Pyschological Evolution of Side Branch PCI

Bon-Kwon Koo, MD, PhD

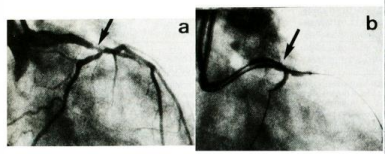
Seoul National University Hospital, Seoul, Korea

Evolution of Bifurcation PCI

Kissing Balloon Coronary Angioplasty

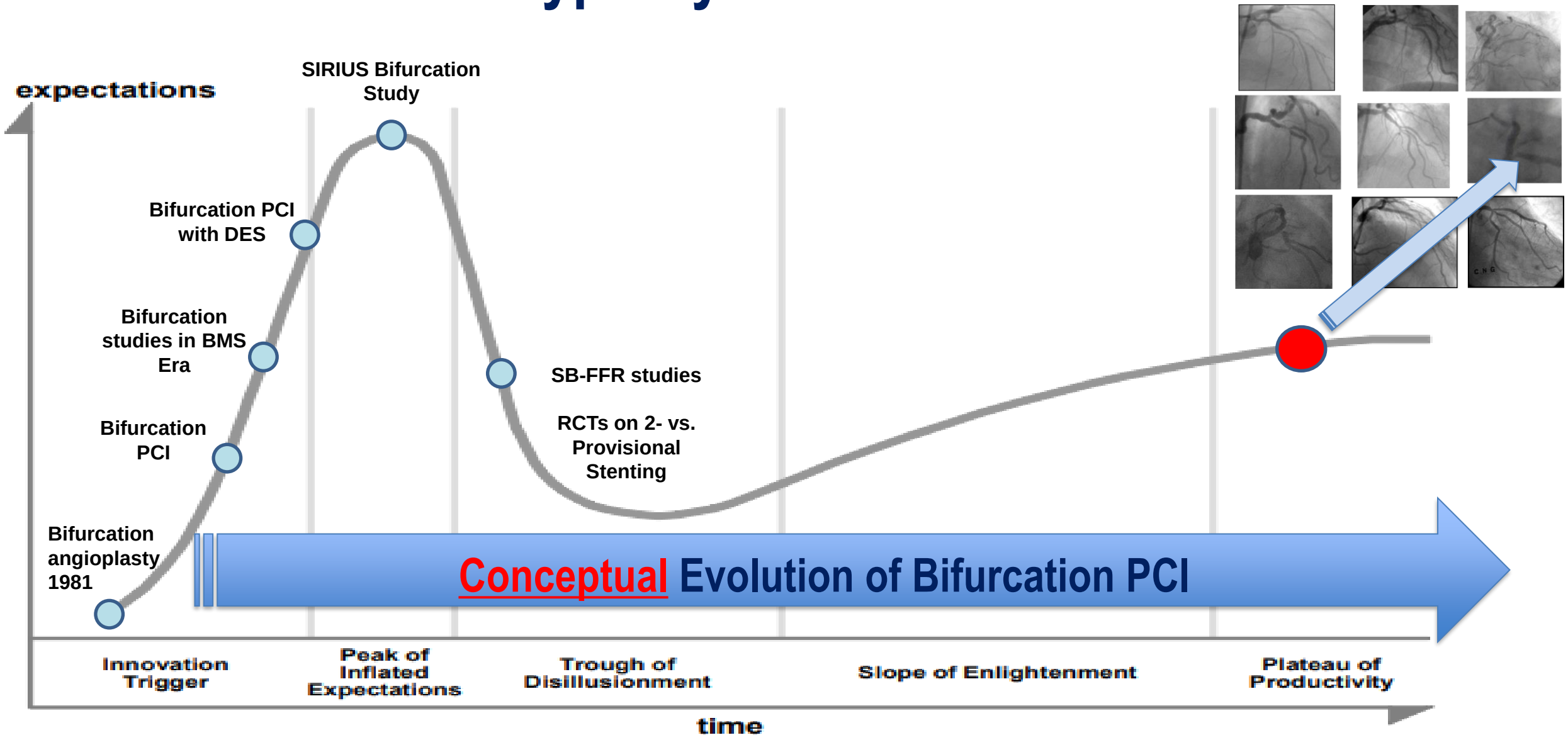
BERNHARD MEIER, MD

Balloon angioplasty of stenoses involving a bifurcation of coronary arteries carries a significant risk of permanent occlusion of 1 of the branches.[1] Kissing balloon angioplasty was first described for aortoplasty in the Leriche syndrome.[2] In 1981, Gruentzig introduced it into coronary angioplasty. Two balloons are simultaneously inflated in a diseased vessel bifurcation. This



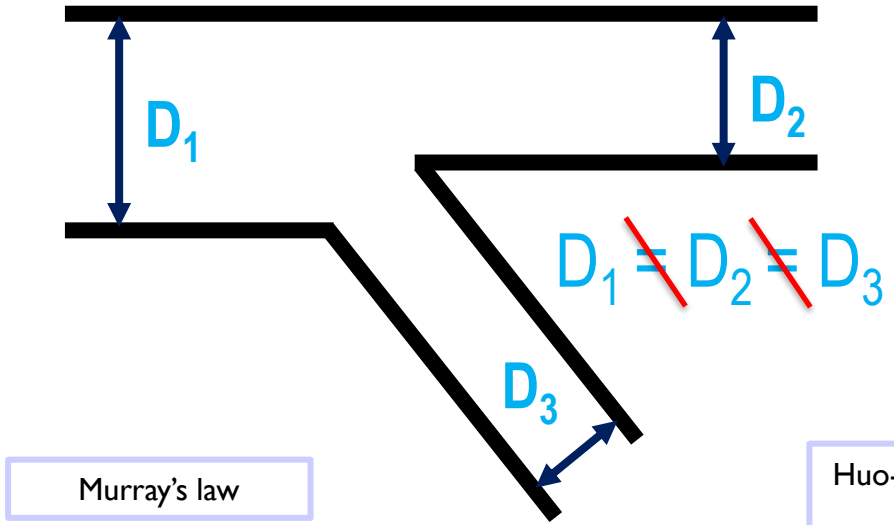
1980 1990 2000 2010 2020

Gartner Hype Cycle in Bifurcation PCI



Conceptual Evolution of Bifurcation PCI

- Fixing the stenotic bifurcation lesion will improve the patient's prognosis.

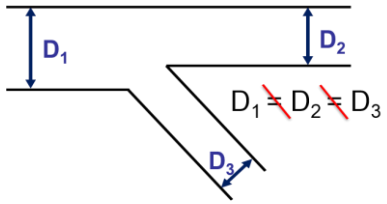


Murray's law

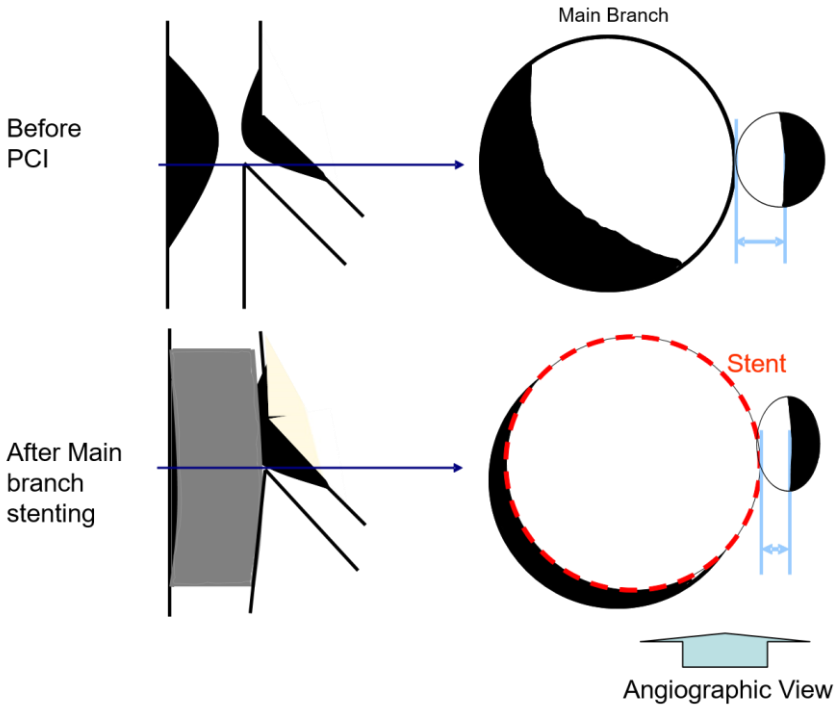
Huo-Kassab's law (2009)

Seiler-Kirkeeide-Gould ratio (1992)

Finet's law (2008)

