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Original Article

Prediction of Successful CTO Percutaneous Coronary Intervention Using J-CTO Score Derived from Computed Tomography Versus Coronary Angiography

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Abstract

Background: Percutaneous coronary intervention [PCI] for coronary chronic total occlusion [CTO] remains a challenge from the technical point of view. Presence of an outcome predictor is of utmost importance.

The aim of the work: This work aimed to compare the accuracy of the CTA-derived versus conventional angiography derived J-CTO scores in prediction of the procedure difficulty and success.

Patients and Methods: Fifty patients were included. They were submitted to CTA before PCI to a CTO. They were submitted to multislice CTA, with calculation of J-CTO score for conventional and CTA before PCI in addition to standard assessment. The primary endpoint was the successful guide wire crossing within 30 minutes of the procedure time. The secondary end point was the successful GW crossing through CTO at any time with restoration of flow and achievement of < 50% residual diameter stenosis and TIMI flow grade 2 to 3.

Results: Forty and 60% required less [success] and more than 30 minutes [failure]. However, the overall success was 82.5%. The primary and secondary failure were significantly associated with a significant increase of diabetes and previous CABG. CT derived J CTO Score has higher sensitivity and specificity for prediction of successful GW crossing within 30 minutes than CA derived J CTO score. In addition, the CT-derived J CTO score can differentiate between successful and failure patients at the cutoff point > 2 with sensitivity of 88.8 %, specificity of 73.17 % and AUC of 0.877 while the CA-derived J-CTO score can differentiate between successful and failure patients at the cutoff point >1 with sensitivity of 77.7 %, specificity of 65.85% and AUC of 0.789.

Conclusion: CT-derived J-CTO score is a useful predictor for difficulty and time efficiency of guide wire [GW] crossing in CTOs, as well as the ultimate success of the procedure.

Keywords: Transthoracic Echocardiography; Coronary angiography; Computed Tomography; J-CTO score.

INTRODUCTION

Despite notable progress in the development of technology, percutaneous coronary intervention [PCI] of coronary chronic total occlusion [CTO] lesions remain technically challenging, and the success rate of a CTO-PCI is lower than PCI of a non-occlusive coronary artery stenosis [1-3].

The main challenging issues are the long duration of the procedure, the need for higher volume of the contrast material, with increased radiation exposure and lower success rate [4-7]. However, the expected benefits of PCI revascularization include the improved quality of life [QoL], improved function of the left ventricle [LV], increased expected long-term survival, increased tolerance to subsequent coronary conditions, and reduced the risk of dangerous arrhythmias[8,9].

To estimate the difficulty of the procedure, an objective index [the J-CTO] score had been introduced. It uses morphologic characteristics of the lesion to estimate the severity. These include entry, shape, calcification, bending, occlusion length and previous revascularization attempt[10].

The use of J-CTO score had been confirmed to be effective in previous studies, reporting an excellent predictive accuracy of 30 minutes wire crossing [11]. However, the recent advances in the coronary computer tomography angiography [CTA] may provide additional benefits and information when compared to the conventional angiographic data in the prediction of the TO-PCI difficulty [12].

For instance, the lesion length may be defined in an accurate manner by coronary CTA than conventional angiography [13]. However, the ability of conventional angiography to coronary CTA to predict the outcome of CTO-PCI difficulty is not compared in sufficient reports [12]. Thus, the current work was designed to address this issue.

THE AIM OF THE WORK

The work aimed to compare the accuracy of the CTA-derived J-CTO score with that of the conventional coronary angiography–derived J-CTO score to predict the procedural success and 30-minutes wire crossing during a CTO-PCI.

PATIENTS AND METHODS

Th This was a prospective observational study, which included 50 patients who underwent computed tomography coronary angiography before PCI to a CTO of the coronary artery. They were selected from the Islamic cardiac center, and Elhussein university hospital [Al-Azhar university, Cairo, Egypt]. Patients were included and the study was completed between August 2022 and March 2024.

The inclusion criteria were patients with CTO [on the basis of previous coronary angiography], who were scheduled for elective PCI trial according to the objective evidence of ischemia or persistent ischemic symptoms attributed to stenosis of the target artery supplying an area of viable myocardium despite optimal medical therapy. The CCTA was performed one month before CI.

The exclusion criteria were history of acute myocardial infarction [MI] in the last 3 months, no coronary CTA within 1 month before intervention, renal insufficiency with estimated GFR < 30 ml/min/1.73 m^2, irregular arrhythmia [e.g., AF and frequent extra systole], severe LV dysfunction [EF<30.0%], uninterpretable CCTA due to poor image quality, inability to perform breath holding, and decompensated heart failure.

Ethical aspects: Before inclusion in the study, the study aim, procedure and all rights of the patient were explained and an informed consent was obtained. The study protocol was submitted, evaluated and approved by the local research and ethics committee of Al-Azhar Faculty of Medicine. The study procures, data collection, and reporting were all completed in line with available guidelines and declaration of Helsinki ethical codes.

Patient assessment was performed in a standard manner. It included full history taking, clinical examination [general and local cardiac examination] and investigations [laboratory and radiological]. The laboratory workup consisted of complete blood count, renal function tests, and lipid profile. However, the imaging investigations included a 12-lead electrocardiogram, standard resting transthorathic echocardiography [TTE] and invasive diagnostic coronary angiography.

From TTE, the following indices of the left ventricle were calculated: end diastolic diameter [EDD], end systolic diameter [ESD], Ejection fraction [EF], fractional shortening [FS] and assessment of regional wall motion abnormalities at rest.

The diagnostic CA was performed using standard modified Seldinger's technique in multiple projections on cardiac angiographic system and stored digitally. For each CTO segment, the J-CTO score was calculated based on the ICA findings according to the criteria of the J-CTO scoring sheet. The J-CTO system is an angiography-based scoring system used to assess the difficulty of CTO crossing. One point is given for each of the following factors associated with a lower probability of successful guide wire [GW] crossing within 30 min [a blunt stump at the entry site, any evident calcification detected within the CTO segment, within lesion bending > 45°, an occlusion length > 20 mm, prior failed attempt to vascularize the CTO]. Accordingly, all lesions were categorized into: [1] Easy [score of 0], 2] Intermediate [score of 1], 3] Difficult [score 2], and 4] Very difficult [score ≥ 3] [14].

