Coronary Angiography Characteristics as Predictor of Successful Chronic Total Occlusion Recanalization

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Abstract

Although remarkable progress in percutaneous coronary intervention (PCI) has been achieved over the last decade, the success rate of chronic total occlusion (CTO) recanalization varies greatly. Coronary angiography characteristics may affect the success rate of CTO recanalization. This study sought to establish a scoring model to predict successful CTO recanalization based on coronary angiography characteristics. We analyze 287 angiography data from patients who underwent elective PCI. Angiography characteristics being measured were lesion location, blunt stump, calcification, ostial lesion, bridging collateral, bending, side branch, tortuosity, previous stent attempt, and lesion length of >20 mm. Data were analyzed using SPSS 25.0. Multivariate analysis shows that side branch lesion ($p = 0.000$), proximal vessels tortuosity ($p = 0.015$), calcified lesion ($p = 0.000$), lesion length of >20 mm ($p = 0.000$), and blunt stump ($p = 0.000$) can predict the successful PCI in the CTO. ROC curve analysis of the score ability to predict successful PCI in the CTO showed area under curve of 0.89 (confidence interval 95%), the cutoff point of ≤2 with a sensitivity of 93.33%, and specificity of 88.23%. We concluded that the five angiography characteristics that strongly associate with successful PCI in the CTO are calcified lesion, blunt stump, lesion length >20 mm, proximal vessel tortuosity, and side branch lesion. This score may help cardiologists to predict the success probability of PCI in the CTO.

Keywords
- angiography
- angioplasty
- CTO
- recanalization
- score

Since it was performed for the first time in 1978 by Andreas Gruentzig, remarkable progress in percutaneous coronary intervention (PCI) has been achieved incredibly over the last decade. Previously known as mission impossible lesions, like left main intervention, bifurcation lesion, and chronic total occlusion (CTO), have now become daily life activity of interventionist cardiology. But it is often stated that successful CTOs recanalization represents the last frontier of interventional cardiology.

The prevalence of CTO was considerably high. CTO was found in 18.4% of the 1,697 patients undergoing diagnostic coronary angiography.[1] Recent studies have shown that recanalization of CTO can provide benefit for patients.[2–4] Mid America Heart Study showed that patients with successful CTO revascularization have higher 10-year survival rates compared with failed attempts (74 vs. 65%; $p < 0.001$).[2] In Italia, TOAST-GISE (Total Occlusion Angioplasty Study) showed successful PCI in CTO is associated with greater freedom from angina (89 vs. 75%), reduced need for coronary artery bypass surgery (2.5 vs. 15.7%), and reduced 1-year incidence of cardiac death or myocardial infarction(1.1 vs. 7.2%).[5] British Columbia Cardiac registry also showed that successful PCI of CTOs was associated with increased survival over 7-years follow-up.[6] Despite these benefits, PCI attempt rate for CTO lesion was very low, which is only 10%.[2] The success rate of PCI in the CTO was noticeably lower compared with non-CTO types in different centers, which varies around 50% to more than 80%.[2,5–7]

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Underappreciated benefit, low success rate, relatively higher cost procedure, and uncertainty of success rate are the main problems for PCI in the CTO. The previous study has reported the involvement of morphology, angulation, missing segment, and presence of multiple lesion to predict successful PCI in the CTO.[8] However, the previous model does not include some complexity which increases PCI difficulties such as proximal vessel tortuosity, ostial lesion, side branch lesion, calcification, and a previous attempt at the lesion.[2–4] Their predictive value for successful recanalization in the CTO lesion is yet to be explored. In addition, with the advancement of the PCI technology, the previous model which was developed 15 years ago may have changed and should be reevaluated. Hence, this study aims to analyze the angiography characteristics and establish a model to predict successful CTO recanalization based on these findings which can be used to facilitate decision making.