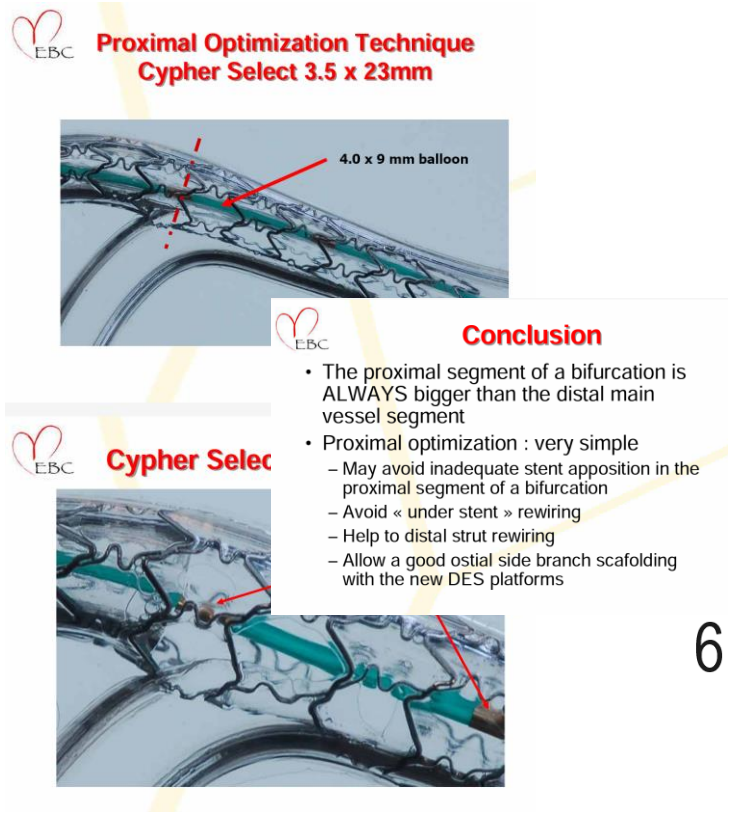


Carina Shift / POT / Effective MSA

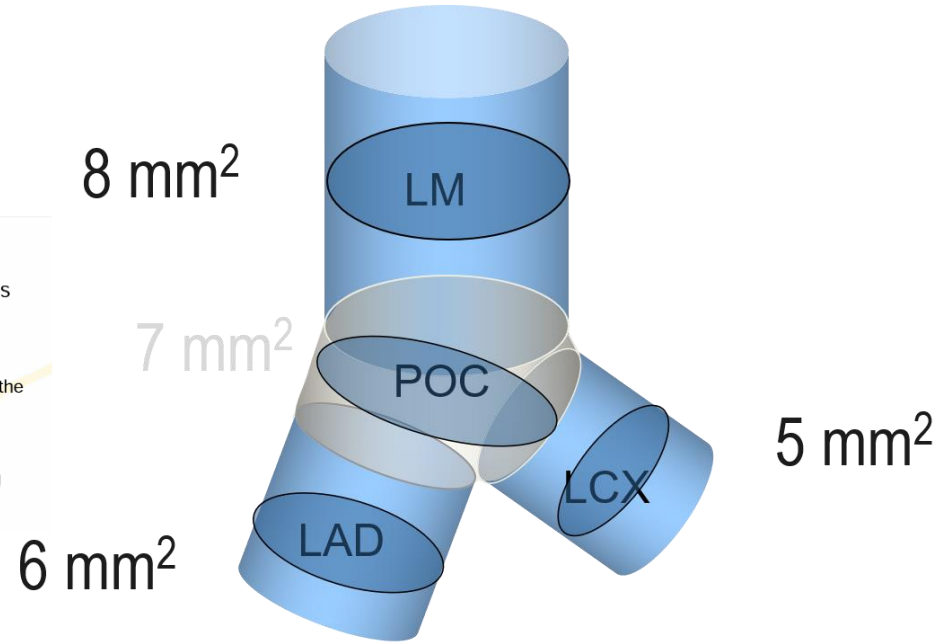


Koo BK. EBC 2008

Koo BK & de Bruyne B. Eurointervention 2010 Koo BK et al. Circ CVI 2010



Darremont O. EBC 2008



Kang et al. Circ Cardiovasc Interv 2011

ALL starts from this ratio!

VOL. 12, 1926 PHYSIOLOGY: C. D. MURRAY 207

sex of Chaetocladium was grown with either sex of Parasitella, both species acted as host to the other parasite and galls were produced characteristic of both Parasitella and Chaetocladium. The parasitic behavior of Chaetocladium has been described in detail by Burgeff.[2]

THE PHYSIOLOGICAL PRINCIPLE OF MINIMUM WORK. I. THE VASCULAR SYSTEM AND THE COST OF BLOOD VOLUME

BY CECIL D. MURRAY

DEPARTMENT OF BIOLOGY, BRYN MAWR COLLEGE

Communicated January 26, 1926

Atherosclerosis, 47 (1983) 55–62
Elsevier Scientific Publishers Ireland, Ltd.

Localization of Atherosclerotic Lesions in the Bifurcation of the Main Left Coronary Artery

Per Grøttum, Aud Svindland and Lars Walløe

Department of Pathology, Oslo City Hospital and Institute of Informatics, University of Oslo (Norway)

(Received 15 October, 1982)
(Accepted 15 November, 1982)

Arterial Wall Shear and Distribution of Early Atheroma in Man

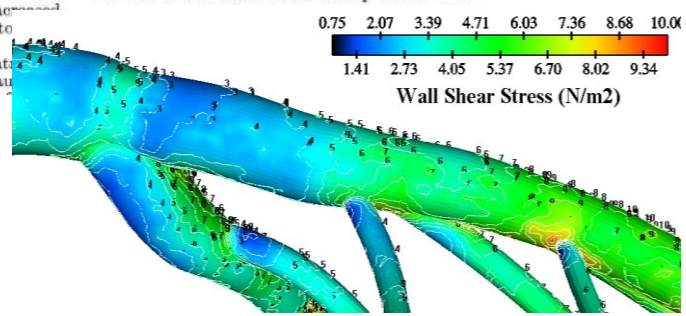
NATURE, VOL. 223, SEPTEMBER 13, 1969

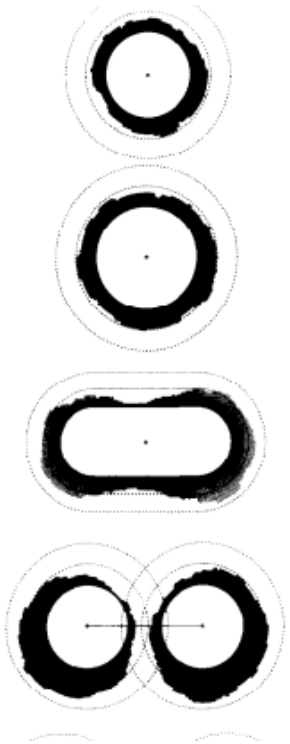
THE patchy distribution of fatty streaking and early atheroma has been associated with arterial blood mechanics. Mustard *et al.*[1] have noted occurrence of atheroma at sites which are thought to experience particle (platelet) deposition as the result of local rapid flow fluctuations (turbulence) or eddies. Others have proposed platelet deposition in regions of flow separation[2]. Texon[3] invoked damage due to Bernoulli-type suction forces in areas of locally increased blood velocity; but this is considered implausible because the forces are negligible in physiological conditions in comparison with normal variations of mean blood pressure. Mitchell and Schwartz[4] reported the sparing of fatty streaking in localized areas, at which they suggest low wall shear rate (the product of velocity gradient and fluid viscosity) is experienced. Fry[5,6] has shown that acute elevation of shear rate on the aortic wall causes endothelial damage and increased permeability to lipids. These theories assign to mechanics a causative role in atherogenesis.

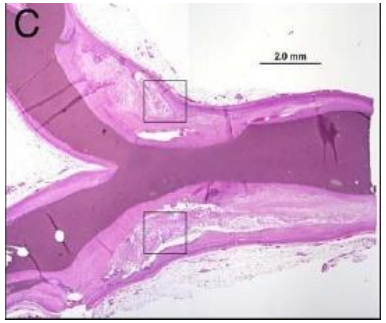
We consider that fluid mechanics has a cont... and inhibiting (or retarding) effect, rather than a cau...

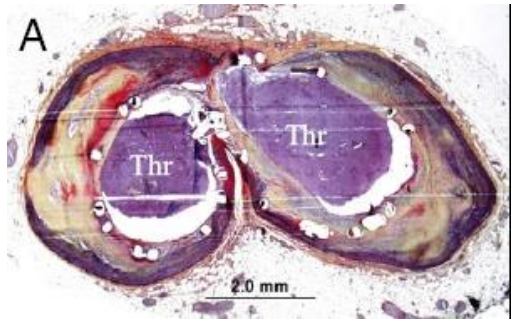
moval rates, may control the rate of accumulation of material constituting atheromatous lesions. It is interesting that this theory predicts that physical exercise involving increase of cardiac output, and hence increased shear rate, might retard the development of atheroma. An overall reduction of shear rate, for example a normal volume flow rate through a dilated artery, will tend to favour the development of atheroma. This is in contrast to other predictions[1,3–6,9].

We thank M. F. Sudlow for advice and assistance. A number of other colleagues, including pathologists, kindly enabled us to study post-mortem material. Financial support for this work was derived in part from the Wates and Nuffield Foundations, the Medical Research Council and the Royal Society. J. M. F. is a travelling scholar of the Gowrie Scholarship Trust Fund.









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Pathological Findings at Bifurcation Lesions

The Impact of Flow Distribution on Atherosclerosis and Arterial Healing After Stent Implantation

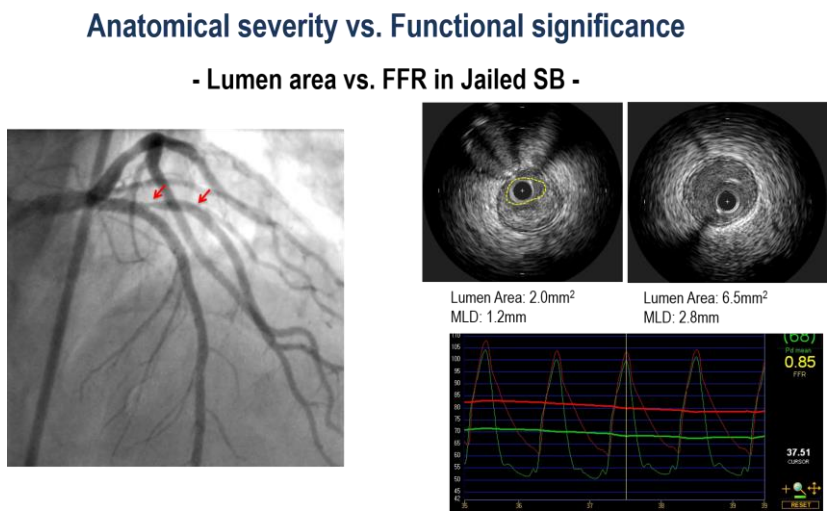
Gaku Nakazawa, MD,* Saami K. Yazdani, PHD,* Aloke V. Finn, MD,† Marc Vorpahl, MD,* Frank D. Kolodgie, PHD,* Renu Virmani, MD*

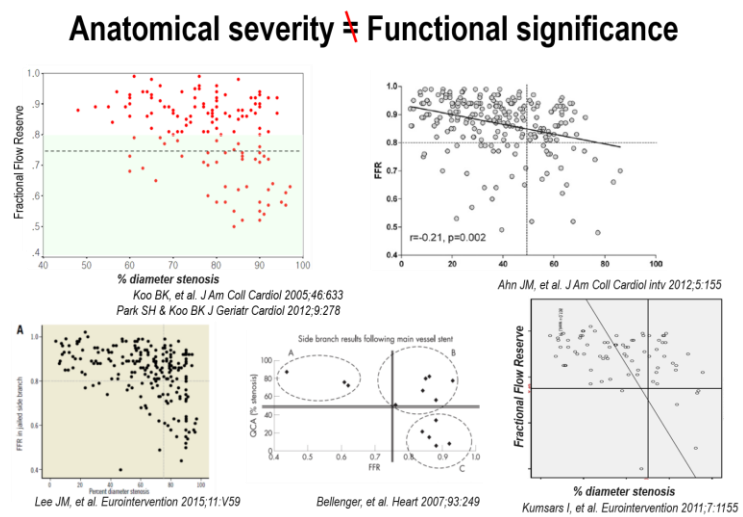
Gaithersburg, Maryland; and Atlanta, Georgia

Soulis et al. J of Biomechanics 2006;39:742

Conceptual Evolution of Bifurcation PCI

- Fixing the stenotic bifurcation lesion will improve the patient's prognosis.
- Fractal structure and ratio
  - The natural fractal ratio is more important than "LARGER".
- **Discordance between anatomy vs. ischemia**
  - Anatomical luminal narrowing does not always mean the presence of ischemia.





