTO PCI is the successful wiring of the CTO segment. In our study, once the wire crosses the CTO segment, the success rate is as high as 82.8% (159 out of 192 cases).Morphology of the CTO lesion is considered to affect the guidewire crossing and therefore is the strongest predictor of failure of CTO PCI procedure.[10]

Despite the extensive research investigating the factors that influence the success of CTO PCI, thereremains ongoing debate within the medical community about the relative impact ofvarious clinical and angiographic factors on the procedure's technical success andoverall clinical outcomes. Traditionally the lesion parameters which are observed to reduce the success rate of CTO PCI include presence of blunt stump, presence of bridging collaterals, presence of side branch at occlusion site; severe tortuosity, calcification, multivessel disease, and lesion length >20 mm.[11,12]

Our study showed occlusion length >20mm, presence of calcification, tortuosityand distal vessel calcium to be independently associated with poor proceduralsuccess of CTO PCI. However, factors such as the presence of a blunt stump, bridging collaterals, collateral filling of a third of the vessel, and multivessel disease did not significantly impact the success or failure rates of CTO PCI.

This suggests that these characteristics, while relevant in other contexts, may not be as influential on procedural outcomes in our specific cohort.The differences in observations regarding factors influencing CTO PCI outcomes may be attributed to variations in devices, techniques and operator experience.

As shown in Table 6, the GAIA and Fielder family of wires were the most successful in crossing CTOs. The main explanation is that, in comparatively softer lesions, success is achieved by polymer-jacketed wires, which are able to locate the microchannel in the CTO segment, regardless of the presence or absence of a tapered stump or the duration of the CTO. On the other hand, in cases where the lesion is hard, the Gaia series, particularly Gaia 2, proved to be successful.Gaia series wires are 0.014″ hydrophilic guide wire with 1.7, 3.5 and 4.5 gm tip load options and has a micro-cone tip. The Gaia wire, with its high manoeuvrability and penetrability due to its micro-cone tip, makes it easier to create an entry route through hard tissue and the fibrous cap. This led us to conclude that the traditional wire escalation technique may not be necessary. If a lubricious wire fails to cross, it may be more effective to proceed directly to a stronger wire rather than using an intermediate wire.

## Conclusion

Recent advances in hardware have made CTO PCI technique safe, effective, and efficient. However, case selection is crucial, and in this context, identifying predictive factors for successful CTO intervention in a specific population is valuable for selecting the most suitable candidates for PCI.Our study demonstrated that an occlusion length of greater than 20 mm, the presence of calcification, tortuosity, and distal vessel calcium were independently associated withpoor procedural success in chronic total occlusion (CTO) percutaneous coronaryintervention (PCI). The wire escalation strategy should be adjusted when the initial

ISSN:0975 -3583,0976-2833 VOL 15, ISSUE 10, 2024

soft (polymer) wire fails. In such cases, it is reasonable to move directly to a high tip-load wire, such as Conquest Pro, GAIA 2, without relying on intermediate wires.

**Limitations**

This study is mainly limited by the fact that it is a single centre non-randomized data. The number of patients was small and majorityof revascularization was done through antegrade approach and <2% was done throughretrogradeapproach.Also, the use of microcatheters in this study was limited to only 20%.

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**Tables**

**Table 1. Association between baseline characteristics and technical success**

| BASE LINE | | Final result | | p value |
|---|---|---|---|---|
| | | Failure (n-53) | Success(N-153) | |
| SEX | FEMALE | 7 (13.2%) | 27 (17.0%) | 0.517 |
| | MALE | 46 (86.8%) | 132 (83.0%) | |
| DIABETES MELLITUS | NO | 18 (34.0%) | 66 (41.5%) | 0.331 |
| | YES | 35 (66.0%) | 93 (58.5%) | |
| HYPERTENSION | NO | 15 (28.3%) | 66 (41.5%) | 0.087 |
| | YES | 38 (71.7%) | 93 (58.5%) | |
| DYSLIPIDEMIA | NO | 21 (39.6%) | 67 (42.1%) | 0.748 |
| | YES | 32 (60.4%) | 92 (57.9%) | |
| PRIOR CAD | CCS | 17 (32.1%) | 62 (39.0%) | 0.42 |
| | UNSTABLE ANGINA | 5 (9.4%) | 7 (4.4%) | |
| | NSTEMI | 16 (30.2%) | 53 (33.3%) | |
| | STEMI | 15 (28.3%) | 37 (23.3%) | |