Methods

Patients Selection

This retrospective cohort study involves patients who underwent elective PCI from January 2011 to January 2014 from three major hospitals which are Soetomo General Hospital, Saiful Anwar General Hospital, and Husada Utama Hospital in East Java, Indonesia. We consecutively selected 287 patients with PCI in the CTO lesion which fulfilled inclusion and exclusion criteria. The inclusion criteria are patients with CTO lesions according to the EURO CTO definition and who underwent PCI in the CTO lesion. Clinical characteristics including age, history of hypertension, dyslipidemia, diabetes mellitus (DM), prior acute coronary syndrome (ACS), abnormal renal function test (RFT), smoking, decreased left ventricular ejection fraction (LVEF), and heart failure were obtained from the medical records. Patients with incomplete angiogram data are excluded. This study had received ethical clearance from the Soetomo General Hospital Ethics Committee. Informed consent was obtained and details which disclose patients' identity were omitted.

Angiography Characteristics

Detailed qualitative and quantitative angiographic assessments were blindly made by two experienced interventional cardiologists with a minimum of 10 years of experience. The angiogram characteristics that were analyzed were CTO lesion location, stump morphology, proximal vessel tortuosity, presence of calcification, side branch lesion, CTO length, bridging collateral, ostial lesion, and vessel bending.

The angiographic morphology of the entry point was classified as tapered if the occluded segment ended in a funnel-shaped form or blunt if it did not. Bending was defined as at least one bend of >45 degree assessed by angiography. CTO length was categorized as either ≥ 20 mm or <20 mm. The presence of proximal vessel tortuosity, ostial lesion, bridging collateral, and side branch is carefully assessed qualitatively and categorized as present or not. The dependent variable is whether PCI in the CTO lesion is successful or failed.

Statistical Analysis

Statistical analysis was performed using SPSS (version 25.0). Univariate analysis using chi-square was used to measure the significant relationships between each independent variable (clinical and angiography characteristics) and successful PCI in the CTO lesion. The likelihood ratio with probabilities of 0.25 for variable removal or entry was used to eliminate the model variables which are not significantly associated with the outcome. Variables with p-value <0.25 then proceed to multivariate analysis using logistic regression with backward stepwise procedures to determine the model which can be used to predict successful PCI in the CTO. The logistic model then tested using the Hosmer–Lemeshow test to know the model applicability. The percentage of explained variation reported will be expressed as Nagelkerke's R-square. Based on the model obtained from logistic regression analysis, we create the score and calculate the percentage of successful PCI in the CTO on our sample based on the total score. Finally, ROC curves were used to determine the cutoff point, specificity, and sensitivity of the scoring model to predict successful PCI in the CTO.

Results

Subjects Characteristics

A total of 3,000 angiograms were evaluated, and 287 angiograms that fulfill the inclusion and exclusion criteria were extracted. Overall PCI in the CTO lesion success rate was 71.3% (205 subjects) and a failure rate of 28.6% (82 subjects). Fifty subjects are females (17.3%) and the other 237 are males (82.7%). The average subject's age is 57 ± 8.6 years old. The youngest is 40 years old and the oldest is 79 years old.

From ►**Table 1**, no significant relationship was observed between the successful and failed PCI in the CTO at various clinical conditions (hypertension, DM, dyslipidemia, prior ACS, smoking, abnormal RFT, decreased LVEF, and heart

Table 1 Clinical condition characteristics and univariate analysis

	PCI in the CTO lesion ($n = 287$)		p-Value
	Success n (%), 205 (71.4)	Failed n (%), 82 (28.6)	
Hypertension	184 (64)	34 (64.5)	0.570
Dyslipidemia	49 (24)	20 (24)	0.612
Diabetes mellitus	90 (44)	24 (29.1)	0.128
Prior ACS	123 (60)	45 (54.4)	0.400
Abnormal RFT	25 (12)	15 (17.7)	0.371
Smoking	131 (64)	55 (67.1)	0.478
Decrease LVEF	25 (12)	17 (20.2)	0.271
Heart failure	25 (12)	9 (11.4)	0.590
Prior PCI	98 (48)	26 (31.6)	0.107

Abbreviations: ACS, acute coronary syndrome; CTO, chronic total occlusion; LVEF, left ventricular ejection fraction; PCI, percutaneous coronary intervention; RFT, renal function test.

