Limits of anatomy to predict physiology

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MAISON EUROPÉENNE DU COEUR EUROPEAN HEART HOUSE

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	Company
• Grant/Research Support (*pending* to institution)	• St Jude Medical • Volcano Corporation
• Non-disclosure agreements (non-financial)	• St Jude Medical • Volcano Corporation

However, Nils Johnson has ***never*** personally received ***any*** money from ***any*** commercial company.

"If you want ***new*** ideas,
read ***old*** books"

-*attributed* to Ivan P. Pavlov
(Russian *physiologist*, 1849-1936,
Nobel prize 1904, "Pavlov's dog")

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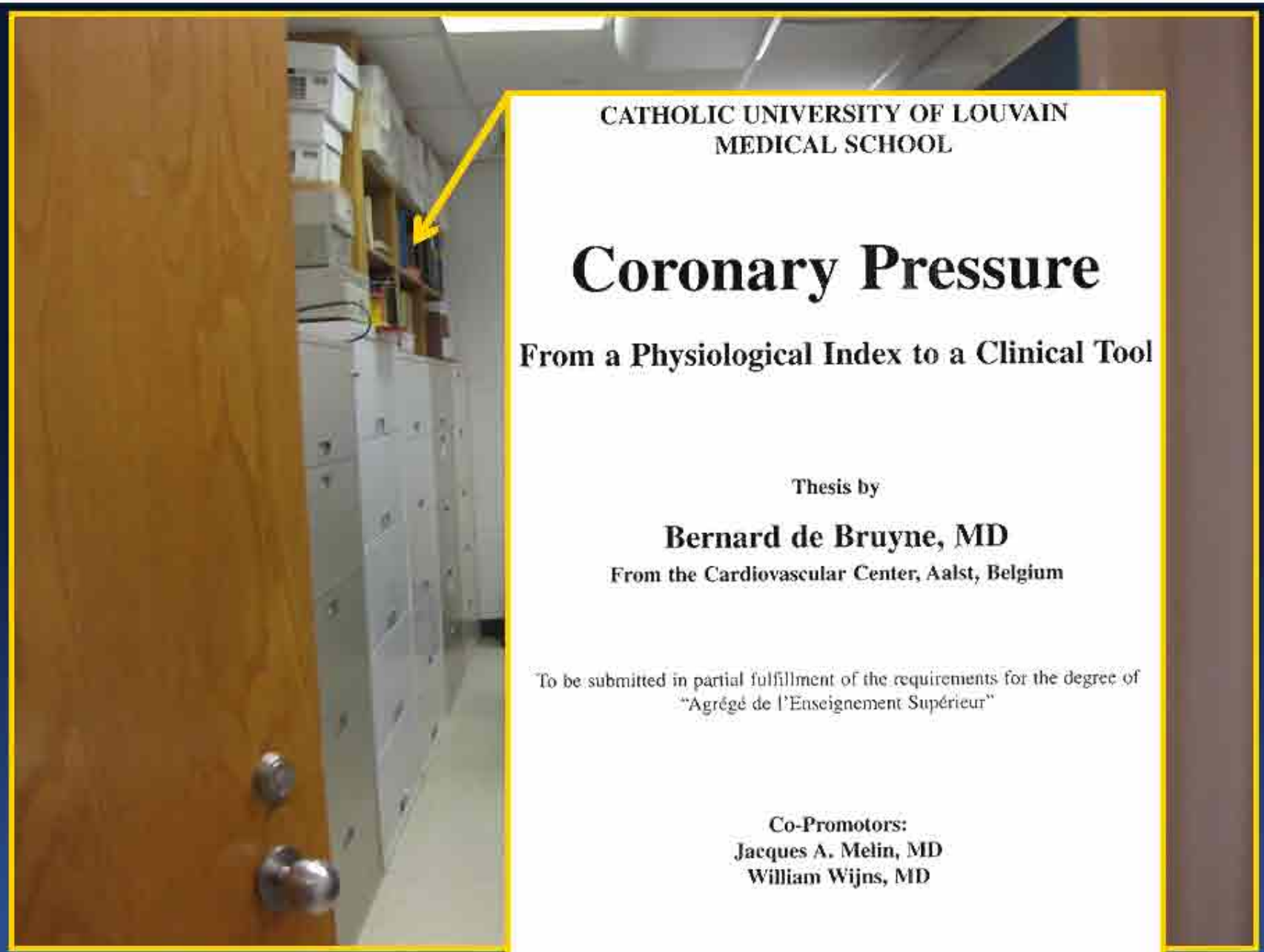

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Coronary Pressure

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

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"cardiologists continue to base *major clinical decisions* about coronary artery disease on *inferences* … based largely on … *morphological data*, such as provided by the coronary arteriogram"

1995

Koo BK, *JACC* 58(19):1989, 2011, Figure 1, panel A

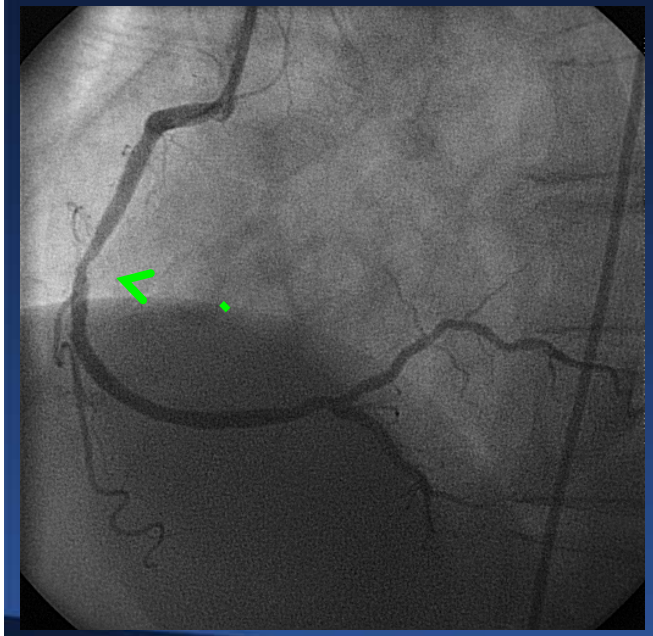
CT angiogram

angiogram

infer

significance

decision



Invasive angiogram

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Koo BK, *JACC* 58(19):1989, 2011, Figure 1, panel A