The multislice CT coronary angiography Technique:

The patient preparation included the following [checking contraindications for nitrates and ß-blocker, instruct the patient to fast 4-6 hours before the scan and avoid caffeine for 12 hours, provide instruction to the patients on how to breathe during the examination, an electrocardiogram signal needs to be acquired, and heart rate control [less than 65 beats per minute].

The premedication included the check of heart rate and blood pressure before administration of medications, then nitrates [5 mg sublingual nitrates] was administered with a systolic blood pressure of at least 100 mmHg, 5 minutes prior to scanning in order to expand coronary arteries and ß-blocker were administered to reach the target pulse of ≤ 65 bpm]. The patient was position in the supine position with both arms above their head [as comfortable as possible]. Then, ECG electrodes were placed and good ECG signals were ensured. The tube voltage was kept at 100 KV if patient's weight ≤100kg BMI <30kg/m^2 or it may reach to 120-140 KV in obese and taller patients.

A retrospective ECG-gated acquisition was performed. It was typically put in mid-diastole in lower heart rates <70 bpm, and the optimal phase of R-R interval was noted for absence of motion artifact in order to analyze the data properly.

The contrast agents were injected in the non-ionic with high iodine concentrations [350 or 370 mg iodine/mL] and an automatic bolus tracking was used to govern contrast timing. The volume of contrast was set to be in a dose of 0.8 ml/kg, injected through Biphasic injection [standard contrast injection].

The contrast media was injected firstly at 5-7 mL/s [total volume of 50 – 90 ml]. Then, 40-50 mL saline injection at 5-7 mL/s by a programmed dual head power injector pump to maintain good opacification of the coronary vessels with wash out of contrast material from the SVC and right side of the heart. Then and for respiratory phase, for breath-hold consistency, a medium-sized breath is easier to reproduce throughout the examination compared to sharp deep breaths.

All CT examinations were performed on multislice 160 – slice single source TOSHIBA Prime Aquilion CT scanner. After a delay of about 10 seconds from the start of injection, series of axial images at the level of the origin of the left main coronary artery is acquired with an interval of 1 second between subsequent images.

The CT coronary angiography data set were processed and various reformatting techniques such as maximum intensity projection, multiplanar reformation and 3D volume rendering were generated. Reconstructed CTA data were used to evaluate the morphology of the CTO lesion and for the calculation of J-CTO score properly.

The CT- derived J-CTO score included previous failed PCI attempt in addition to four morphologic characteristics of a CTO: blunt proximal cap; calcification; bending >45 and length of occluded segment >20 mm.

The morphology of the occlusion entry point was classified as tapered or blunt on the maximum intensity projection image. As defined in the conventional angiography–derived J-CTO score, tapered morphology was an entry point with a funnel-shaped form, whereas blunt morphology lacked a funnel shaped entry point.

A calcified lesion on CTA had a calcified area >50% of the vessel cross-sectional area; this was different from conventional angiography that merely reported the presence or absence of calcification. The length and bending of a CTO segment were evaluated three - dimensionally using CTA. Bending was defined as the presence of at least one bend of >45_ within the length of the occlusion.

The length of occlusion was measured from the proximal margin to the distal margin of the total occluded segment. Length and bending CTA definitions were also consistent with definitions used in conventional coronary angiography [15]. Thus we compared parameters of **J- CTO** score derived from diagnostic CA and from CT coronary angiography.

Percutaneous coronary intervention:

All of the enrolled patients were submitted to CTO-PCI as a staged procedure [i.e., not ad hoc immediately after coronary angiography]; this enables us to consider the strategy using both CTA and conventional coronary angiography findings. CTO was defined as a coronary lesion with TIMI [Thrombolysis in Myocardial Infarction] flow grade 0 for at least 3 months as estimated using clinical information or the results of previous angiography [16].

The primary end point was the wire-crossing time less than 30 minutes, while the secondary end point is procedural success.

The primary endpoint was defined as successful GW crossing through the CTO within 30 minutes of the procedure time, which is the time from insertion of the GW into the vessel to the time it was successfully crossed through the lesion or was pulled out of the vessel because of unsuccessful GW crossing.

The secondary end point was defined as successful GW crossing through CTO at any time, with restoration of flow and achievement of < 50% residual diameter stenosis and TIMI flow grade 2 to 3 [17].

Statistical Analysis:

Data were collected, revised, coded and entered to the Statistical Package for Social Science [IBM SPSS] version 23. The quantitative data were presented as mean, standard deviations and ranges when parametric and median, inter-quartile range [IQR] when data found non-parametric. Also qualitative variables were presented as number and percentages. The comparison between groups with qualitative data were done by using **Chi-square test**. The comparison between two groups with quantitative data and parametric distribution were done by using **Independent t-test.** While the comparison between two groups with quantitative data and non-parametric distribution was done by using **Mann-Whitney test. Receiver operating characteristic curve [ROC]** was used in the quantitative form to determine the best cut off point with its sensitivity, specificity, positive predictive value [PPV], negative predictive value [NPV] and Area under curve [AUC]. Logistic regression analysis in the form of univariate and multivariate was done to assess the predictors of death with their odds ratio [OR] and 95% confidence interval [CI]. The confidence interval was set to 95% and the margin of error accepted was set to 5%. So, the p-value was considered significant as the following: P > 0.05: Non-significant, P < 0.05: Significant

RESULTS

The present study included 50 subjects, they were 8 females [16%] and 42 males [84%] with age ranged between 36 and 75 years [the mean ±SD was 55.4 ±9.39 years].