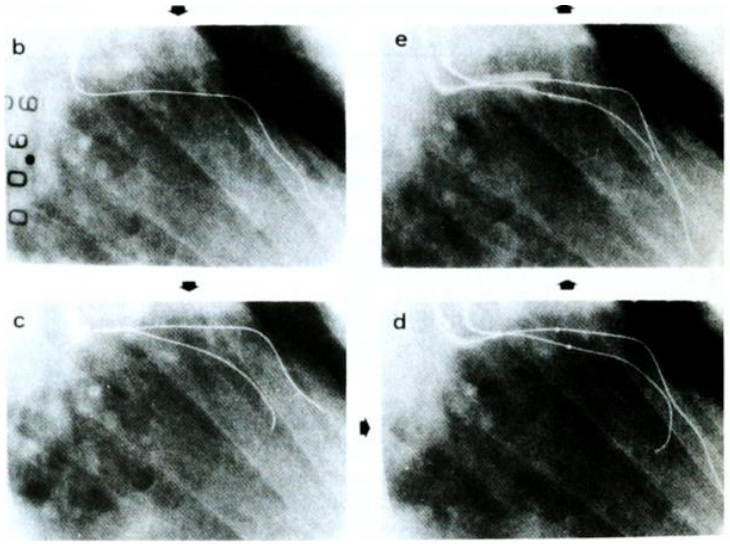
Intracoronary hemodynamics in the beginning

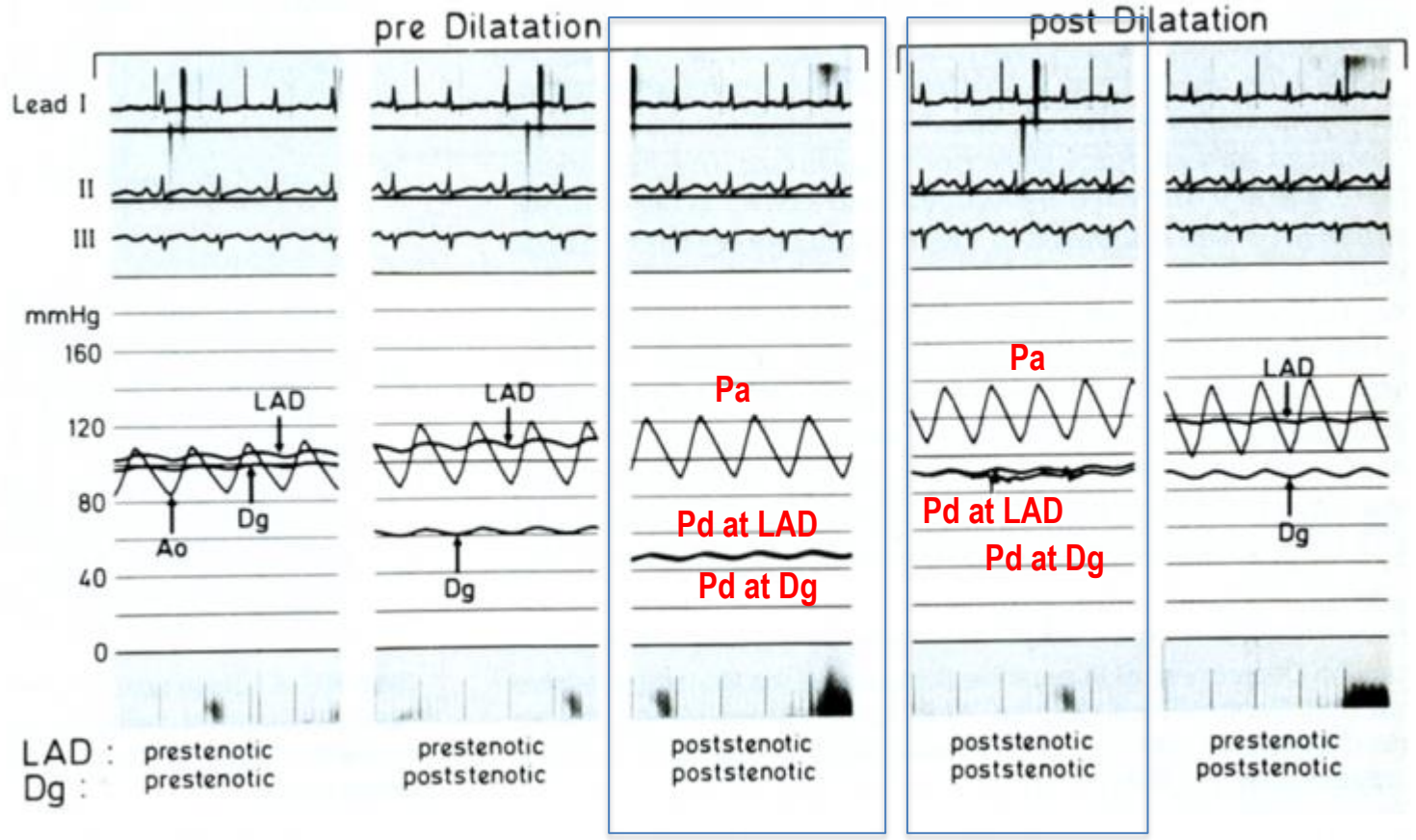
Vol. 46, No. 4, 2005
ISSN 0735-1097/
i:10.1016/j.jacc.20

Kissing Balloon Coronary Angioplasty

BERNHARD MEIER, MD

Balloon angioplasty of stenoses involving a bifurcation of coronary arteries carries a significant risk of permanent occlusion of 1 of the branches.[1] Kissing balloon angioplasty was first described for aortoplasty in the Leriche syndrome.[2] In 1981, Gruentzig introduced it into coronary angioplasty. Two balloons are simultaneously inflated in a diseased vessel bifurcation. This





Meier B. Am J Cardiol 1984

Conceptual Evolution of Bifurcation PCI

- Fixing the stenotic bifurcation lesion will improve the patient's prognosis.
- Fractal structure and ratio
  - The natural fractal ratio is more important than "LARGER".
- Discordance between anatomical severity and functional significance
  - Anatomical luminal narrowing does not always mean presence of ischemia.
- **Clinical relevance**

FFR-guided PCI is better than Angiography-guided PCI, Why NOT in SB PCI?

European Heart Journal (2008) **29**, 726–732
doi:10.1093/eurheartj/ehn045

CLINICAL RESEARCH
Interventional cardiology

Physiological evaluation of the provisional side-branch intervention strategy for bifurcation lesions using fractional flow reserve

Bon-Kwon Koo[1], Kyung-Woo Park[1], Hyun-Jae Kang[1], Young-Seok Cho[2], Woo-Young Chung[2], Tae-Jin Youn[2], In-Ho Chae[2], Dong-Ju Choi[2], Seung-Jae Tahk[3], Byung-Hee Oh[1], Young-Bae Park[1] and Hyo-Soo Kim[1]*

	FFR-guided group	Angio-guided group	P
	N=108	N=108	
Side branch PCI	30%	45%	0.02
TVR	5 (4.6%)	4 (3.7%)	0.7
MI	0	0	1
Cardiac death	0	0	1

