Predicting the success rate of elective percutaneous coronary intervention for prior failure chronic total occlusion: a novel scoring

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Abstract

Background: There is limited data on percutaneous coronary intervention for chronic total occlusion (CTO) with previous failed attempt. The objective of this study is to investigate a risk score for prediction of successful percutaneous coronary intervention for prior failure CTO.

Methods: Patients with previous attempt were enrolled in our study retrospectively from Jan. of 2016 to Dec. of 2019. All clinical and procedural data was collected and analyzed. Univariate and multivariate logistic regression was performed to investigate the predictors of technical success.

Results: A total of 194 patients/CTO lesions were studied. The technical success rate was 66.0%. The multivariate logistic regression showed that occlusion length <20mm (OR= 2.94, 95% CI= 1.36±6.37, score= 1), non-calcification (OR= 2.93, 95% CI= 1.36±6.30, score=1), adequate distal landing zone (OR= 4.46, 95% CI= 2.06±9.66, score=1), Rentrop grade ≥2 (OR= 5.98, CI= 2.46±14.51, score =1), and retrograde approach as initial strategy (OR= 10.28, 95% CI= 3.58±29.50, score =2) was the predictor of re-attempt success of PCI. The technical success rate for a score from 0 to ≥4 was 0%, 17.9%, 46.2%, 77.8%, 93.3% respectively. The area under the receiver operating characteristic curve for the five predictors and integers was 0.837 and 0.832 respectively.

Conclusions: The technical success rate for CTO PCI with previous failure was acceptable. Our score system can be used to predict the success rate of re-attempt CTO PCI.

Introduction

Chronic total occlusion (CTO) is the last bastion of percutaneous coronary intervention (PCI). It has been demonstrated that CTO revascularization can improve the prognosis, reduce the major adverse cardiac event(MACE) such as cardiovascular event[1−3] . Recently, the success rate of CTO PCI has been increased significantly due to the advancement of device and enhancement of experience, especially after the popularity of retrograde approach and publication of hybrid algorithm[4]. It is well known that previous failure is not benefit for the success of re-attempt PCI[5].The purpose of this study is to evaluate the determinants of successful repeat PCI and develop a novel scoring system to predict the successful recanalization in CTO with previous failure.

Results

Patient characteristics We reviewed clinical data of 7430 patients with elective PCI, a total of 194 patients received re-attempt CTO PCI (Figure 1). All procedures were done by high-volume CTO operators. The age of the patients was 58(49, 64), 85.6% was male. 128 procedures were technical success (66.0%). Baseline clinical characteristics were summarized in table 1. There was no significant difference between the two groups except prior myocardial infarction (MI).

Table 1. baseline clinical characteristics

	Overall (n=194)	Success (n=128)	Failure (n=66)	*P* value
Age, yr	58(49, 64)	57(47.5, 64)	59(54, 64)	0.262
Male	166(85.6%)	108(84.4%)	58(87.9%)	0.511
BMI (kg/m^2)	26.0(23.6, 28.0)	26.1(23.6, 28.4)	26.0(23.7, 27.5)	0.463
Hypertension	149(76.8%)	95(74.2%)	54(81.8%)	0.235
Diabetes	60(30.9%)	39(30.5%)	21(31.8%)	0.847
Dyslipidemia	153(78.9%)	98(76.6%)	55(83.3%)	0.274
Smoking	87(44.9%)	60(45.9%)	27(40.9%)	0.429
Prior MI	75(38.7%)	41(32.0%)	34(51.5%)	0.008
CABG history	10(5.2%)	6(4.7%)	4(6.1%)	0.946
CVD	16(8.3%)	13(10.2%)	3(4.6%)	0.284
PVD	5(2.6%)	5(3.9%)	0(0.0%)	0.251
CAD family history	4(2.1%)	4(3.1%)	0(0.0%)	0.359
LVEF(%)	63(59, 66)	63(60, 67)	64(55, 66)	0.407

BMI: body mass index; MI: myocardial infarction; CABG: coronary artery bypass graft; CVD: cerebral vessel disease; PVD: peripheral vascular disease; CAD: coronary artery disease; LVEF: left ventricular eject function.

Angiographic and procedural characteristics The angiographic and procedural characteristics were shown in Table 2. 194 CTO target vessels were enrolled in our study, 86(44.3%) in LAD, 24(12.4%) in LCx and 84(43.3%) in RCA. 128 (66.0%) CTO lesions got technical success. Complication and MACE was summarized in Table 3. There was no different between the two groups. and procedural success rate was 64.4%.

