Acta Biomed 2023; Vol. 94, N. 3: e2023729 DOI: 10.23750/abm.v94i3.13454

Value of different CTO scoring systems in predicting procedural success in coronary chronic total occlusion intervention in Egyptian patients.

Ahmed Mohammed Ali AlAshry[1], *Muhammed Nagy Nagiub*[1], *Magdy Farouk Ahmed Ismael*[1], *Wesam Samir Alghonaimy*[1]

[1]Cardiology department, Faculty of medicine, Helwan University, Cairo, Egypt

[*]Corresponding author: Muhammed Nagy Nagiub, Email: Mohammed_Mohammed_Post@med.helwan.edu.eg

Abstract. Background: CTO intervention is a complex procedure with varying success rates. Objective: This study aims to compare the predictive value of different CTO scoring systems in determining the success of PCI in Egyptian patients. Patients and Methods: In the current study 100 patients with age range from (37-81) years old, presented to the cardiology department at different hospitals. The patients who suffered from CTO of at least one coronary artery and were planned for elective trial of PCI upon the totally occluded artery(s). Experienced CTO operators performed the PCI procedures, recording of procedural variables and assessing immediate post-procedural complications were performed. Logistic regression analysis was conducted to determine the relationship between procedural success rates and score values. The discriminative capacity of the CTO scores was evaluated using the area under the receiver operating characteristic (ROC) curve. Results: In this study, it was found that an inverse linear relationship between procedural success rates and score values across all CTO scoring systems. Also, the predictive capacity of the scores was similar, with slight differences. The PROGRESS and J-CTO scores demonstrated lower predictive significance, while the Euro CTO (CASTLE) score outperformed other scores, followed by the CL score. Conclusion: the CASTLE score was identified as the most effective score in predicting the success of PCI in CTO cases among Egyptian patients. Operators should select the appropriate CTO scoring system based on their experience and the specific characteristics of the cases they handle.

Keywords: Chronic total occlusion (CTO), Percutaneous coronary intervention (PCI), CTO scoring systems, Egyptian patients.

Introduction:

Chronic total occlusion (CTO) lesions still represent the last frontier for coronary interventionist and is a frequent reason for referring patients for coronary artery bypass graft surgery (CABG) [(1)]**.** The success rates of CTO percutaneous coronary intervention (PCI) vary between 55% and 80%, with higher success rates achieved in specialized centers [(2)].

Registry observations and more recent randomized trials are the foundation for the evidence supporting the treatment of a CTO [(3&4)]. There should be no distinction in the management of revascularization between a nonocclusive lesion and a CTO, according to recent guidelines; however, the technical difficulty of opening the occlusion by percutaneous coronary intervention (PCI) needs to be managed [(5)].

Dissection, perforation, and impairment of the ipsilateral collaterals to the distal bed are complications of this procedure. With a successful PCI of CTO, the major adverse coronary event (MACE) rate is approximately 2 to 2.5% percent [(2)]. According to Hoye et al., a MACE rate of approximately 5.6% percent is linked to failed PCI [(1)].

Successful CTO PCI has shown improved clinical outcomes, including reduced mortality, angina, stroke risk, and the need for subsequent CABG [(6)]. The procedure's complexity and potential complications necessitate careful patient selection [(7)] and planning. Advancements in equipment, techniques, and scoring systems have contributed to improved success rates and better outcomes in CTO PCI procedures [(3&7)].

To assess the potential success of the CTO PCI procedure, numerous scoring systems have been developed. The ones that are utilized the most globally are the J CTO score (Multicenter CTO Registry in Japan) [(7)], the clinical and lesion related score (CL) developed by Alessandrino et al [(9)], the Euro CTO (CASTLE) [(9)], and ORA score (Ostial Location, Age ≥ 75 years, Rentrop Grade less than 2) developed by Galassi et al [(3)].

Multiple uses for scoring systems are possible. They first offer a numerical assessment of the propensity

for success and complications. Second, CTO scores enable better case selection by enabling a more objective assessment of anatomical and clinical complexity [8].

The choice to revascularize and the best course of action within the heart team can be customized for each patient, taking into consideration the objective probability of achieving technical/angiographic success with PCI. Third, CTO scores give a helpful framework for directing review of the coronary angiogram. [10&11]. Fourth, standardized classification of CTO lesion complexity enables comparison of results with various approaches, amongst operators, facilities, countries, and regions, for both clinical research and quality enhancement [8].

In this study, comparison between the accuracy of different CTO Scoring Systems in Predicting Procedural Success of Percutaneous Coronary Intervention in Egyptian Patients. The coronary angiography and medical documentation will be used to calculate the J CTO, PROGRESS, CL, CASTLE, and ORA CTO scores; the procedural success will serve as the primary endpoint.

Patients and Methods:

Before participation in this study, written informed consent was taken from all patients after detailed explanation of the procedure. The study was conducted according to the declaration of Helsinki principals and was approved by the Ethical Committee of the Faculty of Medicine, Helwan University.

A prospective comparative study was conducted using a convenience sampling technique, in the cardiology department at Helwan University Hospital (Badr Hospital), International Medical center of Egypt and Kobri Elkoba Military hospital, during a period from December 2021- February 2023. The study included 100 patients with average age (37-81) years old, 94 males and 6 females. Patients who have CTO of at least one coronary artery and were planned for elective trial of PCI upon the totally occluded artery(s) on basis of objective evidence of ischemia or persistent ischemic symptoms thought to be due to the target artery supplying an area of viable myocardium were included in the study. CTO diagnostic criteria: A CTO is defined as an obstruction of a native coronary artery with no luminal continuity and with thrombolysis in myocardial infarction (TIMI) flow grade 0 or 1 for more than 3 months in duration using clinical information or the results of previous angiography.

CTOs that were included were one of the following:

- Certain (angiographically confirmed): A previous angiogram has confirmed the presence of TIMI 0-1 flow for 3 months prior to the planned procedure (either diagnostic CA or previous failed trial of PCI to CTO patients).
- Clinically Confirmed (Likely): a recent acute myocardial infarction in the region of the occluded artery distribution, a recent acute coronary syndrome, or a recent deterioration of the anginal threshold without other potential culprit arteries ≥ 3 months prior to the present angiogram.

Whereas, exclusion criteria included, Patients having one or more of the following: Hemodynamically unstable patients, Baseline renal impairment (serum creatinine > 1.4 mg/dl), Patients with severe left ventricular (LV) dysfunction (EF < 30%), Patients with an irregular cardiac rhythm (e.g, AF and frequent extrasystoles) and Patients who are proved to have non-viable myocardium in the territory supplied by the chronic totally occluded artery by one of the viability studies e.g., Dobutamine stress echocardiography, myocardial perfusion imaging and cardiac MRI.

