Nomogram to Predict Successful Septal Collateral Crossing during Percutaneous Coronary Intervention of Chronic Total Occlusion by retrograde approach: The Sep-CTO score

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Abstract

Septal collaterals are the main collaterals used in retrograde chronic total occlusion (CTO) percutaneous coronary intervention (PCI). However, there is little evidence regarding the selection of an interventional septal collateral (SC). we aimed to identify the predictors of successful guidewire crossing using clinical and anatomical characteristics. Overall, 216 derivation cases and 86 validation cases that included retrograde CTO PCI were analyzed. The technical success rate was 79.1% and there were no significant differences in the Gensini score, SYNTAX score, J-CTO score and Progress Score between two groups. Multivariate logistic regression analysis revealed that diabetes, small size, corkscrew, and side branch at tortuosity were independent factors of success in crossing SCs. We developed a nomogram to predict the success rate, which demonstrates favorable calibration and formed the Sep-CTO score. The calibration and decision curve analysis also demonstrated the reliability and accuracy of this clinical prediction model. The receiver-operating characteristic area of the nomogram was 0.870. Compared to the aforementioned scoring systems, Sep-CTO score was the most powerful. The nomogram may be a useful clinical tool. We found four independent variables to predict the successful guidewire crossing in septal collaterals.

Introduction

Chronic total occlusion (CTO) is defined as grade 0 thrombolysis in myocardial infarction (TIMI) flow for more than 3 months, which is frequently encountered during coronary angiography in patients with coronary artery disease (CAD) [1]. Revascularization of CTO can relieve angina, improve heart function, and decrease mortality [2]. According to the hybrid algorithm, retrograde approach is a crucial and effective technique to recanalize CTO when the antegrade attempt has failed or the occlusion has an ambiguous proximal cap, poor distal target, and appropriate collaterals. Septal collaterals (SC) are the most commonly used vessels in the retrograde technique; they form the most important collateral pathway for CTO percutaneous coronary intervention (PCI) [3]. Compared with the complications rate with epicardial collaterals, it is lower with SC [4].

Successful SC guidewire (GW) crossing is the first step in the retrograde technique. The key is to select the collateral vessel with adequate anatomical characteristics. Several groups have reported on the predictive factors of retrograde CTO PCI [5]. However, those score systems predicted the success rate of GW crossing through both epicardial and septal collaterals, which lacks the representative for septal approach. Furthermore, the predictors were assigned 1–2 points using logistic regression, which carries low sensitivity and specificity for each patient [6-9].

Currently, nomogram is considered a useful tool to evaluate the risk by integrating important clinical and anatomical characteristics. By creating a direct evaluation system, a predictive nomogram may assist operators in selecting the optimal SC vessel. Therefore, the aim of this study was to establish a nomogram for identifying the clinical and potential angiographic predictors of successful GW crossing the SC vessels in retrograde CTO PCI.

Results

Baseline characteristics of participants

Table 1 summarizes the clinical characteristics of the derivation cohort (n=216) and validation cohort (n=86). The mean age was 57.8±10.2 and 58.6±10.0 years in these groups, respectively. The incidences of hyperlipidemia, diabetes, stroke, history of PCI, and smoking were not significantly differently between the groups (all p>0.05). Similarly, there were no statistical significance in the body mass index (BMI), left ventricular ejection fraction, Gensini score, SYNTAX score, J-CTO score, and Progress Score (all p>0.05). The main angiographic characteristics of the two groups are summarized in Table 1.

In the derivation set, the incidence of diabetes was significantly higher in the failed group than that in the successful group (p<0.05). In terms of angiographic characteristics, the failed group demonstrated significantly higher proportion of small size, corkscrew, and side branch at tortuosity than those in the successful group (all p<0.05, Table 2).

Univariate and multivariate analysis

Univariate and multivariate logistic regression analyses were used to explore the association of risk factors with success rate of GW crossing. The univariate analysis demonstrated that diabetes (odds ratio, OR: 2.305), small size (OR: 2.778), corkscrew (OR: 4.028), and side branch at tortuosity (OR: 2.190) were associated with success in GW crossing (all P<0.05). According to multivariate logistic regression analyses, diabetes, small size, corkscrew, and side branch at tortuosity were identified as independent factors in the training cohort (Table 3, Figure 4).

Novel nomogram score system

Corkscrew was the biggest influencing factor on the prognosis, whereas diabetes had the least effect. Validation of the nomogram was performed using bootstrap analyses with 1,000 resamples; the internal validation cohorts revealed favorable discrimination of the nomogram, demonstrating that the nomogram could be clinically implemented (Figure 5).

Validation of the predictive accuracy of the nomogram

Overall, 86 patients were included in the validation cohort between February 2019 and October 2020. The calibration was drawn to evaluate the calibration of the model in the validation set (Figure 6). ROC analyses were used to evaluate the discrimination of the model; the area under the curve (AUC) was 0.870 (95% confidence interval, CI: 0.792–0.948, Table 5) and indicated better predictive accuracy. Additionally, the decision curve analysis (DCA) curve demonstrated that the novel nomogram also included a higher clinical net (Figure 7).

Procedure data and clinical outcome

Table 4 summarizes the procedures and clinical outcome data. Femoral and radial access were used in the majority of patients (91.0%). The high prevalence of GWs used was Sion (Asahi Intecc, Nagoya, Japan), which was 93.3%. The common final crossing technique included the Reverse CART (49.1%), RWE (19.7%), AWE (8.3%), and parallel wires (5.3%). Other techniques included kissing wires (10.1%) and ADR (3.1%). Furthermore, the technical success rate was 79.1% and the procedural success rate was 75.5%. For procedural complications and adverse events, the incidence of CC perforation was 4.6%. One patient developed periprocedural myocardial infarction and six patients developed no-flow or slow-flow.

Discriminatory power of different scores

We also compared the predictive ability of the new model and conventional staging systems by comparing AUC of ROC curves (Table 5; Figure 8). The AUC of Retro-CTO score was 0.698 (95% CI: 0.563–0.834, P<0.05) and Figure 8 illustrates Retro-CTO score's probability of success in different groups. The J-Channel score demonstrated intermediate predictive value (AUC: 0.776; 95% CI: 0.644–0.909; P<0.01). The predictive value of EPI-score included AUC of 0.702 (95% CI: 0.558–0.846; P<0.05). The HLK score demonstrated little predictive value on the septal channel retrograde revascularization (AUC: 0.611; 95% CI: 0.4614–0.761, P=0.19). Compared to those systems, the Sep-CTO score had the strongest predictive power with success rates of 100%, 75%, and 50% for easy, intermediate, and difficult groups, respectively (Figure 9). Additionally, the Sep-CTO score may predict the GW crossing time as well (Figure 10).

Discussion

In this study, the demographic, clinical, and SC anatomical characteristics were analyzed to examine the association between the predictive factors and success with SC GW crossing. New predictive models including a nomogram based on multiple logistic regression were developed and validated. To the best of our knowledge, this is the first attempt to develop a diagnostic method for SC GW crossing based on a nomogram. Our results provide a new perspective on the relevant predictive factors with better discriminatory power. Diabetes, small size, corkscrew, and side branch at tortuosity were significant predictors of success in SC GW crossing (Figure 11).