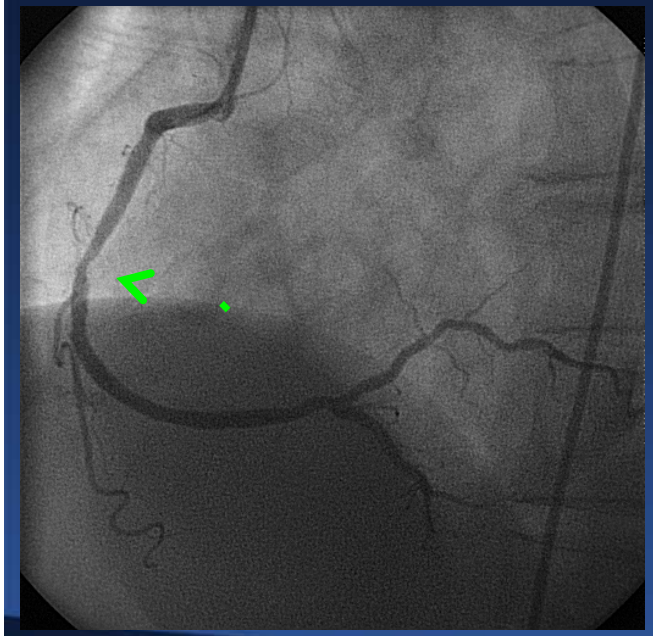
CT angiogram

anatomy

infer

(predict)

physiology



Invasive angiogram

Anatomy to predict physiology

%DS linked to CFR – 1974

Stenosis flow reserve (SFR) – 1986

CT-modeled FFR (FFR_{CT}) – 2010

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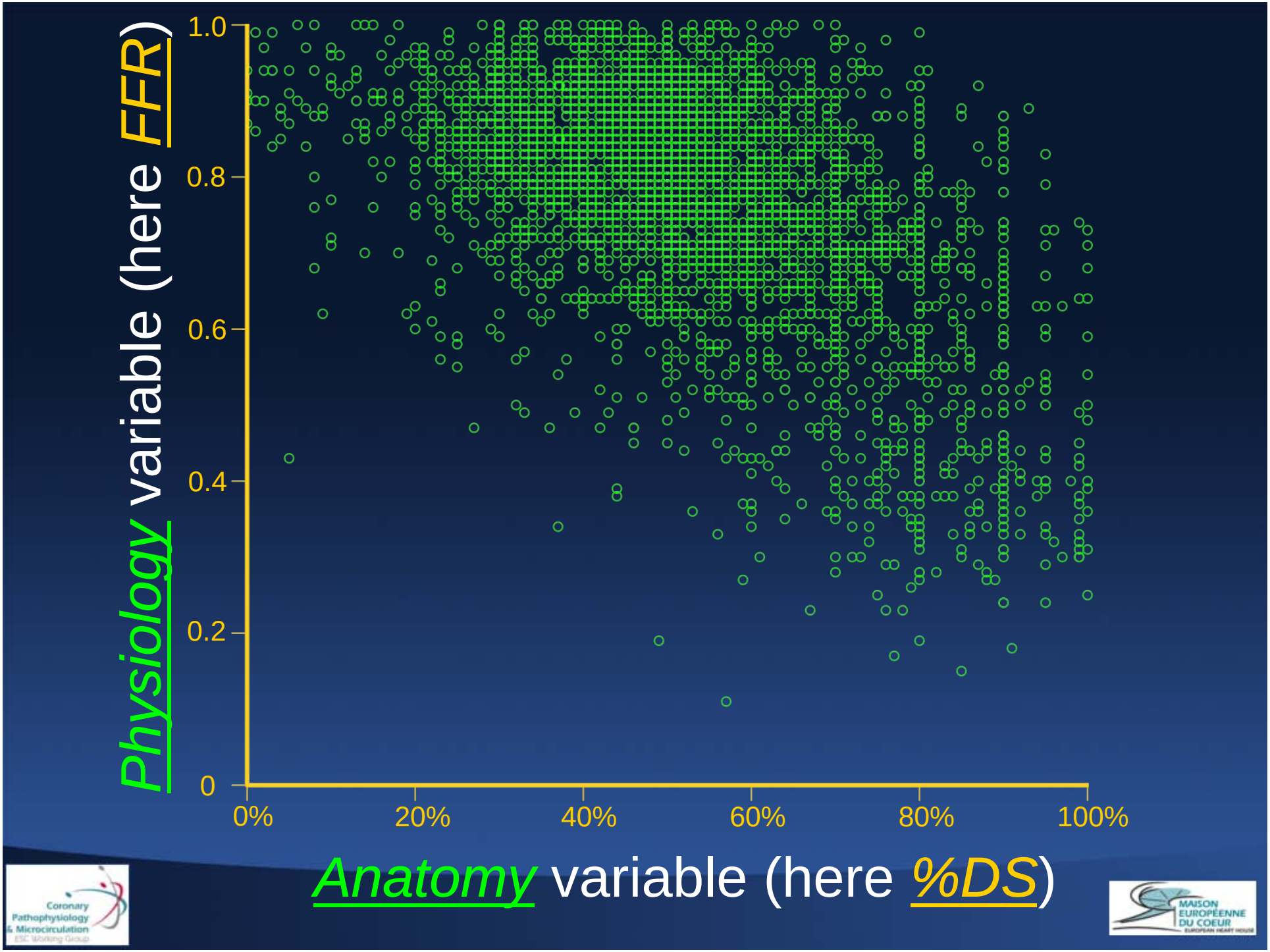
Anatomic predictions

accurate
(work well on average)

imprecise
(uncertain for an individual)


