Intraplaque vs. Extraplaque Tracking: Association with Procedural Outcomes

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Disclosure Statement of Financial Interest

Within the past 12 months, I have had a financial interest/arrangement or affiliation with the organization(s) listed below.

Affiliation/Financial Relationship	Company
Consulting Fees/Honoraria	Abott Vascular, Boston Scientific
Equity	Soundbite, Saranas, Traverse Vascular

Coronary

# Intravascular Ultrasound Analysis of Intraplaque Versus Subintimal Tracking in Percutaneous Intervention for Coronary Chronic Total Occlusions and Association With Procedural Outcomes

Lei Song MD [a, b, c], Akiko Maehara MD [a, b], Matthew T. Finn MD [b], Sanjog Kalra MD, MSc [b], Jeffrey W. Moses MD [a, b], Manish A. Parikh MD [a, b], Ajay J. Kirtane MD, SM [a, b], Michael B. Collins MD [b], Tamim M. Nazif MD [a, b], Khady N. Fall MD, MPH [b], Raja Hatem MD [b], Ming Liao MA [b], Tiffany Kim BA [b], Philip Green MD [b], Ziad A. Ali MD, DPhil [a, b], Candido Batres MD [b], Martin B. Leon MD [a, b], Gary S. Mintz MD [a], Dimitri Karmpaliotis MD, PhD [a, b] ✉
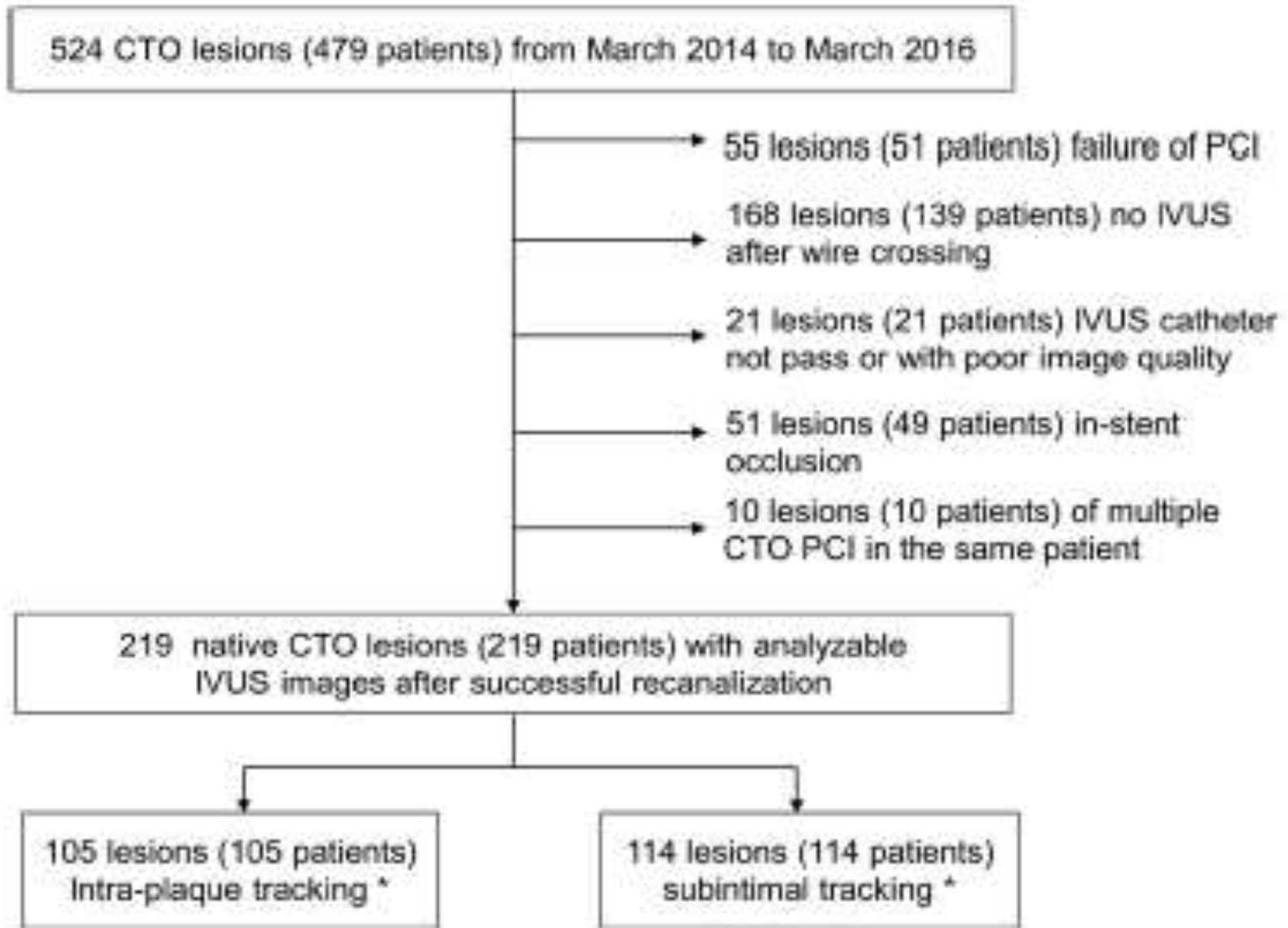
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IVUS tracking patterns examples
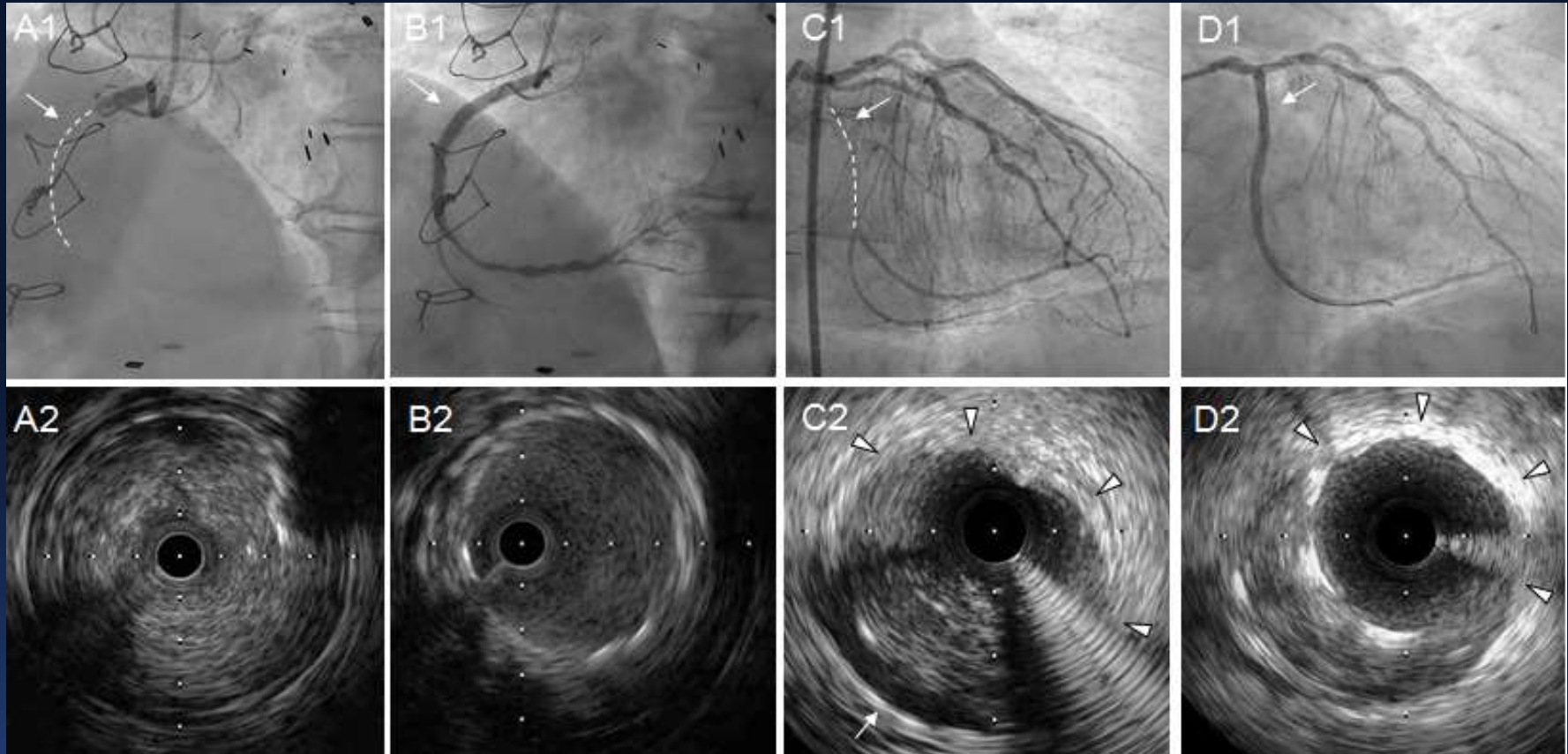
A2 Intraplaque course→ B2 after stenting
C2 Subintimal tracking (IVUS in subintimal space), D2 after stenting

