Anatomy versus physiology

Nils P. Johnson, MD, MS, FACC
Associate Professor of Medicine
Division of Cardiology, Department of Medicine
and the Weatherhead PET Imaging Center
University of Texas Medical School at Houston
Memorial Hermann Hospital – Texas Medical Center
Houston, Texas, United States of America

Disclosure Statement of Financial Interest

Within the past 12+ months, Nils Johnson has had a financial interest/arrangement or affiliation with the organization(s) listed below.

Affiliation/Financial Relationship	Organizations (alphabetical)
• Grant/Research Support (to *institution*)	• St Jude Medical (for CONTRAST study) • Volcano/Philips (for DEFINE-FLOW)
• Educational organizations (travel support for academic meetings but *never honoraria*)	• ASNC (travel award, 2007) • Canadian CPI (Montréal , 2013-15) • CRF (TCT 2012-14, CPIIS 2014) • ESC (ETP physiology courses, 2013-15) • KSIC (annual meeting, 2015) • SCAI (travel award, 2010)

Nils Johnson has *never* personally received *any* money from *any* commercial company. Specifically, he does *not accept* commercial consulting, travel, entertainment, or speaking compensation *of any kind*.

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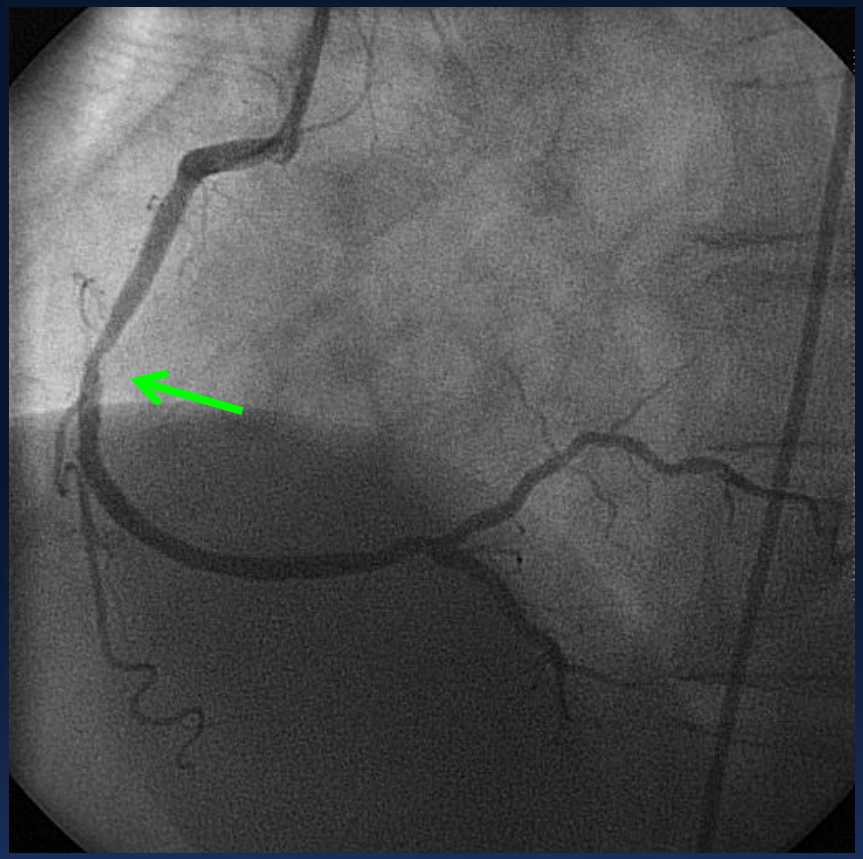

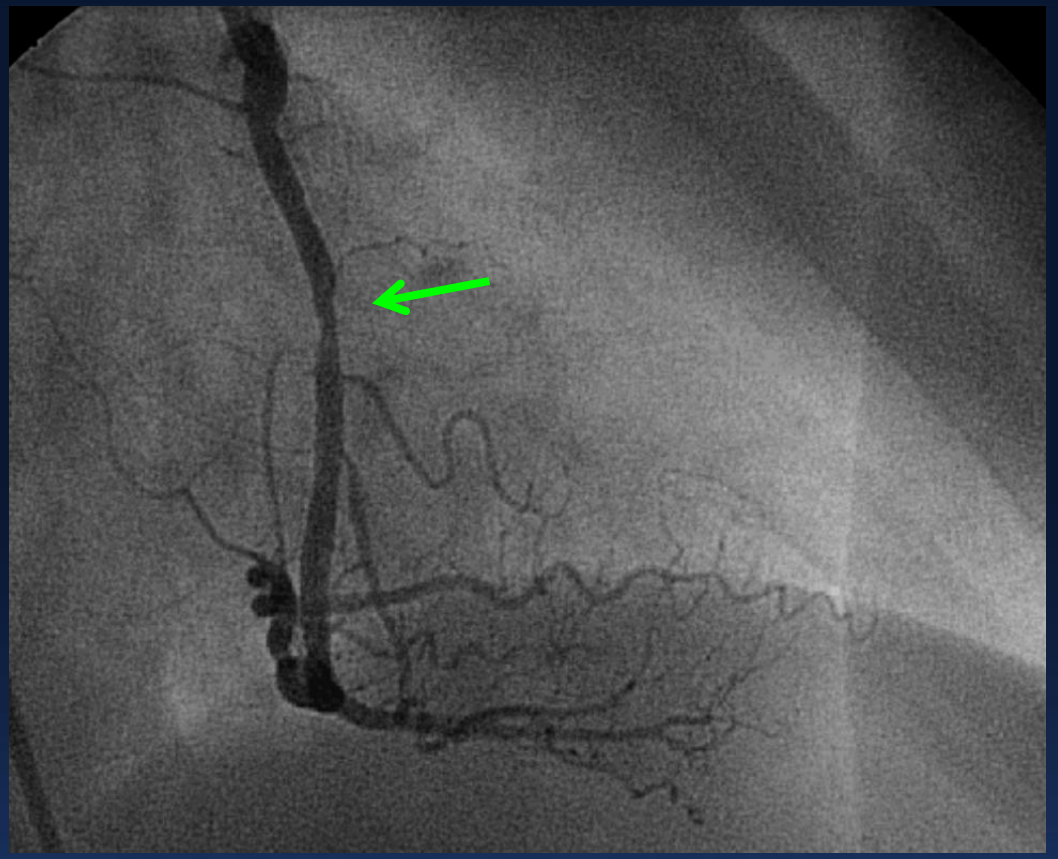

Medical therapy *alone*?
Or *add PCI?*

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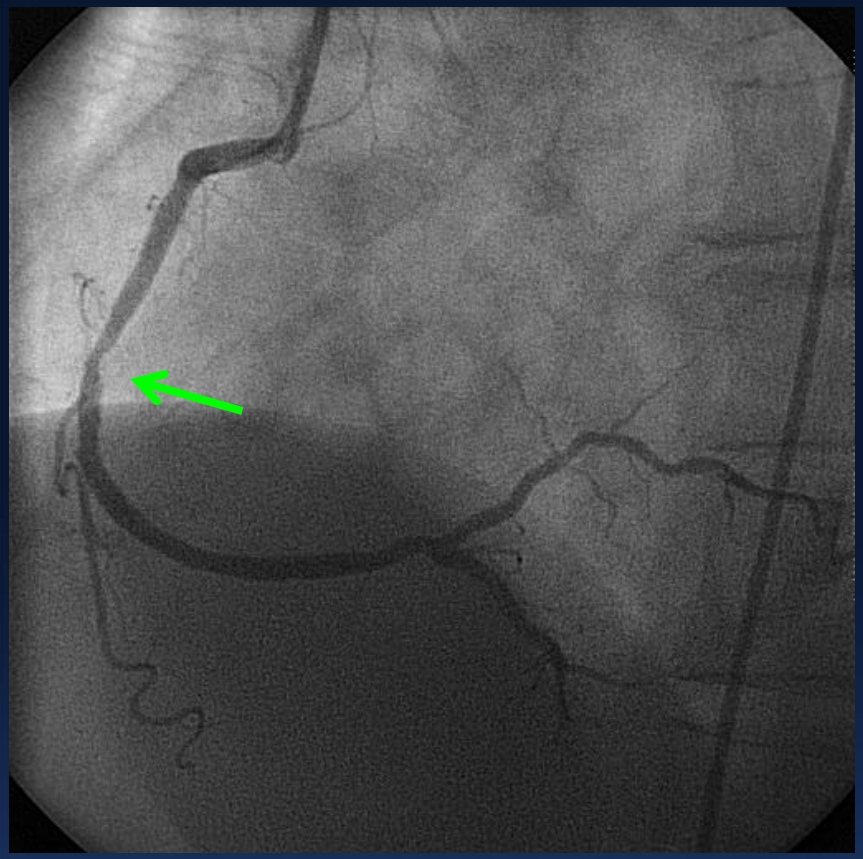
Symptoms

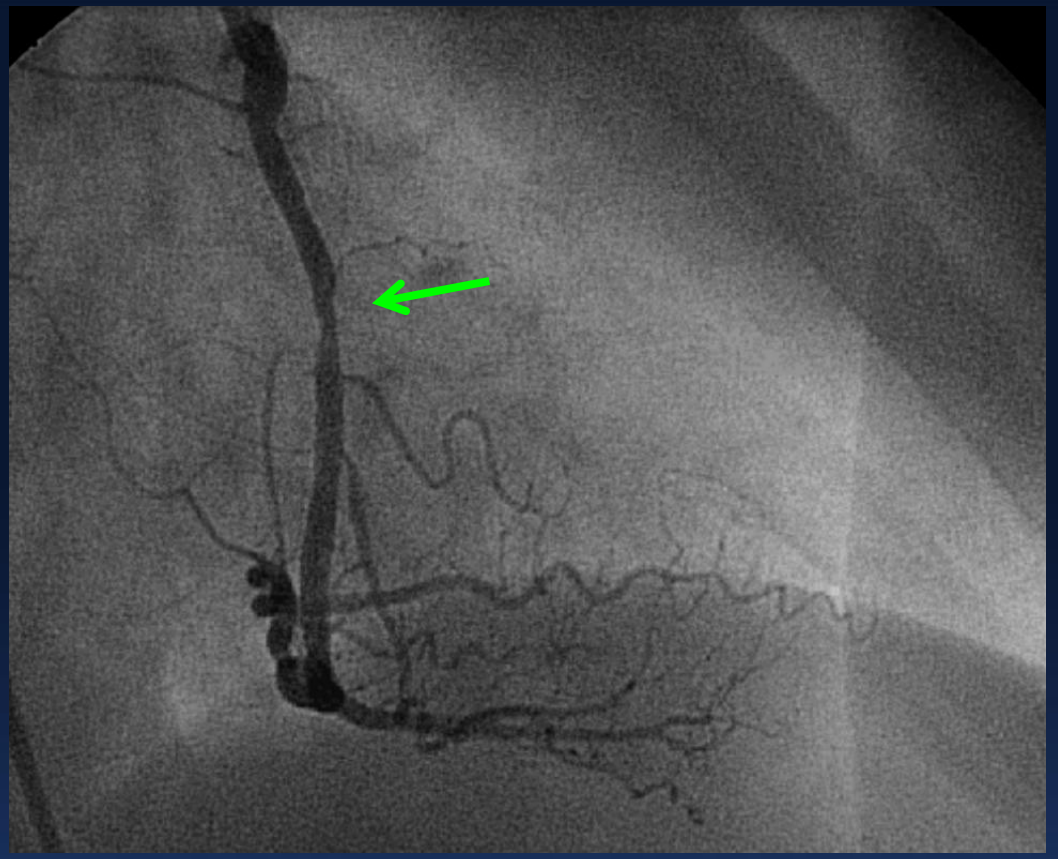
European Heart Journal (2013) **34**, 2949–3003
doi:10.1093/eurheartj/eht296

ESC GUIDELINES

2013 ESC guidelines on the management of stable coronary artery disease (SCAD)

The traditional understanding of SCAD is that of a disease causing exercise- and stress-related chest symptoms





55 year-old woman

- new, typical angina
- CCS class II-III severity despite nitrates
- no beta-blocker due to lung disease

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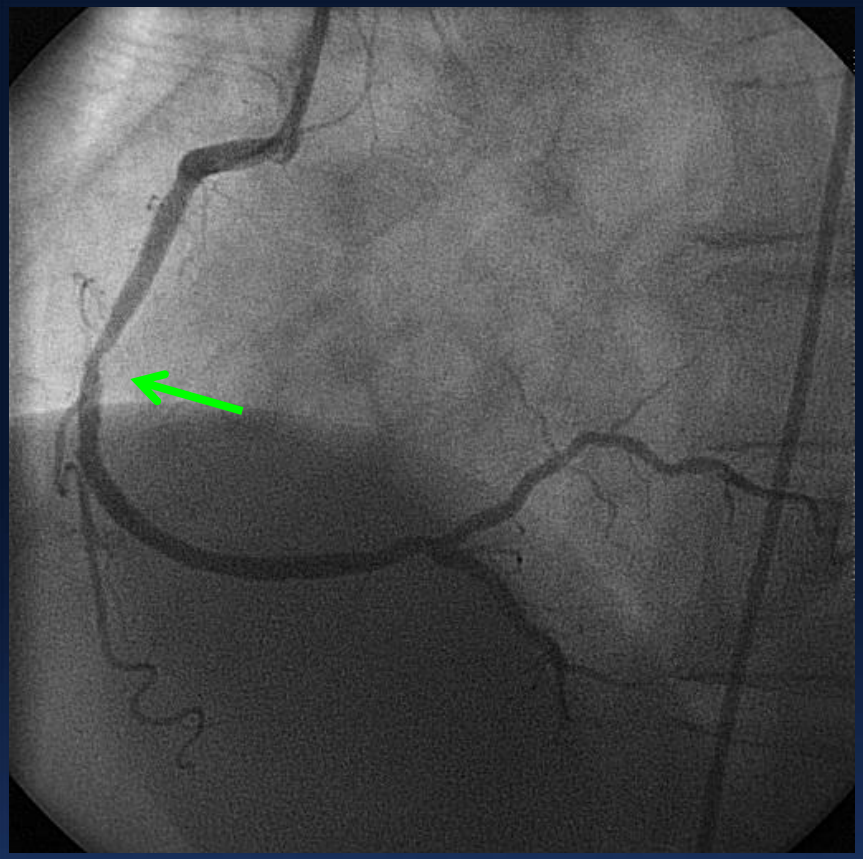
%DS