Physiology variable (here FFR)
1.0
0.8
0.6
0.4
0.2
0
0%
20%
40%
60%
80%
100%
Anatomy variable (here %DS)
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Measurement uncertainty

- CT angiography resolution ≈ 0.6 mm
- Invasive angiography ≈ 0.2 mm
- IVUS ≈ 0.1 mm
- OCT ≈ 0.02 mm
- Pressure wire ≈ 1 mmHg

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“Left main” stenosis

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

“Left main” stenosis

Relative error ΔP/P = 4 * Δradius / radius

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

Test/retest repeatability

- FFR ±0.02
- %DS ±5-8% by QCA
- MLA ±0.3-0.6 mm^2
- MLD ±0.1-0.3 mm

Johnson NP, *Circ Cardiovasc Imaging* 6(5):817, 2013, summary of Table 1

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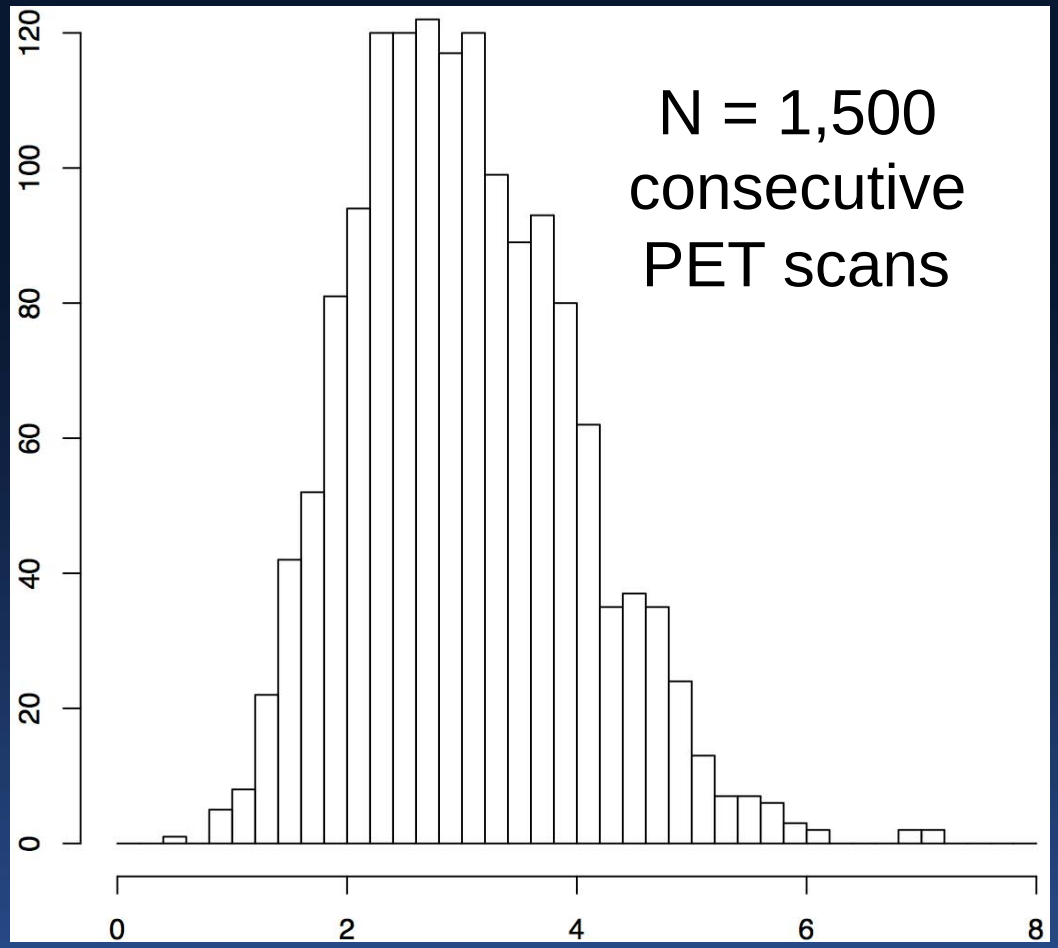
Biologic variability