Single center study design

524 CTO lesions (479 patients) from March 2014 to March 2016

→ 55 lesions (51 patients) failure of PCI

→ 168 lesions (139 patients) no IVUS after wire crossing

→ 21 lesions (21 patients) IVUS catheter not pass or with poor image quality

→ 51 lesions (49 patients) in-stent occlusion

→ 10 lesions (10 patients) of multiple CTO PCI in the same patient

219 native CTO lesions (219 patients) with analyzable IVUS images after successful recanalization

105 lesions (105 patients) Intra-plaque tracking *

114 lesions (114 patients) subintimal tracking *

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Endpoints

- **Composite of Death, MI, TLR all in-hospital**

- **Secondary IVUS determined vascular injury and perforations**

# Baseline Characteristics

	Intraplaque Tracking (n = 105)	Subintimal Tracking (n = 114)	p Value
Age, yrs.	64.1±10.5	64.5±9.2	0.71
Male	83 (79.4%)	101 (88.6%)	0.054
Diabetes mellitus	41 (39.0%)	38 (33.3%)	0.38
Hypertension	96 (91.4%)	108 (94.7%)	0.33
Hyperlipidemia	100 (95.2%)	110 (96.5%)	0.74
Smoking history	44 (41.9%)	68 (59.6%)	0.01
Glomerular filtration rate <60 mL/min	30 (28.6%)	27 (23.7%)	0.41
Current dialysis	7 (6.7%)	5 (4.4%)	0.46
Peripheral artery diseases	11 (10.5%)	19 (16.7%)	0.18
Prior myocardial infarction	31 (29.5%)	44 (38.6%)	0.16
Prior percutaneous coronary intervention	66 (62.9%)	86 (75.4%)	0.04
Prior coronary artery bypass grafting	29 (27.6%)	44 (38.6%)	0.09
Prior heart failure	22 (21.0%)	32 (28.1%)	0.22
Ejection fraction <40%	12 (11.4%)	24 (21.1%)	0.06
Clinical presentation			
Unstable angina	49 (46.7%)	52 (45.6%)	0.88
Stable angina	43 (41.0%)	52 (45.6%)	0.49
Silent ischemia	13 (12.4%)	10 (8.8%)	0.38

Angiographic procedural characteristics

	Intraplaque Tracking (n = 105)	Subintimal Tracking (n = 114)	p Value
Multivessel disease*	86 (81.9%)	97 (85.1%)	0.53
Target vessel			
Right	48 (45.7%)	60 (52.6%)	0.31
Left anterior descending	34 (32.4%)	30 (26.3%)	0.32
Left circumflex	23 (21.9%)	24 (21.1%)	0.88
Target location			
Ostial	8 (7.6%)	13 (11.4%)	0.34
Proximal	18 (17.1%)	19 (16.7%)	0.93
Middle	65 (61.9%)	66 (57.9%)	0.55
Distal	14 (13.3%)	16 (14.0%)	0.88
Side branch at proximal stump	46 (43.8%)	49 (43.0%)	0.90
Blunt proximal stump	28 (26.7%)	57 (50.0%)	<0.001
Moderate calcification	29 (27.6%)	47 (41.2%)	0.04
Severe calcification	33 (31.4%)	44 (38.6%)	0.27
Tortuosity	31 (29.5%)	51 (44.7%)	0.02
Occluded length, mm	15.6±9.0	24.5±14.1	<0.001
Length ≥20 mm	27 (25.7%)	65 (57.0%)	<0.001
Prior attempt failure	21 (20.0%)	25 (21.9%)	0.73
Japan CTO Score	1.6 ± 1.1	2.5 ± 1.1	<0.001
≥2	53 (52.4%)	96 (84.2%)	<0.001
Rentrop class 3	50 (47.6%)	44 (38.6%)	0.18
Retrograde approach	12 (11.4%)	49 (43.0%)	<0.001
Dissection reentry technique	12 (11.4%)	78 (68.4%)	<0.001
Non-CTO vessel treated	18 (17.1%)	21 (18.4%)	0.81
Drug-eluting stent implantation	105 (100%)	109 (95.6%)	0.06
Number of stents in CTO vessel	1.4 ± 0.7	2.0 ± 1.0	<0.001
Total stent length, mm	61.0 ± 27.6	84.1 ± 30.2	<0.001
Branch occlusion (diameter >1.5 mm)	17 (16.2%)	55 (48.2%)	<0.001
Fluoroscopy time, min	41.0 ± 23.1	70.0 ± 33.0	<0.001
Contrast volume, mL	270 ± 129	367 ± 163	<0.001
Radiation exposure dose, Gy	1.4 ± 1.0	2.4 ± 1.7	<0.001

