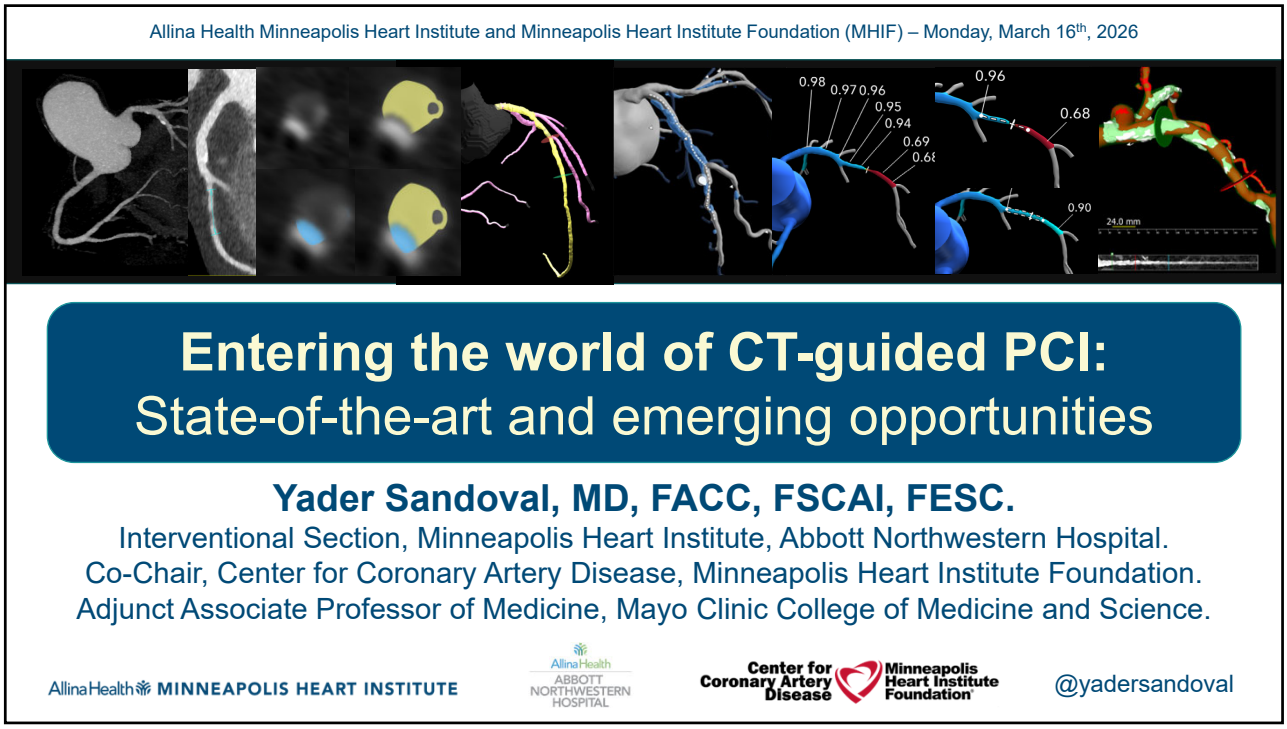

Minneapolis Heart Institute Foundation
GRAND ROUNDS

1


Allina Health Minneapolis Heart Institute and Minneapolis Heart Institute Foundation (MHIF) – Monday, March 16th, 2026
0.98
0.97
0.96
0.95
0.94
0.69
0.68
0.96
0.68
0.90
24.0 mm
Entering the world of CT-guided PCI:
State-of-the-art and emerging opportunities
Yader Sandoval, MD, FACC, FSCAI, FESC.
Interventional Section, Minneapolis Heart Institute, Abbott Northwestern Hospital.
Co-Chair, Center for Coronary Artery Disease, Minneapolis Heart Institute Foundation.
Adjunct Associate Professor of Medicine, Mayo Clinic College of Medicine and Science.
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Center for Coronary Artery Disease
Minneapolis Heart Institute Foundation
@yadersandoval

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DISCLOSURES

- Dr. Sandoval reports consulting and/or speaker honoraria from Abbott Vascular, Boston Scientific, CathWorks, Cleerly, GE Healthcare, HeartFlow, Medtronic, Philips, Roche Diagnostics, and Siemens Healthineers; research support from Cleerly, HeartFlow, and Shockwave Medical; owner, Systole LLC; and holds patent 20210401347 with others.

3

DISCLOSURES

- **I am an interventional cardiologist.**
- **I am not a CT reader.**
- **I am not board certified by the SCCT.**
- **My/our goal is to understand how to best use the available tools to improve patient outcomes.**

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OBJECTIVES

1. Define what is CT-guided PCI and rationale for it.
2. Describe approach to performing CT-guided PCI, such as virtual stenting, plaque and calcium characterization, and CT co-registration, including applications in key lesion subsets.
3. Discuss evidence-base and future directions.

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CCTA-guided PCI: Beyond the report – the interventional cardiologist (either independently if trained in CT-guided PCI or in collaboration with a cardiac imager) must interact with the data to guide pre-procedural planning.

CCTA-guided PCI: definition and key components

CCTA-guided PCI is defined as a PCI procedure in which CCTA information is used to guide PCI planning through a detailed review of the CCTA images by the interventional cardiologist, either in collaboration with a cardiac imager or independently if trained in CCTA-guided PCI. This process informs operators about disease complexity, including lesion morphology and vessel dimensions for device selection, as well as functional significance when feasible.

Sandoval Y, Leipsic J, Collet C, Ali ZA, Azzalini L, Barbato E, Cavalcante JL, Costa RA, Garcia-Garcia HM, Jones DA, Khoo JK, Maran A, Nieman K, Pinilla-Echeverri N, Seto AH, Shlofmitz E, Brilakis ES. Coronary computed tomography angiography to guide percutaneous coronary intervention: Expert opinion from a SCAI/SCCT roundtable. J Cardiovasc Comput Tomogr. 2025 May-Jun;19(3):277-290. doi: 10.1016/j.jcct.2025.04.015. Epub 2025 May 12. PMID: 40360362.

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"Negative" results for SIHD PCI: Are we really surprised?

Poor adoption of modern PCI techniques.

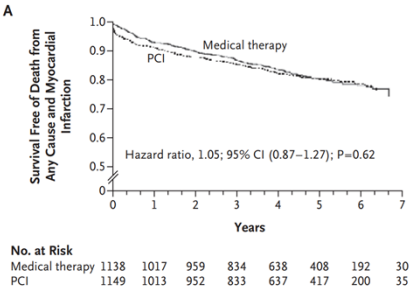
➡ Low use of coronary physiology to identify lesions that benefit from revascularization (**patient selection**).

➡ Low use of intracoronary imaging for PCI guidance.

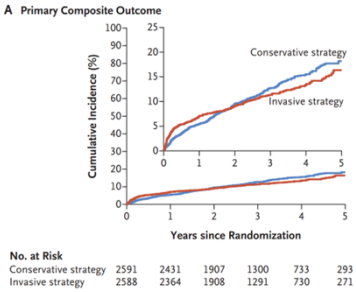
➡ Low use of imaging and/or physiology for assessment post-PCI results.

Downstream effects: under-expanded stents and ISR epidemic, repeat revascularization, poor outcomes.

COURAGE trial



ISCHEMIA trial



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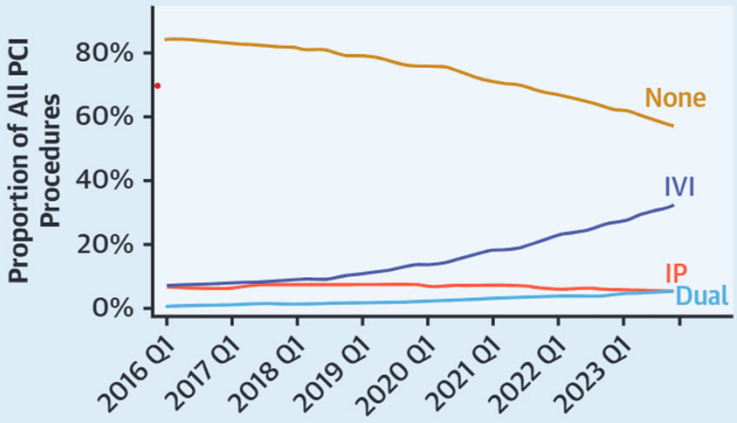
Use of intravascular imaging and invasive physiology during PCI among Medicare beneficiaries in the U.S.

2023: intravascular imaging → 30% and invasive physiology → 5%



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Medina FA et al. Adjunctive Imaging and Physiology During Percutaneous Coronary Intervention: Trends, Outcomes, and Costs Among Medicare Beneficiaries. JACC Cardiovasc Interv. 2026 Jan 12;19(1):15-27.

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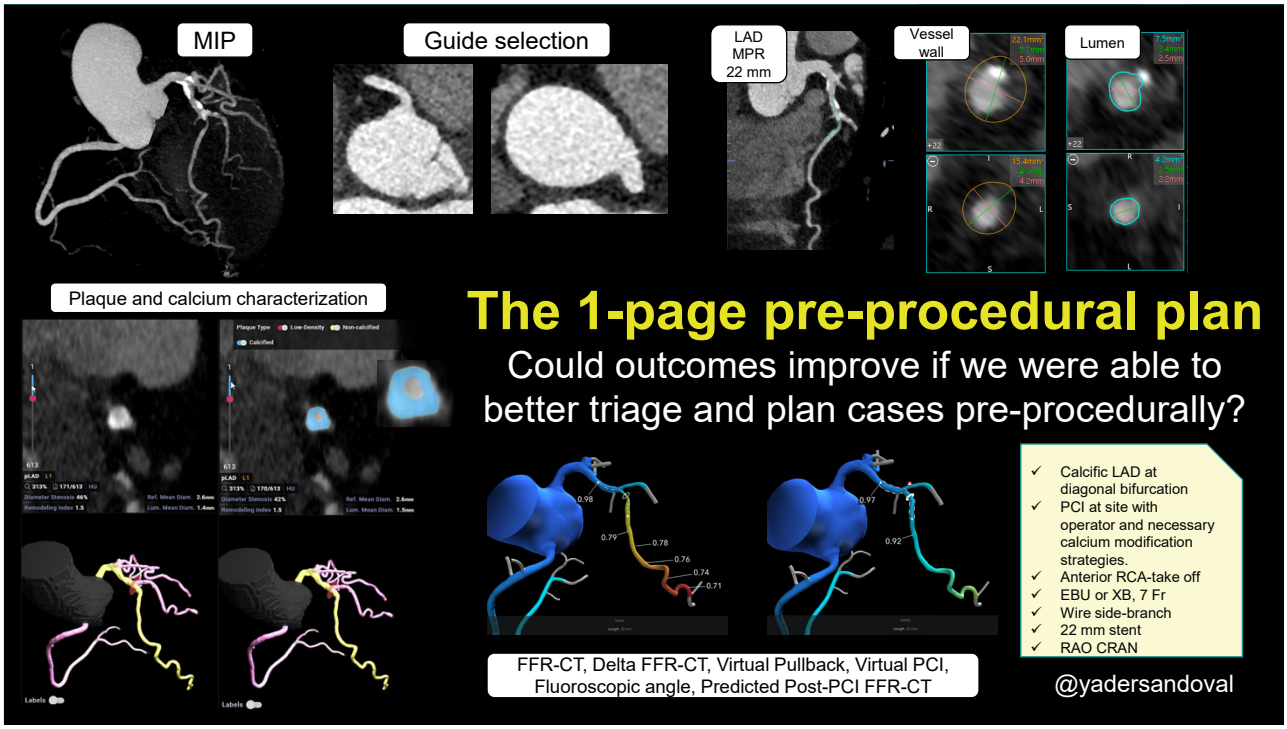

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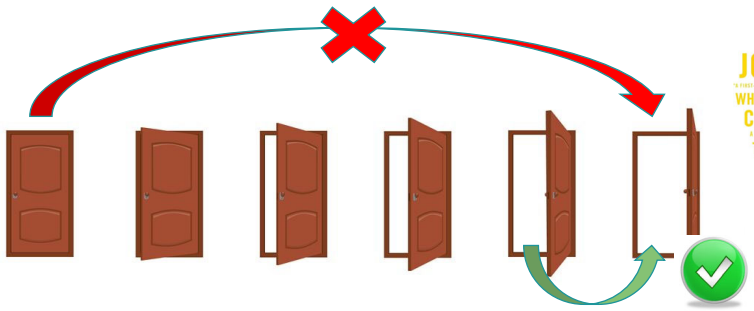
The adjacent possible concept: "Where good ideas come from"

"Ahead of our time" The field was not ready 10 years ago



Technological (and scientific) advances rarely break out of the **adjacent possible**.

The history of progress is, almost without exception, **a story of one door leading to another door.**

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Initial report of "**CT-guided PCI**" in peer-reviewed literature to support CTO PCI in *2010* (>15 years ago!)

Computed tomography angiography-guided percutaneous coronary intervention in chronic total occlusion*

Ping LI, Lu-yue GAI†‡, Xia YANG, Zhi-jun SUN, Qin-hua JIN
(Department of Cardiology, [illegible], China)
†E-mail: luyuegai301@yahoo.com.cn
Received June 30, 2010; Revision accepted July 13, 2010; Crosschecked July 14, 2010

N=74 CTOs

Abstract: Objective: The aim of this study is to investigate if dual-source computed tomography (DSCT) could guide the percutaneous coronary intervention (PCI) of chronic total occlusion (CTO). Methods: We enrolled patients who were confirmed to have at least one native coronary artery CTO by DSCT before they underwent selective PCI in the period from December 2007 to October 2008. A CTO was defined as an obstruction of a native coronary artery with no CT-guided PCI procedure involved placing CT and fluoroscopic images side-by-side on the screen. DSCT images were analyzed for location, segment, plaque characteristics, calcification, and proximal lumen diameter of the CTO before PCI. The guidewire was advanced and manipulated under CT guidance. The PCI was

"The **CT-guided PCI** procedure involved placing CT and fluoroscopic images side-by-side on the screen. DSCT images were analyzed for ***location***, segment, ***plaque characteristics***, ***calcification***, and proximal lumen ***diameter*** of the CTO before PCI".

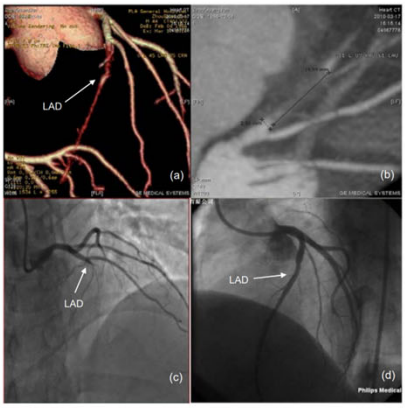

Fig. 1 Computed tomography angiography-guided percutaneous coronary intervention
The lumen of soft tissue was clearly visualized by both volume-rendered (VR) (a) and multiplanar-reformatted (MPR) (b). Coronary angiography (CAG) was performed before (c) and after (d) PCI

Li P, Gai LY, Yang X, Sun ZJ, Jin QH. **Computed tomography angiography-guided percutaneous coronary intervention in chronic total occlusion**. J Zhejiang Univ Sci B. 2010 Aug;11(8):568-74

Slide by Y. Sandoval, M.D.

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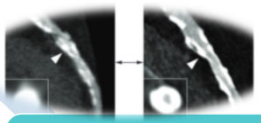
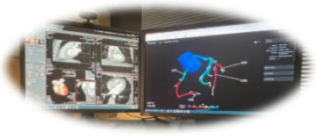
Heart team
(lessons from the TAVR experience)

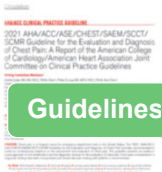
Better hardware
(scanner)



Better software
(visualization tools)

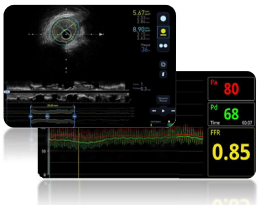


CT-guided PCI:
Why now?



Guidelines, ↑ use

Multidisciplinary collaboration and education



Established role of invasive imaging and physiology for PCI guidance

Slide by Y. Sandoval, M.D.

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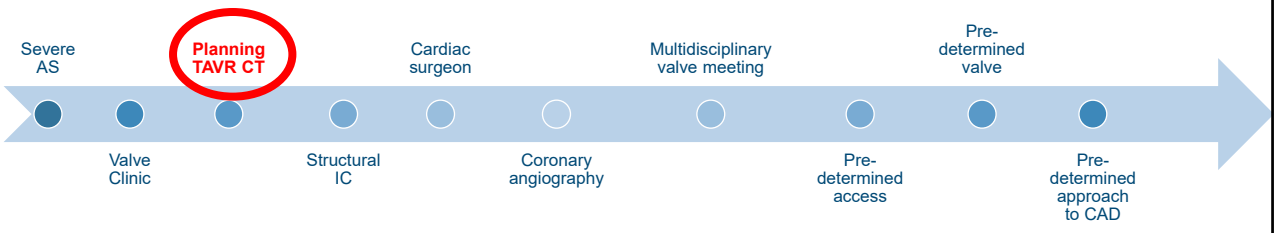
CT-guided PCI and the adjacent possible: Lessons from the heart-team approach and multidisciplinary collaboration

Approach to severe aortic stenosis and TAVR: strategic, multidisciplinary planning



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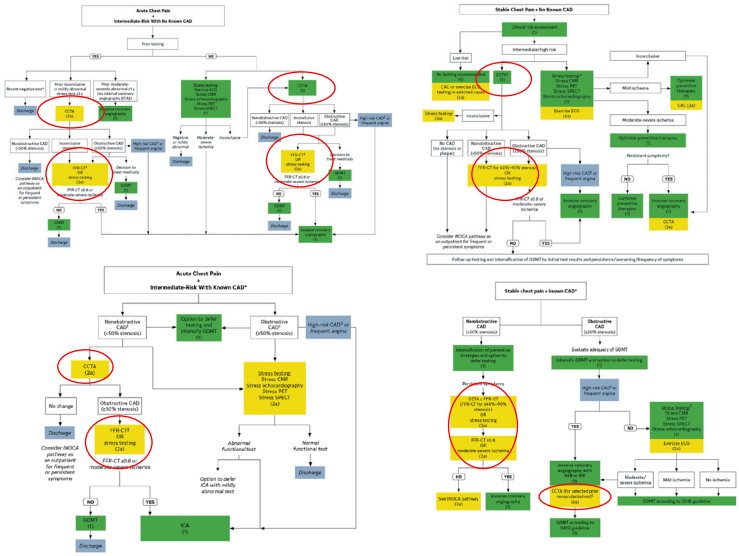
CT-guided PCI and the adjacent possible: Chest Pain Guidelines

Increasing role of coronary CT to evaluate with patients suspected or established CAD.



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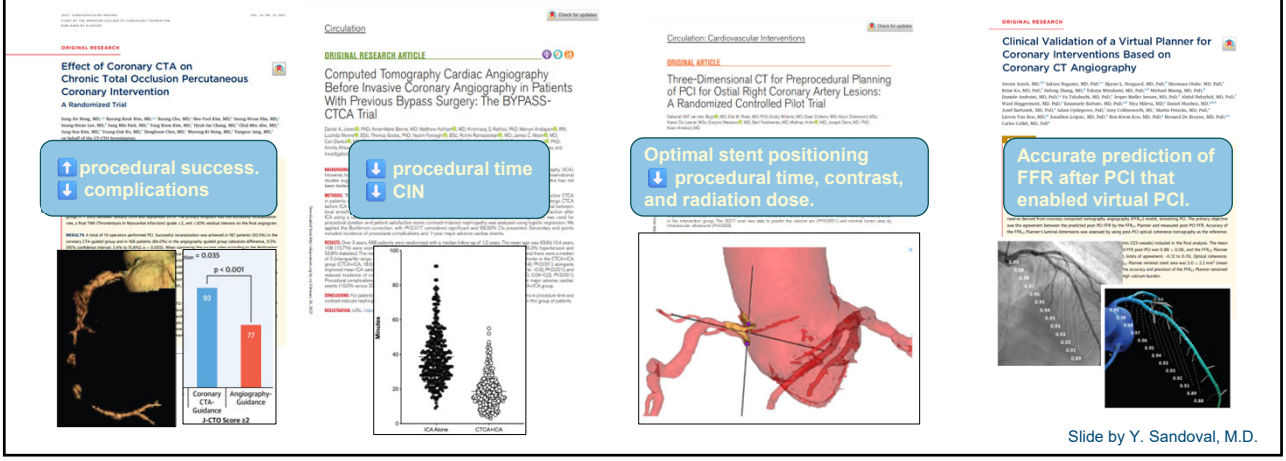
CT-guided PCI and the adjacent possible: ↑ evidence

Randomized trials

Multi-center prospective P3 study

CT-guided CTO PCI	CT-guided ICA prior CABG	CT guidance for ostial lesions	Validation of FFR_{CT} virtual PCI planner
↑ procedural success. ↓ complications	↓ procedural time ↓ CIN	Optimal stent positioning ↓ procedural time, contrast, and radiation dose.	Accurate prediction of FFR after PCI that enabled virtual PCI.



Slide by Y. Sandoval, M.D.

