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**The J-Channel Score as a Difficulty Estimating Tool for Collateral Channel Guidewire Crossing Success from the Japanese CTO-PCI Expert Registry.**

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Predicting Successful Guidewire Crossing via Collateral Channel at Retrograde Percutaneous Coronary Intervention for Chronic Total Occlusion

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Short running title

J-Channel Score for Collateral Channel Selection

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Conflict of interest statement

W. Nagamatsu is a consultant for Asahi Intecc, Abbott Vascular Japan, Terumo, Medtronic Japan, Boston Scientific Japan, Kaneka Medics, and NIPRO. E. Tsuchikane is a consultant for Boston Scientific Japan, Asahi Intecc, NIPRO, and Kaneka Medics. S. Sumitsuji is a consultant for Terumo, Kaneka Medics, NIPRO, Asahi Intecc, Abbott Vascular Japan, Boston Scientific Japan, Medtronic Japan, Biosensors, and Orbus Neich. And he has received grants from Terumo, Kaneka Medics, NIPRO, and Asahi Intecc. O. Katoh is a consultant for Asahi Intecc and NIPRO. The other authors have no conflict of interest to declare.

Portrait


**Abstract**

Aims:

Guidewire (GW) tracking in a collateral channel (CC) is an important step during retrograde chronic total occlusion (CTO) percutaneous coronary intervention (PCI). The aim of this study was to create a prediction score model for CC GW crossing success.

Methods and results:

We analyzed data on 886 CCs included in the Japanese CTO-PCI Expert Registry during 2016. CCs were categorized as septal (n = 610) and non-septal (n = 276). CCs were randomly assigned to derivation and validation sets in a 2:1 ratio. The score was developed by multivariate analysis with angiographic findings. Small vessel, reverse bend, and continuous bends were independent predictors in the septal CC subset. Small vessel, reverse bend, and corkscrew were independent predictors in the non-septal CC subset. The extent of intervention was easy, intermediate, and difficult at 92.9%, 57.4%, and 16.7% in the septal CC subset and 91.7%, 54.3%, and 19.0% in the non-septal CC, respectively, in the validation set. The area under the receiver–operator characteristics curve was >0.7 in derivation and validation sets of both CC subsets.

Conclusions:

The prediction score model can suggest grading of the difficulty of CC GW crossing based on angiographic findings for each type of CC.




Classifications

Miscellaneous, Chronic coronary total occlusion, Other technique, Coronary rupture

Condensed abstract

We created a prediction score model for predicting the success of collateral channel (CC) guidewire (GW) crossing during retrograde percutaneous coronary intervention for coronary chronic total occlusion. Our study revealed new evidence that the angiographic findings, which affected CC GW crossing, showed differences between septal CC and non-septal CC. Information about difficulty should be shared with the examiner for appropriate selection of CCs.

Abbreviations
CTO = chronic total occlusion, PCI = percutaneous coronary intervention,
CC = collateral channel, GW = guidewire, AVG = atrioventricular groove

## Introduction

Recent algorithms of coronary chronic total occlusion (CTO) percutaneous coronary intervention (PCI) have involved retrograde CTO-PCI[1–3]. Technical success of retrograde CTO-PCI is associated with the success of collateral channel (CC) guidewire (GW) crossing[4]. The anatomical morphology of CC affecting CC GW crossing success is an important issue for the success of retrograde PCI[5].

Previous studies have reported the predictors of technical retrograde CTO-PCI success[6,7]. However, only a few studies have examined possible predictors of CC GW crossing success[8,9]. Therefore, in this study, we investigated potential angiographic predictors and established a scoring model for CC GW crossing success based on analyses of the Japanese CTO-PCI Expert Registry[10].



## Methods

*Patient population*

This study was conducted using data from the Japanese CTO-PCI Expert Registry. This was a multicenter, prospective, and non-randomized registry. Other designs were described elsewhere[10]. We used data from about 2706 CTO-PCI procedures that were included from January 2016 to December 2016. On the basis of the uniformity of devices availability, 1621 CTO-PCI undergone in Japan were selected. Of these cases, 685 cases underwent retrograde CTO-PCI. Of these, 1, 2, and 10 cases were excluded because of the presence of two CTO lesions treated in one procedure, inadequate anatomical indication, and inappropriate patient data and lesion background, respectively. After exclusion, 672 cases, including 948 CCs, were investigated. Of these 948 CCs, 19 with CCs attempted via a bypass graft were excluded. Another 43 CCs without tip injection were also excluded, because tip injection was recommended to recognize the anatomical morphology of CC[11]. Thus, in total, 886 CCs in 630 cases were assessed.



*Definitions*

***Procedures***

For estimating lesion difficulty, the J-CTO (Multicenter CTO Registry in Japan) score was used[12]. Technical CTO-PCI success was defined as successful GW crossing and <50% residual stenosis with thrombolysis in myocardial infarction flow grade 3. Major complications were hospital death, myocardial infarction, emergency PCI or coronary artery bypass grafting, cardiac tamponade requiring intensive treatment, and puncture site bleeding requiring blood transfusion or surgical treatment. CC GW crossing success was defined as GW crossing through CC from the retrograde side and reaching the CTO distal vessel segment. CC microcatheter (MC) crossing success was defined as MC crossing through CC from the retrograde side and reaching the CTO distal vessel segment after GW crossing. CC perforation requiring treatment was defined as CC treated with coiling or balloon hemostasis after CC perforation.