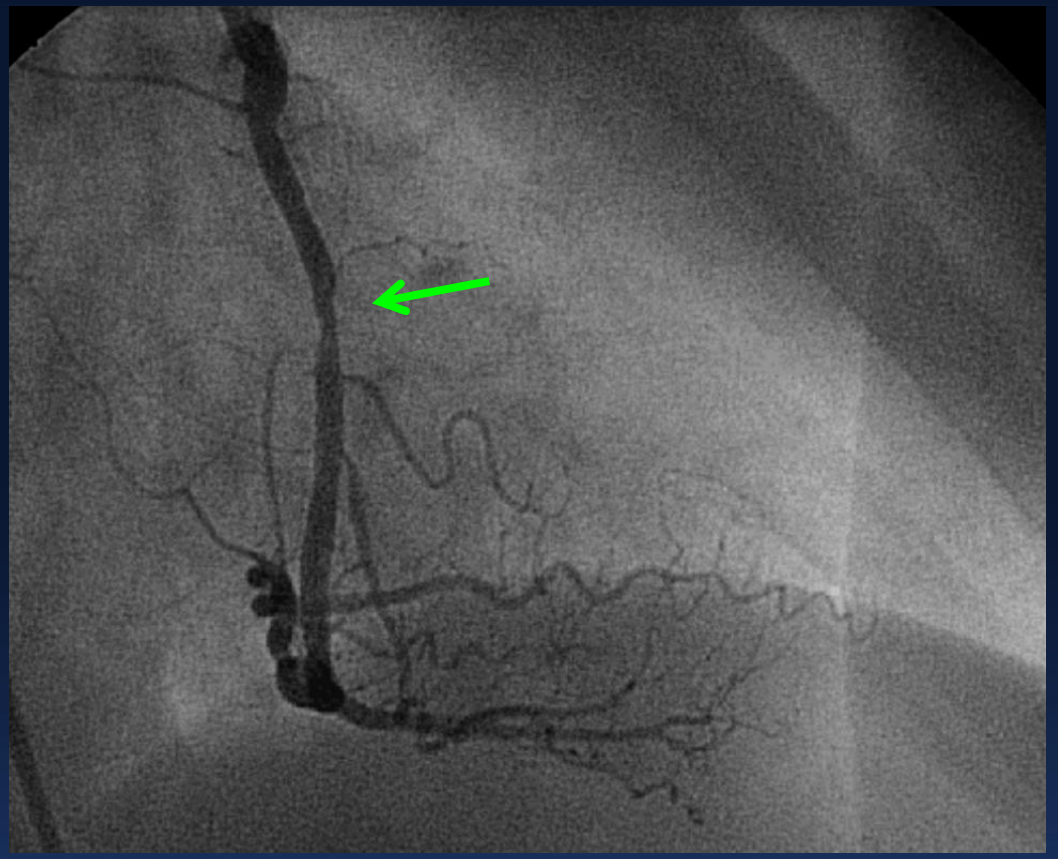
European Heart Journal (2013) **34**, 2949–3003
doi:10.1093/eurheartj/eht296

ESC GUIDELINES

2013 ESC guidelines on the management of stable coronary artery disease

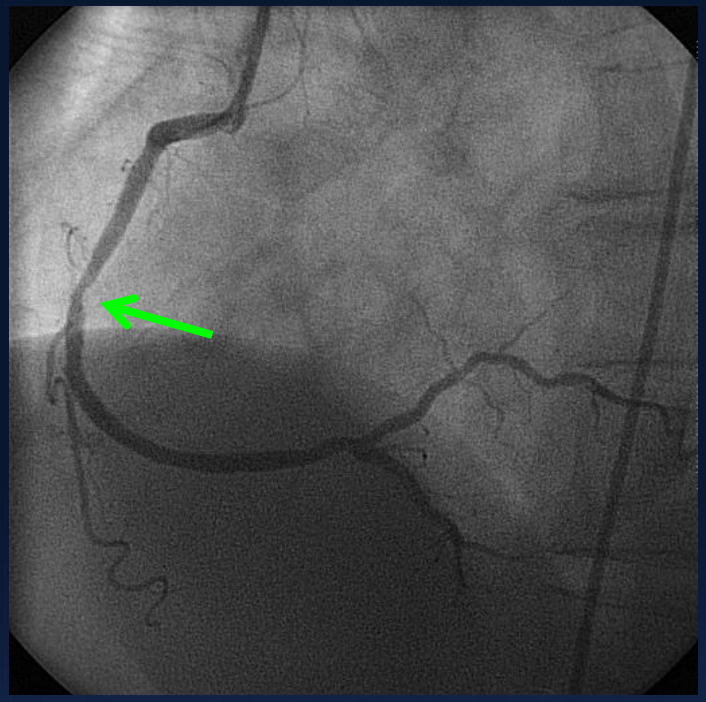
The traditional understanding of SCAD is that of a disease causing exercise- and stress-related chest symptoms due to narrowings of ≥50% in the left main coronary artery and ≥70% in one or several of the major coronary arteries.

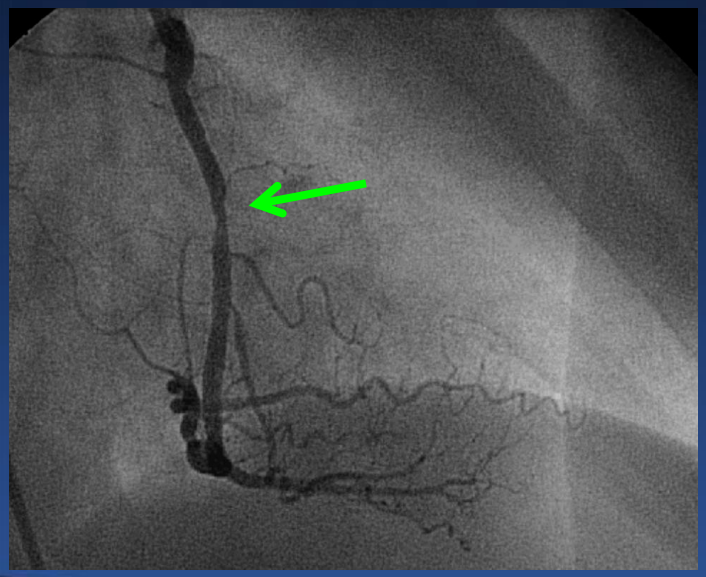




QCA of lesion

- 58% in LAO, 55% in RAO
- referred for angiography directly without non-invasive testing





symptoms,
clinical data,
angiogram

treatment
decision

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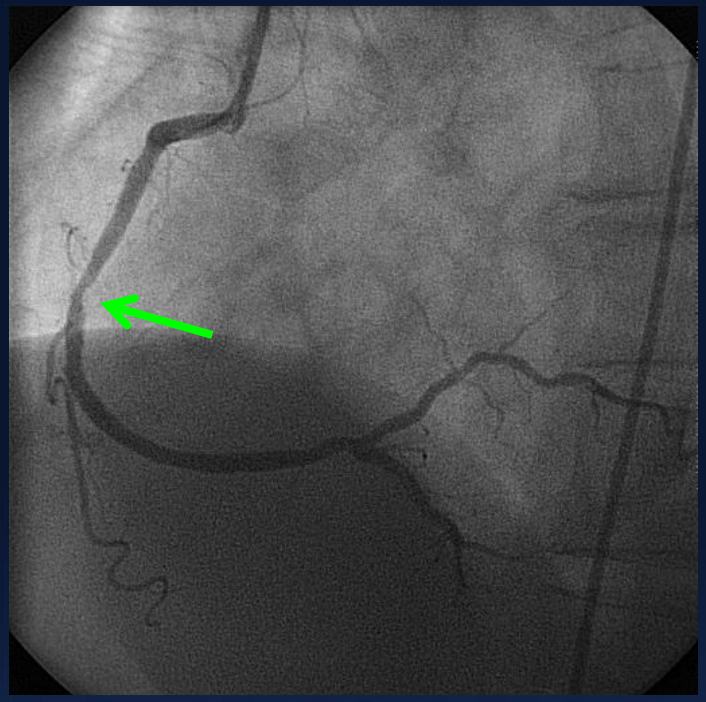

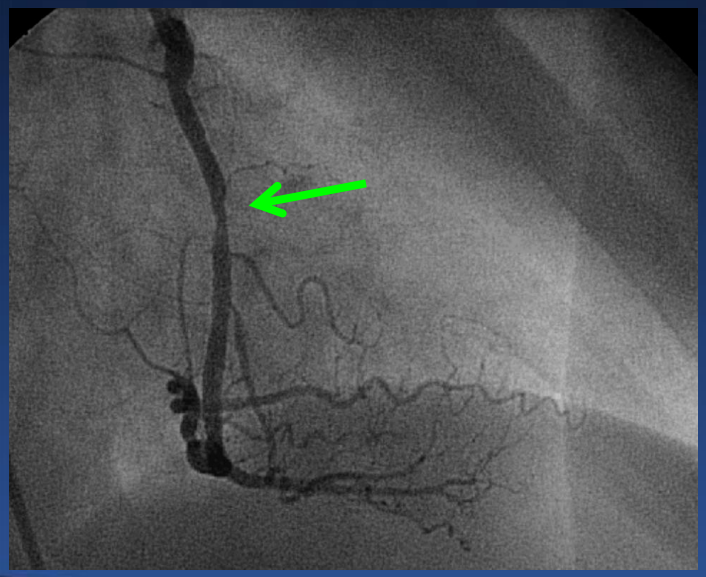

symptoms,
clinical data,
angiogram

predict
significance

treatment
decision

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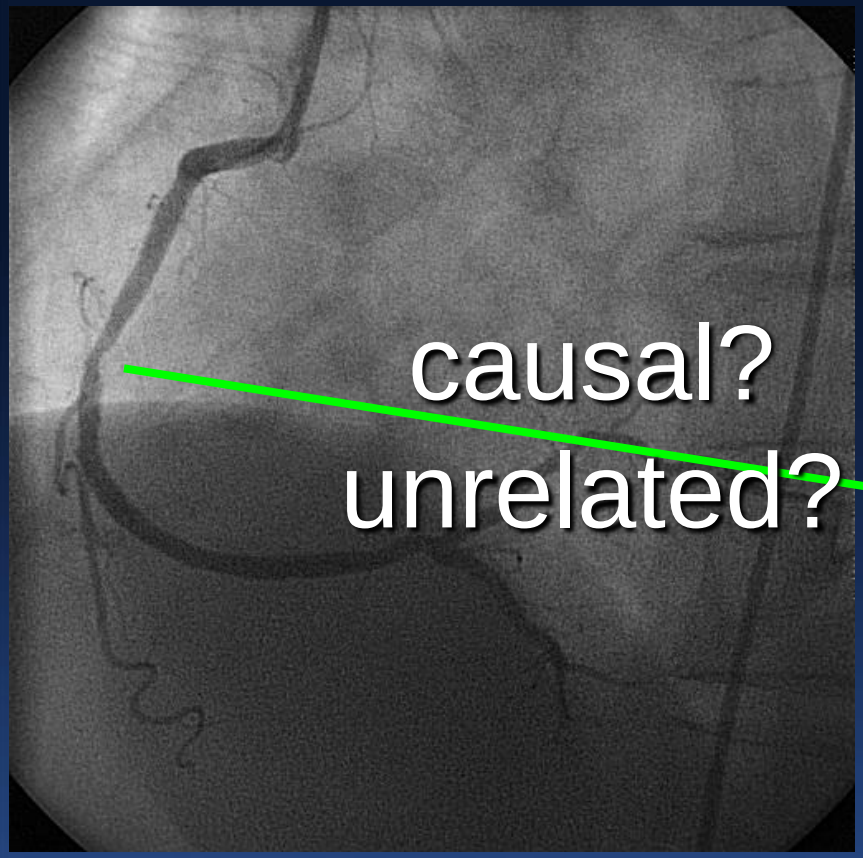
Anatomic predictions

ambiguous
(often unclear if causal)

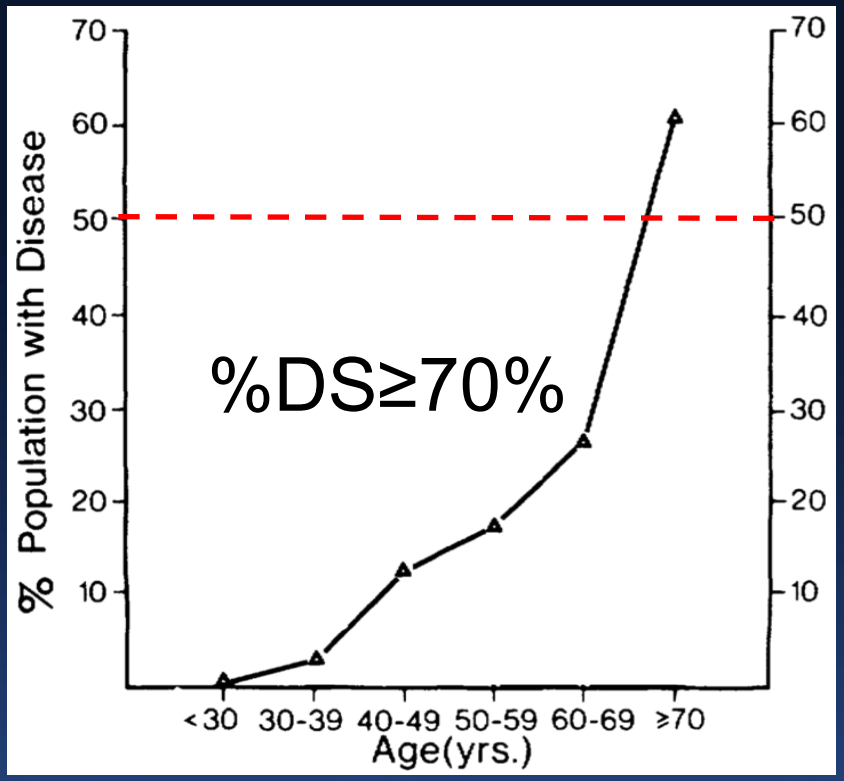
imprecise
(uncertain for an individual)

Cause and effect?



55 year-old woman with new, *typical angina*

Cause and effect?



1,282 men from 15 US centers

"chest pain unrelated to activity, unrelieved by nitroglycerin and *apparently non-cardiac in origin*"

Chaitman BR, *Circulation*. 1981 Aug, 64(2):360-7 (Figure 3, modified excerpt)

Cause and effect?