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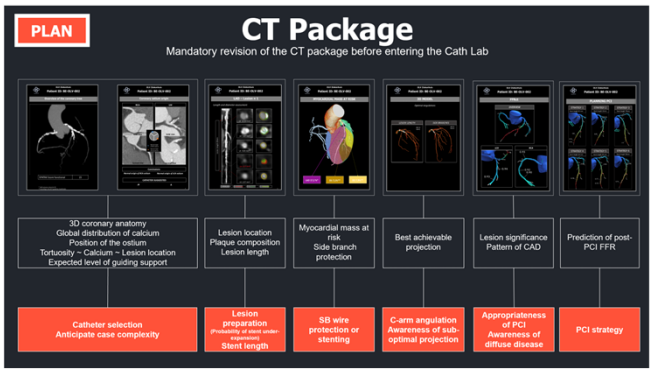
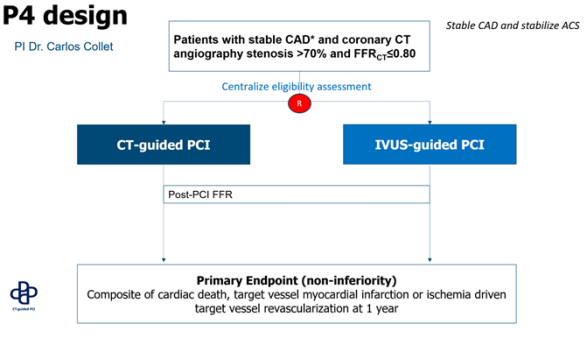
Pivotal P4 randomized trial

CCTA-guided PCI vs. IVUS-guided PCI





*Several investigational applications such as myocardial mass, 3D plaque & calcium models, live CT co-registration guidance

*** Completed enrollment (n=1,104) August '25**

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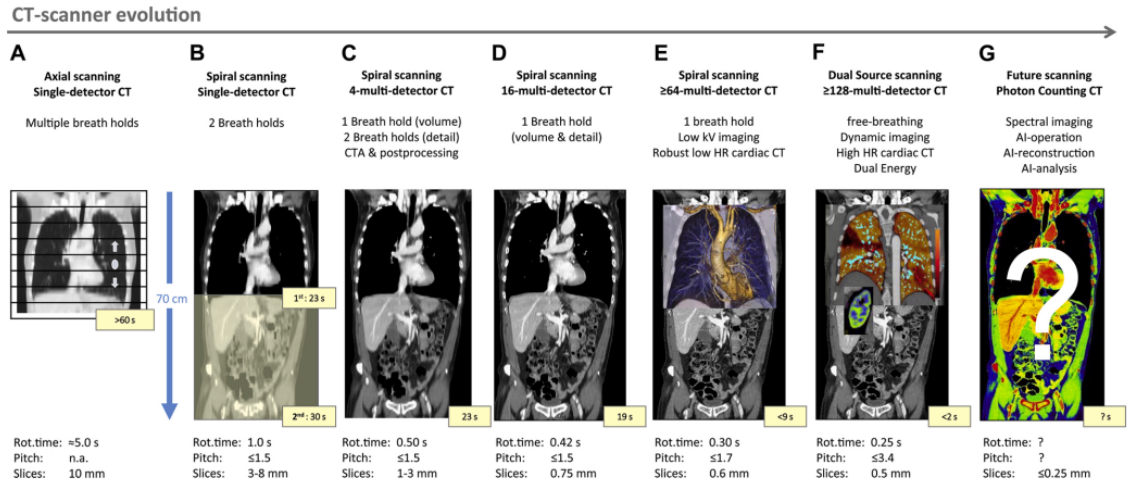
CT-guided PCI: technological improvements, automation, AI.

R. Booij et al. European Journal of Radiology 131 (2020) 109261



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Photon-Counting CT Scanners: Entering a New Era in Coronary Imaging

Photon-counting CT (PCCT) **counts individual x-ray photons** rather than measuring total energy, enabling **higher spatial resolution** and improved tissue characterization compared with conventional CT.

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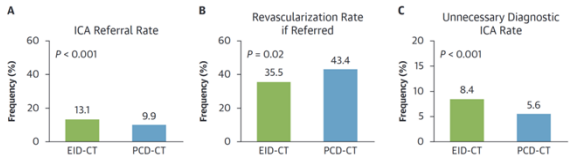
Diagnostic Performance and Clinical Impact of Photon-Counting Detector Computed Tomography in Coronary Artery Disease

Koshiro Sakai, MD, PhD,[a,b,c,*] Doosup Shin, MD,[a,*] Mandeep Singh, BS,[a] Sarah Malik, MD,[a] Ali Dakroub, MD,[a] Zainab Sami, BS,[a] Jonathan Weber, MPH,[a] J. Jane Cao, MD, MPH,[a,d] Roosha Parikh, MD,[a,d] Lu Chen, MD,[a,d] Fernando Sosa, MS, MBA,[a] David J. Cohen, MD, MSc,[a] Jeffrey W. Moses, MD,[a] Richard A. Shlofmitz, MD,[a] Carlos Collet, MD, PhD,[b] Evan Shlofmitz, DO,[a] Allen Jeremias, MD, MSc,[a] Omar K. Khalique, MD,[a,d,e,†] Ziad A. Ali, MD, DPhil.[a,e,†]



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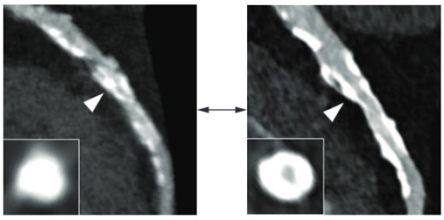
Single-Center Experience With Photon-Counting Detector CT in Evaluation of CAD

Energy-Integrating Detector CT (EID-CT) (N = 3,957)	Photon-Counting Detector CT (PCD-CT) (N = 3,876)
• Scintillator/photodiode • Indirect conversion of photon energies • Reflective Septa	• Semiconductor • Direct conversion of photon energies • Elimination of septa



Improved Spatial Resolution, Less Noise, Less Blooming Artifact

Clinical Impact of PCD-CT	Excellent Diagnostic Performance of PCD-CT
▼ ICA referral (9.9% vs 13.1%) ▼ Unnecessary ICA (5.6% vs 8.4%) ▲ Revascularization if referred (43.4% vs 35.5%)	↑ Accuracy: 97.2% ↑ PPV: 83.3% ↑ Specificity: 98.0%

Sakai K, et al. JACC. 2024;■(■):■-■.

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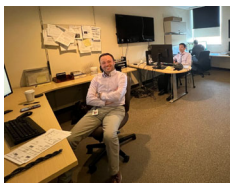
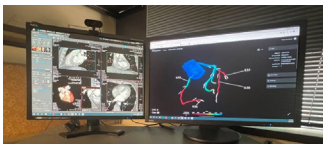
CT-guided PCI and the adjacent possible: Access to image visualization software and ease of use



Affable, Available, Able

CT readers / scanner (2nd floor)



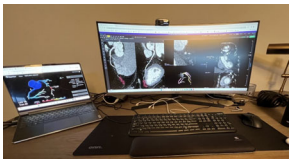
My office

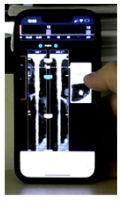
Clinic

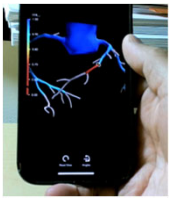
Proximity.

The cath lab (3rd floor)

Personal devices (laptop, iPad, smartphone)







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CT-guided PCI: the case for precision guided PCI

Where?
- **Location selection**:
  - Complex PCI center, surgery on-site, atherectomy, support
  - Hospital without surgery on-site or ambulatory surgical center

Who?
- **Operator selection**:
  - Any operator (low/intermediate complexity)
  - CHIP/complex high-volume coronary operator.

When?
- **Timing selection**:
  - Ad hoc during random day/week given low complexity.
  - Pre-planned, early, complex PCI based on anticipated CCTA findings.

What?
- **Equipment selection**:
  - Anticipated procedural equipment: access site, sheath size, guide selection, high likelihood of requiring advanced calcium modification strategies (lithotripsy, atherectomy), bifurcation or CTO PCI

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CT-guidance for case triage and pre-procedural planning:

Where? Who? When? What?

Where? Anywhere
Who? Anyone
When? Anytime
What? Ad hoc planning

Where? PCI center of excellence
Who? High volume CHIP operator
When? Early AM
What? >=7 Fr guide, atherectomy, CTO-cart

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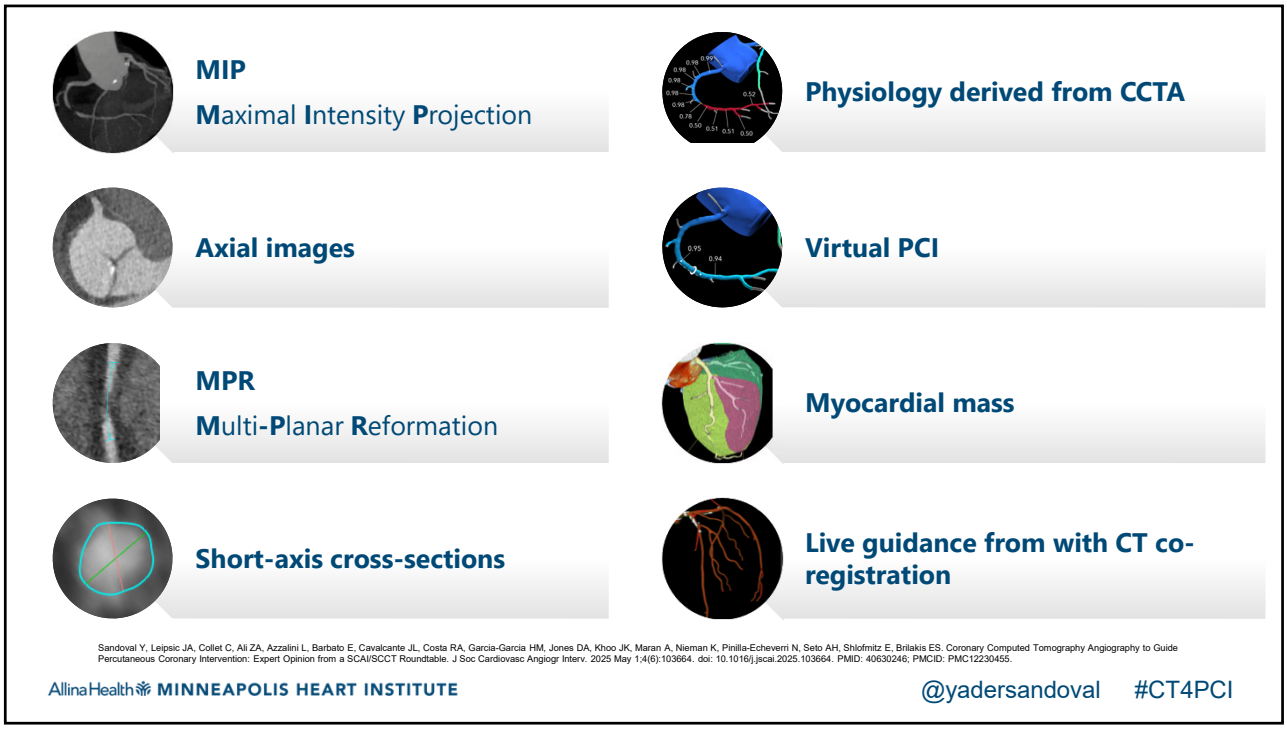
MIP
Maximal Intensity Projection
Physiology derived from CCTA
Axial images
Virtual PCI
MPR
Multi-Planar Reformation
Myocardial mass
Short-axis cross-sections
Live guidance from with CT co-registration
Sandoval Y, Leipsic JA, Collet C, Ali ZA, Azzalini L, Barbato E, Cavalcante JL, Costa RA, Garcia-Garcia HM, Jones DA, Khoo JK, Maran A, Nieman K, Pinilla-Echeverri N, Seto AH, Shlofmitz E, Brilakis ES. Coronary Computed Tomography Angiography to Guide Percutaneous Coronary Intervention: Expert Opinion from a SCAI/SCCT Roundtable. J Soc Cardiovasc Angiogr Interv. 2025 May 1;4(6):103664. doi: 10.1016/j.jscai.2025.103664. PMID: 40630246; PMCID: PMC12230455.
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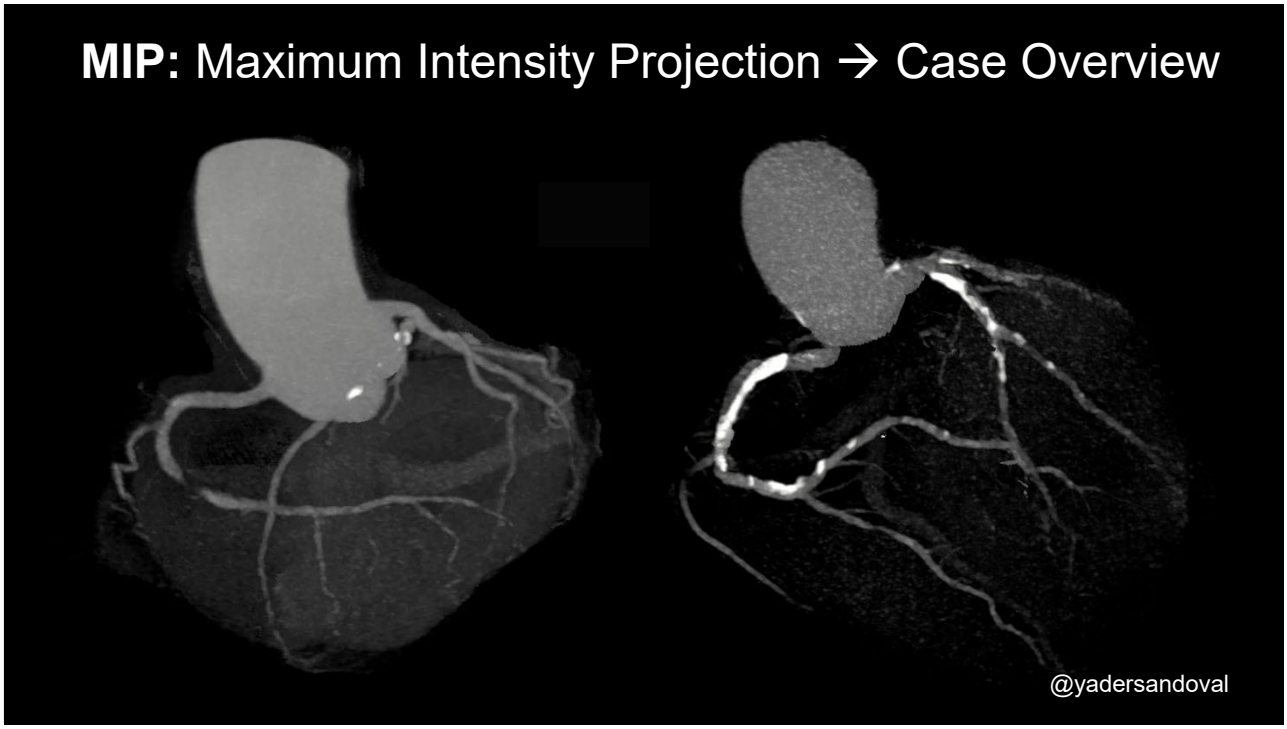
MIP: Maximum Intensity Projection → Case Overview
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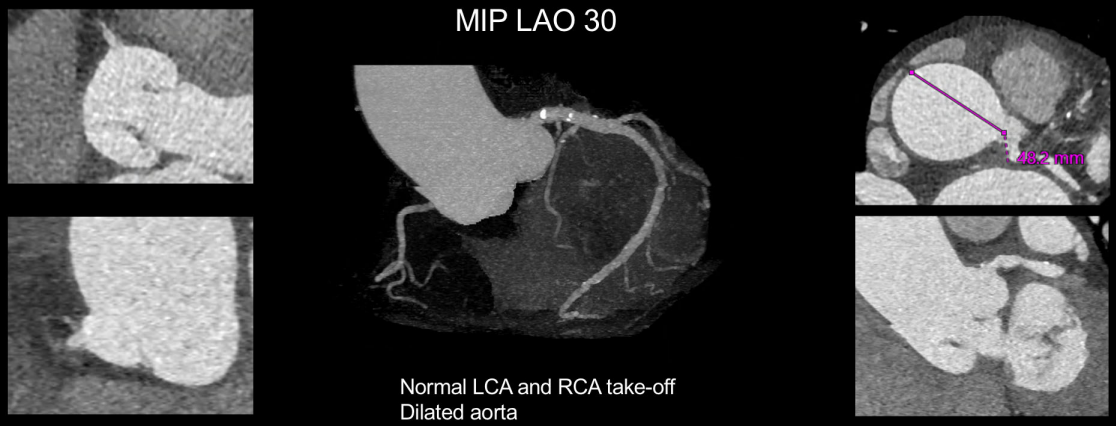
Axial images: coronary ostium, aorta dimensions

RCA ostium

LCA ostium

MIP LAO 30



Normal LCA and RCA take-off
Dilated aorta

RCA with anterior take-off? Y/N = **no**

LCA with usual take-off? Y/N = **no**

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CCTA to help with guide selection → anterior take off RCA

Anticipated benefits: fewer catheters, reduced need for instrumentation ⬇️ radiation, ⬇️ contrast use,

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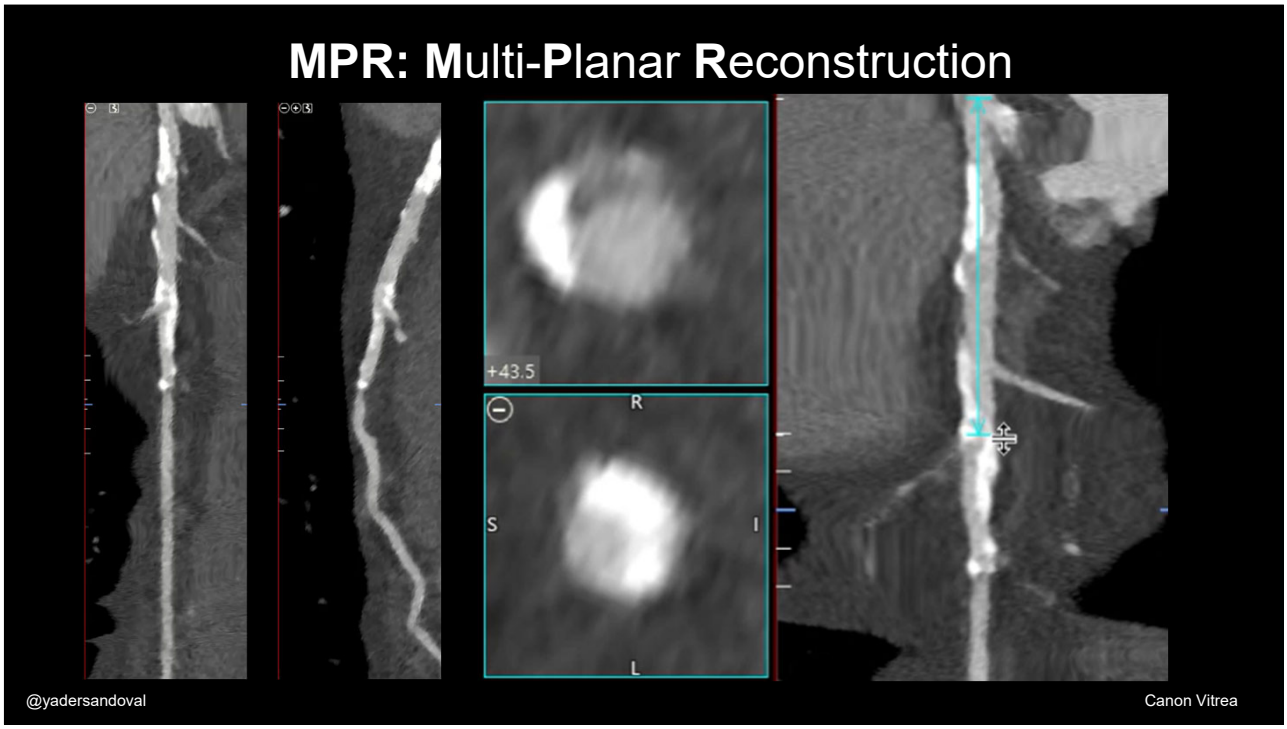
MPR: Multi-Planar Reconstruction
+43.5
R
S
I
L
@yadersandoval
Canon Vitrea

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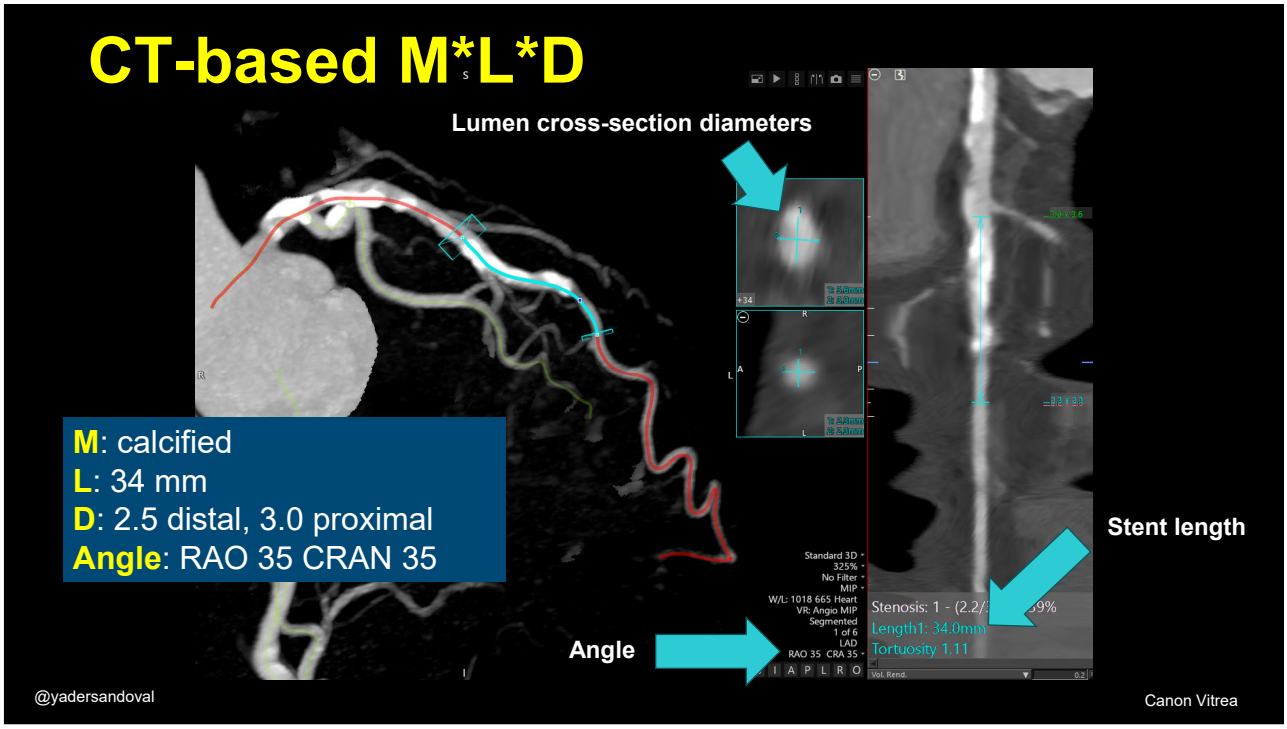
CT-based M*L*D
Lumen cross-section diameters
M: calcified
L: 34 mm
D: 2.5 distal, 3.0 proximal
Angle: RAO 35 CRAN 35
Stent length
Angle
Stenosis: 1 - (2.2/
Length1: 34.0mm
Tortuosity 1.11
@yadersandoval
Canon Vitrea