Table 2. Angiographic and technical characteristics

	Overall (n=194)	Success (n=128)	Failure (n=66)	*P* value
CTO target vessel				0.105
LAD	86(44.3%)	53(41.4%)	33(50.0%)	
LCx	24(12.4%)	13(10.2%)	11(16.7%)	
RCA	84(43.3%)	62(48.4%)	22(33.3%)	
Duration since last attempt(month)	3.0(1.0, 6.0)	3.0(1.0, 5.0)	2.5(2.0, 10.0)	0.390
Time ≥3 months	107(55.15%)	70(54.7%)	33(50.0%)	0.535
J-CTO Score	3(2, 4)	3(2, 3)	3(2, 4)	0.056
J-CTO Score ≥3	117(60.3%)	73(57.0%)	44(66.7%)	0.194
Tapered proximal cap	68(35.1%)	51(39.8%)	17(25.8%)	0.051
Non-calcification	92(47.4%)	70(54.7%)	22(33.3%)	0.005
Bending	41(21.1%)	31(24.2%)	10(15.2%)	0.143
Occlusion length <20mm	103(53.1%)	73(57.0%)	30(45.5%)	0.126
Bifurcation	148(76.3%)	92(71.9%)	56(84.9%)	0.044
Rentrop grade ≥2	150(77.3%)	113(88.3%)	37(56.1%)	<0.001
Werner CC grade ≥1	161(83.0%)	115(89.9%)	46(69.7%)	<0.001
Bridge collaterals	17(8.8%)	9(7.0%)	8(12.12%)	0.235
ISR	14(7.2%)	7(5.5%)	7(10.61%)	0.190
Interventional collaterals	111(57.2%)	88(68.8%)	23(34.9%)	<0.001
Distal vessel diameter (mm)	2.0(1.0, 2.0)	2.0(1.0, 2.0)	1.0(0.7, 2.0)	<0.001
Adequate distal landing zone	103(53.1%)	79(61.7%)	24(36.4%)	0.001
Retrograde approach	90(46.4%)	69(53.9%)	21(31.8%)	0.003
DR approach	51(26.3%)	41(32.0%)	10(15.2%)	0.011
Hybrid	80(41.2%)	58(45.3%)	22(33.3%)	0.108
First strategy				<0.001
Antegrade	139(71.7%)	79(61.7%)	60(90.9%)	
Retrograde	55(28.4%)	49(38.3%)	6(9.1%)	
IVUS	61(31.4%)	49(38.3%)	12(18.2%)	0.004

Procedure duration(min)	120(80, 170)	130(70, 185)	110(90, 165)	0.229
Contrast volume(ml)	300(200,320)	300(210, 320)	290(150, 320)	0.288
Radiation dose (Gy)	5.3(2.4, 8.4)	4.6(2.3,8.2)	6.55(4.4, 10.9)	0.024

CTO: chronic total occlusion; LAD: left anterior descending; LCX: left circumflex; RCA: right coronary artery; ISR: in-stent restenosis; DR: dissection/re-entry; IVUS: intravascular ultrasound.

Table 3. Complications and MACE

	Overall (n=194)	Success (n=128)	Failure (n=66)	*P* value
Peri-operational MI	111(57.2%)	73(57.0%)	38(57.6%)	0.942
Minor bleeding	28(14.4%)	24(18.8%)	4(6.1%)	0.030
Major bleeding	3(1.5%)	3(2.3%)	0(0.0%)	0.523
Perforation	11(5.7%)	5(3.9%)	6(9.1%)	0.249
CIN	8(4.1%)	5(3.9%)	3(4.6%)	1.000
MACE	9(4.6%)	3(2.3%)	6(9.1%)	0.079
Death/ Q-wave MI	0(0.0%)	0(0.0%)	0(0.0%)	-
Stroke	4(2.1%)	0(0.0%)	4(6.1%)	0.023
Emergent repeat PCI/CABG	0(0.0%)	0(0.0%)	0(0.0%)	-
Tamponade	5(2.6%)	3(2.3%)	2(3.0%)	1.000

MACE: major adverse clinical event; MI: myocardial infarction; CIN: contrast induced nephropathy,