Table 2: Lesion characteristics

| Lesion characteristics | | Final result | | p value |
|---|---|---|---|---|
| | | Failure | Success | |
| Target Vessel | LAD | 18 (34.0%) | 71 (44.7%) | 0.087 |
| | RCA | 27 (50.9%) | 54 (34.0%) | |
| | LCX | 8 (15.1%) | 34 (21.4%) | |
| Vessel Involvement | Single Vessel Disease | 13 (24.5%) | 44 (27.0%) | 0.654 |
| | Multivessel Disease | 40 (75.5%) | 115 (71.7%) | |
| Collaterals | Ipsilateral | 18 (34.0%) | 72 (45.3%) | 0.657 |
| | Contralateral | 26 (49.1%) | 65 (40.9%) | |
| | Bridging | 4 (7.5%) | 11 (6.9%) | |

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| | | | | |
|---|---|---|---|---|
| Syntax Score | <22 | 20 (37.7%) | 73 (45.9%) | 0.337 |
| | 23-32 | 18 (34.0%) | 38 (23.9%) | |
| | >32 | 15 (28.3%) | 48 (30.2%) | |
| JCTO Score 1.81 ± 0.9 (Mean ± Sd) | Easy (0) | 1 (1.9%) | 15 (9.4%) | p<0.001 |
| | Intermediate (1) | 8 (15.1%) | 55 (34.6%) | |
| | Difficult (2) | 12 (22.6%) | 66 (41.5%) | |
| | Very Difficult (>3) | 32 (60.4%) | 23 (14.5%) | |
| Occlusion Length >20mm | No | 10 (18.9%) | 68 (42.8%) | 0.002 |
| | Yes | 43 (81.1%) | 91 (57.2%) | |
| Calcification | No | 19 (35.8%) | 107 (67.3%) | p<0.001 |
| | Yes | 34 (64.2%) | 52 (32.7%) | |
| Bend>45 | No | 29 (54.7%) | 123 (77.4%) | 0.002 |
| | Yes | 24 (45.3%) | 36 (22.6%) | |
| Blunt Stump | No | 21 (39.6%) | 80 (50.3%) | 0.117 |
| | Yes | 32 (60.4%) | 79 (49.7%) | |
| Retry Lesion | No | 47 (88.7%) | 148 (93.1%) | 0.307 |
| | Yes | 6 (11.3%) | 11 (6.9%) | |
| Distal Vessel Size Atleast 2mm | No | 21 (39.6%) | 26 (16.4%) | p<0.001 |
| | Yes | 32 (60.4%) | 133 (83.6%) | |
| Distal Vessel Filling AtleastOnethird Of The Total Vessel | No | 23 (43.4%) | 48 (30.2%) | 0.078 |
| | Yes | 30 (56.6%) | 111 (69.8%) | |
| Distal Vessel Calcium | No | 40 (75.5%) | 142 (89.3%) | 0.012 |
| | Yes | 13 (24.5%) | 17 (10.7%) | |
| Ostial Lesion | No | 46 (86.8%) | 133 (83.6%) | 0.584 |
| | Yes | 7 (13.2%) | 26 (16.4%) | |

Table 3: Procedural Characteristics.

| Parameters | | Final result | | p value |
|---|---|---|---|---|
| | | Failure | Success | |
| Number Of CTO Attempted N % | | | | |
| | First Attempt | 146(92%) | 45(85%) | NS |
| | Second Attempt | 11(7%) | 7(13%) | NS |

