Exploring The Success Rate in CTO PCI
Bayesian Approach for Preprocedural Inference and Intraprocedural Revising

Toshikazu Kashiyama[1,2], Atsunori Okamura[2]

1) Sumitomo Hospital
2) Sakurabashi Watanabe Hospital

Disclosure

- The authors have no financial conflicts of interest to disclose concerning the presentation.

Backgrounds

- Various techniques and approaches have been developed to improve the success rate in CTO PCI.

- Whether they can be implemented into real clinical practice is determined by time and resources which can be allocated to each procedure.

- Preprocedural prediction of success rate is important to decide “Which CTO should be treated”, but “How long should we continue, and when should we change strategies” will be answered if likelihood of success is updated during the procedure.

Limitation of Past CTO Studies

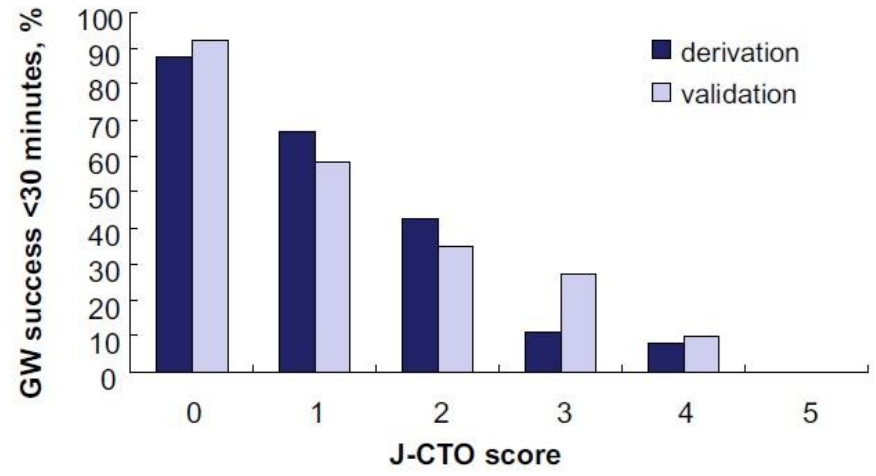


Table 4. Difficulty Score for CTO Lesions (J-CTO Score): 5 Selected Independent Predictors Identified by the Forward/Backward Procedure

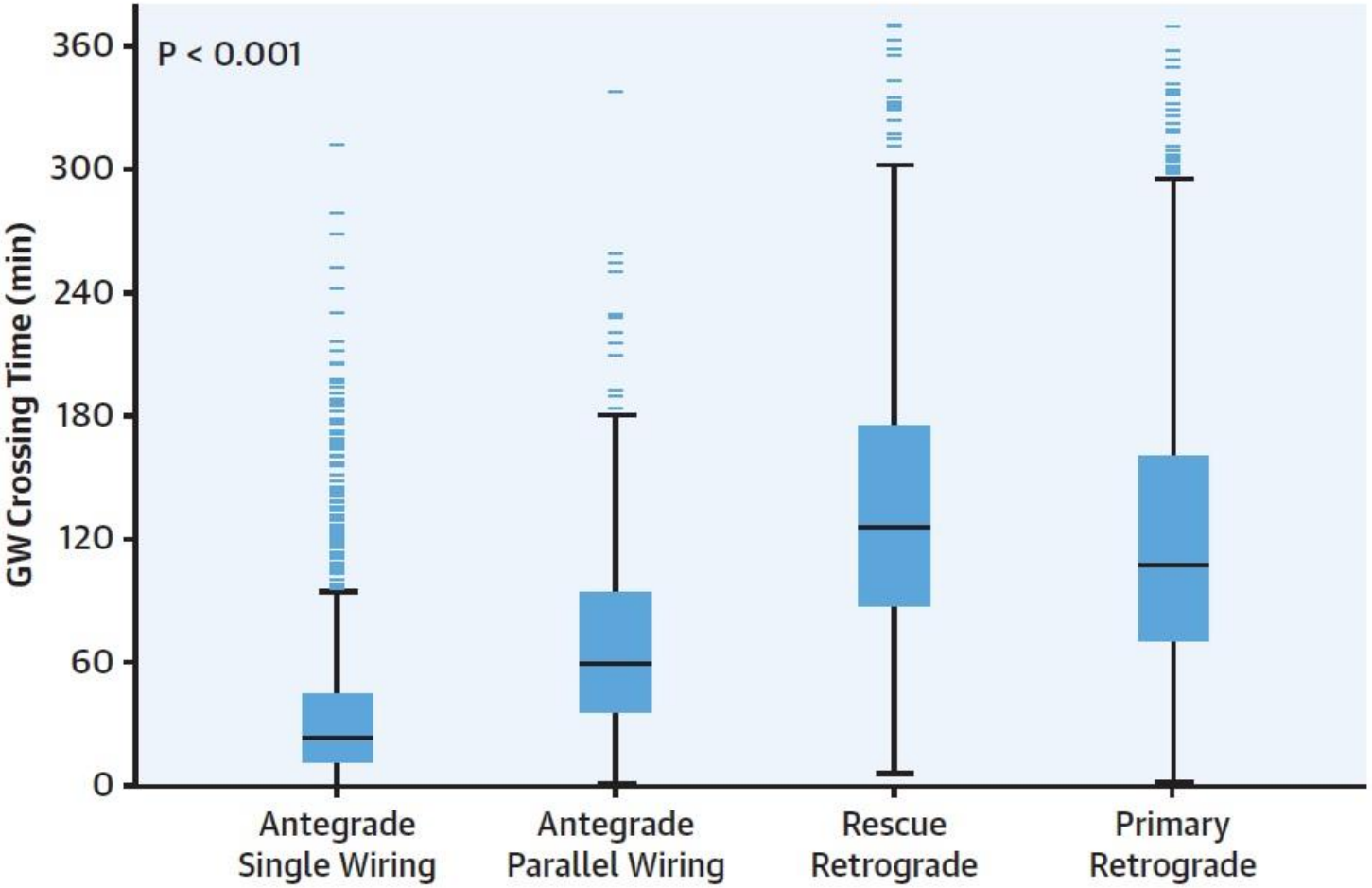
Variables	Odds Ratio (95% CI)	Beta Coefficient	Point
Previously failed lesion	0.39 (0.15–0.97)	0.93	1
Blunt stump type	0.32 (0.18–0.55)	1.14	1
Bending	0.34 (0.20–0.58)	1.09	1
Calcification	0.26 (0.15–0.44)	1.36	1
Occlusion length ≥20 mm	0.19 (0.09–0.39)	1.65	1

Retrograde CTO PCI < 30min??

1. Selection of strategies were not considered.
2. Each variable has different effect on the outcome.

Morino et al. JACC Cardiovasc Interv. 2011;4:213-21.