Logistic multivariate regression The variables in univariate logistic regression included that duration since last attempt, J-CTO score, tapered proximal cap, non-calcification, bending, occlusion length<20mm, bifurcation, Rentrop grade ≥2, Werner CC grade ≥1, interventional collaterals, adequate

distal landing zone, retrograde approach, dissection reentry approach, retrograde as first strategy, and the IVUS. In multivariate regression, 5 variables, which were occlusion length <20mm, non-calcified lesion, Rentrop grade ≥2, adequate distal landing zone, retrograde as first strategy, were proven to be independent significant predictors of successful procedure (table 4). Logistic regression analysis produced an area under the ROC curve of 0.837 (Figure 2). The non-significant Hosmer-Lemeshow goodness of fit indicated the good calibration of the model(P=0.220).

Risk score of redo CTO-PCI Based on the regression coefficients, an integer score was assigned to each of the multivariate predictors resulting in a possible clinical risk score of CTO PCI success ranging from 0 to 6. Figure 3 showed the relationship between the score and the probability of technical success. The probability of technical success for 0 to ≥4 was 0%, 17.9%, 46.2%, 77.8%, 93.3% respectively. The rule performed well on ROC curve analysis for predicting the technical success on redo-CTO PCI (area under curve:0.832, figure 2).

Table 4 multivariable predictors of redo-CTO PCI with previous failure

	Coefficient B	Risk score	OR(95% CI)	P value
Occlusion length <20mm	1.08	1	2.94(1.36±6.37	0.006
Non-calcification	1.07	1	2.93(1.36±6.30)	0.006
Adequate distal landing zone	1.50	1	4.46(2.06±9.66)	0.000
Rentrop grade ≥2	1.79	1	5.98(2.46±14.51)	0.000
Retrograde as initial strategy	2.33	2	10.28(3.58±29.50)	0.000

Discussion

The success rate of CTO PCI was increased significantly with the development of device and advancement of technique recently. The attempt rate of CTO recanalization was decreased before 2004[6], it has been investigated that the success rate in antegrade and retrograde approach was 77%, and 79.8% respectively[7]. The new research demonstrated that the success rate was nearly 90%[1,8]. Experienced experts are willing to challenge the CTO lesions with prior failure[9]. However, the success rate of CTO PCI for previous failure was just acceptable. In our study, the technical success rate was 66.0%, similar with previous study[10]. the acceptable result was related to the lesion characteristics, expert experience and the device.

Morino et al[5] believe that previous failure is an independent predictor of CTO recanalization. Lesion characteristics of CTO with previous failure is different from that with initial attempt. Calcification, bending and long lesion was more common[10], incidence of in-stent restenosis (ISR) was higher, and the

operator is more willing to attempt via retrograde approach[11], so we need a scoring system to evaluate the difficulty of this kind of situation.

There are several scoring systems for predicting the difficulty of CTO lesion[12,13]. lesion characteristics including stump morphology, occlusion length, ostial, target vessel, tortuous, calcification, distal vessel and collaterals play important roles in most of scoring systems. Other parameters such as age and past history is also involved in some systems. J-CTO score is the earliest and widely used scoring system, predicting the probability of guidewire crossing through the CTO in 30 minutes. It consists of 5 identified factors, it is also the only scoring system that uses previous failure as a predictor. Recently, three large studies are published for predicting CTO failure rate[13–16]. All of them studied more than 500 attempted PCI for CTO intervention to find the predictors of CTO-PCI failure. However, none of studies above developed a specific scoring system for CTO with prior failure.

This study is one of the largest retrospective reports to investigate the CTO PCI with previous failure, first proposed a scoring system to assess the difficulty of such procedures. In our study, we examined all factors studied previously for CTO-PCI from lesion characteristics to novel equipment and techniques for CTO recanalization. From multivariate logistic regression, the predictors of technical success consisted of procedural strategy and lesion characteristics. Our result found technical success was not related to proximal morphology and tortuosity, which may associate with advancement of device and technique. These complex problems should be resolved by scratch and go technique, IVUS, or coronary CTA, so that factors are also involved in QRA and CL score[12].