All patients in the study were subjected to patient preparation through full history taking, proper general and local cardiac examination, resting 12-lead ECG, Transthoracic echocardiography for assessment of LV functions and adequate preparation of patients before PCI by loading dose of 300 mg of clopidogrel followed by daily 75 mg maintenance dose or by loading dose of 180 mg of ticagrelor followed by 90 mg twice daily as a maintenance dose. All patients had a serum creatinine test done before the PCI.

Pre-PCI:

The CTO scores were calculated before PCI by experienced operators and results were compared to each other. The calculated scores included: the J-CTO score, the PROGRESS CTO score (Prospective Global Registry for the Study of Chronic Total Occlusion Intervention), the Euro CTO score (CASTLE CTO score), the CL CTO score (The clinical and lesion-related (CL) score by Alessandrino et al. and the ORA CTO score by Galassi et al., CTO scores were calculated regarding many variables (Table 1).

Criteria of Scores	J-CTO (0-5)	Progress-CTO (0-4)	Euro (CASTLE-CTO) (0-6)	CL-CTO (0-8 by 0.5)	ORA-CTO (0-4)
Calcification	Calcification Existence		Calcification Existence	Calcification Existence**	
Tortuosity	Bending > 45	Presence of Two bends > 70 degrees or 1 bend > 90 degree	Presence of two bends > 90 or 1 bend > 120		
Age			Age > 70		Age > 75
Stump	Blunt Proximal Cap	Proximal Cap Ambiguity	Blunt	Blunt	
Length	Occluded segment > 20 mm		Occluded segment > 20 mm	Occluded segment > 20 mm*	
Redo (Previous Failed Attempt)	Yes				
CABG (History)			Yes	Yes*	
MI (History)				Yes	
Location of CTO		LCX		Non-LAD	
Interventional Collaterals		Absence			Collateral Filling**
Ostial CTO					Yes

The score of each item is equal to 1 point except for * = 1.5 points and ** = 2 points.

Table 1. Comparison of diffrent variables of CTO scoring systems used in this study

PCI:

PCI was done by operators highly skilled in CTO interventions.

Post PCI:

The following were counted for all the patients: Procedural success (Primary end point): defined as attainment of a residual diameter stenosis <30% and a TIMI flow rate of grade 2 or 3. Approach success: involving success or failure of the approach either antegrade or retrograde. Immediate Post procedural complications: that occurs within 48 hours after the procedure e.g.: contrast induced nephropathy and peri-

procedural myocardial infarction. All the resulting data obtained from all patients were collected, analyzed, interpreted, and statistically evaluated.

Statistical analysis was performed using SPSS 22 for Windows (SPSS Inc., Chicago, Illinois, USA). Continuous variables were presented as mean ± standard deviation and range. Incidence is presented as percentages. Continuous variables were compared by Student's t-test, while categorical variables were compared by chi-square test or Fisher's exact tests as appropriate. P value of ≤ 0.05 is considered significant.

Results:

In the current study, a total number of 100 patients with CTO, with age ranging from 37-81 years old with Mean age ± SD (59.2 ± 10.14), 96 patients (96%) were males, and 4 patients (4 %) were females. 51 patients (51%) had DM, while 57 patients (57%) had hypertension, 80 patients (80%) were dyslipidemic, 76 patients (76%) were smokers. Among the selected patients 10 patients (10%) had previous CABG, 23 patients (23%) had previous PCI, and 16 patients (16%) experienced previous MI; (Table 2).

Variable	
Age	59.2 ± 10.14
Sex (male)	94%
DM	51%
Hypertension	57%
Dyslipidemia	80%
Smoking	76%
Culprit Artery	
LCX	17%
RCA	51%
LAD	30%
Ramus	2%
Osteal CTO	16%
Previous CABG	10%
Previous PCI	23%
Previous MI	16%

Table 2. Shows demographic and clinical characteristics of selected population presented in percentages or mean ± SD.

Older patients had a significantly increased incidence of failure for the whole procedure (P=0.05) and Patients who suffered a previous MI had a significantly larger incidence of failure (P=0.02).

It was found that the overall success rate in the patients included in the study was 86% with antegrade approach performed in 80% of the selected patients with success rate 85%, while 20% of the patients went through a retrograde approach with 91% success rate (Figure1).

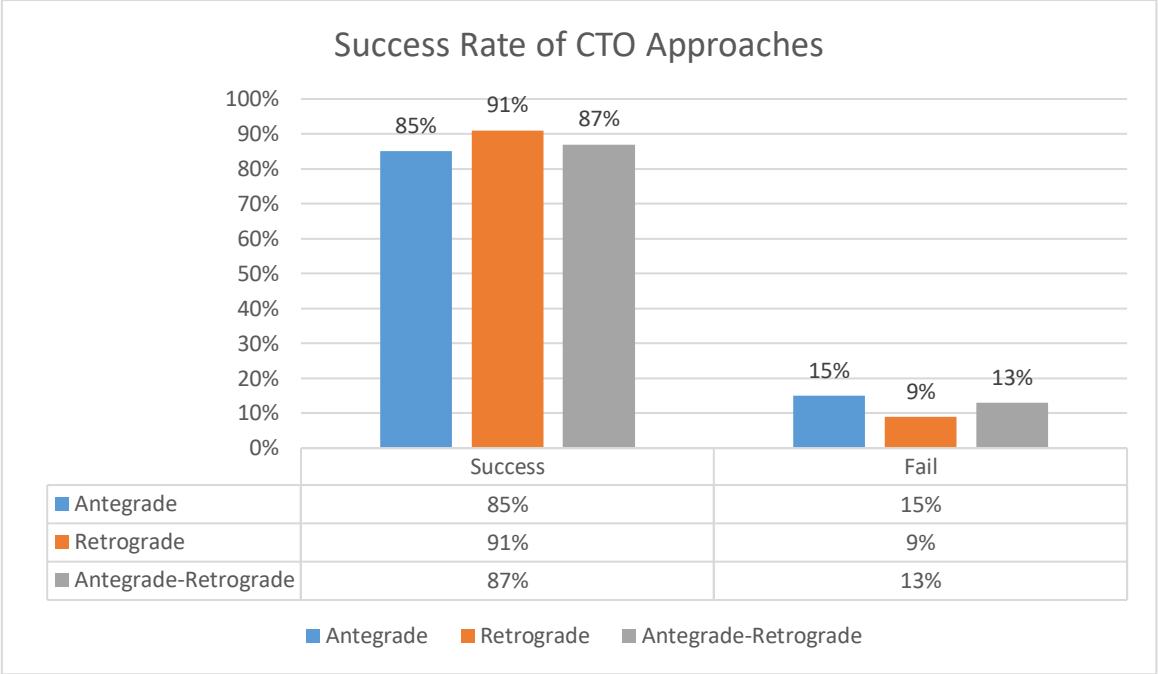


Figure 1. Shows percentages of success for different CTO approaches in relation to selected patients.