Despite remarkable progress in devices, techniques, and experiences over the decades, the recanalization rate of CTO is still low and represents the "final frontier" of PCI [19]. The retrograde technique can improve the success rate of CTO PCI when the antegrade GW cannot reach the true lumen of the occlusion distally. The first retrograde crossing via SC was performed by Surmely in 2009 [20]. Regarding the anatomical distribution of collaterals, the left anterior descending septal collaterals to the posterior descending artery is the common in right coronary artery CTO, and we also found a high frequency of septal collaterals from the posterior descending artery to the left anterior descending in left anterior descending CTO [18]. However, SC are preferred due to higher success rate and lower risk of perforation and tamponade compared to epicardial and saphenous vein grafts [21]. Finding an adequate vessel can improve the operative efficiency and decrease the dose of radiation exposure. In our study, we identified four independent risk factors—diabetes, small size, corkscrew, and side branch at tortuosity—using univariate and multivariate analyses as predictors of successful GW crossing.

Epidemiological evidence indicate that diabetes is a crucial risk factor in cardiovascular diseases. Patients with CTO with diabetes often have reduced coronary collateralization through multiple mechanisms, including decrease pressure gradient, oxidative stress, and inhibition of proangiogenic factors [22]. In this study, compared to the successful group, the prevalence of diabetes was higher in the failed group, which may be associated with more invisible coronary collaterals and difficult to cross with the surfing technique. The small vessels include Werner CC0 in which surfing CC crossing techniques are commonly used. However, controversy remains in this field. Dautov et al. found that invisible SC were crossed with as much success as larger CCs and faster [23]. A previous study enrolled 216 patients with retrograde CTO in whom PCI was attempted and revealed collateral channel size as a predictor of failure [9]. We found that small size was an independent factor related to failure of GW crossing in SC. Corkscrew was the most powerful prediction variable of GW crossing in our study. From our experience, GW crossing is difficult in a corkscrew vessel, especially, if it is small in size. Additionally, manipulation of GW was poor in the collateral channel, especially, the distal segment. When the septal collateral was corkscrew-shaped, it was difficult to prevent perforation. In contrast, the tip of GW is difficult to keep angle in corkscrew. Huang et al. proved that side branch at CCs tortuosity was an independent predictor of procedure success in epicardial collaterals [7]. Similarly, side branch at CCs tortuosity was also significantly associated with GW tracking in SC. This approach resulted in difficult advancement of GW. Besides, due to a lack of support from the catheter, GW steerability is inadequate.

The important predictor of GC crossing included in the nomogram was the Sep-CTO score. Recently, some researchers have focused on the assessment of GW tracking. Scoring systems have been constructed to predict the success of GW tracking in the retrograde approach, such as EPI-score, Retro-CTO score, J-channel score, and HLK score. EPI-score demonstrated that CC tortuosity, side branch at CCs tortuosity, inadequate CCs size, and inadequate CCs exit location were independent predictors associated with technical success in the epicardial channel [7]. Other studies have highlighted that those the score had a significant predicting ability in collateral channels. Consistent with the above results, our single-center study found that the Sep-CTO score was a reliable system in the prediction of successful GW crossing in the septal channel, which also might indicate the GW crossing time. Therefore, given the anatomical features, the assessment of the collateral channels is critical.

In the ERCTO registry, the success rate of GW crossing the collateral channel was 75.3% and the clinical success rate was 71.2% [24]. In our study, retrograde wire advancement to the distal CTO cap through SP was successful in 79.1% of cases, and the rate of retrograde procedural success was 75.5%. Additionally, perforations were observed 14 cases; they were minor and asymptomatic. These findings confirm that septal CCs are safer and, therefore, should be preferred.

Material And Methods

Study Patient and Data Collection

Overall, 216 inpatients with chest pain who underwent attempted retrograde CTO PCI via SC by high-volume operators [10] (>75 total CTO PCIs and >20 retrograde attempts overall) between January 2016 and January 2019 at The Anzhen Hospital were consecutively enrolled. Between February 2019 and October 2020, an independent cohort of consecutive patients was prospectively enrolled using the same inclusion and exclusion criteria. These patients formed the validation cohort in this study. The patients were assigned to the successful (n = 167) or failed (n=49) group based on the outcome of the procedure (Figure 1).

Baseline, procedural, and hospitalization data were recorded. The Gensini score [11], SYNTAX score (Synergy between Percutaneous Coronary Intervention with TAXUS and Cardiac Surgery) [12], J-CTO score (Multicenter CTO Registry in Japan) [13], and Progress Score (Prospective Global Registry for the study of CTO intervention) [14] were calculated by two experienced interventional cardiologists. The study protocol was approved by the Institutional Review Board of The Anzhen Hospital, Beijing, China.

Definitions

CTO was defined as an occlusion lasting for more than 3 months based on the first onset of angina pectoris, previous angiogram, or previous infarction and TIMI grade 0. All procedures in this study followed the hybrid algorithm.

The diagnostic criteria for the classical risk factors, including dyslipidemia [15], hypertension [16], and diabetes [17], were based on authoritative international guidelines. Two experienced interventional cardiologists collected the anatomic characteristics of SC (Figure 2). According to McEntegart MB et al [18]. CC entry angle<90° was described as an acute of <90° between CC and the recipient vessel. CC exit angle<90° was defined as the angle was less than 90° at channel exit. Reverse bend was defined as part of the bend folded at an angle of more than 90°. Continuous bends included more than three successive curves of more than 180°. Corkscrew was described as three or more continuous bends with a ratio of vessel amplitude/vessel diameter (AD ratio)≤2. Side branch at tortuosity was defined as bifurcation within a tortuous part of CC. Small size of the vessels was assessed using Werner's CC score and was defined as CC0 or CC1 (Figure 2,3).

Retro-CTO score was developed by Chai et al.; it includes the Werner's score, diameter of distal CTO lesion (<1.5 mm), and tortuous collateral [6]. EPI-score was developed by Huang et al.; it includes tortuosity, side branch at tortuosity, inadequate size of CCs, and inadequate exit location of CCs [7]. J-channel score includes the vessel size, reverse bend, continuous bends, and corkscrew; it was developed by Nagamatsu et al. in 2020 [8]. HLK score consists of vessel size and tortuosity and was developed by Hsien-Li et al [9].

Successful GW crossing was defined as the guide wire crossing through the SC from the retrograde side and reaching the distal vessel segment. Technical success was defined as successful CTO recanalization with < 20% residual stenosis and TIMI flow grade 3 along with the absence of in-hospital adverse events.

Statistical Methods

Continuous variables are reported as mean ± standard deviation for normally distributed data or median and quartiles (Q1–Q3) for non-normally distributed data. Discrete variables are expressed as frequency and percentage and compared using the chi-squared test. Logistic regression analysis was performed to identify factors. For further analysis, a nomogram was formulated based on the results of multivariable logistic regression analysis. For validating the nomogram, the calibration curves were calculated from the multivariate logistic model. Bootstrapping with 1000 resamples was used for these analyses. Decision curve analysis (DCA) was performed to determine the clinical usefulness of the nomogram for derivation and validation sets. We also performed receiver-operating characteristic (ROC) curve analyses to compare the diagnostic performance of each scoring system in the validation sets. A two-sided p-value<0.05 was considered statistically significant. The statistical computations were performed using SPSS v23.0 (IBM Inc., Armonk, NY, USA), STATA version 16.0 (StataCorp, College Station, TX, USA), and R v3.6.2 (R Foundation for statistical Computing, Vienna, Austria).

