

Title: Comparison of the novel EuroCTO (CASTLE) score with the J-CTO score for predicting technical success of coronary chronic total occlusions percutaneous revascularization.

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Comparison of the novel EuroCTO (CASTLE) score with the J-CTO score for predicting technical success of coronary chronic total occlusions percutaneous revascularization.

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Short running title: EuroCTO (CASTLE) vs. J-CTO for CTO PCI success prediction

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ABSTRACT

Aims: We sought to compare the efficiency of the novel EuroCTO (CASTLE) score with the commonly used Multicentre CTO registry in Japan (J-CTO) score in predicting procedural success of percutaneous recanalization (PCI) for coronary chronic total occlusions (CTOs).

Methods and results: We evaluated 660 consecutive CTO PCIs (mean age: 66 ± 11 years, 84% male). The mean J-CTO and EuroCTO (CASTLE) scores were 1.86 ± 1.2 and 1.74 ± 1.2 , respectively. Antegrade wire escalation, antegrade dissection re-entry and retrograde approach were used in 82%, 14% and 37% of cases, respectively. Receiver-operator characteristic analysis demonstrated equal overall discriminatory capacity between the two scores (AUC: 0.698, 95%CI: 0.653-0.742 $p < 0.001$ for J-CTO vs. AUC: 0.676, 95% CI 0.627-0.725, $p < 0.001$ for EuroCTO; AUC difference: 0.022, $p = 0.5$). However, for more complex procedures [(J-CTO ≥ 3 or EuroCTO (CASTLE) ≥ 4)], the predictive capacity of EuroCTO (CASTLE) score appeared superior (AUC: 0.588, 95% CI 0.509-0.668, $p = 0.03$ for EuroCTO (CASTLE) score vs. AUC: 0.473, 95% CI 0.393-0.553, $p = \text{NS}$ for the J-CTO score, AUC difference: 0.115, $p = 0.04$)

Conclusions: In this study, the novel EuroCTO (CASTLE) score was comparable to the J-CTO score in predicting CTO PCI outcome with a superior discriminatory capacity for the more complex cases.

Keywords: Chronic coronary total occlusion, stable angina, multiple vessel disease

CONDENSED ABSTRACT

We sought to compare the efficiency of the novel EuroCTO (CASTLE) score with the commonly used J-CTO score in predicting procedural success of CTO PCI.

Our analysis demonstrated equal overall discriminatory capacity between the two scores. For more complex procedures [J-CTO ≥ 3 or EuroCTO (CASTLE) ≥ 4], the predictive capacity of EuroCTO (CASTLE) score appeared superior.

IMPACT IN DAILY CLINICAL PRACTICE

Percutaneous revascularization of chronic total occlusions represents the most challenging procedure in the field of coronary interventions. In this setting, technical outcome prediction scores are useful in pre-procedural planning of CTO percutaneous revascularization. The novel EuroCTO (CASTLE) score, derived from the large EuroCTO registry, could be used as an alternative to the commonly applied JCTO score, as it shows similar overall capacity in predicting CTO PCI success rate with a superior discriminatory capacity for the more complex cases.

ABBREVIATIONS

CTO: Chronic total occlusions

TIMI: Thrombolysis in myocardial infarction

PCI: Percutaneous coronary interventions

CABG: Coronary artery bypass graft surgery

J-CTO: Multicentre CTO registry in Japan

AWE: Antegrade wire escalation

ADR: Antegrade dissection and re-entry

CART: Controlled antegrade and retrograde subintimal tracking

RA: Retrograde approach

RWE: Retrograde wire escalation

HL: Hosmer-Lemeshow goodness-of-fit test

AUC: Area under the curve

ROC: Receiver-Operator Characteristics curve

RCA: Right Coronary Artery

INTRODUCTION

Coronary chronic total occlusions, defined as coronary lesions with thrombolysis in myocardial infarction grade 0 flow of at least 3-months duration, are a common finding in patients undergoing invasive diagnostic angiography^{1,2,3}. Over the last decade, the advent of novel techniques and the utilization of more advanced equipment has resulted in high procedural success rates and an upsurge in the number of performed CTO percutaneous coronary interventions^{4,5}. However, the success of CTO interventions can still vary significantly, especially in unselected populations⁶, and apart from lesion complexity and operator experience, it is also liable to several additional factors including patients' clinical characteristics.

Pre-procedural preparation, involving careful identification of various clinical risk factors and meticulous assessment of the diagnostic coronary angiogram to evaluate lesion complexity and plan procedural strategy, is important to achieve successful outcomes in CTO PCI⁷. Success prediction scores are valuable in this direction, as they provide a quantitative evaluation of procedural difficulty and the likelihood of recanalization success and thus facilitating case selection, procedural planning and clinical decision-making⁷. The novel EuroCTO (CASTLE) scoring system has been recently derived and validated from the large multicentre EuroCTO registry including more than 20,000 patients. It is comprised of 2 clinical factors (age ≥ 70 years and previous coronary bypass graft surgery) and 4 angiographic factors (blunt or invisible proximal cap, severe tortuosity, severe calcification and lesion length ≥ 20 mm) with 1 point for each factor resulting in a minimal score of 0 to a maximal score of 6⁸. We sought to compare the technical success predictive efficacy of the novel EuroCTO (CASTLE) score with the widely adopted Multicentre CTO registry in Japan score⁹.