Immediate post procedure complications occurred in the form of CIN in 12% of the selected patients with overall success rate of 91%, while post procedure MI occurred in 7% with overall success rate of 85%, and both occurred in 3% of the patients. Having an overall complication of 19% of the selected patients (Figure 2).

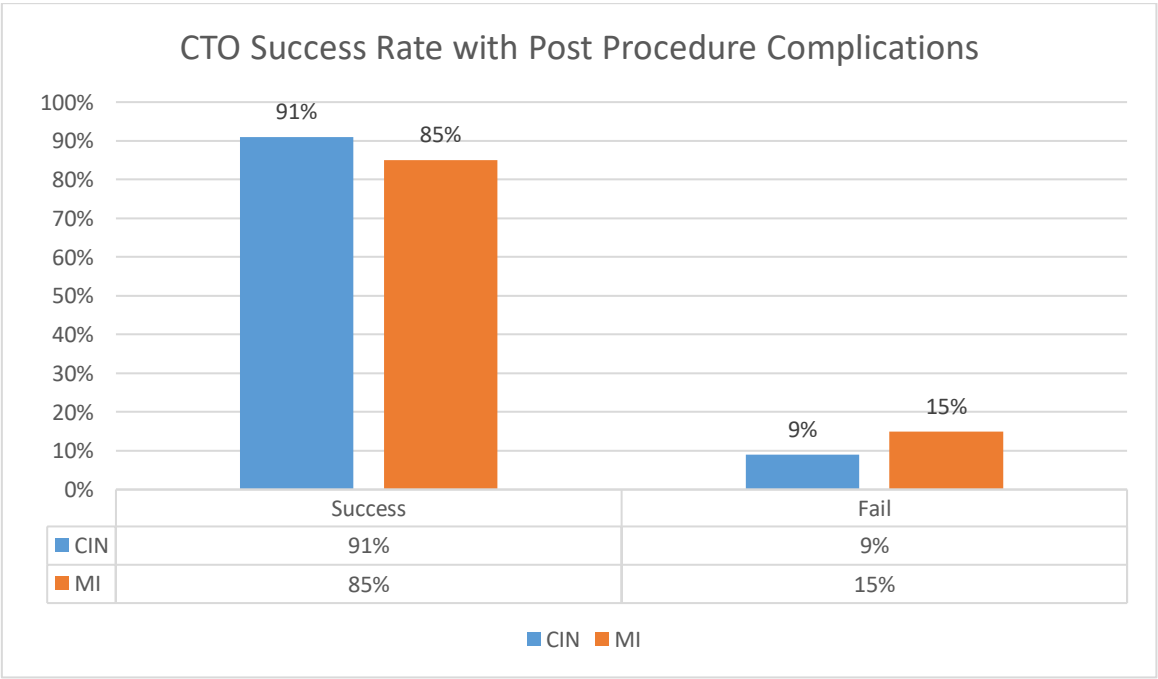


Figure 2. Shows percentages of success with immediate post procedure complications.

As regards the value of different CTO scoring systems in prediction of the procedural outcome, it was found that, the mean and standard deviation for J-CTO Score was 2.47 ± 1.13; Progress CTO 1.06 ± 0.96; Euro (CASTLE) CTO 2.13 ± 1.13; CL CTO 3.98 ± 1.58; ORA CTO 1.22 ± 1.21 (Table 3).

Score	Mean	Standard Deviation
J-CTO	2.47	1.13
Progress-CTO	1.06	0.96
Euro (CASTLE-CTO)	2.13	1.13
CL-CTO	3.98	1.58
ORA-CTO	1.22	1.21

Table 3. percentages or mean ± SD of different scores.

Distribution of the selected patients according to the different CTO scores was found to as follows; J-CTO score distribution shows 9% of score 0 (easy), 18% of score 1 (intermediate), 37% of score 2 (difficult), 36% of score 3-5 (very difficult) from the selected population with the success percentage (Figure 3). As for Progress CTO score distribution shows 24% of score 0 (easy), 46% of score 1 (intermediate), 23% of score 2 (difficult), 7% of score 3-4 (very difficult) from the selected population with the success percentage shown in (Figure 4). Whereas for Euro (CASTLE) CTO score distribution shows 33% of score 0-1 (easy), 34% of score 2 (intermediate), 25% of score 3 (difficult), 8% of score 4-6 (very difficult) from the selected population with the success percentage shown in (Figure 5). As for CL CTO score distribution shows 14% of score 0-1 (easy), 10% of score 1.5-2.5 (intermediate), 58% of score 3-4.5 (difficult), 18% of score 5-8 (very difficult) from the selected population with the success percentage shown in (Figure 6), and finally for ORA CTO score distribution shows 21% of score 0 (easy), 40% of score 1 (intermediate), 23% of score 2 (difficult), 16% of score 3-4 (very difficult) from the selected population with the success percentage shown in (Figure 7).

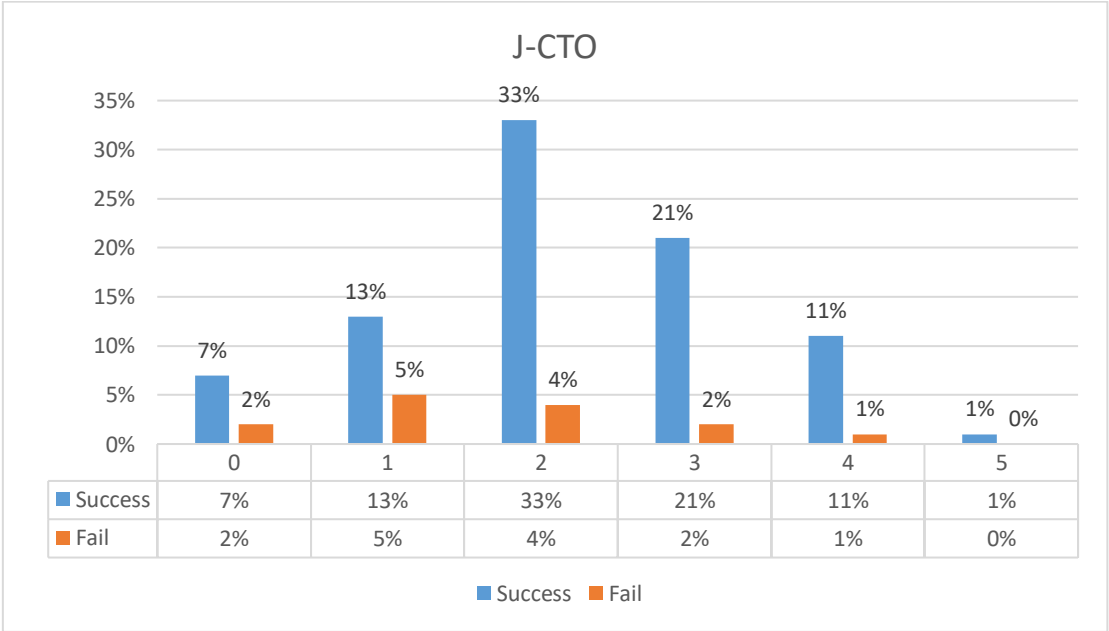


Figure 3. Shows distribution percentage of the selected patients according to the J-CTO score.