Tracking Pattern Percentages by JCTO
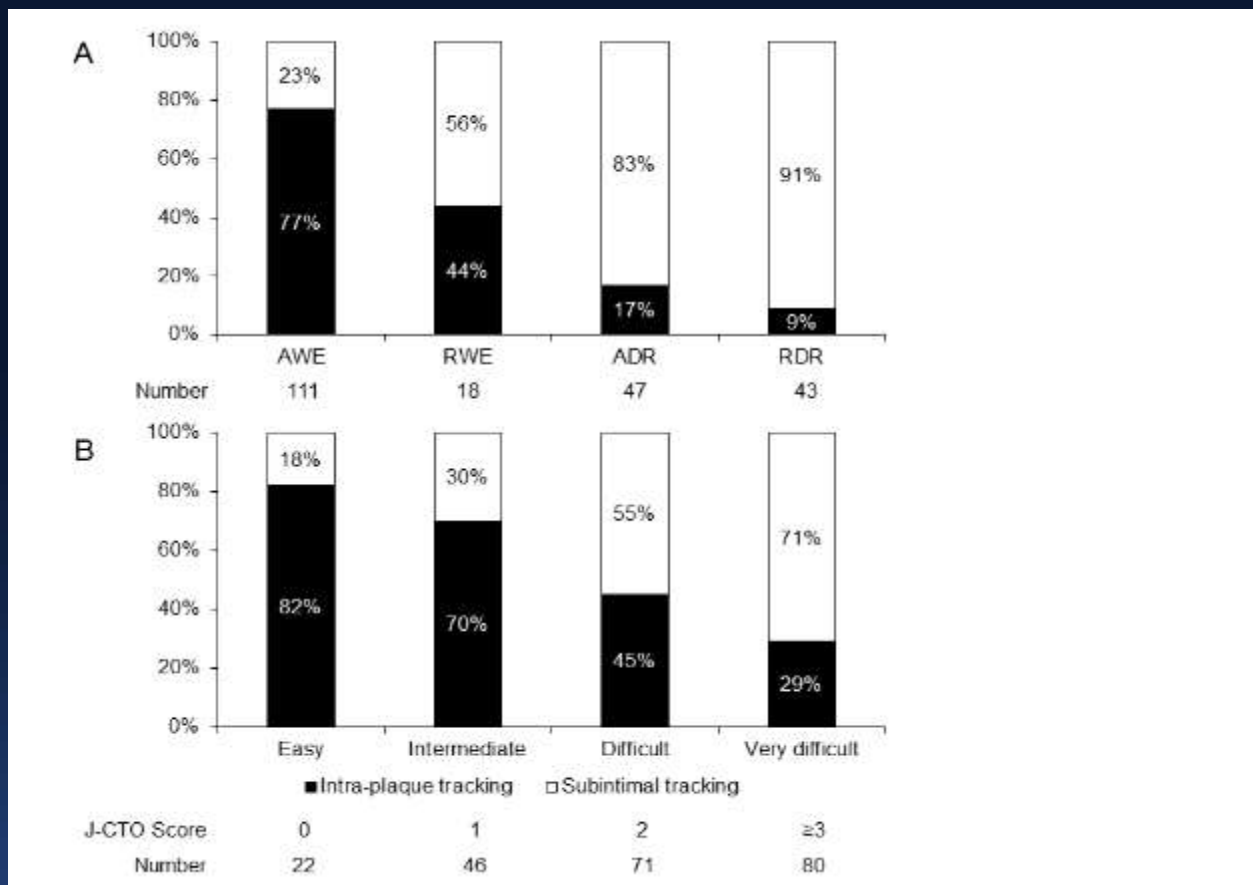
Guidewire Tracking Pattern Compared with Angiography Defined Successful Approach and Difficulty Grades
(A) Guidewire tracking pattern and successful approach by angiography. (B) Guidewire tracking pattern and difficulty grades.

Pre-stenting IVUS Findings in Successfully Recanalized CTO Lesions

	Intraplaque Tracking (n = 105)	Subintimal Tracking (n = 114)	p Value
Occluded segment length, mm	12.2 (8.0-19.9)	19.4 (11.6-29.7)	<0.001
Maximum PB post-balloon, %	82.1 (78.6-85.5)	84.8 (81.2-89.6)	<0.001
Subintimal length, mm	—	21.5 (7.3-37.2)	—
>10 mm	—	68 (59.6%)	—
Calcification in CTO lesion	92 (87.6%)	101 (88.6%)	0.82
Intramedial hematoma	22 (21.0%)	59 (51.8%)	<0.001
Perivascular hematoma	12 (11.4%)	44 (38.6%)	<0.001
Total length of hematoma, mm	9.3 (5.5-13.7)	13.8 (7.1-23.6)	0.06
Perivascular blood speckle	48 (45.7%)	90 (78.9%)	<0.001
Any IVUS-VI *	55 (52.4%)	102 (89.5%)	<0.001

Post-stent Intravascular Ultrasound Findings of Successful Recanalized CTO Lesions

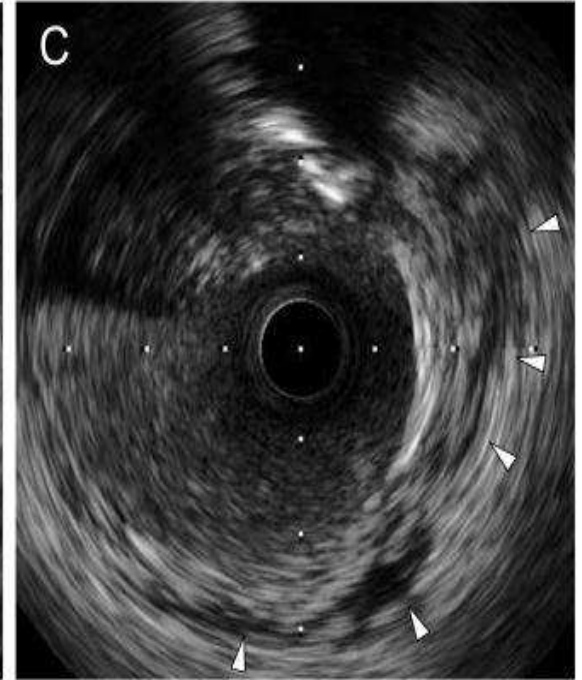|	Intraplaque Tracking (n = 98)	Subintimal Tracking (n = 84)	p Value
Total stent length, mm	47.2 (35.8-60.5)	69.9 (54.9-84.7)	<0.001
Subintimal stent length, mm	—	16.7 (7.3-32.2)	—
MSA in entire stent, mm^2	5.4 (4.2-7.3)	4.8 (3.9-6.1)	0.25
MSA in CTO segment, mm^2	6.1 (5.1-8.3)	6.2 (4.8-6.9)	0.55
Malapposition	16 (16.3%)	12 (14.3%)	0.70
Significant[ll]	10 (10.2%)	7 (8.3%)	0.67
Tissue protrusion	5 (5.1%)	17 (20.2%)	0.002
Significant†	3 (3.1%)	7 (8.3%)	0.19

