Clinical Utility of the J-CTO Score in Coronary Chronic Total Occlusion Interventions: Results from a Multicenter Registry

Abstract

Percutaneous coronary intervention (PCI) of chronic total occlusions (CTO) can currently be performed with high success and low complication rates at experienced centers.[1-7] However, being able to reliably estimate the likelihood of procedural success and complications as well as the technical difficulty of the procedure, could significantly facilitate case selection and decrease the risk for procedural failure, major complications and costs.[8-11]

Morino et al. combined 5 baseline clinical and angiographic CTO parameters into a 5 point scoring system (Japan CTO - J-CTO score) to assess the difficulty of CTO crossing.[12] One point is given for each of the following factors that were associated with lower probability of successful guide wire crossing within 30 minutes: blunt stump, calcification, within lesion bending >45°, occlusion length ≥20mm, and prior failed attempt to revascularize the CTO. The J-CTO score was recently shown to have good discrimination and calibration for procedural efficiency in an independent, single-operator, Canadian cohort,[13] however, the study was underpowered to evaluate association with technical success. We sought to evaluate the predictive capacity of the J-CTO score in a large, multicenter, contemporary CTO PCI registry.

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Methods

Patient population

We reviewed the clinical and angiographic records of consecutive patients who were included in the Prospective Global Registry for the Study of Chronic Total Occlusion Intervention (PROGRESS CTO, NCT02061436)[14-17] between January 2011 and July 2014 at 6 US centers with significant expertise in CTO PCI: Appleton Cardiology, Appleton, Wisconsin; Piedmont Heart Institute, Atlanta Georgia; St. Joseph Medical Center, Bellingham Washington; St. Luke's Health System's Mid-America Heart Institute, Kansas City, Missouri; Torrance Memorial Medical Center, Torrance, California; and VA North Texas Healthcare System, Dallas, Texas. The study was approved by the institutional review board of each center. The J-CTO score was calculated as described by Morino et al.[12] Variability in J-CTO score reporting was examined in a random sample of 10 CTO angiograms, which were assessed by the same operator (for intra-observer variability) and an additional independent operator (for inter-observer variability). The baseline clinical and angiographic characteristics as well as procedural outcomes were compared between easy (J-CTO=0), intermediate (J-CTO=1), difficult (J-CTO=2), and very difficult (J-CTO≥3) CTO lesions.

Definitions

Coronary CTOs were defined as coronary lesions with Thrombolysis in Myocardial Infarction (TIMI) grade 0 flow of at least 3 month duration. Estimation of the occlusion duration was based on first onset of anginal symptoms, prior history of myocardial infarction in the target vessel territory, or comparison with a prior angiogram. Technical success of CTO PCI was defined as successful CTO revascularization with achievement of <30% residual diameter stenosis within the treated segment and restoration of antegrade TIMI grade 3 flow.[18] Procedural success was defined as achievement of technical success with no in-hospital major adverse cardiac events (MACE). MACE included any of the following adverse events prior to hospital discharge: death from any cause, Q-wave myocardial infarction, recurrent symptoms requiring urgent repeat target vessel revascularization with PCI or coronary bypass surgery, tamponade requiring either pericardiocentesis or surgery, and stroke.

Statistical analysis

Descriptive statistics and comparisons

Continuous data were summarized as mean ± standard deviation (normally distributed data) or median (25th and 75th percentile) (non-normally distributed data). Continuous variables were compared using generalized linear models in which the J-CTO score served as the independent continuous variable. The models were tailored to the distributions of each dependent continuous variable and used procedure site as a covariate in order to minimize operator-related bias. Categorical data were presented as frequencies or percentages and compared using the χ^2 or Kruskal-Wallis test, as appropriate.

J-CTO score association with technical success and procedure time

The association of the J-CTO score with technical success and procedure time was assessed in univariable logistic and linear regression. Odds ratios or regression coefficients with their respective 95% confidence intervals were calculated for a 1-point increase of the J-CTO score. The Hosmer-Lemeshow statistic was used to assess calibration and the receiver operator characteristic curve and area under the curve (AUC) were used to assess discrimination of the binary regression model. Statistical analyses were performed with JMP 11.0 (SAS Institute, Cary, North Carolina) and SPSS 22.0 (IBM Corporation, Armonk, New York). A p value of <0.05 was considered statistically significant.