Limitation of Past CTO Studies



Shorter GW crossing time for

Primary retrograde 107 [70-161] min
than
Rescue retrograde 126 [87-174] min

176 [130-229] min if Retro failed

Tanaka et al. J Am Coll Cardiol 2019;74:2392–404

Bayesian Theorem in Clinical Diagnosis

Possibility of Heart Attack

Pre-test Odds

28 y.o. Female
Vegan, Athlete
1:1000 (0.1%)

Test.1

Abnormal ST-segment Pattern

Sensitivity=90%
Specificity=90%

+LR = 9
-LR = 0.11

POSITIVE

Post-test Odds

9:1000 (0.89%)

Updated Pre-test Odds

Test.2

Stress Thallium Scan

Sensitivity=83%
Specificity=94%

+LR = 13.8
-LR = 0.18

POSITIVE

Post-test Odds

124:1000 (11%)

NEGATIVE

1.6:1000 (0.15%)

+LR: (Positive Likelihood Ratio) = sensitivity / (1 – specificity)
-LR :(Negative Likelihood Ratio) = (1 – sensitivity) / specificity

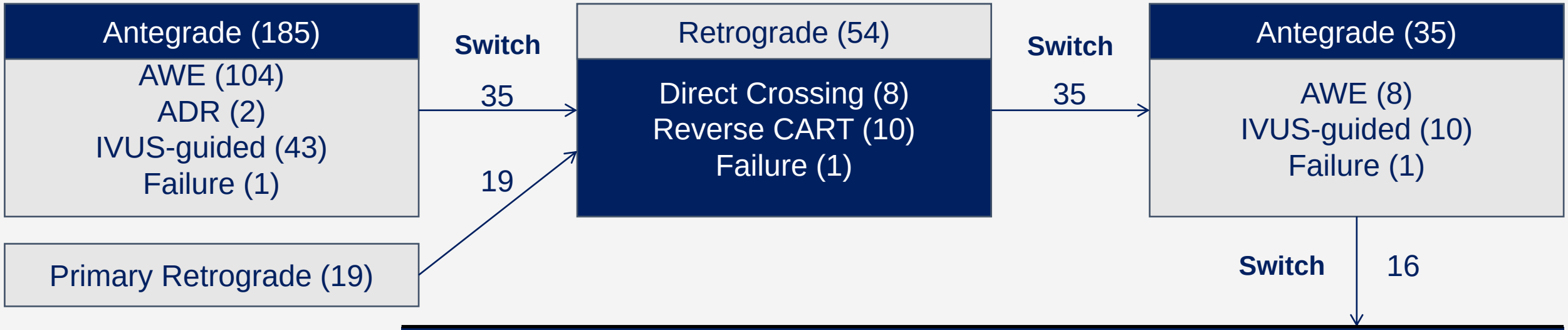
Gill et al. BMJ2005;330:1080–3

Aim of This Study

- To predict the success rate in CTO PCI not only by the total sum of the complexity score but using each variable as a likelihood ratio.

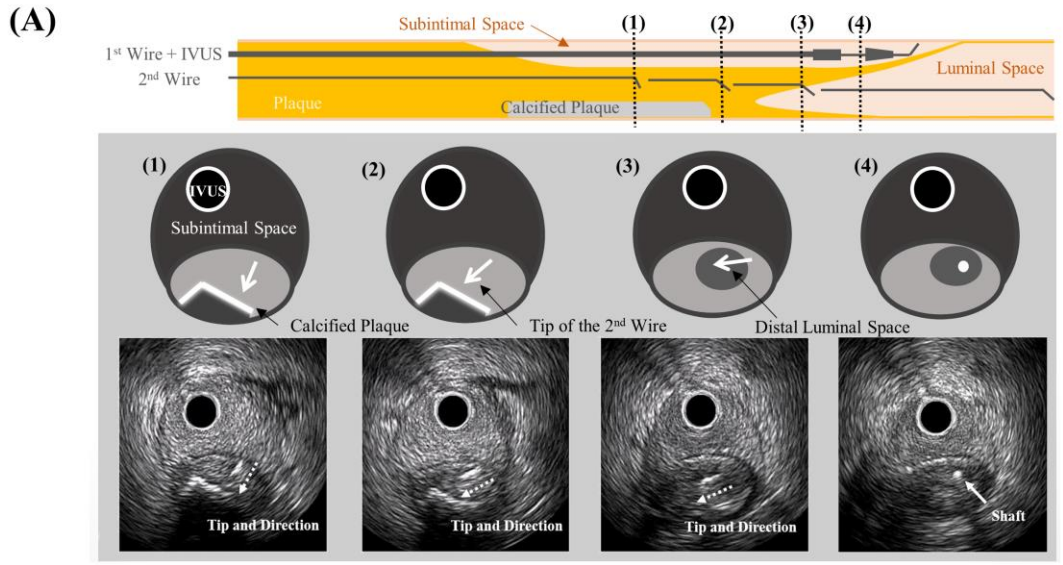
- Not only preprocedural predicted success rate, but intraprocedural factors (*selection of wires, strategies*) are used to update the likelihood of success using Bayesian model.

