A Novel Risk Score in Predicting Failure or Success for Antegrade Approach to Percutaneous Coronary Intervention of Chronic Total Occlusion: Antegrade CTO Score

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Abstract

Total occlusion of a coronary artery for more than 3 months is defined as chronic total occlusion (CTO). The goal of this study was to develop a risk score in predicting failure or success during attempted percutaneous coronary intervention (PCI) of CTO lesions using antegrade approach.

This study was based on retrospective analyses of clinical and angiographic characteristics of CTO lesions that were assessed between February 2012 and February 2014. Success rate was defined as passing through occlusion with successful stent deployment using an antegrade approach.

A total of 188 patients were studied. Mean ± SD age was 59 ± 9 years. Failure rate was 33%. In a stepwise multivariate regression analysis, bridging collaterals (OR = 6.7, CI = 1.97–23.17, score = 2), absence of stump (OR = 5.8, CI = 1.95–17.9, score = 2), presence of calcification (OR = 3.21, CI = 1.46–7.07, score = 1), presence of bending (OR = 2.8, CI = 1.28–6.10, score = 1), presence of near side branch (OR = 2.7, CI = 1.08–6.57, score = 1), and absence of retrograde filling (OR = 2.5, CI = 1.03–6.17, score = 1) were independent predictors of PCI failure. A score of 7 or more was associated with 100% failure rate whereas a score of 2 or less was associated with over 80% success rate.

Most factors associated with failure of CTO-PCI are related to lesion characteristics. A new risk score (range 0–8) is developed to predict CTO-PCI success or failure rate during antegrade approach as a guide before attempting PCI of CTO lesions.

Keywords
- balloon angioplasty
- chronic total occlusion
- complications
- coronary intervention
- percutaneous coronary intervention
- risk score
- stenting
- success rate

Chronic total occlusion (CTO), defined as occlusion of one coronary artery for more than 3 months with TIMI 0–1, has been found in 15 to 30% of cases during routine coronary angiographies. Nowadays, with dedicated devices, many interventional cardiologists prefer to try CTO lesions with different success rates. The benefits of CTO-percutaneous coronary intervention (CTO-PCI) remain controversial. In retrospective nonrandomized studies, CTO-PCI have been shown to improve symptoms, left ventricular function, and potentially survival.[1] Annual CTO-PCI attempt rate among 388 institutions from the National Cardiovascular Data Registry (NCDR) database was 11.5 to 14%.[1] This rate has been

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stable between 2003 and 2007. The British Cardiovascular Intervention Society (BCIS) audit for 2002 showed that only 9% of all PCI procedures are for single vessel CTOs and this has not changed over the last decade.[2] Fefer et al reported 10% attempt rate in a large Canadian registry.[3] Historically low PCI success rate is a major limitation of CTO-PCI that accounts for low PCI attempt rates. In a single-center, multi-decade review from the Mayo Clinic, the procedural success rate for CTO-PCI between 1979 and 1989 was 51%. With the introduction of coronary stents, success rates increased to ≈70%, and this rate has been consistent across several studies.[4]

Of interest, most studies were published within the past 7 years. The pooled angiographic success rate increased with time (68.2% between 2000 and 2002 to 79.4% between 2009 and 2011). For each successive year, the rate of major complications decreased significantly. Many factors are associated with failure for recanalization of CTO lesions. These can be classified into patient's characteristics, lesion characteristics, operator volume, center volume, and using advanced tools and techniques. In this study, we reviewed all patients who underwent CTO-PCI procedure during a 3-year period. We analyzed all factors assumed to be associated with antegrade CTO-PCI success or failure. Factors that were associated with failure were extracted in a multivariate analysis and a new scoring system was developed to predict CTO-PCI failure.

