ORIGINAL ARTICLE

PREDICTORS AND OUTCOMES OF FAILED RECANALIZATION OF CHRONIC TOTAL OCCLUSIONS IN PATIENTS WITH STABLE CORONARY ARTERY DISEASE AT A TERTIARY CARE CARDIAC CENTER

Muhammad Fasih Ullah Khan[1], Muhammad Hasnain Iqbal[2]✉, Naveed Yaqoob[3], Fahad Khalid[3]

[1]Pakistan Institute of Medical Sciences, Islamabad-Pakistan, [2]HBS Medical and Dental College, Islamabad-Pakistan
[3]NUST School of Health Sciences, Islamabad-Pakistan

Background: Chronic Total Occlusions (CTOs) are a challenging subset of coronary artery disease (CAD), often necessitating complex percutaneous coronary intervention (PCI). Despite advancements in tools and techniques, failure to recanalize CTOs remains a significant clinical concern, particularly in stable CAD patients. This study aimed to identify predictors and evaluate outcomes of failed CTO recanalization in a tertiary care cardiac center. **Methods:** A retrospective analysis was conducted on patients with stable CAD who underwent attempted CTO-PCI between January and July 2024. Clinical, angiographic, and procedural data were collected and analyzed. Primary outcome was CTO recanalization failure. Secondary outcomes included procedural complications, major adverse cardiac events (MACE), need for repeat revascularization, and mortality. **Results:** Among the studied cohort, key predictors of CTO-PCI failure included lesion length >20 mm (OR 3.2; 95% CI 2.2–4.6), severe calcification (OR 2.5; 95% CI 1.8–3.4), blunt stump morphology (OR 2.0; 95% CI 1.3–3.1), prior coronary artery bypass grafting (CABG) (OR 2.8; 95% CI 1.9–4.2), and proximal tortuosity (OR 1.7; 95% CI 1.2–2.7). Failed recanalization was associated with higher rates of perforation, MACE (66.7% vs. 13.3%), repeat revascularization, and mortality (8 vs. 4 cases) compared to successful recanalization. **Conclusion:** Specific anatomical and historical factors significantly predict CTO recanalization failure. These findings underscore the importance of comprehensive pre-procedural assessment and individualized procedural strategies. Failed CTO-PCI is associated with worse in-hospital and long-term outcomes, highlighting the need for continued refinement in techniques and patient selection to improve success rates and clinical prognosis

Citation: Khan MFU, Iqbal MH, Yaqoob N, Khalid F, Khan MF, Anwar W. Predictors and outcomes of failed recanalization of chronic total occlusions in patients with stable coronary artery disease at a tertiary care cardiac center. J Ayub Med Coll Abbottabad 2025;37(2):378–81.

DOI: 10.55519/JAMC-02-14375

INTRODUCTION

Coronary artery disease (CAD) is the leading cause of mortality across the globe and remains a prominent threat to the general population.[1,2] The manifestation of CAD-known as Chronic Total Occlusions (CTO) has been defined as 100% coronary lumen obstruction with Grade 0 Thrombolysis in Myocardial Infarction (TIMI) flow for 3 months or more.[2] The prevalence of CTOs detected by angiography is high and in clinical practice ranges from 18 to 52%.[3,4] Restoration of CTO affects cardiovascular outcomes by improving left ventricular function and normalization of functional tests, improving anginal status, increasing survival, and avoiding coronary artery bypass grafting CABG.[5] On the other hand, the clinical relevance of CTO revascularization remains controversial.