METHODS

We analysed 660 consecutive CTO PCI cases performed in a tertiary cardiac centre with a dedicated CTO programme (Essex Cardiothoracic Centre, United Kingdom). All cases performed since the onset of the programme in June 2012 up to November 2018 were included in the analysis. As part of the programme and for auditing purposes, clinical, angiographic and procedural characteristics of the CTO cases were prospectively recorded in a dedicated CTO database. The J-CTO and EuroCTO (CASTLE) scores were calculated according to the algorithms described by Morino et al.⁹ and Szigyarto et al.⁸, respectively. The EUROCTO (CASTLE) score analysis took place retrospectively as the score was introduced only recently. The definitions of the EuroCTO and J-CTO scores variables and the different recanalization techniques can be found in the supplementary material / Supplementary Table 1.

Technical success of CTO PCI was defined as successful CTO revascularization resulting in <30% residual vessel diameter stenosis within the treated segment and restoration of TIMI grade 3 antegrade flow.

Statistical analysis

All quantitative variables were tested for normal distribution according to the Kolmogorov-Smirnov test. Continuous variables are reported as mean and SD values. Categorical variables are expressed as frequency and proportion. Normally distributed continuous variables were compared using Student's t-test, whilst the Mann-Whitney U test was used to compare non-normally distributed continuous variables. Categorical data were compared using the Pearson chi-squared test. To evaluate the trend of efficiency metrics amongst different prediction

score strata, the Jonckheere-Terpstra statistical test was applied. The association between prediction scores and technical outcome was evaluated using the univariate logistic regression analysis and their efficiency as independent factors for predicting successful outcomes in CTO PCI was evaluated using a multivariate logistic regression model accounted for various potential confounding factors. Odds ratios for every 1-point increase of the J-CTO and the EuroCTO (CASTLE) scores with their respective 95% confidence intervals were calculated. Hosmer-Lemeshow goodness-of-fit test was used to assess calibration of both scores in our study population. The HL test analyses the observed versus the predicted outcomes; Theoretically, there should not be any statistically significant difference between the expected and observed counts and thus based on χ^2 distribution, an HL statistic with a p value > 0.05 should be consistent with a good model fit¹⁰. The discriminatory performance of the predictive scores was evaluated by comparing the two scores using the receiver-operator characteristics curve and area under the curve analysis. Differences in AUC between ROC curves were tested as described by Hanley & McNeil¹¹. Statistical analysis was performed with IBM SPSS Statistics Version 24.0 software (IBM Corporation, Chicago, Illinois). A 2-tailed p value of <0.05 was considered statistically significant.

RESULTS

The study included 660 CTO PCIs (mean age: 65.8±10.6 years, 83.8% male). **Table 1** shows the clinical, angiographic and procedural characteristics of the study cases. The indication for CTO PCI was stable angina pectoris in all cases and the most common target PCI vessel was the right coronary artery (66%). More than 30% of the study participants were ≥70 years old and 19% had a history of previous CABG. An AWE approach was the most frequent recanalization approach and it was applied as an initial strategy in 73.9% of cases followed by the RA in

20.4% of cases and ADR in 5.8% of cases. The overall prevalence of AWE, RA and ADR was 82%, 37% and 14%, respectively. Successful CTO recanalization was achieved in 516 cases (78%). Amongst cases with successful CTO PCI, AWE was the successful recanalization strategy used in 67% of cases, RA was used in 22% of cases and ADR in 11% of cases. The mean EuroCTO and J-CTO scores were 1.8 ± 1.2 and 1.9 ± 1.2 , respectively. Failed cases had significantly higher EuroCTO (CASTLE) and J-CTO scores compared to cases with successful CTO PCI (2.4 ± 1.2 vs. 1.6 ± 1.2 , $p < 0.001$ and 2.5 ± 1.0 vs. 1.7 ± 1.2 , $p < 0.001$, respectively).

The EuroCTO (CASTLE) score exhibited superior calibration compared to the J-CTO score in our sample analysis: EuroCTO (CASTLE) score HL $\chi^2 = 0.765$, $p = 0.858$ and J-CTO score HL $\chi^2 = 17.397$, $p = 0.001$. In the multivariate logistic regression analysis, both the EuroCTO (CASTLE) and J-CTO scores were the only independent predictors of successful CTO PCI and for each unit increase of EuroCTO (CASTLE) and J-CTO scores there was a 28% and 36% odds reduction for successful recanalization, respectively (**table 2**). Technical success was significantly lower for higher values of both scores (**Figure 1A, 1B**) and the probability of successful PCI was inversely correlated with both score strata (**Figure 1C, 1D**). The most pronounced difference in success rates of approximately 54% between the lowest scoring grade (least complex cases) and the highest scoring grade (most complex cases) was observed in the EuroCTO (CASTLE) score (**Figure 1B**). The J-CTO score was associated with an overestimation of case complexity compared to the EuroCTO (CASTLE) score as a J-CTO score ≥ 3 was observed in 30% and a EuroCTO (CASTLE) score ≥ 4 in 9% of cases (**Figure 1C, 1D**).