Table 2 Angiography characteristics and univariate analysis

	PCI in the CTO lesion ($n = 287$)		*p*-Value
	Success *n* (%), 205 (71.3)	Failed *n* (%), 82 (28.6)	
Location			0.45
• LAD	113 (54.9)	48 (58.5)	
• LCx	16 (7.8)	8 (10.3)	
• RCA	76.26 (37.2)	26 (31.1)	
Ostial lesion	44 (21.5)	9 (11.1)	0.071
CTO lesion length >20 mm	104 (50.9)	10 (12.6)	0.0
Calcified lesion presence	149 (72.5)	24 (29.6)	0.0
Bending	12 (5.8)	4 (5.1)	0.86
Bridging collateral	88 (43.1)	22 (26.7)	0.032
Proximal vessel tortuosity	52 (25.5)	11 (13.3)	0.045
Stump morphology blunt	129 (62.7)	4 (5.1)	0.0
Any previous attempt	20 (9.8)	4 (5.2)	0.26
Side branch	76 (37.2)	9 (10.37)	0.0

Abbreviations: CTO, chronic total occlusion; LAD, left anterior descendent; LCx, left circumflex; PCI, percutaneous coronary intervention; RCA, right coronary artery.

failure; $p > 0.25$). This suggested that those variables have no predictive value for successful PCI in the CTO. Thus these variables are not included in the model.

Angiography Characteristics

The relationship between angiography characteristics and successful PCI in the CTO was analyzed using chi-square as described in ►**Table 2**.

From ►**Table 2**, there are four variables that have *p*-value ≥0.25 which are ostial lesion ($p = 0.071$), location ($p = 0.45$), any previous attempt ($p = 0.26$), and bending ($p = 0.86$). These four variables will be excluded from further multivariate analysis. Other variables with a significant relationship ($p < 0.25$) with successful PCI in the CTO were: CTO length, calcified lesion, bridging collateral, proximal vessel tortuosity, stump morphology, and side branch. All of these variables were analyzed using logistic regression eliminated one by one backwardly if *p*-value ≥0.25 which can be seen in ►**Table 3**. In the end, there are five significant variables left ($p < 0.05$) which are "side branch" (odds ratio [OR] = 0.24; $p = 0.016$), "blunt stump" (OR = 0.03; $p = 0.000$), "calcification" (OR = 0.19; $p = 0.002$), "CTO length" >20 mm (OR = 0.08; $p = 0.000$), and "proximal vessel tortuosity" (OR = 0.25; $p = 0.02$) whose characteristics can be seen in ►**Fig. 1**. Based on the B value of each variable, we form a logistic model:

$Y = -(4.3 - 1.4$ [Side branch] $- 3.4$ [blunt stump] $- 1.64$ [Calcification] $- 2$ [lesion length] $- 1.39$ [Tortuosity])

Table 3 Logistic regression

Step 4	B	Wald	Sig	Exp (B)
Side branch	−1.455	5.801	0.016	0.24
Blunt stump	−3.452	31.476	0.000	0.03
Calcification	−1.639	9.45	0.002	0.19
Length >20 mm	−2.487	18.19	0.000	0.08
Tortuosity	−1.387	5.43	0.020	0.25
Constant	4.261	42.96	0.000	70.89

Table 4 Scoring model to predict successful PCI in the CTO lesion

Side branches	1
Proximal vessel tortuosity	1
Calcified lesion	2
Lesion length more than 20 mm	2
Blunt stump	3

Abbreviations: CTO, chronic total occlusion; PCI, percutaneous coronary intervention.