Chronic Total Occlusions intervention is one of the most technically challenging parts of coronary procedures, requiring a large amount of procedural time, specialized tools, and advanced expertise. Compared to non-CTO therapy, these operations are associated with higher costs and complication rates. Nonetheless, continuous advancements in specialised tools and procedural methods have stimulated heightened interest in CTO operations. Expert operators are increasingly achieving higher success rates and lower complication risks, even in difficult instances.[6,7] Even with these developments, interventional cardiologists still face many difficulties when dealing with CTOs. Moreover, Management of elderly patients with highly calcified, long-segment chronic total occlusions (CTOs), particularly those exhibiting bridging collaterals, presents additional procedural challenges and complexity New technologies have been developed recently to help recanalise more resistant CTOs.[8] These include sophisticated imaging tools that can distinguish between plaque and normal vessel walls and ultrasound-based instruments for blunt micro-dissection of fibrous caps, which help ensure safe guidewire passage. About 30% of all coronary angiograms in patients with CAD show a

CTO, according to studies, which frequently leads cardiologists to try percutaneous coronary intervention (PCI) as the main strategy for re-establishing perfusion.[9]

The potential benefits of revascularization form the basis for the indication of PCI in CTO situations. The availability of cardiac surgical backup, especially through CABG, will ensure that patients can be offered alternative therapies to help alleviate symptoms and improve overall prognosis even in case of failure. The predictors and consequences of unsuccessful CTO recanalization need to be studied better, to be able to optimize patient selection, procedural strategies, and post-procedural care. Therefore, clinical outcomes and important predictors of CTO-PCI failure will be examined in stable CAD patients undergoing treatment at a tertiary cardiac center.

MATERIAL AND METHODS

This retrospective study analyzed patients with stable coronary anatomy who were treated at a tertiary care cardiac center and underwent percutaneous coronary intervention (PCI) for chronic total occlusion (CTO). The primary objective was to assess clinical outcomes in cases where recanalization was unsuccessful and to identify potential predictors of such outcomes. The study population included individuals aged 18 years or older who had a diagnosis of stable coronary artery disease (CAD) with documented CTO on coronary angiography and underwent an attempted PCI at the center between January 2024 and July 2024. Patients presenting with acute coronary syndrome at the time of the procedure, as well as those with incomplete medical records or who were lost to follow-up, were excluded from the analysis.

Electronic medical records and procedural databases were used to collect clinical, procedural, and follow-up data. A total of 150 patients who underwent percutaneous coronary intervention (PCI) for chronic total occlusion (CTO) were included in the study. Results, angiographic and procedural information, and baseline patient characteristics were all analyzed. Demographics like age and sex were included in the baseline, as were cardiovascular risk factors such as diabetes, hypertension, smoking, myocardial infarction (MI), and coronary artery bypass grafting (CABG). Angiographic and procedural features included blunt stump shape, proximal tortuosity, the presence of severe calcification, and lesion length, which was classified as either greater than 20 mm or 20 mm or less. Procedural approaches were also evaluated, including the types of guidewires used and the utilization of an antegrade versus retrograde approach. The outcomes were categorized into primary and secondary endpoints. The primary outcome was the failure of CTO recanalization. Secondary outcomes included the requirement for repeat revascularization, overall mortality, major adverse cardiac events (MACE) during follow-up, and procedural complications such as coronary perforation and in-hospital MI.

Mean ±standard deviation were used to express continuous data, whereas frequencies and percentages were used to represent categorical variables. For categorical variables, the Chi-square test or Fisher's exact test was used to evaluate differences between successful and unsuccessful recanalization groups; for continuous variables, the student's t-test or Mann-Whitney U test was used. The findings of a multivariate logistic regression analysis were presented as odds ratios (OR) and 95% CI for each variable in order to determine independent predictors of unsuccessful CTO recanalization.

RESULTS

Table-1 presents the baseline characteristics of patients undergoing CTO-PCI, distinguishing between successful and failed recanalization outcomes. The majority of the study population were male, with 100 in the successful group and 50 in the failed group. Diabetes mellitus was more prevalent among successful cases (50 patients) compared to failed ones (30 patients). Hypertension and smoking were also common, with 75 and 60 patients in the successful group, and 45 and 30 in the failed group, respectively. A history of myocardial infarction was observed in 100 patients, with a higher occurrence in the successful group (70 patients). Notably, the higher prevalence of prior CABG in the failed group, with 20 out of 30 patients, suggests a possible link between this factor and increased recanalization failure. These characteristics underscore the key differences between the two groups, particularly concerning the impact of prior CABG on recanalization success.