The discriminatory performance of the two scoring systems in predicting the technical outcome of CTO PCI was evaluated using the ROC curve analysis. Both scores demonstrated

equal overall discriminatory capacity: for the EuroCTO (CASTLE) score, AUC: 0.674, 95% CI: 0.625-0.724, $p < 0.001$, for the J-CTO score, AUC: 0.694, 95% CI: 0.649-0.739, $p < 0.001$; (AUC difference: 0.02, $p = \text{NS}$) (**Figure 2A**). However, for the more complex procedures [EuroCTO (CASTLE) score ≥ 4 or J-CTO score ≥ 3], the discriminatory capacity of EuroCTO (CASTLE) score to predict procedural success appeared superior compared to the J-CTO score (AUC: 0.588, 95% CI 0.509-0.668, $p = 0.03$ for EuroCTO (CASTLE) score vs. AUC: 0.473, 95% CI 0.393-0.553, $p = \text{NS}$ for J-CTO score, AUC difference: 0.115, $p = 0.04$) (**Figure 2B**). In the univariate logistic regression analysis, both scores appeared to have better predictive efficacy for the less complex cases with J-CTO score of < 3 and EuroCTO (CASTLE) score < 4 (**table 3**). We analysed the discriminatory capacity of the two scoring systems across the very early (2012-13) and very late (2017-18) periods of time of our study. The EuroCTO (CASTLE) and J-CTO scores demonstrated a consistent and satisfactory discriminatory capacity over time (AUC: 0.740 95% CI: 0.657-0.882, $p < 0.001$ vs. AUC: 0.733 95% CI: 0.579-0.886, $p = 0.007$ and AUC: 0.723 95% CI: 0.641-0.805, $p < 0.001$ vs. AUC: 0.699, 95% CI: 0.564-0.834, $p = 0.021$, respectively) (**Figure 3**).

Successful recanalization with an AWE approach was predominant in the lower strata of both scores, whereas in more complex cases successful recanalization through RA or ADR approach was more frequently observed (**Figure 4**). Moreover, there was significantly higher radiation dose area product, contrast volume administration, overall procedural time and fluoroscopy time amongst the higher strata of both scores according to the trend analysis (**Figure 5**).

DISCUSSION

The present study compared the efficiency of the novel EuroCTO (CASTLE) score with the widely adopted J-CTO score to predict the technical outcome of CTO PCIs in an unselected cohort of patients treated with contemporary CTO techniques. Our results showed that the EuroCTO (CASTLE) score demonstrated an overall equal predictive performance with the J-CTO score. However, the EuroCTO (CASTLE) score appeared superior in predicting the technical outcome in the more complex cases.

The ability to reliably appraise case complexity and predict outcomes is a favourable concept that can facilitate CTO PCI in various ways. Firstly, it could ease the process of determining the appropriateness of CTO PCI by evaluating the overall risk-benefit ratio of the procedure¹². Secondly, it could help interventional cardiologists during their early stages of training in CTO PCI to select simpler cases and either refer the more complex cases to more experienced operators or perform these with proctor support. Furthermore, objective quantification of lesion complexity allows careful procedural planning, which is an essential step before attempting CTO recanalization both for experienced and non-experienced CTO PCI operators. Finally, determining case complexity, technical outcomes and efficiency metrics could help to evaluate the overall performance of a dedicated CTO programme, identify pitfalls and help to further improve performance and quality measures.

So far, various predicting scoring systems have been developed^{9,13-16}. These scores have been derived from registries that predominantly included a relatively modest number of patients. Additionally, across the different registries there was a great variance regarding the adopted recanalization techniques, CTO PCI success rates, patients' clinical characteristics, case

complexity and operator skills making these scores unattractive for a more generalized adoption. The most commonly used J-CTO score was derived from a cohort of 465 patients treated exclusively with the antegrade approach between 2006 and 2007⁹. The end-point in that study was successful guidewire crossing within 30 min and was achieved in 48 % of the cases.

The EuroCTO group recently reported the development and validation of a novel CTO PCI success-prediction scoring system, the EuroCTO (CASTLE) score. The potential advantages of this prediction score are the large derivation and validation cohort consisting of an unselected and contemporary population of more than 20,000 cases, the homogeneous distribution of operator experience with the majority of the operators performing > 50 CTO PCIs/year and the utilization of a broad spectrum of contemporary CTO PCI techniques and equipment. In our study, we compared the EuroCTO (CASTLE) score with the J-CTO score as the latter is the score most commonly used to assess the complexity of CTO PCIs. The EuroCTO (CASTLE) score demonstrated an overall equal discriminatory capacity with the J-CTO score. However, the EuroCTO (CASTLE) score depicted superior calibration and had better predictive performance than the J-CTO score in the more complex cases. The noticeably large number of patients that were used in the original derivation cohort of the EuroCTO (CASTLE) score and the inclusion of additional objective clinical features such as prior history of CABG and patients' age potentially improved the ability of the EuroCTO (CASTLE) score of predicting the technical outcome in more complex CTO PCIs. Elderly patients and those with a prior history of CABG are likely to have more comorbidities and diffuse and complex atherosclerotic disease that can increase case complexity and thus result in a higher likelihood of unsuccessful outcomes^{17,18}. In contrast to the J-CTO score, in the EuroCTO (CASTLE) score a previously

failed attempt was not incorporated in the final prediction model. This parameter is subject to the operator's technical expertise. Less experienced operators are more likely to fail, simply because they do not master all recanalization techniques and thus have limited options to tackle more difficult CTOs, whilst a more experienced operator might have succeeded in the first attempt. Therefore, for an operator with a good level of CTO PCI experience, a previously failed attempt is not necessarily translated into a more complex procedure or increased chances for failure. In addition, the utilization of the currently expanded armamentarium of dedicated CTO equipment and the implementation of more advanced recanalization techniques compared to those used in the derivation cohort of the J-CTO score, might have blunted the impact of CTO complexity assessed by the J-CTO score and could at least in part explain the inconsistency that we observed in the predictive efficiency in the more complex cases. Finally, although the discriminatory capacity of the EuroCTO (CASTLE) score was superior in the higher complexity subgroup, it was reduced compared to the overall population (AUC 0.588 vs. 0.674 respectively).