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Results

Patient and angiographic characteristics

The present analysis included 650 patients who underwent PCI of 657 CTOs. Of the 657 CTO lesions, 29 were deemed easy (J-CTO=0), 87 were intermediate (J-CTO=1), 163 were difficult (J-CTO=2), and 378 were very difficult (J-CTO≥3). Calculation of the J-CTO score was highly reproducible with identical scores reported in 9 of 10 assessed angiograms. The intra- and inter-observer reproducibility was high (kappa values 0.971 and 0.935, respectively). The following variables had a significant proportion of missing values: age (22%), left ventricular ejection fraction (21%), proximal cap ambiguity (26%), side branch at proximal cap (26%), collateral filling (26%), "interventional" collaterals (26%), CTO vessel diameter (26%), procedure time (26%) and air kerma radiation dose (21%). Clinical characteristics are presented in Table 1. Mean age was 65±10 years, 87% of the patients were men, 42% had diabetes mellitus, 28% had prior MI, 66% had prior PCI, and 36% had prior coronary artery bypass graft surgery (CABG). Among patients with prior CABG, 68% had an occluded graft supplying the CTO target vessel. Patients with J-CTO score ≥3 were older (p=0.002), more likely to be men (p=0.019), and to have dyslipidemia (p=0.012), prior PCI (p=0.004) and prior CABG (p<0.001), and to be current smokers (p=0.036). As anticipated, the distribution of the parameters used for calculation of the J-CTO score (occlusion length, blunt stump, calcification, tortuosity and prior revascularization attempt) was significantly different across the four J-CTO groups (p<0.001). Very difficult lesions were more likely to be located in the right coronary artery (p<0.001), have proximal cap ambiguity (p<0.001) and have larger CTO vessel diameter (p=0.013) (Table 2).

Table 1

Clinical characteristics of the study patients, classified according to J-CTO score.

Variable	Overall	Easy (J-CTO=0)	Intermediate (J-CTO=1)	Difficult (J-CTO=2)	Very difficult (J-CTO≥3)	P
Age (years)	65±10	59±13	64±9	66±9	66±10	0.002
Men (%)	87	68	85	88	88	0.019
Diabetes (%)	42	41	52	39	42	0.20
Dyslipidemia (%)	95	85	91	93	97	0.010
Hypertension (%)	90	96	89	86	91	0.21
Prior MI (%)	28	25	30	38	40	0.17
Prior PCI (%)	66	46	53	67	70	0.004
Prior CABG (%)	36	7	16	31	45	<0.001
Prior valve surgery (%)	4	4	1	6	4	0.36
LVEF (%)	55 (43-60)	55 (47-60)	55 (45-60)	54 (45-60)	54 (40-60)	0.53

Variable	Overall	Easy (J-CTO=0)	Intermediate (J-CTO=1)	Difficult (J-CTO=2)	Very difficult (J-CTO≥3)	P
Prior Stroke (%)	9	0	7	10	10	0.28
PAD (%)	16	4	13	14	19	0.079
Current Smoking (%)	35	44	47	33	32	0.036

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Values are mean ± standard deviation or median (25th -75th percentile).

CTO: chronic total occlusion; MI: myocardial infarction; PCI: percutaneous coronary intervention; CABG: coronary artery bypass grafting; LVEF: left ventricular ejection fraction; PAD: peripheral arterial disease

Table 2

Baseline angiographic characteristics of the PROGRESS CTO registry patients.