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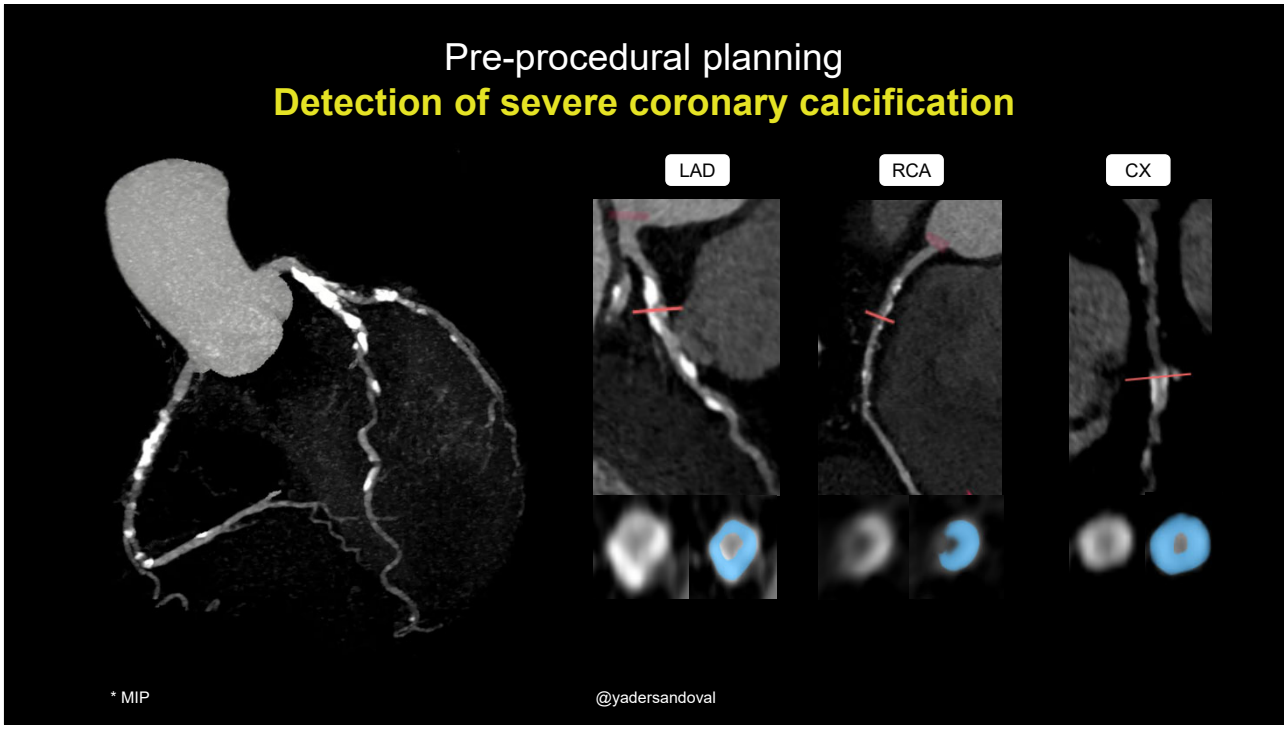
Pre-procedural planning
Detection of severe coronary calcification
LAD
RCA
CX
* MIP
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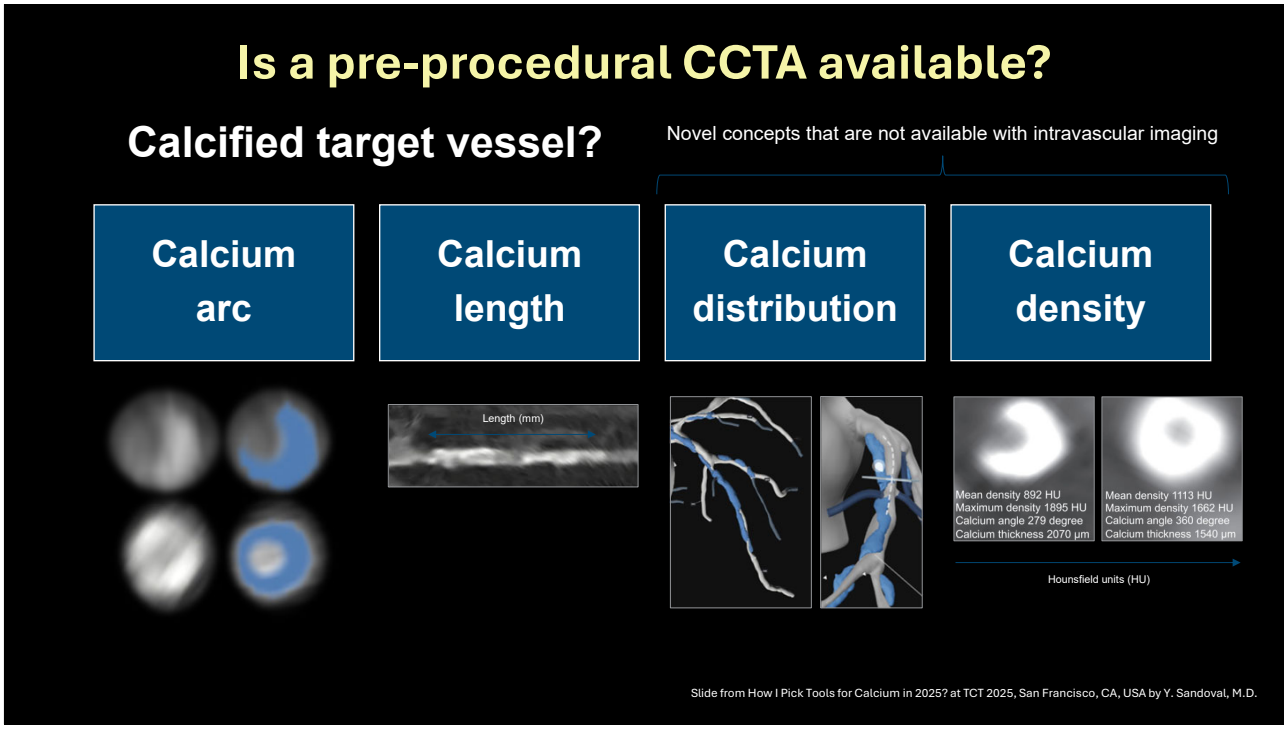
Is a pre-procedural CCTA available?
Calcified target vessel?
Novel concepts that are not available with intravascular imaging
Calcium arc
Calcium length
Calcium distribution
Calcium density
Length (mm)
Mean density 892 HU
Maximum density 1895 HU
Calcium angle 279 degree
Calcium thickness 2070 µm
Mean density 1113 HU
Maximum density 1662 HU
Calcium angle 360 degree
Calcium thickness 1540 µm
Hounsfield units (HU)
Slide from How I Pick Tools for Calcium in 2025? at TCT 2025, San Francisco, CA, USA by Y. Sandoval, M.D.

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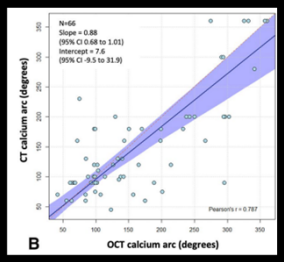
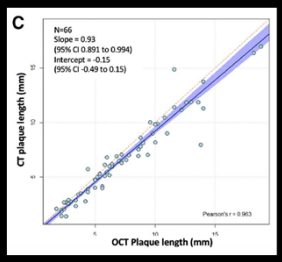
CT plaque/calcium characterization

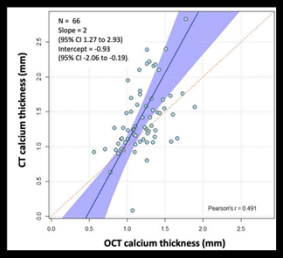
No differences were found concerning calcium length and arc.

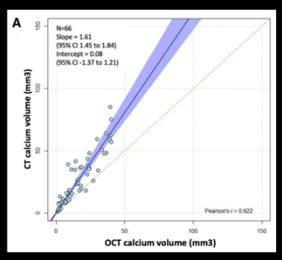
CT over-estimates calcium thickness and volume.

Calcium Arc	Plaque Length	Calcium Thickness	Calcium volume









CT overestimates calcium volume by approximately 60% compared to OCT

Monizzi G et al. Int J Cardiovasc Imaging. 2020 Dec;36(12):2393-2402. doi: 10.1007/s10554-020-01839-z.

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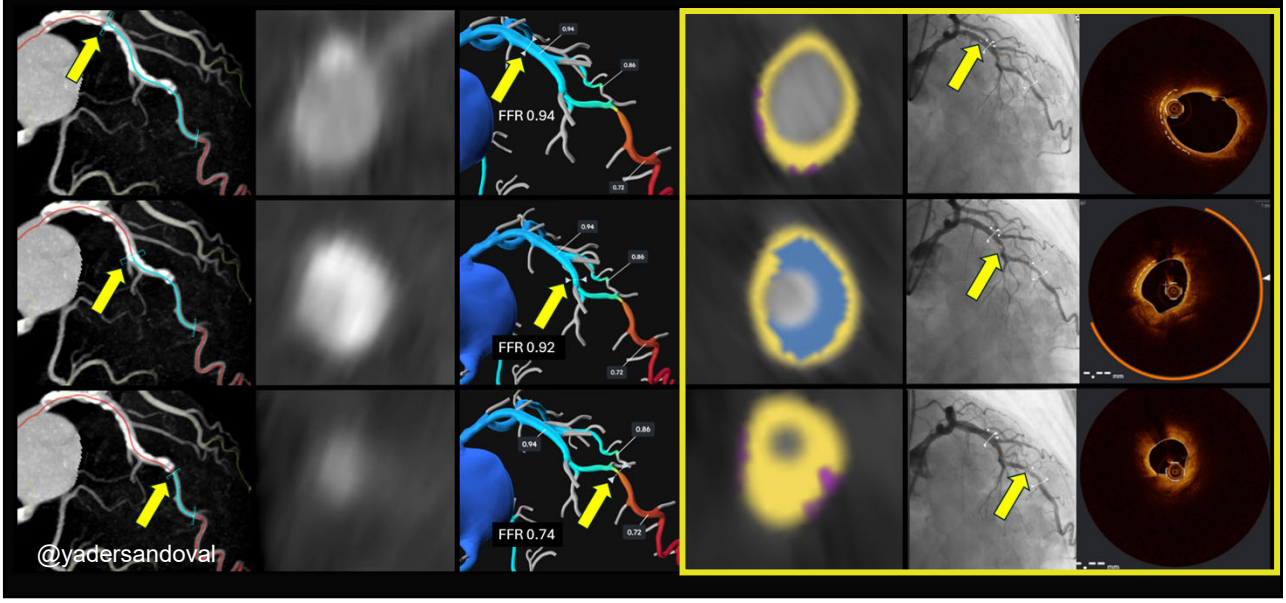
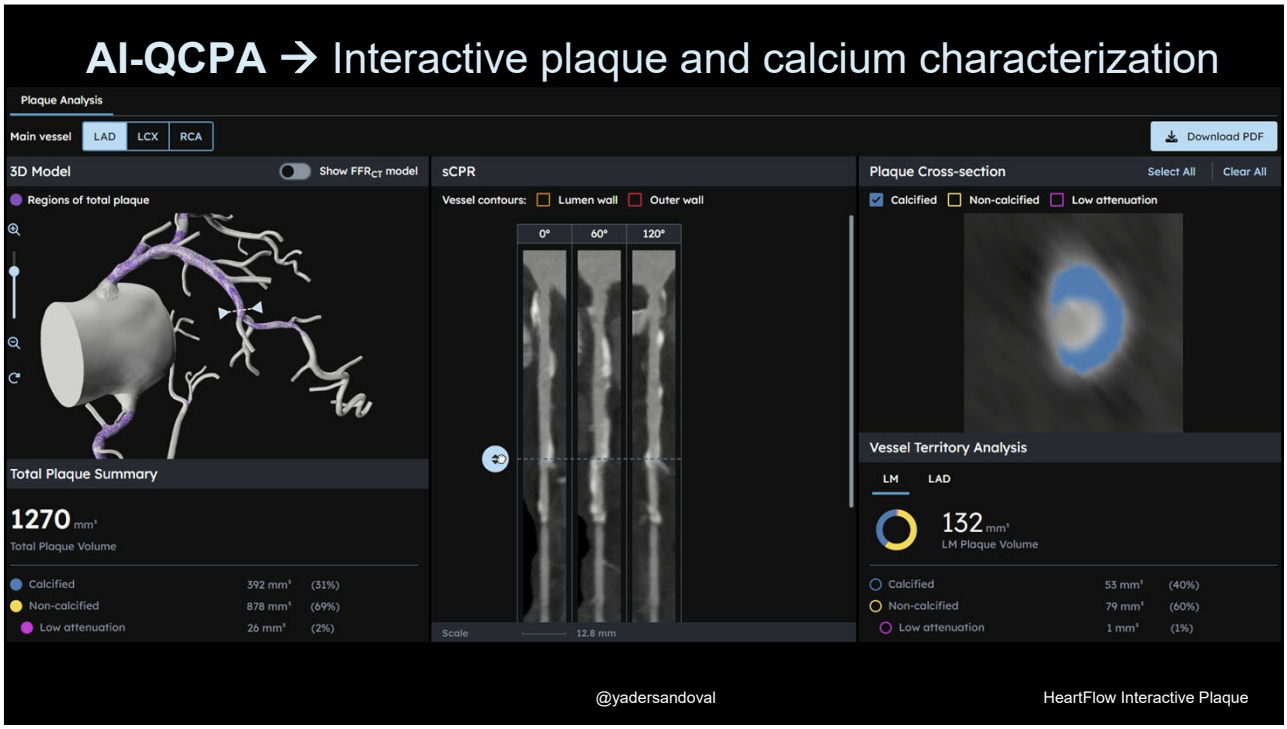
Where do we from here?
FFR-CT synchronization + plaque composition



32


AI-QCPA → Interactive plaque and calcium characterization
Plaque Analysis
Main vessel
LAD
LCX
RCA
Download PDF
3D Model
Show FFRCT model
Regions of total plaque
sCPR
Vessel contours:
Lumen wall
Outer wall
0°
60°
120°
Scale
12.8 mm
Plaque Cross-section
Select All
Clear All
Calcified
Non-calcified
Low attenuation
Total Plaque Summary
1270 mm³
Total Plaque Volume
Calcified 392 mm³ (31%)
Non-calcified 878 mm³ (69%)
Low attenuation 26 mm³ (2%)
Vessel Territory Analysis
LM
LAD
132 mm³
LM Plaque Volume
Calcified 53 mm³ (40%)
Non-calcified 79 mm³ (60%)
Low attenuation 1 mm³ (1%)
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HeartFlow Interactive Plaque

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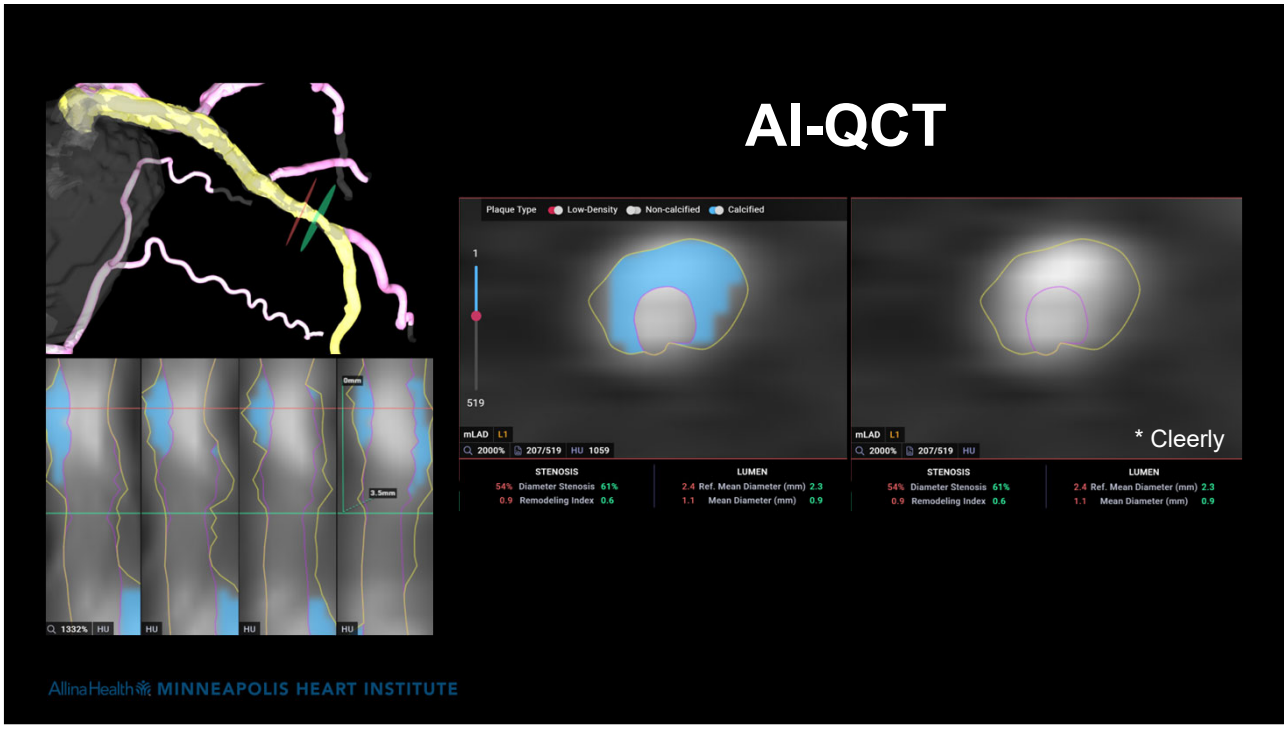
AI-QCT
Plaque Type
Low-Density
Non-calcified
Calcified
1
519
mLAD
L1
2000%
207/519
HU
1059
STENOSIS
54% Diameter Stenosis 61%
0.9 Remodeling Index 0.6
LUMEN
2.4 Ref. Mean Diameter (mm) 2.3
1.1 Mean Diameter (mm) 0.9
* Cleerly
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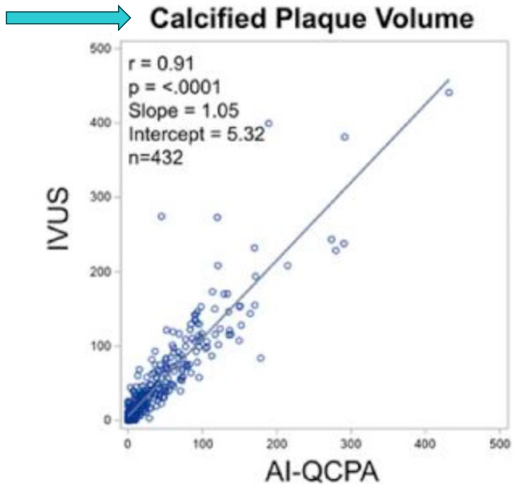

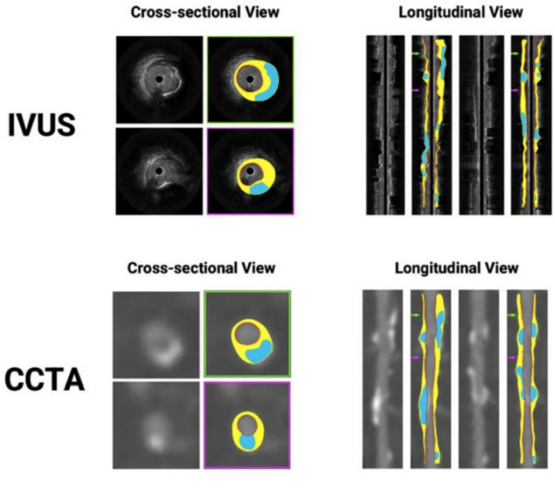

REVEAL PLAQUE: Multicenter study (15 sites, USA & Japan): Automated deep learning-based CCTA analysis of 432 lesions in 237 patients showed strong agreement with core lab-adjudicated IVUS for plaque quantification.

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Narula J, Stuckey TD, Nakazawa G, Ahmadi A, Matsumura M, Petersen K, Mirza S, Ng N, Mullen S, Schaap M, Leipsic J, Rogers C, Taylor CA, Yacoub H, Gupta H, Matsuo H, Rinehart S, Maehara A. Prospective deep learning-based quantitative assessment of coronary plaque by computed tomography angiography compared with intravascular ultrasound: the REVEALPLAQUE study. Eur Heart J Cardiovasc Imaging. 2024 Aug 26;25(9):1287-1295. doi: 10.1093/ehjci/jeae115. PMID: 38700097; PMCID: PMC11346368.

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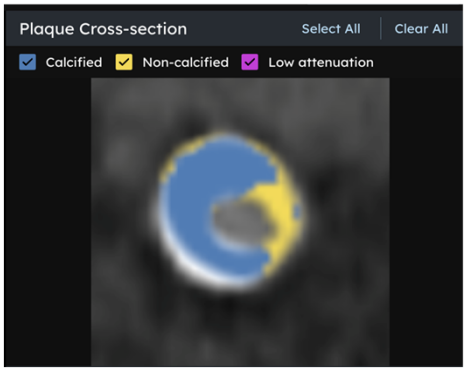
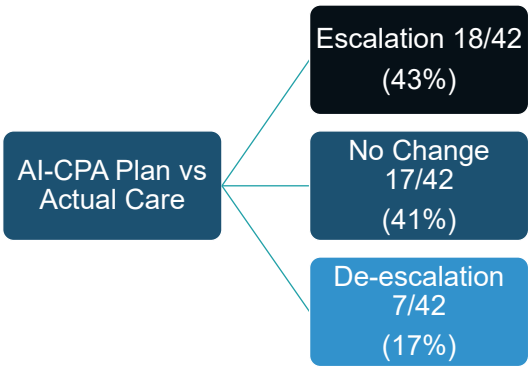
PLAN CALCIUM: CCTA & AI-enabled plaque analysis to inform PCI.

Compared to actual care, **AI-CPA was associated with a change in calcium modification plan in 25 lesions (60%)**, of which 18 (43%) were escalation.





Ankitkumar K. Patel, Yader Sandoval, Sarah Mullen, Campbell Rogers, Nicholas Ng, Saba Mirza, and Ziad Ali.
Coronary CT Angiography and AI-enabled coronary plaque analysis to inform PCI and lesion preparation: The PLAN CALCIUM Study. Presented at TCT 2025.