In our study, the EuroCTO (CASTLE) score demonstrated an almost identical discriminatory capacity with that of the original derivation cohort from the EuroCTO registry (AUC of 0.67 and 0.66, respectively). In our analysis, we included consecutive CTO cases from day-1 of a dedicated CTO PCI programme, thus incorporating all stages of a contemporary CTO PCI learning curve. Therefore, we provide evidence that the EuroCTO (CASTLE) score is generalisable, with excellent reproducibility in different CTO populations and across variable CTO PCI expertise and contemporary CTO PCI modalities.

Higher grades of both scores were associated with significantly higher levels of several procedural efficiency metrics such as radiation exposure, contrast volumes, procedural and fluoroscopy times in keeping with findings of previous studies¹⁹. Beyond the actual predictive ability of technical success, the CTO PCI scoring systems might be advantageous by assisting angiographic review, estimating procedure and lesion complexity and evaluating efficiency metrics, all which can be valuable components of a comprehensive and universal approach to clinical-decision making. Given the higher potential for complications, the decision to proceed with CTO revascularization must be based on a meticulous risk-benefit assessment and an uncluttered discussion with both the patient and the heart team.

LIMITATIONS

A few limitations of this study warrant further discussion. The study is limited by its observational design and even though the population was unselected with enrolment of consecutive patients undergoing CTO PCI, it could be subject to operators' case selection bias especially during the early stages of the dedicated CTO programme. However, the inclusion of cases from the early stages of the programme, when the operators' experience was more limited, enhances the capacity of extrapolating the study results in other populations that encompass a broad spectrum of case difficulty and operator technical experience. Angiographic parameters were assessed by the operators without adjudication from a core laboratory, although we think it is unlikely that the major findings would have been any different as all operators were participating in a dedicated CTO programme and have substantial theoretical and practical knowledge regarding all aspects of CTOs. Finally, it is worth mentioning a limitation not of our study, but of any outcome predicting score. Predicting scores are useful for estimating lesion complexity and planning procedural strategy

and use of equipment, but it is impossible to generate a flawless model with a perfect predictive capacity. Clinical judgment and operator's experience cannot be substituted by any prediction model and are the most important factors for determining a successful and uneventful procedure.

CONCLUSION

In conclusion, the EuroCTO (CASTLE) score demonstrated similar performance with the J-CTO score in predicting the success of CTO PCI with potentially better discriminatory capacity in more complex cases. Both scores were associated with higher values of procedural efficiency measures and thus could assist with preprocedural planning and risk-benefit assessment.

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Table 1.

Clinical, angiographic and procedural characteristics.

Clinical characteristics	N=660
Age, (years) mean years \pm SD	65.8 \pm 10.6
Age > 70 years (%)	236 (35.8)
Male (%)	553 (83.8)
BMI, mean \pm SD	30.5 \pm 5.6
Hypertension (%)	453 (68.6)
Hyperlipidaemia (%)	512 (77.6)
Smoking (%)	162 (24.5)
Diabetes (%)	145 (22.0)
Previous MI (%)	328 (49.7)
Previous PCI (%)	307 (46.5)
Previous CABG (%)	128(19.4)
Previous CVA (%)	36 (5.5)
Peripheral vascular disease (%)	48 (7.3)
Chronic kidney disease (%)	139 (21)
Left ventricular systolic function	
Good (EF > 50%)	425 (71.1)
Moderate (EF: 35-50%)	152 (25.4)
Severe (EF < 35%)	21 (3.5)
CCS, mean \pm SD	2.2 \pm 1.0
NYHA, mean \pm SD	1.8 \pm 0.8

Previous failed target vessel CTO PCI (%)	113 (17.1)
Angiographic characteristics	N=660
Target CTO vessel	
RCA (%)	432 (65.5)
LAD (%)	163 (24.3)
LCx (%)	65 (9.8)
CTO length > 20 mm (%)	363 (55.0)
Blunt proximal cap (%)	288 (43.6)
Calcification (%)	310 (47.0)
Severe calcification (%)	124 (18.8)
Tortuosity (%)	154 (23.3)
Severe tortuosity (%)	19 (2.9)
Procedural characteristics	N=660
Procedural time (minutes), mean±SD	131.3±59.1
Fluoroscopy time (minutes), mean±SD	42.4±25.1
Contrast volume (ml), mean±SD	259.8±92.9
Radiation DAP (mGy), mean±SD	22019.3±28946.6
Number of implanted stents, mean±SD	2.1±1.4
Overall stent length (mm), mean±SD	47.9±34.2
Prediction scores	
J-CTO score, mean±SD	1.9±1.2
EuroCTO (CASTLE) score, mean±SD	1.8±1.2

BMI: Body Mass Index; **MI:** Myocardial infarction; **CABG:** Coronary artery bypass graft surgery; **CVA:** Cerebrovascular accident; **CTO:** Chronic total occlusion; **RCA:** Right coronary artery; **LAD:** Left anterior descending artery; **LCx:** Left circumflex artery; **PCI:** Percutaneous coronary intervention; **CCS:** Canadian cardiovascular society angina pectoris grading; **NYHA:** New York heart association functional classification; **DAP:** Dose area product.

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Table 2.

Multivariate logistic regression analysis for prediction of CTO PCI technical outcome including the two scoring systems and potential confounders.