Variable	Overall	Easy (J-CTO =0)	Intermediate (J-CTO=1)	Difficult (J-CTO=2)	Very difficult (J-CTO≥3)	P
CTO vessel						<0.001
RCA (%)	61	24	57	58	66	
LAD (%)	21	55	35	18	16	

Variable	Overall	Easy (J-CTO =0)	Intermediate (J-CTO=1)	Difficult (J-CTO=2)	Very difficult (J-CTO≥3)	P
LCX (%)	18	21	8	24	18	
Proximal cap ambiguity (%)	27	8	4	16	36	<0.001
Side branch at proximal cap (%)	42	38	27	40	46	0.077
Collateral filling (%)						
Ipsilateral	15	23	12	19	14	
Contralateral	57	31	47	50	62	0.083
Ipsilateral and contralateral	26	46	39	28	22	

Variable	Overall	Easy (J-CTO =0)	Intermediate (J-CTO=1)	Difficult (J-CTO=2)	Very difficult (J-CTO≥3)	P
None	2	0	2	2	2	
Collaterals suitable for retrograde approach (%)	63	46	55	60	66	0.23
CTO vessel diameter (mm)	2.8 (2.5-3.0)	3.0 (2.5-3.0)	3.0 (2.5-3.0)	2.5 (2.5-3.0)	3.0 (2.5-3.0)	0.013
In-stent occlusion (%)	11	14	9	12	11	0.84
CTO occlusion length (mm)	30 (20-50)	17 (10-20)	27 (15-30)	23 (15-38)	38 (25-60)	<0.001

Variable	Overall	Easy (J-CTO =0)	Intermediate (J-CTO=1)	Difficult (J-CTO=2)	Very difficult (J-CTO≥3)	P
Blunt stump (%)	52	0	20	34	67	<0.001
Moderate/Severe calcification (≥50% reference lesion diameter) (%)	59	0	30	52	73	<0.001
Moderate/Severe proximal tortuosity (2 bends >90 deg or 1 bend>120 deg) (%)	34	0	10	26	44	<0.001
Prior attempt to open CTO (%)	17	0	8	10	23	<0.001

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Values are mean ± standard deviation or median (25th -75th percentiles).

LAD: left anterior descending artery; LCX: left circumflex artery; RCA: right coronary artery; CABG: coronary artery bypass graft surgery; CTO: chronic total occlusion

Procedural outcomes

Overall, technical and procedural success was 93.0% and 91.5%, respectively. Technical and procedural success decreased in a stepwise fashion among higher J-CTO strata, whereas MACE increased (Table 3). In addition, the likelihood of success using the retrograde approach increased as J-CTO score increased, whereas the opposite was true for the antegrade approach (p<0.001, Figure 1). Lesions with high J-CTO score were associated with longer fluoroscopy (p<0.001), and procedural (p<0.001) times, higher contrast volume (p=0.049), air kerma radiation dose (p<0.001) and dose area product (p<0.001) (Table 3). Procedural time consistently increased with higher J-CTO scores with very difficult lesions requiring mean procedure times>160 minutes (p for trend <0.001, Figure 2).