	Any CAD	Obstructive CAD	Subgroup of obstructive CAD		
			1VD	2VD	3VD/LM
CACS≤100	1017 (42.5%)	204 (8.5%)	147 (6.1%)	39 (1.6%)	18 (0.8%)
CACS>100	716 (86.8%)	342 (41.5%)	185 (22.4%)	96 (11.6%)	61 (7.4%)

17% had ≥50%DS
2% with 3VD/LM

CONFIRM registry
3,217 patients
asymptomatic
from 12 centers
in 6 countries

Cho I, *Eur Heart J*. 2015 Feb 21;36(8):501-8 (excerpt from Figure 1)

Cause and effect?

ECA survey

13,538 subjects community-based from 5 USA centers

Lifetime prevalence

- Chest pain = 25%
- Fatigue = 24%
- Palpitations = 18%
- Dyspnea = 14%

Kroenke K, *Arch Intern Med*. 1993 Nov 8;153(21):2474-80 (data from Table 1)

Cause and effect?

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Cause and effect?

"It has been shown that in a *randomly selected group of asymptomatic 60-year old men*, the *prevalence of apparently significant coronary stenoses is 20%*. Therefore, one must assume that in a number of such patients, the *presence of a lesion may be coincidental* and that a *direct relation* between the angiographic lesion and the chest pain is *unclear*."

-Bech GJ, De Bruyne B, …, Pijls NH
JACC. 1998 Mar 15;31(4):841-7 (my color and *emphasis* added)

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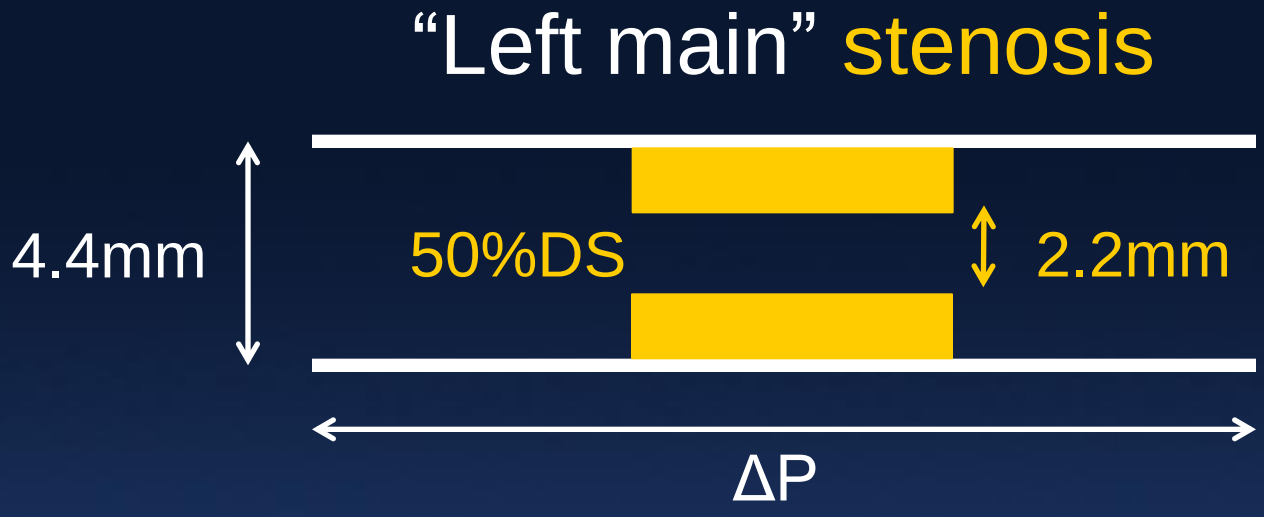
Anatomic predictions

ambiguous
(often unclear if causal)

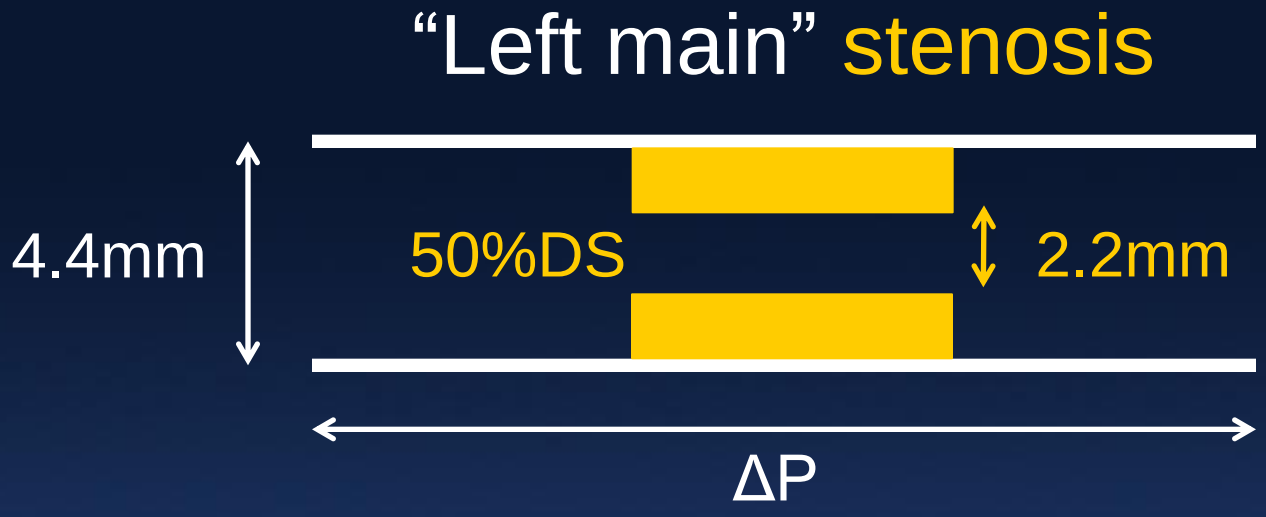
imprecise
(uncertain for an individual)

Individual *imprecision*



Poiseuille law: $\Delta P \propto 1 / radius^4$

Individual *imprecision*

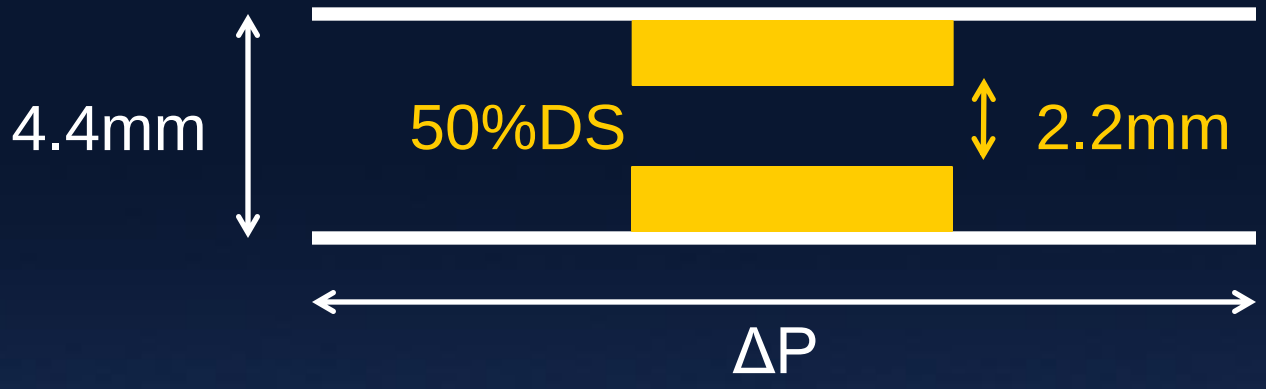


Poiseuille law: $\Delta P \propto 1 / radius^4$

(physiology ∝ anatomy)

Individual *imprecision*

"Left main" stenosis

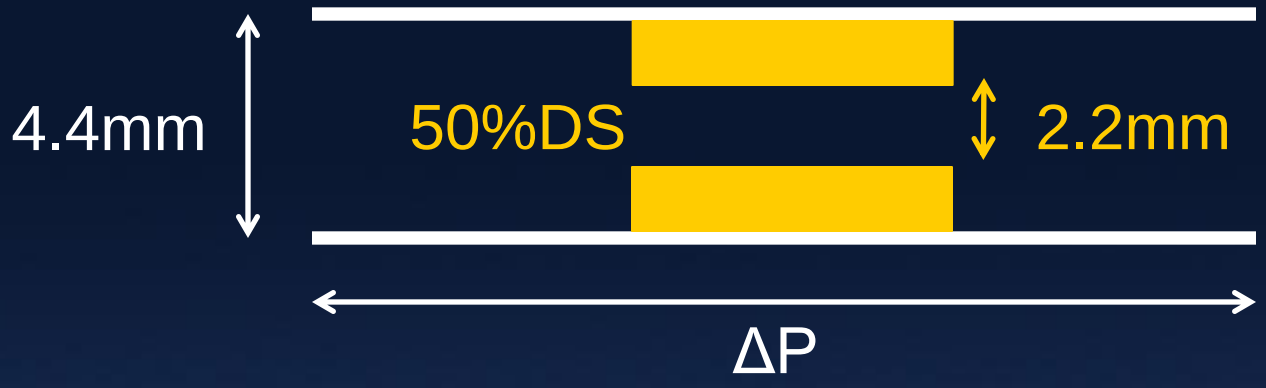


Relative error ΔP/P = 4 * Δradius / radius

(*error* in physiology ∝ *error* in anatomy)

Individual *imprecision*

"Left main" stenosis

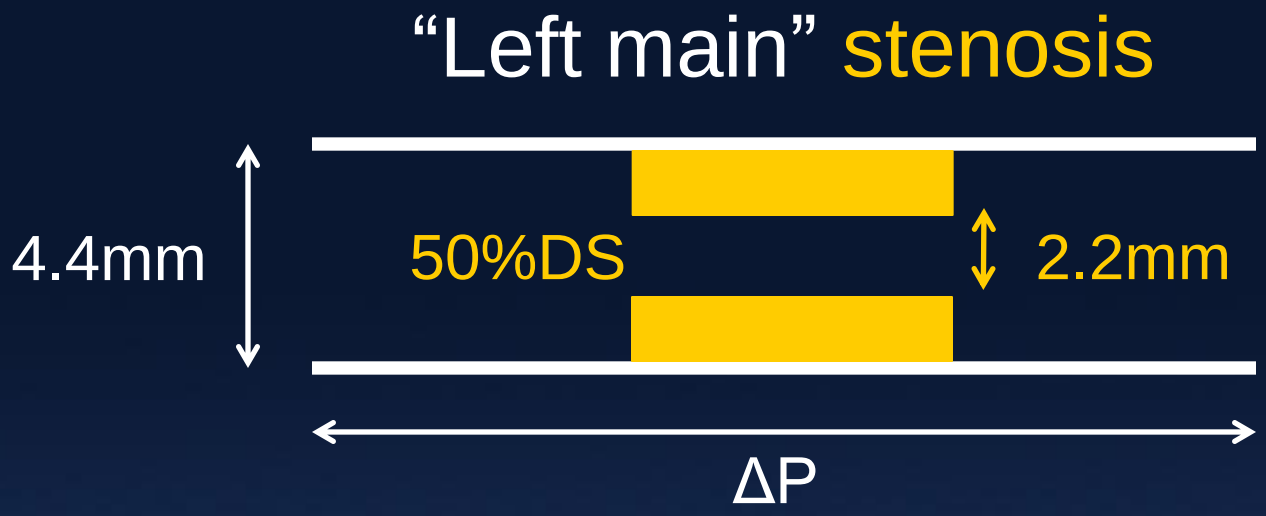


Relative error ΔP/P = 4 * Δradius / radius

(*error* in physiology ∝ *error* in anatomy)