Koo BK, et al. Eur Heart J 2008

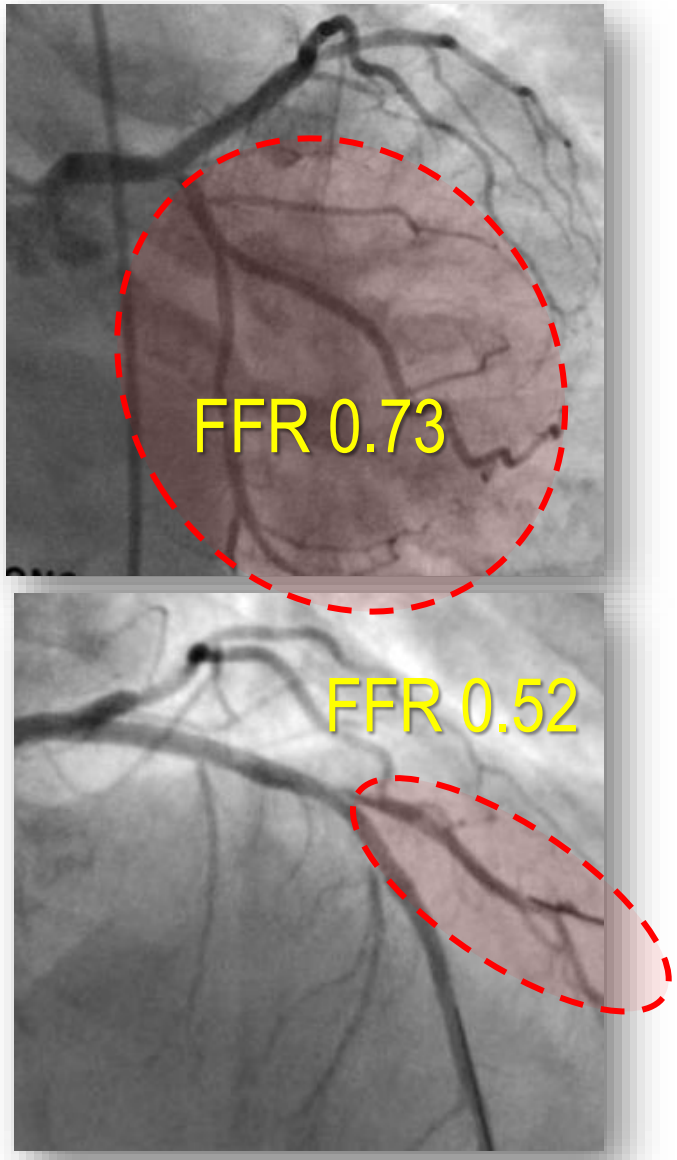
Results (3): One-year clinical outcomes

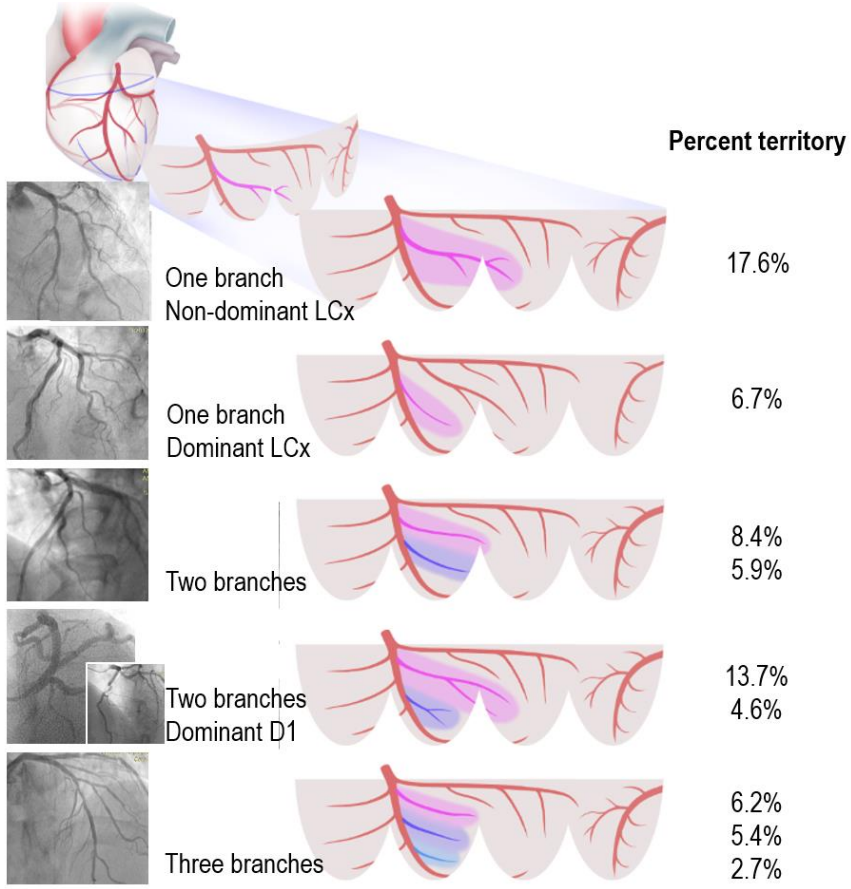
	Angio group (n=160)	FFR group (n=160)	p
Cardiac death, n(%)	1 (0.6)	2 (1.3)	0.56
MI, n(%)	22 (13.8)	19 (11.9)	0.74
TLR, n(%)	8 (5.0)	5 (3.1)	0.57
CABG, n(%)	0	0	-----
TVR, n(%)	11 (6.9)	9 (5.6)	0.82
MACE, n(%)	29 (18.1)	29 (18.1)	1.00
ST-def/prob, n(%)	2 (1.3)	1 (0.6)	0.56

tct2014

Chen SL, et al. JACC Cardiovasc Interv 2015

Clinical relevance is more important than physiological indexes!





Jeon WK, Koo BK, et al. Eurointervention 2020

ST-segment elevation after 1 minute occlusion

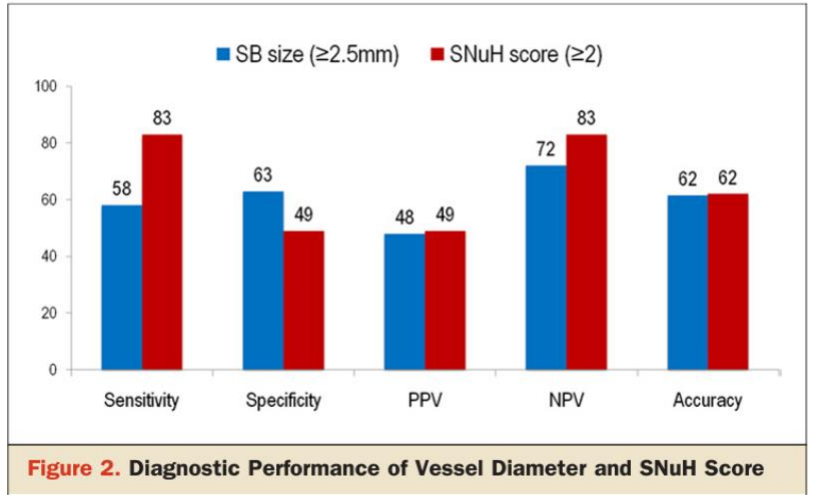
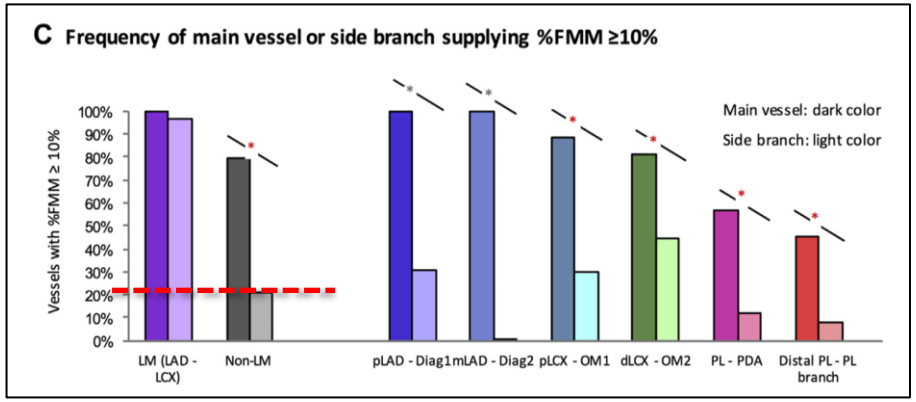