According to primary endpoint, patients were divided into those with successful and failed GW crossing through the CTO within 30 minutes. The successful subgroup were 20 CTO cases [40.0%] and the second subgroup included 30 CTO case [60%] required more than 30 minutes. According to secondary endpoint [i.e., successful GW crossing through CTO at any time with restoration of flow and achievement of < 50% residual diameter stenosis and TIMI flow grade [2 to 3]], the subgroup with successful revisualization were 41 CTO case [82.5%] while failed revascularization reported among 9 CTO case that accounts [17.5%].

Part I: Results according to primary end point [successful and failed GW crossing within 30 minutes].

The results of the current work showed that, there was no significant difference found between failed and succeeded subgroups except significant increase of diabetes mellitus and previous CABG in failed than the succeeded subgroup [56.7%, 56.7% vs 20.0%, 25.0% respectively]. In addition, there was significant increase of proximal and osteal segments and significant decrease of mid segment in the failed than the succeeded subgroup [Table 1].

Results showed that, there was statistically significant increase in the percentage of patients with calcification > 50%, blunt stump and length of occlusion > 20 mm in patient with FGW than patients with SGW within 30 minutes. Also, there was statistically significant increase in the median J CTO score and J CTO score classification which found higher in patients with FGW than patients with SGW within 30 minutes. However, there was no significant difference between the two studied groups regarding bending angle [Table 2].

Table [3] showed that there was significant increase in the percentage of patients with blunt stump and length >20 mm in patients with FGW than patients with SGW within 30 minutes, while no significant difference was observed regarding calcification and bending angle using CA derived J-CTO score. However, there was significant increase of median J CTO score and J CTO score classification by CA [it was higher in patients with FGW within 30 minutes than patients with SGW within 30 minutes].

Table [4] showed that there was highly statistically significant increase in the percentage of patients with TIMI flow 2 to 3 in patients with SGW within 30 minutes [100.0%] than patients with FGW within 30 minutes [70.8%]. In addition, there was statistically significant increase in the median number of wires in patients with FGW within 30 minutes than patients with SGW within 30 minutes and significant increase of median time to wire cross in FGW patients.

Figure [1] represented the Receiver operating characteristic curve [ROC] for CT derived J-CTO score and CA derived J-CTO scores as predictors to differentiate between patients with SGW within 30 minutes and patients with FGW within 30 minutes. This curve showed that, the CT-derived J CTO score can differentiate between the two studied groups at the cutoff point > 2 with sensitivity of 60%, specificity of 95% and AUC of 0.878 while the CA-derived J-CTO score can differentiate between the two studied groups at the cutoff point >1 with sensitivity of 56%, specificity of 80% and AUC of 0.733. So CT derived J CTO Score has higher sensitivity and specificity for prediction of successful GW crossing within 30 minutes than CA derived J CTO score.

Part II: Final Procedure outcome [vascularization].

According to final outcome, the failed cases showed significant increase of diabetes mellitus and previous CABG than success cases [77.8%, 77.8% vs 34.1% and 36.6%, respectively]. In addition, failed was significantly associated with the affected segment, where proximal and osteal segments were significantly higher among failed than success groups [77.8%, 22.2% vs 41.5% and 22.2%, respectively]. Interestingly no failure was reported in mid segments [Table 5].

Table [6] showed that there was significant increase in the percentage of patients with calcification > 50%, blunt stump and length > 20 mm in patient with failure than patients with successful outcome while there was no significant difference found between the two studied groups regarding the percentage of patients with bending angel. However, there was statistically highly significant increase in the median CT J CTO score and CT-derived J CTO score classification which found higher in patients with failure than patients with successful outcome.

Table [7] showed that there was statistically significant increase in the percentage of patients with length > 20 mm in failure group than successful group, while no significant relation found between outcome of the studied patients and the other J CTO score parameters. However, the median J CTO score and J CTO score classification was higher in failure than successful group.

Table [8] showed that there was statistically significant relation found between outcome of the studied patients and total time which was found higher in failure group than successful group. The number of wires was significantly higher in failure group than successful group.

Figure [2]: ROC curve for CT derived J CTO score and CA derived J CTO score as a predictor to differentiate between successful and failure patients. It revealed that, the CT-derived J CTO score can differentiate between successful and failure patients at the cutoff point > 2 with sensitivity of 88.8 %, specificity of 73.17 % and AUC of 0.877 while the CA-derived J-CTO score can differentiate between successful and failure patients at the cutoff point >1 with sensitivity of 77.7 %, specificity of 65.85% and AUC of 0.789. So CT-derived J-CTO Score has higher sensitivity and specificity for prediction of outcome and final procedure success of CTO revascularization than CA-derived J CTO score.

Part III: Case presentation:

Figures 3 to 5, represented case of a female 43 years old, History of CABG since 2020, No history of DM, No HTN, BMI 27 kg/m^2, patient Complain of Chest pain CCS III, ECG shows no specific changes, and Echo shows LVEF: 45%, RWMA: Hypokinetic inferior wall. CT-derived J CTO score was: 1 [intermediate] blunt stump only while other parameters were 0. Time to successful wire crossing to CTO RCA was 25 minutes where 2 wires were used

Figures 6 to 8 represented a 49 years old male known Diabetic and HTN, History inferior STEMI and PCI to RCA by one DES in 7-2022, Patient complains of typical chest pain [CCS grade II]. ECG shows Q wave in inferior leads. Echo shows EF 40%, RWMA in the form of anterior septal, anterior wall hypokinesia and entire apex hypokinesia. MPI shows partially reversible ischemia at the anterior and anterolateral segments CT-derived J CTO score was found 2 [difficult] in the form of calcification and length > 20 mm. Time to successful wire crossing was 40 minutes where 2 wires were used.