	OR	95% CI	p
<i>EuroCTO (CASTLE) score</i>	<i>0.698</i>	<i>0.532-0.916</i>	<i>0.009</i>
<i>J-CTO score</i>	<i>0.683</i>	<i>0.516-0.909</i>	<i>0.008</i>
Male gender	0.803	0.392-1.647	0.6
BMI	0.985	0.941-1.032	0.5
Chronic kidney disease	0.760	0.405-1.426	0.4
Previous MI	1.168	0.679-2.012	0.6
Previous PCI	1.021	0.600-1.736	0.9
Diabetes	1.181	0.657-2.123	0.6
Peripheral vascular disease	1.371	0.622-3.022	0.434
Target CTO vessel LAD	0.357	0.125-1.018	0.06
Target CTO vessel RCA	0.635	0.240-1.683	0.4
Left ventricular function good	2.280	0.521-9.985	0.3
Left ventricular function moderate	2.451	0.538-11.160	0.2

BMI: Body Mass Index; **MI:** Myocardial infarction; **CTO:** Chronic total occlusion; **RCA:** Right coronary artery; **LAD:** Left anterior descending artery; **PCI:** Percutaneous coronary intervention; **OR:** Odds ratio; **CI:** Confidence interval

Table 3.

Univariate logistic regression analysis of the capacity of both scoring systems in predicting a successful technical outcome of CTO PCI across the different scoring strata.

J-CTO score	OR	95% CI	P
1	10.5	2.3-48.2	0.002
2	5.3	1.4-20.0	0.014
3	1.8	0.5-6.4	NS
4	0.831	0.2-3.0	NS
5	1.4	0.4-5.7	NS
EuroCTO (CASTLE) score	OR	95% CI	P
1	17.5	3.6-84.2	<0.001
2	10.1	2.3-44.8	0.002
3	6.0	1.4-26.3	0.017
4	3.1	0.7-13.8	NS
5	2.5	0.5-11.4	NS

OR: Odds ratio; **CI:** Confidence interval

FIGURE LEGENDS

Figure 1.

- A. Observed rates of technical success of CTO PCI across J-CTO score strata
- B. Observed rates of technical success of CTO PCI across EuroCTO (CASTLE) score strata
- C. Distribution of J-CTO score strata across study cases. The green line demonstrates the predictive mean probability of successful CTO PCI according to the J-CTO score stratification. There is an evident discrepancy between the observed (**figure 1A**) and predicted success rates (green line) in the more complex cases with a J-CTO score of ≥ 3 .
- D. Distribution of EuroCTO (CASTLE) score strata across study cases. The green line demonstrates the predictive mean probability of successful CTO PCI according to the EuroCTO (CASTLE) score stratification. The EuroCTO (CASTLE) score depicts a good agreement between the observed (figure 1B) and the predicted success rates (green line) across all score strata.

Figure 2.

- A. Receiver operating characteristics curves (ROC) for success prediction for the J-CTO and the EuroCTO (CASTLE) scores in the whole study cohort.
- B. ROC curves for success prediction for the J-CTO and the EuroCTO (CASTLE) scores in the more complex cases with J-CTO score ≥ 3 or EuroCTO (CASTLE) score of ≥ 3 .

Figure 3.

- A. Receiver operating characteristics (ROC) curves for success prediction for the J-CTO and the EuroCTO (CASTLE) scores in the study cohort between years 2012-2013.

- B.** ROC curves for success prediction for the J-CTO and the EuroCTO (CASTLE) scores in the study cohort between years 2017-2018.

Figure 4.

- A.** Rates of successful techniques across J-CTO score strata.
- B.** Rates of successful techniques across EuroCTO (CASTLE) score strata.

Figure 5.

CTO PCI efficiency metrics including contrast volume, radiation dose area product, fluoroscopy and procedural time across the J-CTO and EuroCTO (CASTLE) scores strata.

Figure 1.