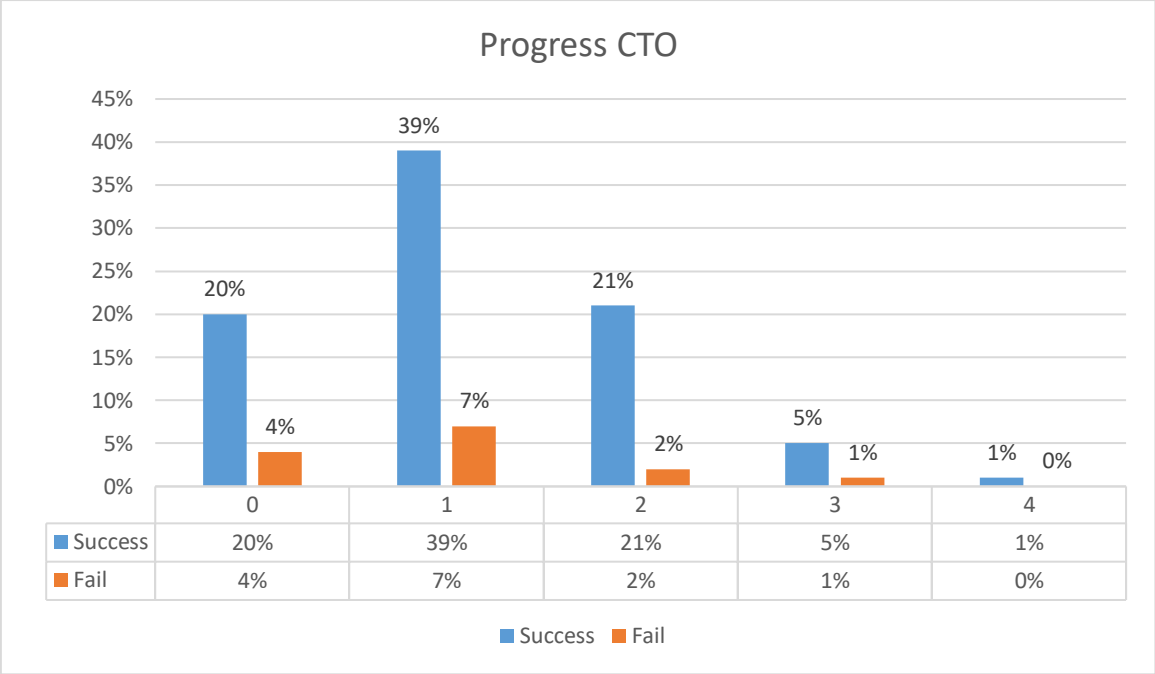


Figure 4. Shows distribution percentage of the selected patients according to the Progress CTO score.