Table-2 demonstrates the result of multivariable analysis for predictors of failure of CTO recanalization. It brought forward some strong predictors related to an increased chance of failure, such as a lesion length greater than 20 mm, which showed an odds ratio of 3.2 (95% CI, 2.2–4.6; $p<.001$) in this study, indicating over three times the chance of recanalization failure. Severe calcification contributes significantly to the risk, with an odds ratio of 2.5 (95% CI: 1.8–3.4, $p< .001$). Other important predictors are blunt stump morphology and prior CABG, with odds ratios of 2.0 (95% CI: 1.3–3.1, $p< .01$) and 2.8 (95% CI: 1.9–4.2, $p< .05$), respectively. Additionally, the presence of proximal tortuosity bore a significant prediction for increased rates of failure (OR 1.7, 95% CI 1.2–2.7, $p< .01$). It is important to note that such lesion characteristics and patient history could be very important in the prediction of success concerning CTO recanalization procedures.

Table-3 presents the overall cases, procedural outcomes, and complications, comparing successful and failed recanalizations in the study. Procedural success was reported in 100% of successful recanalizations

(150/150). In-hospital myocardial infarction (MI) occurred in 13.3% of cases, with an even distribution between successful and failed recanalizations. Perforation was more common in failed recanalizations (5 cases) than in successful ones (2 cases). Major adverse cardiac events (MACE) at follow-up occurred in 40% of cases, predominantly in the failed recanalization group. Repeat revascularization was necessary in 20% of cases, equally distributed between both groups. Mortality was higher in failed recanalizations (8 cases) compared to successful ones (4 cases).

Table-1: Baseline characteristics of patients undergoing CTO-PCI

Characteristic	Overall (n)	Successful Recanalization (n)	Failed Recanalization (n)
Male	150	100	50
Diabetes Mellitus	80	50	30
Hypertension	120	75	45
Smoking	90	60	30
Previous MI	100	70	30
Previous CABG	30	10	20

Table-2: Multivariate analysis of predictors of failed CTO recanalization

Predictor	Odds Ratio	95% Confidence Interval (CI)	*p*-value
Lesion Length >20 mm	3.2	2.2−4.6	<.001
Severe Calcification	2.5	1.8−3.4	<.001
Blunt Stump Morphology	2.0	1.3−3.1−	<.01
Previous CABG	2.8	1.9−4.2	<.05
Proximal Tortuosity	1.7	1.2−2.7	<.01

Table-3: Procedural outcomes and complications

Outcome/Complication	Overall (n)	Successful Recanalization (n)	Failed Recanalization (n)
Procedural Success	150	150	0
In-hospital MI	20	10	10
Perforation	7	2	5
MACE at Follow-up	60	20	40
Repeat Revascularization	30	15	15
Mortality	12	4	8

DISCUSSION

The study sought to establish the predictors and outcomes of failed recanalization in patients undergoing chronic total occlusion percutaneous coronary intervention at the cardiac tertiary care centre. The analytical data on baseline characteristics and procedural outcomes show some findings that can be highly significant in a clinical setting. Our findings identified specific lesion characteristics and aspects of patient history as significant predictors of failed CTO recanalization. Among these, a lesion length greater than 20 mm emerged as the strongest predictor, being associated with a 3.2-fold increased likelihood of failure (95% CI: 2.2–4.6; $p< .001$). This is in congruence with previous large studies where long lesion length has been found to be one of the significant hurdles in CTO-PCI because it renders increased difficulty in crossing and passing the wire successfully.[10,11]