***Angiographic definitions***

CCs were classified into three types[8]: septal, epicardial, and atrioventricular groove (AVG). AVG CCs were on the AVG, with the CC connected between left circumflex artery and right coronary artery. Two CC subsets were defined: septal and non-septal (epicardial and AVG CC). Figure 1 depicts angiographic definitions. The small and large vessels were classified with reference to Werner's CC grade[13]. Large vessel size was defined as CC2. Small vessel size was defined as CC0 or CC1 (Figure 1A). A significant CC vessel bend was described as an angle of bend of ≥45°. A reverse bend was described as part of bend folded at >90° angle (Figure 1B). Continuous bend was specified when the height of bend (a) exceeded the length between bends (b), that is, when a > b (Figure 1C). At least three continuous bends (except corkscrew morphology) were considered variables of continuous bends. Corkscrew was defined as three or more continuous bends with a ratio of vessel amplitude/vessel diameter (AD ratio) ≤2 (Figure 1D). Acute angle with a distal recipient vessel was described as acute angle of <45° between CC and recipient vessel[5]. If the CC did not have any bends, this morphology was defined as straight. These angiographic findings were observed by an experienced

CTO examiner.

*Statistical analysis*

In each CC subset, CC samples were randomly categorized to the derivation and validation sets in a 2:1 ratio. Both derivation and validation sets were compared using Chi-square or Fisher's exact test, as appropriate. For each CC subset derivation set, univariate analysis was performed between variables and CC GW crossing success by Chi-square or Fisher's exact test, as appropriate. After these univariate analyses, variables with statistical significance ($P < 0.10$) were analyzed by a multivariable model using logistic regression analysis. The prediction score model was defined by comparison with a beta coefficient for each CC subset. The summed score for each CC subset was graded into three categories: easy, intermediate, and difficult. To confirm the accuracy of the prediction score model, a receiver–operator characteristics (ROC) curve analysis was performed using the derivation and validation sets[14]. Furthermore, analysis of GW trends in each angiographic variable was conducted. All statistical analysis was performed using R software (packaged version 3.4.1; The R Foundation for Statistical Computing, Vienna, Austria). Continuous variables were summarized as mean and SD. $P < 0.05$ was considered statistically significant.

## Results

Baseline patient data and CC characteristics are summarized in Table 1. The number of septal and non-septal CCs was 610 (68.8%) and 276 (31.2%), respectively.

Clinical results are presented in Table 2. The technical CTO-PCI success rate was 84.8%. The CC GW crossing success rate was 61.2%. The CC GW crossing success rate among CC subsets was not significantly different. The rate of occurrence of CC perforation requiring treatment was 3.7% (33 CCs).

*Septal CC subset*

A total of 610 septal CCs was randomly allocated to a derivation set (407 CCs) and a validation set (203 CCs) in a 2:1 ratio. No significant difference was noted between the derivation and validation sets for any variable (Table 3). In the derivation set, the CC GW crossing success rate was 61.9%. Univariate analysis revealed a significant difference in angiographic variables of small size, reverse bend, and continuous bends between the successful and unsuccessful groups for CC GW crossing (Table 4). Those three variables were analyzed during the multivariable analysis. Small vessel size, reverse bend, and continuous bends were revealed as significant independent predictors. The value of the beta coefficient of small vessels, reverse bend, and continuous bends was 2.09, 1.51, and 0.81, respectively (Table 5).

*Non-septal CC subset*

A total of 267 non-septal CCs was randomly assigned to the derivation set (184 CCs) and validation set (92 CCs) in a 2:1 ratio. No significant difference was noted between the two sets for any variable (Table 3). In the derivation set, the CC GW crossing success rate was 57.1%. Univariate analysis revealed a significant difference in angiographic variables for small size, reverse bend, continuous bends, and corkscrew between the successful and unsuccessful groups for CC GW crossing (Table 4). Those four variables were analyzed by multivariable analysis. Small vessel size, reverse bend, and corkscrew were found to be significant independent predictors. The value of the beta coefficient of small vessel size, reverse bend, and corkscrew was 2.43, 1.46, and 1.51, respectively (Table 5).

*Developing a prediction score for estimating the difficulty of CC GW crossing success: J-Channel score*

For scoring, the value of the beta coefficient 2.43 was considered a score of 3, 2.09 was a score of 2, and 0.81–1.51 was a score of 1. The variable factors of small vessel size, reverse bend, continuous bends, and corkscrew provided scores of 2, 1, 1, and 0, respectively, in the septal CC subset and scores of 3, 1, 0, and 1, respectively, in the non-septal CC subset. The area under the ROC curve of derivation and validation sets was 0.744 and 0.743, respectively, in the septal CC subset and 0.757 and 0.826, respectively, in the non-septal CC subset (Figure 2).

Figure 3 depicts the risk groups of derivation and validation sets of each type of CC. The summed scoring numbers were assigned to three risk groups: easy, intermediate, and difficult defined as 0, 1–2, and ≥3, respectively. The rate of CC GW crossing success in the easy, intermediate, and difficult risk groups was 92.9%, 57.4%, and 16.7%, respectively, in the validation set of the septal CC subset and 91.7%, 54.3%, and 19.0%, respectively, in the validation set of non-septal CC subset.