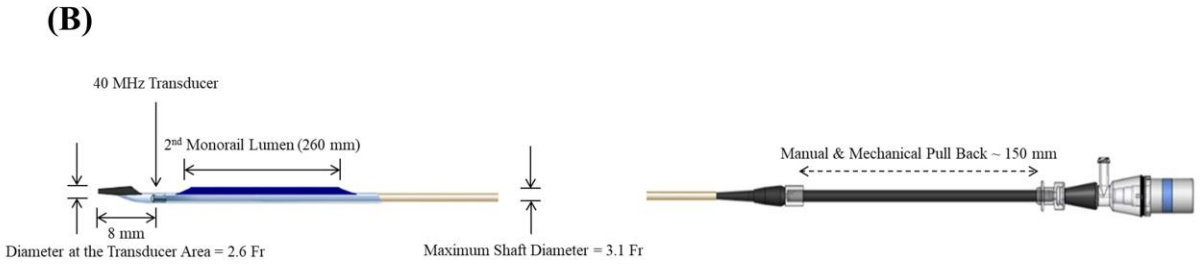
Participant Flow

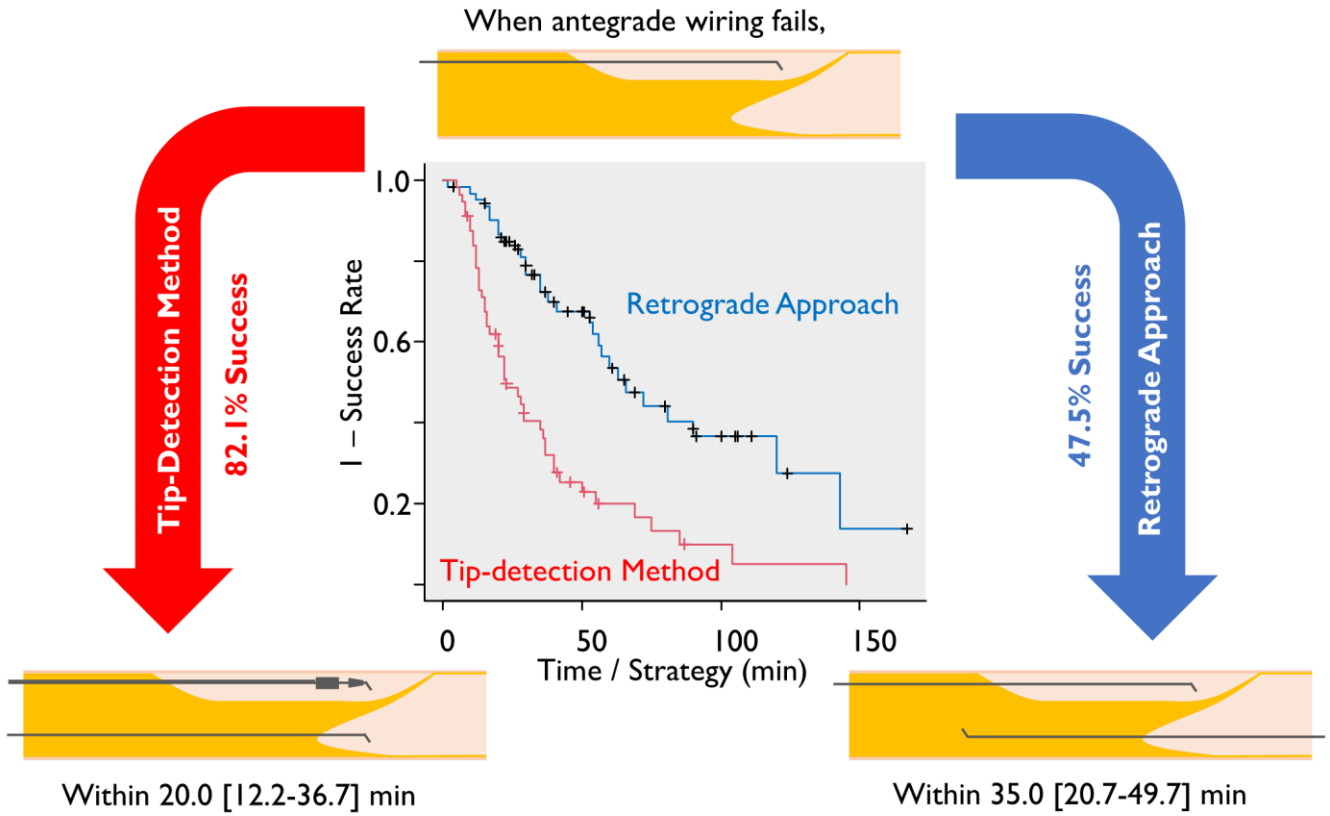


Ante / Retro	Strategy	Ante / Retro	Strategy	Ante / Retro	Strategy
A>R>A>R	CART	A>R>A>R>A	IVUS-guided	R>A>R	Reverse CART
A>R>A>R	Reverse CART	A>R>A>R>A	AWE	R>A>R	Direct Crossing
A>R>A>R	Reverse CART	R>A>R	Reverse CART	R>A>R	Direct Crossing
A>R>A>R	Reverse CART	R>A>R	Reverse CART	R>A>R	Direct Crossing
A>R>A>R	Direct Crossing	R>A>R	Reverse CART	R>A>R>A>R	Reverse CART
A>R>A>R	Direct Crossing				

IVUS-guided (Tip-detection) Strategy







Kashiyama et al. TCTAP2023, ESC2023

Procedural Outcome

Almost the same with J-CTO study

Successfully treated finally using….	Total (199)	All AWE (113)	IVUS-guided (54)	Retrograde (32)
Time for Wire Passing (min)	29 [11-78.5]	12.5 [5.25-22]	61 [41.2-125]	94 [61–112]
Number of Wires used	3 [2-5]	2 [2-3]	4 [3-5]	5 [4-7]
Contrast Volume (ml)	138 [110-180]	130 [106-167.5]	130 [110-177.5]	170 [120-220]
Radiation Dose (mGray)	2312 [1507-3566]	1845 [1271-2793]	2708 [2065-4058]	3782 [2473-4372]
Fluoroscopic Time (min)	56 [37.2-86.7]	41.5 [27-55.7]	76 [55-103.7]	83 [72-113]

End point = Successful Lesion Crossing within 15 min with AWE, and + 60min with IVUS-guided or Retrograde

End Point = GW crossing < 15 min with AWE

	Success (%)	Failure (%)	Odds Ratio	95% C.I.	Positive Likelihood Ratio	Negative Likelihood Ratio
J-CTO score						
Proximal Cap Ambiguity	26 (44.1)	74 (51.0)	0.76	0.39 - 1.45	**0.86**	**1.14**
Calcification	29 (49.2)	83 (57.2)	0.72	0.37 - 1.38	**0.86**	**1.19**
Bending > 40°	33 (55.9)	87 (60.0)	0.85	0.44 - 1.64	**0.93**	**1.10**
Occlusion Length > 20mm	22 (38.6)	80 (56.3)	0.49	0.24 - 0.95	**0.69**	**1.41**
Retry Lesion	1 (1.7)	25 (17.2)	0.08	0.00 - 0.53	**0.10**	**1.19**
Progress-CTO score						
Absence of Interventional Collaterals	35 (59.3)	65 (44.8)	1.79	0.93 - 3.48	**1.32**	**0.74**
Moderate / Severe Tortuosity	12 (20.3)	52 (35.9)	0.46	0.20 - 0.97	**0.57**	**1.24**
Circumflex CTO	11 (18.6)	36 (24.8)	0.69	0.29 - 1.54	**0.75**	**1.08**
CT-RECTOR score						
Multiple Occlusion	24 (40.7)	58 (40.0)	1.03	0.52 - 1.98	**1.02**	**0.99**
Blunt Stump	22 (37.3)	61 (42.1)	0.82	0.41 - 1.59	**0.89**	**1.08**
Severe Calcification	20 (33.9)	70 (48.3)	0.55	0.27 - 1.07	**0.70**	**1.28**
Bending > 45°	24 (40.7)	82 (56.6)	0.53	0.27 - 1.01	**0.72**	**1.37**
Duration of CTO > 1year	42 (71.2)	108 (74.5)	0.85	0.41 - 1.78	**0.96**	**1.13**