- Invasive = 4*0.2mm/1.1mm = 73% ΔP/P

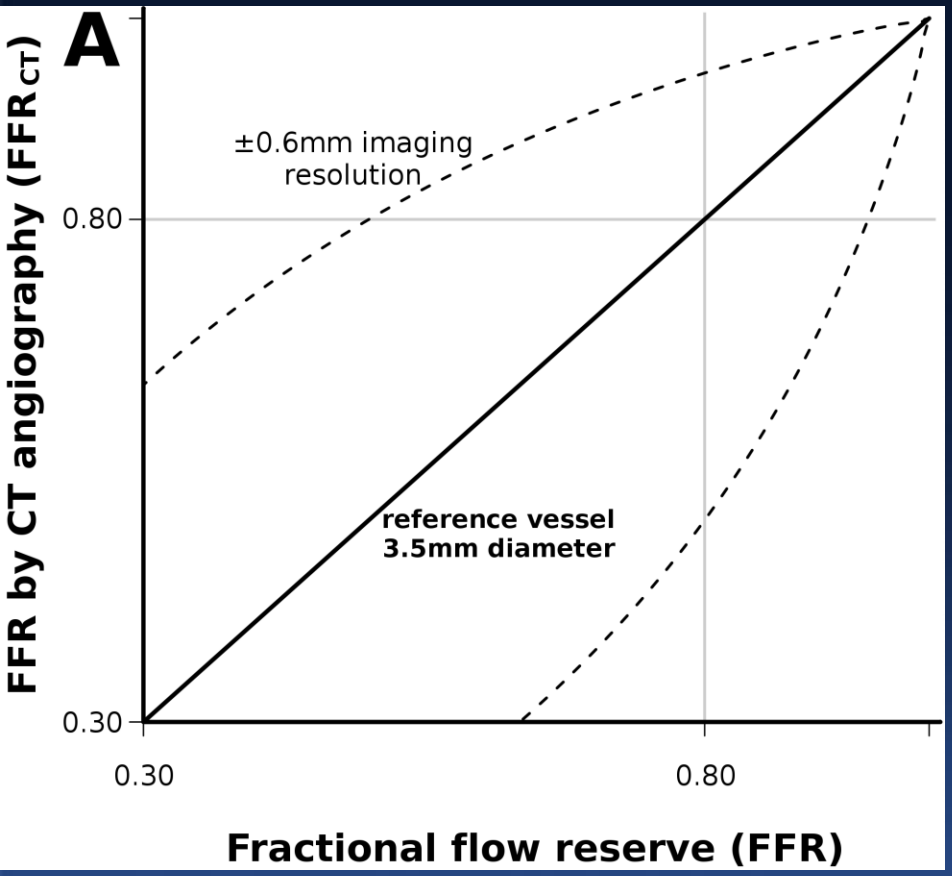
Individual *imprecision*



Relative error ΔP/P = 4 * Δradius / radius

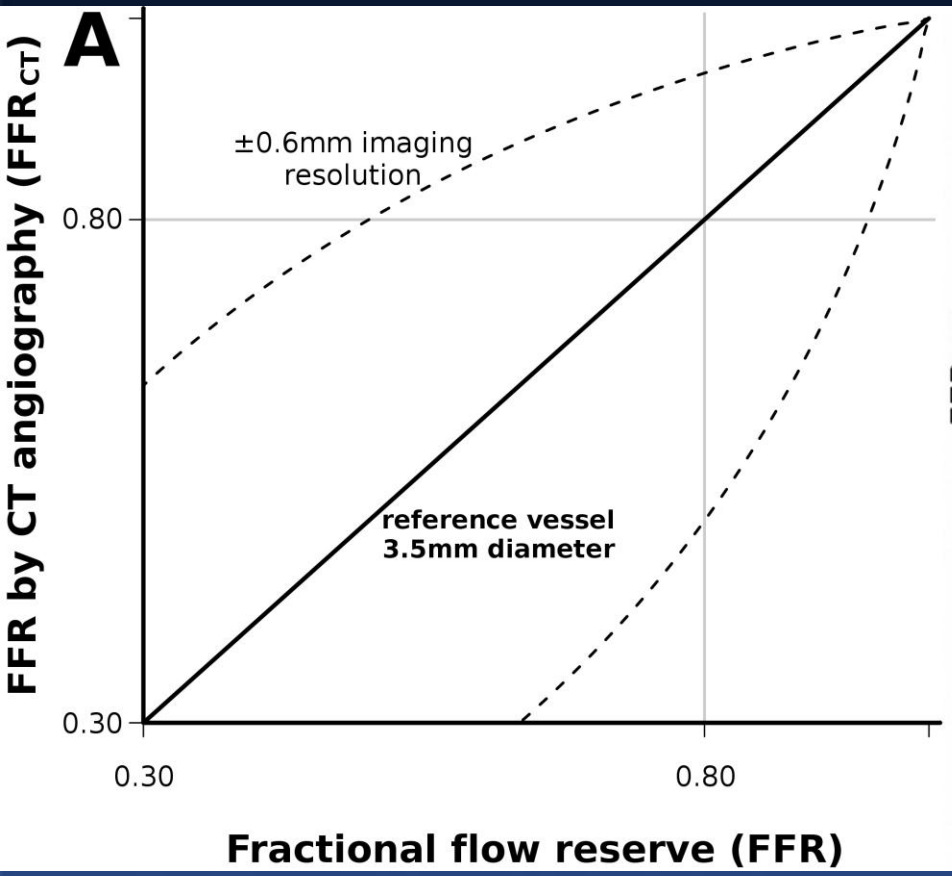
- CTA = 4*0.6/1.1 = 218% error in ΔP/P
- Invasive = 4*0.2/1.1 = 73%
- IVUS = 4*0.1/1.1 = 36%
- OCT = 4*0.02/1.1 = 7%

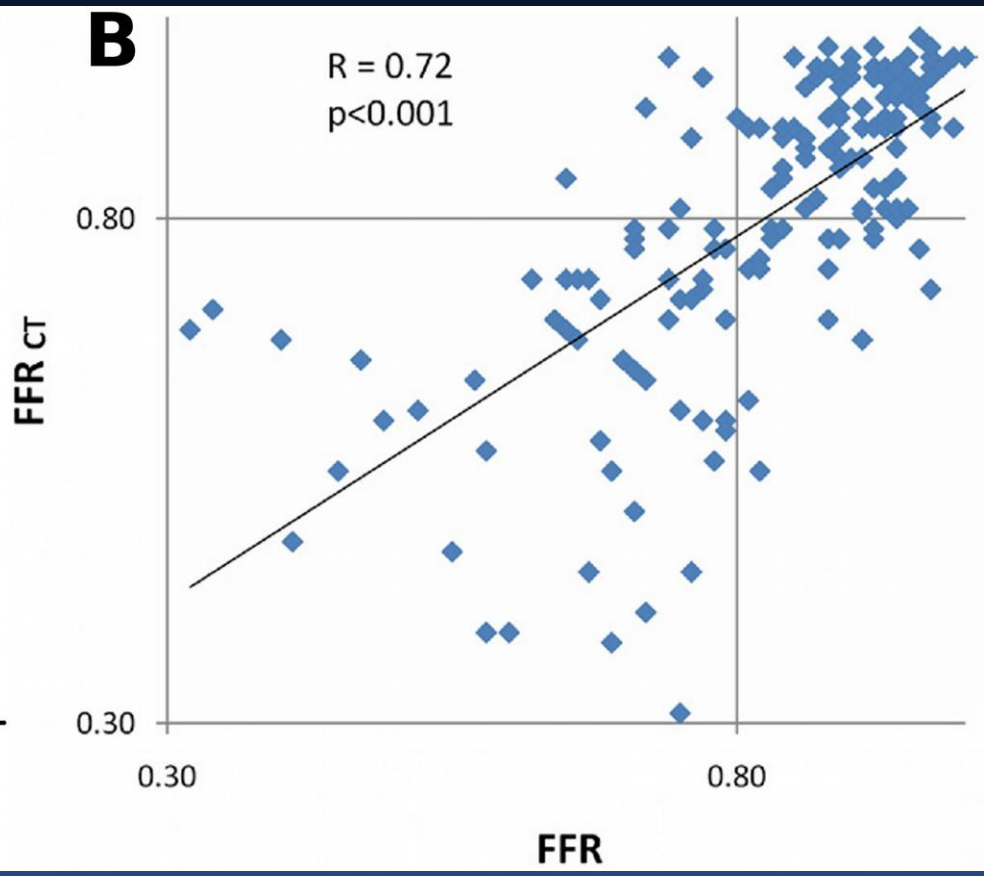
CT-*modeled* FFR



Johnson NP, *Circ Cardiovasc Imaging* 6(5):817, 2013, Figure 4A

CT-*modeled* FFR

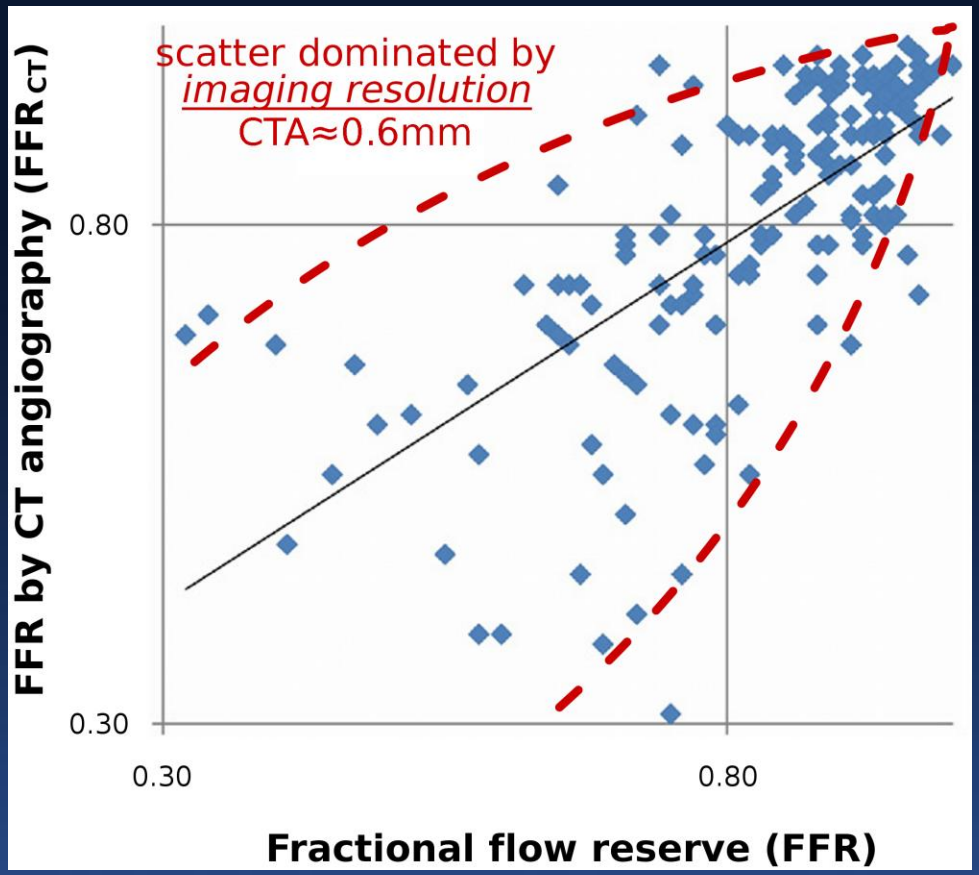




Johnson NP, *Circ Cardiovasc Imaging* 6(5):817, 2013, Figure 4A

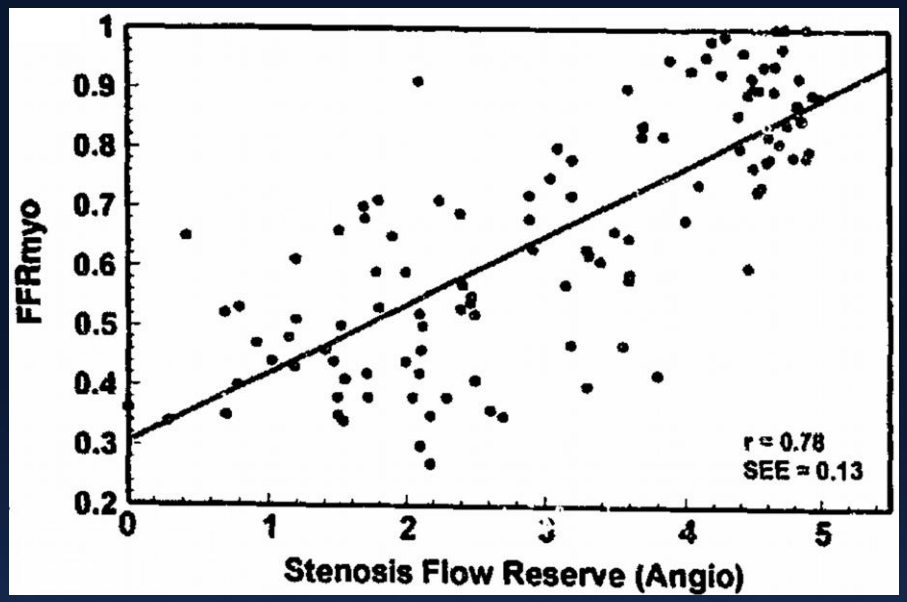
Koo BK, *JACC* 58(19):1989, 2011, Figure 4

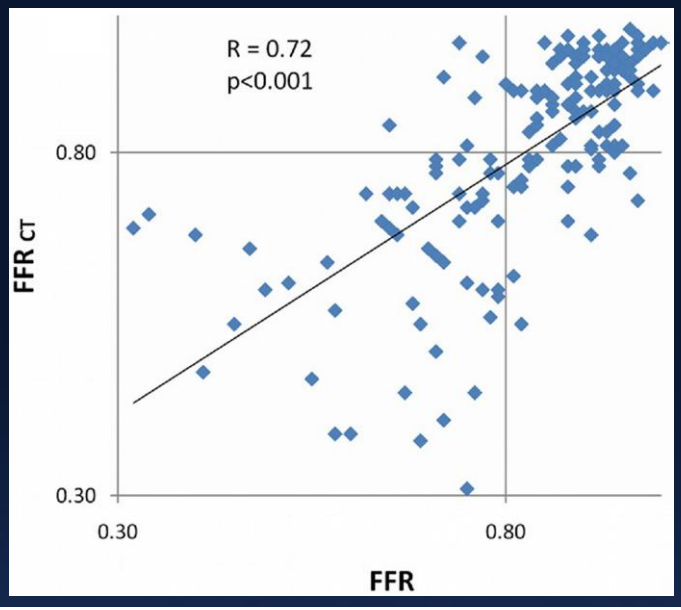
CT-*modeled* FFR

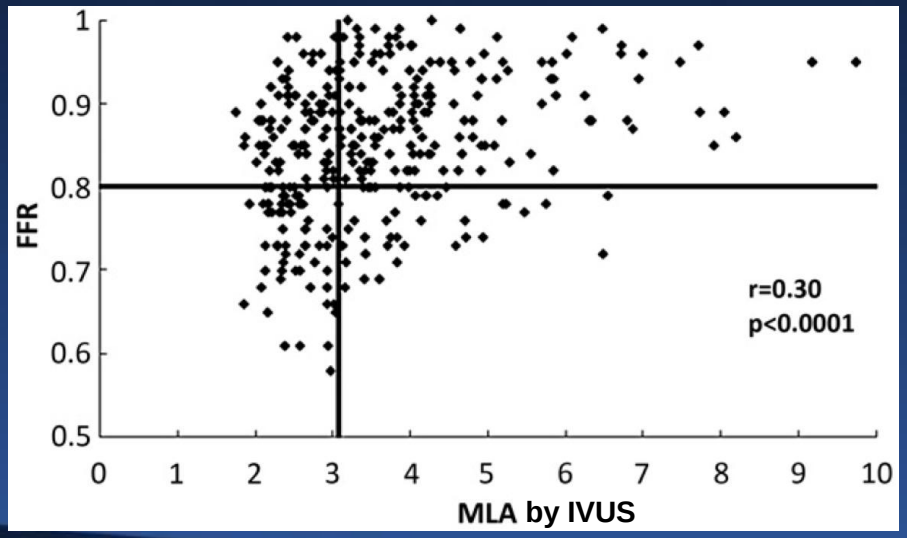


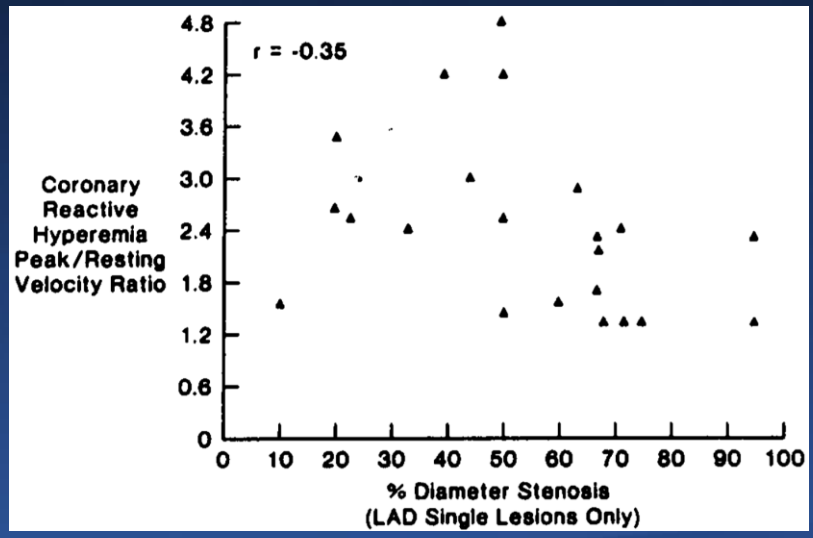
Johnson NP, *Circ Cardiovasc Imaging* 6(5):817, 2013, Figure 5A