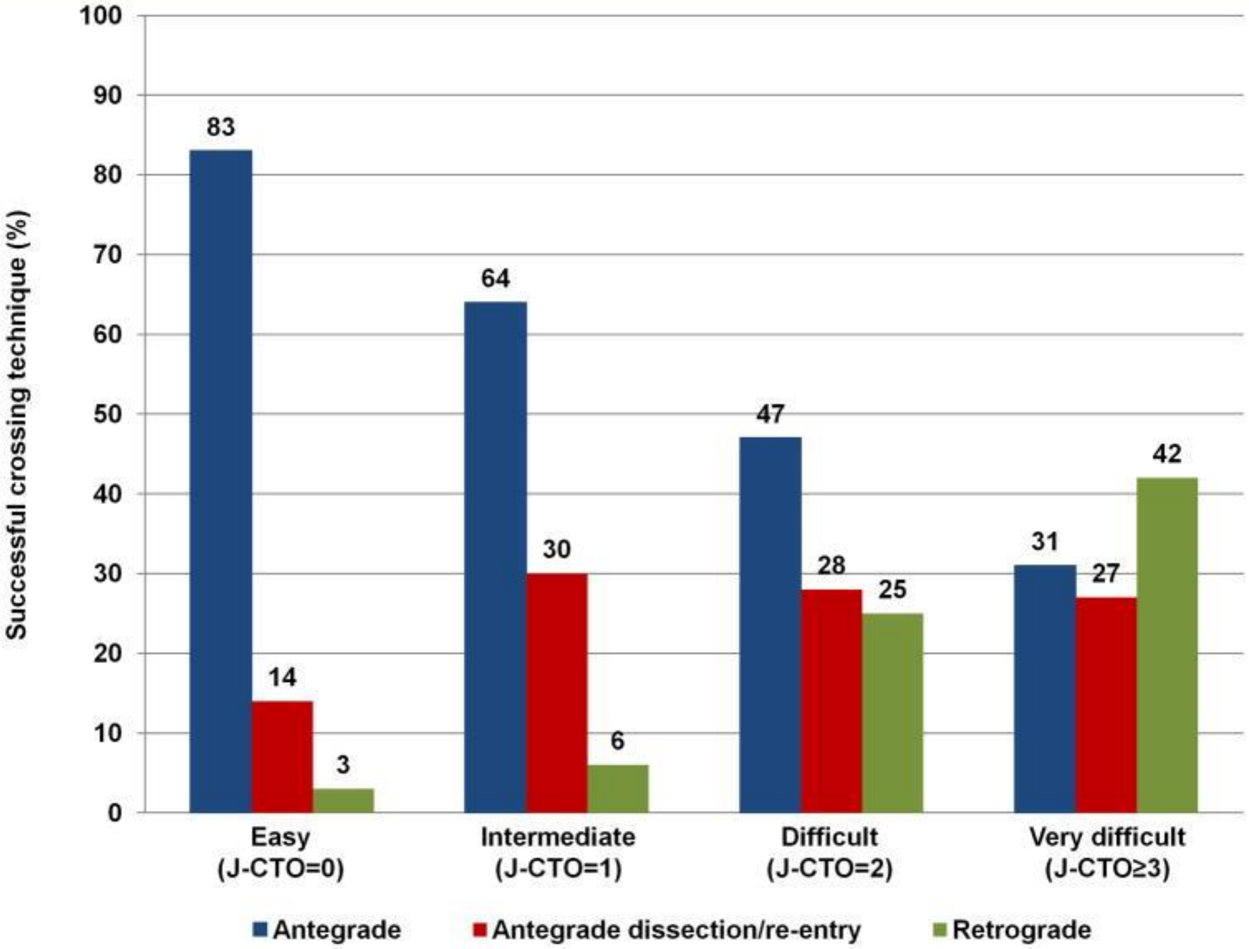

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Figure 1

Successful crossing technique among the study lesions, classified according to J-CTO score.