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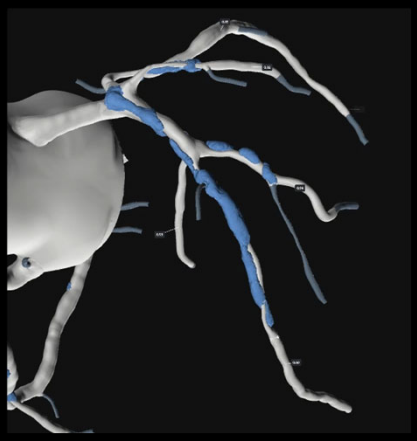
Case 1: Elderly male with dyspnea and CCTA with severe, diffuse calcified CAD

Maximal intensity projection (MIP)

* Standard post-processing CCTA software

3D plaque and calcium distribution



* Heartflow interactive plaque

Live Case at CT for PCI 3.0 Summit in Minneapolis, MN by Y. Sandoval, M.D.

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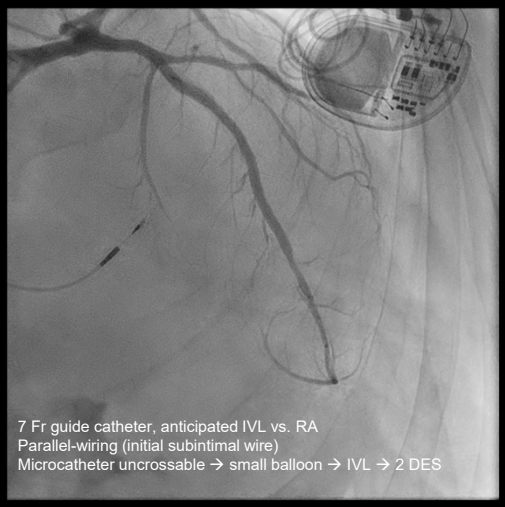
CT-guided calcium modification: preparedness, no surprises



Live Case at CT for PCI 3.0 Summit in Minneapolis, MN by Y. Sandoval, M.D.

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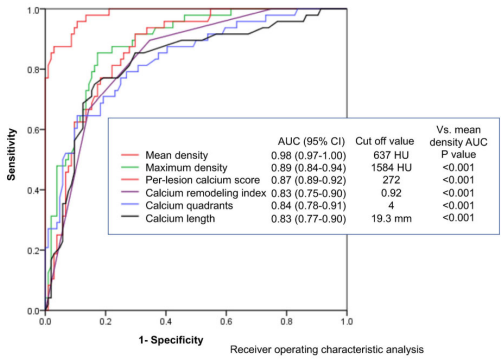
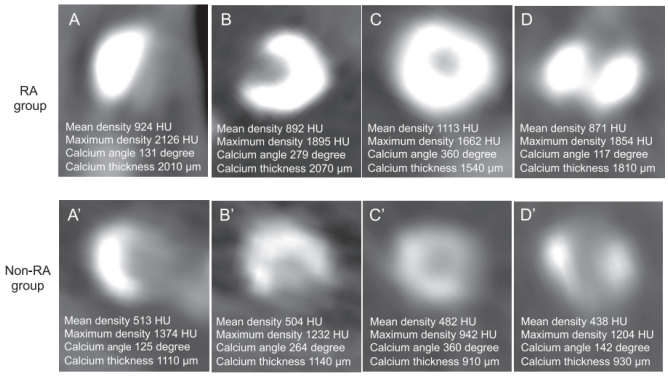
CT-guided calcium assessment: calcium density



	AUC (95% CI)	Cut off value	Vs. mean density AUC P value
Mean density	0.98 (0.97-1.00)	637 HU	<0.001
Maximum density	0.89 (0.84-0.94)	1584 HU	<0.001
Per-lesion calcium score	0.87 (0.89-0.92)	272	<0.001
Calcium remodeling index	0.83 (0.75-0.90)	0.92	<0.001
Calcium quadrants	0.84 (0.78-0.91)	4	<0.001
Calcium length	0.83 (0.77-0.90)	19.3 mm	<0.001



✓ ROC curve analysis among 154 lesions revealed 637 Hounsfield units (HU) as the best mean density cutoff value for predicting RA.
✓ Multivariate logistic regression analysis showed that a mean calcium level >637 HU was a strong independent predictor for using RA.

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Kurogi K et al. Mean density of computed tomography for predicting rotational atherectomy during percutaneous coronary intervention. J Cardiovasc Comput Tomogr 2023;17:120-129.

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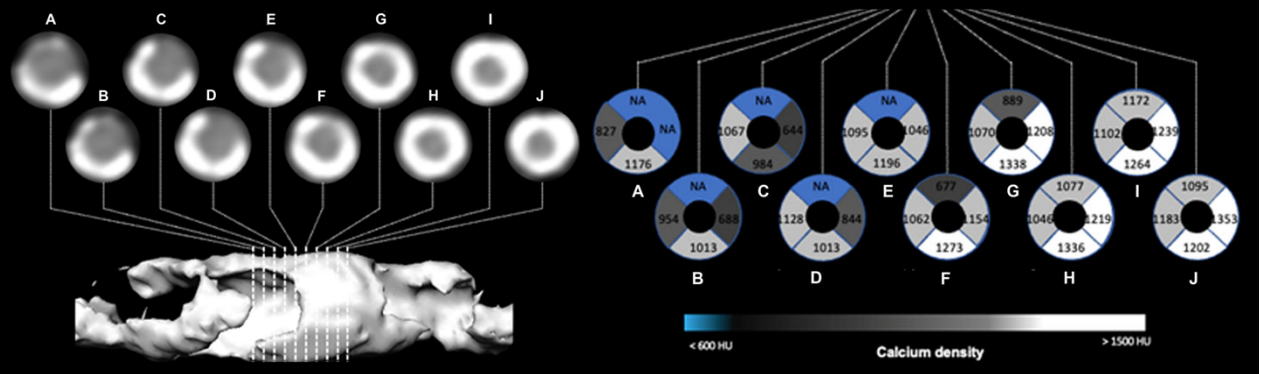
CT-guided calcium assessment: calcium density



Tajima A, Bouisset F, Ohashi H, Sakai K, Mizukami T, Rizzini ML, Gallo D, Chiastra C, Morbiducci U, Ali ZA, Spratt JC, Ando H, Amano T, Kitslaar P, Wilgenhof A, Sonck J, De Bruyne B, Collet C. Advanced CT Imaging for the Assessment of Calcific Coronary Artery Disease and PCI Planning. J Soc Cardiovasc Angiogr Interv. 2024 Mar 26;3(3Part B):101299.

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Calcium Density: a novel predictor of stent underexpansion

Multivariable analysis for MSA < 5.5 mm²		
Variables	Exp (β) (95% CI)	p-value*
Calcium length, IVUS	1.00 (0.96 to 1.03)	0.823
Total calcium angle, IVUS	1.00 (0.99 to 1.00)	0.433
Calcified nodule, IVUS	1.47 (0.65 to 3.30)	0.347
Calcium Density, CCTA	**0.39 (0.17 to 0.86)**	**0.020**
Maximum inflation pressure	0.96 (0.86 to 1.07)	0.448

*Adjusted by clinical and procedural variables.

CRF TCT

Collet et al – P4 [unpublished] – Presented at TCT 2025

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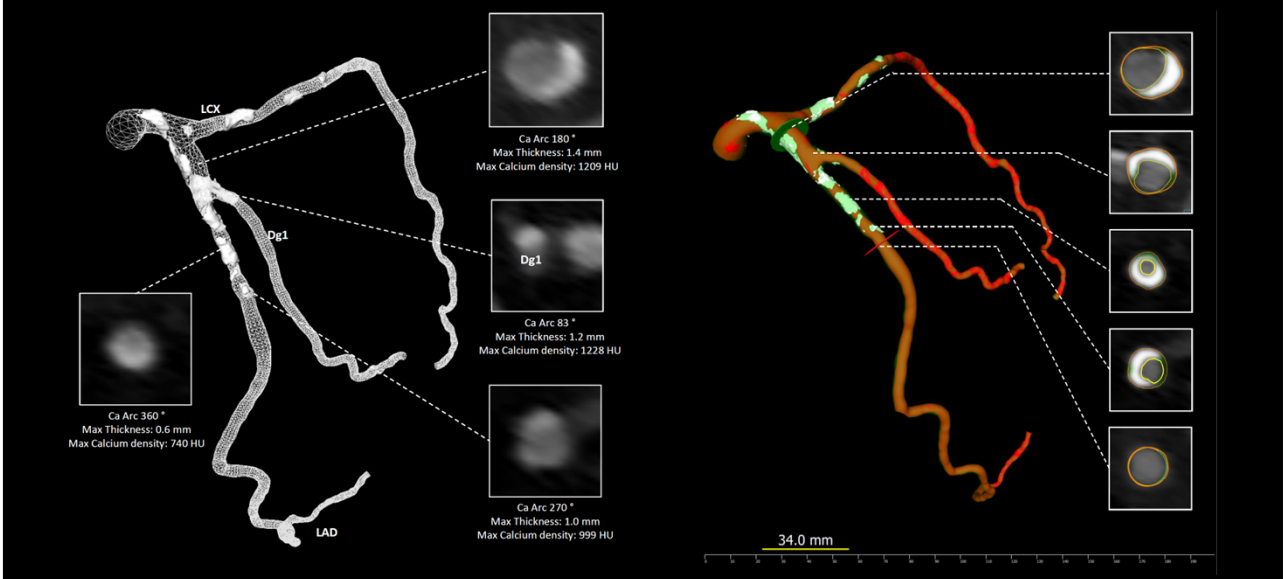
CT plaque and calcium characterization in the P4 randomized trial



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* Investigational (P4 RCT)

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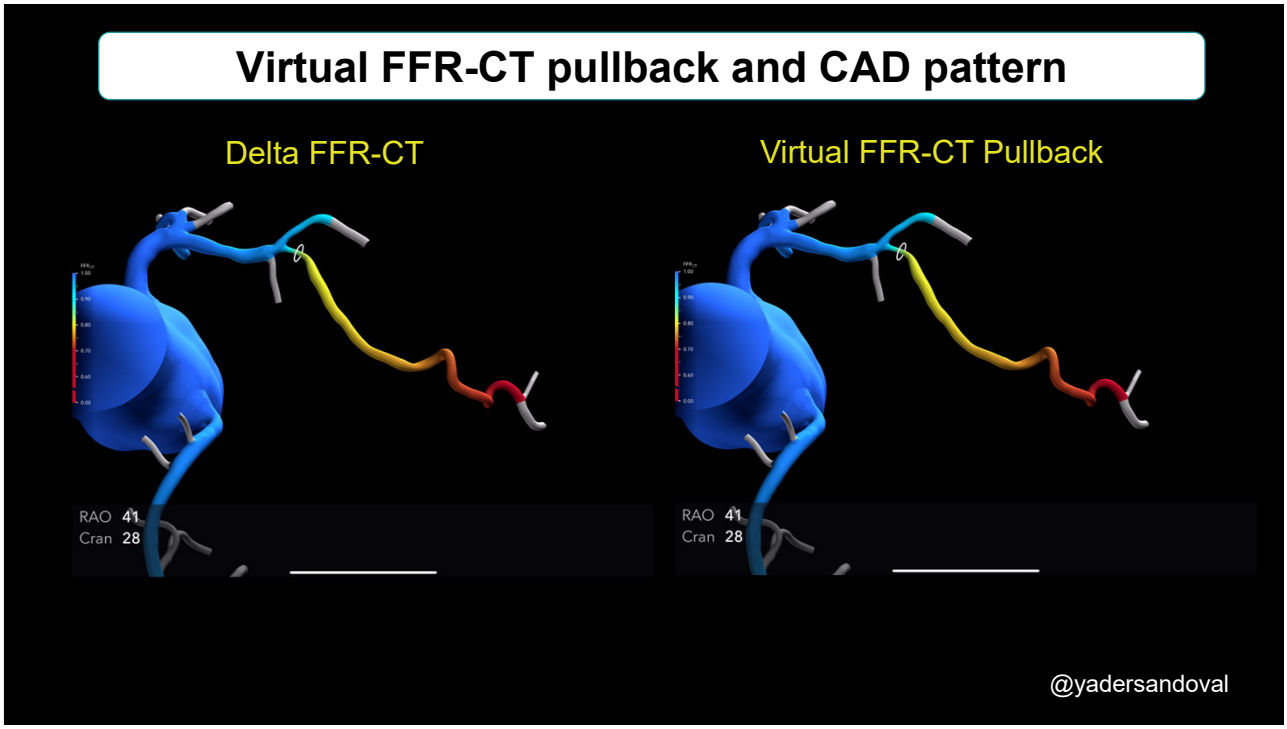
Virtual FFR-CT pullback and CAD pattern
Delta FFR-CT
Virtual FFR-CT Pullback
RAO 41
Cran 28
RAO 41
Cran 28
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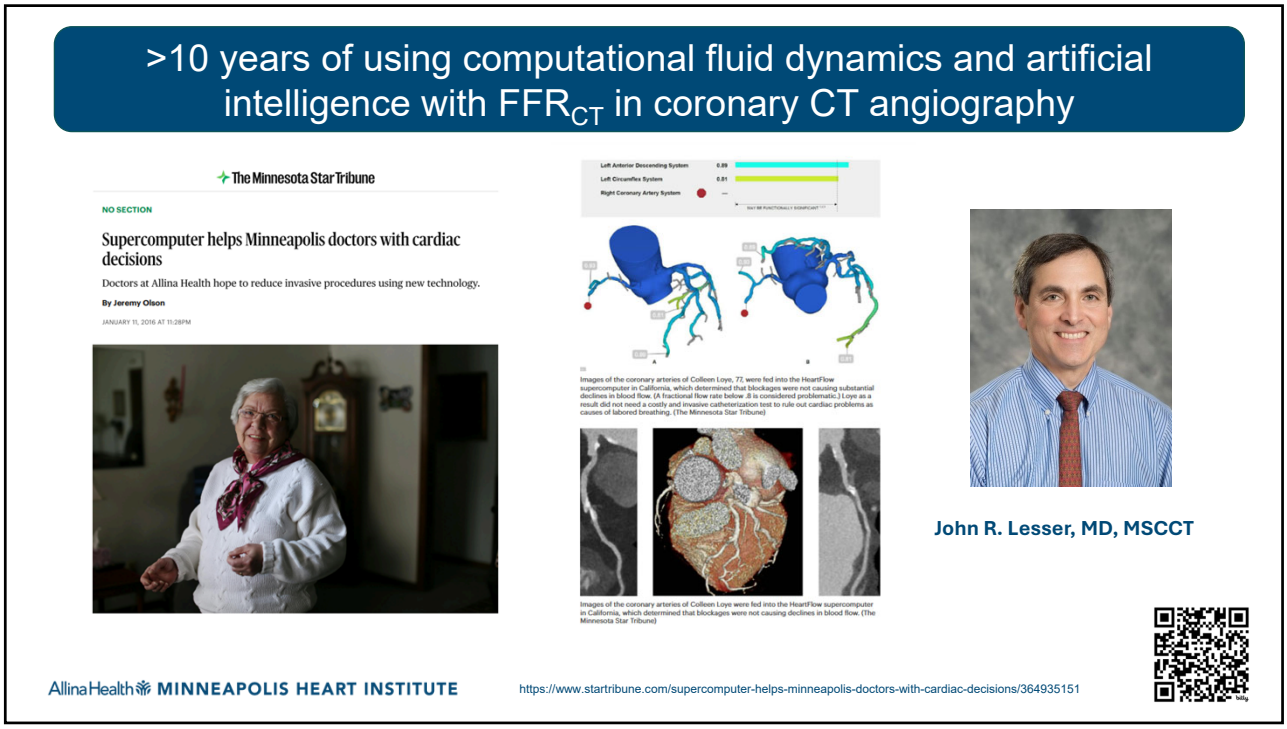
>10 years of using computational fluid dynamics and artificial intelligence with FFR$_{CT}$ in coronary CT angiography
The Minnesota Star Tribune
NO SECTION
Supercomputer helps Minneapolis doctors with cardiac decisions
Doctors at Allina Health hope to reduce invasive procedures using new technology.
By Jeremy Olson
JANUARY 11, 2016 AT 11:28PM
Images of the coronary arteries of Colleen Loye, 77, were fed into the HeartFlow supercomputer in California, which determined that blockages were not causing substantial declines in blood flow. (A fractional flow rate below .8 is considered problematic.) Loye as a result did not need a costly and invasive catheterization test to rule out cardiac problems as causes of labored breathing. (The Minnesota Star Tribune)
Images of the coronary arteries of Colleen Loye were fed into the HeartFlow supercomputer in California, which determined that blockages were not causing declines in blood flow. (The Minnesota Star Tribune)
John R. Lesser, MD, MSCCT
Allina Health MINNEAPOLIS HEART INSTITUTE
https://www.startribune.com/supercomputer-helps-minneapolis-doctors-with-cardiac-decisions/364935151

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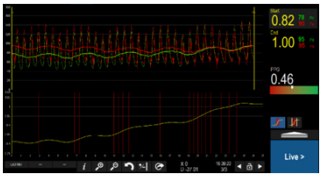
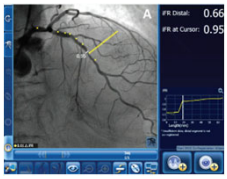
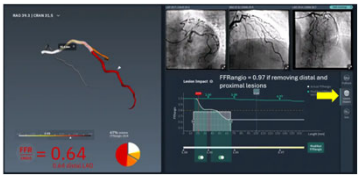
From Physiology 1.0 (Defer vs. Treat) to Physiology 2.0 → functional significance, disease pattern, PCI planning

	Pressure-wire based physiology	Angiography-derived physiology
1 **Functional significance** (> or <= 0.80		
2 **Disease phenotype** (focal, diffuse or mixed and case selection)		
3 **PCI planning**		

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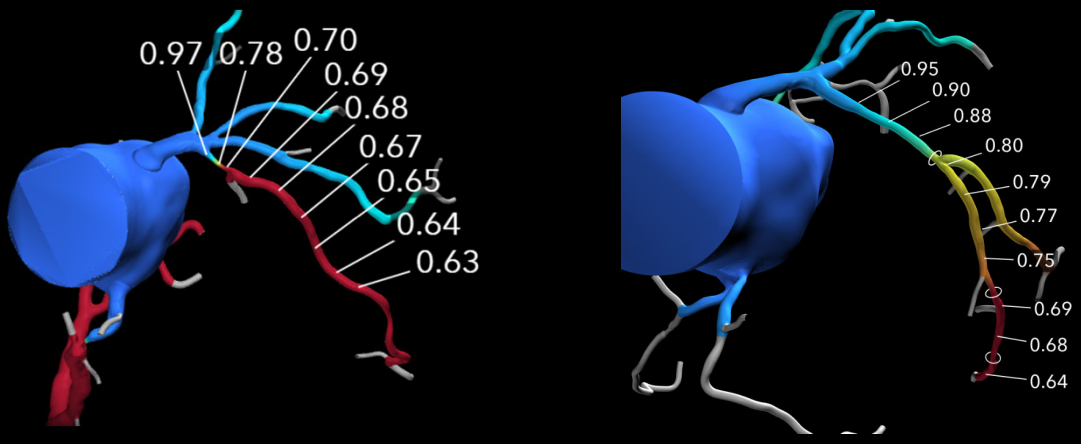
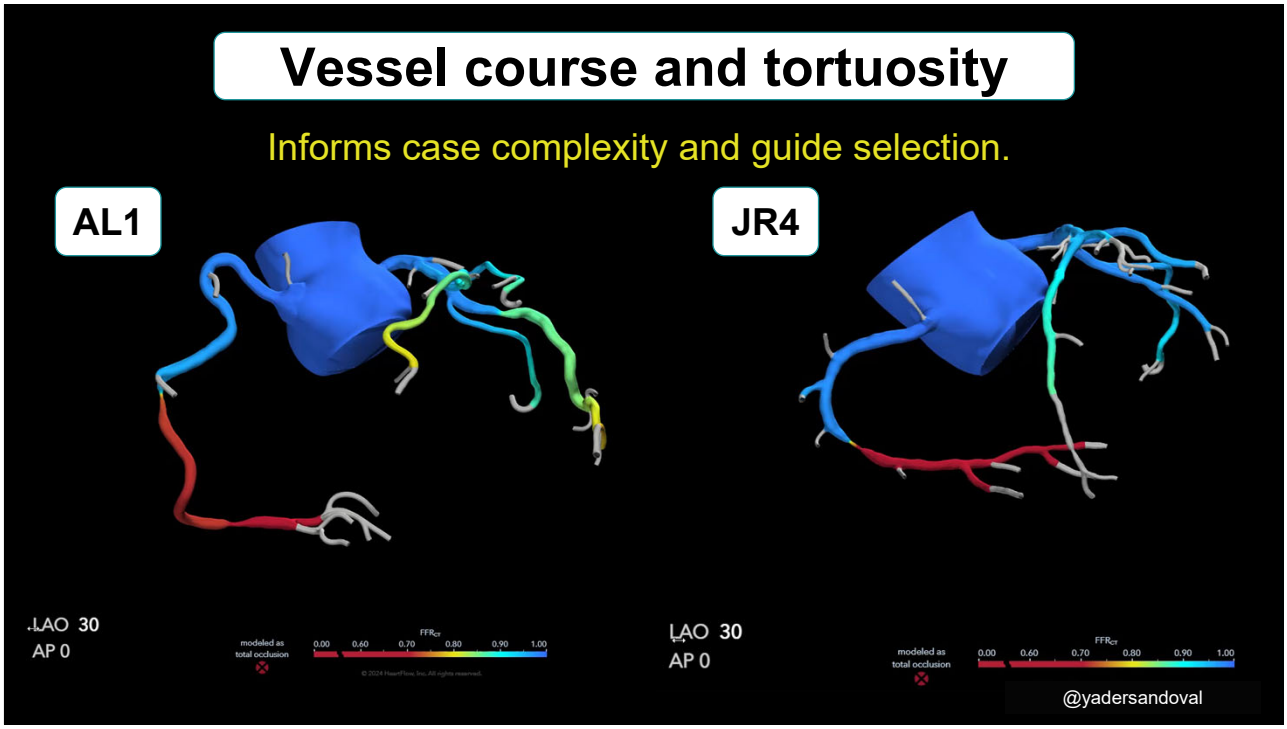
Virtual FFR-CT pullback and CAD pattern