Patients and Methods

Study Design

We defined CTO as the lesions with TIMI 0 antegrade flow and the duration of occlusion ≥ 3 months. In this retrospective, cross-sectional study, all patients with CTOs that were found during routine coronary angiography during 2012 to 2014 in a university-based hospital (Shahid Modarres Hospital, Saadat Abad St., Tehran, Iran) were assessed. Patients were evaluated for presence of inducible ischemia with thallium scan or stress echocardiography. All patients had multi-vessel disease and were candidates for CTO-PCI attempt using antegrade approach as the first strategy. If this attempt failed, they were then referred for coronary bypass grafting (CABG) if indicated. Recorded data included: baseline characteristics, procedural material and details of coronary anatomy, and patients' characteristics. Patients were identified as undergoing single versus multi-vessel PCI. Patients with acute occlusions and those with CTO of a saphenous venous graft were excluded in this analysis. Operator had a minimum case volume of 200 PCI procedures per year with more than 10 years of experience. Simultaneous contralateral coronary angiography was not utilized routinely from the beginning in any case. If the operators considered it necessary during the procedure, the contralateral femoral artery was punctured with a 6 Fr introducer with contralateral injections. First attempt of CTO crossing was done using soft guide wires without support. If it failed, the guide wires were exchanged for the stiffer ones with an over-the-wire (OTW) support system (fine cross or Corsair air).

Guide wire characteristics were grouped into three categories: (1) polymer jacketed-tip guide wires (e.g., Pilot, Whisper, Fielder XT); (2) exposed-coil, moderate stiffness guide wires (e.g., Miracle Bros 3, 4.5, and 6); and (3) exposed-coil, stiff-tip guide wires (e.g., Miracle Bros 12, Confianza Pro 9 and 12). The starting and usage of specific guide wires were left to the discretion of the physician in charge of the case. Procedural success was defined as stent deployment with < 20% residual stenosis with TIMI flow grade 3. Recorded angiographic characteristics included the morphologic features of the occlusion (with or without stump); the presence of calcification; the presence of a side branch at the point of the occlusion; bending at the point of the occlusion; or vessel tortuosity proximal to the occlusion. The length of the occlusion was measured by cine angiography with manual calipers. Vessel diameters proximal and distal to the occlusion were also measured by the edge detection method. The length of the occluded segment and distal vessel diameter were measured when there was good distal filling of the vessel by collateral circulation. The procedure was terminated after a total of ≥ 60 minutes of fluoroscopy, when an occlusion could not be crossed with guide wires, or when a major complication was encountered. All patients were treated with DES after canalization of CTO.

Statistical Analysis

Statistical analysis was performed by using the Student *t*-test for comparison of group means and the chi-square test for comparison of discrete variables. Values are given as the mean value ± SD. To determine independent predictors of PCI failure, all 17 baseline demographic and clinical parameters in ►**Table 1** were prescreened by univariate logistic regression analysis. Subsequently, seven univariate predictors of PCI failure were subjected to multivariate logistic regression analysis with stepwise, backward, and forward procedures where potential predictors of PCI failure were entered and retained in the model at $p < 0.10$. A probability value of < 0.05 was considered statistically significant.

Derivation and Validation of an Integer Risk Score

Independent predictors of PCI failure, according to the preceding model, formed the basis of the clinical integer risk score. We attributed a weight to each variable on the basis of the regression coefficient. Each integer amount is a rounding of the exact figure obtained from the logistic model (►**Table 2**). The total risk score for any individual patient was the summation of the six independent variables present. The area under the receiver-operating characteristics curve for the integer score was determined by calculating the C-statistic in logistic regression analyses with CTO-PCI failure as the dependent variable, and the integer score as the independent variable. The total risk score for any individual patient was the summation of the six independent variables present. All calculations and statistical analyses were performed using SPSS (version 18).

Results

A total of 188 procedures were done on 183 patients during the study period. In 62 patients (33%), CTO-PCI attempts were