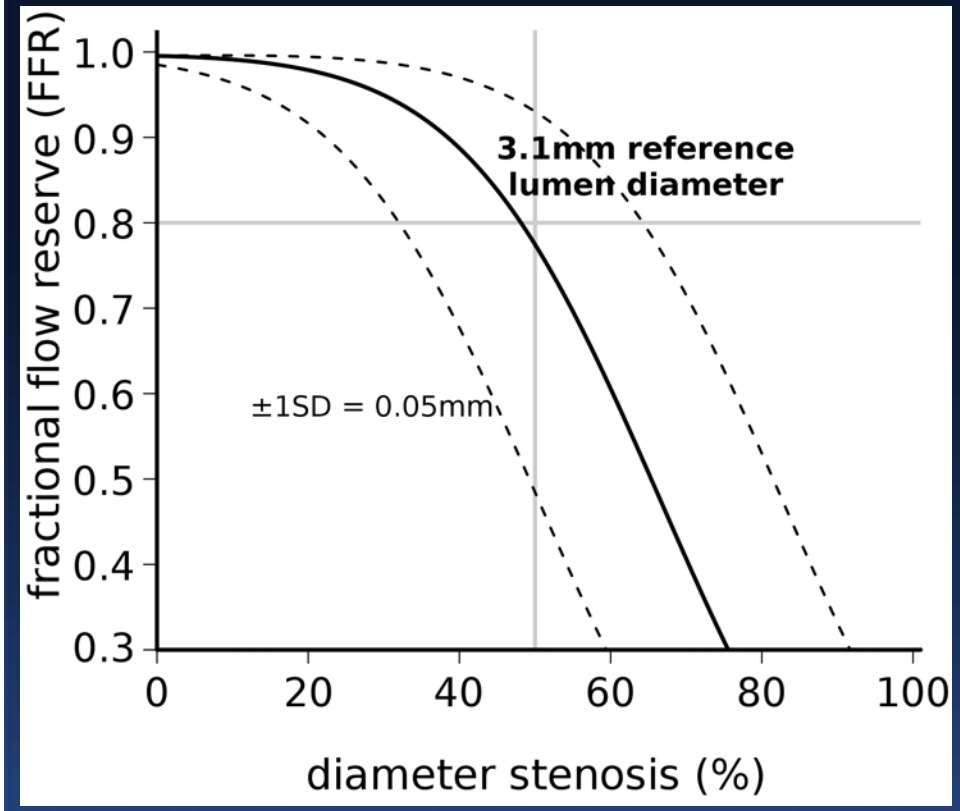


group vs individual

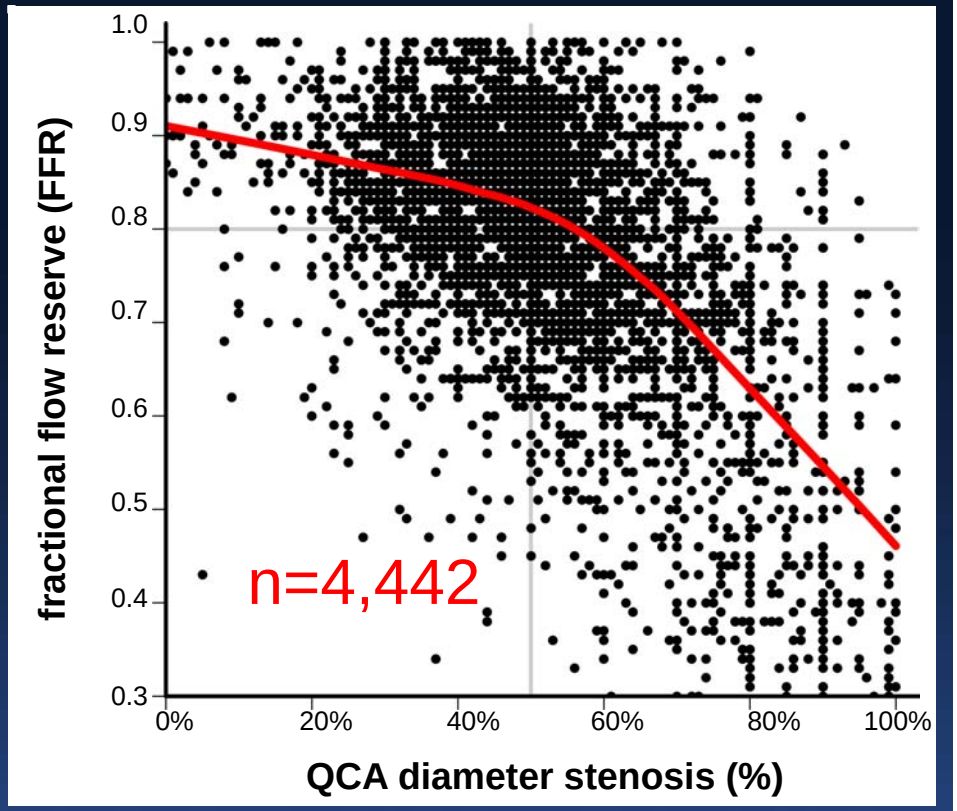
mode = 2.72 (most common)
mean = 3.04 ± 0.97
median = 2.95 (IQR 2.32-3.68)
range from 0.58 to 7.13

Johnson NP, *JACC Cardiovasc Imaging* 5(4):430, 2012, unpublished data

%DS



Johnson NP, *Circ Cardiovasc Imaging* 6(5):817, 2013, Figure 1A



Unpublished, multicenter data

%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.

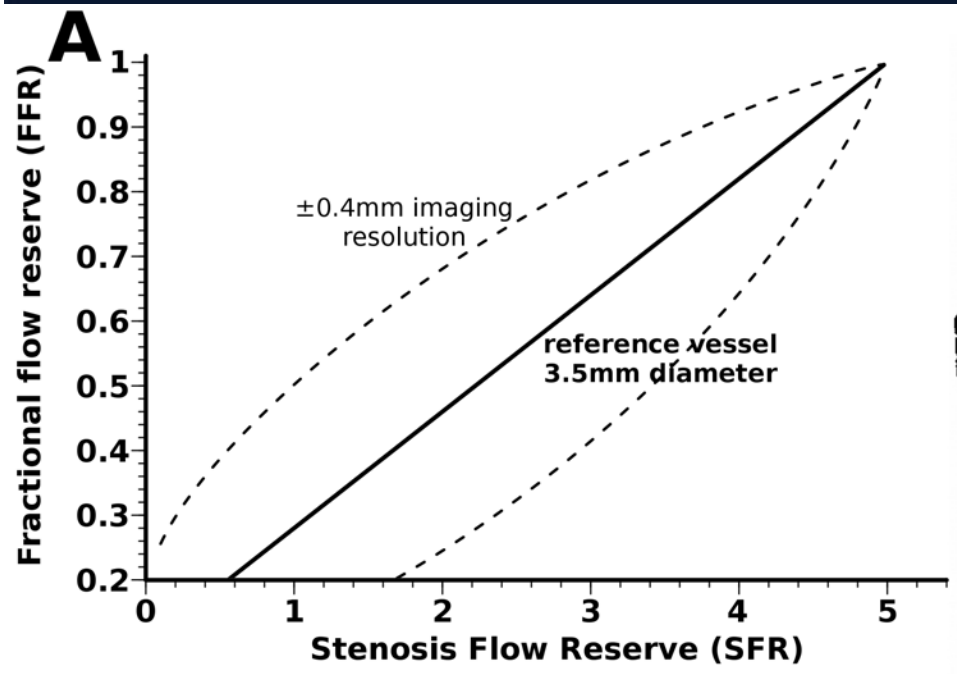
Stenosis flow reserve (SFR)