Example of IVUS-Vascular Injury
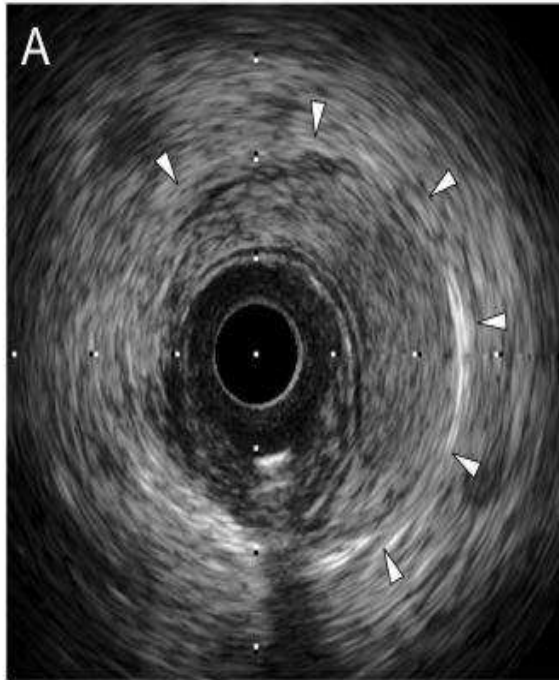

Intramedial hematoma   Perivascular hematoma   Perivascular blood speckle

Clinical outcomes – In hospital

	Intraplaque Tracking (n = 105)	Subintimal Tracking (n = 114)	p Value
Composite cardiovascular endpoint*	2 (1.9%)	9 (7.9%)	0.04
All-cause death	0	0	—
SCAI PMI	2 (1.9%)	8 (7.0%)	0.10
Universal definition PMI	3 (2.9%)	10 (8.8%)	0.06
Target lesion revascularization	0	1 (0.9%)	1.00
Secondary cardiovascular endpoint†	22 (21.0%)	64 (56.1%)	<0.01
Any dye staining/extravasation	4 (3.8%)	16 (14.0%)	0.01
Clinically significant perforation‡	1 (1.0%)	7 (6.1%)	0.07
Collateral injury	1 (1.0%)	0	0.48
Wire perforation	0	3 (2.6%)	0.25
Balloon/stent related	0	4 (3.5%)	0.12
Tamponade	1 (1.0%)	2 (1.8%)	1.00
Stent thrombosis	0	0	—
In-hospital CABG	0	0	—
Stroke	1 (1.0%)	0	0.48
Acute renal failure	1 (1.0%)	1 (0.9%)	1.00

IVUS Procedure related outcomes
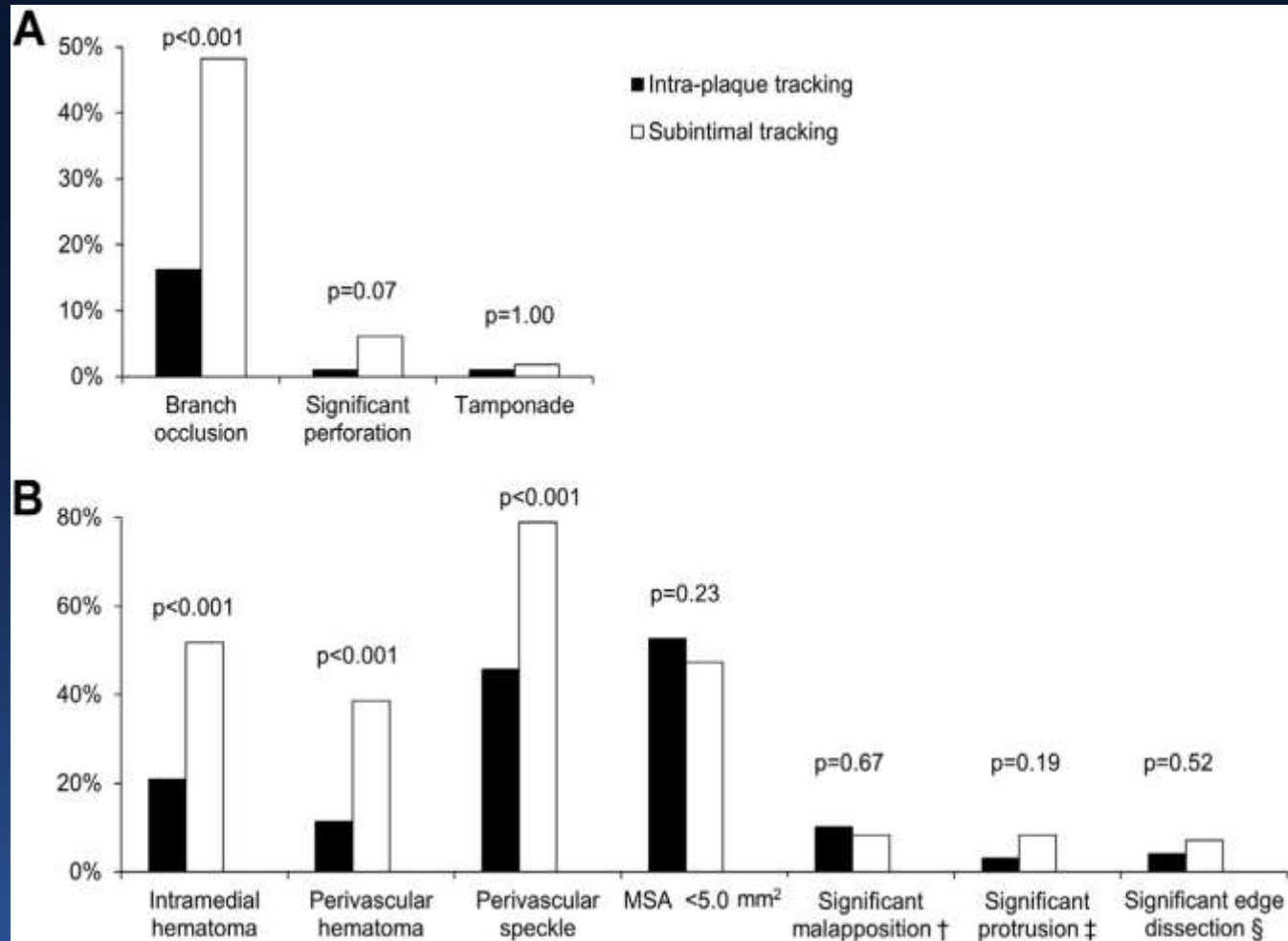
Conclusions in-hospital data