Our result was the first scoring system involving procedural strategy. It has been investigated that complex cases, as quantified by the J-CTO score, had a higher incidence of in-hospital MACE and should preferably be performed following proper planning and preparation[17]. All of cases in this study was not the initial attempt, the median of J-CTO score was 3, 60.3% of cases was very difficult. With sufficient preparation, 55 cases (28.4%) of the lesions directly initiated the retrograde approach in this study. most cases (89.1%) had technical success. We found retrograde approach as initial strategy was an independent predictor in planed PCI. In general, as long as there are collaterals available for intervention, retrograde approach can be initiated [18]. Initiation in retrograde seems to be complicated and prolonged the operation time, but actually it can avoid the antegrade dissection induced by excessive manipulation of guidewire, shorten the operation time and improve the success rate. However, the premise of starting the retrograde is interventional collaterals. Although the premise of starting the retrograde is interventional collaterals, the absence of interventional collaterals is not the contra-indication of retrograde approach. In this situation, one of useful skills is septal surfing. In this study, retrograde approach was not selected as initial strategy in all of patients without interventional collaterals, and only 2 patients received successful retrograde PCI after antegrade failure. In addition, the operators judge the difficulty of antegrade based on the condition of the proximal cap, the quality of the landing zone, the length of the occlusion, and the previous failure reason.

Regarding factors, our patients with a score of 0 showed 100% failure, so further attempt should be avoided for this kind of patients due to poor vessel condition. Ischemia evaluation and risk balancing should be needed in patients with a score of 1~2. Higher success rate was seen in patients with score of 3 or more, the elective redo CTO PCI should be performed by experienced expert after fully preparation.

With regard to in-hospital MACE, the overall results were acceptable and similar with other CTO PCI reports for previous failure[10,11], but were worse than in previous “all comer” reports [19–21]. One reason of the worse result may be previous failure of the enrolled patients. On the other hand, the more aggressive operations should be attempted in retry PCI to receive successful result.

There are several limitations in this study. Firstly, this was a retrospective study with inherent disadvantage. Secondly, this was single center study with small sample of population, and the reasons of previous failure were not mentioned. Therefore, larger clinical trial is expected.

In conclusion the technical success rate for CTO PCI with previous failure was acceptable. Our score system can be used to predict the success rate of re-attempt CTO PCI. In patients with a score of 0, the re-attempt should be avoided, redo-CTO PCI should be attempted with caution in patients with a score of 1~2, and the success rate should be higher with a score of 3 or more.

Methods

Study population: We reviewed the clinical and angiographic data of patients in our center from Jan. of 2016~Dec. of 2019. This study was approved by the ethics committee of Beijing Anzhen Hospital, the research was performed in accordance with guidelines and all the patients or their legal guardians signed informed consents. The patients who were enrolled had at least one CTO vessel. And the procedures were performed by experienced interventional cardiologists. All procedures were scheduled with contralateral injection. Ad hoc CTO PCI was excluded. The patients were classified into technical success or failure groups.

Definition Coronary CTOs were defined as coronary lesions with Thrombolysis in Myocardial Infarction (TIMI) grade 0 flow of at least 3 months duration. Estimation of the duration of occlusion was clinical, based on the first onset of angina, prior history of myocardial infarction in the target vessel territory, or comparison with a prior angiogram. Interventional collaterals were defined as collaterals considered amenable to crossing by a guidewire and a microcatheter by the operator. Tapered proximal cap was defined as tapering or funnel shape at the proximal cap. Adequate distal landing zone was defined as a distal vessel segment with a diameter larger than 2.0 mm, and without diffuse disease. Rentrop grade reflect the myocardial collateral flow. Grade 0, no visible filling of any collateral channel; grade 1, filling of the side branches of the occluded artery, with no dye reaching the epicardial segment; grade 2, partial filling of the epicardial vessel; grade 3, complete filling of epicardial vessel by collateral vessels. The size of the collateral channels is described by the Werner collateral connection (CC) grade: CC0, no continuous connection; CC1, continuous thread-like connection; CC2, continuous, small side branch-like connection.

Dissection and re-entry(DR) was defined as a guidewire was intentionally introduced into the subintimal space, and re-entry into the true lumen the other side after intentional or inadvertent subintimal guidewire crossing, included controlled DR and wire based DR. The retrograde approach was defined as CTO-PCI with an attempt to cross the collateral channels with a guidewire to reach the distal end of the CTO lesion. Technical success was defined as successful CTO revascularization with achievement of <30% residual diameter stenosis within the treated segment and restoration of Thrombolysis in Myocardial Infarction grade 3 antegrade flow. Procedural success was defined as the achievement of technical success without any major adverse clinical event (MACE). In-hospital MACE included any of the following adverse events prior to hospital discharge: death, Q-wave myocardial infarction, urgent repeat target vessel revascularization with either PCI or coronary artery bypass graft surgery (CABG), tamponade requiring either pericardiocentesis or surgery, and stroke.