*The analysis of GW trends*

The prevalence of used GW in the CC GW crossing success group is shown in Figure 4. Those GWs were final GWs for CC negotiation. The total ratio of different GWs (SUOH03 (48.3%), SION (31.9%), and XTR (9.2%); Asahi Intecc, Nagoya, Japan) was 89.4%. In these three types of GWs, a multivariate analysis was performed for the angiographic variables (Table 6). XTR and SION GWs showed a statistically significant use for small vessel size. SUOH03 GW showed a statistically significant use for the reverse bend.

*Sub-analyses for CC perforation requiring treatment*

Sub-analysis of non-septal category was performed for estimating complications. The rate of occurrence of septal, epicardial, and AVG CC perforations was 1.3%, 6.4%, and 16.7%, respectively, with statistical significance. Epicardial and AVG CC variables were analyzed by a multivariable analysis for CC perforation requiring treatment in all CCs. The value of the odds ratio of epicardial and AVG CC was 5.12 and 15.00, respectively, with statistical significance. Multivariate analyses were performed for the angiographic variables in epicardial and AVG CC categories. This analysis revealed that morphology of reverse bend in AVG CC was an independent predictor of CC perforation requiring treatment (Table 7).

## Discussion

CC GW crossing success is a key stage of retrograde CTO-PCI[4]. However, only a few studies have examined interventional CCs. Previous reports have suggested that predictors of CC GW crossing success were vessel size, tortuosity, side branch at CC tortuosity, and inadequate CC exit locations[8,9]. Because, in the actual procedure, CC tortuosity and subset are important issues for GW passage. In this study, variables of angiographic anatomical findings of CC subset, especially detail of tortuosity (Figure 1), were investigated.

Our study revealed new evidence that the angiographic findings that affected CC GW crossing had differences between septal CCs and non-septal CCs (Table 5). The values of beta coefficient were developed to address the difficulty estimating the score for CC GW crossing success. For convenience of clinical usage, the scoring model was adjusted (Figure 5). However, the examination of area under the ROC curve in the derivation and validation sets for each type of CC showed positive results (Figure 2). Although each CC had a complex anatomy, this score simplified anatomical information.

The examiners in the Japanese CTO-PCI Expert Registry had the required experience and options for devices. This score depicted the difficulty of CC GW crossing success and did not predict the success rate.

*Septal CC subset*

The variable of the small channel was a strong factor compared with other variables (Table 5). From the analysis of GW trends, XTR GW showed a strong relationship with the small vessel size CC (Table 6). The ratio of used XTR GW in septal CC was higher than non-septal CC (Figure 4). The use of this type of GW posed a risk of vessel perforation, because of its tapered tip and polymer jacket, even low tip load. Conversely, the frequency of occurrence of CC perforation requiring treatment was significantly low in the septal CC subset compared with non-septal CC (Table 2). As reported by a previous study[15], we found septal CC to be safe. On the basis of this result, if there was no difference in the difficulty for estimating the CC GW crossing success between septal and non-septal CC, the preference in terms of safety would be septal CC.

*Non-septal CC subset*

Small vessel size, reverse bend, and corkscrew were factors affecting prediction. In the non-septal CC subset, the odds ratio of small vessel size was 11.40. Conversely, in the septal CC subset, the odds ratio of small vessel size was 8.09 (Table 5). We hypothesized that examiners tended to use XTR GW with a small vessel (Table 6); however, cardiac tamponade easily occurred with perforation in non-septal CC[16]. Therefore, examiners may avoid the use of XTR for small vessels in non-septal CCs.

Because of these reasons, the factor of small vessel size was a stronger predictor for non-septal CC than septal CC. The factor of corkscrew shape was not significant in septal CCs. Generally, non-septal CCs were longer than septal CCs. Similarly, other characteristics of non-septal CC may be involved in the factor of corkscrew shape. Further research is needed to confirm these points. Continuous bends were not a significant factor in non-septal CCs. One reason was that the bending part in non-septal CCs was easily straightened when GW or MC were inserted.

*Complications and AVG CCs*

In the AVG CC category, the complication of CC perforation requiring treatment occurred with a significantly high ratio (16.7%), and the odds ratio was significantly higher than in the epicardial CC subset (15.00 vs. 5.12). We expected vulnerability of AVG CC. The reverse bend variable of AVG CC was a significant factor for CC perforation requiring treatment (Table 7). AVG CC with a reverse bend had a significant risk of perforation requiring treatment. SUOH03 GWs showed a tendency of applying reverse bend in the successful CC GW crossing group (Table 6). Low tip load (0.3gf) of SUOH03 GWs may safely function in a reverse bend.