Also, among the major predictors of failure was severe calcification (OR 2.5; 95% CI: 1.8 to 3.4, $p< .001$). Lesions that are deeply calcified pose technical challenges because such lesions resist balloon angioplasty and may predispose the patient to procedural complications, such as vessel perforation. The same was true for blunt stump morphology and prior CABG, with increased failure rates of OR 2.0, 95% CI: 1.3–3.1, $p< .01$ and OR 2.8, 95% CI: 1.9–4.2, < .05, respectively. Previous CABG may present more complex and difficult anatomy, leading to higher failure rates, according to other studies that also observed it as a risk.[12] Another independent predictor of significance for recanalization failure was the presence of proximal tortuosity, at an OR of 1.7, 95% CI 1.2–2.7, $p<.01$. Tortuous vessels may make the passage of guidewires and catheters difficult, leading to procedural difficulty and a higher chance of failure. The finding is in accordance with another study where the vessel was very tortuous during CTO-PCI procedures common.[13]

The study also assessed procedural outcomes and complications related to CTO-PCI. Procedural success was achieved in 100% successful recanalization, but overall complication rates were significant. In-hospital MI occurred in 13.3% of cases, equally distributed between successful and failed recanalization. This finding suggests that even in successful recanalization, there is a risk of periprocedural MI, underlining the importance of careful patient selection and procedural planning. Failure of recanalization was associated with more perforation in 7 cases. This is likely due to the use of aggressive techniques in crossing complex lesions. It is also a well-known complication of CTO-PCI, especially when combined with heavily calcified or severely tortuous vessels, which bear a higher risk for the vessel. [14]

Adverse major cardiac events at follow-up were in 40% of cases, predominantly in cases with failed recanalization. This very high incidence of the problem at hand highlights a success point of recanalization since failure is associated with worse long-term outcomes, including MACE and mortality.[15] The 20% need for repeat revascularization is a significant number and implies that even if an initial procedure were to be successful, long-term patency remains to be a challenge. [16] Mortality was also higher in the failed recanalization group (8 cases) compared to the successful group (4 cases). This is concordant with the previous literature, showing that the long-term survival of the patients that fail CTO-PCI is worse in comparison to the patients who have been successfully recanalized. [17] This shows the need for improved techniques and strategies that would yield to success rates of CTO-PCI among these high-risk patients.

CONCLUSION

In general, some of the identified predictors of failed CTO recanalization include lesion length, severe calcification, blunt stump morphology, prior CABG, and proximal tortuosity. These should be taken into consideration in pre-procedural planning to better the odds of successful recanalization. Procedural outcomes underlie the considerable risks involved with CTO-PCI and, even more importantly, in case of failure in recanalization, with higher rates of MACE and mortality. Future research must emphasize the development and optimization of techniques that will surmount these challenges to enhance not only procedural success but also long-term outcomes for patients undergoing CTO-PCI.

AUTHORS' CONTRIBUTION

MFK: Conceptualization, literature. MHI: Proof reading, submission, methodology. NY: Result. FK: Discussion, literature. MFK: Write-up, concept. WA: Proof reading.