If each factor is positive,

> Pre-test odds x Positive Likelihood Ratio

If each factor is negative,

> Pre-test odds x Negative Likelihood Ratio

End Point = GW crossing < 75 min with IVUS-guided or Retrograde

	Success (%)	Failure (%)	Odds Ratio	95% C.I.	Positive Likelihood Ratio	Negative Likelihood Ratio
J-CTO score						
Proximal Cap Ambiguity	50 (48.1)	50 (50.0)	0.93	0.51 - 1.66	**0.96**	**1.04**
Calcification	55 (52.9)	57 (57.0)	0.85	0.47 - 1.52	**0.93**	**1.10**
Bending > 40°	61 (58.7)	59 (59.0)	0.99	0.54 - 1.78	**0.99**	**1.01**
Occlusion Length > 20mm	46 (46.0)	56 (56.6)	0.65	0.35 - 1.18	**0.81**	**1.24**
Retry Lesion	11 (10.6)	15 (15.0)	0.67	0.26 - 1.66	**0.71**	**1.05**
Progress-CTO score						
Absence of Interventional Collaterals	55 (52.9)	45 (45.0)	1.37	0.76 - 2.47	**1.18**	**0.86**
Moderate / Severe Tortuosity	27 (26.0)	37 (37.0)	0.60	0.31 - 1.13	**0.70**	**1.18**
Circumflex CTO	21 (20.2)	26 (26.0)	0.72	0.35 - 1.45	**0.78**	**1.08**
CT-RECTOR score						
Multiple Occlusion	45 (43.3)	37 (37.0)	1.30	0.71 - 2.36	**1.17**	**0.90**
Blunt Stump	43 (41.3)	40 (40.0)	1.06	0.58 - 1.92	**1.03**	**0.98**
Severe Calcification	39 (37.5)	51 (51.0)	0.58	0.31 - 1.04	**0.74**	**1.28**
Bending > 45°	53 (51.0)	53 (53.0)	0.92	0.51 - 1.65	**0.96**	**1.04**
Duration of CTO > 1year	73 (70.2)	77 (77.0)	0.70	0.35 - 1.37	**0.91**	**1.30**

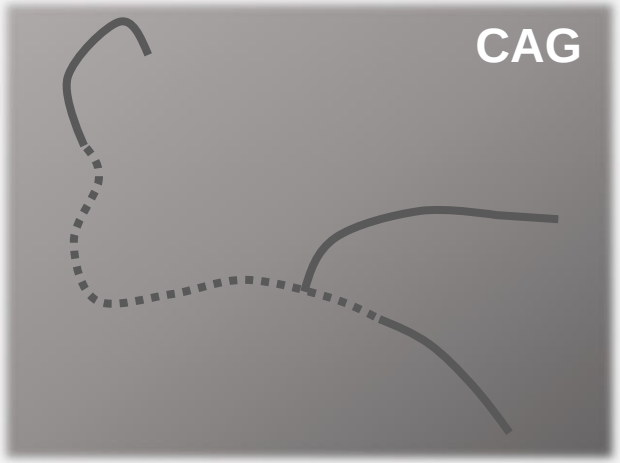
If each factor is positive,

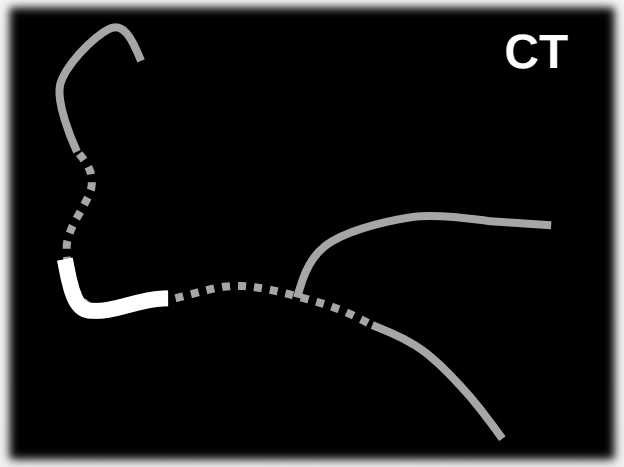
> Pre-test odds x Positive Likelihood Ratio

If each factor is negative,

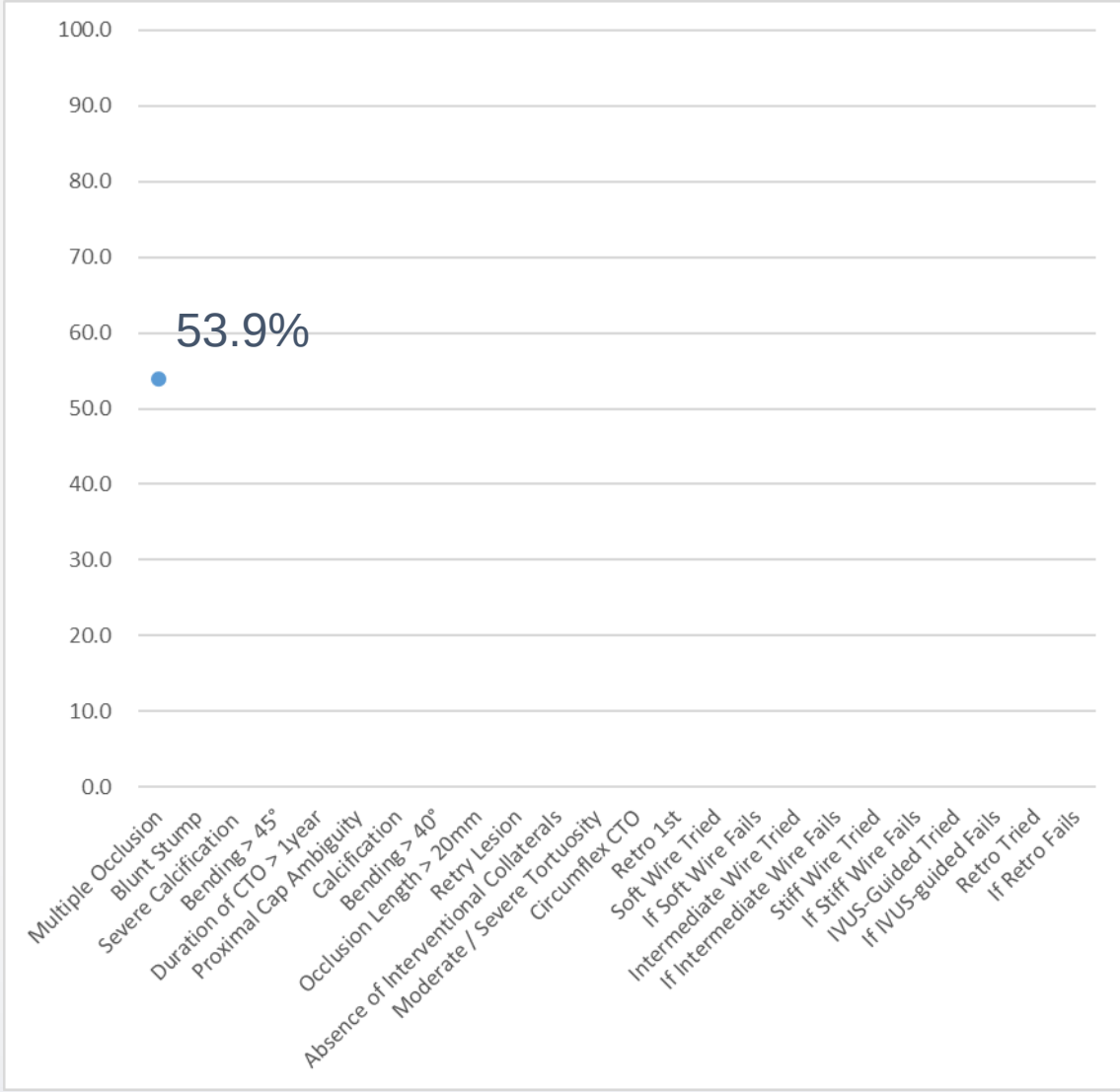
> Pre-test odds x Negative Likelihood Ratio