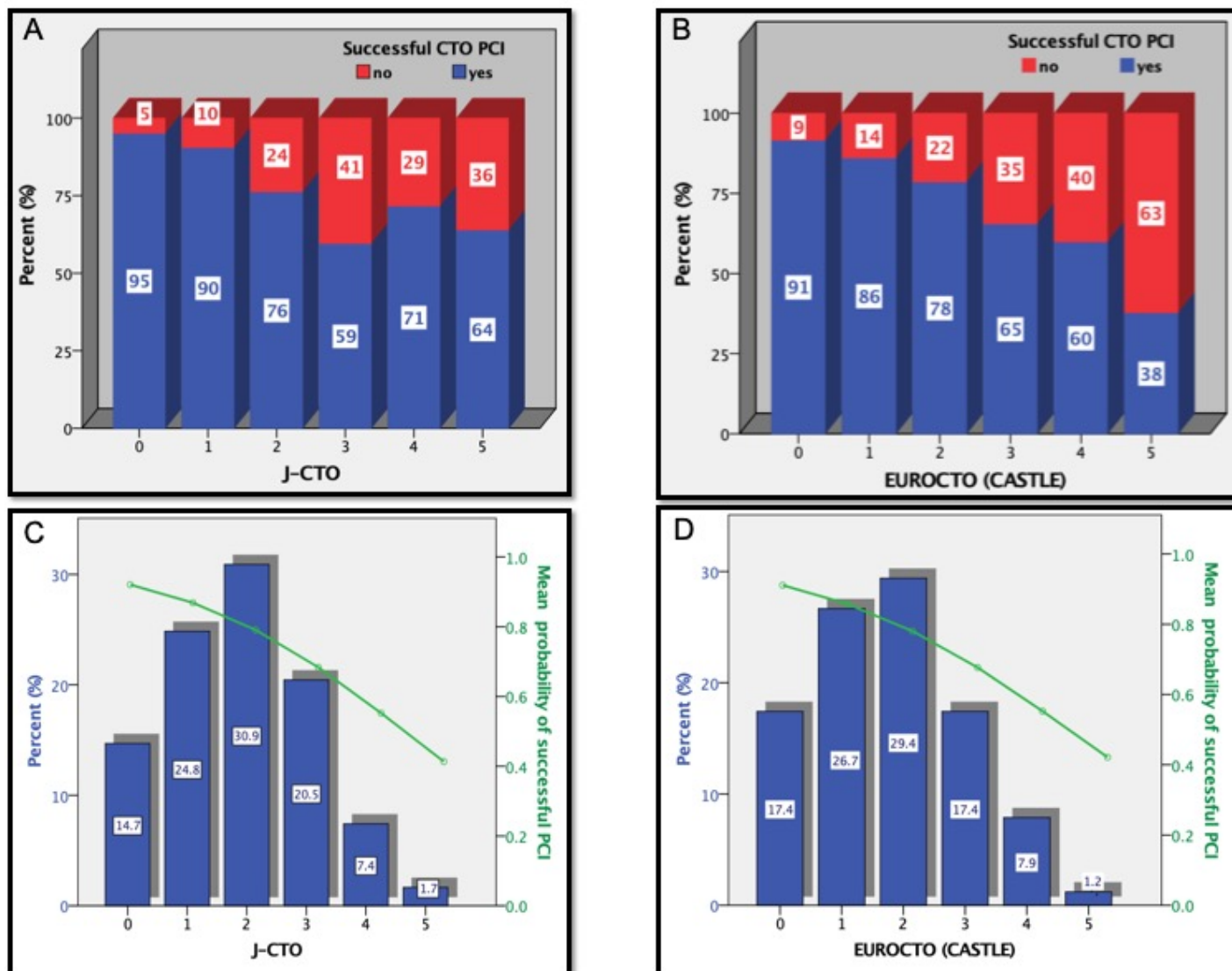


Figure 2.

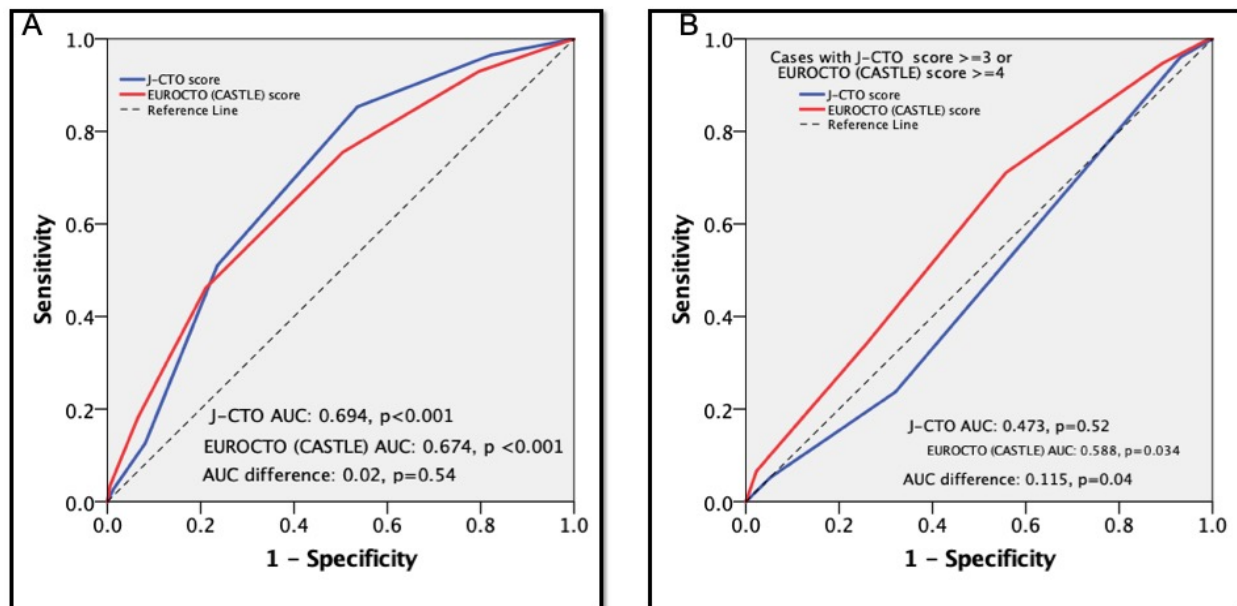


Figure 3.