If the variables were present, we gave the value of "0," and if absent we gave the value of "1." Thus, the complete formula to measure PCI in the CTO lesion success probability (P) is:

$$p(x) = \frac{1}{1 + e^{-(4.3 - 1.4(side\ branch) - 3.4(blunt\ stump) - 1.64(calcification) - 2(length\ more\ than\ 20) - 1.39(tortuosity))}}$$

To simplify the prediction, we transform this formula into the scoring model which can be seen in ►**Table 4**.

The Goodness of Fit Test

We performed the Hosmer–Lemeshow test and Negelkerke's R-square analysis. Hosmer–Lemeshow test concludes that the model is fit ($p = 0.613$) and the Negelkerke's R-square coefficient 0.688 showed a moderate to strong relationship.

Specificity and Sensitivity Test

Based on our scoring model, each score from 287 angiogram samples was calculated. The percentage of the successful PCI in the CTO was then calculated for each total score. As seen in ►**Table 5**, a high success rate (>90%) was observed on the total score of 0 and 1, while a low success rate (<5%) was observed on the total score of 7 and 8.

The total score was then analyzed with ROC analysis to predict its sensitivity and specificity for successful PCI in the CTO. ►**Fig. 2** showed that based on the ROC curve, the AUC of the score is 0.89. The score is having a cutoff point of ≤2 with a sensitivity of 93.33% and specificity of 88.23%, positive predictive value of 93.3%, and negative predictive value of 83.3% to predict successful PCI in the CTO.