Likelihood of GW crossing < 15min with AWE + 60min with IVUS-guided or Retro (%)



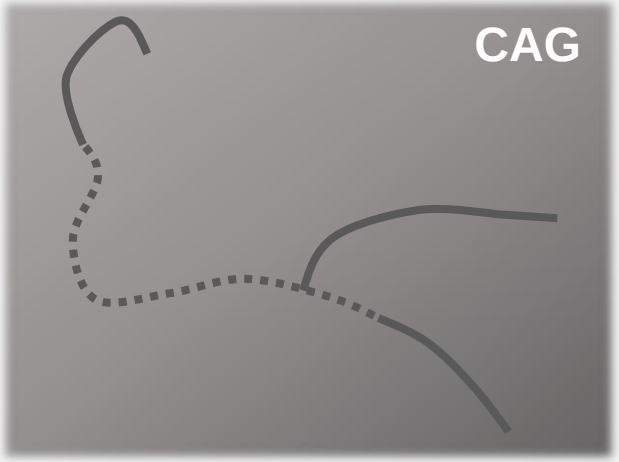


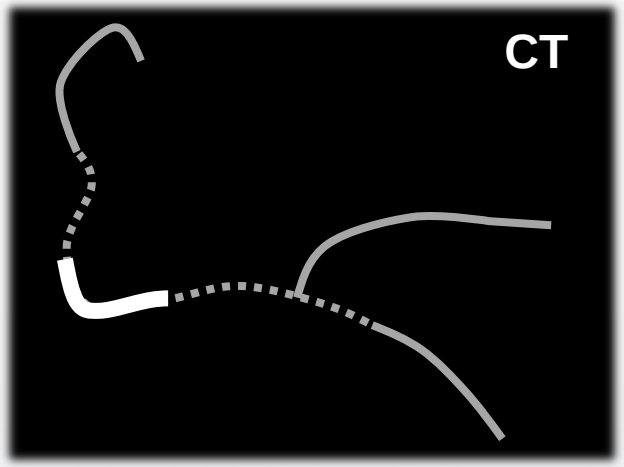
		%
Multiple Occlusion	P	53.9
Blunt Stump		
Severe Calcification		
Bending > 45°		
Duration of CTO > 1year		
Proximal Cap Ambiguity		
Calcification		
Bending > 40°		
Occlusion Length > 20mm		
Retry Lesion		
Absence of Interventional Collaterals		
Moderate / Severe Tortuosity		
Circumflex CTO		
Retro 1st		
Soft Wire Tried		
If Soft Wire Fails		
Intermediate Wire Tried		
If Intermediate Wire Fails		
Stiff Wire Tried		
If Stiff Wire Fails		
IVUS-Guided Tried		
If IVUS-guided Fails		
Retro Tried		
If Retro Fails		



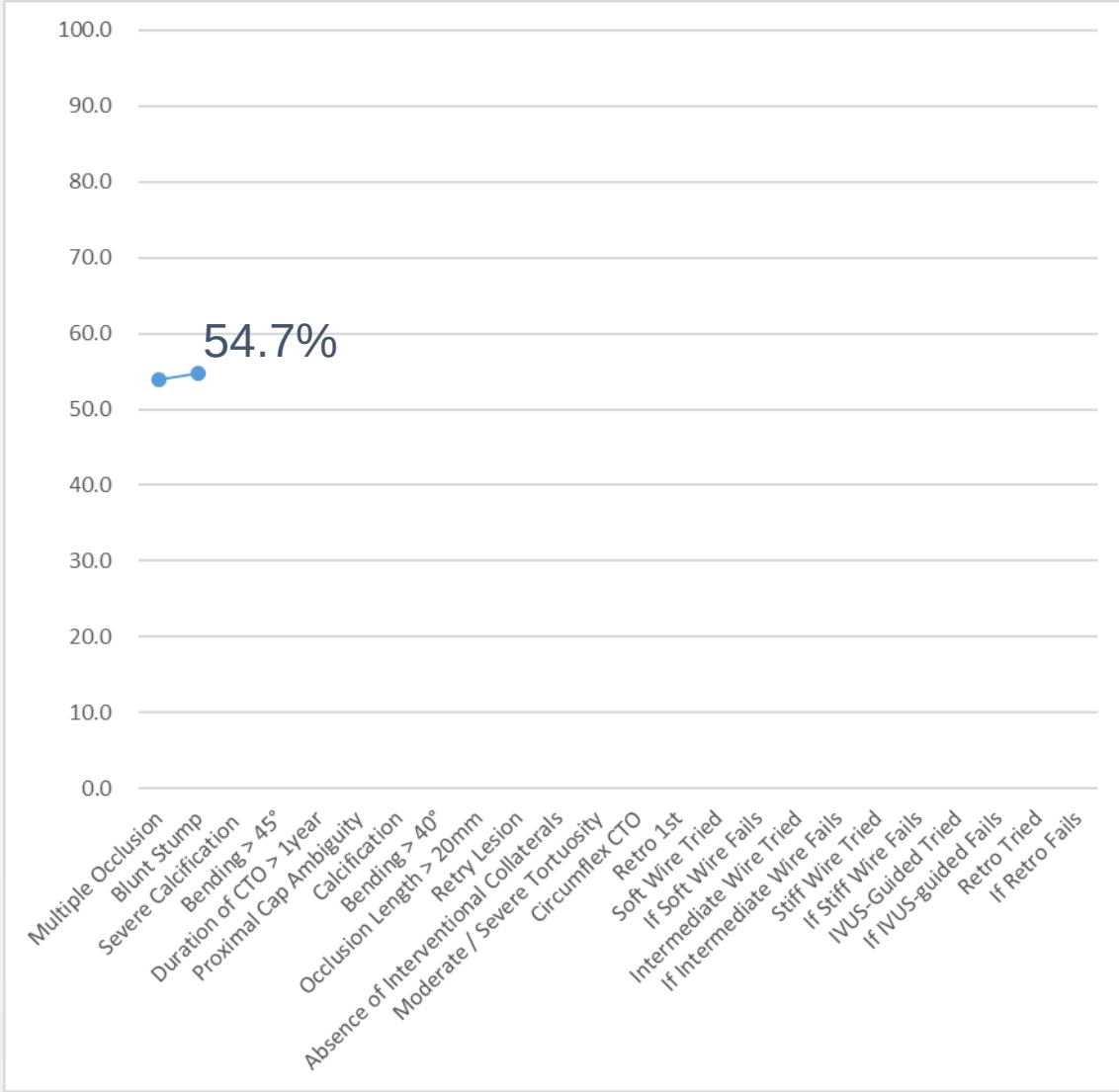
P: Positive, N: Negative

Likelihood of GW crossing < 15min with AWE + 60min with IVUS-guided or Retro (%)