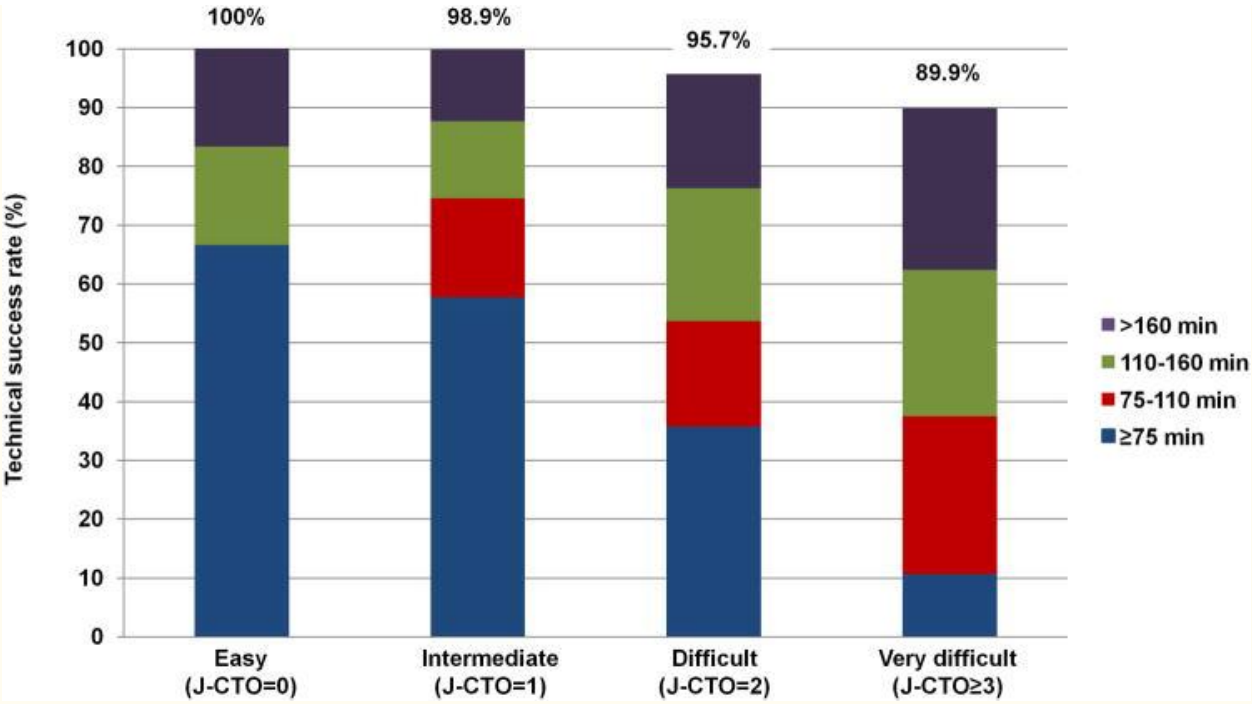

Figure 2

Technical success rates and procedure time among study lesions, classified according to J-CTO score.

Table 3

Procedural outcomes among study patients, classified according to J-CTO score.

Variable	Overall	Easy (J-CTO=0)	Intermediate (J-CTO=1)	Difficult (J-CTO=2)	Very difficult (J-CTO≥3)	P
Approach changes in one case	0.6±0.8	0.2±0.4	0.3±0.5	0.5±0.8	0.7±0.9	<0.001
Crossing strategies used (%)						

Variable	**Overall**	**Easy (J-CTO=0)**	**Intermediate (J-CTO=1)**	**Difficult (J-CTO=2)**	**Very difficult (J-CTO≥3)**	**P**
Antegrade wiring	67	97	80	74	58	<0.001
Antegrade dissection & re-entry	37	3	34	39	61	0.053
Retrograde	44	13	10	34	41	<0.001
Initial crossing strategy (%)						
Antegrade wiring	62	97	78	72	52	
Antegrade dissection & re-entry	17	3	21	15	17	<0.001
Retrograde	21	0	1	13	31	

Variable	**Overall**	**Easy (J-CTO=0)**	**Intermediate (J-CTO=1)**	**Difficult (J-CTO=2)**	**Very difficult (J-CTO≥3)**	**P**
Successful approach (%)	39	83	63	45	28	
Antegrade wiring	25	14	30	30	25	
Antegrade dissection & re-entry	29	3	6	24	38	<0.001
Retrograde	7	0	1	1	9	
None						
Stenting in successful cases (%)	98	100	99	98	98	0.77
Stents per patient (N)	2.6±1.1	1.7±0.8	2.2±1.0	2.3±1.1	2.8±1.0	<0.001

Variable	Overall	Easy (J-CTO=0)	Intermediate (J-CTO=1)	Difficult (J-CTO=2)	Very difficult (J-CTO≥3)	P
Fluoroscopy time (min)	41 (26-66)	20 (10-35)	24 (14-39)	34 (22-54)	54 (35-77)	<0.001
Procedure time (min)	111 (77-160)	50 (39-134)	68 (51-103)	102 (61-135)	123 (92-183)	<0.001
Contrast volume (mL)	250 (190-350)	233 (150-338)	240 (165-314)	260 (175-350)	260 (200-367)	0.049
Air Kerma Radiation dose (Gray)	3.6 (2.2-5.8)	2.7 (1.4-4.2)	2.3 (1.4-4.1)	3.3 (2.0-5.4)	4.5 (2.7-6.2)	<0.001
Technical Success (%)	93.0	100.0	98.9	95.7	89.9	0.003