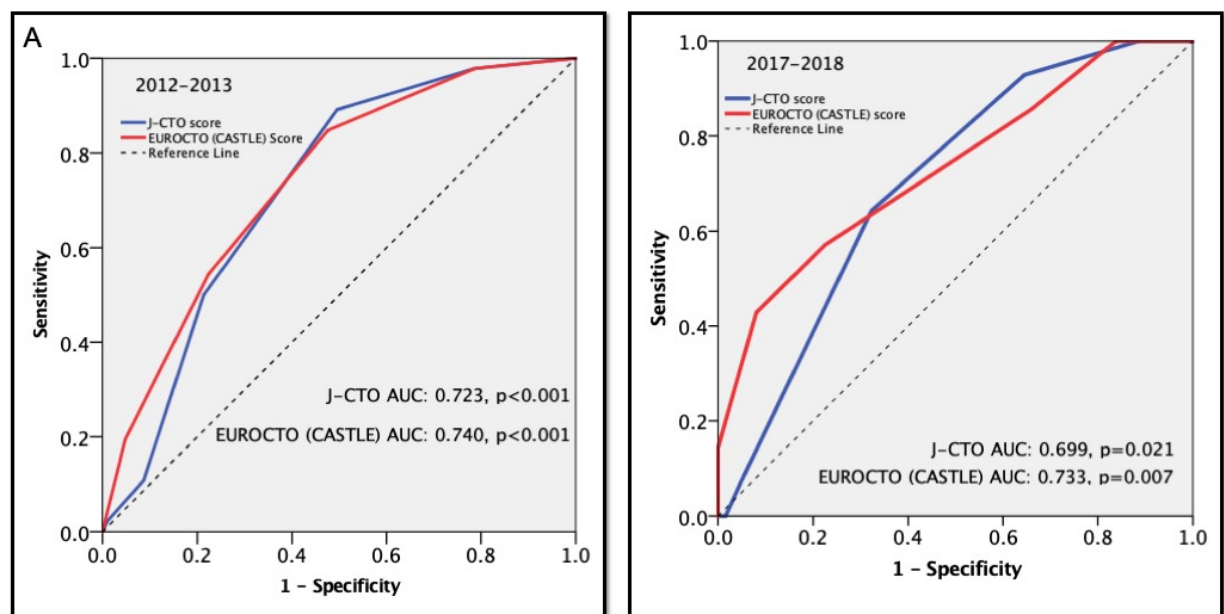


Figure 4.

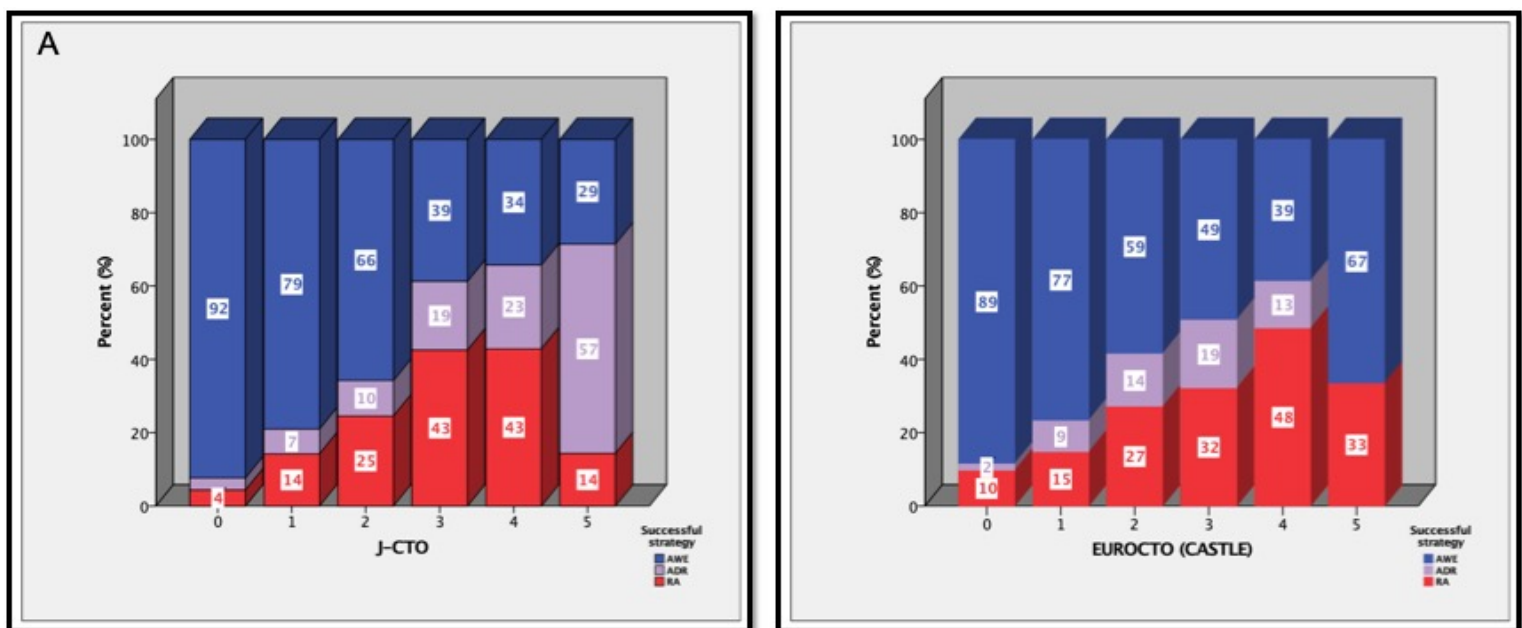
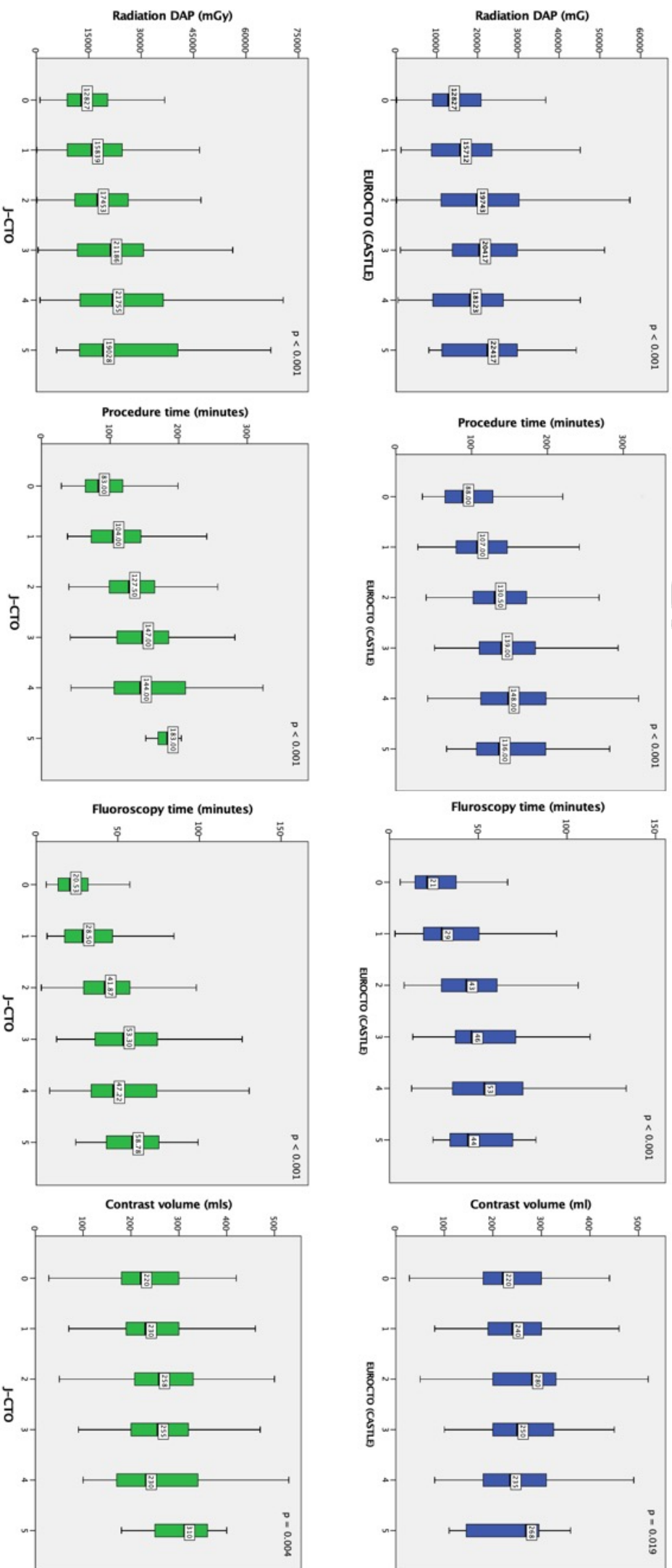