		%
Multiple Occlusion	P	53.9
Blunt Stump	N	54.7
Severe Calcification		
Bending > 45°		
Duration of CTO > 1year		
Proximal Cap Ambiguity		
Calcification		
Bending > 40°		
Occlusion Length > 20mm		
Retry Lesion		
Absence of Interventional Collaterals		
Moderate / Severe Tortuosity		
Circumflex CTO		
Retro 1st		
Soft Wire Tried		
If Soft Wire Fails		
Intermediate Wire Tried		
If Intermediate Wire Fails		
Stiff Wire Tried		
If Stiff Wire Fails		
IVUS-Guided Tried		
If IVUS-guided Fails		
Retro Tried		
If Retro Fails		



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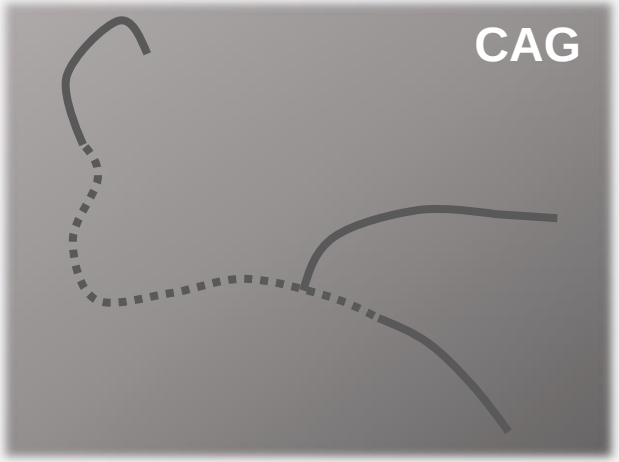
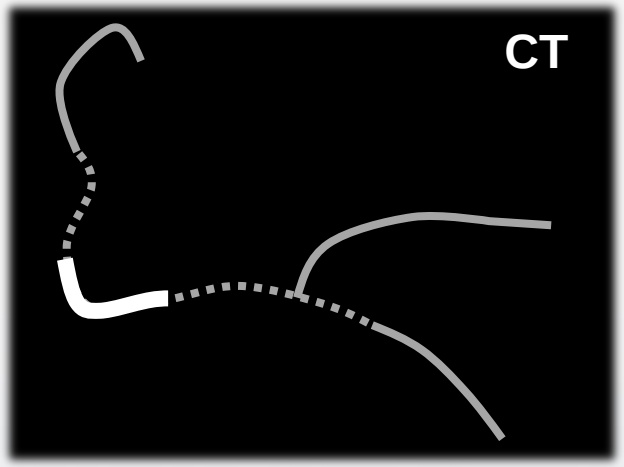
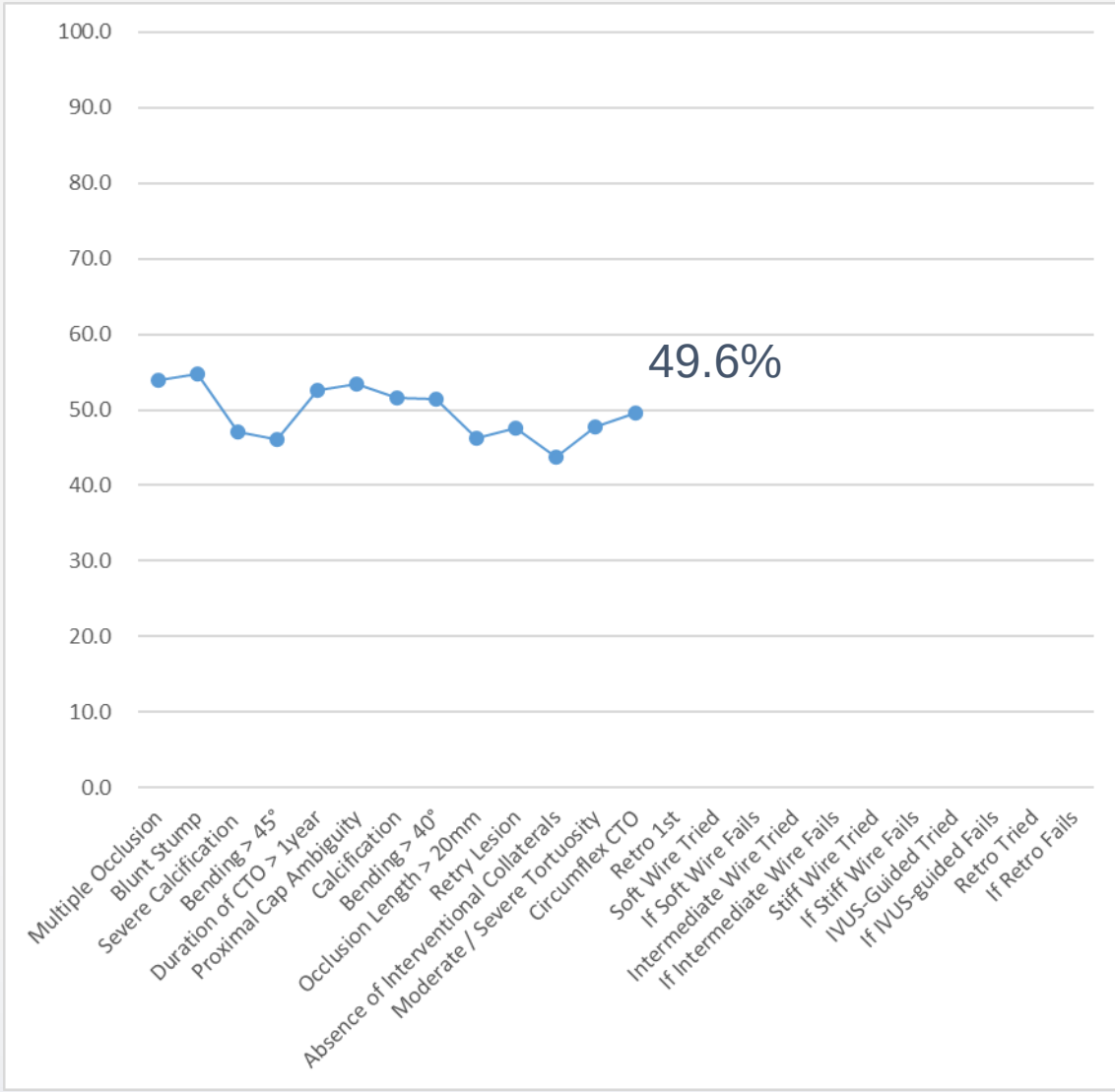
Likelihood of GW crossing < 15min with AWE + 60min with IVUS-guided or Retro (%)