Variable	Overall	Easy (J-CTO=0)	Intermediate (J-CTO=1)	Difficult (J-CTO=2)	Very difficult (J-CTO≥3)	P
Procedural Success (%)	91.5	100.0	98.9	93.8	88.2	0.002
MACE (n, %)	11 (1.7)	0 (0)	0 (0)	3 (1.9)	8 (2.1)	0.48
Death	2 (0.3)	0 (0)	0 (0)	0 (0)	2 (0.5)	0.69
MI	5 (0.8)	0 (0)	0 (0)	2 (1.2)	3 (0.8)	0.71
Emergency CABG	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	NA
Emergency PCI	1 (1.5)	0 (0)	0 (0)	1 (0.6)	0 (0)	0.39
Pericardiocentesis	4 (0.6)	0 (0)	0 (0)	0 (0)	4 (1.1)	0.40
Stroke	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	NA

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Values are mean ± standard deviation or median (25^{th} -75^{th} percentile).

DES: drug eluting stents; BMS: bare metal stents; MACE: major adverse cardiac events; NA: not applicable

J-CTO score association with technical success and procedure time

On univariable analysis a one point increase in J-CTO score was associated with a two-fold increase in the odds of technical failure (odds ratio [OR] 2.04, 95% confidence interval [95% CI] 1.52-2.80, p<0.001). The regression model demonstrated satisfactory goodness-of-fit (Hosmer-Lemeshow χ^2=1.243, p=0.743) and discrimination (AUC=0.705) (Figure 3). For every 1-point increase in J-CTO score, procedure time increased by approximately 20 minutes (regression coefficient 22.33, 95% CI 17.45-27.22, p<0.001).