Anatomy *versus* physiology







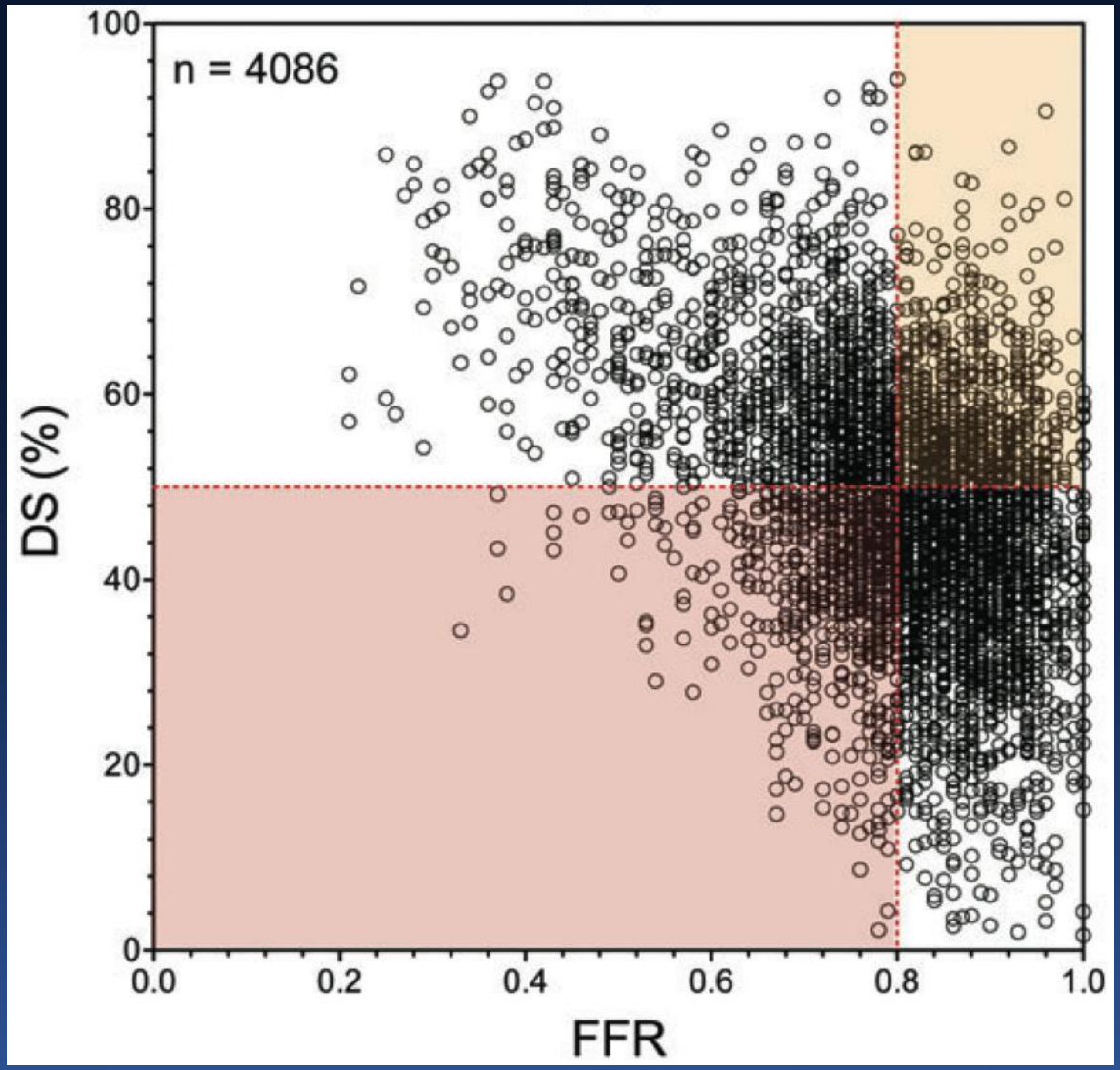


SFR (angiography) = Bartúnek J, *JACC*. 1995 Aug;26(2):328-34 (Figure 3, bottom)
FFR_{CT} (CT angiography) = Koo BK, *JACC*. 2011 Nov 1;58(19):1989-97 (Figure 4)
MLA (IVUS) = Waksman R, *JACC*. 2013 Mar 5;61(9):917-23 (Figure 1A)
%DS (angiography) = White CW, *NEJM*. 1984 Mar 29;310(13):819-24 (Figure 2)

Anatomy *versus* physiology

“anatomy”

(QCA)



“physiology”

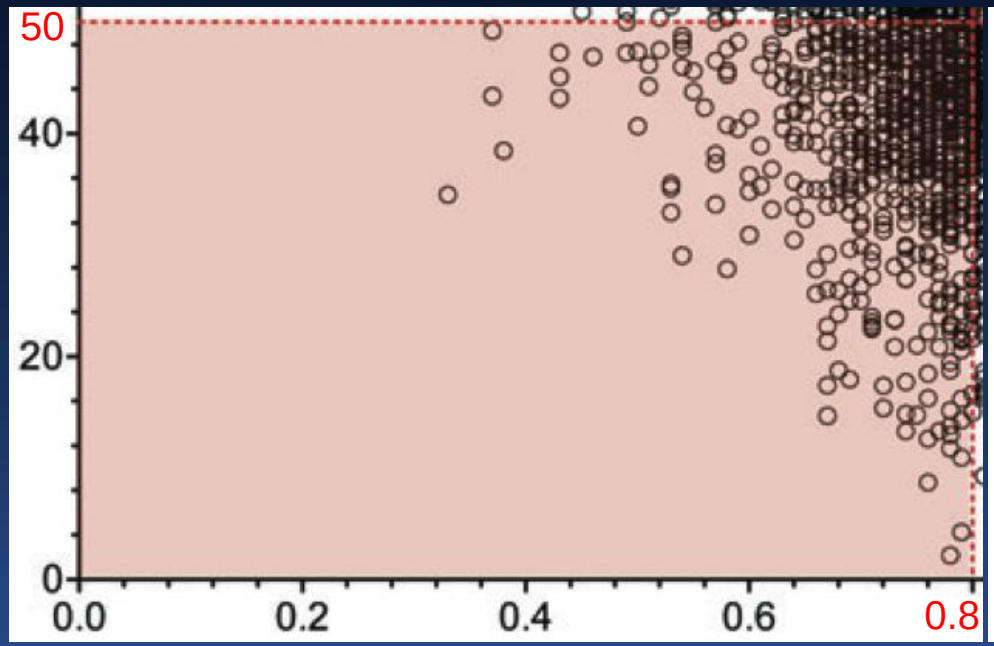
Toth G, *Eur Heart J* 2014 Oct 21;35(40):2831-8 (Figure 1A)

Anatomy *versus* physiology

Mild anatomy, *severe* physiology

➔ How to treat?

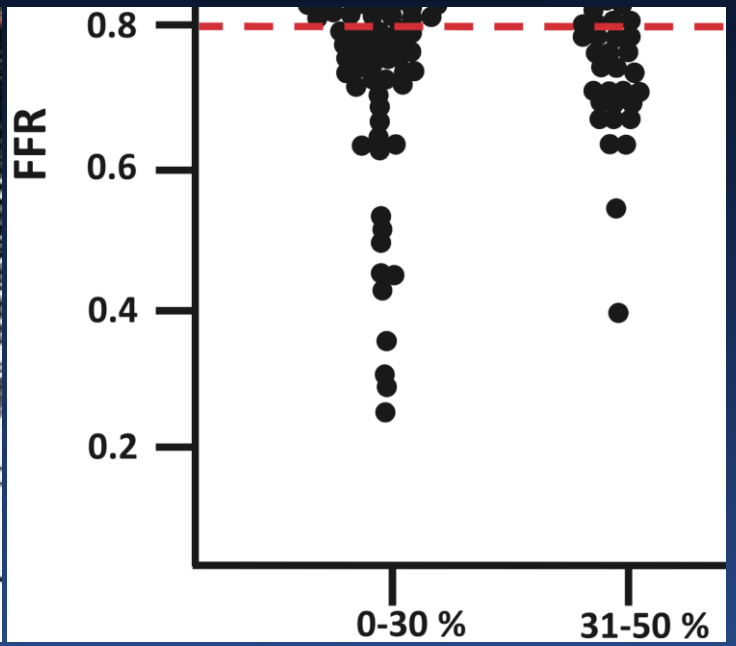
Aalst



%DS

FFR

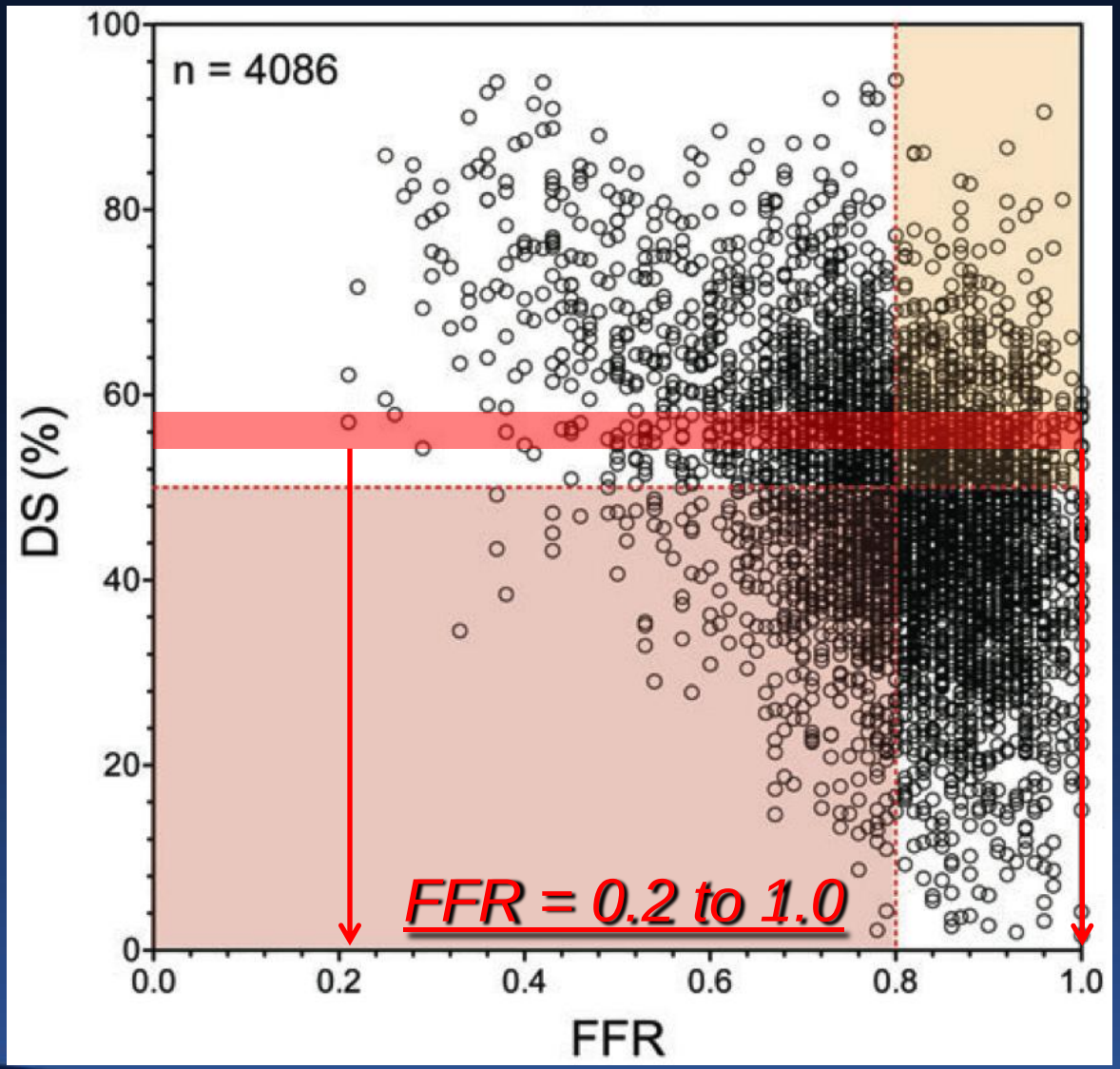
RIPCORD

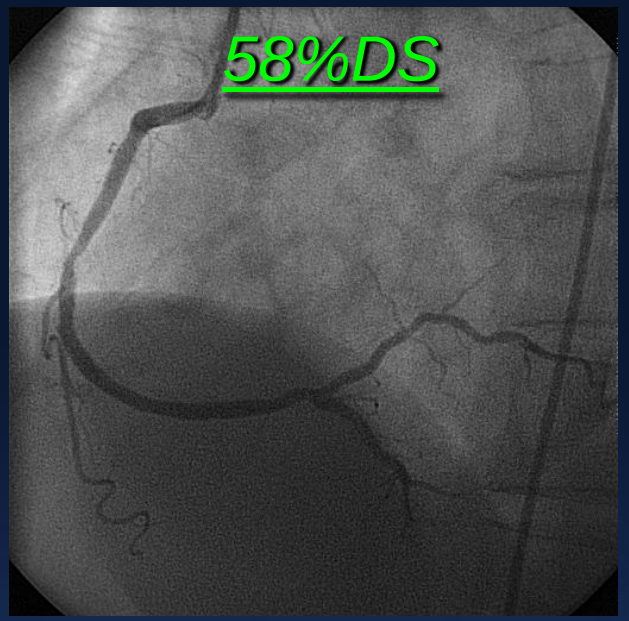


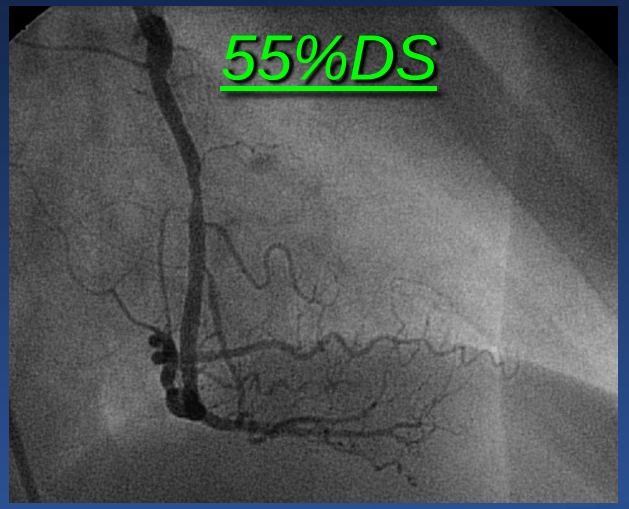
%DS

Aalst = Toth G, *Eur Heart J.* 2014 Oct 21;35(40):2831-8 (part of Figure 1A)
RIPCORD = Cruzen N, *Circ Cardiovasc Interv.* 2014 Apr;7(2):248-55 (part of Figure 2)