Ethics approval and consent to participate.

The protocol of this study and informed consent of all participants were approved by the Ethics Institutional Review Board of The Anzhen Hospital, Beijing, China. All methods were carried out in accordance with relevant guidelines and regulations, besides,informed consent was obtained from all subjects.

Consent for publication.

Authors give full consents for publication of this present article.

Limitations

Our study had some limitations. First, some selection bias was inevitable due to the retrospective design and single-center nature of the study. Second, the operator’s experience plays a crucial role in CTO PCI; this study included high-volume operators. Therefore, this scoring system may not be applicable to beginners. Finally, our nomogram may be a useful non-laboratory clinical tool. Further prospective multicenter studies are required to assess its acceptability and usability.

Conclusion

To our knowledge, this is the first application of logistic regression to produce a nomogram in predicting the success of GW crossing in retrograde CTO PCI in China. The Sep-CTO score can be used for judging the difficulty of GW crossing and carries strong translatability to clinical applications.

Declarations

Authors' contributions

Tong Liu for wrote article; Yuchao Zhang for collect data; Zheng Wu for guide; Yun Lv for analysis; Jinghua Liu for review the article.

Additional Information

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Competing interests

None

Data availability

availability

Ethics approval

Yes

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Tables

Table 1. Clinical and angiographic characteristics in the derivation and validation sets.

Variable	Derivation set (n=216)	Validation set (n=86)	*t/Z*	P-value
Age (years)	57.8±10.2	58.6±10.0	0.615	0.539
BMI (kg/m^2)	26.2±3.8	26.4±4.6	0.271	0.787
Male (%)	164 (75.9)	66 (76.7)	0.023	0.880
Diabetes (%)	62 (28.7)	22 (25.6%)	0.299	0.585
Hypertension (%)	138 (63.9)	58 (67.4)	0.341	0.559
Dyslipidemia (%)	137 (63.4)	52 (60.5)	0.23	0.631
Smoking (%)	84 (38.9)	31 (36.0)	0.211	0.646
Stroke (%)	24 (11.1)	10 (11.6)	0.016	0.898
LVEF (%)	60.7±8.3	60.7±9.4	0.027	0.978
History of PCI (%)	77 (35.6)	33 (38.4)	0.197	0.657
Target CTO vessel				
RCA (%)	133 (61.6)	50 (58.1)	0.304	0.581
LAD (%)	83 (38.4)	36 (41.9)	0.304	0.581
Score systems				
Gensini score	54 (45,64)	52 (43,64)	-0.624	0.531
SYNTAX score	22 (19,25)	21 (19,24)	-1.319	0.187
J-CTO score	2.0±1.0	2.1±1.0	1.059	0.660
Progress Score	1.0 (0,1.0)	1.0 (0,1.0)	-1.014	0.311
Angiographic characteristics				
SC entry angle<90° (%)	14 (6.5)	6 (7.0)	0.024	0.876
SC exit angle<90° (%)	17 (7.9)	7 (8.1)	0.006	0.938
Small size (%)	50 (23.1)	12 (14.0)	3.187	0.074
Inadequate SC exit location (%)	34 (15.7)	12 (14.0)	0.152	0.696
Reverse bend (%)	23 (10.6)	5 (5.8)	1.709	0.191
Continuous bends (%)	35 (16.2)	9 (10.5)	1.627	0.202
Corkscrew (%)	66 (30.6)	23 (26.7)	0.43	0.512
Side branch at tortuosity (%)	60 (27.8)	21 (24.4)	0.354	0.552

BMI: body mass index; LVEF: left ventricular ejection fraction; PCI: percutaneous coronary intervention; RCA: right coronary artery; LAD: left anterior descending; SC: septal collateral.

Table 2. Clinical and angiographic characteristics in the derivation sets.

Variable	successful group (n=167)	failed group (n=49)	t/Z	P-value
Age (years)	57.7±10.2	58.4±10.2	-0.377	0.706
BMI (kg/m^2)	26.3±3.8	25.9±3.9	0.569	0.570
Male (%)	129 (77.2)	35 (71.4)	0.701	0.402
Diabetes (%)	41 (24.6)	21 (42.9%)	6.204	0.013
Hypertension (%)	104 (62.3)	34 (69.4)	0.831	0.362
Dyslipidemia (%)	103 (61.7)	34 (69.4)	0.971	0.324
Smoking (%)	62 (37.1)	22 (44.9)	0.211	0.646
Stroke (%)	19 (11.4)	5 (10.2)	0.053	0.818
LVEF (%)	60.7±8.0	60.5±9.4	0.154	0.877
History of PCI (%)	58 (34.7)	19 (38.8)	0.27	0.603
Target CTO vessel				
RCA (%)	105 (62.9)	28 (57.1)	0.526	0.468
LAD (%)	62 (37.1)	21 (42.9)	0.526	0.468
Score systems				
Gensini score	54 (46,64)	56 (46,68)	-0.336	0.737
SYNTAX score	22 (19,25)	23 (12,31)	-0.349	0.727
J-CTO score	2.0±1.0	2.0±1.0	0.743	0.459
Progress Score	1.0 (0,1.0)	1.0 (0,1.0)	-1.434	0.152
Angiographic characteristics				
SC entry angle□90° (%)	10 (6.0)	4 (8.2)	0.296	0.587
SC exit angle□90° (%)	11 (6.6)	6 (12.2)	1.673	0.196
Small size (%)	31 (18.6)	19 (38.8)	8.7	0.003
Inadequate SC exit location (%)	24 (14.4)	10 (20.4)	1.041	0.308
Reverse bend (%)	16 (9.6)	7 (14.3)	0.881	0.348
Continuous bends (%)	27 (16.2)	8 (16.3)	0.001	0.979
Corkscrew (%)	39 (23.4)	27 (55.1)	17.996	0.001
Side branch at tortuosity (%)	40 (24.0)	20 (40.8)	5.371	0.020

BMI: body mass index; LVEF: left ventricular ejection fraction; PCI: percutaneous coronary intervention; RCA: right coronary artery; LAD: left anterior descending; SC: septal collateral.

Table 3. Univariate and multivariate logistic regression analyses for predictors of successful guidewire crossing.

Variables	Univariable		Multivariable	
	OR (95% CI)	P-value	OR (95% CI)	*P*-value
BMI, kg/m^2	0.974 (0.891–1.066)	*0.568*	-	-
Diabetes	2.305 (1.183–4.489)	0.014	2.604 (1.238–5.481)	0.012
Hypertension	1.408 (0.711–2.788)	0.326	-	-
Smoking	1.380 (0.724–2.629)	0.327	-	-
History of PCI	1.190 (0.617–2.296)	0.603	-	-
SC entry angle<90°	1.396 (0.418–4.661)	0.588	-	-
SC exit angle<90°	1.979 (0.692–5.657)	0.203	-	-
Small size	2.778 (1.387–5.565)	0.004	3.990 (1.763–9.028)	0.001
Inadequate SC exit location	1.528 (0.674–3.463)	0.310	-	-
Reverse bend	1.573 (0.607–4.074)	0.351	-	-
Continue bend	1.012 (0.427–2.396)	0.979	-	-
Corkscrew	4.028 (2.067–7.851)	<0.001	4.087 (1.993–8.382)	<0.001
Side branch at tortuosity	2.190 (1.119–4.285)	0.022	3.036 (1.375–6.703)	0.006
J-CTO score	0.871 (0.605–1.254)	0.457	-	-
Progress Score	0.714 (0.415–1.228)	0.223	-	-
SYNTAX score	0.995 (0.909–1.089)	0.995	-	-
Gensini score	1.003 (0.983–1.023)	0.771	-	-

BMI: body mass index; PCI: percutaneous coronary intervention; SC: septal collateral.