Focal versus diffuse CAD



46


Vessel course and tortuosity
Informs case complexity and guide selection.
AL1
JR4
LAO 30
AP 0
modeled as total occlusion
0.00 0.60 0.70 0.80 0.90 1.00
LAO 30
AP 0
modeled as total occlusion
0.00 0.60 0.70 0.80 0.90 1.00
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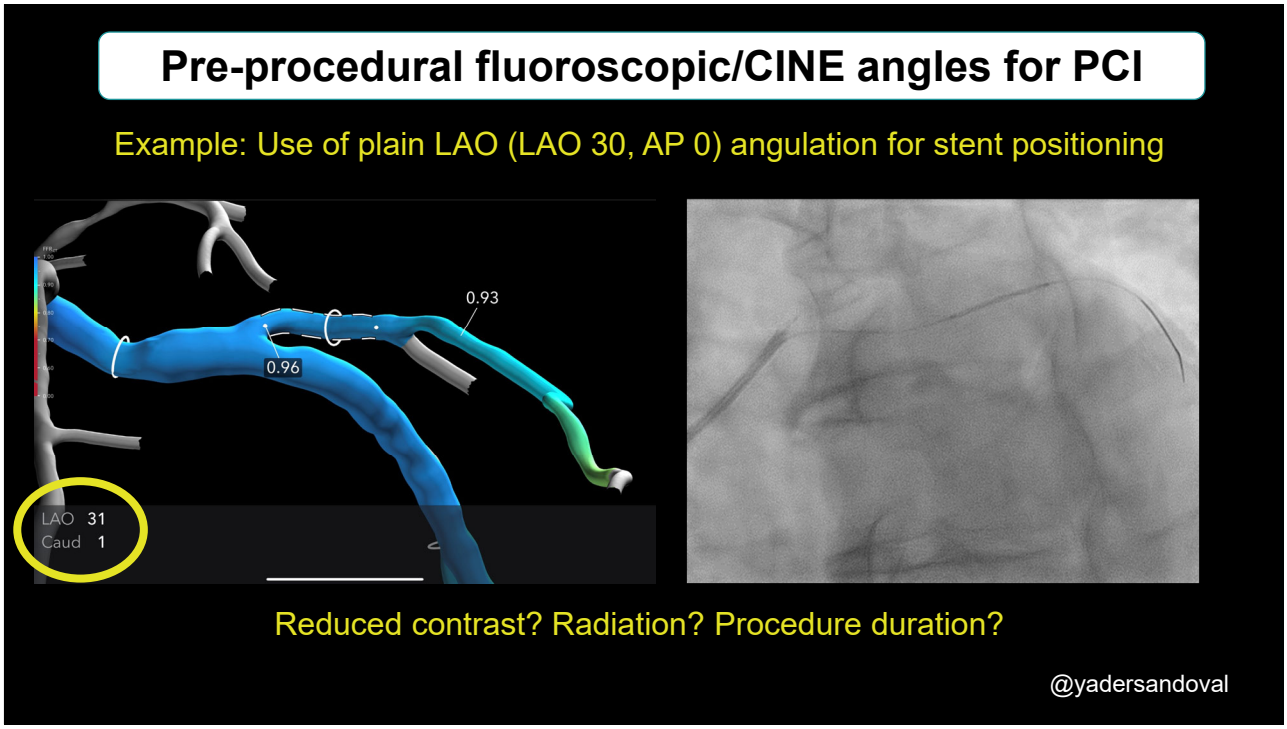
Pre-procedural fluoroscopic/CINE angles for PCI
Example: Use of plain LAO (LAO 30, AP 0) angulation for stent positioning
0.93
0.96
LAO 31
Caud 1
Reduced contrast? Radiation? Procedure duration?
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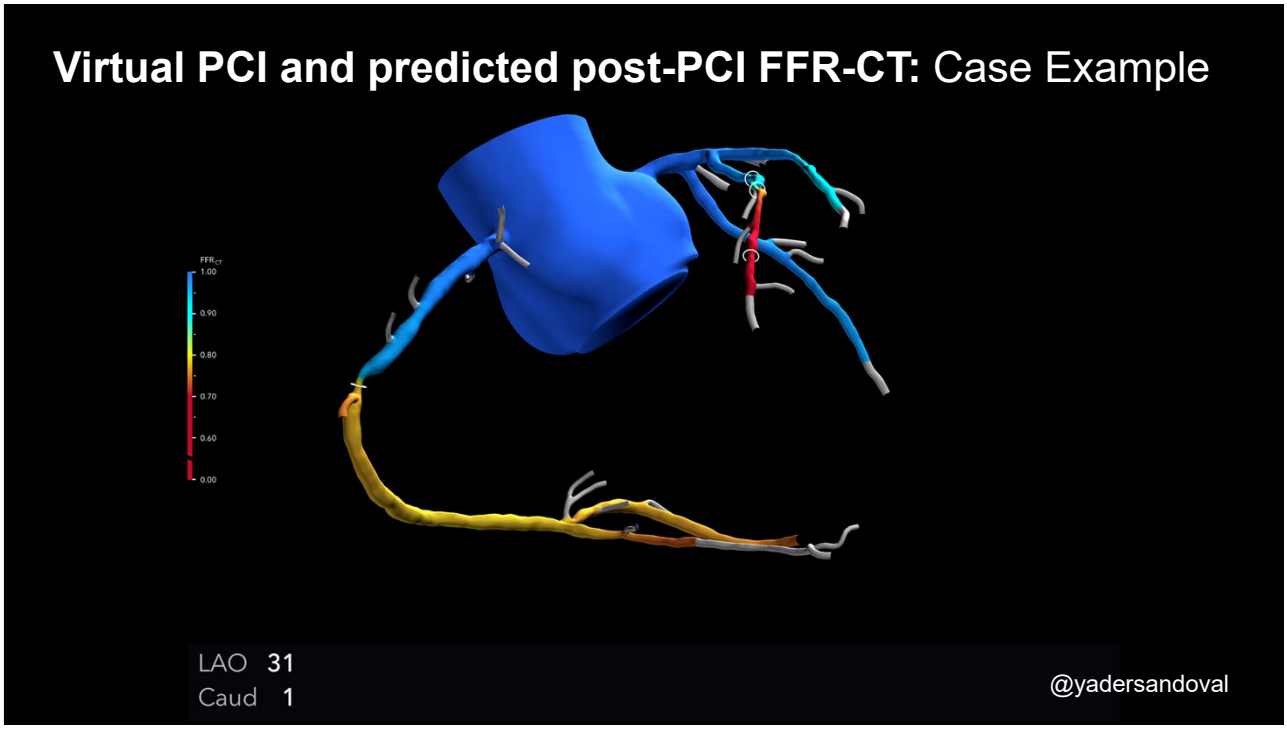
Virtual PCI and predicted post-PCI FFR-CT: Case Example
FFR_CT
1.00
0.90
0.80
0.70
0.60
0.00
LAO 31
Caud 1
@yadersandoval

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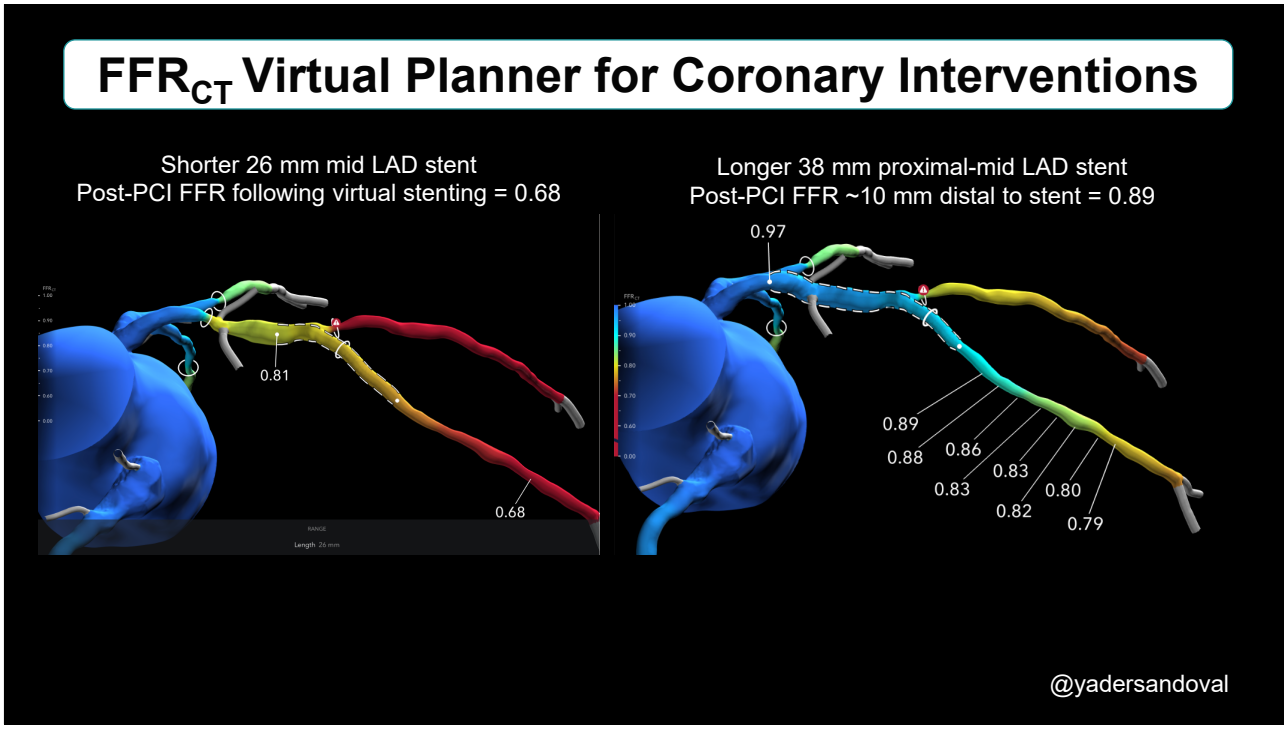
FFR_CT Virtual Planner for Coronary Interventions
Shorter 26 mm mid LAD stent
Post-PCI FFR following virtual stenting = 0.68
Longer 38 mm proximal-mid LAD stent
Post-PCI FFR ~10 mm distal to stent = 0.89
0.81
0.68
0.97
0.89
0.88
0.86
0.83
0.83
0.80
0.82
0.79
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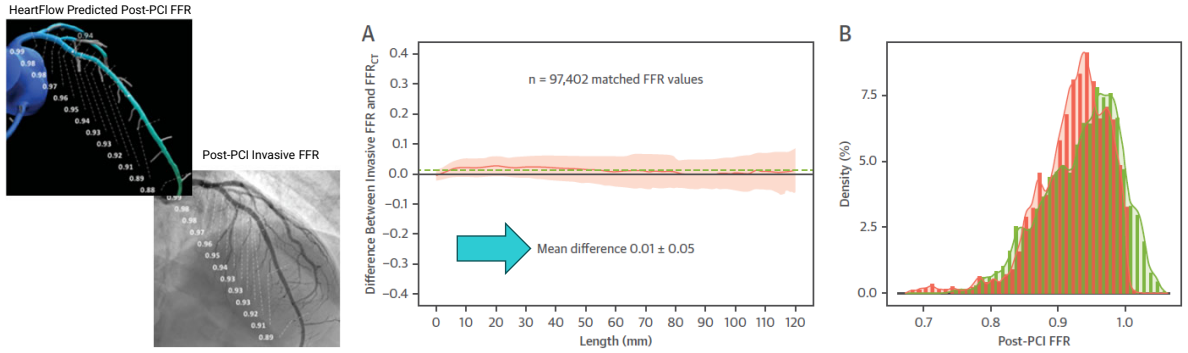
P3: Clinical validation of a virtual planner for coronary interventions based on coronary CT angiography



- Prospective study of patients with hemodynamically significant CAD undergoing PCI 120 patients (123 vessels)
- Endpoint: Agreement of predicted post-PCI FFR$_{CT}$ values with post-PCI invasive FFR measurement

Sonck J & Collet C et al. Clinical Validation of a Virtual Planner for Coronary Interventions Based on Coronary CT Angiography. JACC Cardiovasc Imaging. 2022 Jul;15(7):1242-1255.

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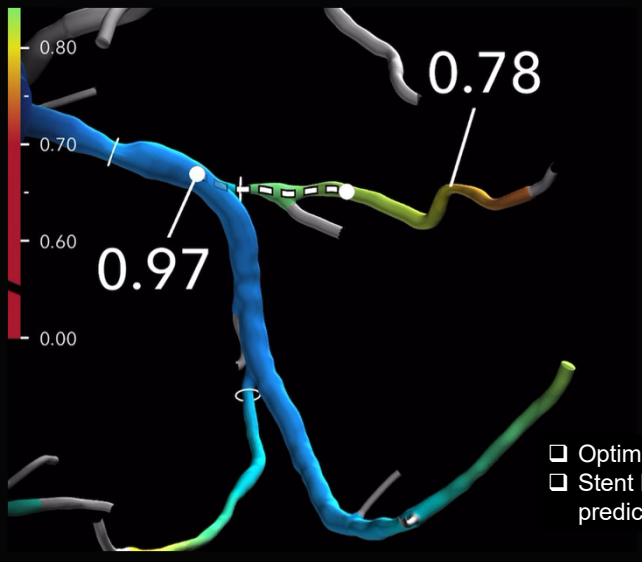
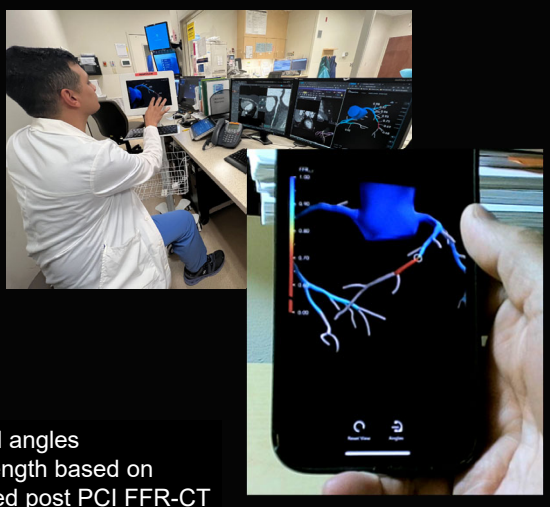
April 2023
FFR-CT based virtual planner implemented for PCI guidance





- ❑ Optimal angles
- ❑ Stent length based on predicted post PCI FFR-CT

FFR$_{CT}$ virtual planner for pre-procedural guidance

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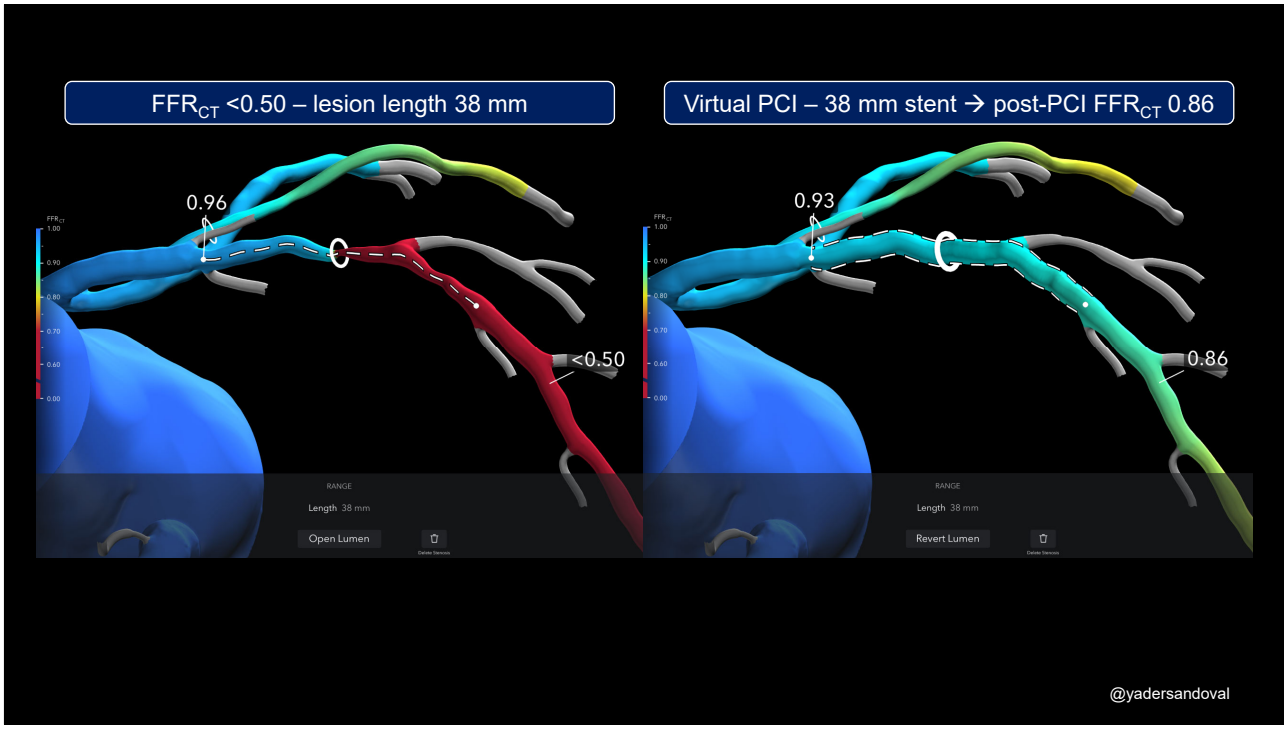
FFR$_{CT}$ <0.50 – lesion length 38 mm
Virtual PCI – 38 mm stent → post-PCI FFR$_{CT}$ 0.86
0.96
<0.50
0.93
0.86
RANGE
Length 38 mm
Open Lumen
Revert Lumen
@yadersandoval

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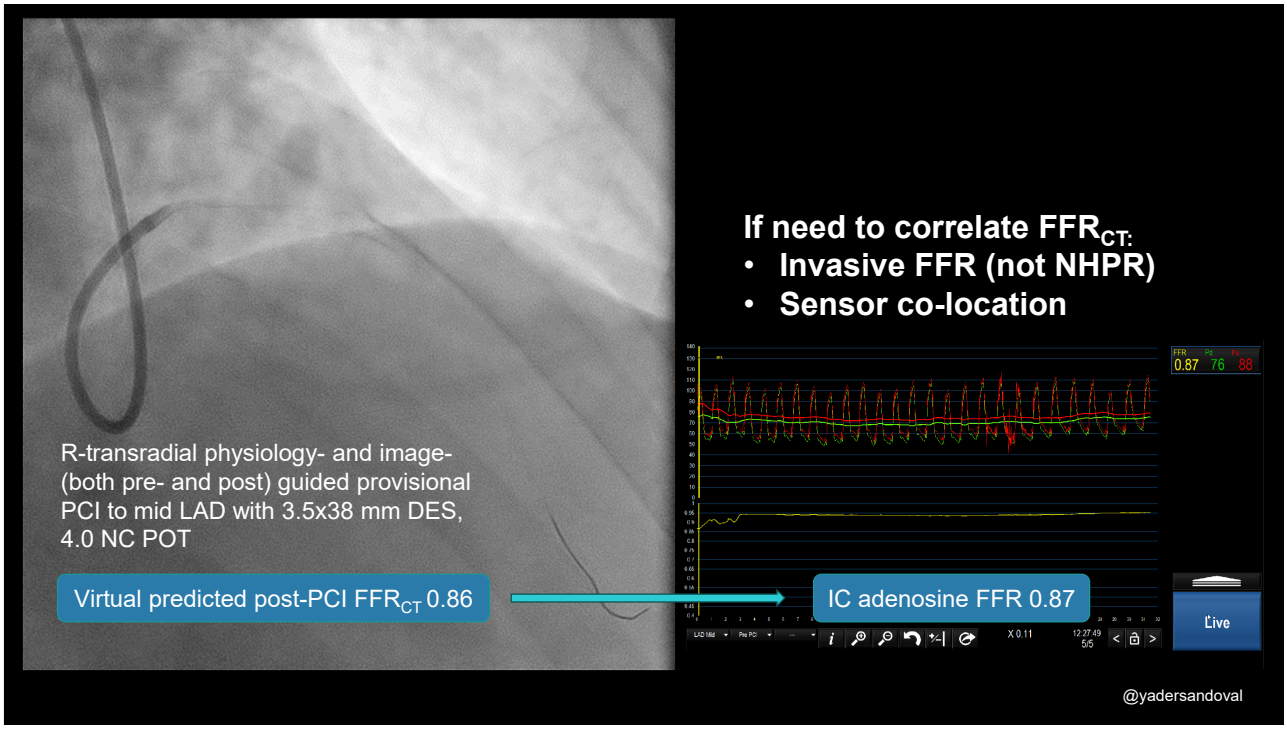
If need to correlate FFR$_{CT}$:
• Invasive FFR (not NHPR)
• Sensor co-location
R-transradial physiology- and image-(both pre- and post) guided provisional PCI to mid LAD with 3.5x38 mm DES, 4.0 NC POT
Virtual predicted post-PCI FFR$_{CT}$ 0.86
IC adenosine FFR 0.87
0.87 76 88
Live
@yadersandoval