Table [1]: Comparison between patients with successful and failed GW crossing within 30 minutes regarding demographic data, co-morbidities, ECG, LV EF [%], calcium score, target vessels and segment

		Total	SGW Within 30 minutes	FGW within 30 minutes	Test value	P-value
		No. = 50	**No. = 20**	**No. = 30**		
Sex	Female	8 [16.0%]	5 [25.0%]	3 [10.0%]	2.009	0.156
	Male	42 [84.0%]	15 [75.0%]	27 [90.0%]		
Age	Mean ± SD	55.4 ± 9.39	56.05 ± 9.83	54.97 ± 9.23	0.396	0.694
	Range	36 – 75	40 – 71	36 – 75		
Diabetes		21 [42.0%]	**4 [20.0%]**	**17 [56.7%]**	***6.623***	***0.010****
Hypertension		26 [52.0%]	12 [60.0%]	14 [46.7%]	0.855	0.355
Current smoker		18 [36.0%]	6 [30.0%]	12 [40.0%]	0.521	0.470
Family history of CAD		6 [12.0%]	1 [5.0%]	5 [16.7%]	1.547	0.214
Previous MI		6 [12.0%]	1 [5.0%]	5 [16.7%]	1.547	0.214
Previous CABG		22 [44.0%]	**5 [25.0%]**	**17 [56.7%]**	***4.884***	***0.027****
Previous PCI		21 [42.0%]	9 [45.0%]	12 [40.0%]	0.123	0.726
Previous stoke or TIA		0 [0.0%]	0 [0.0%]	0 [0.0%]	–	–
Renal disease		0 [0.0%]	0 [0.0%]	0 [0.0%]	–	–
Chest pain		50 [100.0%]	20 [100.0%]	30 [100.0%]	–	–
Hyperlipidemia		16 [32.0%]	4 [20.0%]	12 [40.0%]	2.206	0.137
BMI	Mean ± SD	29.48 ± 2.48	29.2 ± 2.59	29.67 ± 2.43	-0.649	0.519
	Range	24 – 36	24 – 32	24 – 36		
ECG	NSR	31 [62.0%]	14 [70.0%]	17 [56.7%]	0.905	0.341
	Abnormal	19 [38.0%]	6 [30.0%]	13 [43.3%]		
LV EF %]	Mean ± SD	54.24 ± 10.38	53.1 ± 10.62	55 ± 10.33	-0.630	0.532
	Range	30 – 79	30 – 68	32 – 79		
Calcium score	Median [IQR]	2 [0 – 32]	2 [2 – 2]	16.1 [0 – 40]	-0.967	0.333
	Range	0 – 143	0 – 22	0 – 143		
Target vessel	LAD	21 [42.0%]	10 [50.0%]	11 [36.7%]	0.95	0.621
	RCA	24 [48.0%]	8 [40.0%]	16 [53.3%]		
	LCX	5 [10.0%]	2 [10.0%]	3 [10.0%]		
Segment	Mid	21 [42.0%]	14 [70.0%]	7 [23.3%]	***11.806***	***0.003****
	Proximal	24 [48.0%]	**6 [30.0%]**	**18 [60.0%]**		
	Osteal	5 [10.0%]	**0 [0.0%]**	**5 [16.7%]**		

SGW: successful guidewire crossing before 30 min. **FGW**: failure for guidewire to cross before 30 min.

Table [2]: Comparison between patients with successful and failed GW crossing within 30 minute regarding CT derived J-CTO score parameters

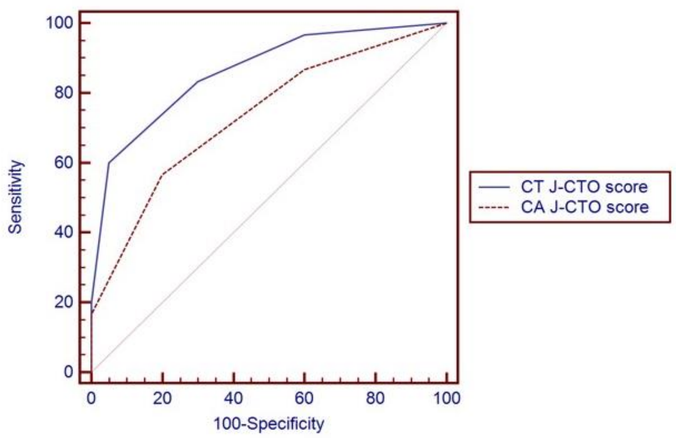
CT derived J CTO score		Total	SGW Within 30 minutes	FGW within 30 minutes	Test	P-value
		No. = 50	**No. = 20**	**No. = 30**		
Calcification >50%	No	24 [48%]	15 [75%]	9 [30%]	9.736	0.002*
	Yes	26 [52%]	5 [25%]	21 [70%]		
Blunt stump	No	33 [66%]	18 [90%]	15 [50%]	8.556	0.003*
	Yes	17 [34%]	2 [10%]	15 [50%]		
Bending angel>45°	No	43 [86%]	19 [95%]	24 [80%]	2.243	0.134
	Yes	7 [14%]	1 [5%]	6 [20%]		
Length > 20mm	No	18 [36%]	13 [65%]	5 [16.7%]	12.167	0.001*
	Yes	32 [64%]	7 [35%]	25 [83.3%]		
CT derived J CTO score	Median [IQR]	2[1 – 3]	1[0 – 2]	3[2 – 3]	-4.409	<0.001*
	Range	0 – 5	0 – 3	0 – 5		
CT derived J CTO score classifications	Easy	9 [18%]	8 [40%]	1 [3.3%]	20.196	<0.001*
	Intermediate	10 [20%]	6 [30%]	4 [13.3%]		
	Difficult	12 [24%]	5 [25%]	7 [23.3%]		
	Very difficult	19 [38%]	1 [5%]	18 [60%]		

Table [3]: Comparison between patients with successful and failed GW crossing within 30 minute regarding CA derived J-CTO score