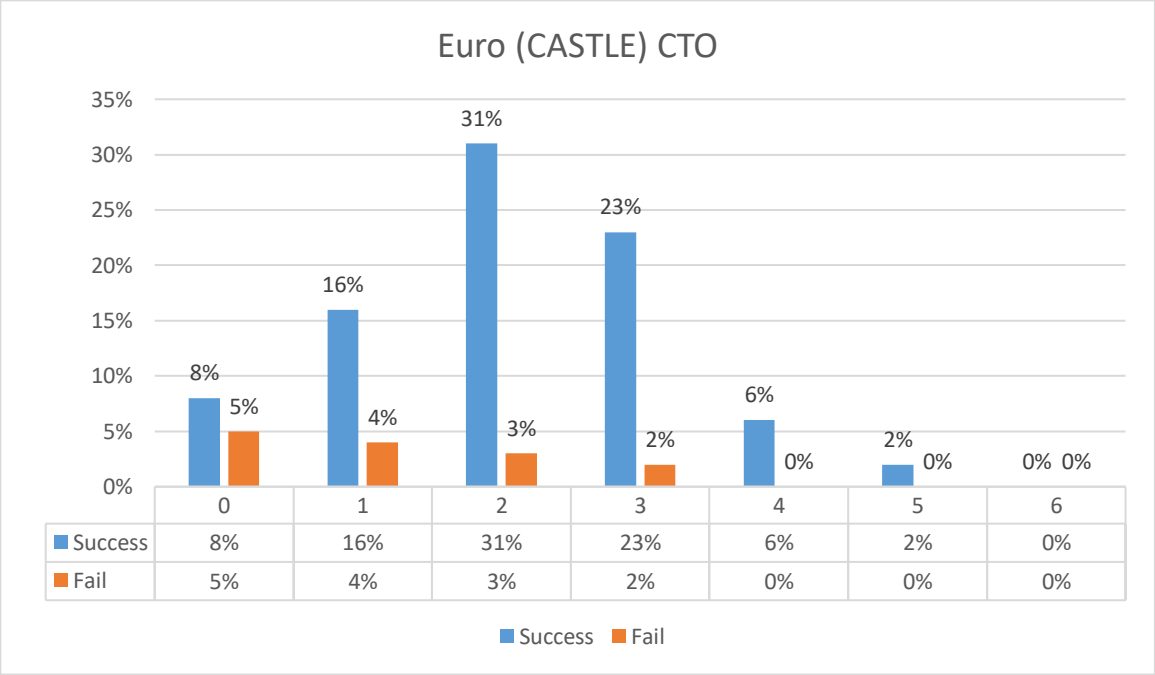
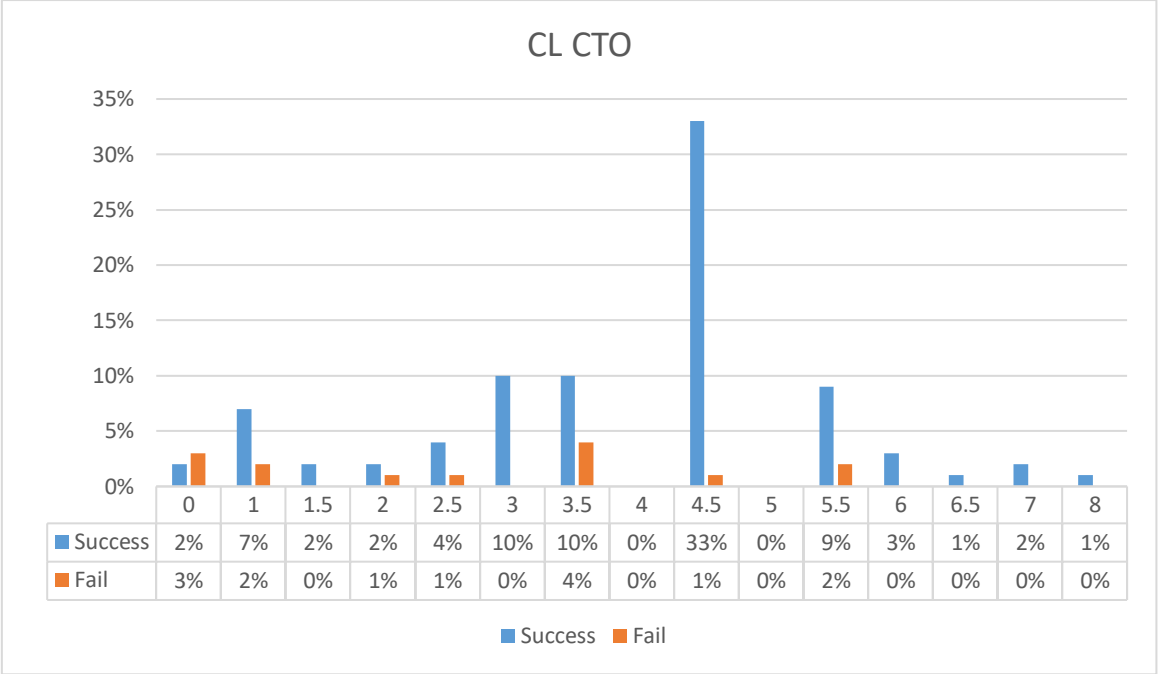
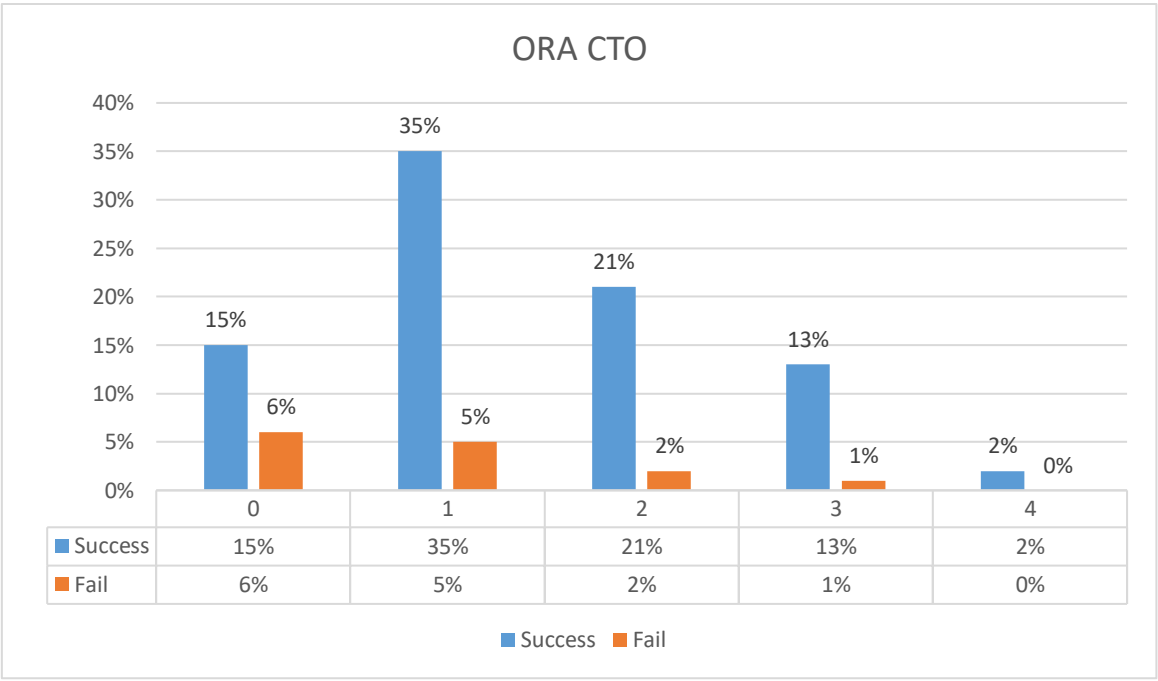


Figure 5. Shows distribution percentage of the selected patients according to Euro (CASTLE) CTO score.



	0	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	8
Success	2%	7%	2%	2%	4%	10%	10%	0%	33%	0%	9%	3%	1%	2%	1%
Fail	3%	2%	0%	1%	1%	0%	4%	0%	1%	0%	2%	0%	0%	0%	0%

Figure 6. Shows distribution percentage of the selected patients according to the CL CTO score.



	0	1	2	3	4
Success	15%	35%	21%	13%	2%
Fail	6%	5%	2%	1%	0%

Figure 7.Shows distribution percentage of the selected patients according to the ORA CTO score.

A logistic regression analysis was performed and the reflection of all scores showed an inverse linear relationship between procedural success rate with score value ($p < 0.001$ in all scores).

A comparison between the predicted and observed success rates for each score depending on logistic regression analysis was done for J-CTO, Progress CTO, Euro (CASTLE) CTO, CL CTO, ORA CTO. It was observed that success rates were higher than predicted success rates in the upper categories of different scores and on the other hand the predicted success rates were higher than the observed ones in the lower categories of different scores (Figures 8,9,10,11,12). That means that there was

an overestimation for the actual success rates in the lower categories of each score and an underestimation in the higher categories.