*Limitations*

This study is based on a multicenter registry. Therefore, it involves bias in case selection, examiner skill, and institution. Moreover, this registry does not include any standardized CTO-PCI procedure. Therefore, each case involves selection bias with respect to the retrograde procedure, CCs, and devices. The primary end point is not CC MC crossing success or CTO-PCI technical success. However, in this study, the CTO-PCI technical success rate after CC GW crossing success was reasonable (91.0%). Regarding the evaluation of CC complications, the frequency of CC perforation requiring treatment was not equal to clinical cardiac tamponade or other clinical major complications. There was a possibility of variability in angiographic evaluation, because angiographic findings were observed by an experienced CTO examiner. Angiographic findings of CC were based on tip injection findings. There was a possibility of wire passage through CC without tip injection. In this study, native CCs are investigated. There is a limitation for estimating bypass graft CCs. In the GW evaluation, only final GWs are investigated. There is a possibility that initial or second GW is not investigated. Because CC GW crossing success is closely related to GW technology, further validation is needed to confirm the effects of future GWs.

*Conclusions*

The J-Channel score as a prediction tool based on angiographic findings for each type of CC can be used for judging the difficulty of CC GW crossing success with retrograde CTO-PCI.

**Impact on daily practice**

We created a prediction score model (J-Channel score) for measuring the difficulty of CC GW crossing success in retrograde CTO-PCI. The angiographic findings, which affected CC GW crossing, had differences between septal CC and non-septal CC. The proposed scoring model can evaluate the difficulty of CC GW crossing success by angiographic findings for each type of CC, and information about difficulty can be shared with examiners for appropriate selection of CCs.

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Conflict of interest statement

W. Nagamatsu is a consultant for Asahi Intecc, Abbott Vascular Japan, Terumo, Medtronic Japan, Boston Scientific Japan, Kaneka Medics, and NIPRO. E. Tsuchikane is a consultant for Boston Scientific Japan, Asahi Intecc, NIPRO, and Kaneka Medics. S. Sumitsuji is a consultant for Terumo, Kaneka Medics, NIPRO, Asahi Intecc, Abbott Vascular Japan, Boston Scientific Japan, Medtronic Japan, Biosensors, and Orbus Neich. And he has received grants from Terumo, Kaneka Medics, NIPRO, and Asahi Intecc. O. Katoh is a consultant for Asahi Intecc and NIPRO. The other authors have no conflict of interest to declare.

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Figure legends

Figure 1. Definitions of Angiographic Findings. (A) Arrows = large size CC as CC2; Arrowheads = small size CC as CC1. Large vessel size was defined as CC2. Small vessel size was defined as CC0 or CC1. CC grade (CC0–2) was proposed by Werner[13]. (B) The reverse bend was described as a part of bend folded at >90° angle. (C) Continuous bend was defined as the height of bend (a) exceeding the length between bends (b), that is, when a > b. At least three continuous bends except corkscrew morphology were termed with variables of continuous bends. (D) Corkscrew was defined as three or more continuous bends with a ratio of vessel amplitude/vessel diameter (AD ratio) ≤2. CC = collateral channel.

Figure 2. Receiver–Operator Characteristics Curves for Evaluation of the New Scoring Model. The area under the curve of derivation and validation sets was 0.744 and 0.743, respectively, in the septal CC subset and 0.757 and 0.826, respectively, in the non-septal CC subset. CC = collateral channel; AVG = atrioventricular groove.

Figure 3. Relationships between the CC GW Crossing Success and the Risk Groups. Relationships between the CC GW crossing success and the risk groups that were defined as easy, intermediate, and difficult due to total score in derivation and validation sets. GW = guidewire; CC = collateral channel; AVG = atrioventricular groove.

Figure 4. Prevalence of GW types in the CC GW Crossing Success Group. The ratio of the numbers of GW types used (SUOH03, SION, and XTR; Asahi Intecc, Nagoya, Japan) was 89.4%. A smaller number of XTR GWs were used in non-septal CCs. GW = guidewire; CC = collateral channel; AVG = atrioventricular groove.

Figure 5. Summary of the J-Channel Score. The J-Channel Score as a difficulty estimating tool for CC GW crossing success from the Japanese CTO-PCI Expert Registry. CC grades (CC0–2) were proposed by Werner[13]. GW = guidewire; CC = collateral channel; AVG = atrioventricular groove.

Table 1. Baseline Patient and Collateral Channel Characteristics

| Per Patient (n = 630) | |
|---|---|
| Age | 65.8 ± 10.7 |
| Male | 559 (88.7%) |
| Diabetes | 280 (44.4%) |
| Hyperlipidemia | 499 (79.2%) |
| Hypertension | 152 (75.4%) |
| Smoking | 352 (55.9%) |
| Prior MI | 323 (51.3%) |
| Prior CABG | 37 (5.9%) |
| CTO target vessel | |
| LAD | 180 (28.6%) |
| LCX | 56 (8.9%) |
| RCA | 394 (62.5%) |
| LMT | 0 (0.0%) |
| Prior failed attempt | 194 (30.8%) |
| J-CTO score | 2.2 ± 1.1 |
| **Per Collateral Channel (n = 886)** | |
| Channel type | |
| Septal CC | 610 (68.8%) |
| Non-Septal CC | 276 (31.2%) |
| Epicardial CC | 204 (23.0%) |
| AVG CC | 72 (8.1%) |

Values are mean ± SD or n (%).

MI = myocardial infarction; CABG = coronary artery bypass graft; CTO = chronic total occlusion; LAD = left anterior descending artery; LCX = left circumflex artery; RCA = right coronary artery; LMT = left main trunk; J-CTO = Multicenter CTO Registry of Japan; CC = collateral channel; AVG = atrioventricular groove.