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| | | | | |
|---|---|---|---|---|
| | >2 Attempt | 2(1%) | 1(2%) | NS |
| Anti Platelet | Clopidogrel | 48 (90.6%) | 143 (89.9%) | |
| | Ticagrelor | 5 (9.4%) | 16 (10.1%) | 0.894 |
| Guide Wire Approach Used | Antegrade | 52 (98.1%) | 157 (98.7%) | |
| | Retrograde | 1 (1.9%) | 2 (1.3%) | 0.737 |
| Imaging | No | 53 (100%) | 156 (98.1%) | |
| | Ivus | 0 (0%) | 3 (1.9%) | 0.314 |
| Use Of Calcium Debulking Strategy | No | 53 (100%) | 152 (95.6%) | |
| | Scoring Balloon | 0 (0%) | 6 (3.8%) | |
| | Rota | 0 (0%) | 1 (0.6%) | 0.299 |
| Lesion Crossed In Less Than 30min | No | 50 (94.3%) | 55 (34.6%) | |
| | Yes | 3 (5.7%) | 104 (65.4%) | p<0.001 |
| Access Route | Radial | 23 (43.4%) | 83 (52.2%) | |
| | Femoral | 19 (35.8%) | 44 (27.7%) | |
| | Dual Injection | 11 (20.8%) | 32 (20.1%) | 0.468 |

TABLE 4 :Association between procedure and technical success

| Final Result | | N | Mean | Std. Deviation | Std. Error Mean | t value | p value |
|---|---|---|---|---|---|---|---|
| No Of Wires Used | Success | 159 | 2.37 | .79 | .06 | 1.675 | 0.095 |
| | Failure | 53 | 2.58 | .81 | .11 | | |
| Stent Per Lesion | Success | 159 | 1.27 | .61 | .05 | 14.156 | NA |
| | Failure | 0 | 0 | 0 | 0 | | |
| Stent Length Mm | Success | 159 | 41.06 | 23.38 | 1.85 | 12.168 | NA |
| | Failure | 53 | 0 | 0 | 0 | | |
| Stent Diameter | Success | 159 | 2.7 | .69 | .05 | 27.458 | NA |
| | Failure | 53 | 0 | 0 | 0 | | |
| Number Of Balloons Used | Success | 159 | 3.5 | 1.25 | .09 | 11.552 | NA |
| | Failure | 53 | 1.3 | 1.33 | .18 | | |
| Procedure Time | Success | 159 | 67.2 | 34.80 | 2.76 | 0.059 | 0.953 |
| | Failure | 53 | 66.8 | 31.55 | 4.33 | | |
| Fluro Time | Success | 159 | 24.07 | 12.10 | .95 | 0.022 | 0.982 |

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| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Min | Failure | 53 | 24.11 | 12.30 | 1.68 | | |
| Contrast Volume | Success | 159 | 191.35 | 71.10 | 5.63 | 1.878 | 0.062 |
| | Failure | 53 | 170.10 | 72.11 | 9.90 | | |

**Table 5:Number of wires that were used to cross the CTO successfully**

| No of wires | No of patients |
|---|---|
| 1 | 27 |
| 2 | 88 |
| 3 | 50 |
| 4 | 9 |
| 5 | 2 |
| 6 | 1 |

**Table 6:Showing the wire that successfully crossed the CTO**

| Wire that crossed | No. of Cases |
|---|---|
| Fielder XT A | 50 |
| GAIA 2 | 42 |
| CROSS IT 100 | 23 |
| GAIA 1 | 17 |
| CROSS IT 200 | 12 |
| PROGESS 80 | 12 |
| PROGRESS 120 | 11 |
| PILOT 150 | 6 |
| PILOT 200 | 5 |
| GAIA 3 | 5 |
| MIRACLE 6 | 3 |
| CONQUEST PRO 12 | 2 |
| WHISPER Extra support | 2 |
| MIRACLE 3 | 1 |
| SUOH 3 | 1 |