Figure 2. Diagnostic Performance of Vessel Diameter and SNuH Score

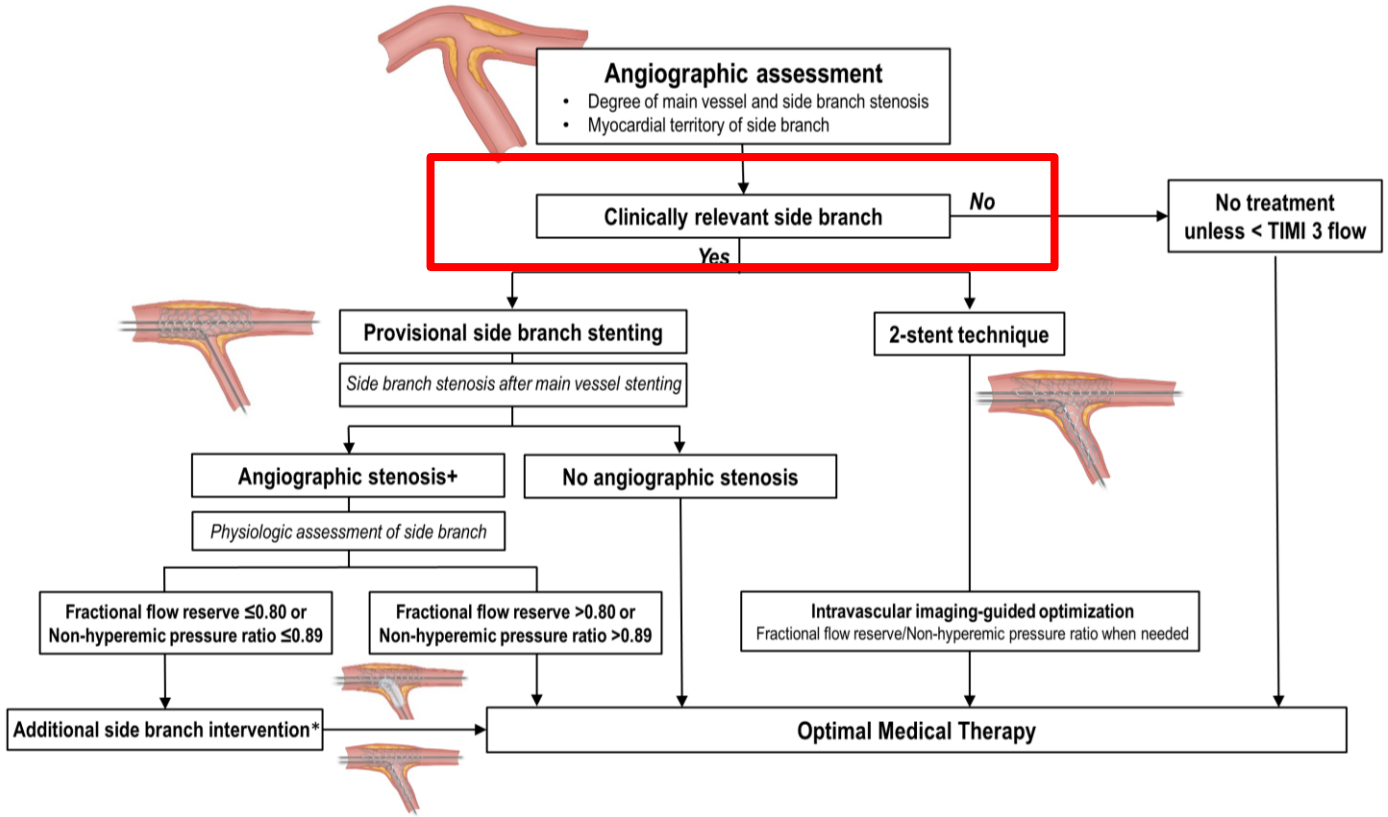
Koo BK, Lee SP, et al. JACC interv 2012



Kim HY, Choi JH, et al. JACC interv 2017

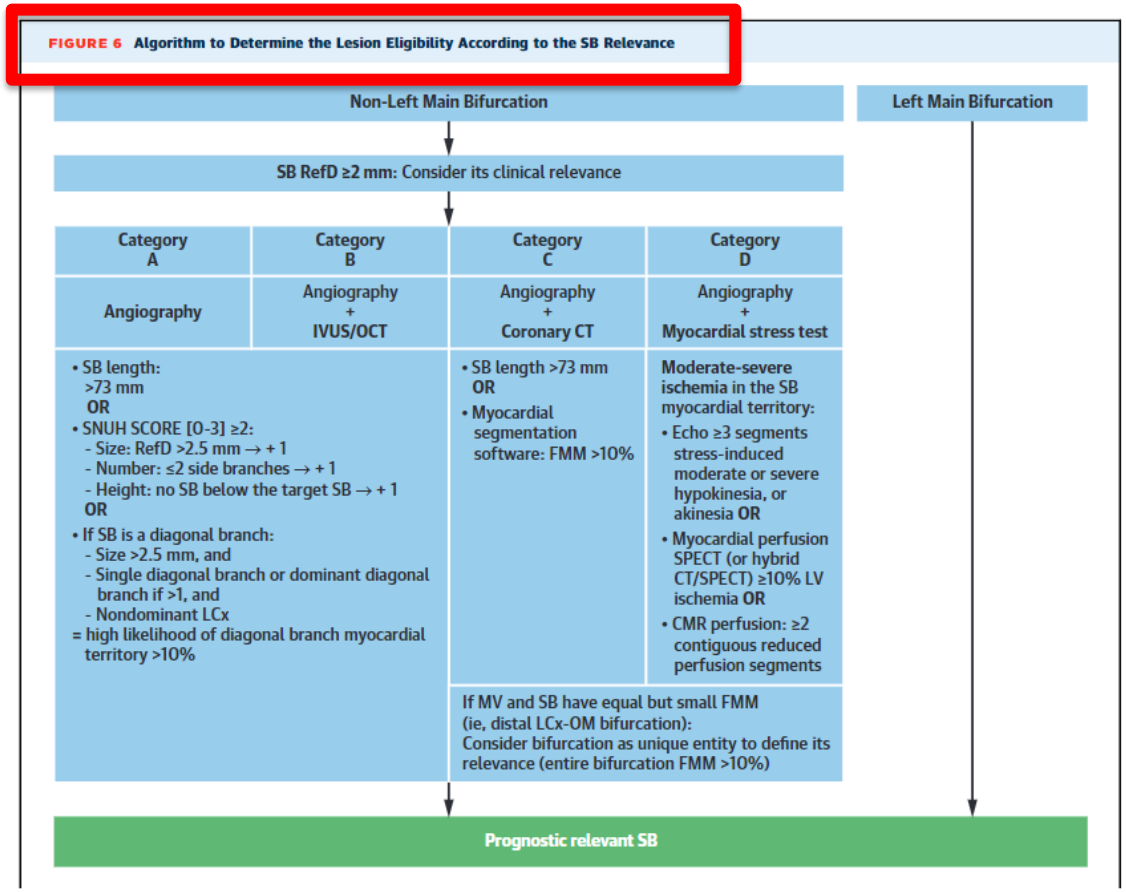
Clinical relevance: 1st step in side branch assessment

KBC-JBC-EBC consensus 2022



JACC intervention 2022

Bif-ARC 2022



JACC 2022

Origin of Clinical relevance

Risk of Side Branch Occlusion During Coronary Angioplasty

BERNHARD MEIER, MD, ANDREAS R. GRUENTZIG, MD, SPENCER B. KING III, MD, JOHN S. DOUGLAS, Jr., MD, JAY HOLLMAN, MD, THOMAS ISCHINGER, MD, FRED AUERON, MD, and KATHY GALAN, RN

To assess the risk of side branch occlusion during percutaneous transluminal coronary angioplasty (PTCA), 600 consecutive procedures w lyzed. On the basis of pre-PTCA angiogra patients in whom the balloon was actuall 365 side branches in 302 patients (54% o were deemed in jeopardy. A total of branches in 102 patients (18%) originate lesion segment itself, i.e., their take-off rowed (Group I, 33% of side branches whereas 243 side branches in 214 patien originated from the immediate vicinity of th in a way that they were subjected to t occlusion during balloon dilatation (Grou of side branches at risk). Patency of side was determined by consensus of 2 obser teria for occlusion were disappearance, collaterals, or stagnation of flow. After PT 365 side branches (5%) were occluded

ciated with chest pain in 5 patients, creatine kinase increase in 6, left anterior hemiblock, septal Q

(Am J Cardiol 1984;53:10–14)

Implications: Of course, the described cohort of patients was selected regarding suitability for PTCA. Anticipation of problems due to side branch occlusion was a selection criteria. Therefore, patients with stenoses in or around bifurcations of large vessels were disqualified if complete revascularization of both vessels by PTCA was unlikely. In such cases, bypass grafts to both vessels were recommended.

With this in mind, some conclusions can still be drawn from the described results. Only side branches intimately involved in the lesion to be dilated (high-risk side branches) are at a relevant risk for iatrogenic occlusion. Occlusion of side branches not involved in the stenosis (low-risk side branches) just by contact with the dilating balloon is rare. Significant consequences of side branch occlusions are unlikely if selection of patients is guided by the relevance of the side branches at risk.

References

1. Gruentzig AR, Senning A, Siegenthaler WE. Nonoperative dilatation of coronary-artery stenosis. N Engl J Med 1979;301:61–68.
2. Dorros G, Cowley MJ, Simpson J, Bentivoglio LG, Block PC, Bourassa M, Detre K, Gosselin AJ, Gruentzig AR, Kelsey SF, Kent KM, Mock MB, Mullin

JACC Vol. 21, No. 3
March 1, 1993:783–97

Measurement From Arteriograms of Regional Myocardial Bed Size Distal to Any Point in the Coronary Vascular Tree for Assessing Anatomic Area at Risk

CHRISTIAN SEILER, MD, RICHARD L. KIRKEEIDE, PHD, K. LANCE GOULD, MD, FACC
Houston, Texas

Objectives. To obtain the size of regional myocardial mass for individual coronary arteries in vivo.

Background. The anatomic site of occlusion in a coronary artery does not predict the size of the risk area because location of the occlusion does not account for the size of the artery or of its dependent myocardial bed.

Methods. Intracoronary radiolabeled microspheres were injected and coronary arteriograms were quantitatively analyzed by semiautomated methods. The coronary artery lumen areas and the sum of epicardial coronary artery branch lengths distal to the points where radiomicrospheres had been injected were determined from both in vivo and postmortem coronary arteriograms. Regional myocardial mass distal to the point of each microsphere injection was correlated with corresponding distal summed coronary branch le

Results. 1) related to sum point in the c

mined for any location on a coronary arteriogram. 2) The fraction of total left ventricular mass at risk distal to a stenosis could be determined from the corresponding fraction of total coronary artery tree length independently of the scale or X-ray magnification used to measure absolute branch lengths. 3) Cross-sectional lumen area at any point in the left coronary artery tree was closely related to the size of the dependent vascular bed with a curvilinear relation similar to that observed in humans with normal coronary arteriograms.

Conclusions. On coronary arteriograms, the anatomic area at risk for myocardial infarction distal to any point in the coronary artery tree can be determined from the sum of distal coronary artery branch lengths. There is a curvilinear relation between coronary artery lumen area and dependent regional myocardial

Basic Structure–Function Relations of the Epicardial Coronary Vascular Tree

Basis of Quantitative Coronary Arteriography for Diffuse Coronary Artery Disease

Christian Seiler, MD; Richard L. Kirkeeide, PhD; and K. Lance Gould, MD

(*Circulation* 1992;85:1987–2003)