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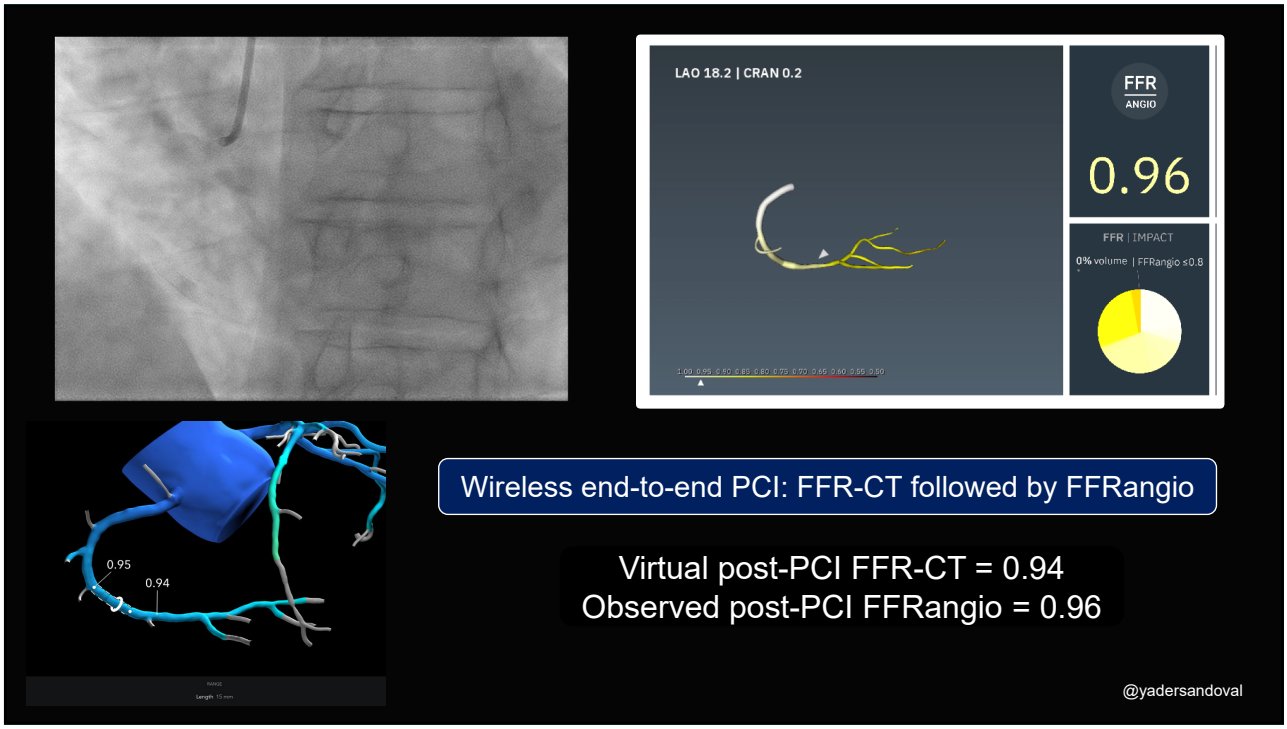
LAO 18.2 | CRAN 0.2
FFR
ANGIO
0.96
FFR | IMPACT
0% volume | FFRangio ≤0.8
0.95
0.94
Wireless end-to-end PCI: FFR-CT followed by FFRangio
Virtual post-PCI FFR-CT = 0.94
Observed post-PCI FFRangio = 0.96
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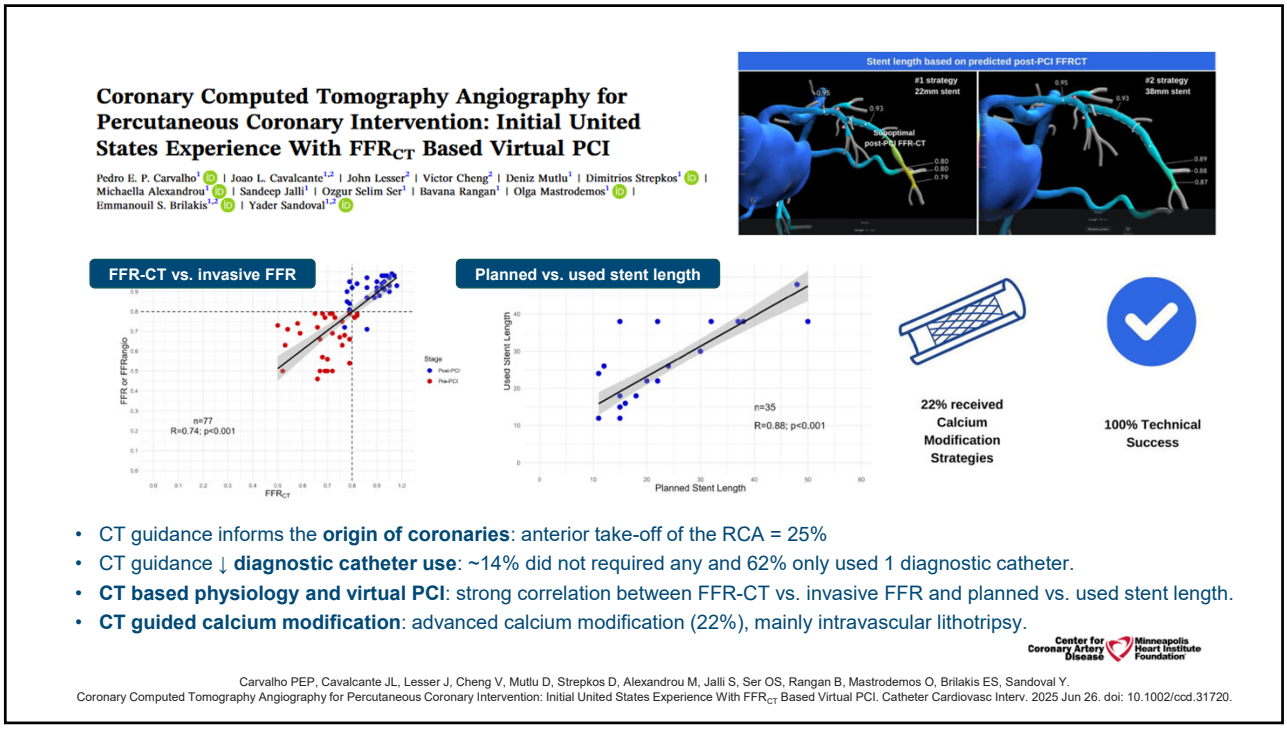
Coronary Computed Tomography Angiography for Percutaneous Coronary Intervention: Initial United States Experience With FFR$_{CT}$ Based Virtual PCI
Pedro E. P. Carvalho | Joao L. Cavalcante | John Lesser | Victor Cheng | Deniz Mutlu | Dimitrios Strepkos | Michaella Alexandrou | Sandeep Jalli | Ozgur Selim Ser | Bavana Rangan | Olga Mastrodemos | Emmanouil S. Brilakis | Yader Sandoval
Stent length based on predicted post-PCI FFRCT
#1 strategy 22mm stent
#2 strategy 38mm stent
Suboptimal post-PCI FFR-CT
FFR-CT vs. invasive FFR
n=77
R=0.74; p<0.001
Planned vs. used stent length
n=35
R=0.88; p<0.001
Planned Stent Length
22% received Calcium Modification Strategies
100% Technical Success
CT guidance informs the origin of coronaries: anterior take-off of the RCA = 25%
CT guidance ↓ diagnostic catheter use: ~14% did not required any and 62% only used 1 diagnostic catheter.
CT based physiology and virtual PCI: strong correlation between FFR-CT vs. invasive FFR and planned vs. used stent length.
CT guided calcium modification: advanced calcium modification (22%), mainly intravascular lithotripsy.
Center for Coronary Artery Disease
Minneapolis Heart Institute Foundation
Carvalho PEP, Cavalcante JL, Lesser J, Cheng V, Mutlu D, Strepkos D, Alexandrou M, Jalli S, Ser OS, Rangan B, Mastrodemos O, Brilakis ES, Sandoval Y.
Coronary Computed Tomography Angiography for Percutaneous Coronary Intervention: Initial United States Experience With FFR$_{CT}$ Based Virtual PCI. Catheter Cardiovasc Interv. 2025 Jun 26. doi: 10.1002/ccd.31720.

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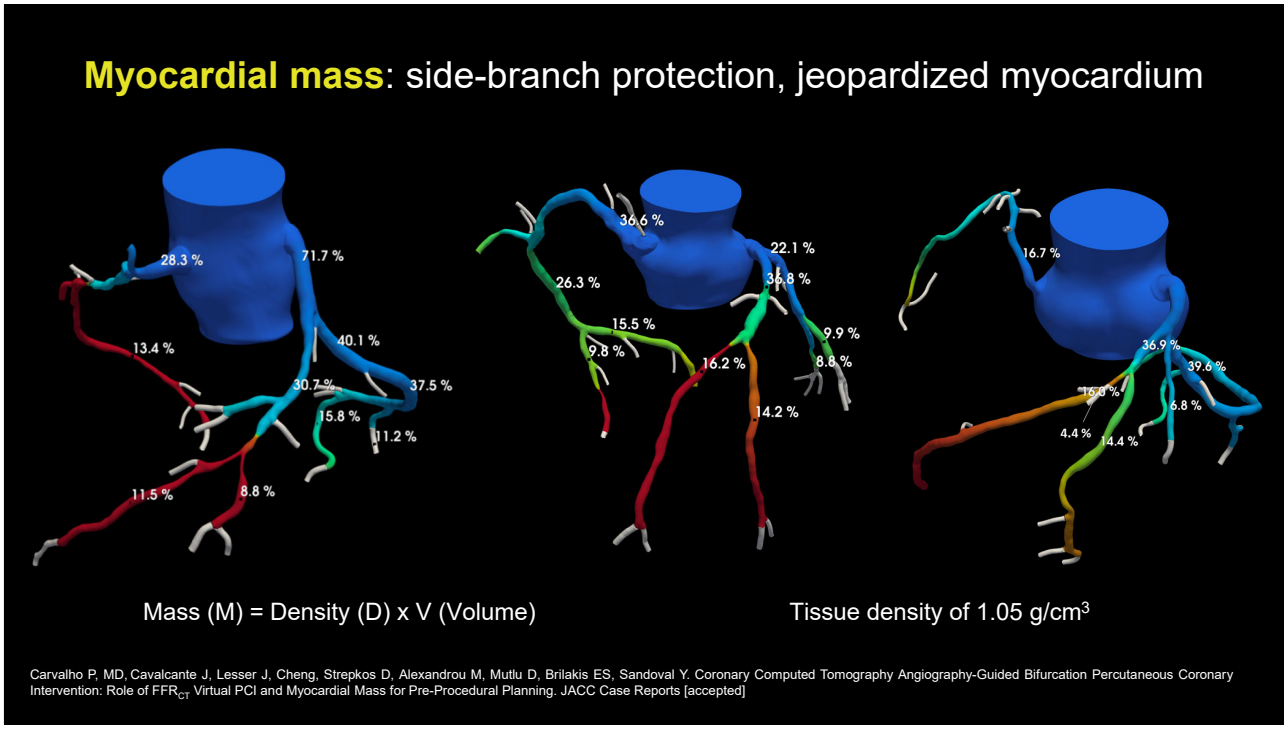
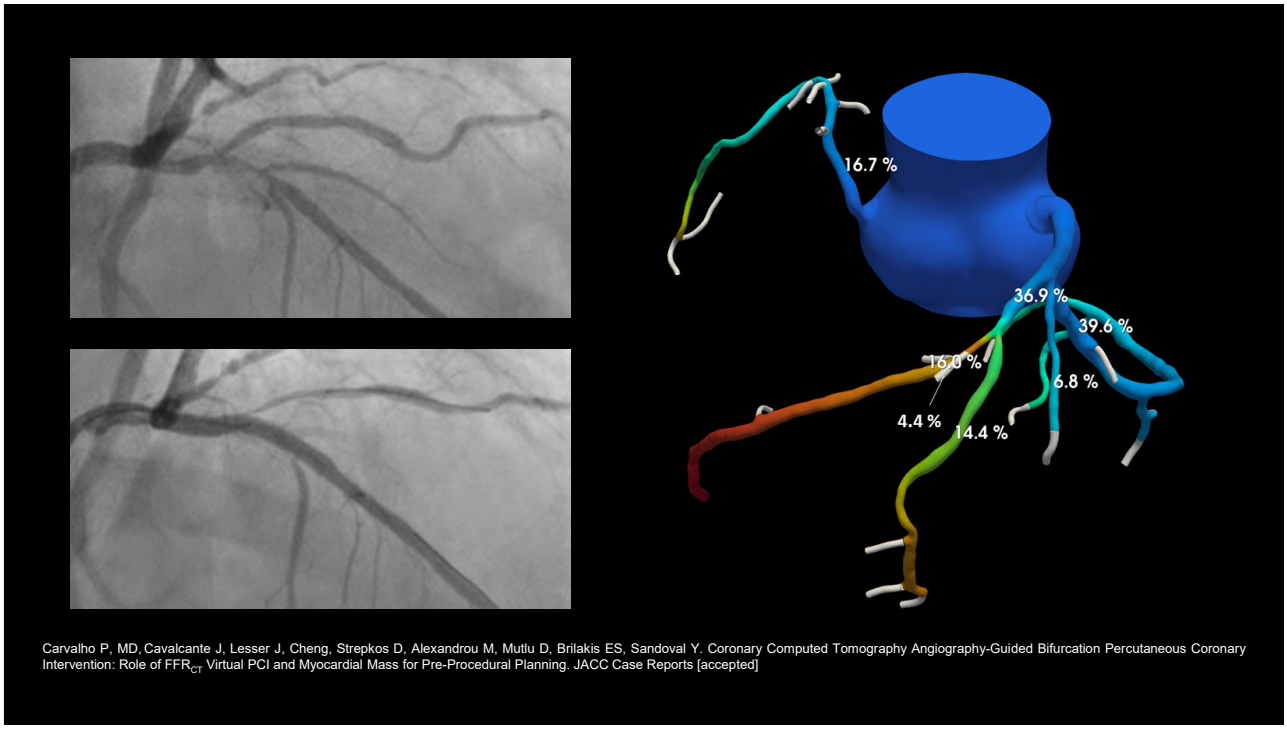

Myocardial mass: side-branch protection, jeopardized myocardium
28.3 %
71.7 %
13.4 %
40.1 %
30.7 %
37.5 %
15.8 %
11.2 %
11.5 %
8.8 %
36.6 %
22.1 %
26.3 %
36.8 %
15.5 %
9.9 %
9.8 %
16.2 %
8.8 %
14.2 %
16.7 %
36.9 %
39.6 %
16.0 %
6.8 %
4.4 %
14.4 %
Mass (M) = Density (D) x V (Volume)
Tissue density of 1.05 g/cm3
Carvalho P, MD, Cavalcante J, Lesser J, Cheng, Strepkos D, Alexandrou M, Mutlu D, Brilakis ES, Sandoval Y. Coronary Computed Tomography Angiography-Guided Bifurcation Percutaneous Coronary Intervention: Role of FFRCT Virtual PCI and Myocardial Mass for Pre-Procedural Planning. JACC Case Reports [accepted]

57


16.7 %
36.9 %
39.6 %
16.0 %
6.8 %
4.4 %
14.4 %
Carvalho P, MD, Cavalcante J, Lesser J, Cheng, Strepkos D, Alexandrou M, Mutlu D, Brilakis ES, Sandoval Y. Coronary Computed Tomography Angiography-Guided Bifurcation Percutaneous Coronary Intervention: Role of FFRCT Virtual PCI and Myocardial Mass for Pre-Procedural Planning. JACC Case Reports [accepted]

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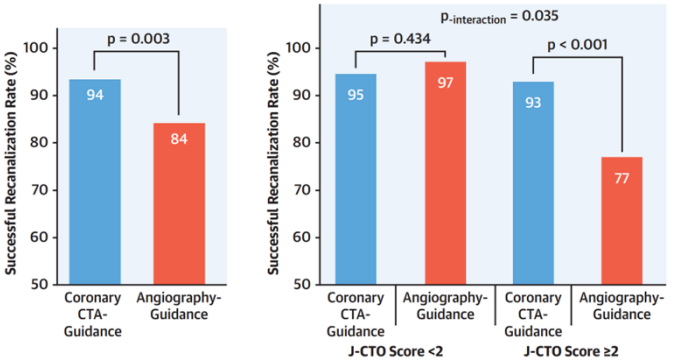
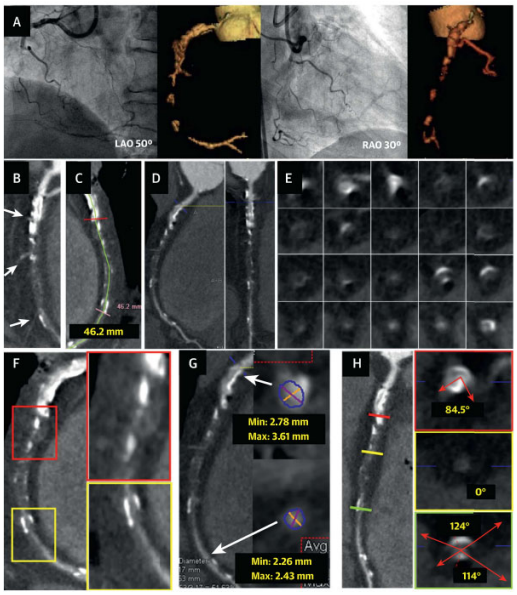
Effect of Coronary CTA on Chronic Total Occlusion Percutaneous Coronary Intervention

A Randomized Trial





CT-CTO Trial (NCT020376986): pre-procedural CCTA guidance for CTO resulted in higher success rates with numerically fewer immediate periprocedural complications such as coronary perforations or PPMI than angiography guidance.

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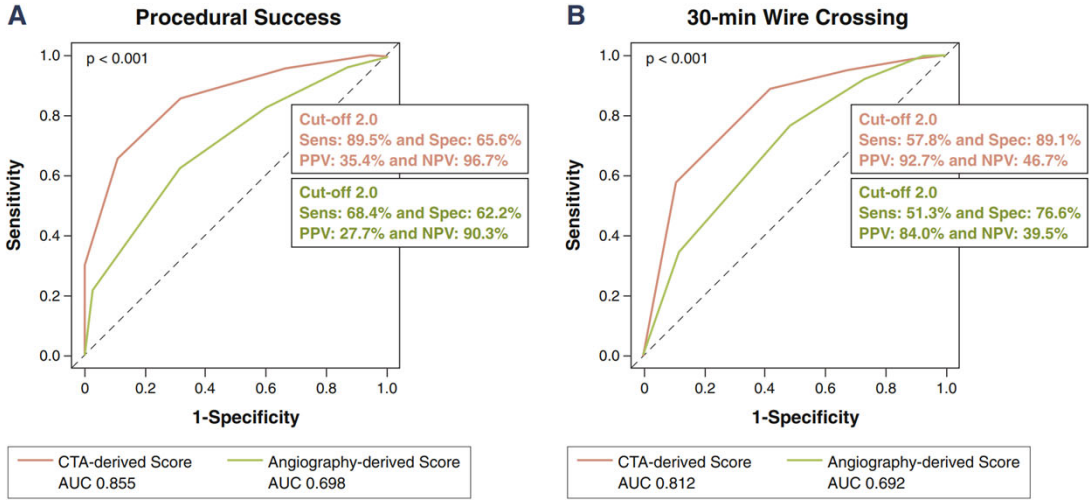
CCTA-based scores for CTO PCI: better than angiography-based scores



Fujino A et al. Accuracy of J-CTO Score Derived From Computed Tomography Versus Angiography to Predict Successful Percutaneous Coronary Intervention. JACC Cardiovasc Imaging. 2018 Feb;11(2 Pt 1):209-217.

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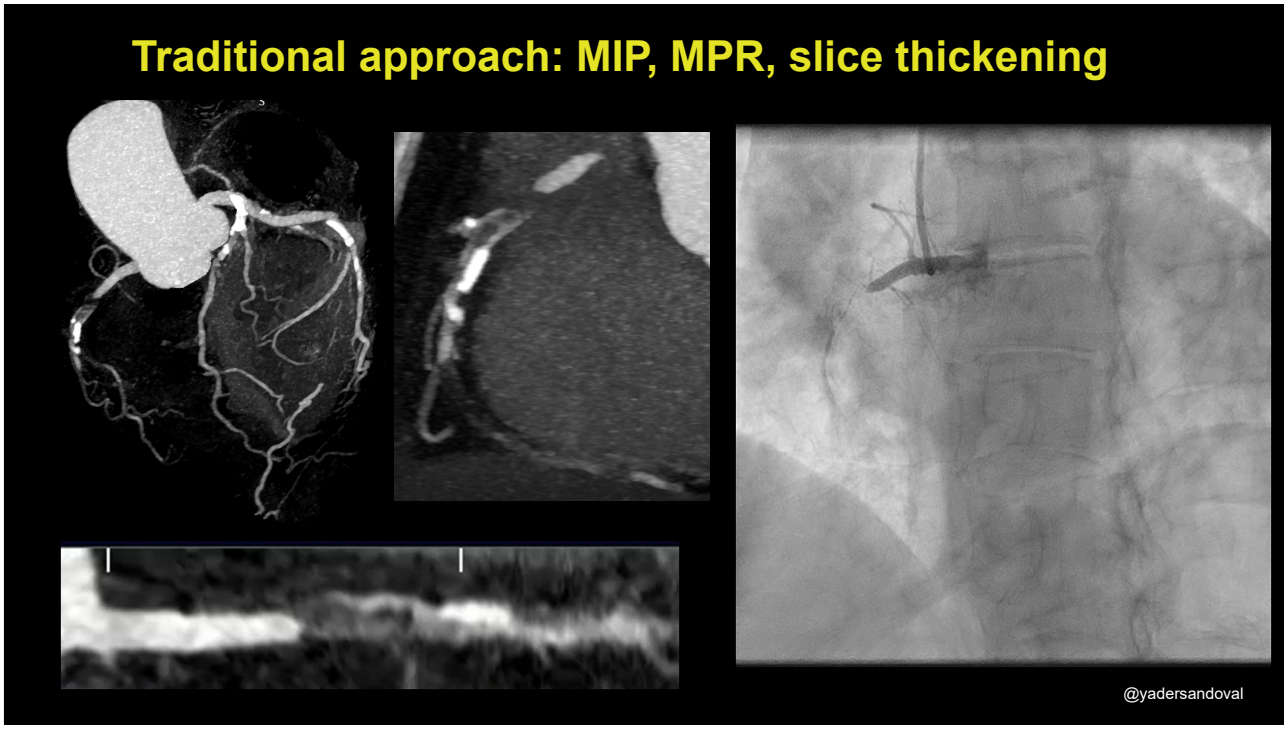
Traditional approach: MIP, MPR, slice thickening
@yadersandoval