Table 4. Procedure and complication outcomes.

Procedure Date (n=302)	
Vascular access	
Femoral and femoral (%)	25(8.2)
Fermoral and radial (%)	275(91.0)
Radial and radial (%)	2(0.8)
Successful guidewire crossing CC (n=239)	
Sion	191(79.9)
Fielder series	32(13.4)
Sionblue	6(2.5)
Suoh03	10(4.2)
Final Crossing technique (n=228)	
Reverse CART (%)	112(49.1)
RWE (%)	45(19.7)
Kissing wires (%)	23(10.1)
AWE (%)	19(8.3)
Parallel wires (%)	12(5.3)
ADR (%)	7(3.1)
Others (%)	10(5.3)
GW Crossing success (%)	239(79.1)
Technical success (%)	228(75.5)
Contrast volume (mL)	331.6±130.3
Radiation dose (mGy)	5178.0(2838.0,14311.0)
Fluoroscopy time (min)	72.4±40.2
guidewire cross SC time (min)	25.6±19.3
Total procedure time (min)	169.7±70.1
Procedural complication and adverse event	
SC perforation (%)	14 (4.6)
Coronary perforation (%)	2 (0.7)
Pericardial perforation (%)	0 (0)

Periprocedural myocardial infarction (%)	1 (0.3)
No-flow/slow-flow (%)	6 (2.0)
Ventricular fibrillation (%)	1 (0.3)
Death (%)	0 (0)

Table 5. ROC Curve analysis of Sep-CTO score, Retro-CTO score, J-Channel score, EPI-score, and HLK score.

Factors	AUC	P	95%CI	Se (%)	Sp (%)	LR+	LR-	OR	YI	Cut-off point
Sep-CTO Score	0.870	< 0.001	0.792–0.948	0.929	0.708	3.18	0.10	31.8	0.637	89
Retro-CTO score	0.698	0.019	0.563–0.834	0.429	0.792	2.06	0.72	2.86	0.278	0.5
J-Channel score	0.776	0.001	0.644–0.909	0.857	0.611	2.20	0.23	9.57	0.468	0.5
EPI-score	0.702	0.017	0.558–0.846	0.643	0.736	2.44	0.49	4.98	0.379	1.5
HLK score	0.611	0.190	0.461–0.761	0.347	0.929	4.89	0.70	6.99	0.276	2.5

Figures

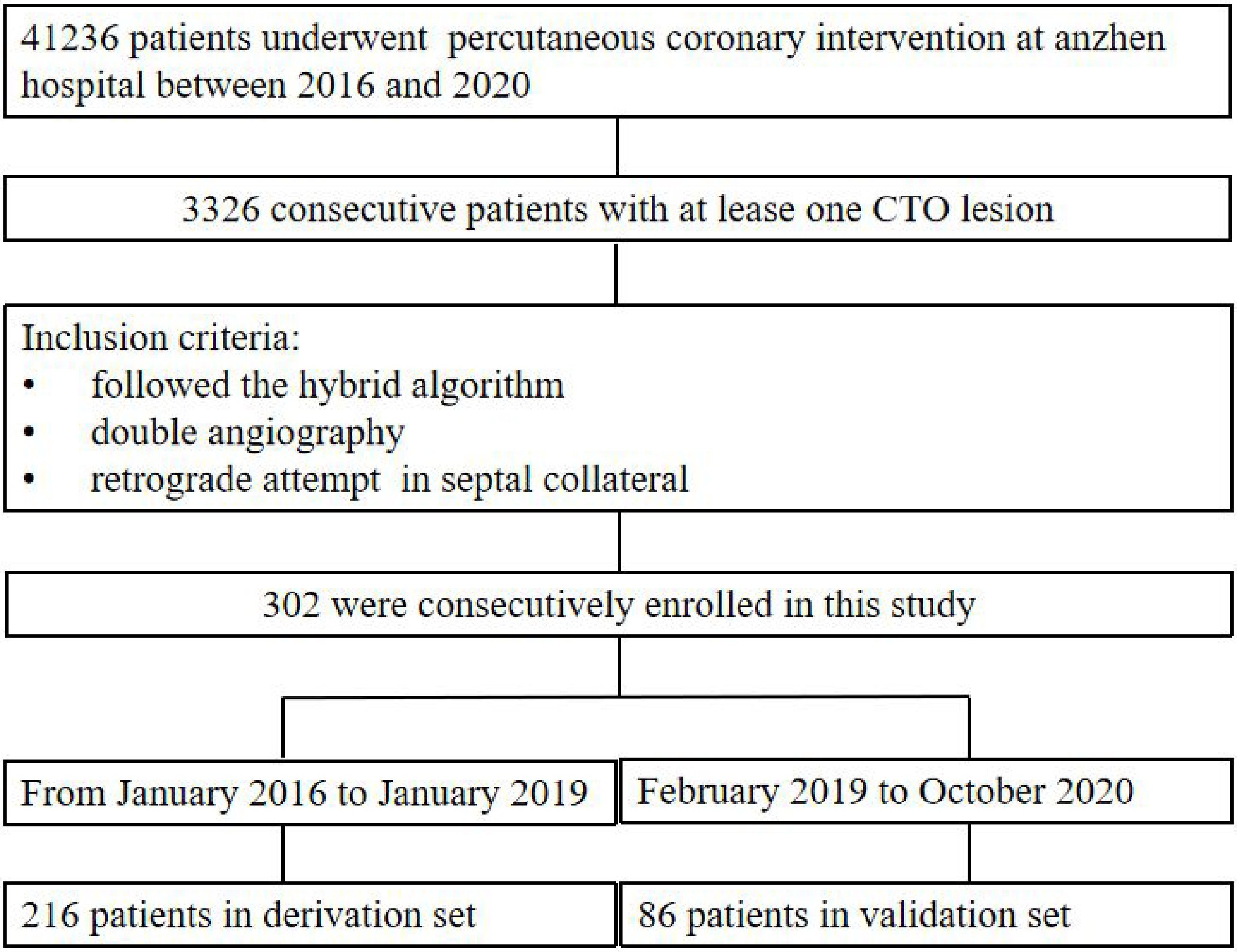

Figure 1

Population flowchart of retrograde CTO PCI. CTO, chronic total occlusion; PCI, percutaneous coronary intervention.