Conceptual Evolution of Bifurcation PCI

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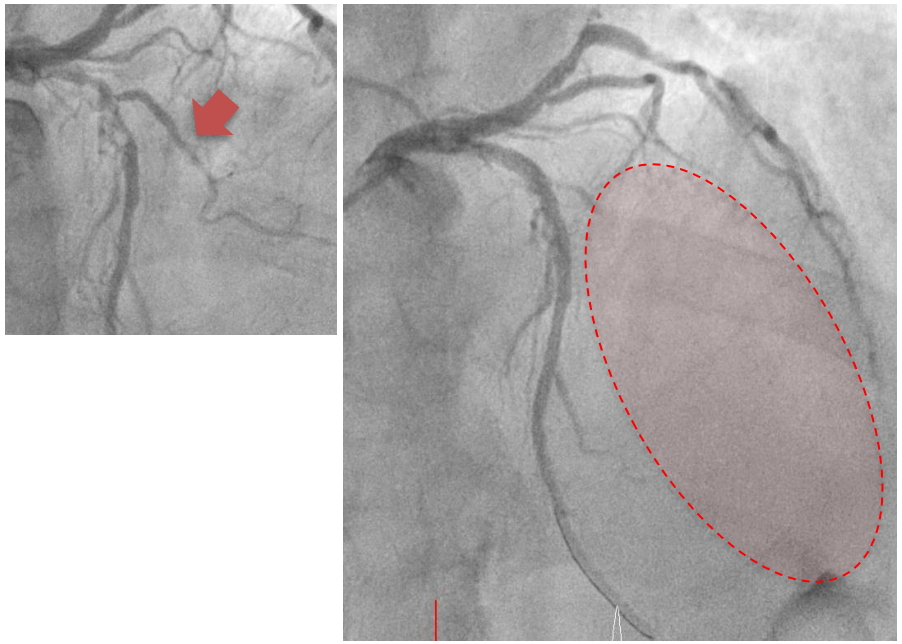
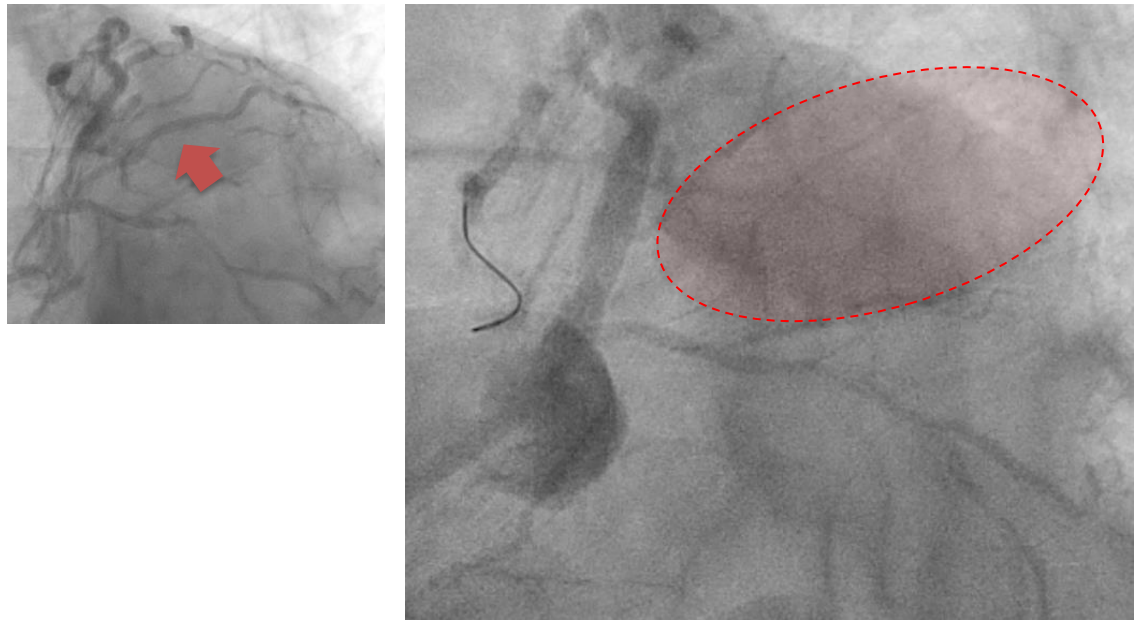
- Fractal structure and ratio
  - The natural fractal ratio is more important than "LARGER".
- Discordance between anatomical severity and functional significance
  - Anatomical luminal narrowing does not always mean presence of ischemia.
- Clinical relevance
  - Presence of ischemia does not guarantee the benefit of PCI.
- **Structure-Function relationship**

Macrostructure – Function Relationship

SB occlusion after MB stenting



SB occlusion after MB stenting

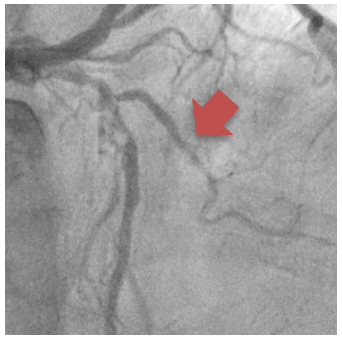


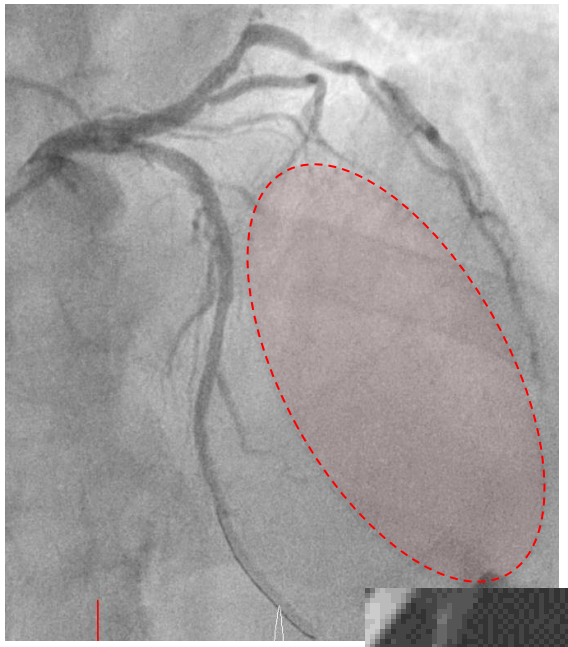
Koo BK. EBC 2018

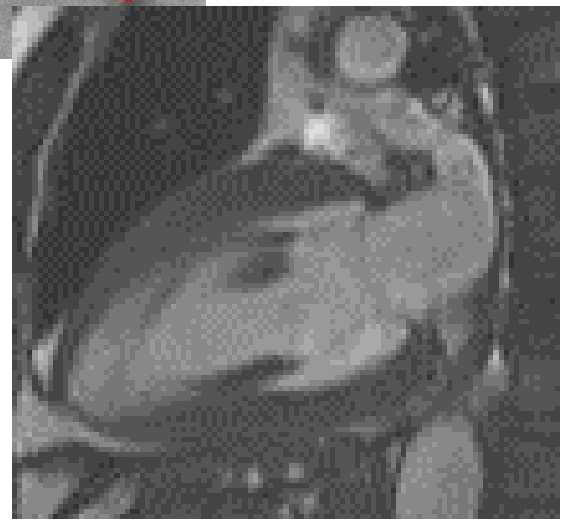
Courtesy of Hyun-Jong Lee MD
Sejong Hospital

Macrostructure – Function Relationship

SB occlusion after MB stenting







Koo BK. EBC 2018

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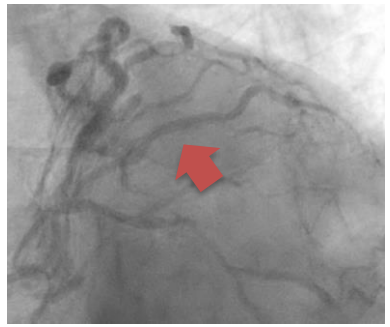
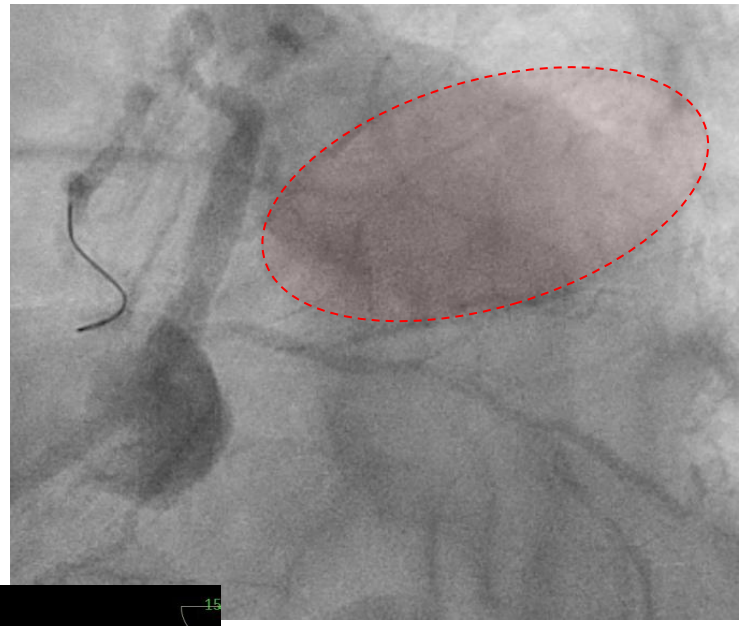
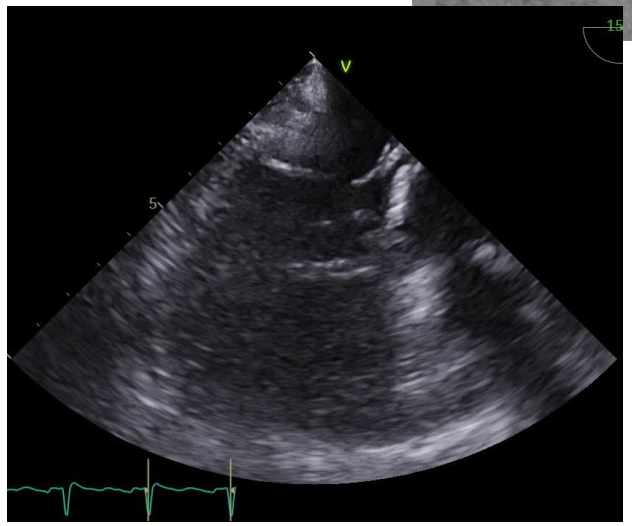






Courtesy of Hyun-Jong Lee MD
Sejong Hospital

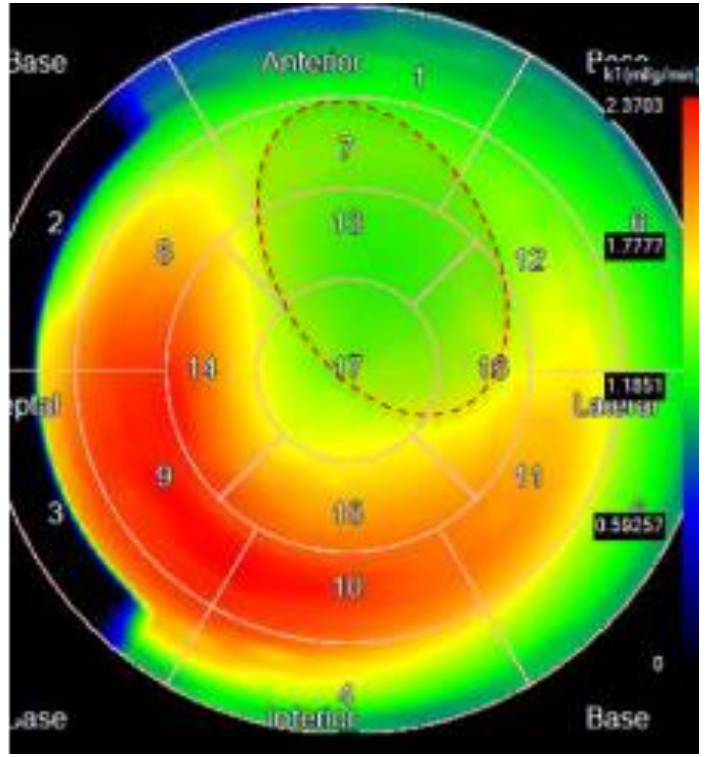
ISCHEMIC territory = Clinical/Prognostic relevance?