Anatomy *versus* physiology







Toth G, *Eur Heart J* 2014 Oct 21;35(40):2831-8 (Figure 1A)

The New England
Journal of Medicine

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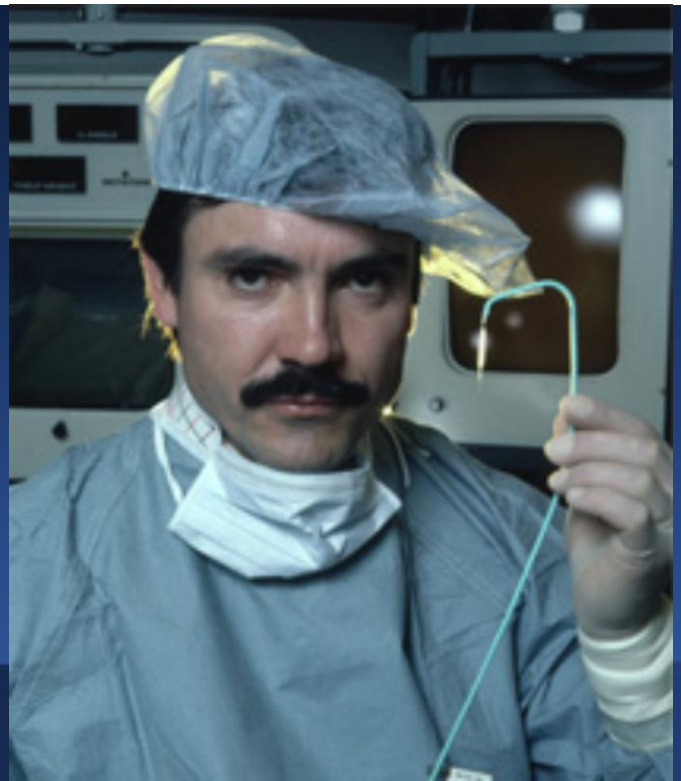
Volume 301 JULY 12, 1979 Number 2

NONOPERATIVE DILATATION OF CORONARY-ARTERY STENOSIS

Percutaneous Transluminal Coronary Angioplasty

ANDREAS R. GRÜNTZIG, M.D., ÅKE SENNING, M.D., AND WALTER E. SIEGENTHALER, M.D.



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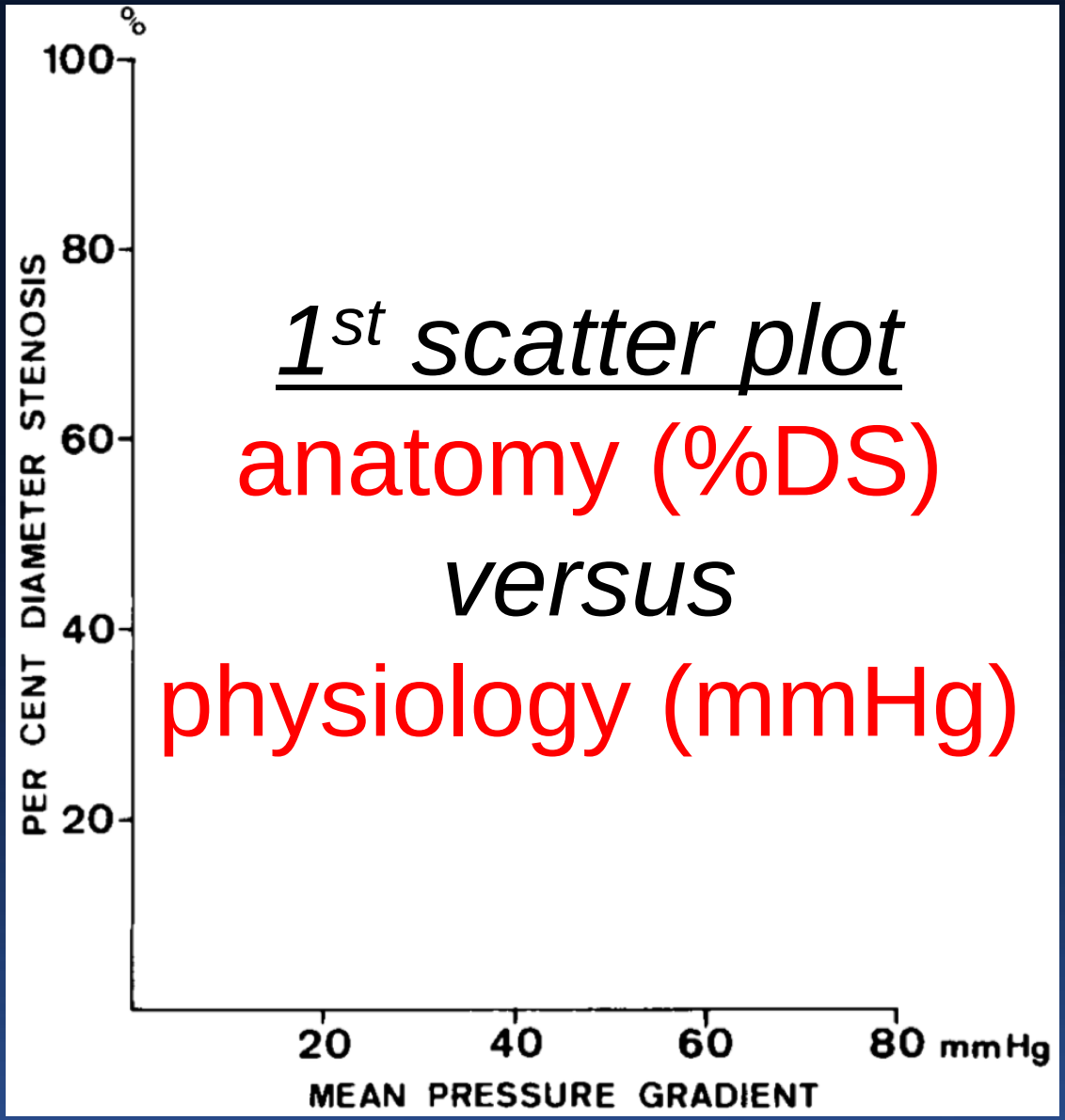
“anatomy”



1st scatter plot

anatomy (%DS)

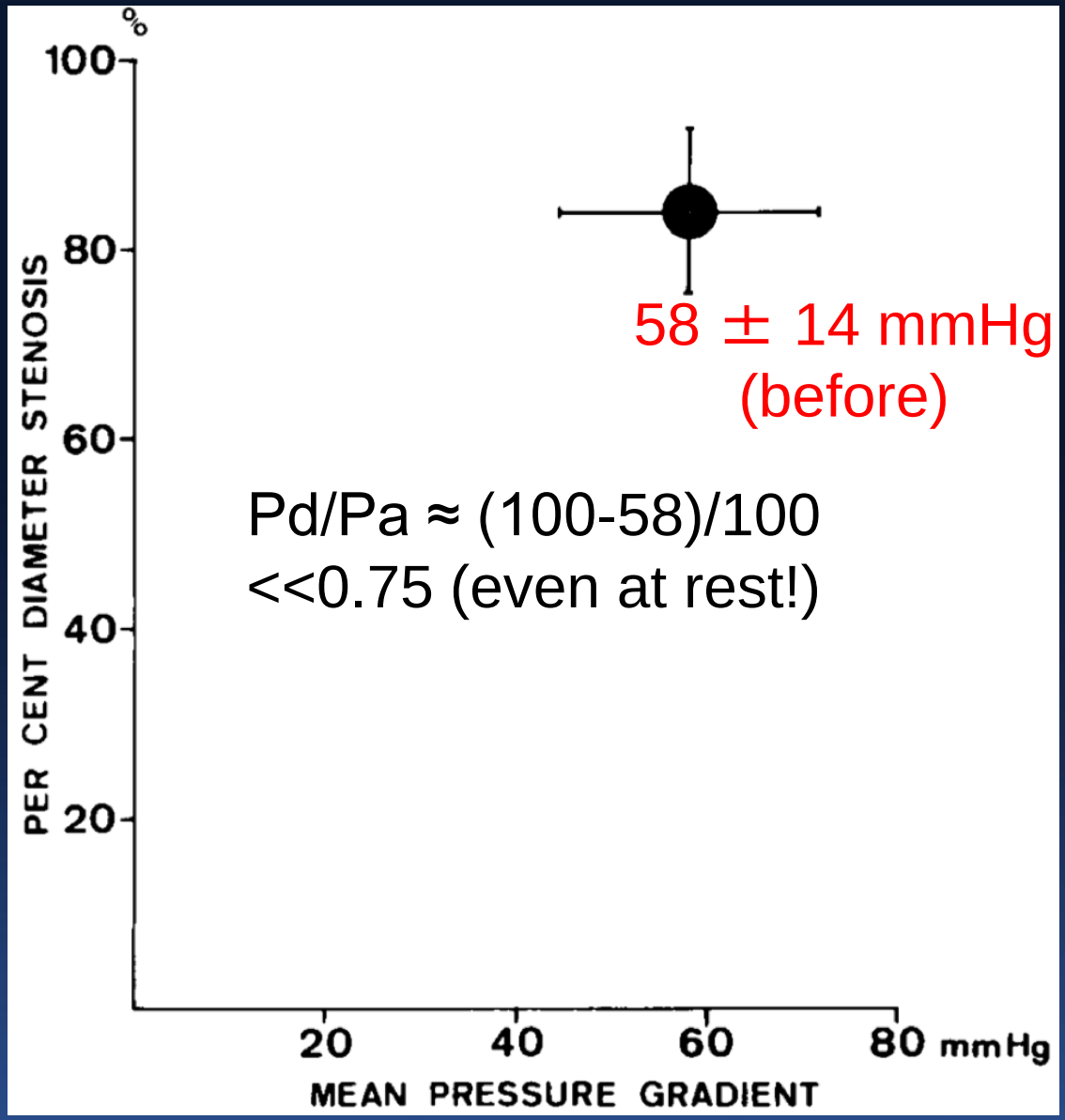
versus

physiology (mmHg)

“physiology”

Grüntzig AR, *NEJM* 1979 Jul 12;301(2):61-8 (modified Figure 3)

“anatomy”



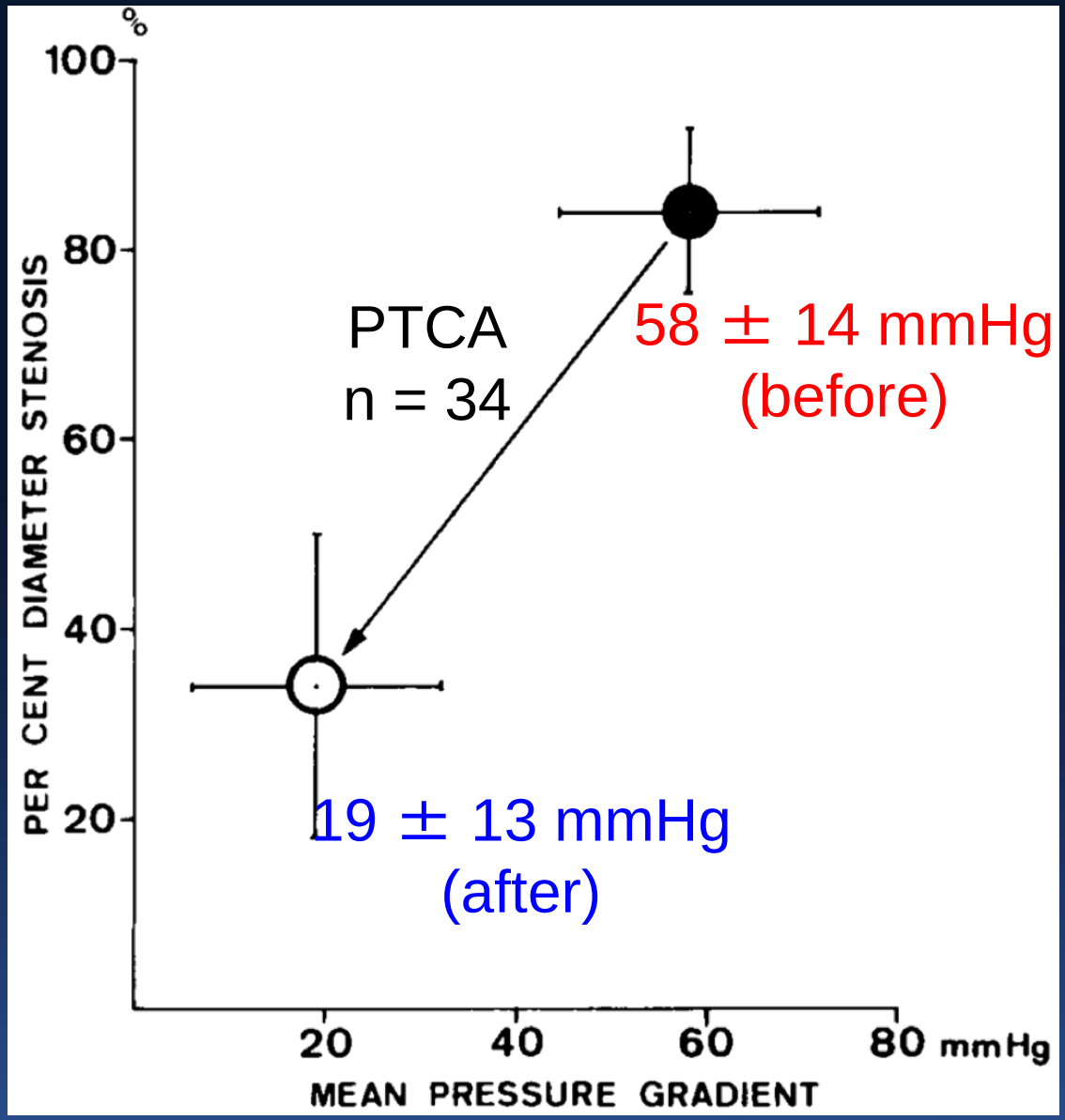
58 ± 14 mmHg
(before)

Pd/Pa ≈ (100-58)/100
<<0.75 (even at rest!)