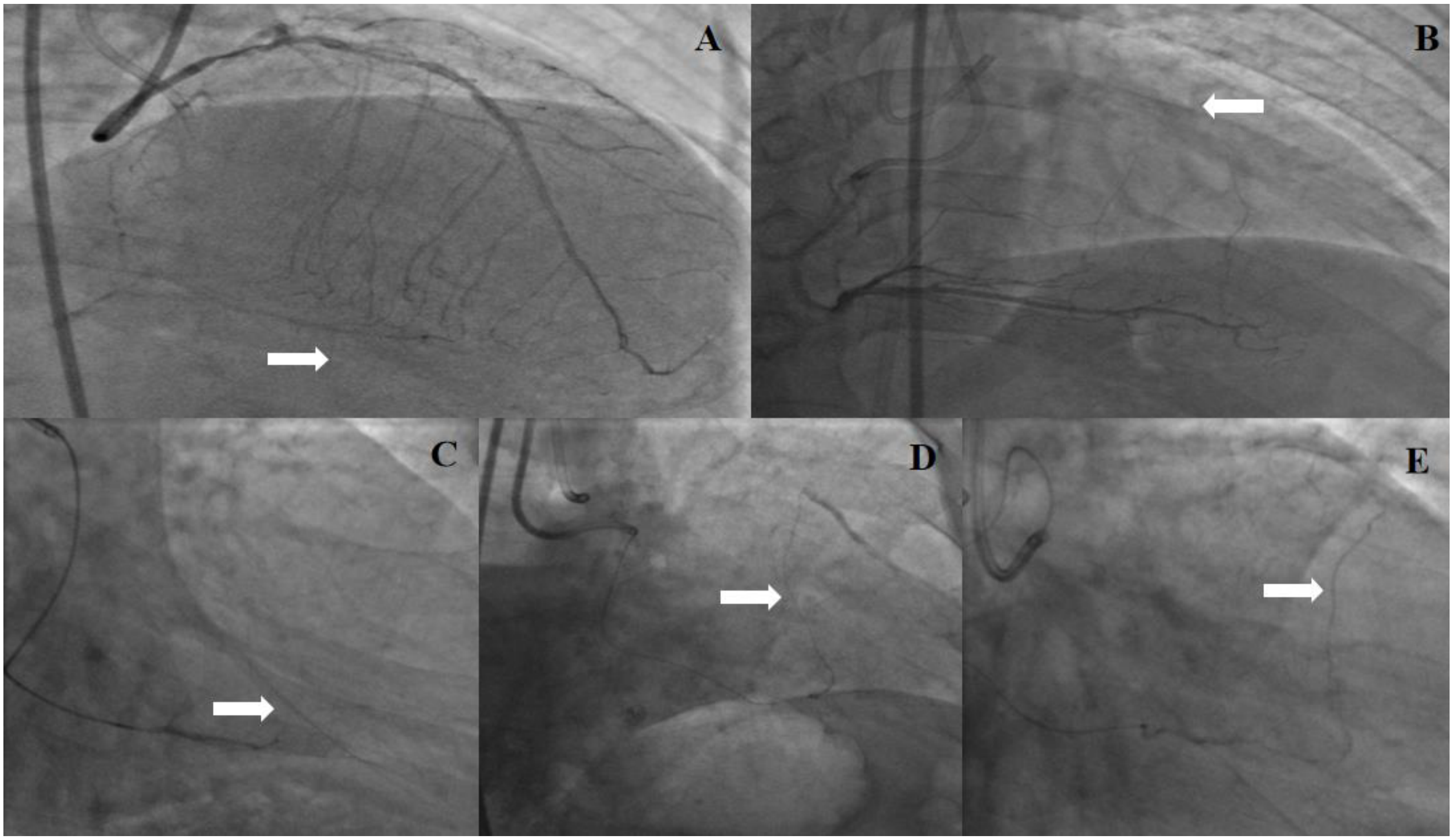

Figure 2

Septal collaterals and Werner’s CC score. A, From the left anterior descending to the right coronary artery. B, From the right coronary artery to the left anterior descending. C, Werner’s CC score 0. D, Werner’s CC score 1. E, Werner’s CC score 2.

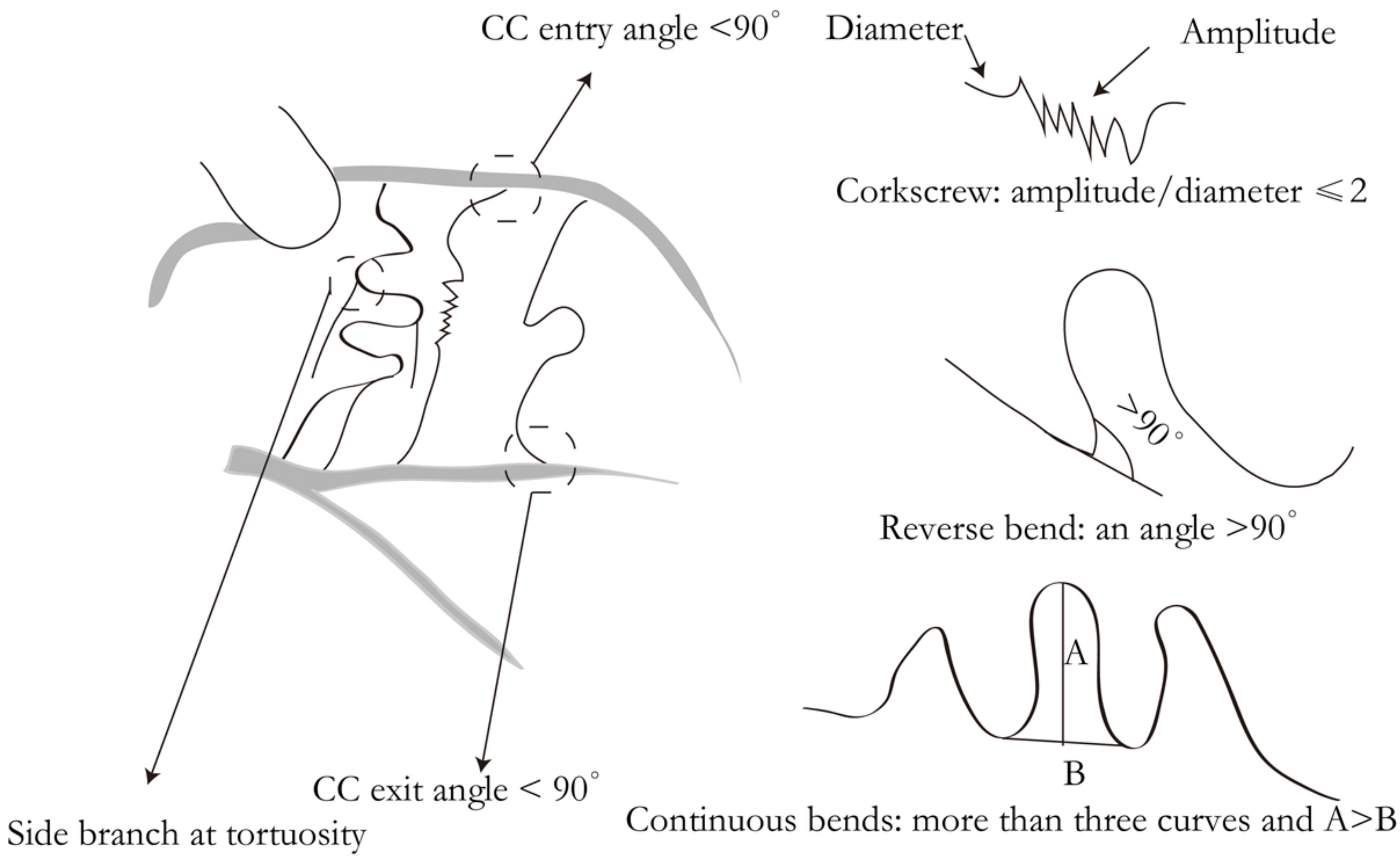

Figure 3

Anatomic characteristics of the septal collateral vessels.