- **219 CTOs – 105 intraplaque course and 114 had subintimal course as determined by IVUS**

- **Subintimal tracking occurred in more complex anatomical subsets with a higher JCTO score (1.6 vs. 2.5, p <0.001)**

- **No deaths in either group, but higher rates of composite of death, MI, in-hospital TLR occurred the subintimal arm. Driven by periprocedural MI.**

- **Higher rates of secondary IVUS endpoint- dye staining/extravasation, branch occlusion, or MI.**

- **Non-significant higher rate of perforation in subintimal tracking arm.**

CTO IVUS 1 Year results

WILEY

ORIGINAL STUDIES

Intravascular ultrasound analysis of intraplaque versus subintimal tracking in percutaneous intervention for coronary chronic total occlusions: One year outcomes
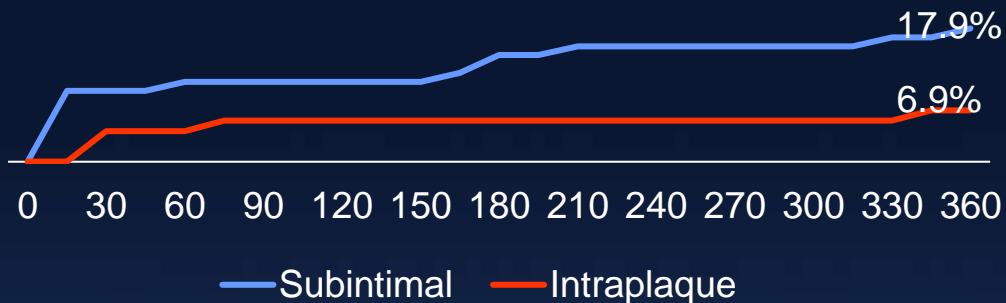
Matthew T. Finn MD, MS[1,2] | Darshan Doshi MD, MS[1,2] | Jacob Cleman MD[1] | Lei Song MD[3] | Akiko Maehara MD[1] | Raja Hatem MD[4] | Björn Redfors MD, PhD[2,5] | Sanjog Kalra MD, MS[6] | Justin A. Fried MD[1] | Ming Liao MA[1] | Candido Batres MD[1] | Jeffery W. Moses MD[1,2] | Manish A. Parikh MD[1,2] | Michael B. Collins MD[1,2] | Tamim M. Nazif MD[1,2] | Khady N. Fall MD[1] | Phillip Green MD[1,2] | Ajay J. Kirtane MD[1,2] | Ziad A. Ali MD DPhil[1,2] | Martin B. Leon MD[1,2] | Gary S. Mintz MD[1,2] | Dimitri Karmpaliotis MD, PhD[1,2]

Unadjusted 1-Year Outcomes in Successfully Recanalized CTO Lesions

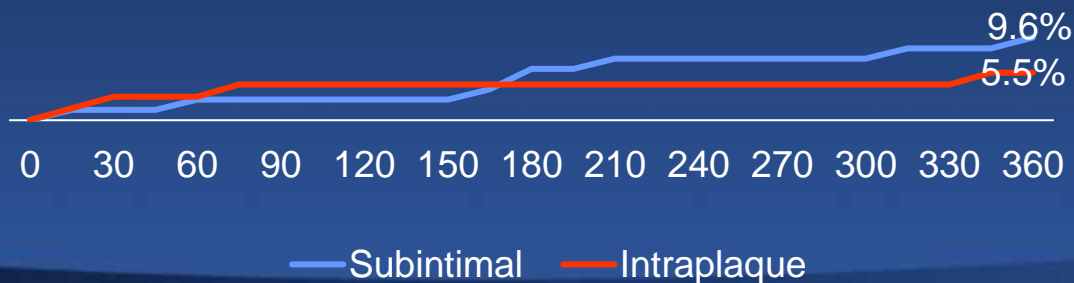|	Intraplaque Tracking (n = 73)	Subintimal Tracking (n = 84)	HR/OR;* 95% CI	P Value log rank
1-Year outcomes				
Target Vessel Failure†	5 (6.9)	15 (17.9)	2.74 (1.00-7.54)	0.04
Major Adverse Cardiovascular Events	7 (9.6)	17 (20.3)	2.24 (0.93-5.41)	0.06
All-Cause Death	3 (4.1)	3 (3.6)	0.86 (0.17- 4.24)	0.85
Cardiovascular Death	2 (2.8)	2 (2.4)	0.86 (0.12-6.10)	0.88
Target Vessel MI	2 (1.9)	8 (9.6)	3.52 (0.75-16.60)	0.08
Peri-Procedural MI	2 (2.7)	6 (7.14)	2.73 (0.53-13.97)*	0.29
Definite/ Probable Stent Thrombosis	1 (1.4%)	0 (0.0)	0.29 (0.012-7.13)*	0.47
Target Vessel Revascularization	2 (2.8)	7 (8.5)	3.12 (0.64-15.03)	0.13
Coronary Artery Bypass Grafting	0 (0.0)	1 (1.19)	2.64 (0.11-65.8)*	1.0
Cardiovascular Rehospitalization	9 (12.7)	8 (9.7)	0.71 (0.28-1.85)	0.51
Change In Ejection Fraction	+2.0% ± 11	+3.7% ± 12.2		0.59

1 Year: Target Vessel Failure

P log rank = 0.04

17.9%

6.9%

0 30 60 90 120 150 180 210 240 270 300 330 360

——— Subintimal   ——— Intraplaque

Landmark Discharge to 1 Year: Target Vessel Failure

P log rank = 0.36

9.6%
5.5%

0 30 60 90 120 150 180 210 240 270 300 330 360

——— Subintimal   ——— Intraplaque

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1 Year Major Adverse Cardiovascular Events

P log rank = 0.06

20.3%

9.6%

0   30   60   90   120 150 180 210 240 270 300 330 360

— Subintimal   — Intraplaque
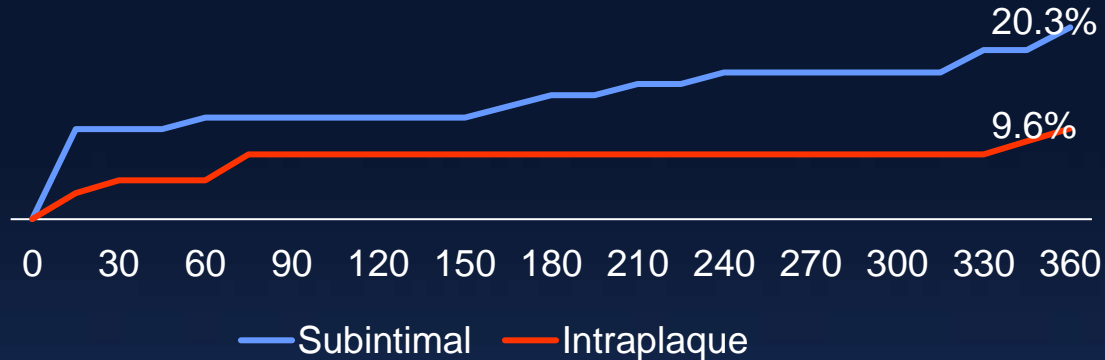
Discharge to 1 Year Major Adverse Cardiovascular Events