Table 1 Baseline characteristics

	Successful CTO-PCI	Unsuccessful CTO-PCI	*p*-Value
Patient characteristics			
Age, yrs	59.5 ± 8.9	57.6 ± 9.5	0.2
Male/female	89/37	50/12	0.14
Diabetes	26 (31.7)	12 (30.8)	0.91
Previous CABG	10 (7.9%)	10 (16.4%)	0.07
Previous MI	(26.4%)	22 (38.6%)	0.1
CTO vessel			
LAD (N)	43 (34.1%)	25 (41%)	0.3
LCX (N)	40 (31.7%)	22 (36.1%)	
RCA (N)	43 (34.1%)	14 (23%)	
Lesion characteristics			
Length ≥ 20 mm	71 (56.3%)	43 (69.4%)	0.09
Calcification	45 (35.7%)	39 (63%)	0.0004
Bending	43 (34.1%)	35 (56.5%)	0.003
Bridging collaterals	11 (8.7%)	15 (24.2%)	0.004
Stump	118 (93.7%)	32 (51.6%)	0.0001
Vessel diameter (mm)	2.78 ± 0.42	2.77 ± 0.49	0.9
Distal visualization	51 (40.5%)	14 (22.6%)	0.015
Proximal lesion	26 (20.6%)	17 (27.4%)	0.3
Near side branch	29 (23%)	37 (60%)	0.0007
Proximity of CTO	45 (35.7%)	21 (34.4%)	0.86
Procedural characteristics			
Guide wire			
Polymerjacketed-tip ($n =$)	66	55	NS
Exposed-coil moderate stiffness ($n =$)	48	30	
Exposed-coil, stiff-tip ($n =$)	20	23	

Table 2 Multivariable predictors of CTO-PCI failure and risk score

Variable	Model coefficient	Model coefficient rounded	Clinical risk score	Std. error	OR	95% CI	*p*-Value
Bridging collaterals	1.91	2	2	0.63	6.7	1.97–23.17	0.002
No stump	1.75	2	2	0.55	5.8	1.95–17.09	0.002
Calcification	1.16	1	1	0.40	3.2	1.46–7.707	0.004
Bending	1.02	1	1	0.40	2.8	1.28–6.10	0.010
Retrograde	0.92	1	1	0.45	2.5	1.03–6.17	0.042
Side branch	0.98	1	1	0.46	2.7	1.08–6.57	0.032

Abbreviations: CI, confidence interval; OR, odds ratio.
Note: Clinical risk score assigned to each of the three variables represents model coefficient (rounded to whole unit).

unsuccessful. Baseline and clinical criteria are shown in ►**Table 1**. Mean age of overall population was 59 ± 9 years; 74% were men; 20% were diabetic; and 10.5% had previous CABG. We found no statistically significant difference in success rates among six operators (min. = 61.9%, max. = 75%, mean 67%, *p*-value = 0.77).

Causes of CTO-PCI Failure

Seven common reasons for primary CTO-PCI failure ($n = 62$) included: presence of bridging collaterals ($n = 26$), presence of calcification in culprit vessel ($n = 84$), presence of bending more than 90 degree proximal to the cut of part ($n = 78$), absence of stump in the culprit vessel ($n = 38$), no guidance of retrograde filling ($n = 65$), presence of near side branch ($n = 66$), and previous CABG ($n = 20$).

On multivariate analysis, presence of bridging collaterals (odds ratio [OR]: 6.7; 95% confidence interval [CI]: 1.97–23.17, $p = 0.002$, score = 2), absence of stump (OR: 5.8; 95% CI: 1.95–17.09, $p = 0.002$, score = 2), presence of calcification (OR: 3.21; 95% CI: 1.46–7.07, $p = 0.004$, score = 1), presence of bending (OR: 2.8; 95% CI: 1.28–6.10, $p = 0.010$, score = 1), absence of guidance in retrograde filling (OR: 2.5; 95% CI: 1.03–6.17, $p = 0.042$, score = 1), and presence of near side branch (OR: 2.7; 95% CI: 1.08–6.57, $p = 0.032$, score = 1) were the six independent predictors of CTO-PCI failure.

Risk Score of CTO-PCI Failure

Based on the regression coefficients, an integer score was assigned to each of the multivariate predictors resulting in a possible clinical risk score of CTO-PCI failure ranging from 0 to 8. The incidence of predicted CTO-PCI failure increased from 8 to 100% (►**Fig. 1**). Internal validation with bootstrapping provided a C-statistic of 0.839 (95% CI: 0.778–0.9). The model provided good calibration as indicated by the nonsignificant Hosmer-Lemeshow goodness of fit ($p = 1.0$). In patients with score 7 or more, CTO-PCI was associated with 100% failure rate. On the other hand, highest success rates of over 80% were seen in patients with a score of 2 or less.