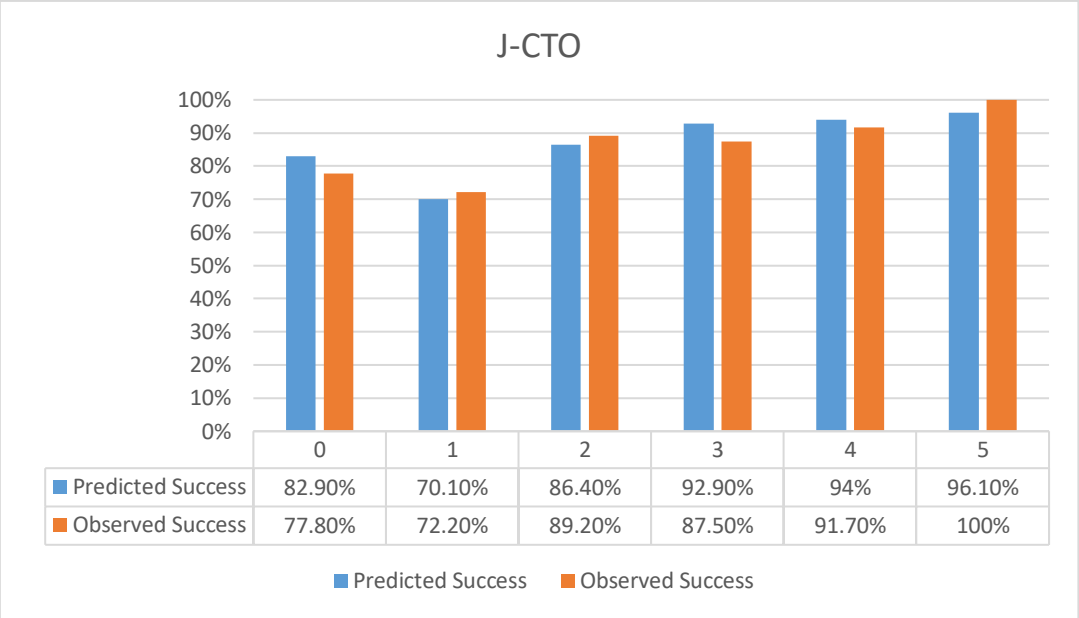


Figure 8. Expected success rate compared to observed success rate for J-CTO with Linear trend p value p<0.001

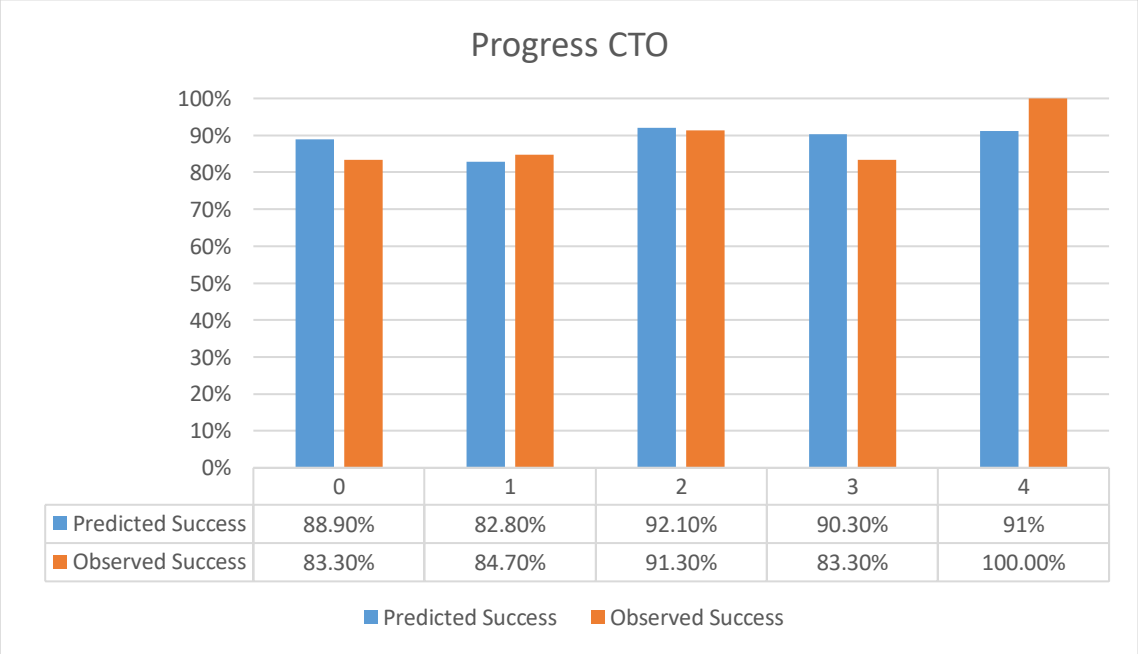
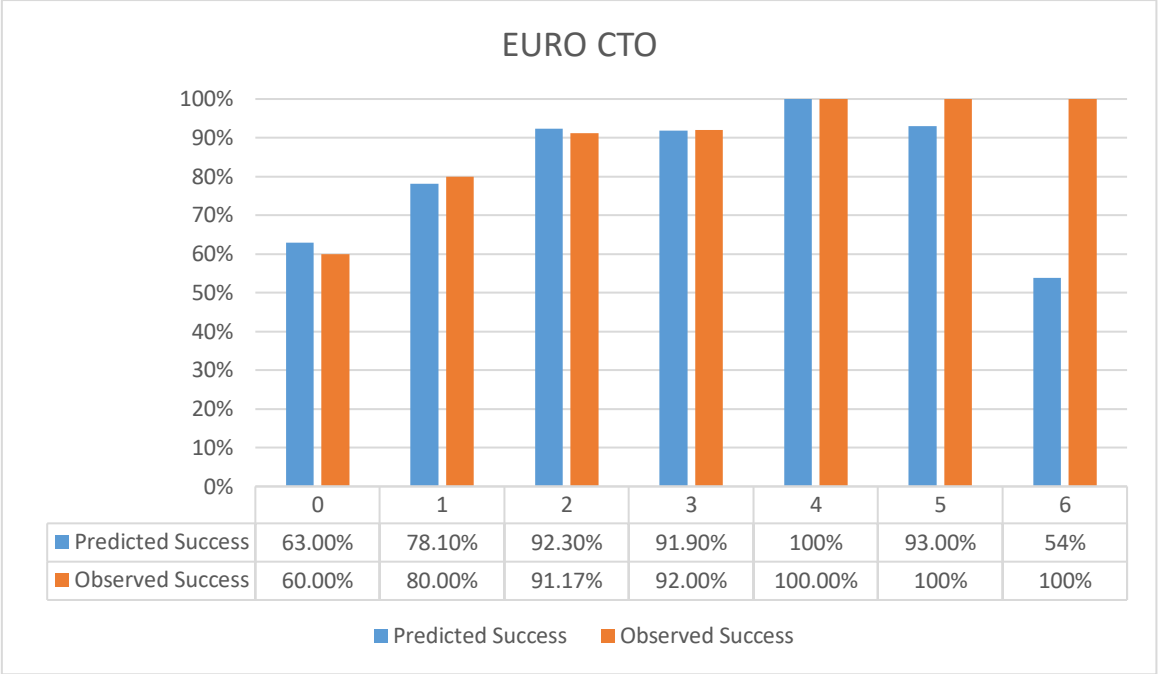
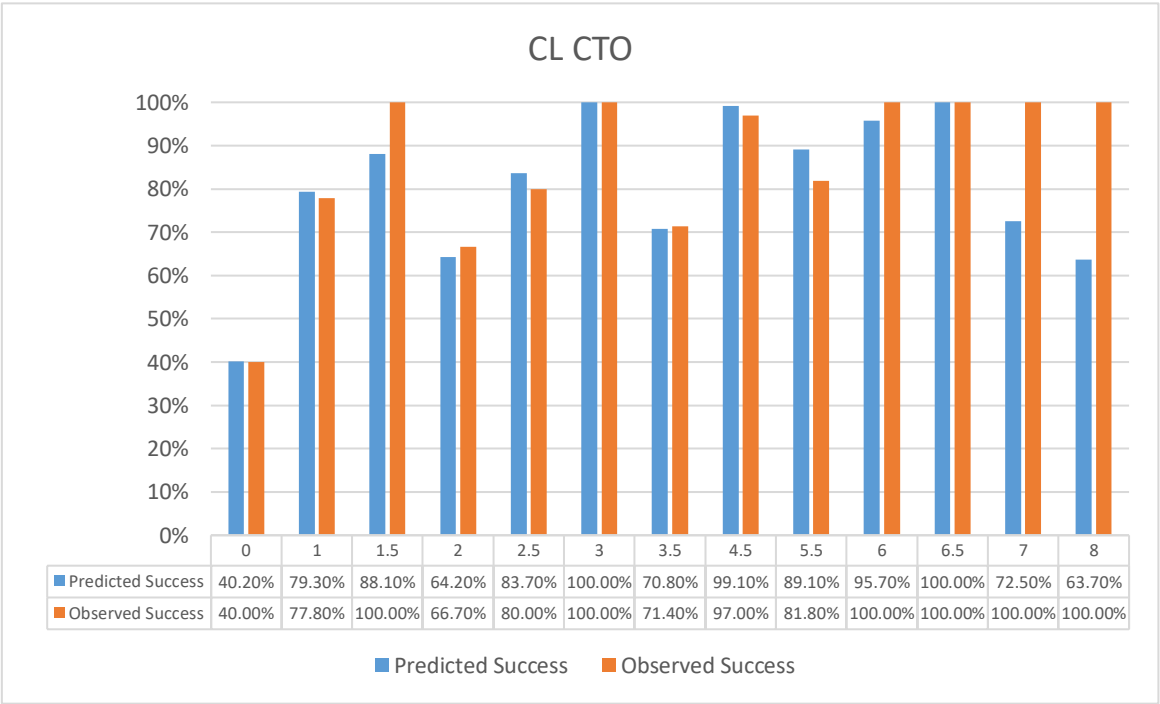