Interventional Procedures All patients were pretreated with dual anti-plantlet drugs. and weight-adjusted heparin was administered to maintain activated clotting time (ACT)>300 s. After admission, the expert team made deeply analysis of previous failed angiographic data, then the planed PCI was performed. The guide catheters (usually 7 Fr) were introduced for both CTO and for the donor site of the coronary arteries. To evaluate CTO lesion morphology, bilateral simultaneous coronary injections were usually performed. The selection of procedural strategy and devices was dependent on the operator's discretion and patient's coronary anatomy.

Statistics Continuous variables were presented as median (interquartile range) and were compared using the Mann-Whitney U test. Categorical data are reported as frequencies or percentages and compared using the chi-square test or chi-square test with continuity correction. Logistic regression was performed to analyze the predictors of success the redo PCI in CTO. Variables with P value <0.10 or clinical significance on univariate analysis were included in the multivariate regression. A 2-sided P value of <0.05 was considered to indicate statistical significance. The results of the multivariate analysis were used to develop a clinical prediction model. We attributed a weight to each variable on the basis of the regression coefficient. Each integer amount is a rounding of the exact figure obtained from the logistic model. The sensitivity and specificity of the logistic regression model and integer model was assessed by the under area of receiver operating characteristic (ROC) curve. The Hosmer-Lemeshow test was used to assess calibration. All statistical analyses were performed with SPSS 24.0 (IBM, Chicago, Illinois).

Declarations

Conflict of interest: The authors declare that they have no conflicts of interest and no relationships with industry.