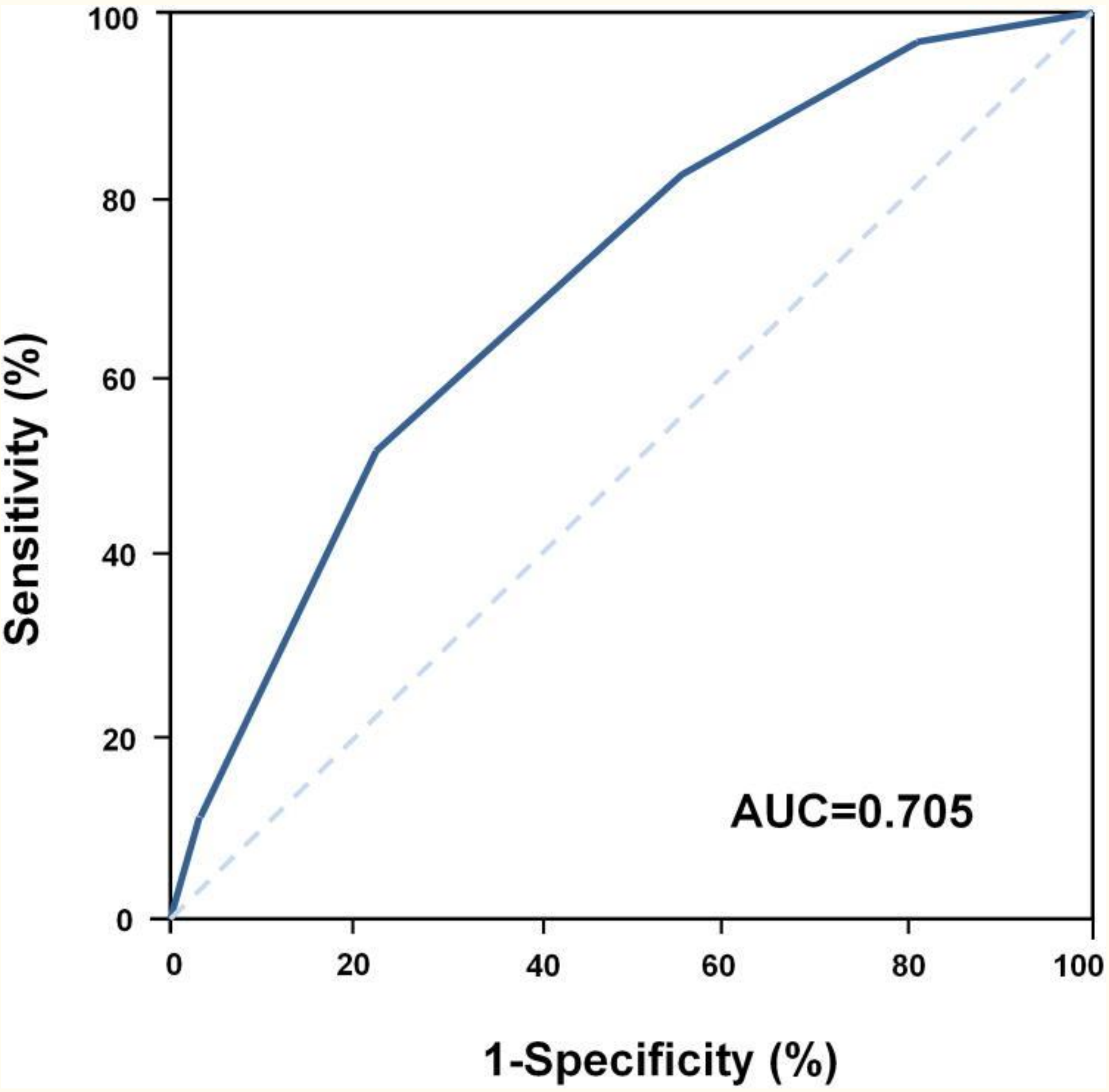

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Figure 3

Receiver operating characteristic (ROC) curve illustrating the performance of the J-CTO score in the prediction of technical failure.

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Discussion

Our study demonstrates that compared with low, high J-CTO scores are associated with: (a) lower technical and procedural CTO PCI success rates; (b) longer fluoroscopy and total procedure time, higher patient dose and higher contrast administration; (c) more frequent use of the retrograde approach; and (d) higher MACE.

The primary endpoint of the study that developed the J-CTO score (Japanese CTO registry) was probability to cross the CTO with the guidewire in <30 minutes, not final technical success. This probability was 90% for low-complexity lesions, but <10% for lesions with J-CTO score ≥4. Technical success also declined in a stepwise fashion with more challenging lesions (97.8% for easy lesions vs. 73.3% for lesions with scores ≥3), however on multivariable analysis the J-CTO score components were not directly linked to clinical outcomes.

Procedural success

Similar to the original J-CTO score study by Morino et al, higher J-CTO scores were associated with lower procedural success in the PROGRESS CTO registry, even though overall success was significantly higher: procedural success was 100.0% for easy lesions, but even in very difficult lesions (J-CTO≥3) final success was 89.9%, suggesting that approximately 9 of 10 of these highly challenging lesions can be successfully recanalized at experienced centers. 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. These results are in line with previous reports that have linked final failure of CTO PCI to one or more of the J-CTO score's components.[19-23]

Nombela-Franco et al. demonstrated sufficient discrimination of the J-CTO score in predicting guidewire crossing within the first 30 minutes. J-CTO scores ≥3 required a median guidewire working time of 69 (33-118) minutes, whereas when J-CTO score was <3 the corresponding median time ranged from 8 to 30 minutes (depending on J-CTO score category). Similar trends were noted for other measures of efficiency, such as fluoroscopy time, radiation dose and total procedure time, where higher J-CTO scores were associated with lower efficiency in a stepwise fashion. However, the J-CTO score was not associated with final angiographic success (c-statistic 0.399 [95% confidence interval 0.286-0.511], p=0.136). This could be related to the relatively small sample size (209 patients), however it is also possible that operator experience and use of newer “hybrid” techniques blunted the effect of complexity on decreasing revascularization success. Indeed, success rate was 90.4% overall and 87.2% in the most challenging lesions (J-CTO score≥3). Our results demonstrate significant association between the J-CTO score and procedure time as well as final technical success. This is in line with the results of the J-CTO and other studies, in which higher J-CTO score was associated with lower success rates.[3, 12]

Techniques

More complex lesions were more likely to require use of the retrograde approach to achieve procedural success. The retrograde approach has been shown to improve procedural success rates, but may also carry increased risk for complications,[5, 24] can be more labor intensive, and may require longer time and specialized equipment and training.[25, 26] Pre-procedure 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.