“physiology”

Grüntzig AR, *NEJM* 1979 Jul 12;301(2):61-8 (modified Figure 3)

"anatomy"



"physiology"

Grüntzig AR, *NEJM* 1979 Jul 12;301(2):61-8 (modified Figure 3)

Anatomy *versus* physiology

Fractional Flow Reserve

versus

Angiography for

Multivessel

Evaluation

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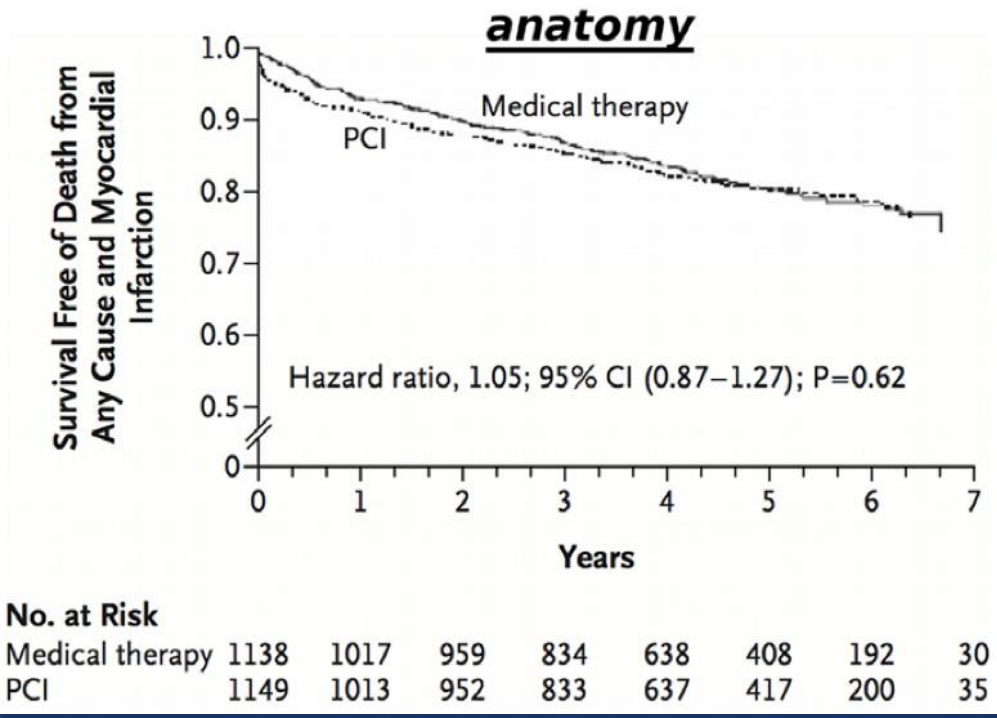
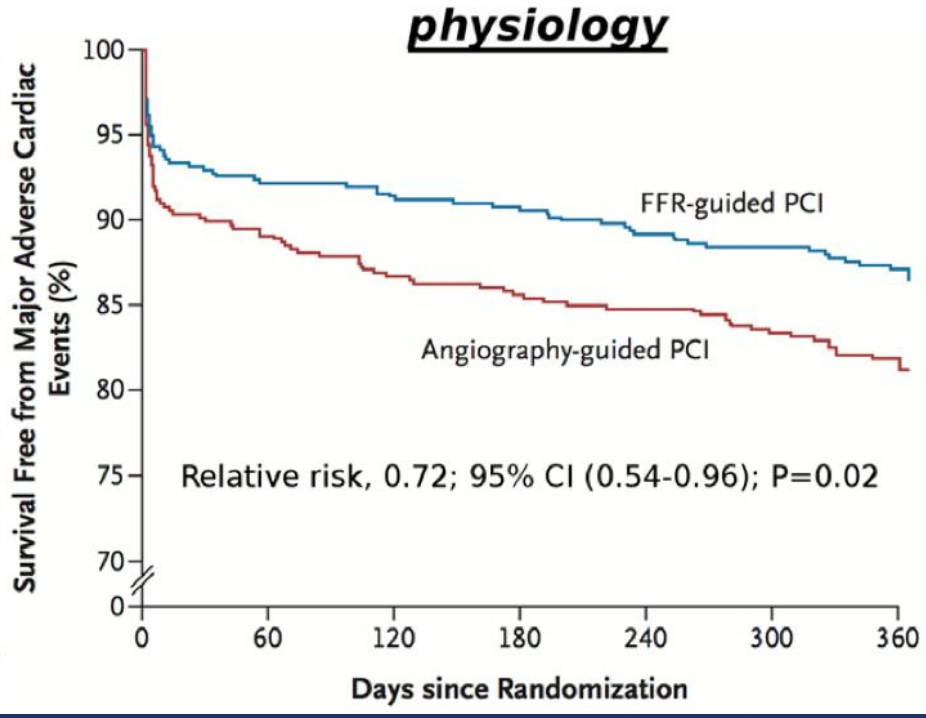
Anatomy *versus* physiology

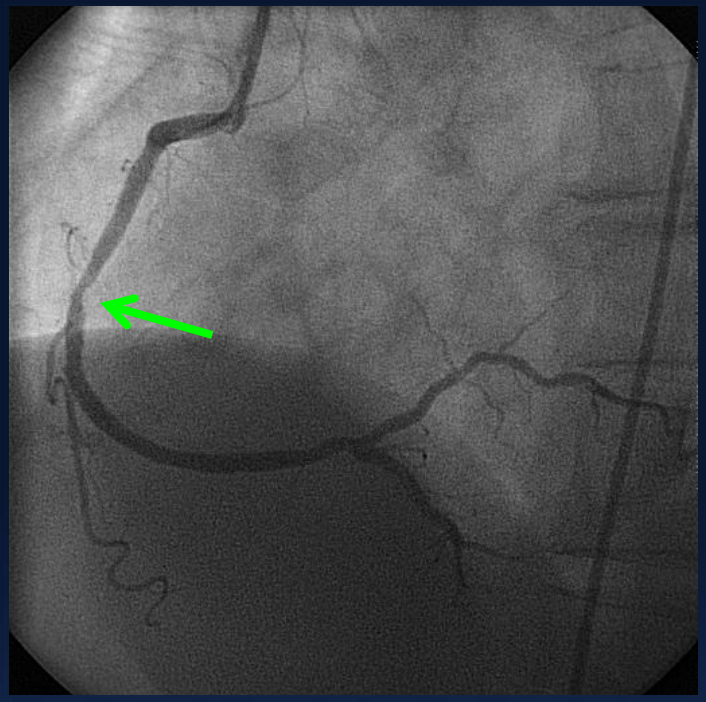


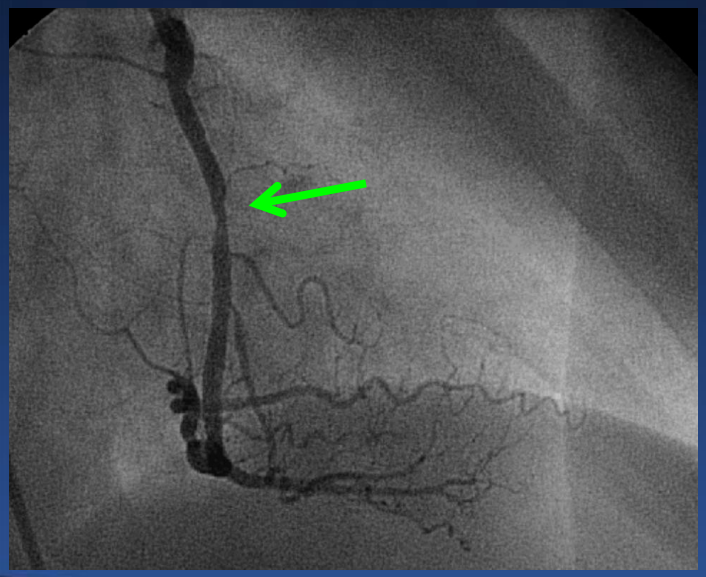


COURAGE

FAME

Johnson NP, *Circ Cardiovasc Imaging*. 2013 Sep;6(5):817-32 (Figure 6)





symptoms,
clinical data,
angiogram

predict
significance

treatment
decision

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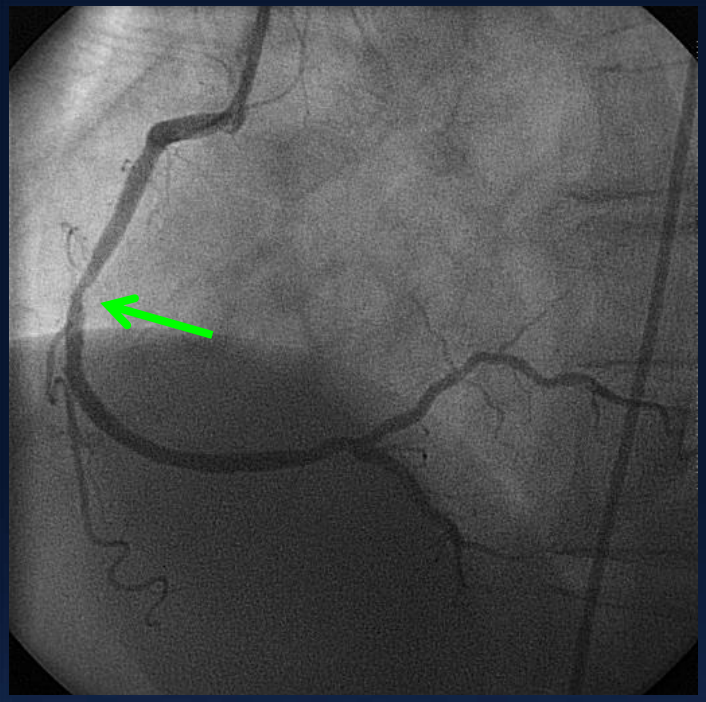

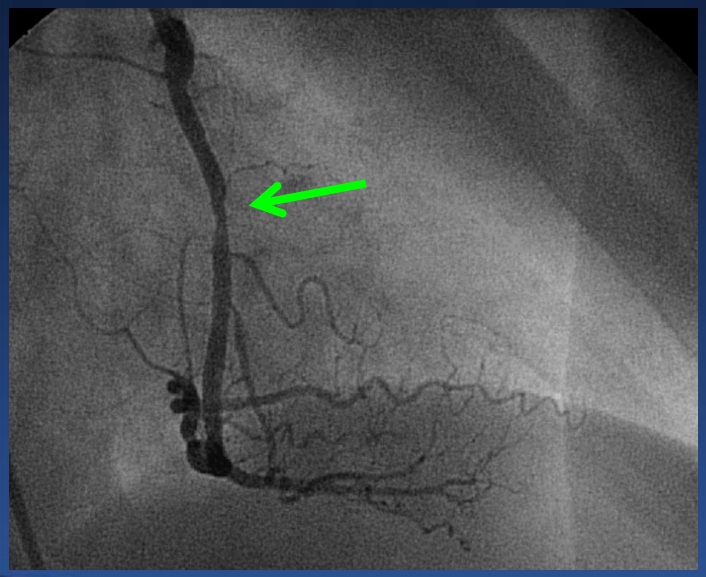

symptoms,
clinical data,
angiogram

~~*guess*~~

~~significance~~

treatment
decision

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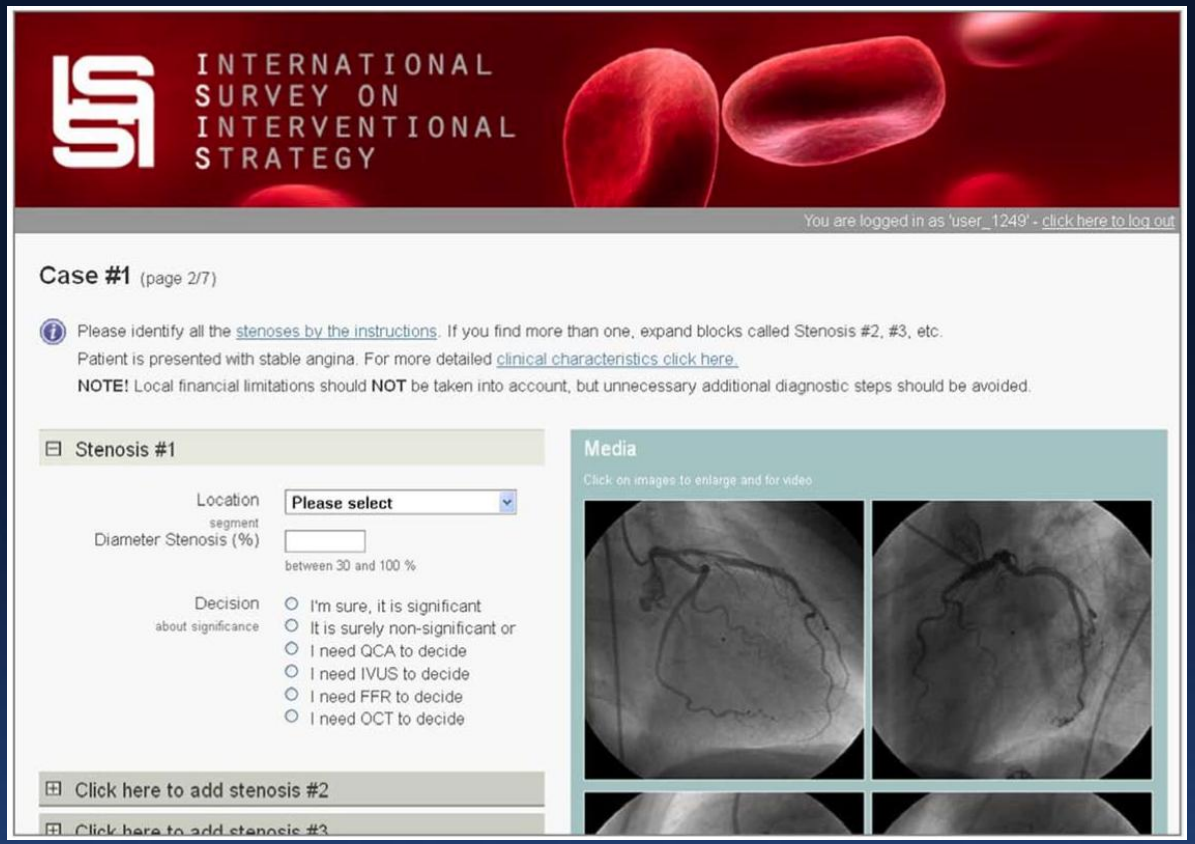
EUROPEAN HEART HOUSE