Discussion

CTO-PCI success rate has been studied extensively in the last decades. A review of the National Heart, Lung, and Blood Institute's Dynamic Registry has shown a decrease in the attempt rate of PCI for CTO from 1997 to 1998 to 2004.[5] Since then, and during 2000 to 2011, CTO-PCI attempt rates have increased and success rates have increased to 77% in antegrade approach and 79.8% with retrograde approach.[6] It is concluded that CTO-PCI carries low risk for procedural complications despite high success rates. The first report of the ERCTO registry by the Euro CTO club shows a high procedural success rate (83.2% in antegrade approach and 64.5% in retrograde approach).[7] Because of recent improvements in endovascular techniques and dedicated devices, the success rate of CTO-PCI has significantly improved. A report from Salarifar et al showed a success rate of 82.2% in 221 patients.[8] Another large report showed a success rate of 50%.[9] It seems that variable success rates highly depend on patient selection in different studies. Multiple factors are associated with CTO-PCI failure. Not only coronary angiography but also multislice CT angiography can be used to estimate difficulty in wire crossing in percutaneous coronary intervention for CTO. In MSCA, bending, shrinkage, and severe calcification are significant predictors for wiring success.[10] Morino et al reported unsuccessful guide wire crossing through CTO predictors to be calcification, bending, blunt stump, occlusion length > 20 mm, and previously failed lesion.[11] They established a model to predict the probability of successful guide wire crossing within 30 minutes. This score was validated by Nombela-Franco et al.[12] The success rate of the use of dedicated CTO devices and techniques to open a CTO were increased with new devices. So, summation of patient characteristics, lesion characteristics, dedicated devices, and operator skills seems to be associated with CTO-PCI success. In multiple studies, lesion characteristics of CTOs remained the most important factor in predicting success.[13,14] Recently, three large studies are published for predicting CTO failure rate.[15–17] All of them studied more than 500 attempted PCI for CTO intervention. Like previous studies, they found different predictors to be associated with CTO-PCI failure. Comparison of these studies with our current study is summarized in ►**Table 3**.

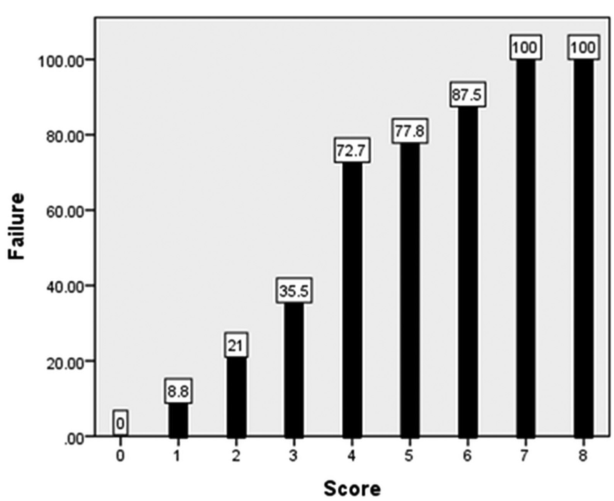

Fig. 1 CTO-PCI failure according to clinical risk score. Novel risk score based on six independent predictors of CTO-PCI failure (female sex, previous coronary artery bypass graft, presentation in cardiogenic shock). Total score ranges from 0 to 8.

In this study, we analyzed all factors previously studied for CTO-PCI failure despite the utilization of novel equipment and techniques for CTO recanalization. This study is the first report that developed a new score after the procedural failure. Like other studies,[18] our success rate is near 70%. We found no difference in failure rate among our operators or different strategy of guide wire selection while some studies put emphasis on the impact of both tapered and stiff-tip guide wire and operator experience.[19,20] We accessed the guide wire characteristics in our multivariate analysis and we found no effect on success rate, which may be due to appropriate wire selection in our cases and the effect of CTO vessel characteristics rather than dedicated devices. (In 10% of cases, we used tornus after the wire crossed the CTO.)