CA derived J CTO score		Total	SGW Within 30 minutes	FGW within 30 minutes	Test value	P-value
		No. = 50	No. = 20	No. = 30		
Calcification	No	43 [86%]	17 [85%]	26 [86.7%]	0.028	0.868
	Yes	7 [14%]	3 [15%]	4 [13.3%]		
Blunt stump	No	34 [68%]	17 [85%]	17 [56.7%]	4.427	0.035*
	Yes	16 [32%]	3 [15%]	13 [43.3%]		
Bending angel>45°	No	48 [96%]	20 [100%]	28 [93.3%]	1.389	0.239
	Yes	2 [4%]	0 [0%]	2 [6.7%]		
Length>20mm	No	27 [54%]	15 [75%]	12 [40%]	5.918	0.015
	Yes	23 [46%]	5 [25%]	18 [60%]		
CA derived J CTO score	Median [IQR]	1 [1 – 2]	1 [0 – 1]	2 [1 – 2]	-2.901	0.004
	Range	0 – 3	0 – 2	0 – 3		
CA derived J CTO score classifications	Easy	12 [24%]	8 [40%]	4 [13.3%]	8.742	0.033
	Intermediate	17 [34%]	8 [40%]	9 [30%]		
	Difficult	16 [32%]	4 [20%]	12 [40%]		
	Very difficult	5 [10%]	0 [0%]	5 [16.7%]		

Table [4]: Comparison between patients with successful and failed GW crossing within 30 minute regarding TIMI flow, number of wires and time to wire cross.

		Total	SGW Within 30 minutes	FGW within 30 minutes	Test value	P-value
		No. = 50	No. = 20	No. = 30		
TIMI flow II to III	No	9 [18.0%]	0 [0.0%]	9 [30.0%]	7.317	0.007*
	Yes	41 [82.0%]	20 [100.0%]	21 [70.0%]		
number of wires	Median [IQR]	3 [2 – 4]	2.5 [2 – 3]	4 [3 – 5]	-2.931	0.003*
	Range	1 – 7	1 – 5	2 – 7		
Time to wire cross	Median [IQR]	40 [26 – 60]	25 [21.5 – 28]	55 [40 – 95]	-5.960	<0.001*
	Range	15 – 180	15 – 30	35 – 180		



Parameter	AUC	Cut of Point	Sensitivity	Specificity	PPV	NPV
CT J-CTO score	0.878	>2	60.00	95.00	94.7	61.3
CA J-CTO	0.733	>1	56.67	80.00	81.0	55.2

Figure [1]: Receiver operating characteristic curve [ROC] for CT derived J-CTO score and CA derived J-CTO scores as a predictor to differentiate between patients with SGW within 30 minutes and patients with FGW within 30 minutes.

Table [5]: Relation between final outcome of the studied patients and their Demographic Data, Co-morbidities, ECG, LV EF % and calcium score.

		Final procedure success		Test value	P-value
		Success	**Failure**		
		No. = 41	**No. = 9**		
Sex	Female	8 [19.5%]	0 [0.0%]	2.091	0.148
	Male	33 [80.5%]	9 [100.0%]		
Age	Mean ± SD	55.46 ± 9.2	55.11 ± 10.82	0.101	0.920
	Range	36 – 75	39 – 72		
Diabetes		**14 [34.1%]**	**7 [77.8%]**	5.767	0.016*
Hypertension		23 [56.1%]	3 [33.3%]	1.532	0.216
Current smoker		14 [34.1%]	4 [44.4%]	0.340	0.560
Family history of CAD		4 [9.8%]	2 [22.2%]	1.086	0.297
Previous MI		6 [14.6%]	0 [0.0%]	1.497	0.221
Previous CABG		**15 [36.6%]**	**7 [77.8%]**	5.082	0.024*
Previous PCI		18 [43.9%]	3 [33.3%]	0.338	0.561
Previous stoke or TIA		0 [0.0%]	0 [0.0%]	–	–
Renal disease		0 [0.0%]	0 [0.0%]	–	–
Chest pain		41 [100.0%]	9 [100.0%]	–	–
Hyperlipidemia		12 [29.3%]	4 [44.4%]	0.781	0.377
BMI	Mean ± SD	29.2 ± 2.38	30.78 ± 2.64	-1.774	0.082
	Range	24 – 33	27 – 36		
ECG	NSR	28 [68.3%]	3 [33.3%]	3.828	0.050
	Abnormal	13 [31.7%]	6 [66.7%]		
LV EF %]	Mean ± SD	53.98 ± 9.86	55.44 ± 13.11	-0.381	0.705
	Range	30 – 75	32 – 79		
Calcium score	Median [IQR]	2 [0 – 33]	4.05 [0 – 26.1]	-0.238	0.812
	Range	0 – 88	0 – 143		
Target vessel	LAD	19 [46.3%]	2 [22.2%]	4.147	0.126
	RCA	17 [41.5%]	7 [77.8%]		
	LCX	5 [12.2%]	0 [0.0%]		
Segment	Mid	21 [51.2%]	0 [0.0%]	8.277	0.016*
	Proximal	17 [41.5%]	7 [77.8%]		
	Osteal	3 [7.3%]	2 [22.2%]		

Table [6]: Relation between outcome of the studied patients and parameters of J-CTO score derived from CT

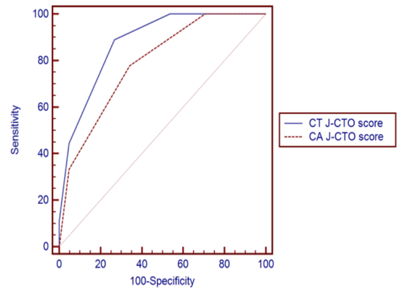
CT derived J CTO score		Final procedure success		Test	P-value
		Success	**Failure**		
		No. = 41	**No. = 9**		
Calcification >50%	No	23 [56.1%]	1 [11.1%]	5.984	0.014*
	Yes	18 [43.9%]	8 [88.9%]		
Blunt stump	No	30 [73.2%]	3 [33.3%]	5.219	0.022*
	Yes	11 [26.8%]	6 [66.7%]		
Bending angel>45°	No	36 [87.8%]	7 [77.8%]	0.616	0.432
	Yes	5 [12.2%]	2 [22.2%]		
Length > 20 mm	No	18 [43.9%]	0 [0.0%]	6.174	0.013*
	Yes	23 [56.1%]	9 [100.0%]		
J CTO score	Median [IQR]	2 [1 – 3]	3 [3 – 4]	3.593	0.001*
	Range	0 – 4	2 - 5		
J CTO score classifications	Easy	9 [22.0%]	0 [0.0%]	12.410	0.006*
	Intermediate	10 [24.4%]	0 [0.0%]		
	Difficult	11 [26.8%]	1 [11.1%]		
	Very difficult	11 [26.8%]	8 [88.9%]		