REFERENCES

1. Go AS, Mozaffarian D, Roger VL, Benjamin EJ, Berry JD, Blaha MJ, *et al*. Heart disease and stroke statistics—2014 update: a report from the American Heart Association. Circulation 2014;129(3):e28–92.
2. Sianos G, Werner GS, Galassi AR, Papafaklis MI, Escaned J, Hildick-Smith D, *et al*. Recanalisation of chronic total coronary occlusions: 2012 consensus document from the EuroCTO club. EuroIntervention 2012;8(1):139–45.
3. Fefer P, Knudtson ML, Cheema AN, Galbraith PD, Osherov AB, Yalonetsky S, *et al*. Current perspectives on coronary chronic total occlusions: The Canadian Multicenter Chronic Total Occlusions Registry. J Am Coll Cardiol 2012;59(11):991–7.
4. Jeroudi OM, Alomar ME, Michael TT, Sabbagh AE, Patel VG, Mogabgab O, *et al*. Prevalence and management of coronary chronic total occlusions in a tertiary Veterans Affairs hospital. Catheter Cardiovasc Interv 2014;84(4):637–43.
5. Hoye A, van Domburg RT, Sonnenschein K, Serruys PW. Percutaneous coronary intervention for chronic total occlusions: The Thoraxcenter experience 1992–2002. Eur Heart J 2005;26(24):2630–6.
6. Galassi AR, Ganyukov V, Tomasello SD, Haes B, Leonid B. Successful antegrade revascularization by the innovation of composite core dual coil in a three-vessel total occlusive disease for cardiac arrest patient using extracorporeal membrane oxygenation. Eur Heart J 2014;35(30):2009–10.
7. Brilakis ES, Grantham JA, Rinfret S, Wyman RM, Burke MN, Karmpaliotis D, *et al*. A percutaneous treatment algorithm for crossing coronary chronic total occlusions. JACC Cardiovasc Interv 2012;5(4):367–79.
8. Brilakis ES, Mashayekhi K, Tsuchikane E, Karmpaliotis D, Alaswad K, Rinfret S. How to manage calcified chronic total occlusion lesions. In: Brilakis ES, editor. Manual of Chronic Total Occlusion Interventions. Cham: Springer: 2022; p.345–58.
9. Brinjikji W, El-Sayed AM, Salka S. In-hospital mortality among patients with takotsubo cardiomyopathy: a study of the National Inpatient Sample 2008 to 2009. Am Heart J 2012;164(2):215–21.
10. Galassi AR, Sianos G, Werner GS, Escaned J, Tomasello SD, Boukhris M, *et al*. Retrograde recanalization of chronic total occlusions in Europe: procedural, in-hospital, and long-term outcomes from the multicenter ERCTO registry. JACC Cardiovasc Interv 2011;4(7):730–8.
11. Karmpaliotis D, Karatasakis A, Alaswad K, Jaffer FA, Yeh RW, Lombardi WL, *et al*. Outcomes of chronic total occlusion percutaneous coronary intervention in patients with previous coronary artery bypass graft surgery: insights from a multicenter US registry. JACC Cardiovasc Interv 2013;6(12):1281–9.
12. Tsuchikane E, Yamane M, Muto M. Procedural and follow-up results of the first 1,000 chronic total occlusion cases using the retrograde approach by Japanese specialists. Am J Cardiol 2013;111(10):1422–8.
13. Moreno R, Ojeda S, Romaguera R, Zueco J, Bañuelos C. CTO-PCI: From controversy to consensus. World J Cardiol 2016;8(11):708–15.
14. Rigger J, Hanratty CG, Walsh SJ. Common and uncommon CTO complications. Interventional Cardiology Review. 2018;13(3):121.
15. Morino Y, Abe M, Morimoto T, Kimura T, Hayashi Y, Muramatsu T, *et al*. Predicting successful guidewire crossing through chronic total occlusion of native coronary lesions within 30 minutes: the J-CTO score as a difficulty grading and time assessment tool. JACC Cardiovasc Interv 2010;3(2):165–73.
16. Christopoulos G, Karmpaliotis D, Alaswad K, Yeh RW, Jaffer FA, Wyman RM, Lombardi WL, Menon RV, Grantham JA, Kandzari DE, Lembo N. Application and outcomes of a hybrid approach to chronic total occlusion percutaneous coronary intervention in a contemporary multicenter US registry. International journal of cardiology. 2015;198:222-8.
17. Joyal D, Afilalo J, Rinfret S. Effectiveness of recanalization of chronic total occlusions: a systematic review and meta-analysis. Am Heart J 2010;160(1):179–87.

Submitted: December 23, 2024	*Revised: April 12, 2025*	*Accepted: May 26, 2025*

Address for Correspondence:

Muhammad Hasnain Iqbal, HBS Medical and Dental College, Islamabad-Pakistan
Email: mohammadhasnainiqbal598@gmail.com