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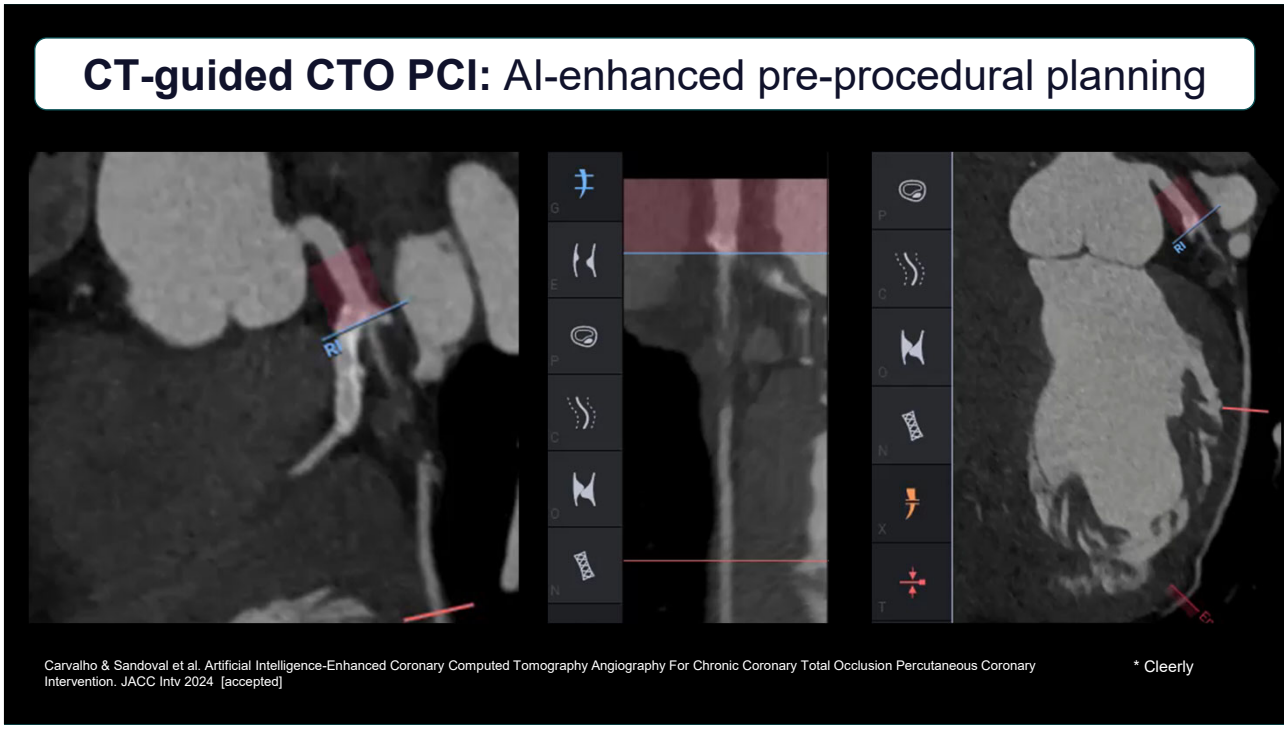
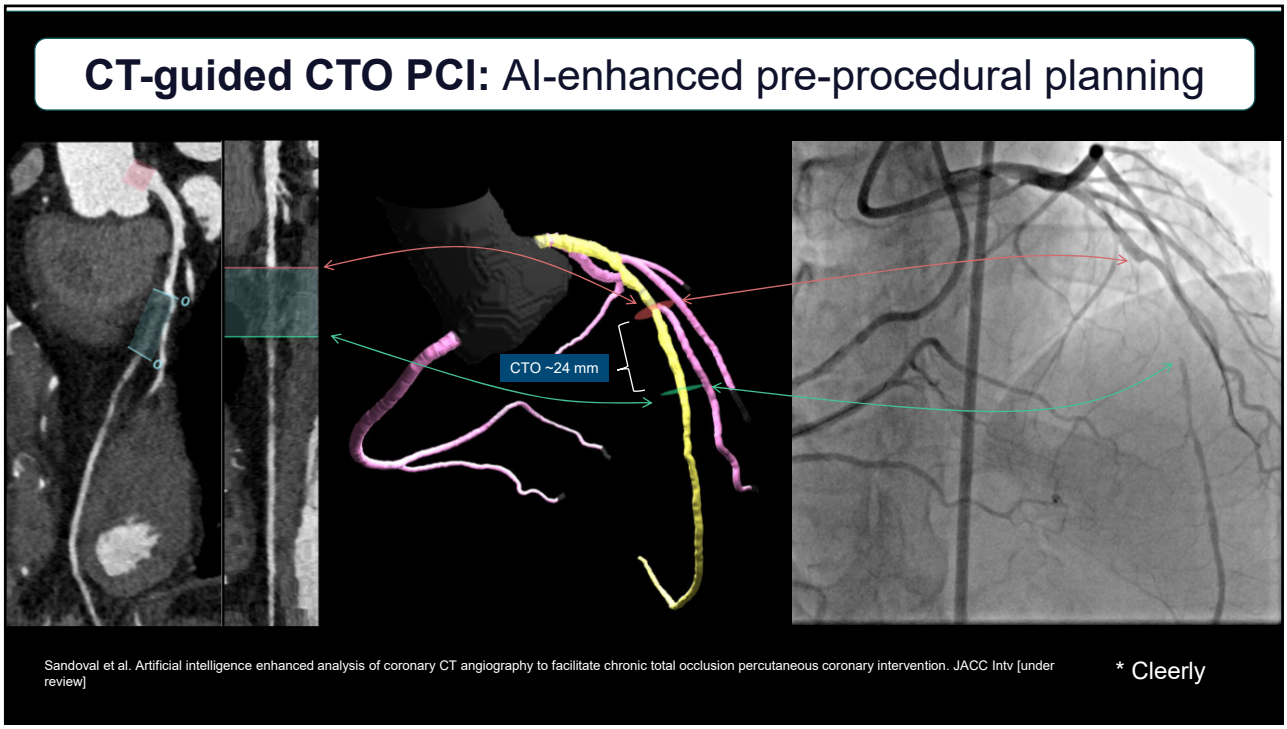
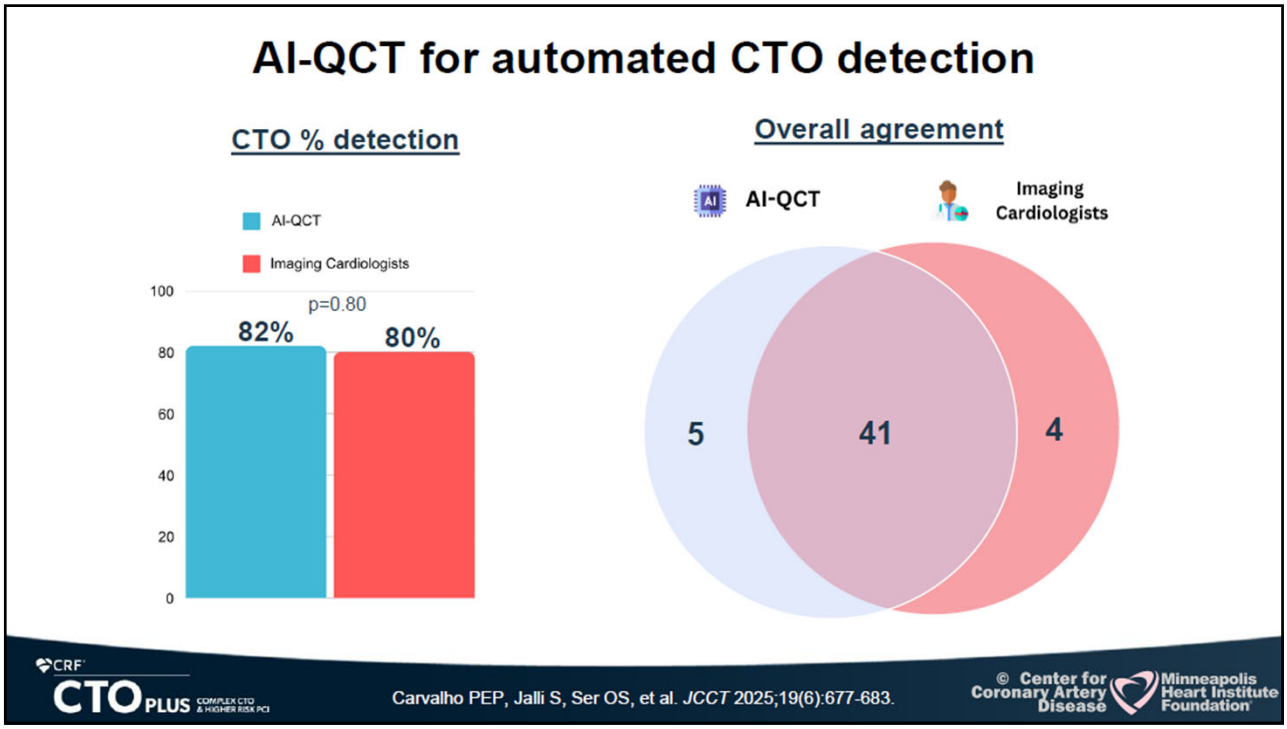

CT-guided CTO PCI: AI-enhanced pre-procedural planning
Carvalho & Sandoval et al. Artificial Intelligence-Enhanced Coronary Computed Tomography Angiography For Chronic Coronary Total Occlusion Percutaneous Coronary Intervention. JACC Intv 2024 [accepted]
* Cleerly

62


CT-guided CTO PCI: AI-enhanced pre-procedural planning
CTO ~24 mm
Sandoval et al. Artificial intelligence enhanced analysis of coronary CT angiography to facilitate chronic total occlusion percutaneous coronary intervention. JACC Intv [under review]
* Cleerly

63


AI-QCT for automated CTO detection
CTO % detection
AI-QCT
Imaging Cardiologists
100
80
60
40
20
0
p=0.80
82%
80%
Overall agreement
AI-QCT
Imaging Cardiologists
5
41
4
CTO PLUS
Carvalho PEP, Jalli S, Ser OS, et al. JCCT 2025;19(6):677-683.
© Center for Coronary Artery Disease
Minneapolis Heart Institute Foundation

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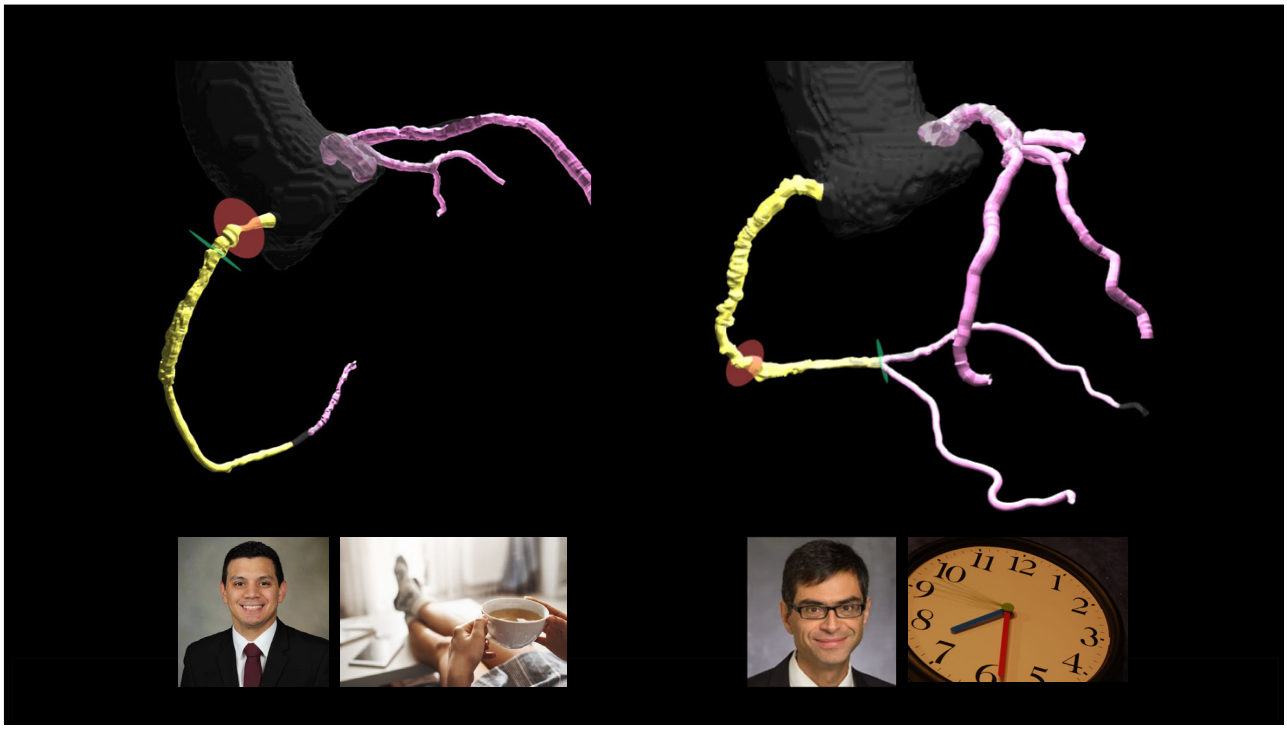

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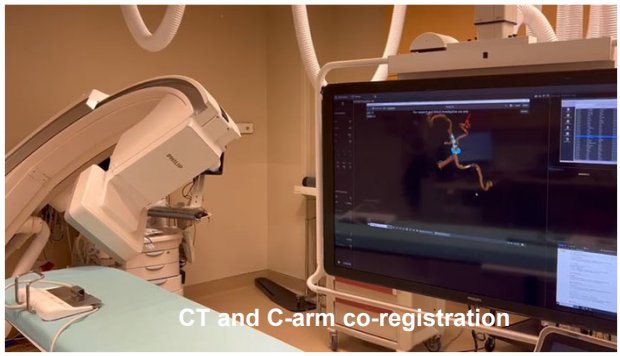
From pre- to intra-procedural guidance
CCTA and C-arm co-registration



Investigational 3D Plaque* Medis (P4)

3D MIP and C-arm co-registration
*Courtesy GE

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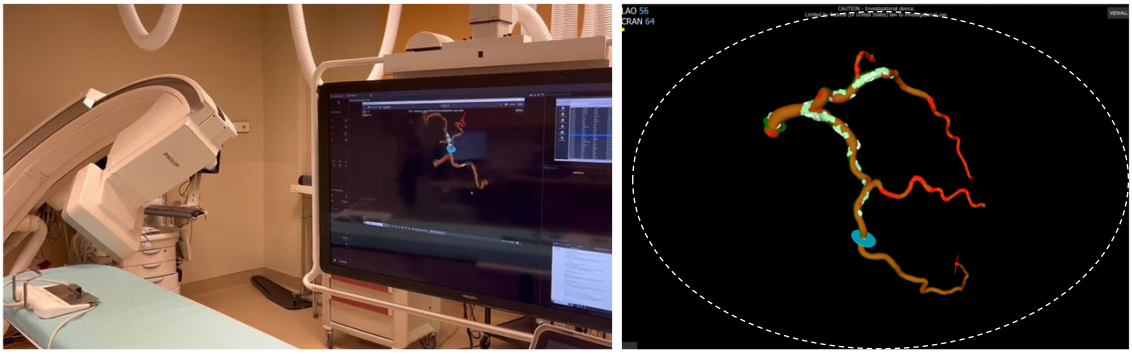
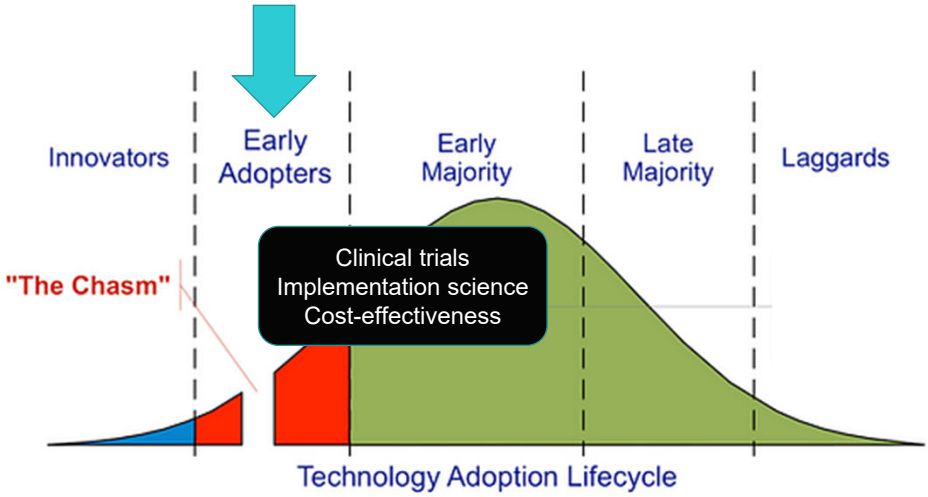
Intra-procedural CT guidance for PCI planning



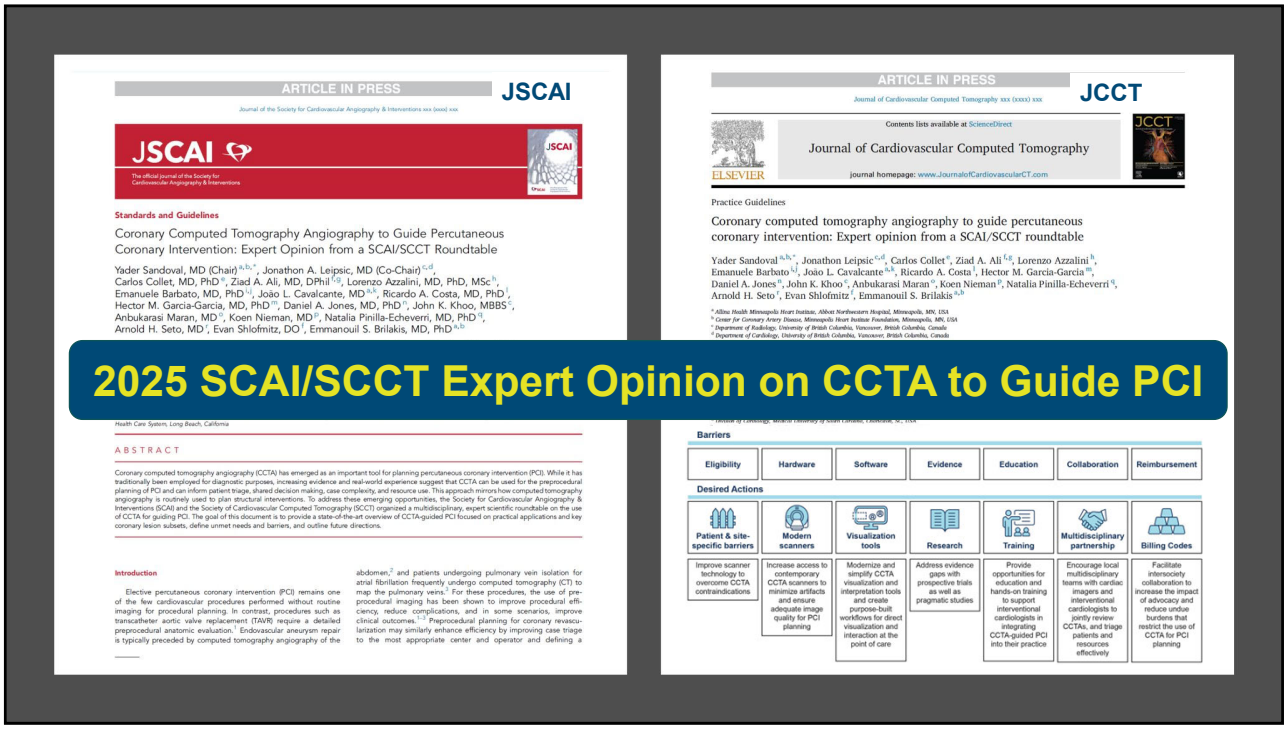
C-arm and CT co-registration in P4 trial with **option for intra-procedural planning if needed**.

67

CT-guided PCI: The Early Adopters – Defining what is needed to move forward.



68



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Coronary Computed Tomography Angiography (CCTA) CCTA to guide PCI:
Expert Opinion from a SCAI and SCCT Scientific Roundtable

Minneapolis, Minnesota, USA – October 2024

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Sandoval Y, Leipsic J, Collet C, Ali ZA, Azzalini L, Barbato E, Cavalcante JL, Costa RA, Garcia-Garcia HM, Jones DA, Khoo JK, Maran A, Nieman K, Pinilla-Echeverri N, Seto AH, Shlofmitz E, Brilakis ES. Coronary computed tomography angiography to guide percutaneous coronary intervention: Expert opinion from a SCAI/SCCT roundtable. J Cardiovasc Comput Tomogr. 2025 May-Jun;19(3):277-290.

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Barriers and Desired Actions to Advance the Use of Coronary Computed Tomography Angiography-Guided Percutaneous Coronary Interventions

Barriers

Eligibility	Hardware	Software	Evidence	Education	Collaboration	Reimbursement

Desired Actions

Patient & site-specific barriers	Modern scanners	Visualization tools	Research	Training	Multidisciplinary partnership	Billing Codes
Improve scanner technology to overcome CCTA contraindications	Increase access to contemporary CCTA scanners to minimize artifacts and ensure adequate image quality for PCI planning	Modernize and simplify CCTA visualization and interpretation tools and create purpose-built workflows for direct visualization and interaction at the point of care	Address evidence gaps with prospective trials as well as pragmatic studies	Provide opportunities for education and hands-on training to support interventional cardiologists in integrating CCTA-guided PCI into their practice	Encourage local multidisciplinary teams with cardiac imagers and interventional cardiologists to jointly review CCTAs, and triage patients and resources effectively	Facilitate intersociety collaboration to increase the impact of advocacy and reduce undue burdens that restrict the use of CCTA for PCI planning

Sandoval Y, Leipsic JA, Collet C, Ali ZA, Azzalini L, Barbato E, Cavalcante JL, Costa RA, Garcia-Garcia HM, Jones DA, Khoo JK, Maran A, Nieman K, Pinilla-Echeverri N, Seto AH, Shlofmitz E, Brilakis ES. Coronary Computed Tomography Angiography to Guide Percutaneous Coronary Intervention: Expert Opinion from a SCAI/SCCT Roundtable. J Soc Cardiovasc Angiogr Interv. 2025 May 1;4(6):103664.