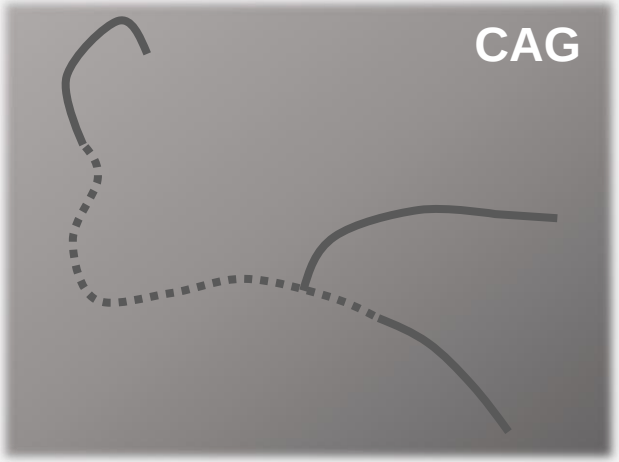


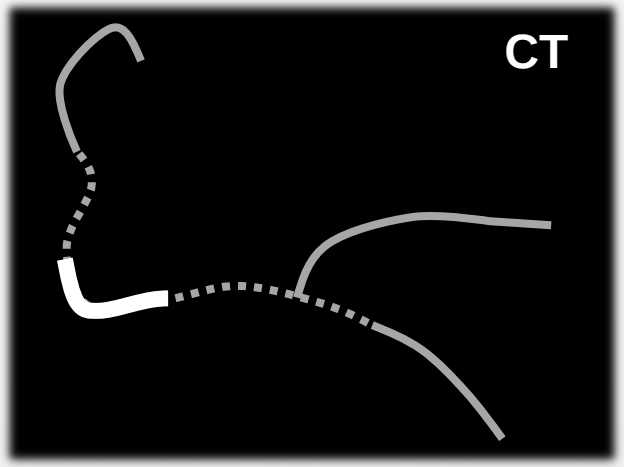
		%
Multiple Occlusion	P	53.9
Blunt Stump	N	54.7
Severe Calcification	P	47.1
Bending > 45°	P	46.1
Duration of CTO > 1year	N	52.6
Proximal Cap Ambiguity	N	53.5
Calcification	P	51.6
Bending > 40°	P	51.5
Occlusion Length > 20mm	P	46.3
Retry Lesion	N	47.6
Absence of Interventional Collaterals	N	43.7
Moderate / Severe Tortuosity	N	47.7
Circumflex CTO	N	49.6
Retro 1st		
Soft Wire Tried		
If Soft Wire Fails		
Intermediate Wire Tried		
If Intermediate Wire Fails		
Stiff Wire Tried		
If Stiff Wire Fails		
IVUS-Guided Tried		
If IVUS-guided Fails		
Retro Tried		
If Retro Fails		

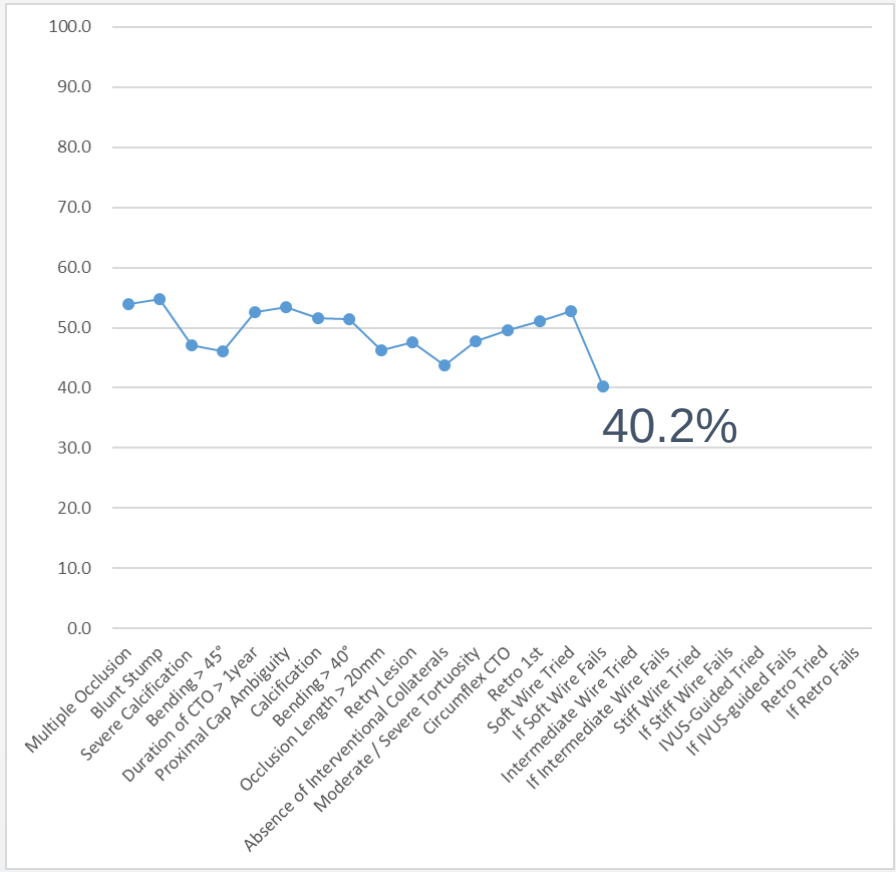


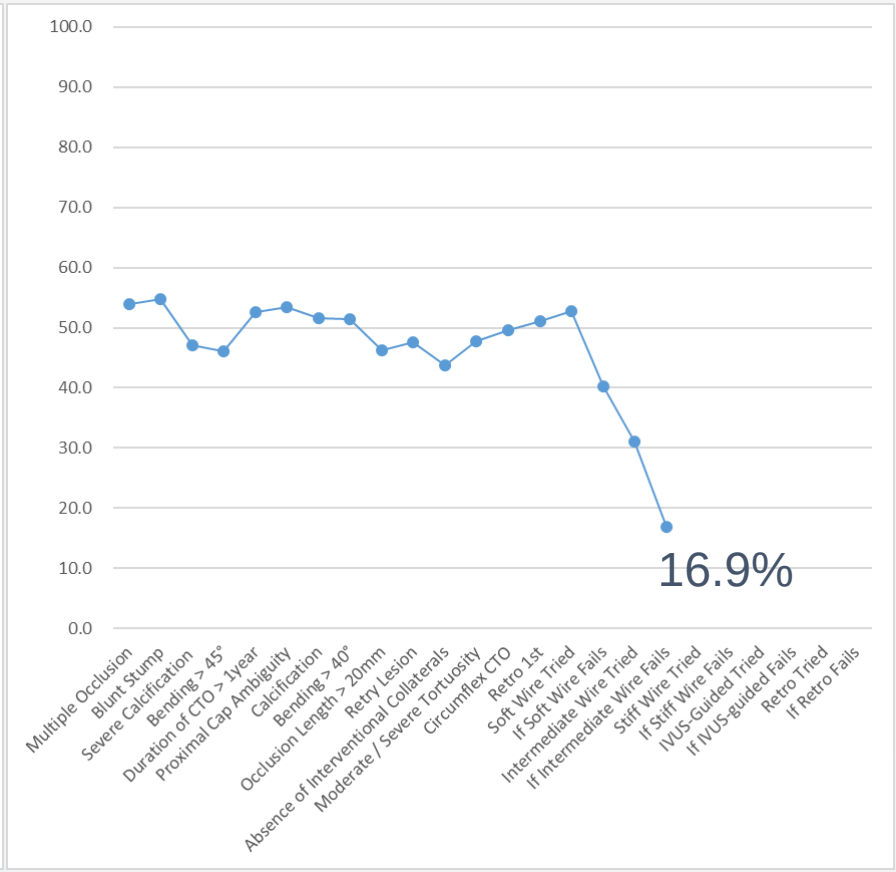
P: Positive, N: Negative

Likelihood of GW crossing < 15min with AWE + 60min with IVUS-guided or Retro (%)









If soft wire failed.