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Figures

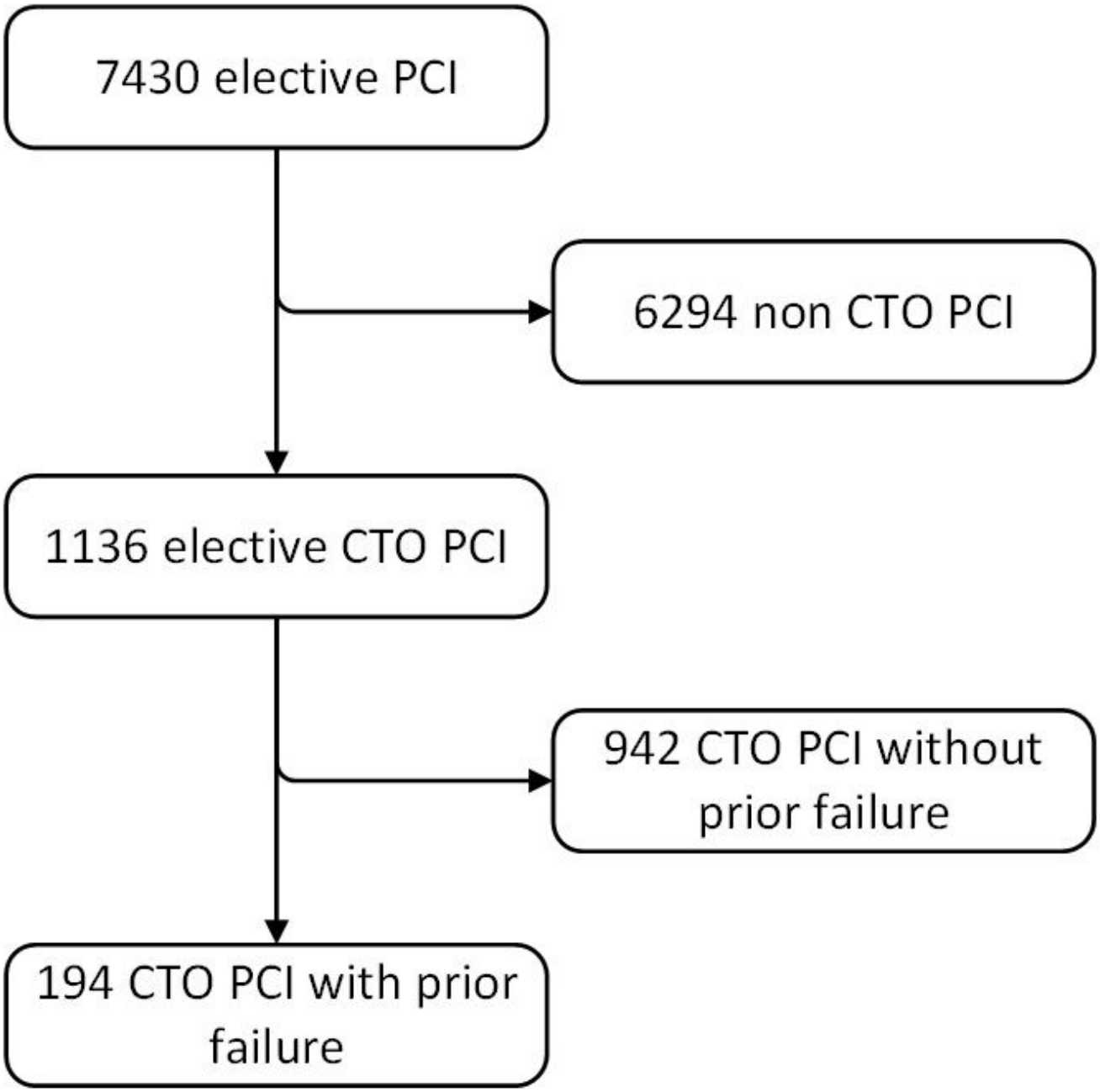

Figure 1

Flowchart of patient enrollment

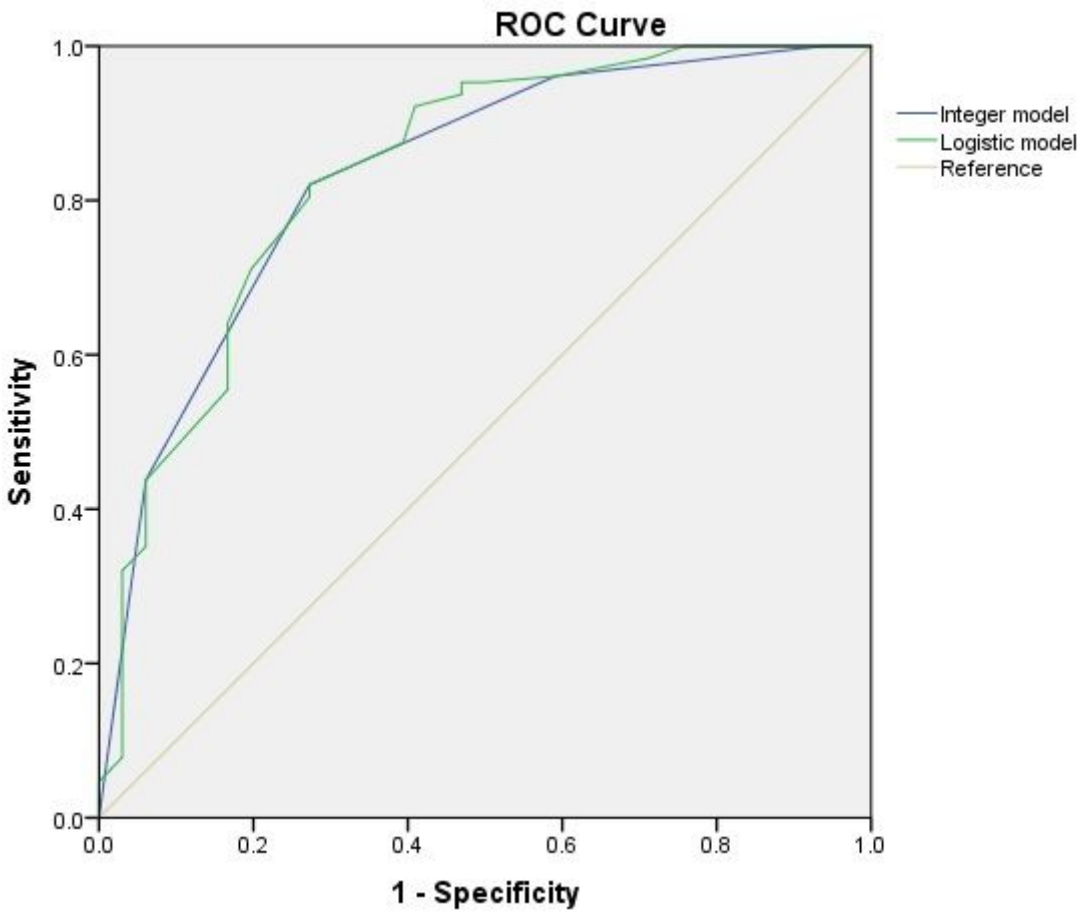

Figure 2

ROC curve of predictors.