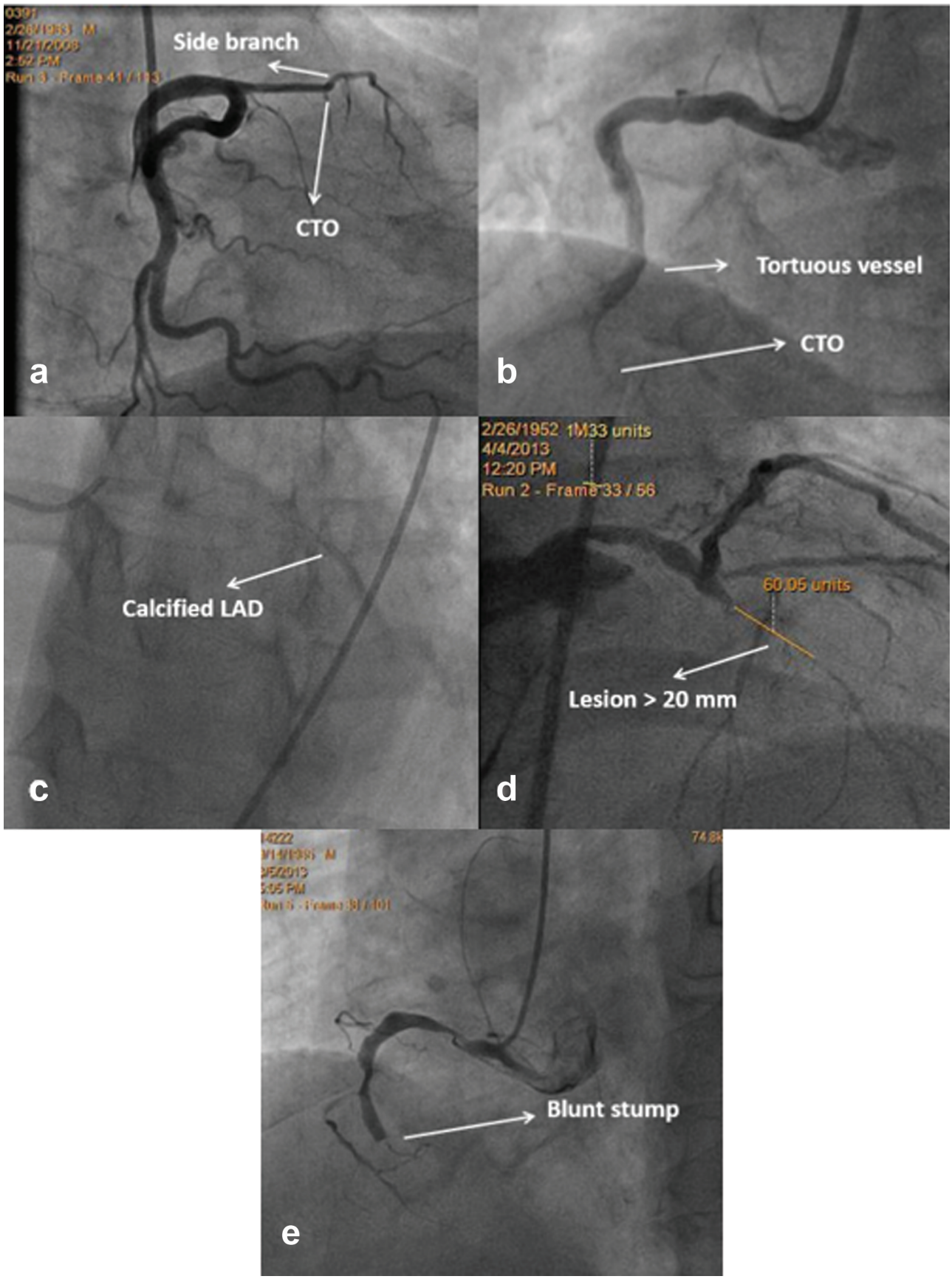

Fig. 1 Angiography characteristic in the scoring model: (**A**) Appearance of the side branch, (**B**) tortuous lesion, (**C**) calcification, (**D**) lesion length of more than 20 mm measured from the proximal occlusion to the distal retrograde filling from contralateral collaterals or bridging collateral, (**E**) blunt stump.

Table 5 Probability of successful PCI in the CTO lesion based on the total score

Total score	Probability of success
0	98.2%
1	95.3%
2	88.1%
3	73.1%
4	50.2%
5	26.9%
6	11.9%
7	4.7%
8	1.8%

Abbreviations: CTO, chronic total occlusion; PCI, percutaneous coronary intervention.

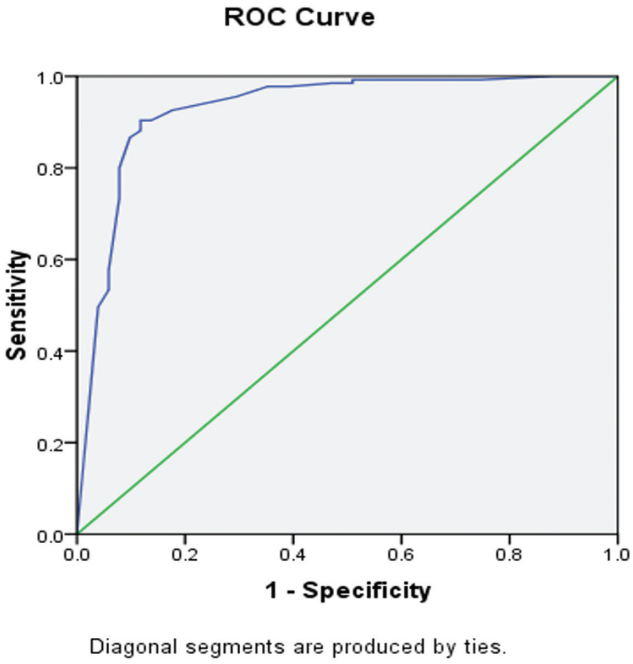

Fig. 2 Receiver operating characteristic (ROC) curve analysis for the scoring model to predict successful PCI in the CTO lesion. CTO, chronic total occlusion; PCI, percutaneous coronary intervention.

Discussion

The main findings of our study were: (1) The CTO attempt success rate was comparable with other studies; and (2) Five angiographic parameters have a strong relationship and could be used as a predictor for successful PCI in the CTO.

This study showed the overall CTO attempt success rate was 71.3%. This finding is consistent with the Canadian CTO registry where the success rate of CTO-PCI procedural attempts was 70%.[1] Few newer studies also exhibit comparable success rates of PCI in the CTO, which were around 68 to 72%,[9,10] though other registries from CTO specialized centers showed better success rates surpassing 80%.[11,12] With similar success rates, this research result may be comparable with other studies.