If intermediate wire failed.

Soft wire: tip load ~1g, Intermediate wire: tip load 3~6g, Stiff wire: tip load 9g~

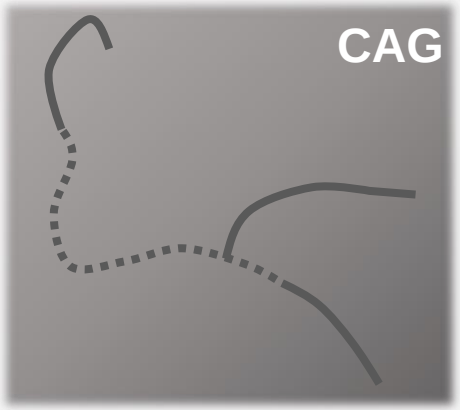
Likelihood of GW crossing (%)

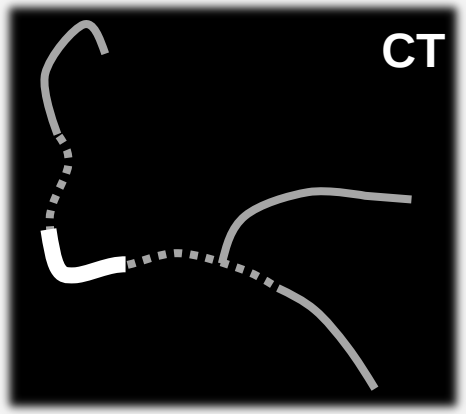
	<15min with AWE		+60min with Retro or IVUS	
	Easiest	Hardest	Easiest	Hardest
Preprocedural Estimated Success Rate	90.6	0.6	82.3	16.7
If Soft Wire Failed	85.1	0.0	76.1	12.3
If Intermediate Wire Failed	23.3	0.0	49.0	7.9
Using Antegrade Stiff Wire	10.6	0.0		
IVUS-guided Approach			75.5	11.7
Retrograde Approach			60.7	6.2

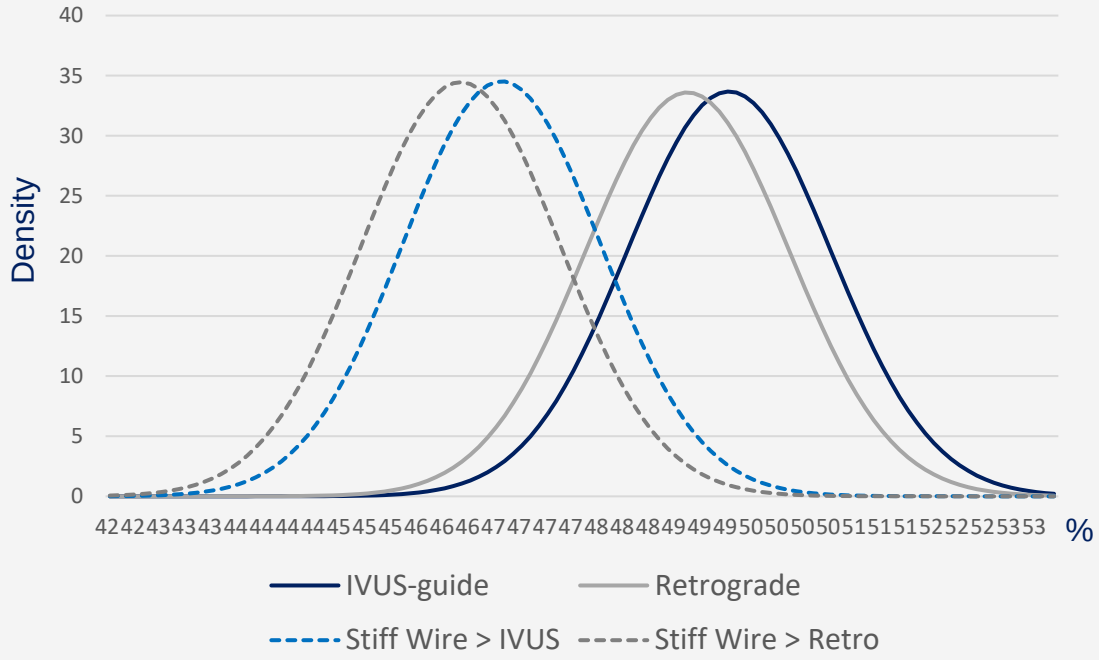
Soft wire: tip load ~1g, Intermediate wire: tip load 3~6g, Stiff wire: tip load 9g~

Easiest case: low J-CTO, PROGRESS-CTO, and CT-RECTOR score
Hardest case: high J-CTO, PROGRESS-CTO, and CT-RECTOR score

Likelihood of GW crossing < 15min with AWE + 60min with IVUS-guided or Retro (%)







When intermediate wire fails

- IVUS-guided μ= 49.2
- Retrograde μ= 48.7
- Antegrade Stiff Wire
  - IVUS-guided μ=46.6
  - Retrograde μ=46.1

Preprocedural Complexity Score J-CTO Score	AWE < 15min		+60min Retro or IVUS	
	+LR	-LR	+LR	-LR
Retry Lesion	0.10	1.19	0.71	1.05

Intraprocedural Factors	AWE < 15min		+60min Retro or IVUS	
	+LR	-LR	+LR	-LR
When Intermediate Wire Failed	0.11	1.81	0.45	1.53
Antegrade Stiff Wire	0.39	1.79		
Retrograde 1st			0.56	1.06

+LR = Positive Likelihood Ratio, -LR = Negative Likelihood Ratio

Initial Probability	Likelihood Ratio	Posterior Probability
50%	0.5	33.3%
	0.4	28.5%
	0.3	23.0%
	0.2	16.6%
	0.1	9.1%

Clinical Implication from the Analysis

- Each variable in the complexity scores, and choice of strategies and wires affect the success rate differently.
- Each factor also acts differently depending on whether operators will attempt AWE alone or advanced approaches (retrograde or IVUS-guided approach).
- “Previous failure” and “failure in antegrade intermediate wires” are the major factors to determine low likelihood of success, especially when antegrade wiring approach is the only available option.

Conclusion

- When CTO lesion cannot be crossed using intermediate wires, early switching to IVUS-guided (the tip-detection) strategy or the retrograde approach can maximize the success rate in the limited procedural time.

- Especially true for previously failed cases.

- Bayesian approach is useful in not only preprocedural but intraprocedural phases.