Figure 9. Expected success rate compared to observed success rate for Progress CTO with Linear trend p value p<0.001.



	0	1	2	3	4	5	6
Predicted Success	63.00%	78.10%	92.30%	91.90%	100%	93.00%	54%
Observed Success	60.00%	80.00%	91.17%	92.00%	100.00%	100%	100%

Figure 10. Expected success rate compared to observed success rate for Euro CTO with Linear trend p value p<0.001.



	0	1	1.5	2	2.5	3	3.5	4.5	5.5	6	6.5	7	8
Predicted Success	40.20%	79.30%	88.10%	64.20%	83.70%	100.00%	70.80%	99.10%	89.10%	95.70%	100.00%	72.50%	63.70%
Observed Success	40.00%	77.80%	100.00%	66.70%	80.00%	100.00%	71.40%	97.00%	81.80%	100.00%	100.00%	100.00%	100.00%

Figure 11. Expected success rate compared to observed success rate for CL CTO with Linear trend p value p<0.001.

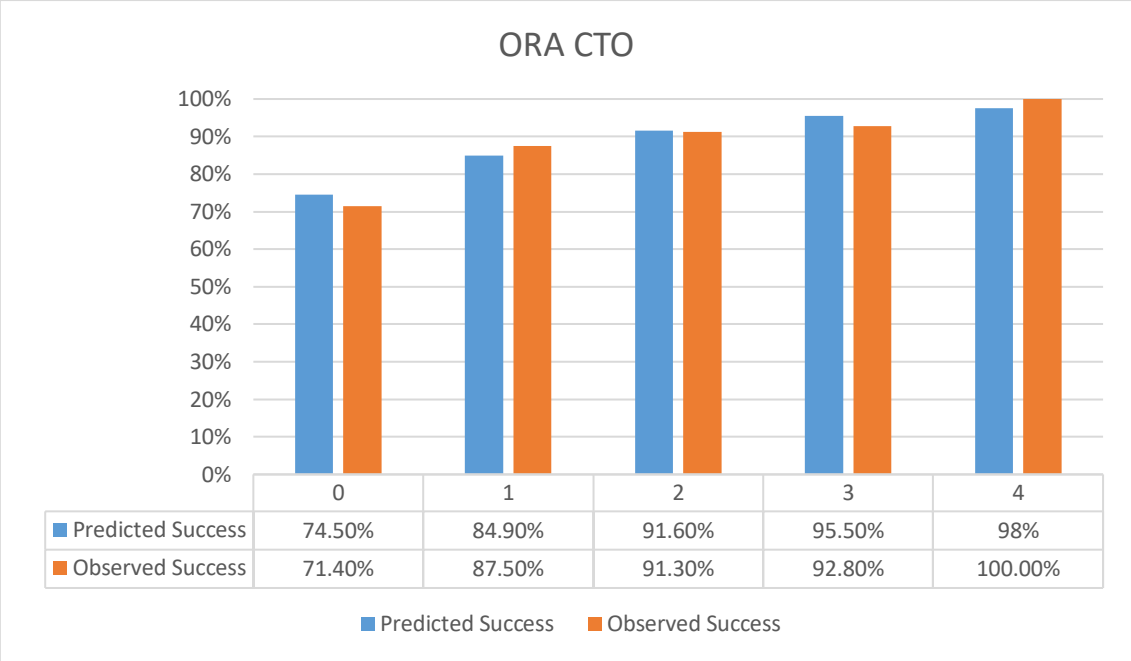


Figure 12. Expected success rate compared to observed success rate for ORA CTO with Linear trend p value p<0.001.

The discrimination of the scores for procedural success was tested using the AUC of the ROC curve (Figure 13).

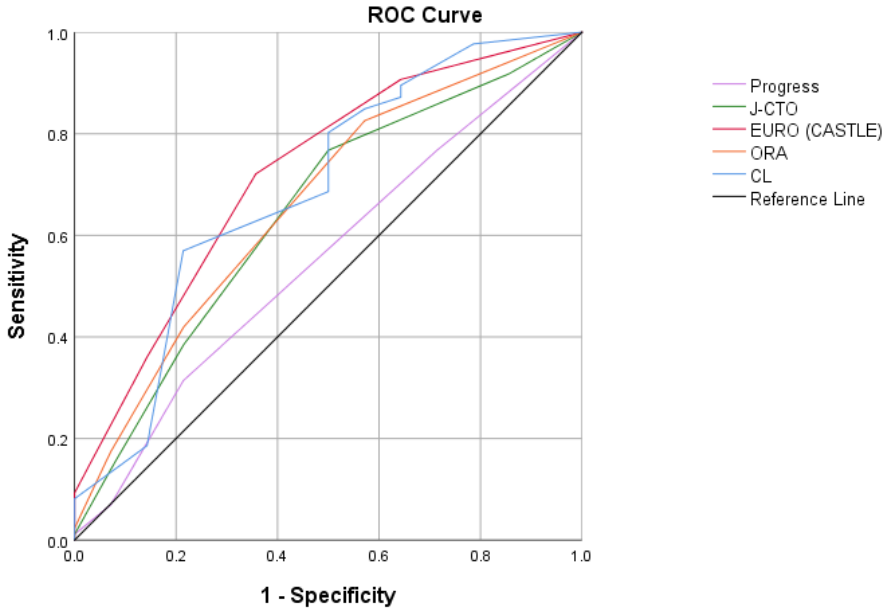


Figure 13. Shows ROC curve and AUC curve each score discriminating procedural success