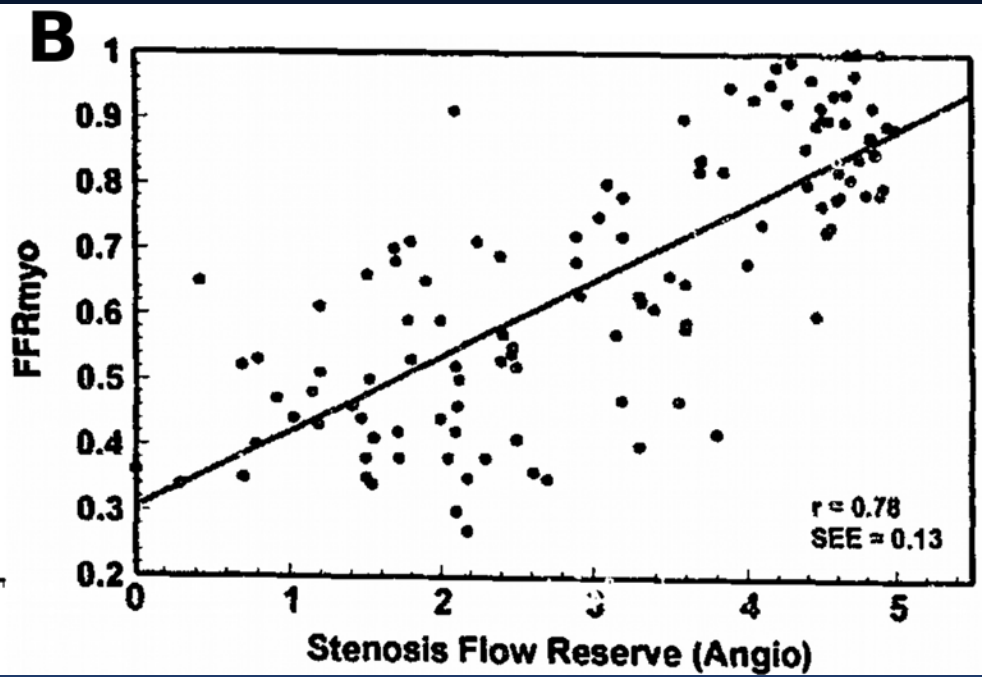
- Introduced in 1986
- Gould and Kirkeeide
- Anatomy from QCA
- *Modeled* CFR
- Commercially available from Philips

CT-modeled FFR (FFR_{CT})

- Introduced in 2010
- Taylor and colleagues
- Anatomy from CT angiogram
- *Modeled* FFR
- Commercial distribution by HeartFlow (not yet in USA)

QCA-modeled CFR





Johnson NP, *Circ Cardiovasc Imaging* 6(5):817, 2013, Figure 3A

Bartúnek J, *JACC* 26(2):328, 1995, Figure 3 (bottom)