Table [7]: Relation between outcome of the studied patients and parameters of J-CTO derived from CA

CA derived J CTO score		Final procedure success		Test value	P-value
		Success	**Failure**		
		No. = 41	**No. = 9**		
Calcification	No	35 [85.4%]	8 [88.9%]	0.076	0.783
	Yes	6 [14.6%]	1 [11.1%]		
Blunt stump	No	29 [70.7%]	5 [55.6%]	0.781	0.377
	Yes	12 [29.3%]	4 [44.4%]		
Bending angel>45°	No	40 [97.6%]	8 [88.9%]	1.445	0.229
	Yes	1 [2.4%]	1 [11.1%]		
Length>20mm	No	25 [61%]	2 [22.2%]	4.462	0.035
	Yes	16 [39%]	7 [77.8%]		
CA derived J CTO score	Median [IQR]	1[0 – 2]	2 [2 – 3]	-2.814	0.005
	Range	0 – 3	1 – 3		
CA derived J CTO score classifications	Easy	12 [29.3%]	0 [0%]	9.589	0.022
	Intermediate	15 [36.6%]	2 [22.2%]		
	Difficult	12 [29.3%]	4 [44.4%]		
	Very difficult	2 [4.9%]	3 [33.3%]		

Table [8]: Relation between outcome of the studied patients and number of wires and time to wire cross among the studied patients

		Final procedure success		Test	P
		Success	**Failure**		
		No. = 41	**No. = 9**		
Number of wires	Median [IQR]	3 [2 – 4]	5 [4 – 6]	**3.555**	**<0.001***
	Range	1 – 7	4 – 6		
Time to wire cross	Median [IQR]	35 [25 – 50]	110 [60 – 123]	**3.901**	**<0.001***
	Range	15 – 120	50 – 180		



Parameter	Cut of Point	AUC	Sensitivity	Specificity	PPV	NPV
CT derived J CTO score	>2	0.877	88.89	73.17	42.1	96.8
CA derived J CTO score	>1	0.789	77.78	65.85	33.3	93.1

Figure [2]: Receiver operating characteristic curve [ROC] for CT derived J CTO score and CA derived J CTO score as a predictor to differentiate between successful and failure patients.

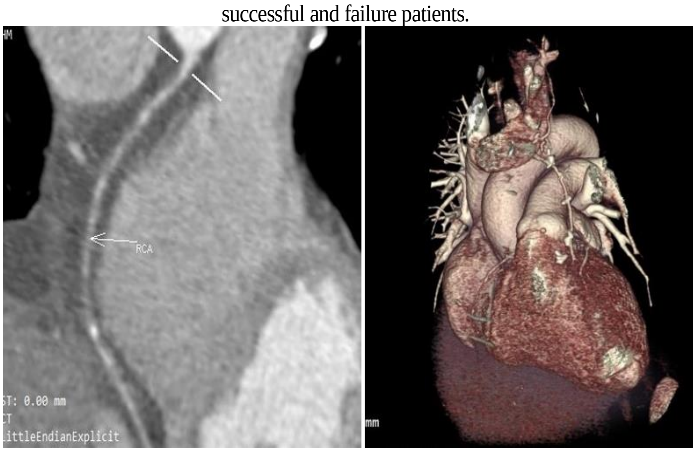


Figure [3]: CCTA. [A] curved multiplaner reformatting of RCA showing mid RCA CTO [B] Three-dimensional [3D] volume rendering image of CTO RCA

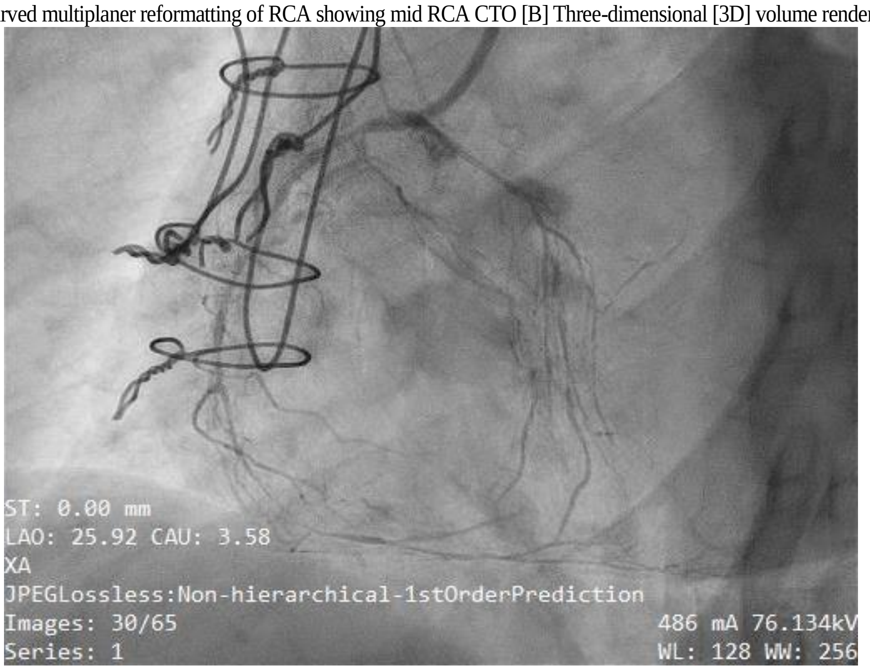


Figure [4]: Invasive coronary angiography LAO caudal view showing mid RCA CTO before PCI