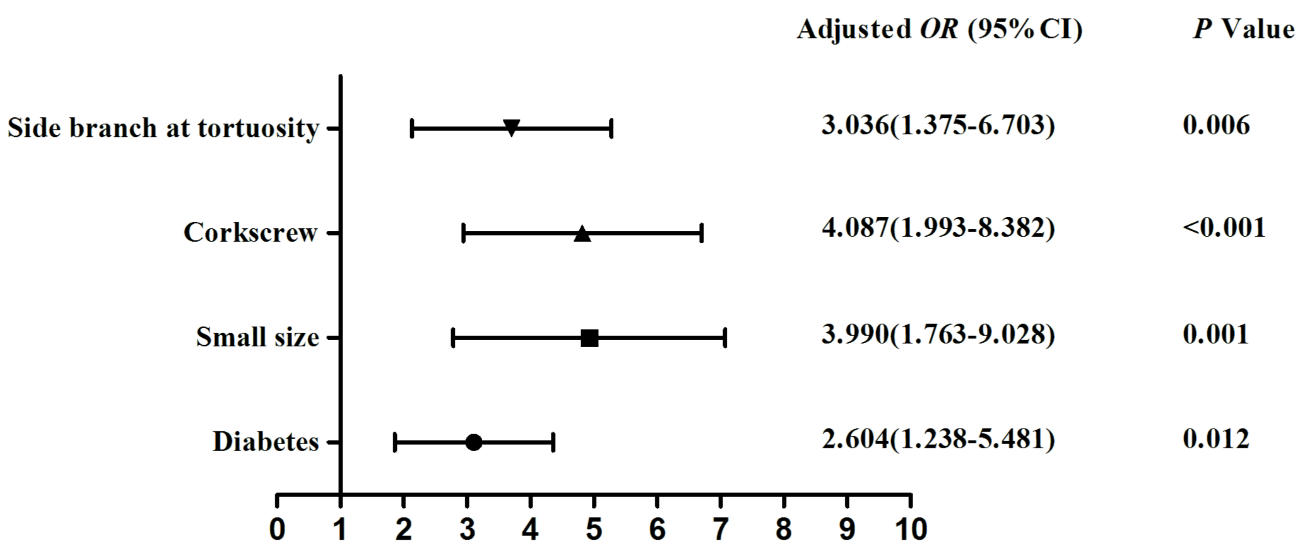

Figure 4

Forest plot of guidewire crossing success.

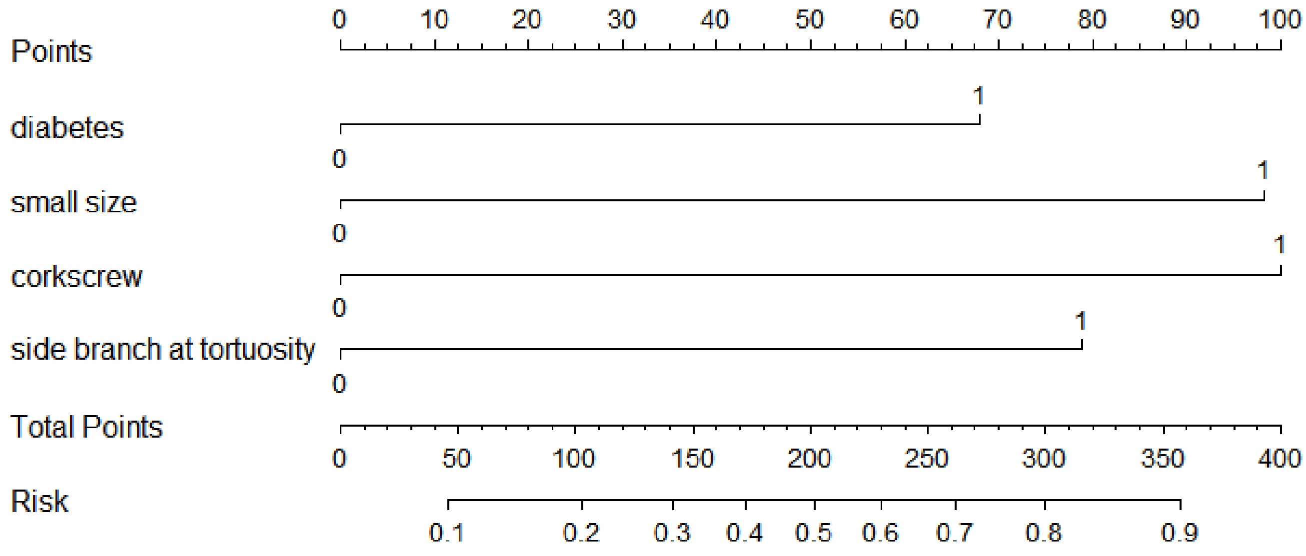

Figure 5

A nomogram prediction model for the probability of guidewire crossing.

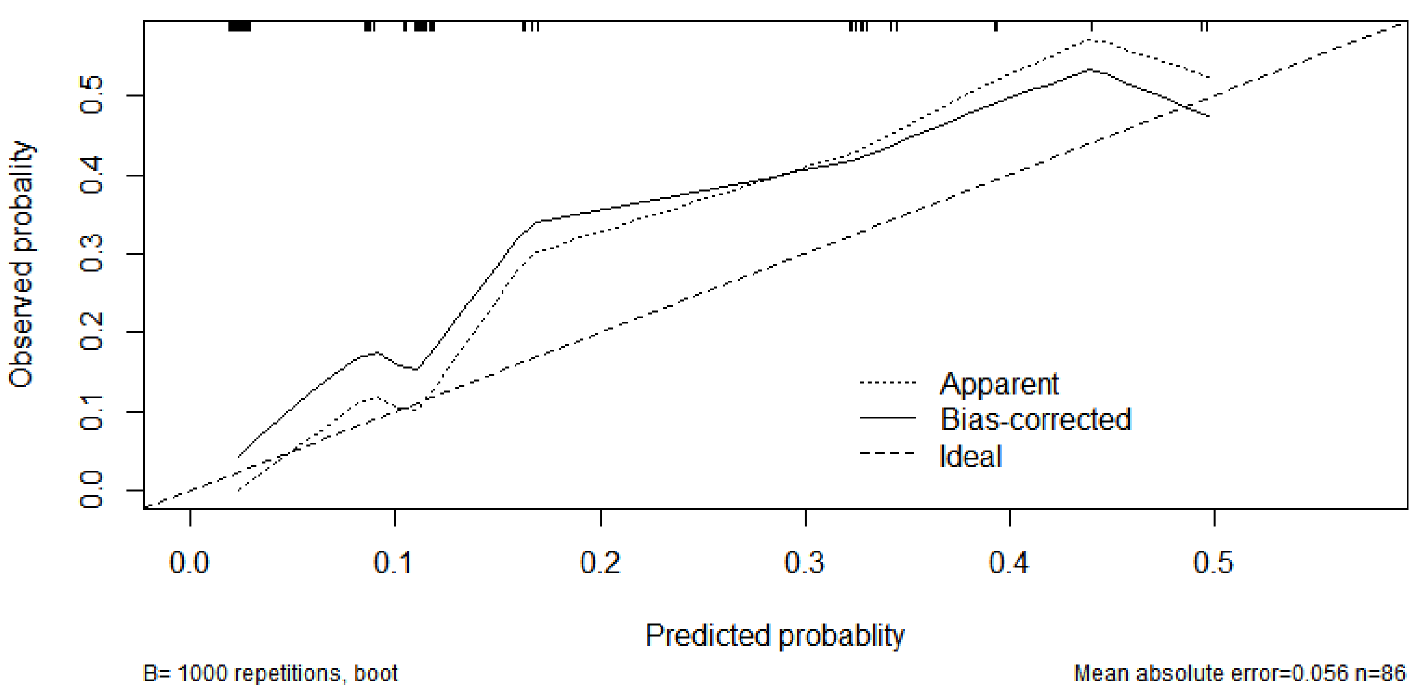

Figure 6

Calibration curves of the nomogram for predicting guidewire crossing in the validation cohort.