SCAI

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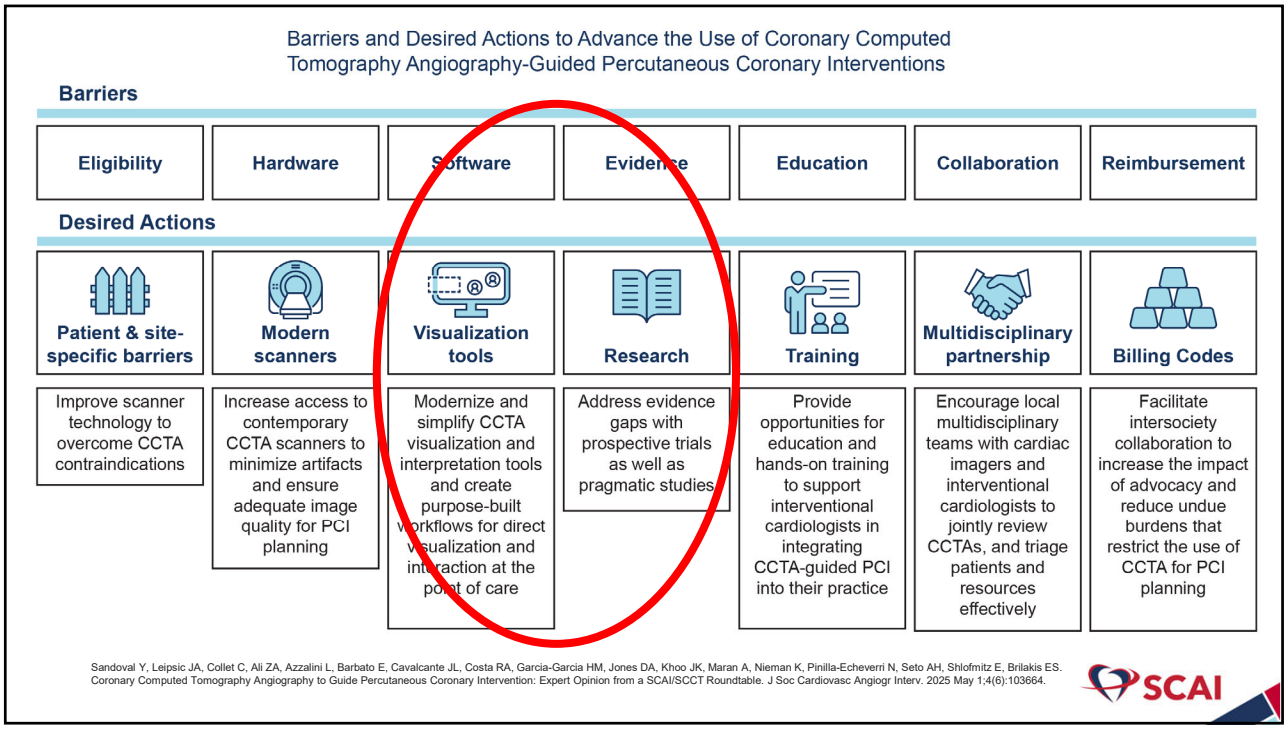
Barriers and Desired Actions to Advance the Use of Coronary Computed Tomography Angiography-Guided Percutaneous Coronary Interventions
Barriers
Eligibility
Hardware
Software
Evidence
Education
Collaboration
Reimbursement
Desired Actions
Patient & site-specific barriers
Improve scanner technology to overcome CCTA contraindications
Modern scanners
Increase access to contemporary CCTA scanners to minimize artifacts and ensure adequate image quality for PCI planning
Visualization tools
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Sandoval Y, Leipsic JA, Collet C, Ali ZA, Azzalini L, Barbato E, Cavalcante JL, Costa RA, Garcia-Garcia HM, Jones DA, Khoo JK, Maran A, Nieman K, Pinilla-Echeverri N, Seto AH, Shlofmitz E, Brilakis ES. Coronary Computed Tomography Angiography to Guide Percutaneous Coronary Intervention: Expert Opinion from a SCAI/SCCT Roundtable. J Soc Cardiovasc Angiogr Interv. 2025 May 1;4(6):103664.
SCAI

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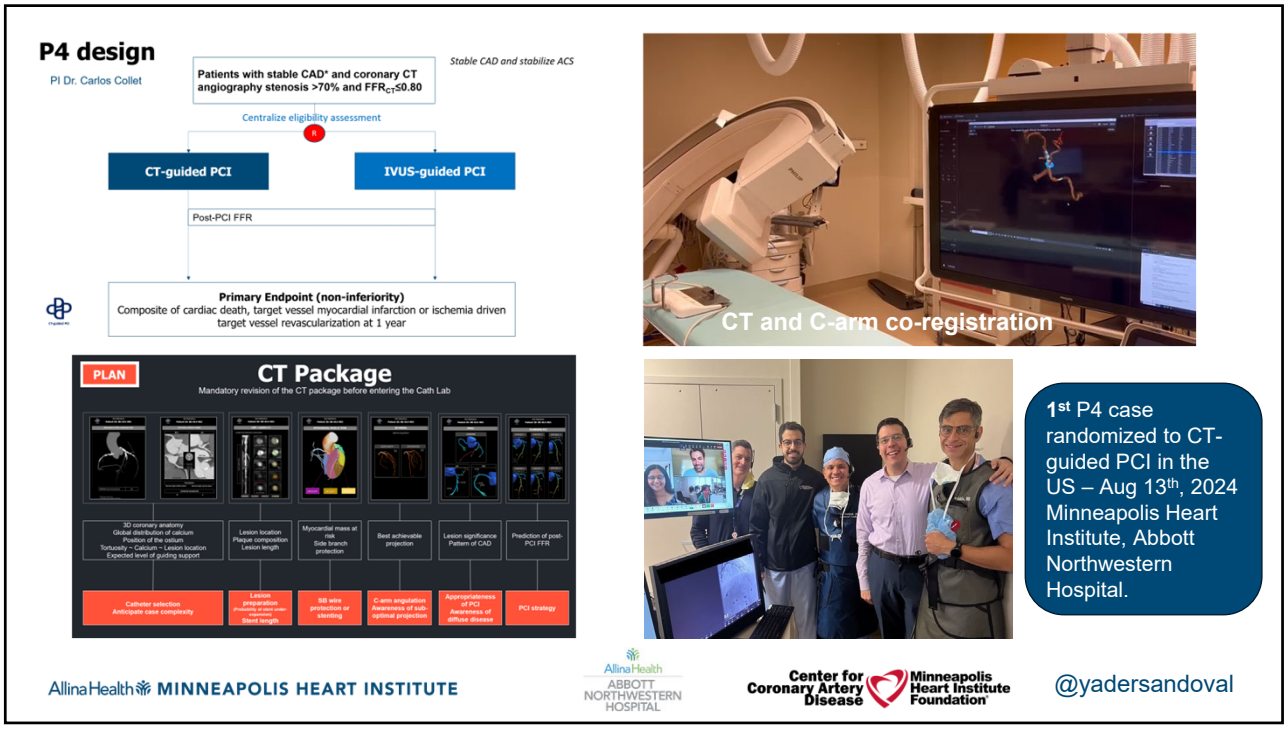
P4 design
PI Dr. Carlos Collet
Patients with stable CAD* and coronary CT angiography stenosis >70% and FFRCT≤0.80
Stable CAD and stabilize ACS
Centralize eligibility assessment
R
CT-guided PCI
IVUS-guided PCI
Post-PCI FFR
Primary Endpoint (non-inferiority)
Composite of cardiac death, target vessel myocardial infarction or ischemia driven target vessel revascularization at 1 year
PLAN
CT Package
Mandatory revision of the CT package before entering the Cath Lab
CT and C-arm co-registration
1st P4 case randomized to CT-guided PCI in the US – Aug 13th, 2024 Minneapolis Heart Institute, Abbott Northwestern Hospital.
AllinaHealth MINNEAPOLIS HEART INSTITUTE
AllinaHealth ABBOTT NORTHWESTERN HOSPITAL
Center for Coronary Artery Disease
Minneapolis Heart Institute Foundation
@yadersandoval

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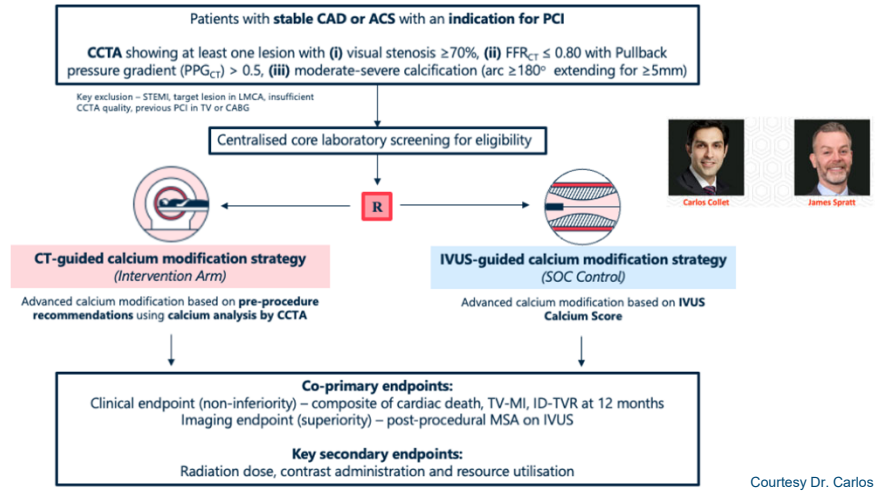
OPTIMAL ("P5") Trial: CT-guided vs. IVUS-guided calcium modification



Courtesy Dr. Carlos Collet

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The Coronary computed Tomography angiography to PLAN PCI (**CT-PLAN PCI**) Trial

Investigator-initiated
Multicenter, 4 US sites
Prospective RCT

Adult patients with pre-procedural CCTA within 90-days with obstructive CAD and FFR$_{CT}$ ≤0.80 referred for non-emergent PCI

Screening

Randomization

CCTA-guided PCI (n = 100 vessels)

- CCTA-based M*L*D*P for lesion morphology including calcium characterization, myocardial mass, stent length based on optimal landing zones, stent diameter, FFR$_{CT}$, and optimal projections.
- Pre- and post-PCI FFR and HD-IVUS.
- Mandatory post-PCI pressure-wire FFR (blinded).

Routine PCI (n = 100 vessels)

- Routine PCI as per local standard of care.
- Pre- and post-PCI FFR and HD-IVUS.
- Without access to CCTA planning package or dedicated CCTA PCI planning tools.
- Mandatory post-PCI pressure-wire FFR (blinded).

Primary endpoint (superiority): Procedural time

Secondary:

- Procedural outcomes: contrast volume, radiation dose, fluoroscopy time
- Post-PCI FFR (pressure-wire) and post-PCI stent expansion (HD-IVUS)
- PCI outcomes, including in-hospital MACE and post-procedural myocardial injury and infarction.
- Resource utilization (# catheters, balloons, stents)
- Frequency of advanced calcium modification strategies.

Principal investigator:
Yader Sandoval, M.D.
Chairperson:
Emmanouil S. Brilakis, M.D., PhD
Coordinating Center: MHIF-CCAD
Sponsors:
Heartflow
SHOCKWAVE MEDICAL

Center for Coronary Artery Disease | Minneapolis Heart Institute Foundation

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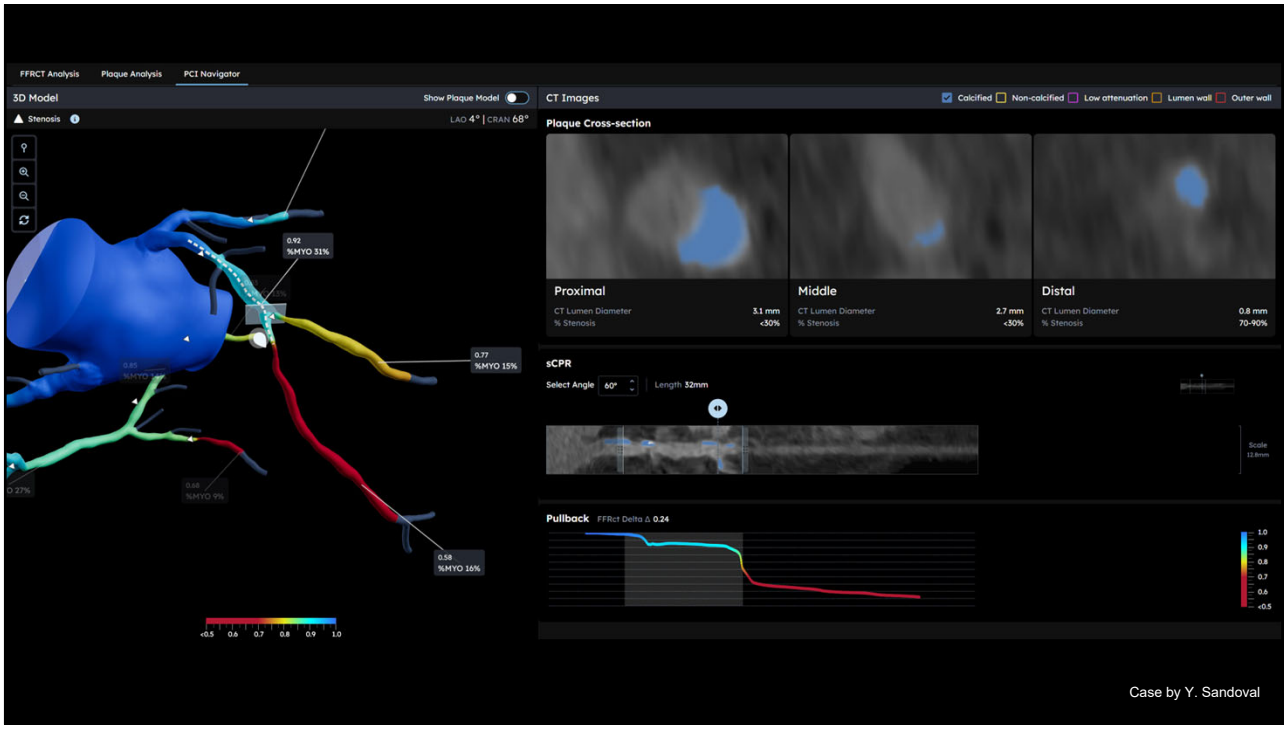

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NAVIGATE-PCI Registry

PIs: Dr. Ziad Ali, Dr. Todd Villines

CT-guided PCI Planning with PCI Navigator

Primary Objective	Assess how PCI Navigator influences interventional cardiologist confidence, decision-making, and procedural efficiency
# Patients	~2500 patients
# Sites	~30 US sites

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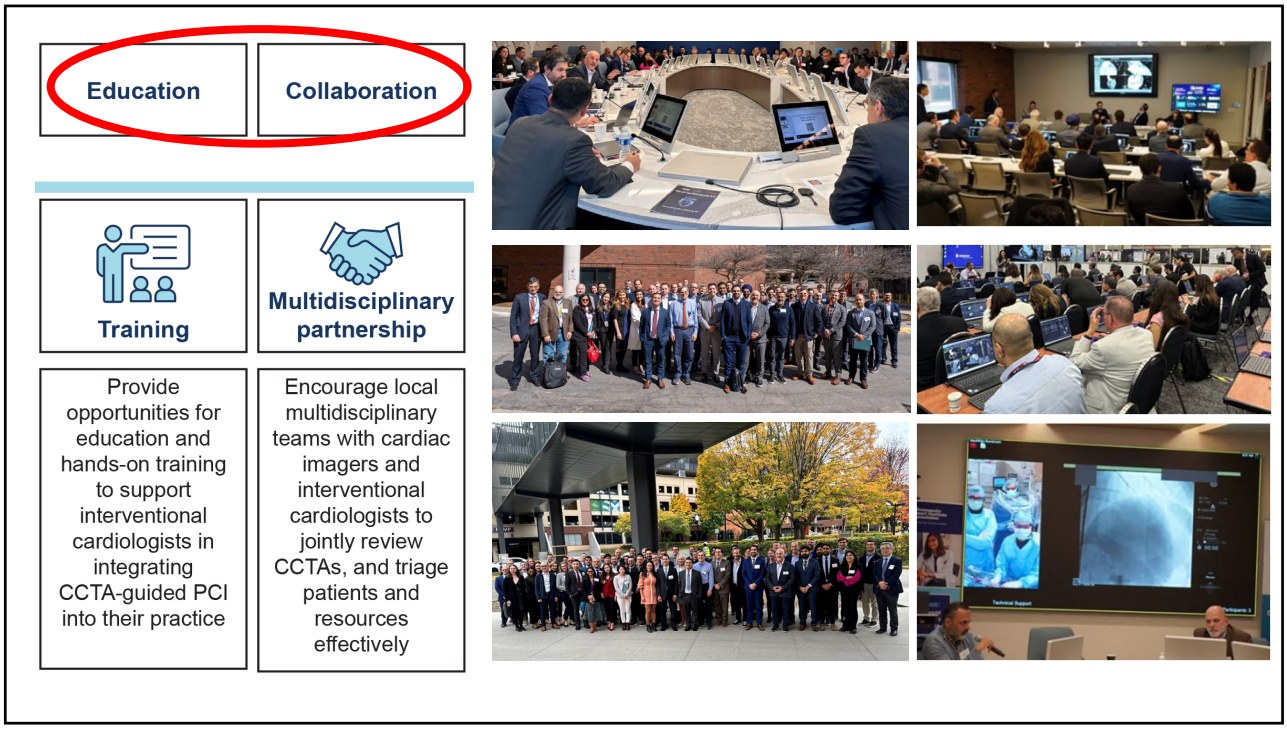
Education
Collaboration
Training
Multidisciplinary partnership
Provide opportunities for education and hands-on training to support interventional cardiologists in integrating CCTA-guided PCI into their practice
Encourage local multidisciplinary teams with cardiac imagers and interventional cardiologists to jointly review CCTAs, and triage patients and resources effectively

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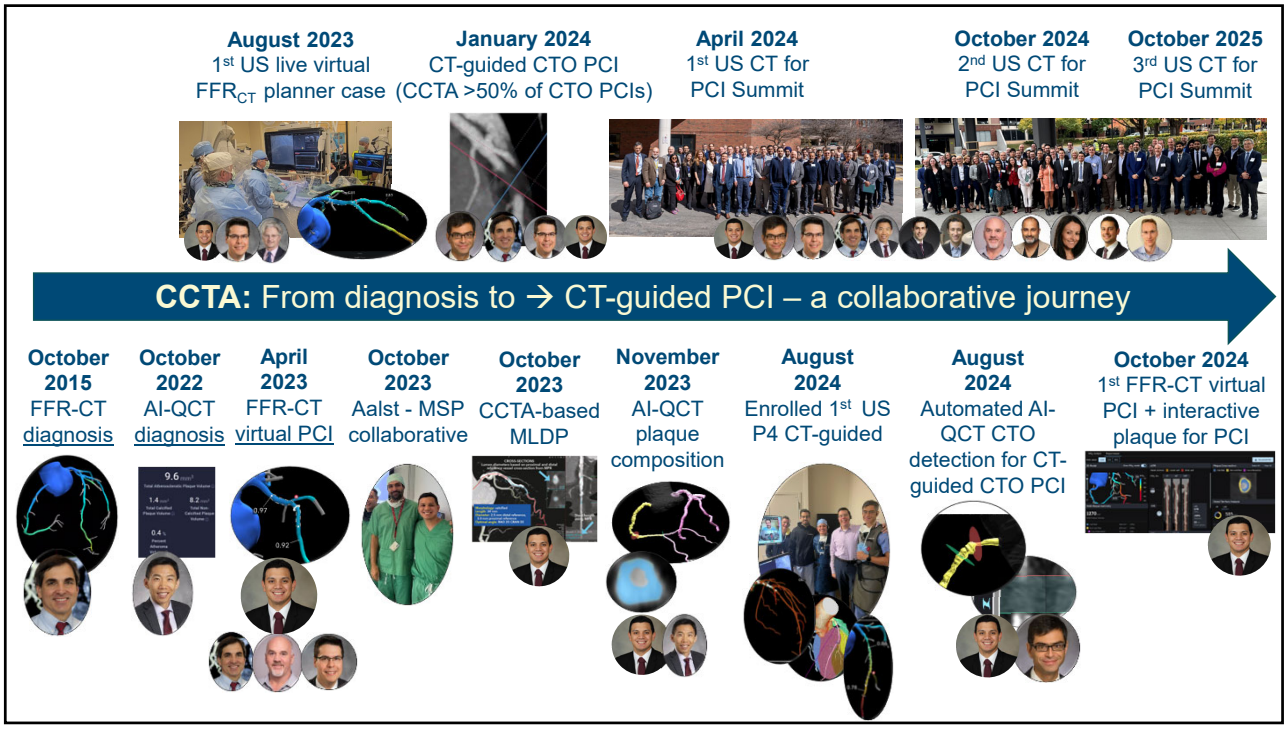
August 2023
1st US live virtual FFRCT planner case
January 2024
CT-guided CTO PCI (CCTA >50% of CTO PCIs)
April 2024
1st US CT for PCI Summit
October 2024
2nd US CT for PCI Summit
October 2025
3rd US CT for PCI Summit
CCTA: From diagnosis to → CT-guided PCI – a collaborative journey
October 2015
FFR-CT diagnosis
October 2022
AI-QCT diagnosis
April 2023
FFR-CT virtual PCI
October 2023
Aalst - MSP collaborative
October 2023
CCTA-based MLDP
November 2023
AI-QCT plaque composition
August 2024
Enrolled 1st US P4 CT-guided
August 2024
Automated AI-QCT CTO detection for CT-guided CTO PCI
October 2024
1st FFR-CT virtual PCI + interactive plaque for PCI

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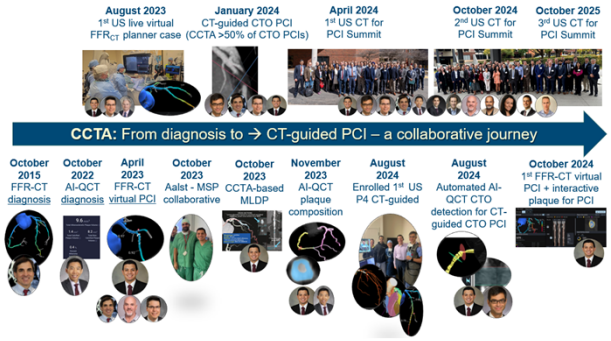
Where to in 2026?



- Broader clinical adoption
- Await P4 RCT results
- CT-PLAN PCI RCT
- OPTIMAL RCT
- NAVIGATE PCI registry
- 4th annual CT-guided PCI summit

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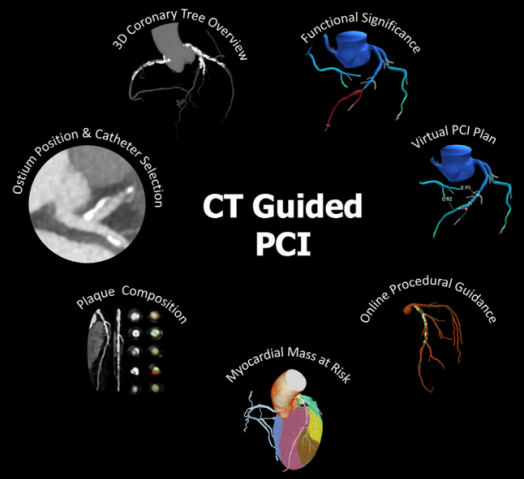
The past

Abnormal CT with obstructive CAD (yes/no) → *binary* approach for referring patients to the cath lab for invasive angiography, possible PCI

The future is here!

Abnormal CT with obstructive CAD (yes/no) → case triage, treatment modality, pre-procedural planning, calcium assessment, guide selection, FFR-CT, virtual PCI, morphology, length,



@yadersandoval #CT4PCI

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Yader Sandoval, MD, FACC, FSCAI, FESC.
Interventional Section, Minneapolis Heart Institute, Abbott Northwestern Hospital, Minneapolis, MN
Co-Chair, Center for Coronary Artery Disease (CCAD), Minneapolis Heart Institute Foundation
Adjunct Associate Professor of Medicine, Mayo Clinic College of Medicine and Science

Contact: yader.sandoval@allina.com

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