Figure [5]: Invasive coronary angiography LAO caudal view showing mid RCA after revascularization

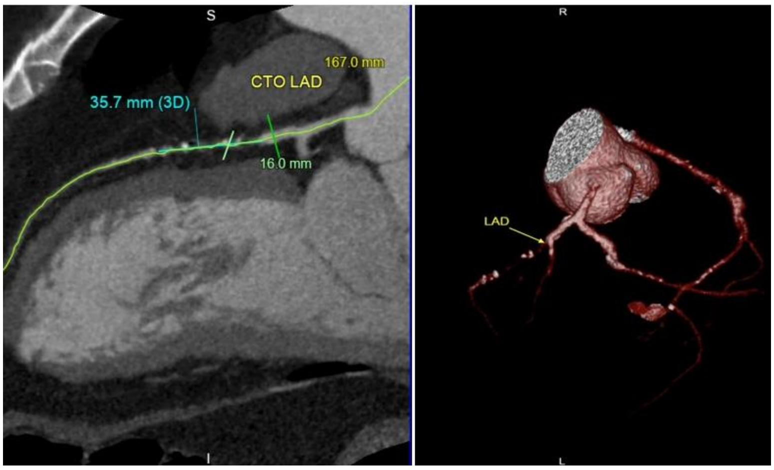


Figure [6]: CCTA. [A] curved multiplaner reformatting of LAD showing mid LAD CTO [B] Three-dimensional [3D] volume rendering image of CTO LAD

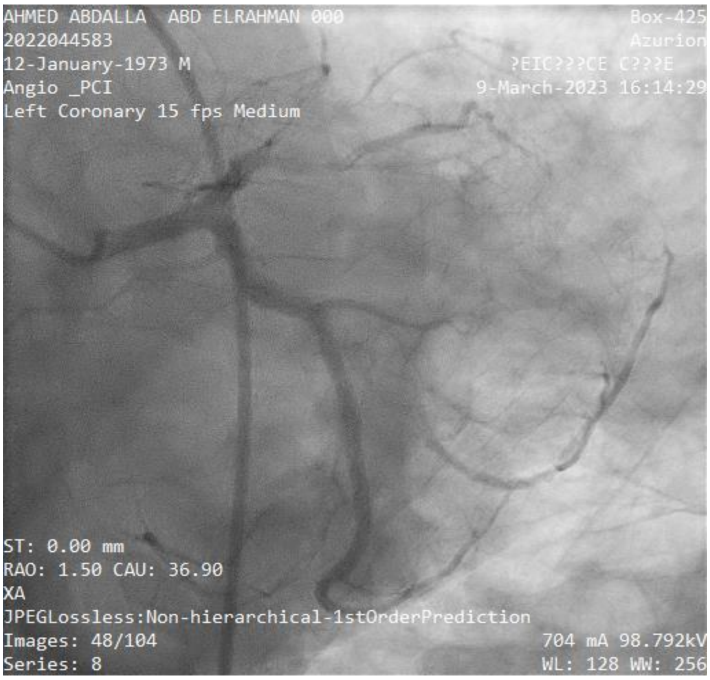


Figure [7]: Invasive coronary angiography RAO caudal view showing mid CTO LAD before PCI

Figure [8]: Invasive coronary angiography LAO caudal view showing mid CTO LAD after revascularization

DISCUSSION

In the current work, the successful GW within 30 minutes was achieved in 20 case [40%], while 30 case [60%] showed failure of GW within 30 minutes. These results are comparable to those reported by **Tan *et al.*** [18] and **Opolski *et al.*** [14] who reported that, SGW within 30 minutes achieved in 55% and 53.7 % respectively and FGW within 30 minutes achieved in 45% and 46% respectively. They also reported comparable results as regard demographics, electrocardiogram, LV ejection fraction and calcium scores. In addition, the same authors reported comparable results regarding associated comorbid conditions and affected segment. Furthermore, **Tan *et al.*** [18] and **Opolski *et al.***[14] reported that the group with failed GW crossing was more likely to have an occlusion length greater than 20 mm, multiple occlusions, a blunt stump, bending greater than 45°,calcification > 50% of the cross-sectional area in any route of the CTO lesion, as determined by CCTA [these results are confirmed in the current work].

Our study showed that there was a statistically significant increase in the median J CTO score and JCTO score classification, which were higher in patients with FGW than patients with SGW within 30 minutes. This is concordant with **Christopoulos *et al.*** [19] who reported that probability of successful GW crossing within 30 minutes was 90% for low-complexity lesions, but <10% for lesions with J-CTO score ≥4.

CT-derived J CTO Score has higher sensitivity and specificity for prediction of successful GW crossing within 30 minutes than CA-derived J CTO score and this is agreeing with what found in **Tan *et al.*** [18] **and Opolski *et al.*** [14] who reported higher significance of CT-derived J CTO score in predicting successful GW crossing within 30 min than that for the J-CTO score. This is also comparable to those reported by **Fujino *et al*.** [20] who reported that, the CT-derived J CTO score can differentiate between patients with SGW within 30 minutes and patients with FGW within 30 minutes at cut off point 2, sensitivity of 57%, specificity of 89% and AUC of 0.812 while the J-CTO score can differentiate between the two studied groups at the cutoff point 2 with sensitivity of 51%, specificity of 76 % and AUC of 0.692

In the current work, out of a total of 50 CTO case, the final procedural success was reported in 41 case [82.5%] with successful revascularized while failure was reported in 9 cases [17.5%]. These results are in line with **Galassi *et al.*** [21] who reported overall procedural success in 82.9% of cases. In addition, previous studies reported that, the procedural success rates were between 58.9% and 73% [22, 23]. The reported success rate of CTO-PCI has reached > 80% owing to the use of new sophisticated techniques and development of specialized devices, as reported by **Bryniarski *et al.*** [24]. This is likely because of the application of novel crossing strategies [e.g., the retrograde technique and dissection or re-entry approach], novel equipment [e.g., microcatheters, guidewires, over the wire balloons and DES] and increased operator experience.