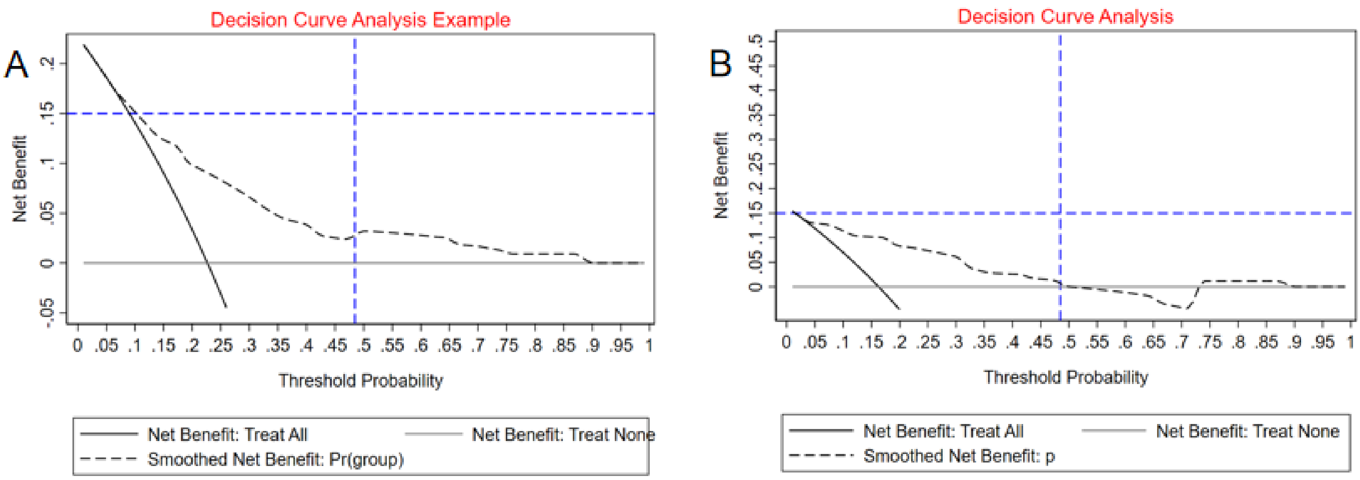

Figure 7

Decision curve analysis (DCA) of the nomogram for predicting successful guidewire crossing in the derivation cohort (A) and validation cohort (B).

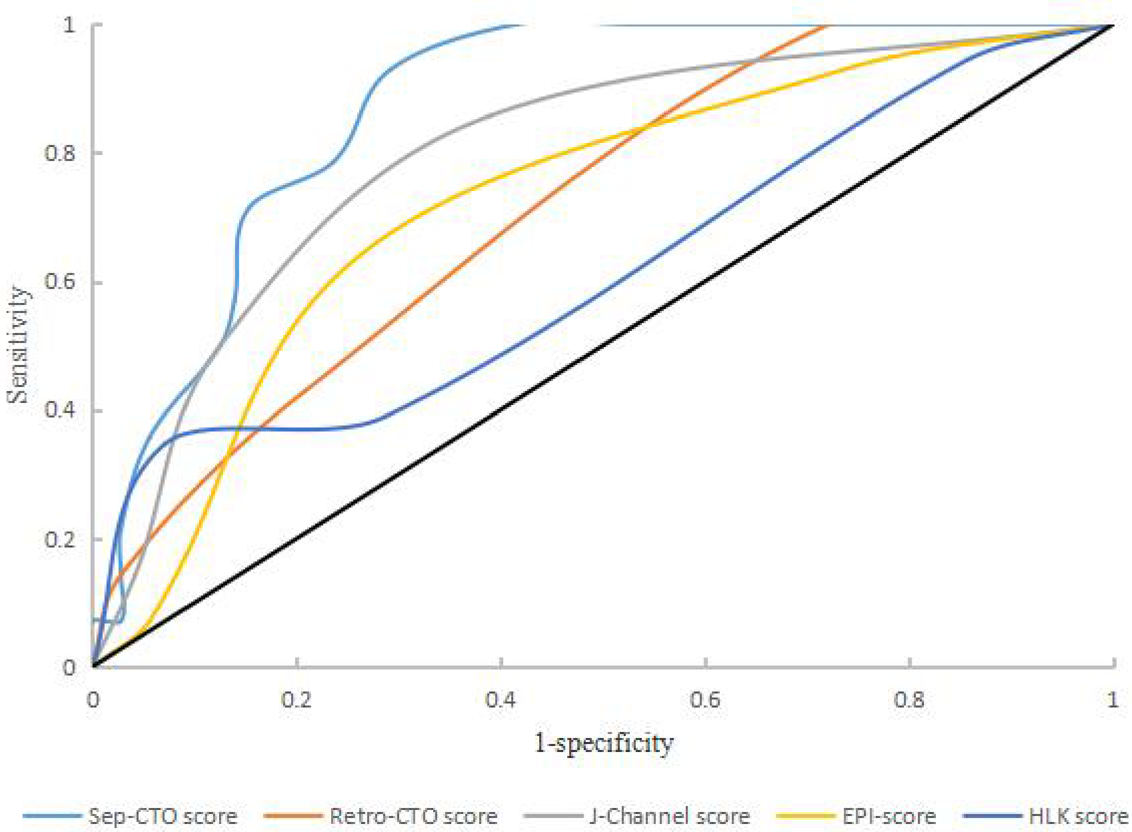

Figure 8

ROC curve for the five CTO scores. ROC, receiver-operating characteristics; CTO, chronic thrombotic occlusion.