Table 2. Clinical Results

| Per Patient (n = 630) | | | |
|---|---|---|---|
| Technical success | | 531 (84.8%) | |
| Technical success after CC GW crossing success | | 463 (91.0%) | |
| Major complication | | 24 (3.8%) | |
| Cardiac tamponade or Septal hematoma due to channel perforation | | 6 (1.0%) | |
| **Per CC (n = 886)** | | | **p Value** |
| CC GW crossing success | | 542 (61.2%) | |
| Septal CC | | 381 (62.5%) | 0.264 |
| Non-Septal CC | | 161 (58.3%) | |
| CC MC crossing success | | 514 (58.0%) | |
| Septal CC | | 358 (58.7%) | 0.557 |
| Non-septal CC | | 156 (56.5%) | |
| CC perforation requiring treatment | | 33 (3.7%) | |
| Septal CC | | 8 (1.3%) | <0.001 |
| Non-Septal CC | | 25 (9.1%) | |
| **Angiographic Variables** | **Septal CC (n = 610)** | **Non-Septal CC (n = 276)** | **p Value** |
| Small vessel | 332 (54.4%) | 65 (23.6%) | <0.001 |
| Reverse bend | 133 (21.8%) | 116 (42.0%) | <0.001 |
| Continuous bends | 81 (13.3%) | 91 (33.0%) | <0.001 |
| Corkscrew | 61 (10.0%) | 25 (9.1%) | 0.714 |
| Acute angle with distal recipient vessel | 8 (1.3%) | 2 (0.7%) | 0.733 |
| Straight | 222 (36.4%) | 33 (12.0%) | <0.001 |

Values are n (%).

CC = collateral channel; GW = guidewire; MC = micro catheter.

Table 3. Lesion Characteristics in the Derivation and Validation Sets

| | Septal CC | | | Non-Septal CC | | |
|---|---|---|---|---|---|---|
| | Derivation Set (n = 407) | Validation Set (n = 203) | p Value | Derivation Set (n = 184) | Validation Set (n = 92) | p Value |
| Small size | 54.8% | 53.7% | 0.863 | 23.9% | 22.8% | 0.881 |
| Reverse bend | 22.1% | 21.2% | 0.836 | 41.3% | 43.5% | 0.796 |
| Continuous bends | 14.5% | 10.8% | 0.254 | 34.2% | 30.4% | 0.588 |
| Corkscrew | 10.6% | 8.9% | 0.568 | 10.3% | 6.5% | 0.377 |
| Acute angle with distal recipient vessel | 1.5% | 1.0% | 1.0 | 0.0% | 2.2% | 0.11 |
| Ipsilateral CC | 3.7% | 3.0% | 0.815 | 28.3% | 34.8% | 0.271 |
| CC GW crossing success | 61.9% | 63.5% | 0.723 | 57.1% | 60.9% | 0.605 |
| CC MC crossing success | 57.5% | 61.1% | 0.433 | 56.0% | 57.6% | 0.898 |
| CC perforation required treatment | 1.5% | 1.0% | 1.0 | 9.2% | 8.7% | 1.0 |

Values are %.

Abbreviations as in Table 2.

Table 4. Univariate Analysis in the Derivation Set

| | Septal CC | | | Non-Septal CC | | |
|---|---|---|---|---|---|---|
| | Successful (n = 247) | Unsuccessful (n = 160) | p Value | Successful (n = 105) | Unsuccessful (n = 79) | p Value |
| Small size | 41.3% | 76.8% | <0.001 | 11.4% | 40.5% | <0.001 |
| Reverse bend | 15.9% | 32.3% | <0.001 | 34.3% | 50.6% | 0.034 |
| Continuous bends | 11.1% | 20.0% | 0.020 | 25.7% | 45.6% | 0.007 |
| Corkscrew | 9.9% | 11.6% | 0.620 | 4.8% | 17.7% | 0.006 |
| Ipsilateral CC | 3.2% | 4.5% | 0.590 | 29.5% | 26.6% | 0.742 |

Values are %.

Abbreviations as in Table 2.

Table 5. Multivariable Analysis in the Derivation Set

| | Septal CC | | | Non-Septal CC | | |
|---|---|---|---|---|---|---|
| | OR (95% CI) | p Value | Beta Coefficient | OR (95% CI) | p Value | Beta Coefficient |
| Small vessel | 8.09 (4.68-14.0) | <0.001 | 2.09 | 11.40 (4.51-28.80) | <0.001 | 2.43 |
| Reverse bend | 4.50 (2.46-8.26) | <0.001 | 1.51 | 4.32 (1.97-9.47) | <0.001 | 1.46 |
| Continuous bends | 2.24 (1.16-4.33) | 0.017 | 0.81 | 2.08 (0.96-4.50) | 0.063 | 0.73 |
| Corkscrew | - | - | - | 4.55 (1.20-17.30) | 0.026 | 1.51 |

OR = odds ratio; CI = confidence interval; other abbreviations as in Table 2.