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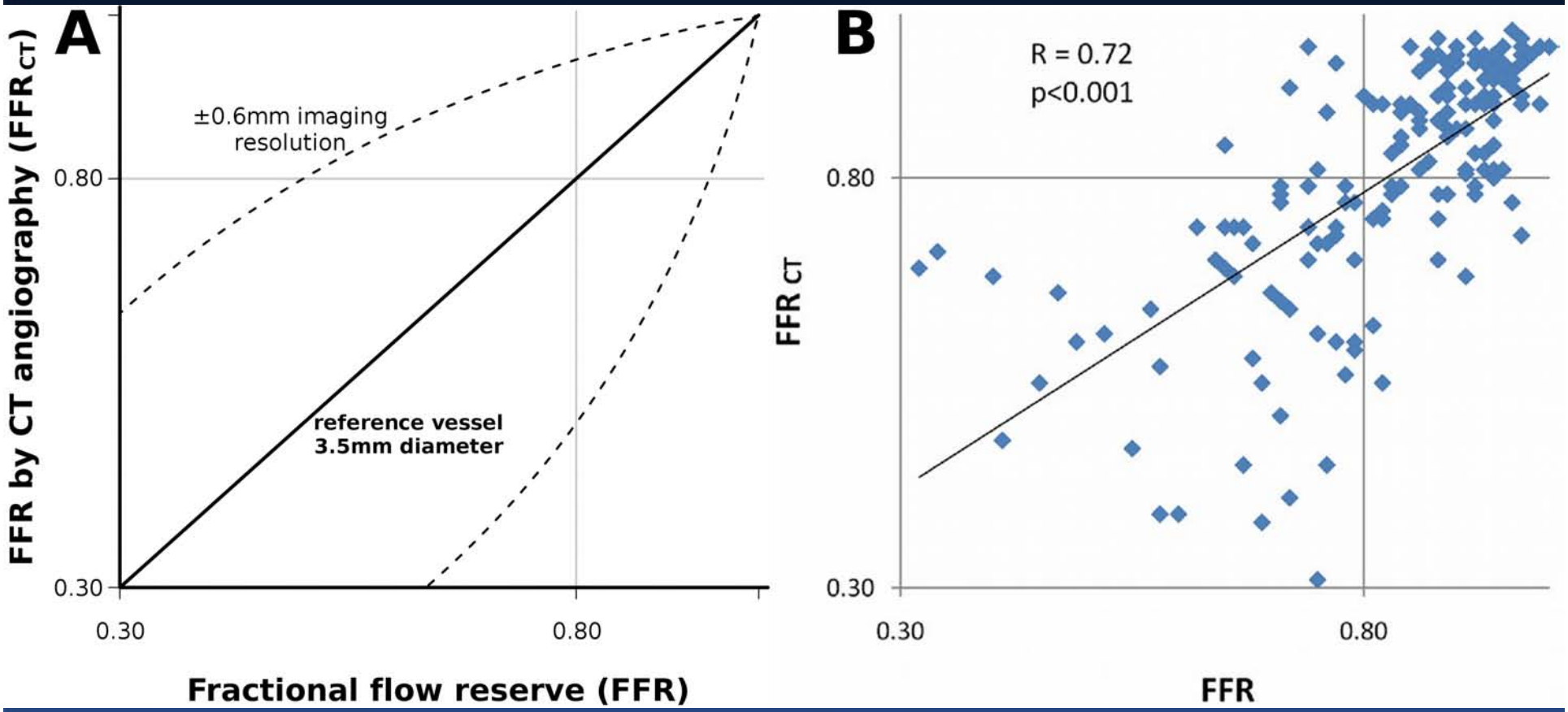
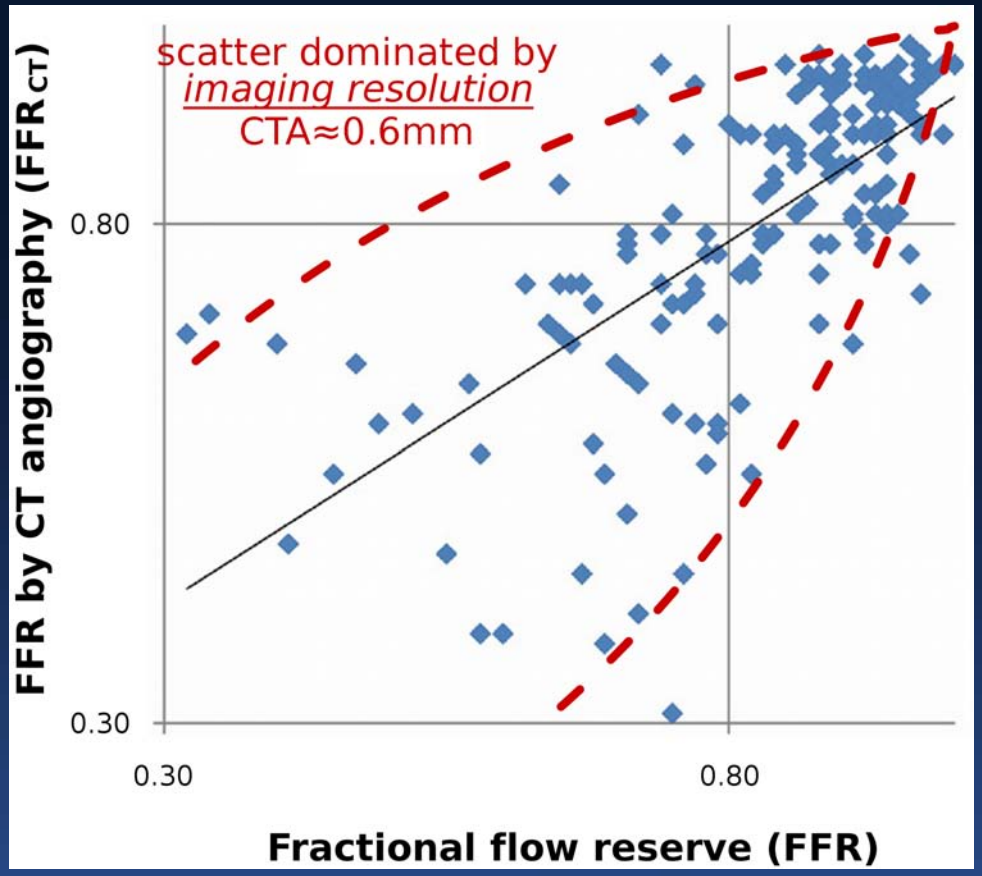
CT-modeled FFR



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

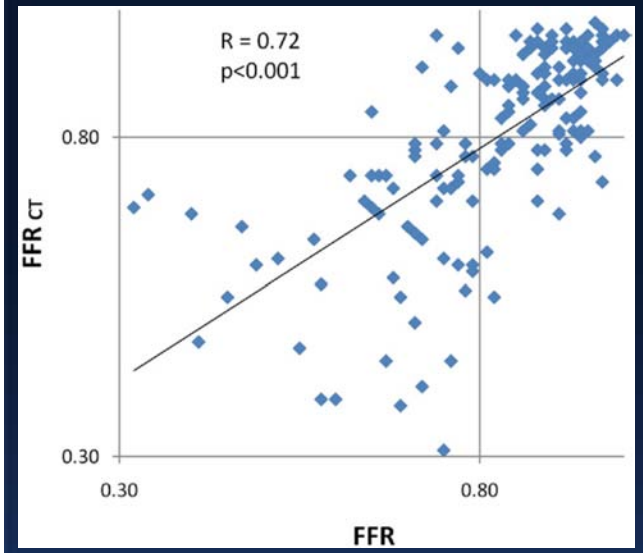
Koo BK, *JACC* 58(19):1989, 2011, Figure 4