P log rank = 0.29

12.4%
6.7%

0   30   60   90   120 150 180 210 240 270 300 330 360

— Subintimal   — Intraplaque

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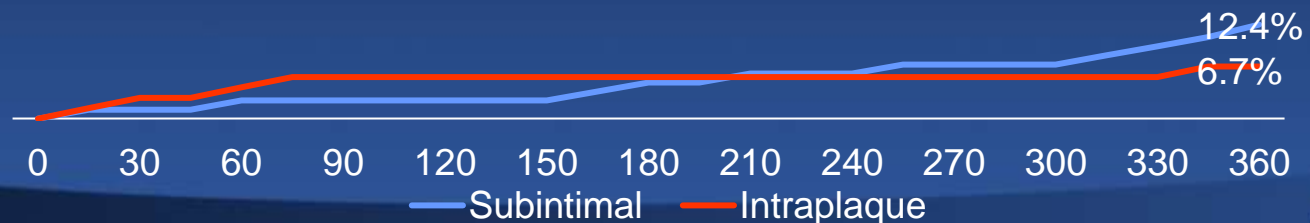
MV adjustment no significant differences at a year

Predictors of Target Vessel Failure*	Univariate			Multivariable		
	HR	95% CI	P Value	HR	95% CI	P value
Subintimal Tracking	2.74	1.00-7.54	0.04	1.51	0.38-6.00	0.55
Japanese CTO Score‡	1.75	1.20 -2.56	0.004	1.40	0.74-2.62	0.30
History of Coronary Artery Bypass Grafting	1.51	0.63-3.66	0.85	0.75	0.20-2.77	0.66
History of Percutaneous Coronary Intervention	2.51	0.74-8.56	0.14	4.87	0.81-29.21	0.08
Retrograde approach	2.38	0.99-5.7	0.053	1.55	0.39-6.1	0.53
IVUS Vascular injury	3.83	0.88-16.50	0.07	2.50	0.25-24.86	0.43
Minimal Stent Area	0.87	0.63-1.19	0.37	0.98	0.68-1.41	0.92
Angiographic and IVUS predictors of MACE*	HR	95% CI	P Value	HR	95% CI	Adjusted P value
Subintimal Tracking	2.24	0.93-5.41	0.06	1.83	0.52-6.46	0.34
Japanese CTO Score‡	1.60	1.13-2.26	0.008	1.37	0.80-2.36	0.25
History of Coronary Artery Bypass Grafting	1.60	0.70-3.50	0.27	0.83	0.26-2.62	0.74
History of Percutaneous Coronary Intervention	1.69	0.63-4.51	0.30	2.14	0.57-8.04	0.26
Retrograde approach	2.04	0.91-4.55	0.08	1.30	0.38-4.27	0.78
IVUS Vascular injury	2.14	0.73-6.27	0.16	1.02	0.22-4.76	0.97
Minimal Stent Area	0.99	0.76-1.28	0.01	1.12	0.84-1.49	0.46