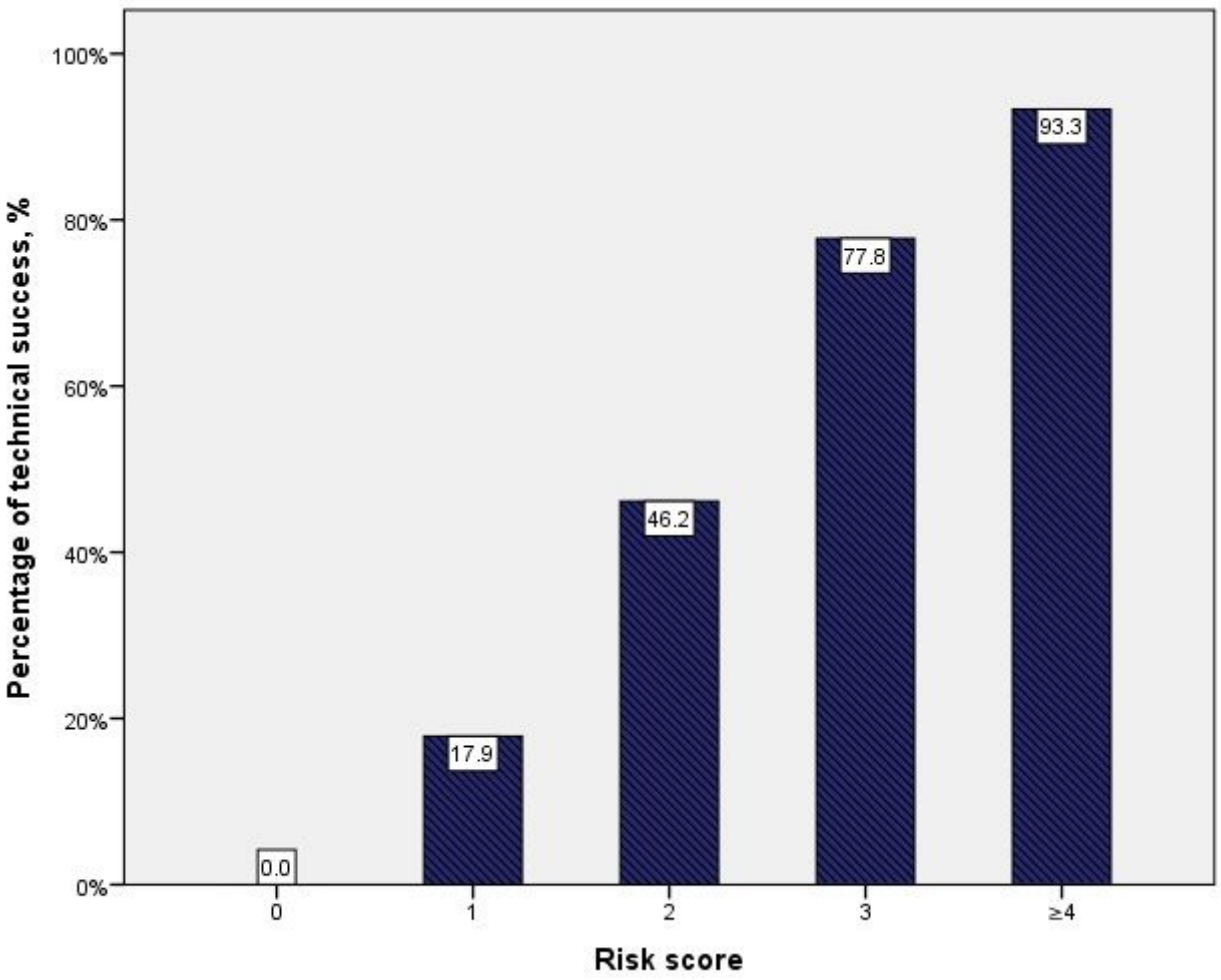

Figure 3

Relationship between the score and the probability of technical success