The predictive capacity of different CTO scores appeared to be near to each other with small differences but AUC from PROGRESS score was lower than other scores as (AUC 0.553, 95% CI: 0.53 – 0.59, p < 0.007) followed by J-CTO score which showed (AUC 0.645, 95% CI: 0.62 – 0.68, p<0.001) followed by ORA score which showed (AUC 0.663, 95% CI: 0.64 – 0.70, p < 0.001) followed by CL and CASTLE scores as they were near to each other's, however CASTLE score was superior to CL score as it showed (AUC 0.721, 95% CI: 0.70 – 0.76 , p<0.001) compared to CL score which showed (AUC 0.691, 95% CI: 0.67 – 0.73, p < 0.001); which means that PROGRESS and J-CTO score were less significant in prediction of success rate while EURO (CASTLE) CTO

score was superior to other scores with small differences higher than CL score. ORA CTO score shows intermediate probability in prediction of success of PCI in CTO cases (Table 4).

	AUC	AUC CI
Progress	0.553	0.53 – 0.59
J-CTO	0.645	0.62 – 0.68
EURO (CASTLE)	0.721	0.70 – 0.76
ORA	0.663	0.64 – 0.70
CL	0.691	0.67 – 0.73

Table 4. Shows ROC curve and AUC curve each score discriminating procedural success.

Discussion:

Analysis of demographic and clinical characteristics of our study patients in relation to PCI outcome revealed a significant effect of patient's age on the procedure outcome with more failure in older patients. The effect of age may be related to increased CTO duration. Also, increased age seems to be related to more severe calcification. Also, Patients who suffered a previous MI had a significantly larger incidence of failure.

An important point was observed in this study that calculating different scores to the same patients (Not different cohorts) were important due to the presence of different variables, different categories for each score and for proper selection of the best score suitable for application on the Egyptian patients as the heterogeneous characteristics of different cohorts may be the direct cause for the appearance of different scores worldwide with different criteria and categories for each score except for some similarities between them.

As only Euro CASTLE and CL scores has clinical variables included in their criteria as for previous CABG for example which is a known factor that increases the failure rate in the CTO PCI with a recent study from the progress database that found 5% less recanalization success in CABG patients compared to non-CABG patients [(12)]. Another important note was that the definition of tortuosity and calcification were slightly different between different scores and may be depending on the operator himself to some extent, but they were still the same for severe tortuosity and severe calcification in different scores as they considered to be from the important factors to be consistently calculated. And it is notable that only two scores considered the evaluation of collateral circulation (PROGRESS and ORA scores) despite their importance in planning for the best approach in the CTO PCI. And despite these differences, it is very important to make a proper evaluation for each CTO case calculating one or more CTO scores for proper classification of the case complexity and for procedural planning especially for operators early in the CTO PCI learning curve.

Comparing the predictive results of different CTO scores in our study with the original values of the different cohorts of the different scores it was higher at our study this may be due to the new devices and techniques used nowadays performing more complex cases in comparison to the older J-CTO, Progress and CL scores in contrary to the Euro CASTLE CTO score which is the most recent with derived data from Euro CTO club.

There have been some published score comparisons that suggest the scores may perform as well as or better than the original cohorts. Karastakis et al. compared CL, J-CTO and PROGRESS scores in a cohort from the PROGRESS CTO registry [(13)].

Also, another comparison was made between J-CTO, PROGRESS and CL scores to CASTLE score which showed the same results of the original cohorts [(14)].

In our study PROGRESS and J-CTO score were less significant in prediction of success rate while EURO (CASTLE) CTO score was superior to other scores with small differences higher than CL score. ORA CTO score shows intermediate probability in prediction of success of PCI in CTO cases which is the same results of **Salinas et. al., 2021** with nearly the same order of the used CTO

scores in both studies except for the ORA score which is not used in the other study [14].

An interesting observation was noted which is Observed success rates were higher than predicted success rates in the upper categories of different scores and on the other hand the predicted success rates were higher than the observed ones in the lower categories of different scores. That means that there was an overestimation for the actual success rates in the lower categories of each score and an underestimation in the higher categories. Which also means there should be a proper planning for each CTO case with calculating of at least two CTO scores for reaching a better success result and this should be done especially for less experienced operators unlike Very experienced operators with higher success rates (over 90%) will be less interested in calculating CTO scores in the purpose of knowing success rate but in order to know the risk of different complications especially for CASTLE and CL score respectively (Both have Clinical variables in addition to the angiographical ones). CASTLE is easier to calculate as has less criteria than CL score.

Finally, and according to our study CASTLE score is the best score in predicting the success of PCI in CTO cases among the Egyptian patients who took place in this study as it was originally depending on the largest cohort, operators, and techniques between the other scores, and it contains clinical variables and less criteria to be counted.

Other CTO scores were beyond the scope of this study due to the presence of special technique or device (CrossBoss and hybrid techniques in Europe, RECHARGE registry [15]; or the use of other methods for the assessment of the CTO cases (CT-RECTOR [16] or KCCT [17] scores) so they were excluded from this study depending only on the more commonly and widespread scores.

Conclusion:

According to this study, it was found that CASTLE score was the best among Egyptian patients who took place in this study as it was originally depending on the largest cohort, operators and techniques between the other scores and it contains clinical variables and less criteria to be counted, followed by CL score with slight differences in between but more criteria in CL score then ORA CTO score with intermediate performance followed by J-CTO and progress scores with slightly worse efficiency.

Different operators should choose the proper CTO score according to their experiences either for the proper choice of the CTO cases to perform or for minimizing the risk of complications and according to our study CASTLE and CL scores were the best for both experienced and less experienced operators.

Many factors influence the difficulty of the CTO PCI not only the criteria of different scores but also the criteria of the cohort included and according to our study group CASTLE and CL scores were the best. Finally, there should always be a proper planning for each CTO case whatever the CTO score to guarantee the maximum chances of success.

Financial disclosure:

The authors declared low potential conflicts of interest with respect to the research, authorship and/or publication of this article.

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