CT-modeled FFR

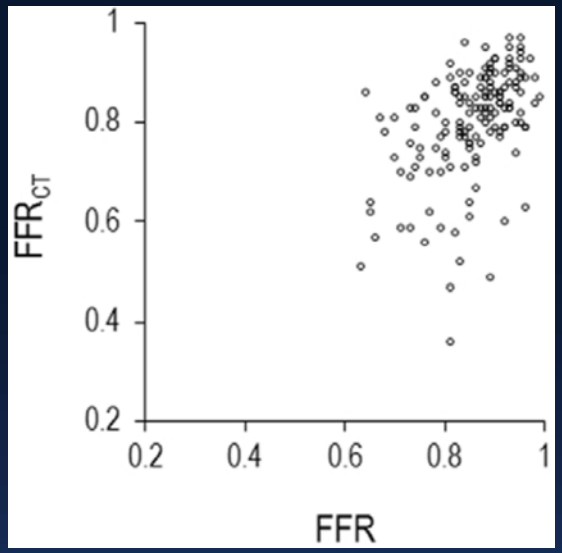


Johnson NP, *Circ Cardiovasc Imaging* 6(5):817, 2013, Figure 5A

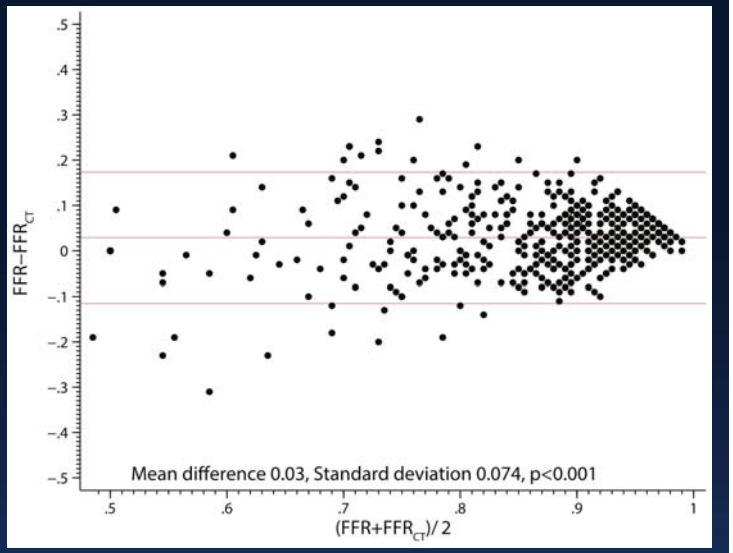
CT-modeled FFR



DISCOVER-FLOW (2011)



DeFACTO (2012)



NXT (2013)

DISCOVER FLOW = Koo BK, *JACC* 58(19):1989, 2011, Figure 4
DeFACTO = Nakazato R, *Circ Cardiovasc Imaging* 6(6):881, 2013, Figure 1A
NXT = Nørgaard BL, *JACC* 63(12):1145, 2014, Figure 3

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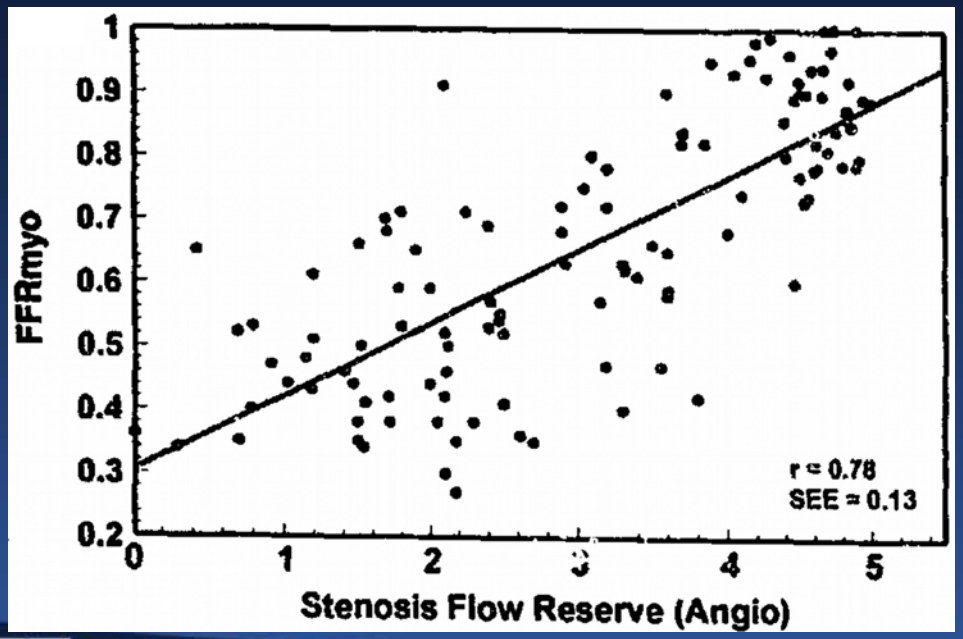
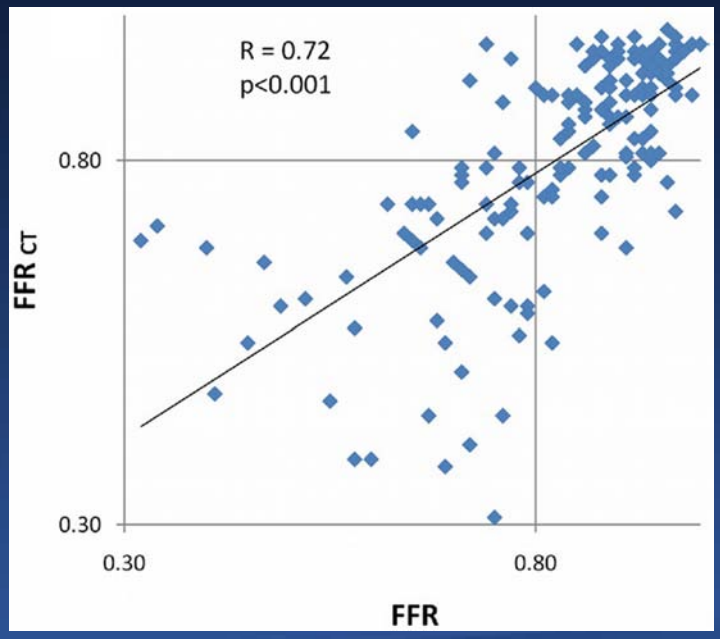
Physiology models