In our study, 114 patients (60%) had lesion length more than 20 mm, among them 62% underwent successful recanalization. Unlike other studies, we found vessel size and lesion length were not predictors of failure rate.[21,22] This high rate of success despite long lesion shows that with new devices the importance of lesion length is diminished. After regression analysis, we found CTO lesion characteristics are important factors in predicting failure rate among CTO-PCI attempts. These include: presence of bridging collaterals, absence of stump, presence of calcification, presence of bending, absence of retrograde filling, and presence of near side branch. Like other studies, we found the presence of bridging collaterals to

Table 3 Differences in predictors among recent CTO studies

Model	Predictor	Odd's ratio (95% CI)
CL scoring[15]	Blunt stump	1.39 (1.05–1.81)
	Non-LAD lesion	1.56 (1.14–2.15)
	Previous MI	1.6 (1.17–2.2.0)
	Lesion length > 20 mm	2.04 (1.54–2.7)
	Previous CABG	2.45 (1.17–2.2)
	Lesion calcification	2.72 (1.78–4.16)
Progress CTO[16]	Blunt stump	3.86 (1.49–10.43)
	Severe tortuosity	3.25 (1.22–9.28)
	LCX CTO	2.69 (1.00–7.14)
	Absence of collaterals	2.4 (0.92–6.55)
Galassi et al[17]	Poor collateral filling	4.01 (2.29–7.03)
	Age > 75 years	2.34 (1.05–5.15)
	Ostial location	1.96 (1.07–3.61)
	Bridging collaterals	6.7 (1.97–23.17)
	Blunt stump	5.8 (1.95–17.9)
Current study	Presence of calcification	3.21 (1.46–7.07)
	Bending	2.8 (1.28–6.10)
	Presence of near side branch	2.7 (1.08–6.57)
	Absence of retrograde filling	2.5 (1.03–6.1)

Abbreviations: CABG, coronary artery bypass graft; LAD, Left anterior descending; LCX, left circumflex; MI, myocardial infarction.

be the most powerful predictor of CTO-PCI failure (OR = 6.7). Besides this factor, absence of stump was also another important predictor of failure rate with similar weight (OR = 5.8). Regarding factors, our patients with a score of 7 or more showed 100% failure rate. Highest success rates were seen in patients with a score of 2 or less (60% of our patients had a score of 2 or less). We call this score system as "antegrade CTO score."

Conclusion

Most factors associated with failure of CTO-PCI are related to lesion characteristics. A new risk score (range 0–8) is developed to predict CTO-PCI success or failure rate during antegrade approach as a guide before attempting PCI of CTO lesions. Therefore, based on our study, in patients with a score of more than 7, antegrade CTO-PCI should be avoided, and antegrade CTO-CI should be attempted with high success rate in patients with a score of 2 or less.

Study Limitations

This is a retrospective observational study with limitations inherent to such a design. Also, the effect of CTO revascularization on patients' symptoms and any need for repeat revascularization were not studied. This was a single center study with the involvement of experienced operators. Therefore, this scoring system may not be valid in small institutions with low PCI numbers and inexperienced operators.

Conflict of Interest

None of the authors has any conflict of interest.

Acknowledgment

This study was approved by institutional review board of Shahid Beheshti University of Medical Sciences, Tehran, Iran.