Table 6. Multivariable Analysis for GW Trends in the CC GW Crossing Success Group

| | SUOH03 | | SION | | XTR | |
|---|---|---|---|---|---|---|
| | **OR (95% CI)** | **p Value** | **OR (95% CI)** | **p Value** | **OR (95% CI)** | **p Value** |
| Small vessel | 0.46 (0.31-0.68) | <0.001 | 1.50 (1.01-2.23) | 0.042 | 3.43 (1.82-6.45) | <0.001 |
| Reverse bend | 1.61 (1.03-2.51) | 0.038 | 0.63 (0.38-1.04) | 0.07 | 1.32 (0.59-3.00) | 0.5 |
| Continuous bends | 1.36 (0.69-2.71) | 0.38 | 0.67 (0.30-1.49) | 0.33 | 0.28 (0.05-1.66) | 0.16 |
| Corkscrew | 0.56 (0.23-1.36) | 0.2 | 1.72 (0.65-4.56) | 0.28 | 6.06 (0.97-37.80) | 0.054 |

Abbreviations as in Table 2 and 5.

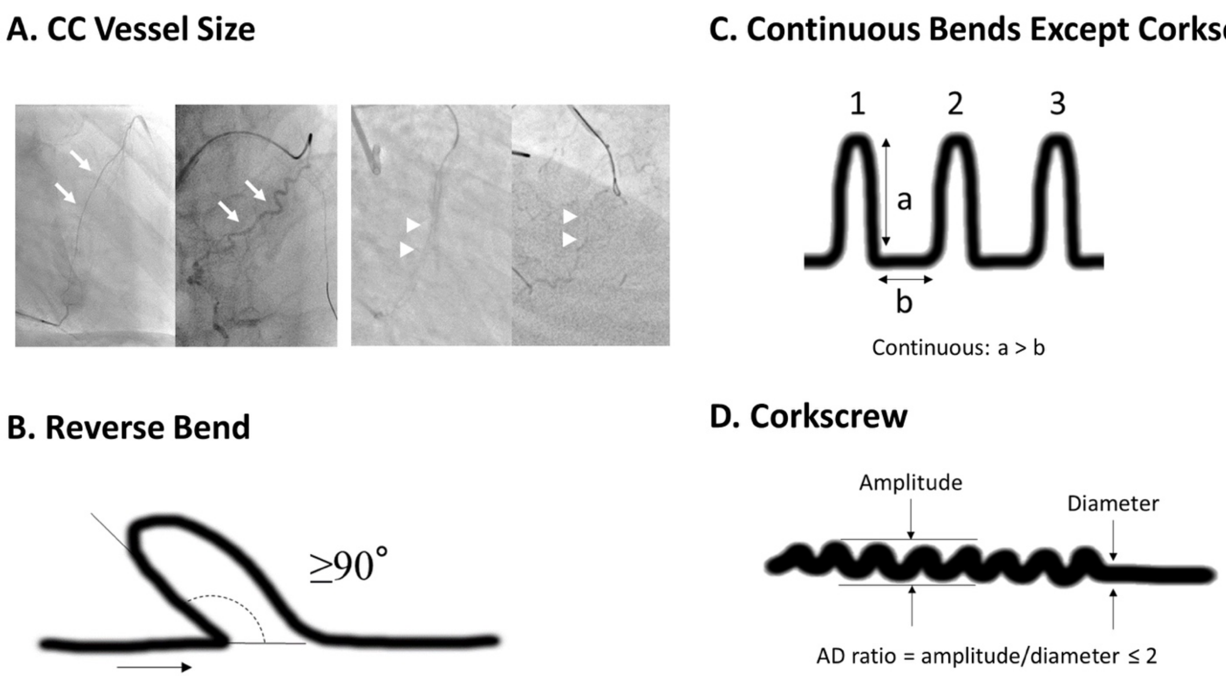
Table 7. Sub-analyses for CC Perforation Requiring Treatment

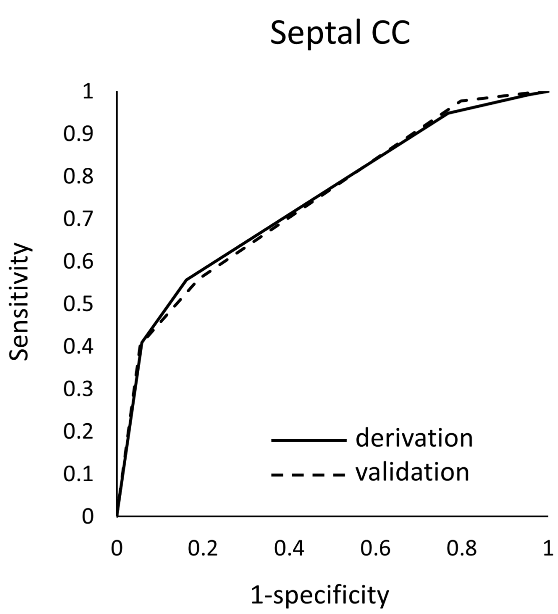
| | Per CC | p Value |
|---|---|---|
| CC perforation requiring treatment | 33/886 (3.7%) | |
| Septal CC | 8/610 (1.3%) | <0.001 |
| Epicardial CC | 13/204 (6.4%) | |
| AVG CC | 12/72 (16.7%) | |