Model	Author	Year	N	Correlation	AUC	Accuracy
SFR	Bartúnek	1995	110	0.78	0.89	84%
	Di Mario	1996	21	0.57	0.87	80%
FFR_{CT}	DISCOVER-FLOW	2011	159	0.68	0.90	84%
	DeFACTO	2012	407	0.63	0.81	69%
	NXT	2014	251	0.82	0.90	81%

little Δ in 20 yrs





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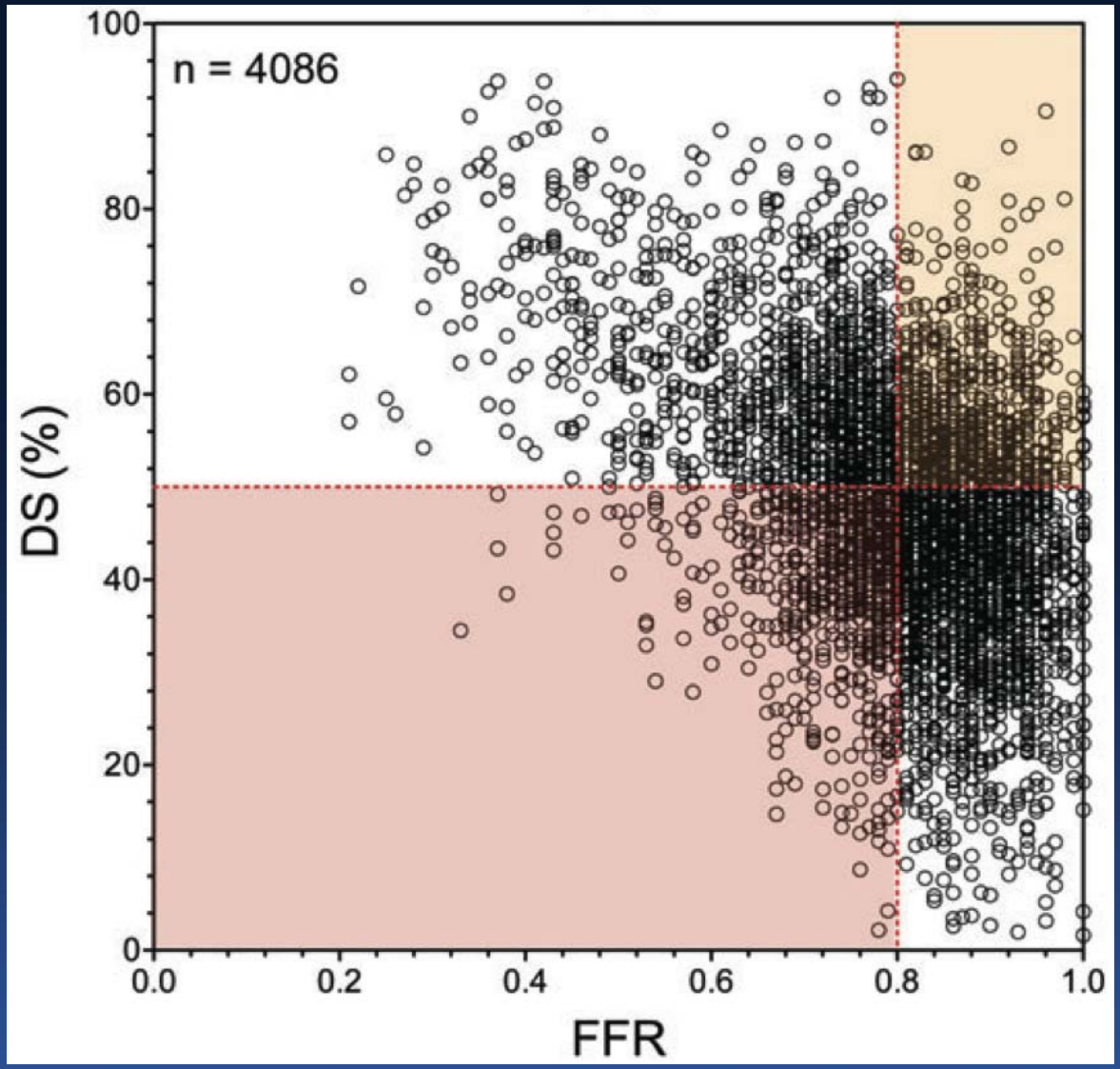
From a Physiological Index to a Clinical Tool

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

1995

"*too weak to be clinically relevant*"



Toth G, *Eur Heart J*. 2014 Mar 18. [Epub ahead of print], Figure 1A