References

1 Grantham JA, Marso SP, Spertus J, House J, Holmes DR Jr, Rutherford BD. Chronic total occlusion angioplasty in the United States. JACC Cardiovasc Interv 2009;2(6):479–486
2 BCIS. British Cardiovascular Intervention Society audit data 2002: www.bcis.org.uk
3 Fefer P, Knudtson ML, Cheema AN, et al. Current perspectives on coronary chronic total occlusions: the Canadian Multicenter Chronic Total Occlusions Registry. J Am Coll Cardiol 2012; 59(11):991–997
4 Shah PB. Management of coronary chronic total occlusion. Circulation 2011;123(16):1780–1784
5 Abbott JD, Kip KE, Vlachos HA, et al. Recent trends in the percutaneous treatment of chronic total coronary occlusions. Am J Cardiol 2006;97(12):1691–1696
6 Patel VG, Brayton KM, Tamayo A, et al. Angiographic success and procedural complications in patients undergoing percutaneous coronary chronic total occlusion interventions: a weighted meta-analysis of 18,061 patients from 65 studies. JACC Cardiovasc Interv 2013;6(2):128–136
7 Galassi AR, Tomasello SD, Reifart N, et al. In-hospital outcomes of percutaneous coronary intervention in patients with chronic total occlusion: insights from the ERCTO (European Registry of Chronic Total Occlusion) registry. EuroIntervention 2011;7(4):472–479
8 Salarifar M, Mousavi MR, Saroukhani S, et al. Percutaneous coronary intervention to treat chronic total occlusion: predictors of technical success and one-year clinical outcome. Tex Heart Inst J 2014;41(1):40–47
9 Sohrabia B, Ghaffaria S, Habibzadeh A, Chaichib P, Kamalifar A. Outcome of successful versus unsuccessful percutaneous coronary intervention in chronic total occlusions in one year follow-up. Cardiol Rev 2013;4(2):68–73
10 Ehara M, Terashima M, Kawai M, et al. Impact of multislice computed tomography to estimate difficulty in wire crossing in percutaneous coronary intervention for chronic total occlusion. J Invasive Cardiol 2009;21(11):575–582
11 Morino Y, Abe M, Morimoto T, et al; J-CTO Registry Investigators. Predicting successful guidewire crossing through chronic total occlusion of native coronary lesions within 30 minutes: the J-CTO (Multicenter CTO Registry in Japan) score as a difficulty grading and time assessment tool. JACC Cardiovasc Interv 2011;4(2): 213–221

12 Nombela-Franco L, Urena M, Jerez-Valero M, et al. Validation of the J-chronic total occlusion score for chronic total occlusion percutaneous coronary intervention in an independent contemporary cohort. Circ Cardiovasc Interv 2013;6(6):635–643

13 Maeremans J, Selleslagh P, Di Serafino L, Barbato E, Dens J. Impact of negative lesion characteristics of chronic total occlusions on procedural outcome and strategy. Acta Cardiol 2013;68(5):455–461

14 Han YL, Wang SL, Jing QM, et al. Percutaneous coronary intervention for chronic total occlusion in 1263 patients: a single-center report. Chin Med J (Engl) 2006;119(14):1165–1170

15 Alessandrino G, Chevalier B, Lefèvre T, et al. A clinical and angiographic scoring system to predict the probability of successful first-attempt percutaneous coronary intervention in patients with total chronic coronary occlusion. JACC Cardiovasc Interv 2015;8(12):1540–1548

16 Christopoulos G, Kandzari DE, Yeh RW, et al. Development and validation of a novel scoring system for predicting technical success of chronic total occlusion percutaneous coronary interventions: the PROGRESS CTO (Prospective Global Registry for the Study of Chronic Total Occlusion Intervention) Score. JACC Cardiovasc Interv 2016;9(1):1–9

17 Galassi AR, Boukhris M, Azzarelli S, Castaing M, Marzà F, Tomasello SD. Percutaneous coronary revascularization for chronic total occlusions: a novel predictive score of technical failure using advanced technologies. JACC Cardiovasc Interv 2016;9(9): 911–922

18 Prasad A, Rihal CS, Lennon RJ, Wiste HJ, Singh M, Holmes DR Jr. Trends in outcomes after percutaneous coronary intervention for chronic total occlusions: a 25-year experience from the Mayo Clinic. J Am Coll Cardiol 2007;49(15):1611–1618

19 Thompson CA, Jayne JE, Robb JF, et al. Retrograde techniques and the impact of operator volume on percutaneous intervention for coronary chronic total occlusions an early U.S. experience. JACC Cardiovasc Interv 2009;2(9):834–842

20 Mitsudo K, Yamashita T, Asakura Y, et al. Recanalization strategy for chronic total occlusions with tapered and stiff-tip guidewire. The results of CTO new techniQUE for STandard procedure (CONQUEST) trial. J Invasive Cardiol 2008;20(11):571–577

21 Choi JH, Song YB, Hahn JY, et al. Three-dimensional quantitative volumetry of chronic total occlusion plaque using coronary multidetector computed tomography. Circ J 2011;75(2): 366–375

22 Chen SL, Ye F, Zhang JJ, et al. Clinical outcomes of percutaneous coronary intervention for chronic total occlusion lesions in remote hospitals without on-site surgical support. Chin Med J (Engl) 2009; 122(19):2278–2285