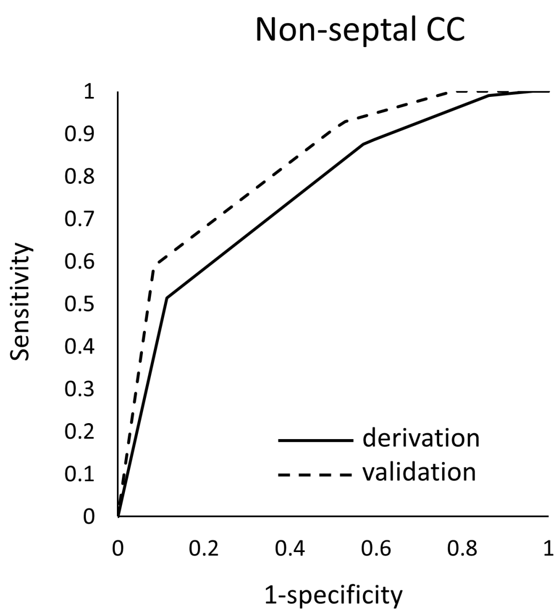
| | OR (95% CI) | p Value |
|---|---|---|
| Epicardial CC | 5.12 (2.09-12.50) | <0.001 |
| AVG CC | 15.00 (5.92-38.30) | <0.001 |

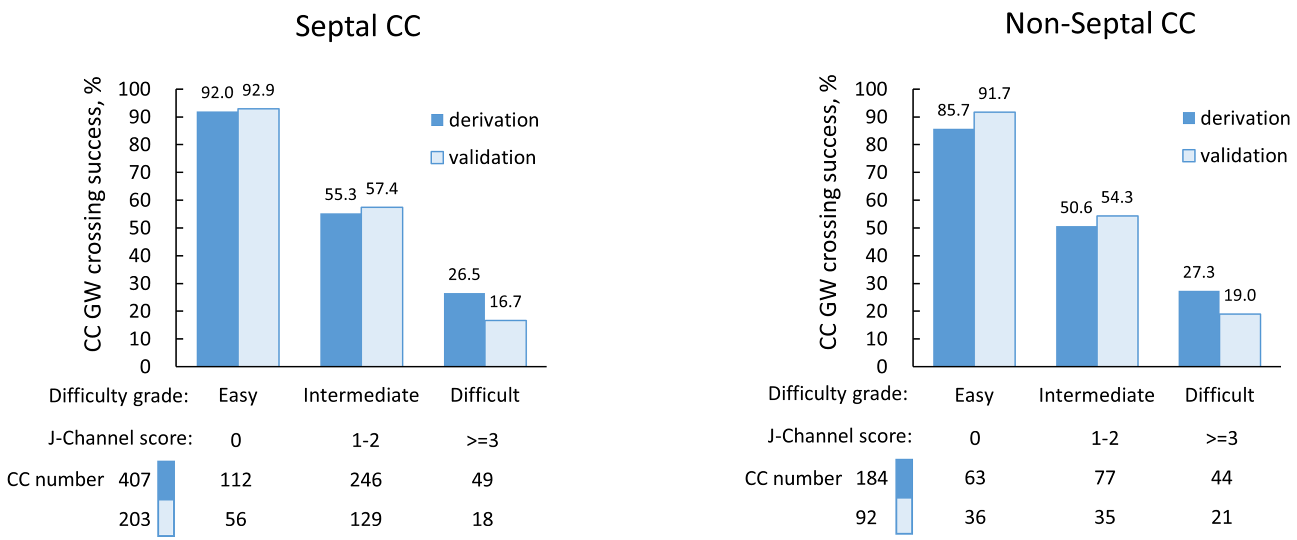
| | Epicardial CC | | AVG CC | |
|---|---|---|---|---|
| | OR (95% CI) | p Value | OR (95% CI) | p Value |
| Small vessel | 0.83 (0.21-0.15) | 0.790 | 6.15 (0.97-38.90) | 0.054 |
| Reverse bend | 1.11 (0.33-3.74) | 0.870 | 6.67 (1.14-38.90) | 0.035 |
| Continuous bends | 0.79 (0.17-3.61) | 0.760 | 1.16 (0.27-5.05) | 0.840 |
| Corkscrew | 4.28 (0.71-25.90) | 0.110 | 1.57 (0.19-13.00) | 0.680 |