In our study, no significant difference was found between failure and success regarding patient demographic data, co-morbidities, ECG, LV ejection fraction and calcium score. However, DM and previous CABG were significantly higher in the failed group. These results agree with **Suero *et al.*** [23] who reported that demographic data, co morbidities and LV EF% are the same between success and failure groups except higher incidence of previous CABG in the failed group. In addition, **Brilakis *et al.*** [25] reported that previous CABG surgery has been associated with lower procedural success rates, likely due to more extensive calcification and negative remodeling and possible distortion of the native coronary artery anatomy from the graft anastomoses.

Our results showed non-significant relation between outcome of and the target vessel. These results are concordant with **Sapontis *et al.*** [26].

Regarding CT-derived J CTO score, our results are comparable to those reported by **Hoe** [27] who reported that the 3D nature of CCTA allows accurate measurements of length that do not suffer from calibration limitations, foreshortening, or absence of collateral filling, as occurs with coronary angiography. The good ability of CCTA to identify calcifications at the CTO has also been confirmed in a study where intravascular ultrasound [IVUS] was used as the gold standard for detecting the presence of calcification at CTO. CCTA had a significantly higher sensitivity compared to CAG for the detection of calcification; compared with IVUS, the sensitivity of CTCA to detect calcification in CTO was 82% while CAG sensitivity was 66%. CTCA also underestimated the severity of calcification in only 9% while CAG underestimated in 30%. This is also concordant with

Singh *et al.* [28] who reported that CCTA imaging can complement CA by allowing detailed delineation of the calcification, vessel course, and tortuosity. This can help in selection of appropriate hardware for PCI. Accurate measurement of lesion length by CA may be difficult due to foreshortening, calibration limitations, and lack of visualization of the distal vessel in the absence of collateral filling. CCTA allows detailed evaluation of coronary calcification. It also allows better visualization of the vessel on MPR images, avoids vessel overlap and demonstrates the three-dimensional picture of the CTO lesion. In addition, **Rolf *et al.*** [29] reported that calcification, lesion length and stump morphology were underestimated by invasive angiograms.

Our study also showed a statistically significant increase in the median CT- derived J CTO score and CT- derived J CTO score classification in the failure group. This is concordant with **Christopoulos *et al.*** [19] who reported that high J-CTO scores are associated with [a] lower technical and procedural CTO PCI success rates; [b] more frequent use of the retrograde approach; and [c] higher MACE. Procedural success was 100.0% for easy lesions, but even in very difficult lesions [J-CTO≥3], final success was 89.9%. Therefore, the J-CTO score may be more useful for CTO PCI cases selection at less experienced centers, with lower success rates, especially early in the learning curve. Pre procedural calculation of the J-CTO score may encourage the operator to switch earlier to a retrograde approach. If the PCI center does not have retrograde CTO PCI experience, referral to a CTO PCI center should be considered for complex lesions

Regarding CA- derived J CTO score, we found a statistically significant increase in the percentage of patients with length > 20 mm in failure group than successful group with p-value = 0.035, while no statistically significant relation found between outcome of the studied patients and the other J CTO score parameters, and this is comparable to the reported in **Sapontis *et al.*** [26] study. They showed that, failed CTO lesions were more likely to have length of the lesion more than 20 mm, bending angel and blunt stump and no difference found between successful and failed group regarding second attempt and severe calcification. The same authors also found higher JCTO in the failed group and the failed group had more wires used with higher total time in the successful group, and these results are confirmed in the current work. Comparable results were also reported by **Christopoulos *et al.*** [19] and **Galassi *et al.*** [21].

The ROC curve in the current study showed that the CT-derived J CTO score can differentiate between successful and failure patients as regard final procedure success at cut off point > 2 with sensitivity of 88%, specificity of 73% and AUC of 0.877 while the J-CTO score can differentiate between successful and failure patients at the cutoff point >1 with sensitivity of 77%, specificity of 65.85% and AUC of 0.789. These results agree with **Nombela-Franco *et al.***[30] who found the J-CTO score showed good discriminatory and calibration capacity for guidewire CTO crossing within 30 minutes but did not predict the final success rate, So CT – derived J CTO Score has higher sensitivity and specificity for prediction of outcome and final procedure success of CTO revascularization than CA- derived J CTO score which is concordant with **Tan *et al.*** [18] who demonstrated significantly higher diagnostic accuracy and improved classification of the CT- derived J CTO score compared with the CA– derived J-CTO score for the prediction of final PCI success. This is also concordant with **Fujino *et al.*** [20] who showed that the CT-derived J CTO score can differentiate between successful and failure patients as regard final procedure success at cut off point 2, sensitivity of 89%, specificity of 65% and AUC of 0.855 while the J-CTO score can differentiate between the two studied groups at the cutoff point 2 with sensitivity of 68%, specificity of 62 % and AUC of 0.698.

In conclusion, CT-derived J CTO score is a useful tool for predicting the difficulty and time efficiency of guidewire [GW] crossing in chronic total occlusions [CTOs], as well as the ultimate success of the procedure. The CT-derived J CTO score outperformed the CA-derived J-CTO algorithm in predicting GW crossing time and final procedure success. Thus, CT-derived J CTO score may be used as a valuable tool for risk assessment and procedural planning for CTO interventions. However, results must be treated cautiously due to study limitations, which included the relatively small sample size, need to validate cutoff points of the scores on a global scale, potential institutional bias, as the study was performed in a single center and the inclusion of morphologic findings included only in the J-CTO score, although other scores introduced additional information [e.g., arterial remodeling, presence of a side branch, etc..]. Thus, future research with large and diverse populations from more than one institution [center] and inclusion of additional parameters are recommended to validate the results of the current work, remove institutional bias and permitting globalization of results.

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