The present study confers five factors that may affect the success of the PCI in the CTO lesion. The first parameter is side branches at the occlusion site. Side branch at the occlusion was shown to increase the difficulty of PCI in the CTO.[13] Another study with larger sample size coming from various centers in the United States showed that side branch at proximal cap was associated with failure of PCI in CTO lesion independently.[14]

The second parameter is lesion tortuosity. Tortuosity was also proven to affect the success rate of PCI in the CTO lesion. Previous scoring method, The Prospective Global Registry for the Study of Chronic Total Occlusion (PROGRESS CTO) score, also involves vessel tortuosity which is shown to affect the success rate of PCI in the CTO,[15] suggesting that tortuosity is quite well established to predict PCI success. Interestingly, other variables in the PROGRESS CTO score which are proximal cap ambiguity, circumflex CTO, and absence of interventional collaterals were not evaluated in this research.[15]

The third parameter is lesion calcification. This research identifies that calcification may predict the success of the PCI in the CTO lesion. Previously, it was concluded that calcification was strongly correlated with the successful coronary intervention of CTO.[9] Various other researches also showed consistent findings which exhibited that a higher calcification can be a strong predictor of failure of PCI in the CTO lesion.[5,7,16,17]

The fourth parameter was the lesion length of more than 20 mm. Similar findings were reported in two studies involving a large sample size of CTO patients undergoing PCI which also showed that the lesion length of more than 20 mm increases the failure rate of PCI in the CTO lesion.[16,17]

The last parameter is the anatomy of the stump. Blunt stump may decrease the possibility of a guidewire to cross the lesion. Meanwhile, the tapered proximal stump, which is believed to have a potentially patent microchannel, may facilitate negotiating guidewire across the cap. Similarly, previous research also showed that blunt stump increased the risk of PCI failure in the CTO.[16] The other studies with larger sample size also reported blunt stump as an independent predictor of unsuccessful PCI.[17,18]

The score developed in this research demonstrated better discriminatory ability to predict successful PCI in the CTO compared with another score (sensitivity of 93.33% and specificity of 88.23%). Other popular scores such as J-CTO score is shown to have sensitivity of 93.3 to 100% and specificity of 5.2 to 22.0% and PROGRESS CTO score is shown to have sensitivity of 80.0 to 90.0% and specificity of 30.6 to 68.3% for scores 0 to 1.[15] This suggest that our score may have improved specificity and sensitivity to predict the success of PCI in the CTO which may help decision making process for interventional cardiologist.

Interestingly, in this study, the remaining parameters such as the location of CTO, ostial lesion, bending, collaterals, and any previous attempt had no impact on the failure or success of PCI in the CTO. While PROGRESS CTO score showed

circumflex CTO, absence of interventional collaterals may affect the success rate of PCI in the CTO lesion[15] The study, for instance, J-CTO score which was previously used to predict PCI success showed some similarities with our present study and hence concludes that stump morphology, CTO length, and calcification could predict the success of PCI in the CTO. Arguably, these differences may be due to the variability of device used, technique, and operator's experience. Thus, further study should consider minimizing these variations to develop predictors for successful PCI in the CTO with improved consistency.

Conclusion

Angiography characteristics which are: lesion length >20 mm, calcified lesion, blunt stump, proximal vessel tortuosity, and side branch may be used as a scoring model to predict successful PCI procedure in the CTO lesion.

Note

PROGRESS CTO: The Prospective Global Registry for the Study of Chronic Total Occlusion

EURO-CTO: A Randomized Multicentre Trial to Evaluate the Utilization of Revascularization or Optimal Medical Therapy for the Treatment of Chronic Total Occlusions

TOAST-GISE: Total Occlusion Angioplasty Study-Società Italiana di Cardiologia Invasiva

Conflict of Interest

None.

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