Figure 5.



Supplementary material

Definitions of the EuroCTO and J-CTO variables

The angiographic morphology of the proximal cap was classified as tapered if the occluded segment ended proximally in a funnel shaped form, blunt if it did not and invisible or ambiguous if the guidewire target was not angiographically apparent. The presence of calcification was assessed by angiographic criteria as mild (spots), moderate (involving $\leq 50\%$ of the reference vessel diameter) and severe (involving $> 50\%$ of the reference vessel diameter). Mild tortuosity was defined as the presence of 1 bend $> 45^\circ$ and $< 90^\circ$, moderate tortuosity was defined as a segment containing either two bends $> 70^\circ$ or a single bend $> 90^\circ$ and severe tortuosity was defined as the presence of 2 bends $> 90^\circ$ or 1 bend $> 120^\circ$. Vessel tortuosity involved either the proximal segment of the vessel adjacent to the CTO lesion or the occlusive segment. For the EuroCTO (CASTLE) score calculation the presence of tortuosity was confined only in the pre-occlusive segments of the CTO vessel. Occlusion length was measured from the beginning of the occluded segment to the distal vessel filling from collateral connections using bilateral contrast injections.

Recanalization techniques

The techniques used for vessel recanalization were categorised into antegrade wire escalation (AWE), antegrade dissection and re-entry (ADR) and retrograde approach (RA). The latter group included the retrograde wiring (RW) and reverse controlled antegrade and retrograde subintimal tracking (CART) techniques. The approach was defined as RA if a guidewire was introduced into a collateral channel that was supplying the distal target vessel and AWE if the recanalization attempt involved an antegrade guide wire tracking through the

proximal cap without introducing a guide wire into a collateral channel. In antegrade cases, where a wire or a device-based vessel dissection was implemented to achieve successful recanalization either primarily or as a bailout strategy, the procedure was defined as ADR. In RA cases, the RWE technique, the reverse CART or both strategies were used to successfully cross the lesion and achieve entry to the proximal true lumen of the vessel.

Additional multicollinearity analysis

We performed additional multicollinearity analysis to test for potential multicollinearity between the two scoring systems in the regression model analysis. There was a statistically significant correlation in the bivariate correlation analysis between the two variables ($r = 0.688$, $p < 0.001$). However, the performed collinearity diagnostics did not demonstrate any significant collinearity as this is shown in the supplementary table 1 below with a good variance inflation factor of < 3 for both variables. Moreover, after performing the multivariate logistic regression analysis with only one of the scoring systems included in each model both scores were still remained the only independent predictors of successful CTO PCI outcome (OR: 0.568, 95% CI: 0.460-0.700, $P < 0.001$ for the EUROCTO (CASTLE) score; OR: 0.572, 95% CI: 0.464-0.707, $p < 0.001$ for the J-CTO score)

Supplementary table 1 Collinearity statistics including tolerance and variance inflation factor for all the variables incorporated in the final multivariate regression analysis for the identification of potential independent predictors for successful CTO PCI.

Coefficients

Model	Collinearity Statistics	
	Tolerance	VIF
Gender	.952	1.051
Diabetes	.937	1.067
Target_CTO_Vessel	.963	1.038
JCTO_Score	.494	2.024
CASTLE_Score	.494	2.023
Previous_MI	.821	1.218
Previous_PCI	.872	1.147
LV_function	.853	1.173
PVD	.958	1.044
CKD Stage	.896	1.115
BMI	.944	1.059