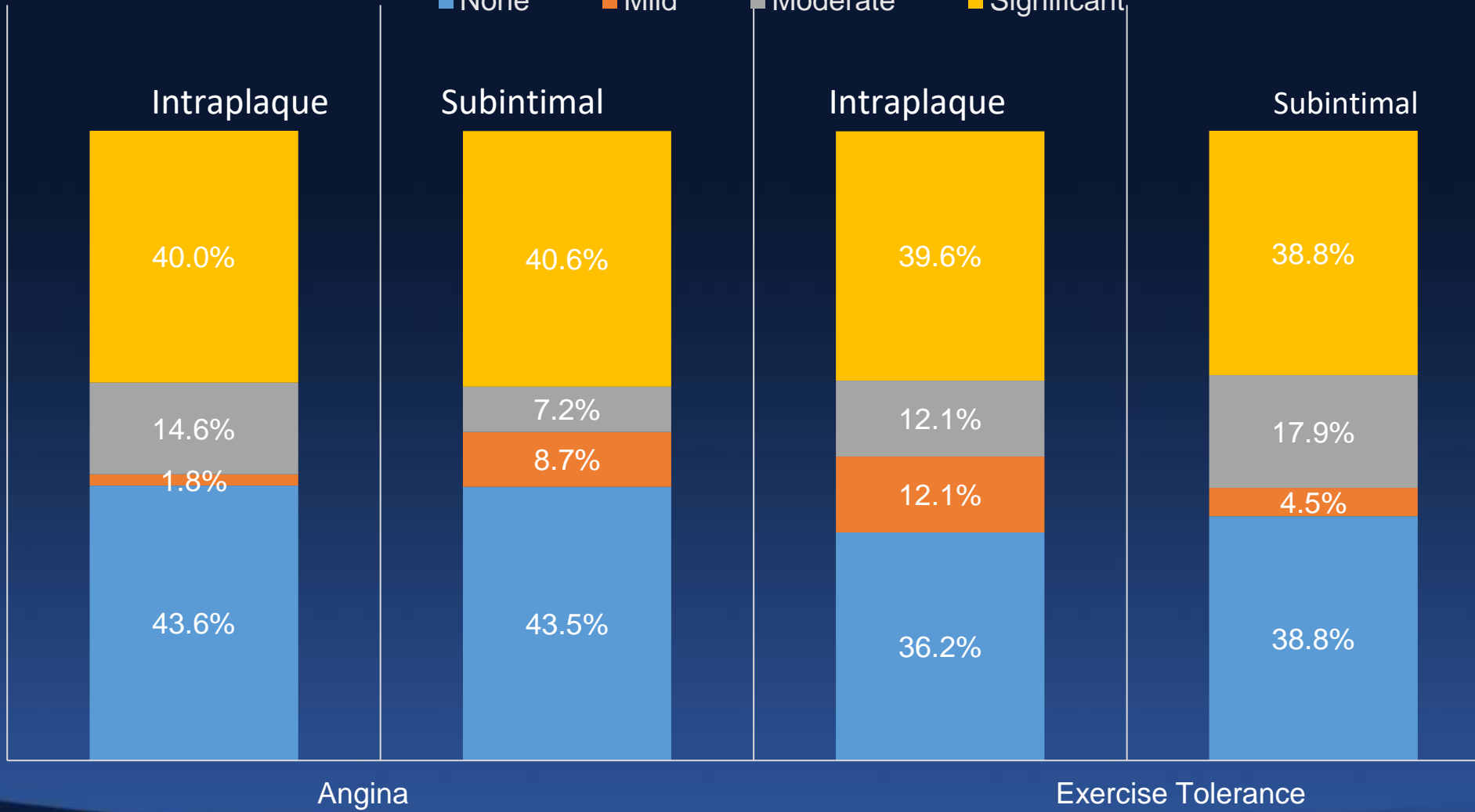*Multivariable Models also adjusted for Age, Gender, DM, and Ejection Fraction
†Log rank test used
‡treated as an ordinal variable
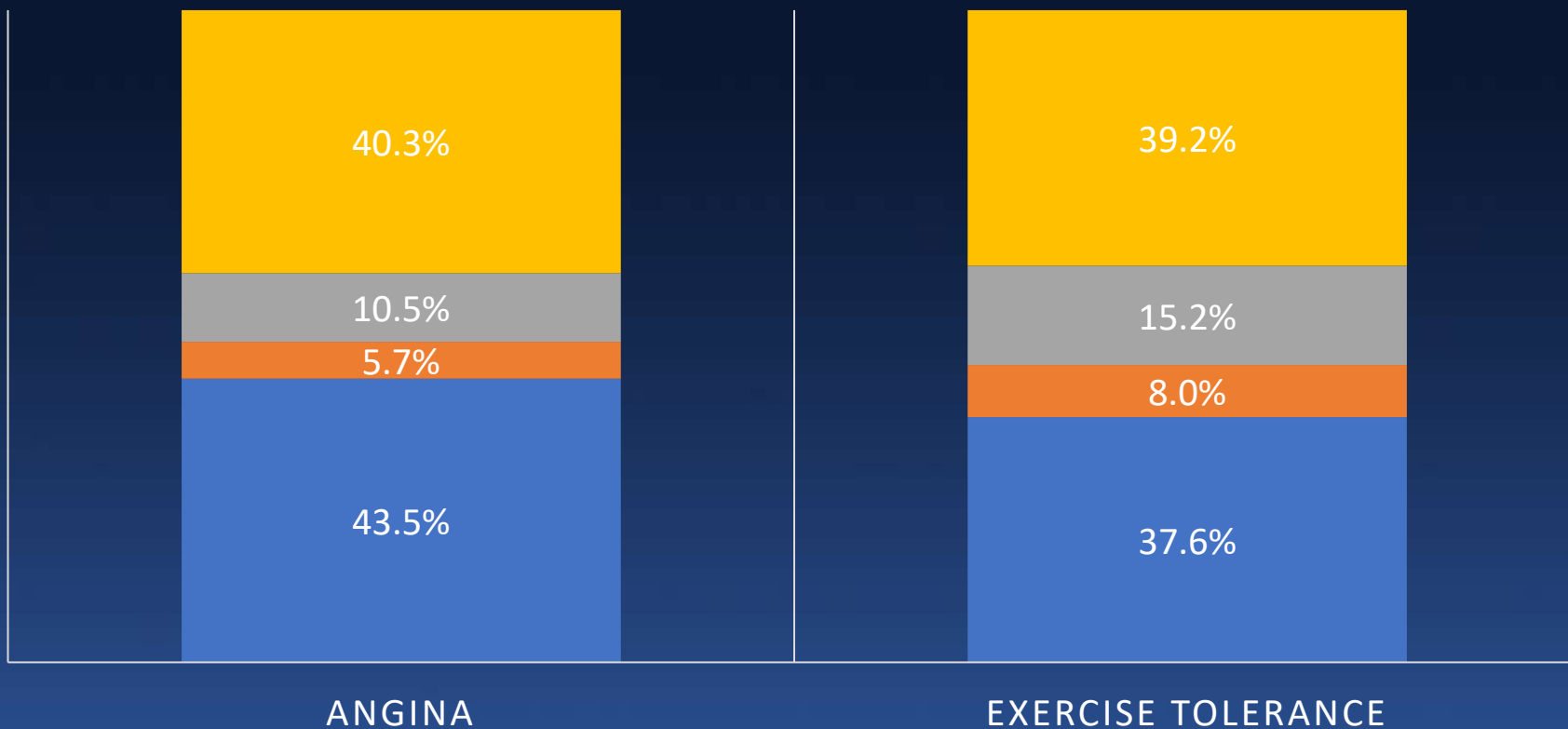Abbreviations: CTO – chronic total occlusion, IVUS – intravascular ultrasound.