Efficiency

The J-CTO score was originally developed to estimate the degree of difficulty of CTO PCI, as measured by the time required for successful guidewire crossing. Our study confirms the association of the J-CTO score with several metrics of efficiency (procedure time, fluoroscopy time, and radiation dose), even among highly skilled centers and operators. Estimation of the difficulty can assist with appropriate procedural scheduling. Furthermore, it may further motivate the operator to use contrast and radiation sparingly, optimizing radiation safety and minimizing the risk for contrast nephropathy. In lesions with high J-CTO score early change of crossing strategy should be considered, as persistence with a failing strategy may result in unnecessary delays and predispose to failure.[1]

Practical utility of the J-CTO score for procedural planning

Our study suggests that the J-CTO score could facilitate optimal planning for patients who require CTO PCI both at seasoned and at less experienced centers and operators. At centers with limited experience in CTO PCI, success in occlusions with high (≥3) J-CTO scores is likely to be low. Moreover, lesions with high J-CTO score are likely to require extensive equipment and resource utilization and high radiation dose, which could limit subsequent CTO recanalization attempts. Such patients may be best referred upfront to tertiary CTO PCI centers to maximize the likelihood for success and minimize risk and resource utilization. Such patients: (a) are highly likely to require retrograde CTO PCI recanalization, which is often not feasible at inexperienced sites; and (b) are more likely to experience major adverse cardiac events, which could also be treated more efficiently at experienced, high-volume centers.

Even at experienced centers, a priori knowledge of the J-CTO score can be used to optimize scheduling of CTO PCI patients. For example scheduling treatment of several patients with high J-CTO scores during the same day should be avoided, as this could lead to excessive operator and staff fatigue, which could in turn translate into lower chance for success and higher risk for complications for cases performed later in the day.

Study limitations

The study used technical failure and total procedure time as markers of CTO PCI efficacy and efficiency, respectively. Procedural success (technical success in the absence of MACE) and lesion crossing within 30 minutes were not evaluated. Angiographic analysis was performed by the operator and not an independent core-laboratory and clinical events were not adjudicated by a dedicated clinical events committee. All 6 centers that participated in the PROGRESS CTO registry were part of the “hybrid” algorithm development and all operators had significant expertise with all available CTO crossing techniques (antegrade, retrograde, antegrade dissection and re-entry). It is unknown whether our findings will apply to lower-volume operators, or operators trained in antegrade-only techniques, especially given the higher need for retrograde techniques among high J-CTO strata. However, the case mix treated at such centers may be more favorable with fewer highly-complex patients or patients with prior failed CTO PCI attempts (23% for patients with J-CTO score ≥3 in our study). Finally, although every possible effort was made to eliminate operator-related bias, such bias is still possible.

In conclusion, our large, multicenter registry confirms the utility of the J-CTO score for predicting both the success and efficiency of CTO PCI. At experienced centers procedural success can be achieved in most lesions, even those with high J-CTO scores. However, a high J-CTO score is associated with higher likelihood of technical failure, MACE and a lengthy procedure.

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Acknowledgments

Study data were collected and managed using REDCap electronic data capture tools hosted at University of Texas Southwestern Medical Center.[27] REDCap (Research Electronic Data Capture) is a secure, web-based application designed to support data capture for research studies, providing 1) an intuitive interface for validated data entry; 2) audit trails for tracking data manipulation and export procedures; 3) automated export procedures for seamless data downloads to common statistical packages; and 4) procedures for importing data from external sources.

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Footnotes

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