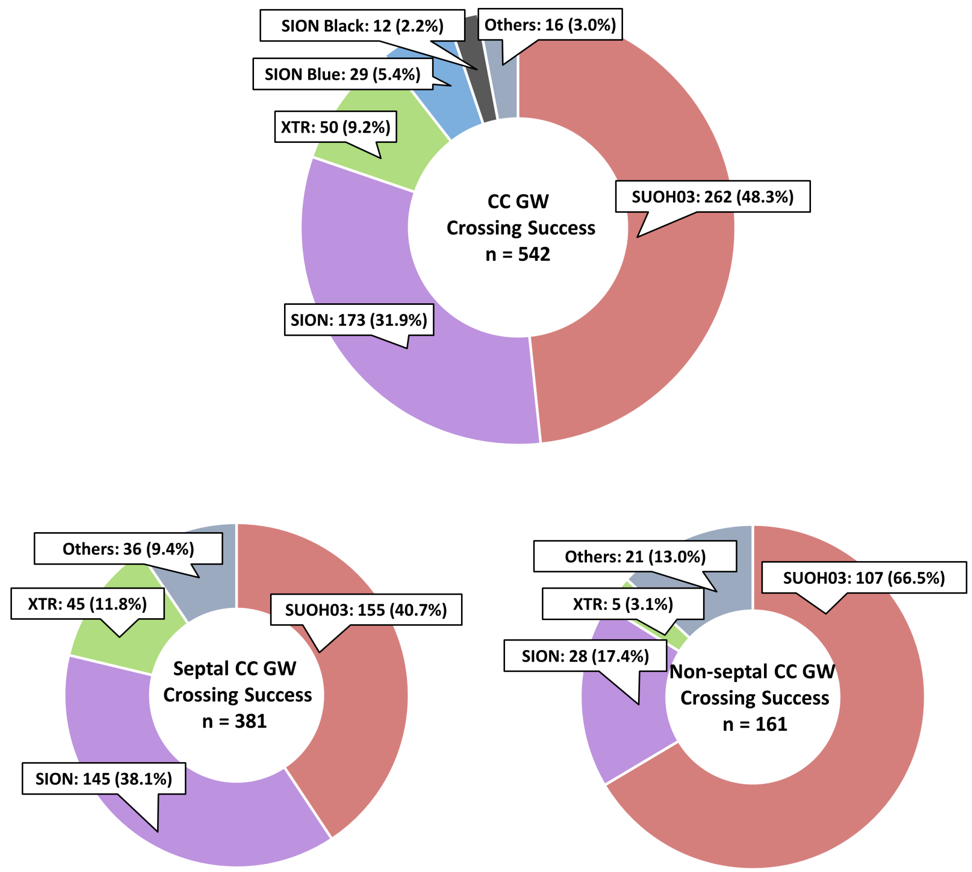
Abbreviations as in Table 1, 2, and 5.


A. CC Vessel Size
C. Continuous Bends Except Corkscrew
1
2
3
a
b
Continuous: a > b
B. Reverse Bend
≥90°
D. Corkscrew
Amplitude
Diameter
AD ratio = amplitude/diameter ≤ 2


Septal CC
Sensitivity
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
1
1-specificity
derivation
validation

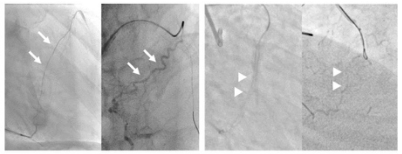

Non-septal CC
Sensitivity
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.2
0.4
0.6
0.8
1
1-specificity
derivation
validation


Septal CC
CC GW crossing success, %
100
90
80
70
60
50
40
30
20
10
0
92.0
92.9
55.3
57.4
26.5
16.7
derivation
validation
Difficulty grade:
Easy
Intermediate
Difficult
J-Channel score:
0
1-2
>=3
CC number
407
112
246
49
203
56
129
18
Non-Septal CC
CC GW crossing success, %
100
90
80
70
60
50
40
30
20
10
0
85.7
91.7
50.6
54.3
27.3
19.0
derivation
validation
Difficulty grade:
Easy
Intermediate
Difficult
J-Channel score:
0
1-2
>=3
CC number
184
63
77
44
92
36
35
21

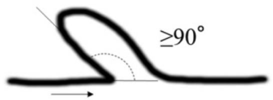

SION Black: 12 (2.2%)
Others: 16 (3.0%)
SION Blue: 29 (5.4%)
XTR: 50 (9.2%)
CC GW
Crossing Success
n = 542
SUOH03: 262 (48.3%)
SION: 173 (31.9%)
Others: 36 (9.4%)
XTR: 45 (11.8%)
SUOH03: 155 (40.7%)
Septal CC GW
Crossing Success
n = 381
SION: 145 (38.1%)
Others: 21 (13.0%)
SUOH03: 107 (66.5%)
XTR: 5 (3.1%)
SION: 28 (17.4%)
Non-septal CC GW
Crossing Success
n = 161

# J-Channel Score

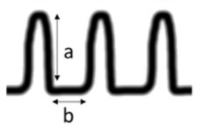
**A. CC Vessel Size**
- *Large (CC2)*
- *Small (CC0 or CC1)*




**B. Reverse Bend**
- *None: <90 °*
- *Yes: ≥90 °*




**C. Continuous Bends**
- *None: ≤2*
- *Yes: ≥3*




**D. Corkscrew**
- *None*
- *Yes: Continuous bends ≥3 with AD ratio ≤2*


| | Septal | Non septal |
|---|---|---|
| **CC Vessel Size:** *Small* | **2** | **3** |
| **Reverse Bend:** *Yes* | **1** | **1** |
| **Continuous Bends:** *Yes* | **1** | **0** |
| **Corkscrew:** *Yes* | **0** | **1** |
| **Total Score** | | |

**Category of Difficulty (Total Score)**
- **Easy: 0**
- **Intermediate: 1-2**
- **Difficult: ≥3**

*How to use:*
*1st Classify CC into type of CC.*
*2nd Sum up numbers on vertical frame as type of CC.*
*3rd Estimate difficulty.*