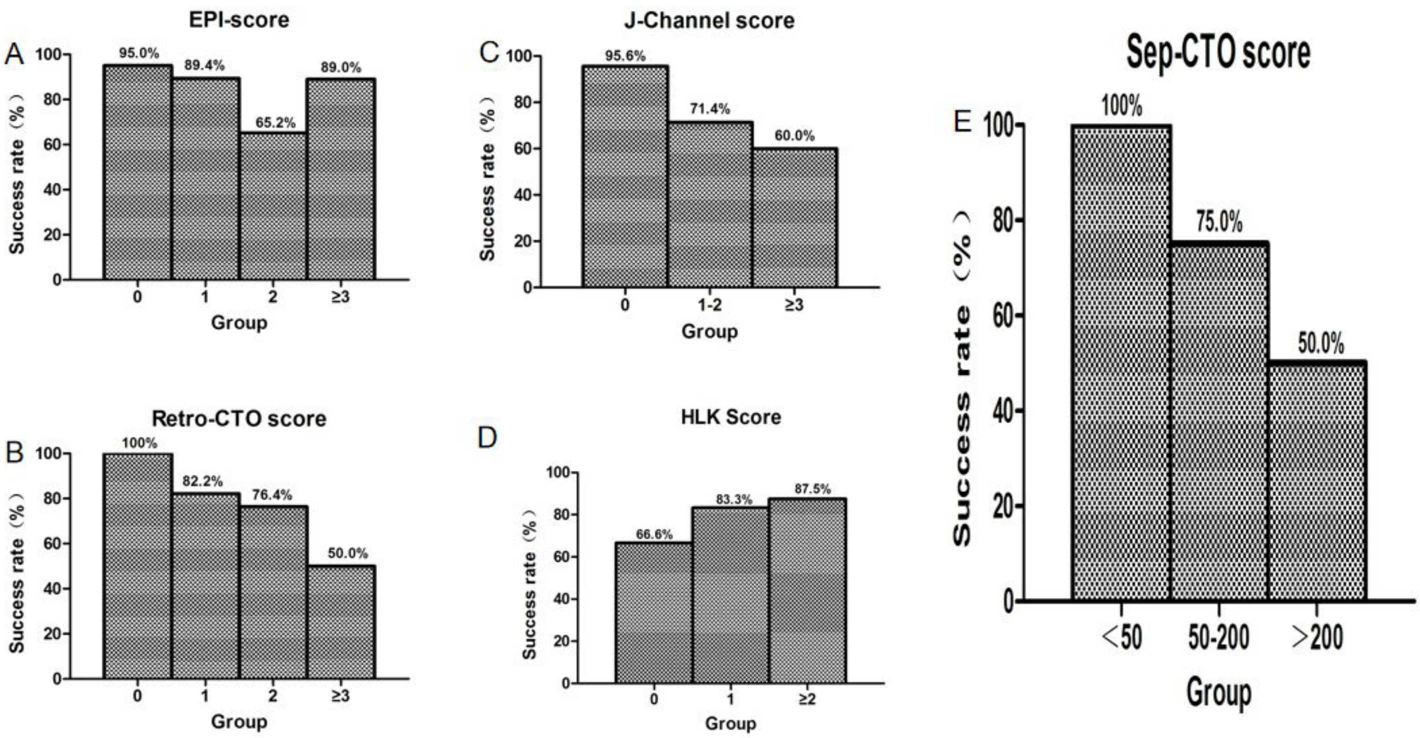

Figure 9

Probabilities of predicting success of guidewire crossing in different groups. EPI-score (A), Retro-CTO (B), J-Channel score (C), HLK score (D), and Sep-CTO score (E).

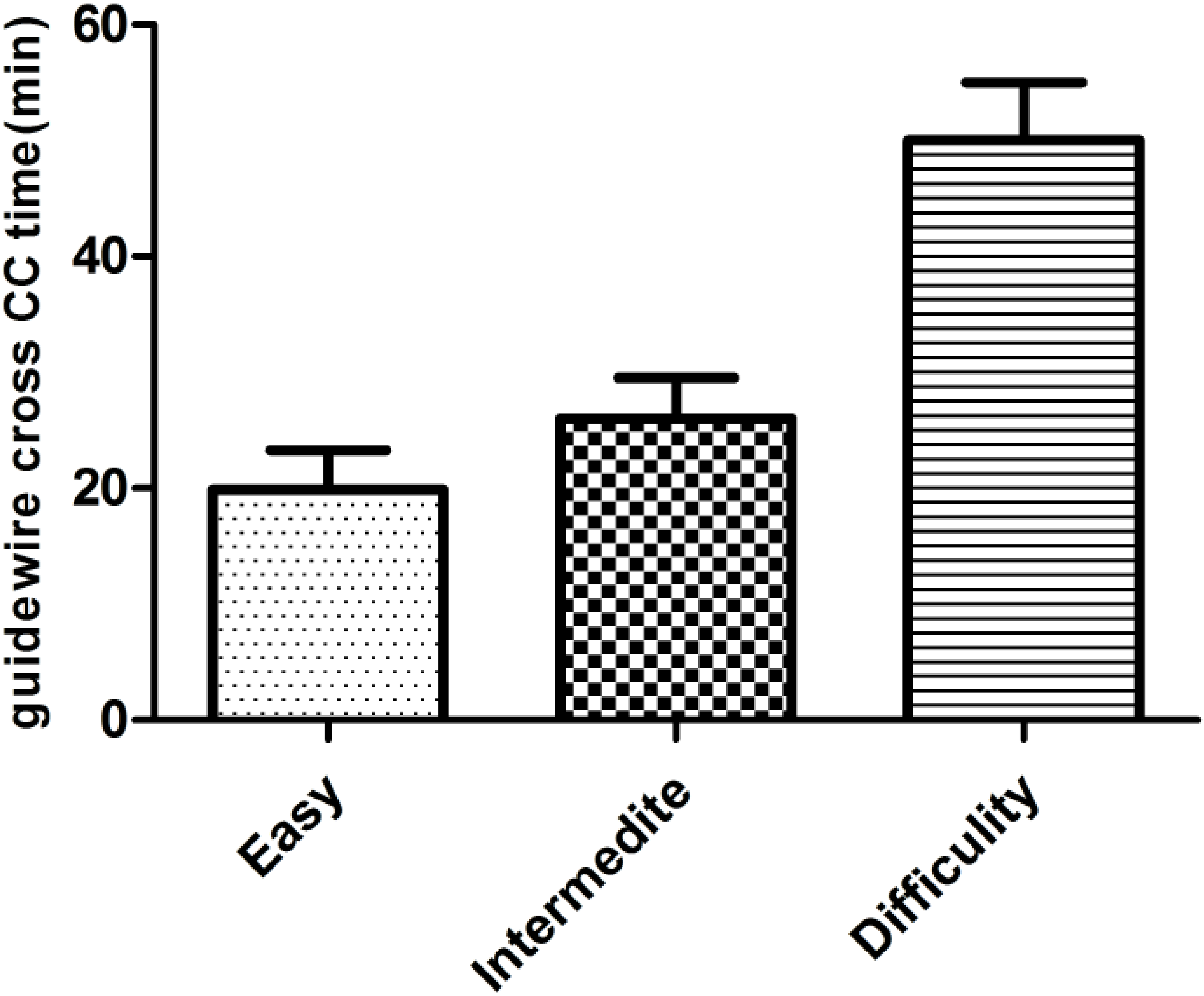

Figure 10

Time of GW crossing success using Sep-CTO score

Sep-CTO score

A Diabetes
- -Yes
- -No

B Small size
- -Yes
- -No

C Crokscrew
- -Yes
- -No

D Side branch at tortuosity
- -Yes
- -No

	Septal
Diabetes:Yes	68
Small size:Yes	98
Crokscrew: Yes	100
Side branch at tortuosity:Yes	80
Total score	

Category of difficulty (total score)	
-Easy:<50	**(Risk:<0.1)**
-Intermediate:50-200	**(Risk:0.1-0.5)**
-Difficult:>200	**(Risk:>0.5)**

Figure 11

Summary of the Sep-CTO score