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PATIENT REPORTED SYMPTOM IMPROVEMENT AT 1 YEAR - INTRAPLAQUE VS. SUBINTIMAL
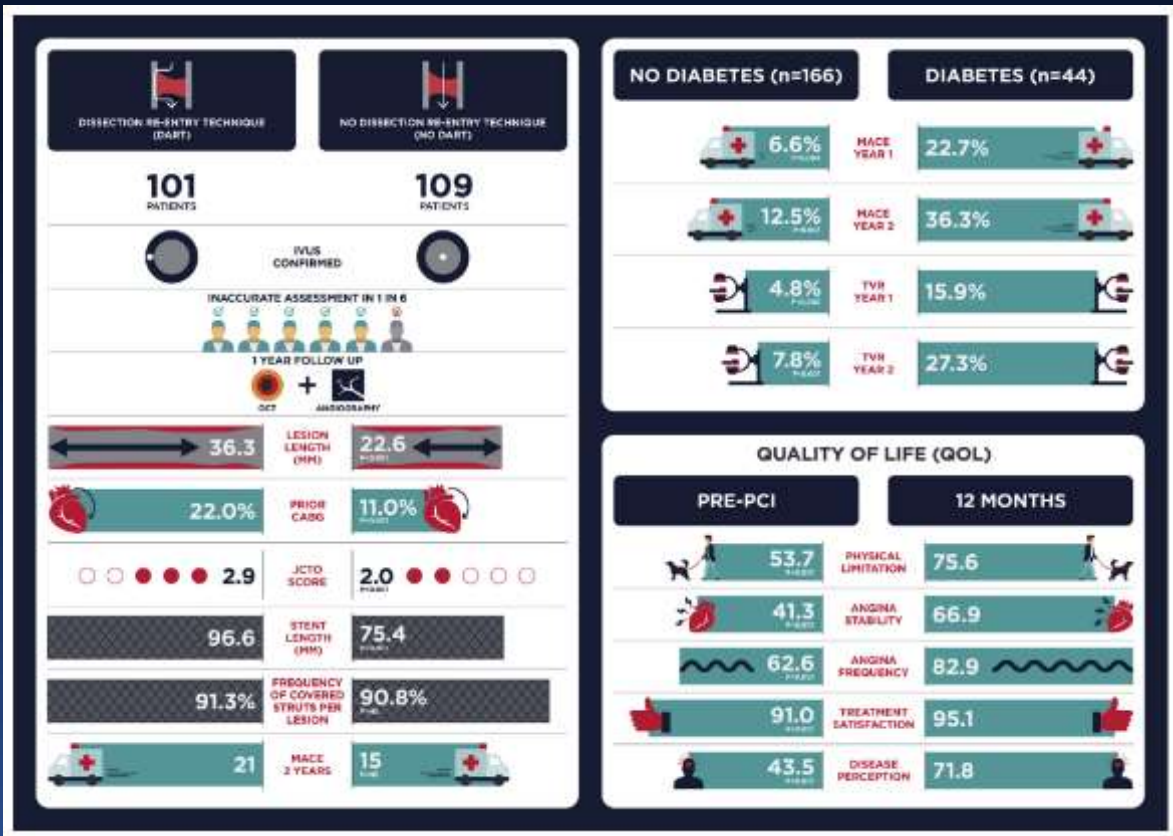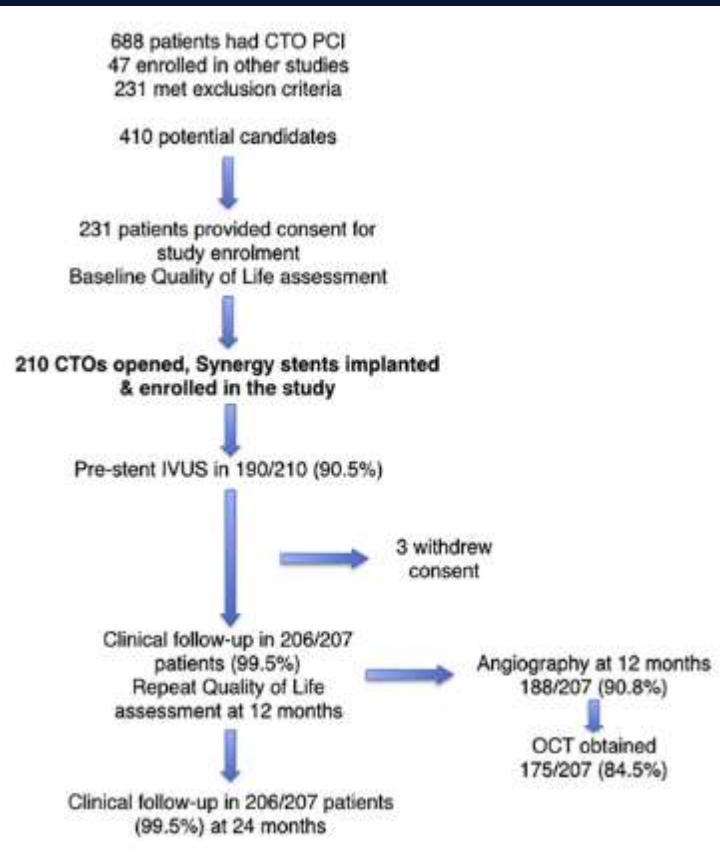
PATIENT REPORTED SYMPTOM IMPROVEMENT AT 1 YEAR OVERALL COHORT

CONSISTENT CTO Study

Walsh S, Spratt J. *JACC Cardiovasc Interv.* 2020:1448 – 57.

CONSISTENT CTO Study

688 patients had CTO PCI
47 enrolled in other studies
231 met exclusion criteria

410 potential candidates

231 patients provided consent for
study enrolment
Baseline Quality of Life assessment

**210 CTOs opened, Synergy stents implanted
& enrolled in the study**

Pre-stent IVUS in 190/210 (90.5%)

3 withdrew
consent

Clinical follow-up in 206/207
patients (99.5%)
Repeat Quality of Life
assessment at 12 months

Angiography at 12 months
188/207 (90.8%)

OCT obtained
175/207 (84.5%)

Clinical follow-up in 206/207 patients
(99.5%) at 24 months

	All Patients (N = 167)	DART (N = 79)	No DART (n = 87)	p Value
Struts analyzed per segment	2,689.4 ± 1,306.4	2,665.1 ± 1,253.2	2,689.8 ± 1,344.9	0.903
Proximal reference				
Minimal diameter (mm)	3.1 ± 0.7	3.1 ± 0.6	3.0 ± 0.7	0.327
Maximal diameter (mm)	3.7 ± 0.7	3.8 ± 0.7	3.6 ± 0.7	0.068
Distal reference				
Minimal diameter (mm)	2.5 ± 1.3	2.5 ± 0.6	2.4 ± 0.5	0.244
Maximal diameter (mm)	2.9 ± 1.7	3.1 ± 0.7	2.8 ± 0.6	0.003
In-stent CS area (mm^2)	8.2 ± 2.5	8.6 ± 2.7	7.9 ± 2.2	0.068
Neointimal hyperplasia area at maximal obstruction (mm^2)	1.8 ± 1.3	1.9 ± 1.4	1.7 ± 1.1	0.305
Neointimal hyperplasia area (mm^2)	1.3 ± 0.7	1.4 ± 0.7	1.3 ± 0.6	0.323
Neointimal obstruction (%)	16.9 ± 8.0	16.3 ± 8.1	17.4 ± 7.9	0.377
Stent area stenosis (%)	31.1 ± 15.3	31.8 ± 16.0	30.4 ± 14.6	0.556
Frequency of covered struts per lesion (%)	91.1 ± 9.8	90.1 ± 10.0	91.9 ± 9.6	0.238
Frequency of uncovered struts per lesion (%)	6.4 ± 6.4	7.0 ± 6.6	5.9 ± 6.1	0.226
Maximum consecutive length of uncovered struts (mm)	1.9 ± 1.9	2.1 ± 2.0	1.8 ± 1.8	0.311
Maximum	13.2	10.0	13.2	
Frequency of malapposed struts per lesion (%)	2.5 ± 4.7	2.9 ± 4.7	2.2 ± 4.6	0.334
Maximum consecutive length of malapposed struts (mm)	1.2 ± 1.7	1.4 ± 1.9	1.0 ± 1.6	0.143
Maximum	9.6	9.6	8.7	
Persistent dissection in stent	6 (3.6)	4 (5.1)	2 (2.3)	0.425
Aneurysm formation	11 (6.6)	8 (10.1)	3 (3.4)	0.119

Walsh S, Spratt J. *JACC Cardiovasc Interv.* 2020:1448 – 57.

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Conclusions from the IVUS studies

- In adjusted analyses, subintimal tracking was not associated with TVF at 1-year, despite numerically higher upfront rates of MI and TLR.

- Subintimal tracking was a marker of higher patient and anatomic CTO complexity with greater use of the retrograde approach

- Patients had significant symptom improvement regardless of tracking type

- Zero in hospital deaths with only 3 clinically significant tamponade events.

THANK YOU