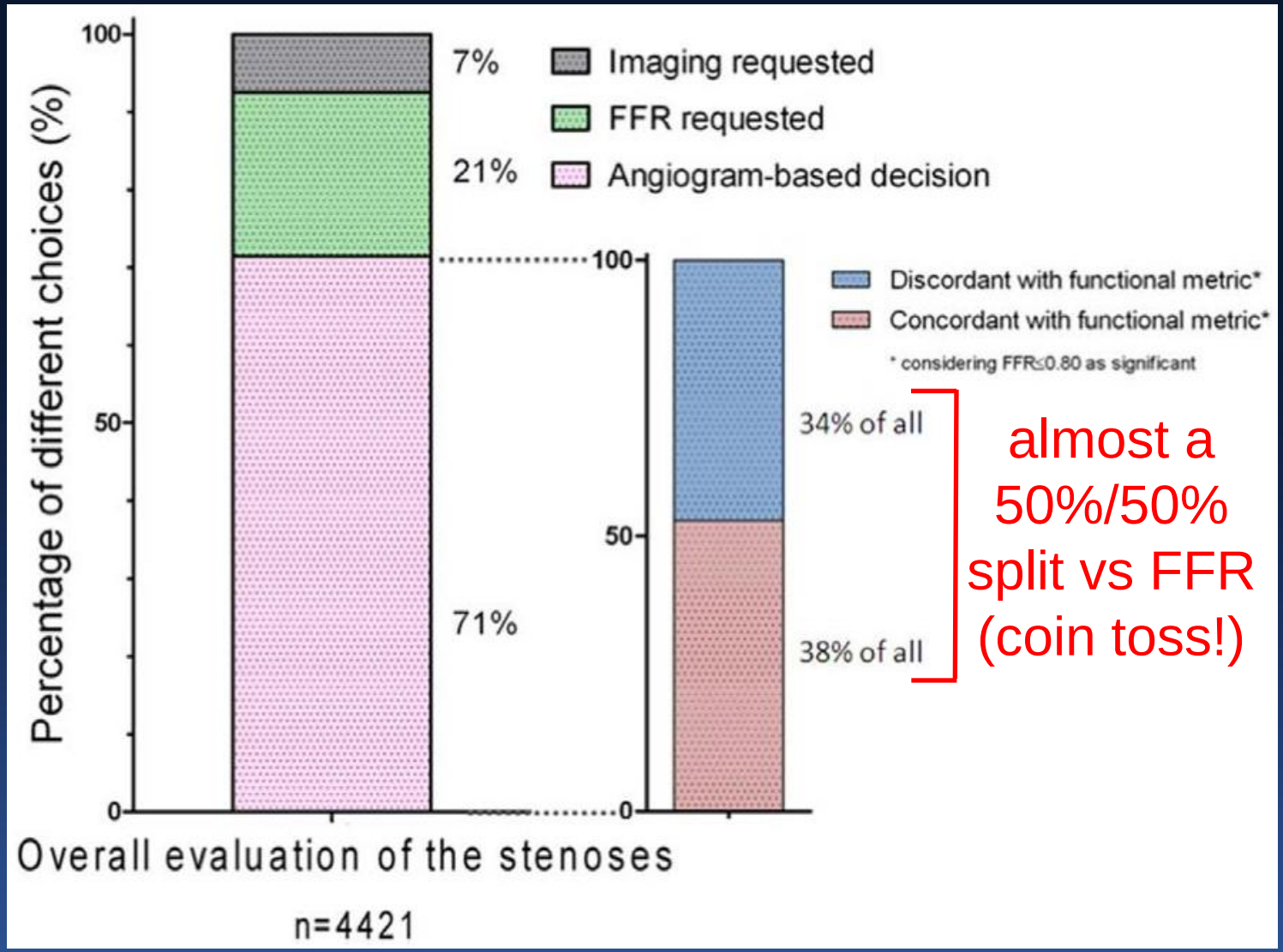
Do we *guess*?



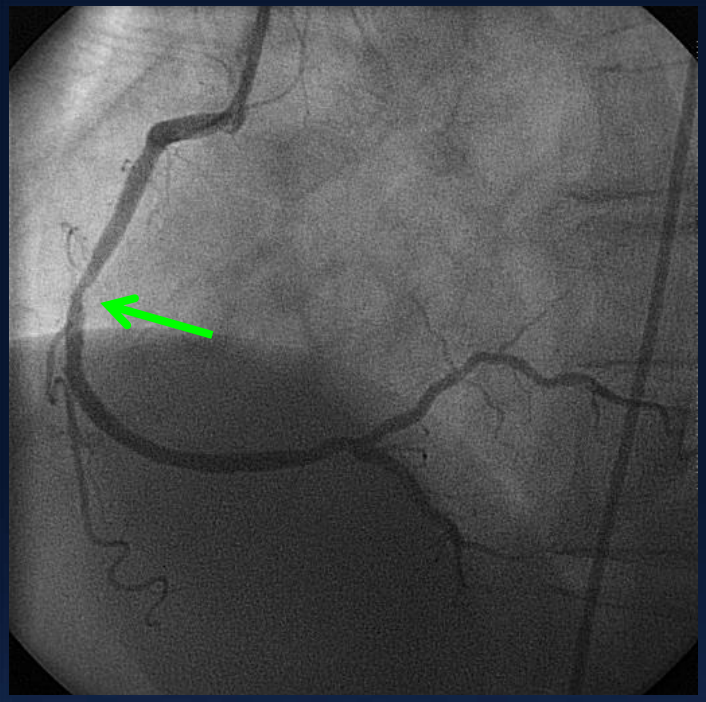
"Participants were asked to make their decisions assuming *ideal world conditions*, *without considering any financial restrictions* or local regulations, but only after the best clinical practice achievable in this virtual catheterization laboratory."

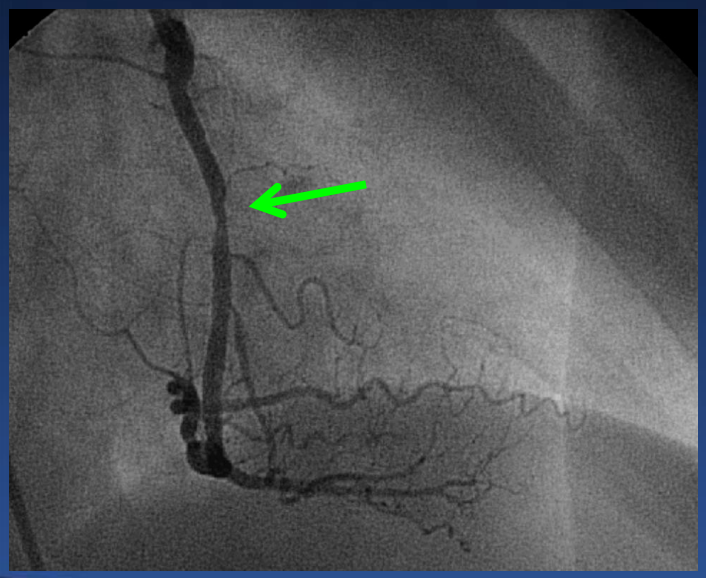
Toth GG, *Circ Cardiovasc Interv*. 2014 Dec;7(6):751-9 (Figure 1)

Do we *guess*?



Toth GG, *Circ Cardiovasc Interv*. 2014 Dec;7(6):751-9 (Figure 4 with *my annotations*)





symptoms,
clinical data,
angiogram

measure
significance

treatment
decision

Coronary Pathophysiology & Microcirculation
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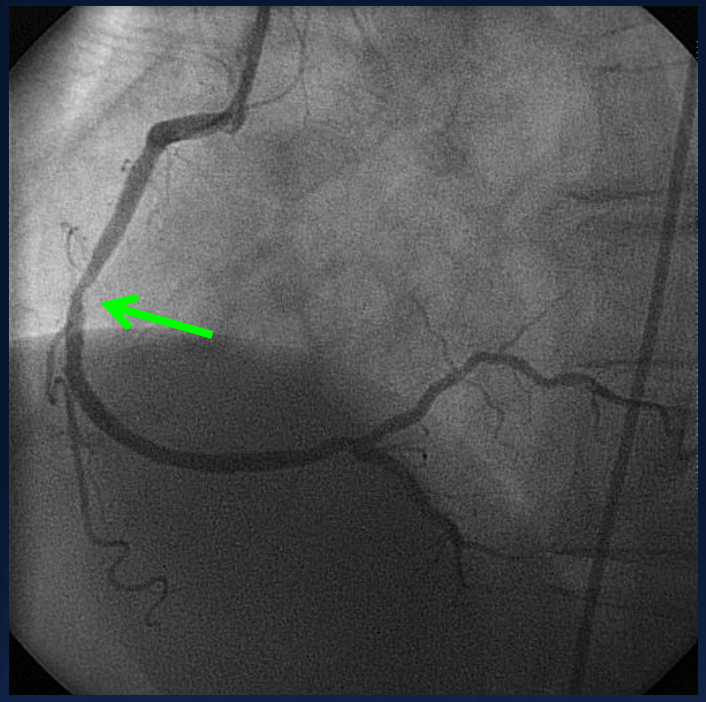
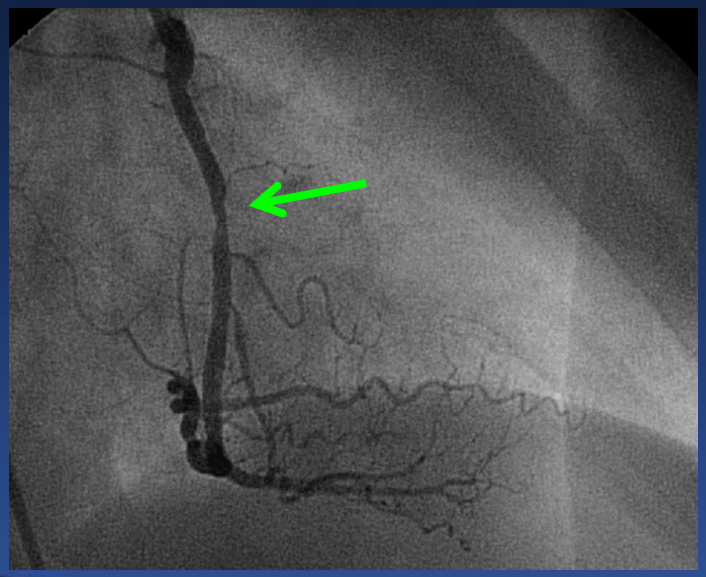
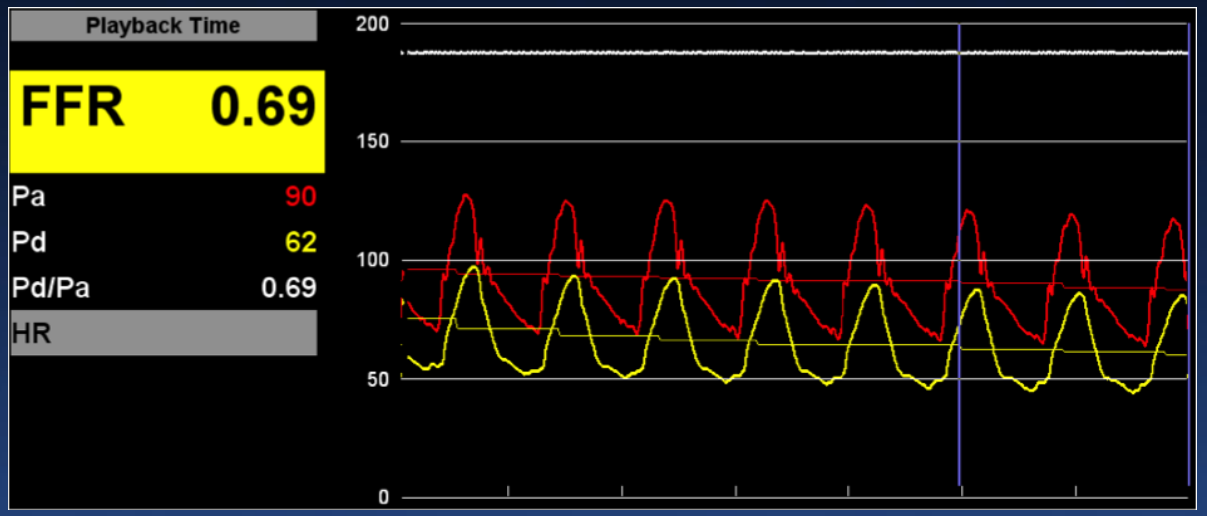
EUROPEAN HEART HOUSE





symptoms, clinical data, angiogram



treatment decision

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MAISON EUROPÉENNE DU COEUR
EUROPEAN HEART HOUSE

CATHOLIC UNIVERSITY OF LOUVAIN
MEDICAL SCHOOL

Coronary Pressure

From a Physiological Index to a Clinical Tool

Thesis by

Bernard de Bruyne, MD
From the Cardiovascular Center, Aalst, Belgium

To be submitted in partial fulfillment of the requirements for the degree of
"Agrégé de l'Enseignement Supérieur"

Co-Promotors:
Jacques A. Melin, MD
William Wijns, MD

1995

CATHOLIC UNIVERSITY OF LOUVAIN
MEDICAL SCHOOL

Coronary Pressure

From a Physiological Index to a Clinical Tool

"Albeit often statistically significant, the correlations between angiographic and functional indices … are *too weak to be clinically relevant*"

1995