Anatomical stenosis → Ischemia → Large territory (clinically relevant ischemia)

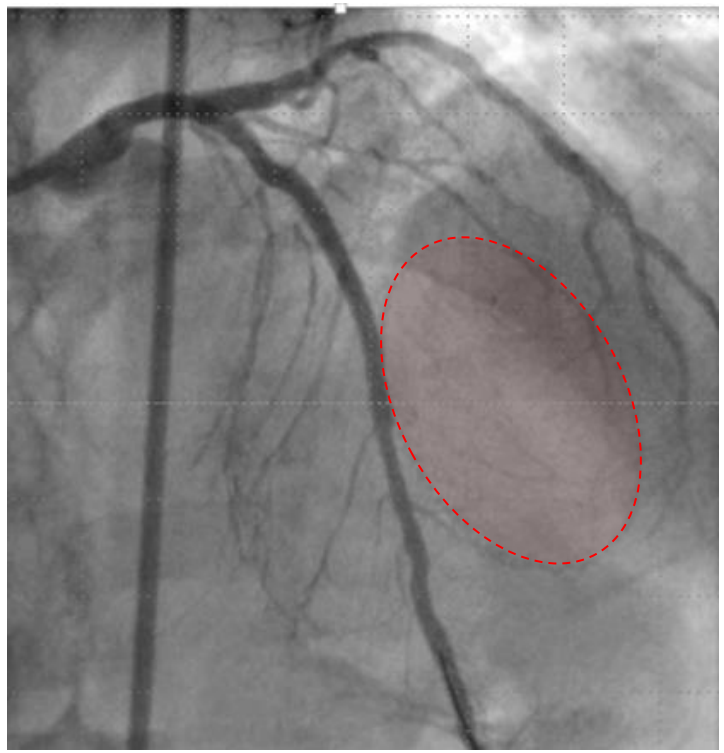
Angina
Arrhythmia
LV dysfunction
Cardiac death

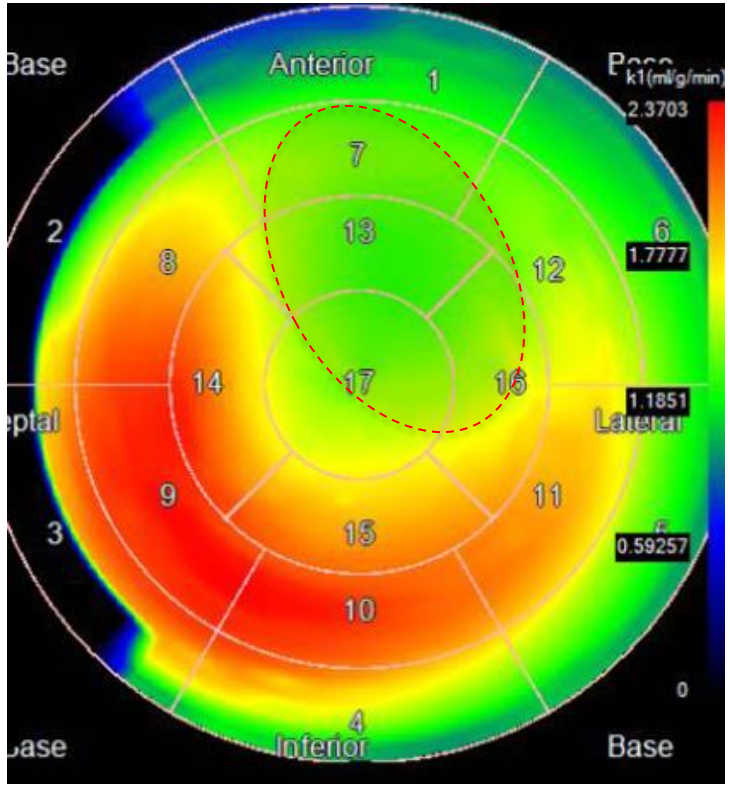
REVASCULARIZATION

Relief of ischemia
Improve symptom, LV dysfunction
Improve survival

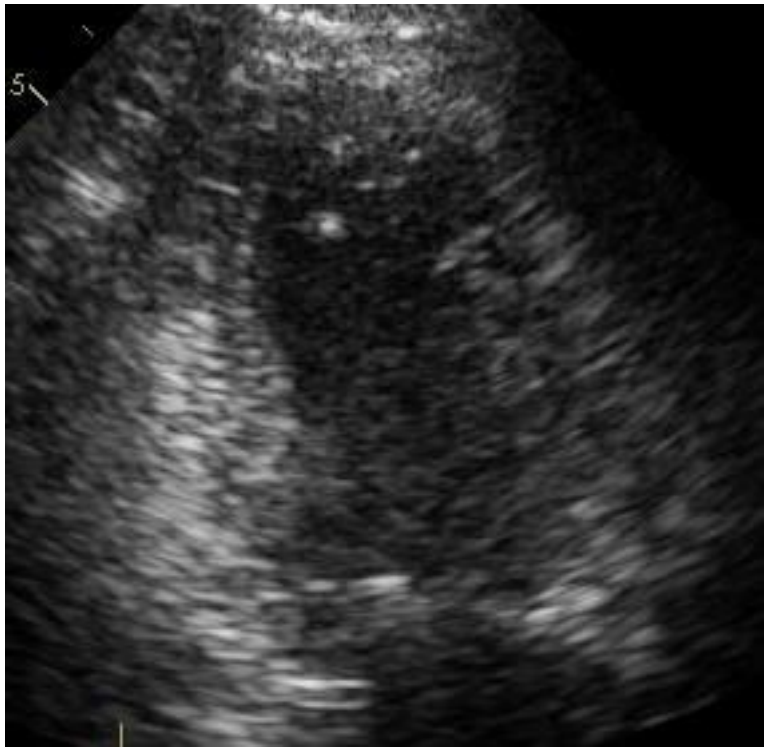


ISCHEMIC territory ≠ Clinical/Prognostic relevance?





Ammonia PET



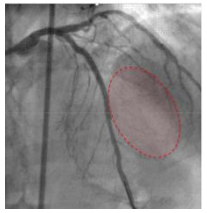
Exercise Echo

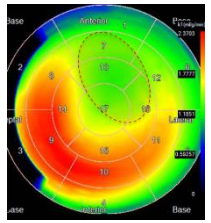
Koo BK. EBC 2022

Microstructure – Function Relationship

A missing piece in "SB puzzle"

Anatomical stenosis → Ischemia → Large territory (clinically relevant ischemia

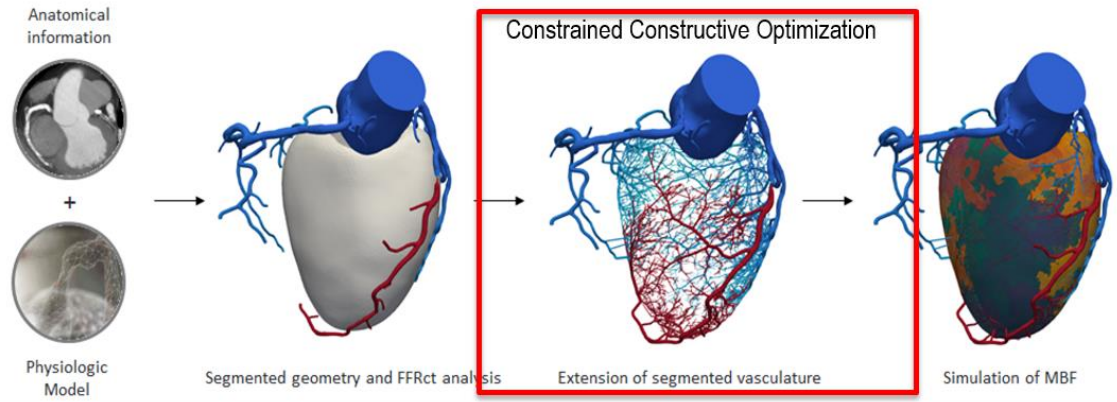




~~Angina~~
~~Arrhythmia~~
~~LV dysfunction~~
~~Cardiac death~~

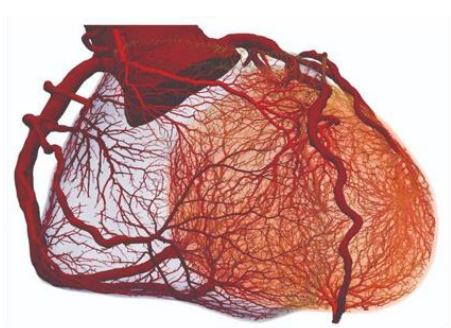
Revascularization

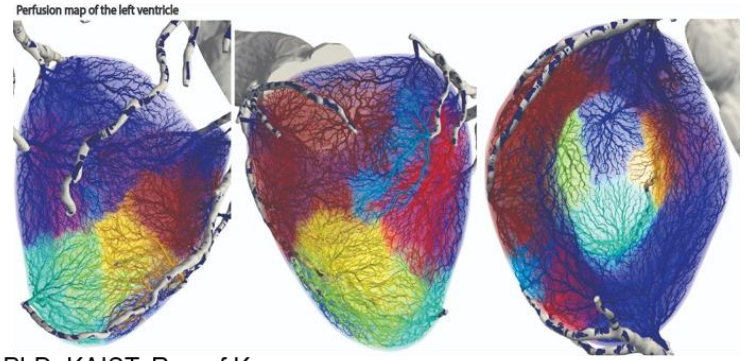
Relief of ischemia
Improve symptom, LV dysfunction
Improve survival



Papamanolis L, et al. Ann Biomed Eng 2021

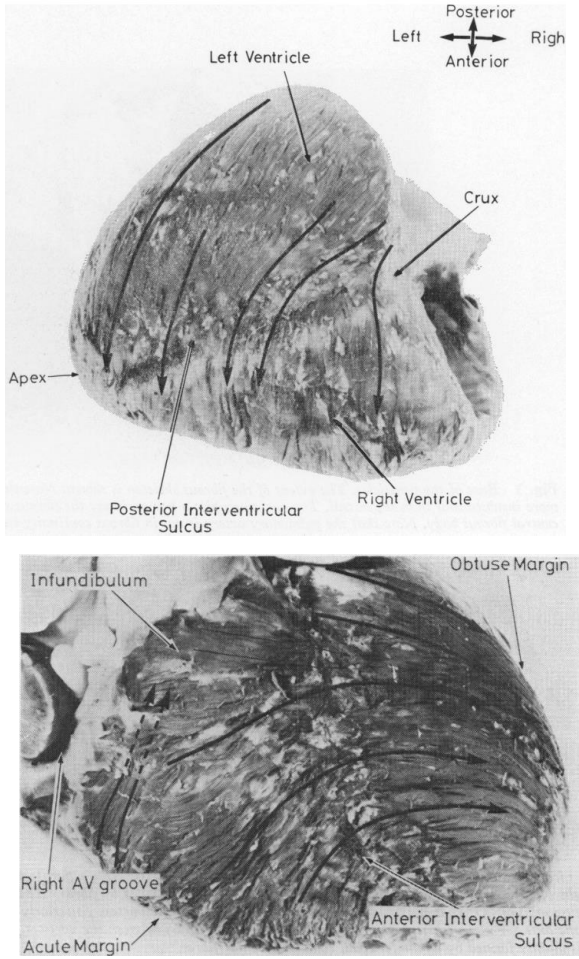
Tissue Growth-based Optimization (GBO)





Courtesy of HJ Kim, PhD, KAIST, Rep of Korea

Microstructure – Function Relationship



Greenbaum R, et al. Heart 1981

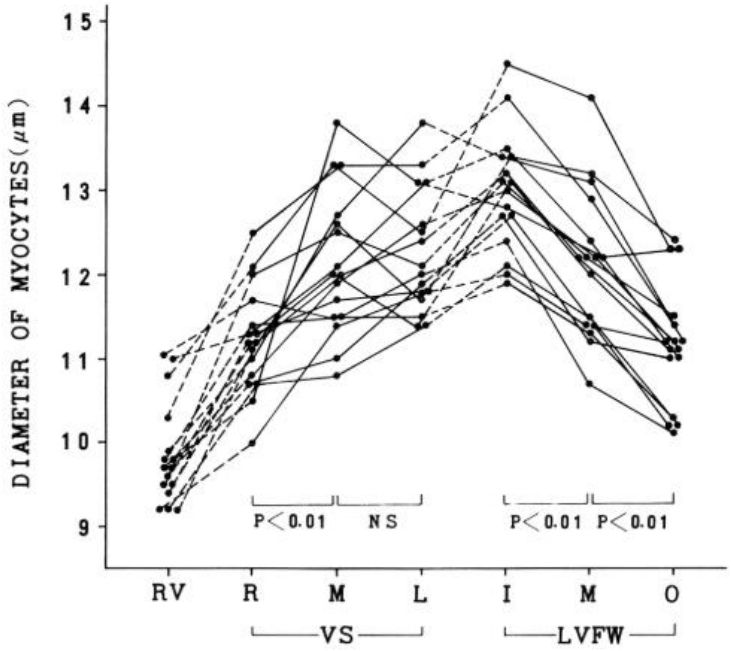


FIGURE 2. *Regional distribution of myocardial fiber diameter in normal adult hearts. The solid and broken lines connect the values for a given case. The diameter decreases from the inner to the outer third of the left ventricular free wall (LVFW), and from the left ventricular to the right ventricular side of the ventricular septum (VS). RV = right ventricle; R = right ventricular side; M = middle third; L = left ventricular side; I = inner third; O = outer third.*

Hoshino T, et al. Circulation 1982

ORIGINAL CONTRIBUTION

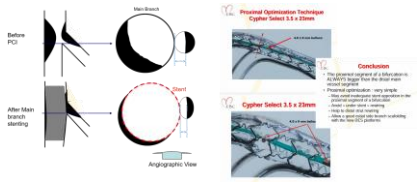
Regional differences of myocardial infarct development and ischemic preconditioning

Schulz, et al. Basic Res Cardiol 2005

Conclusion

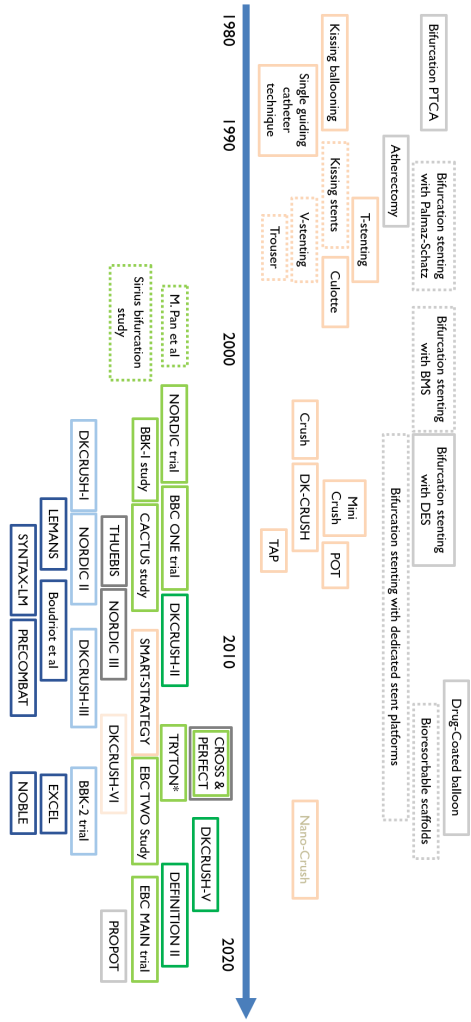
In pigs, **regional differences in infarct development and protection** from it exist in the LAD perfusion territory….., but apparently related to pre-existing structural differences.

Conceptual Evolution



- **Fractal ratio**

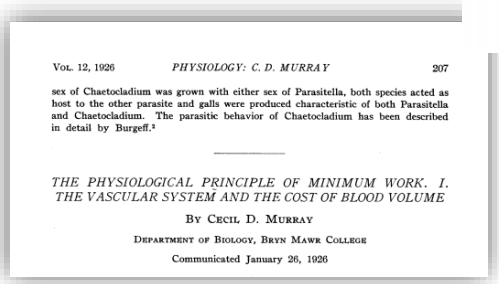
Technical Evolution



Evolution of Bifurcation PCI

At which stage is your psychological evolution staying?

1926 — Fractal ratio — Anatomy-Ischemia — Clinical relevance — Structure-Function — 2024



Vol. 12, 1926 PHYSIOLOGY: C. D. MURRAY 207

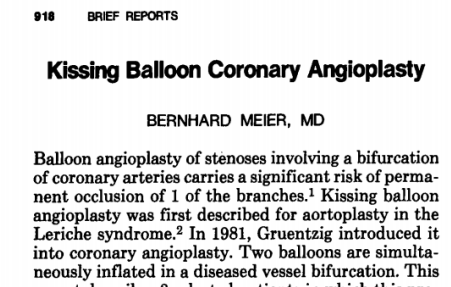
sex of Chaetocladium was grown with either sex of Parasitella, both species acted as host to the other parasite and galls were produced characteristic of both Parasitella and Chaetocladium. The parasitic behavior of Chaetocladium has been described in detail by Burgeff.[3]

THE PHYSIOLOGICAL PRINCIPLE OF MINIMUM WORK. I. THE VASCULAR SYSTEM AND THE COST OF BLOOD VOLUME

By Cecil D. Murray

Department of Biology, Bryn Mawr College

Communicated January 26, 1926

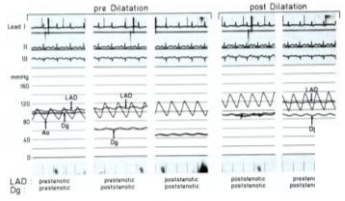


918 BRIEF REPORTS

Kissing Balloon Coronary Angioplasty

BERNHARD MEIER, MD

Balloon angioplasty of stenoses involving a bifurcation of coronary arteries carries a significant risk of permanent occlusion of 1 of the branches.[1] Kissing balloon angioplasty was first described for aortoplasty in the Leriche syndrome.[2] In 1981, Gruentzig introduced it into coronary angioplasty. Two balloons are simultaneously inflated in a diseased vessel bifurcation. This



Risk of Side Branch Occlusion During Coronary Angioplasty

BERNHARD MEIER, MD, ANDREAS R. GRUENTZIG, MD, SPENCER B. KING III, MD, JOHN S. DOUGLAS, Jr., MD, JAY HOLLMAN, MD, THOMAS ISCHINGER, MD, FRED AUERON, MD, and KATHY GALAN, RN

(Am J Cardiol 1984;53:10–14)

intimately involved in the lesion to be dilated (high-risk side branches) are at a relevant risk for iatrogenic occlusion. Occlusion of side branches not involved in the stenosis (low-risk side branches) just by contact with the dilating balloon is rare. Significant consequences of side branch occlusions are unlikely if selection of patients is guided by the relevance of the side branches at risk.

References

1. **Gruentzig AR, Senning A, Siegenthaler WE.** Nonoperative dilatation of coronary-artery stenosis. N Engl J Med 1979;301:61–68.
2. **Dorros G, Cowley MJ, Simpson J, Bentivoglio LG, Block PC, Bourassa M,**

Basic Structure–Function Relations of the Epicardial Coronary Vascular Tree

Basis of Quantitative Coronary Arteriography for Diffuse Coronary Artery Disease

Christian Seiler, MD; Richard L. Kirkeeide, PhD; and K. Lance Gould, MD