Noninvasive cardiac imaging by CT & MR
Change of Diagnostic Workflow

Berlin

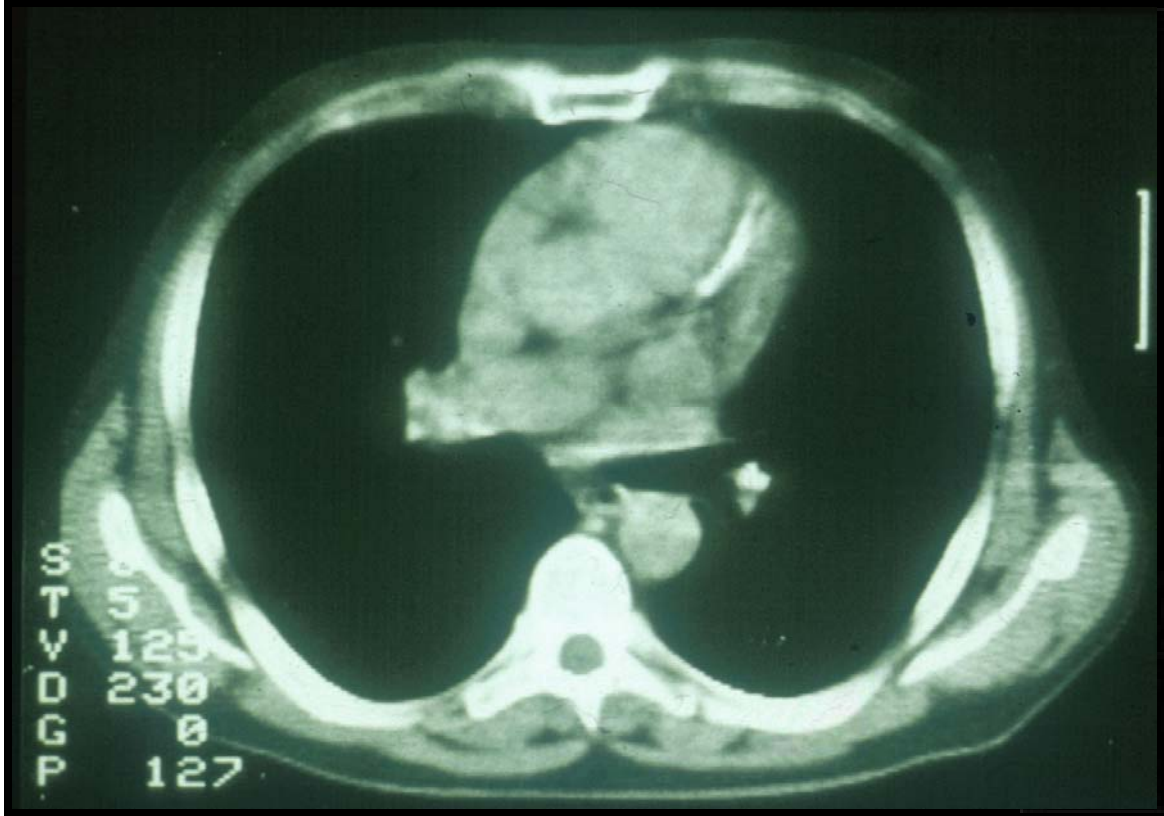
Clinical Examples

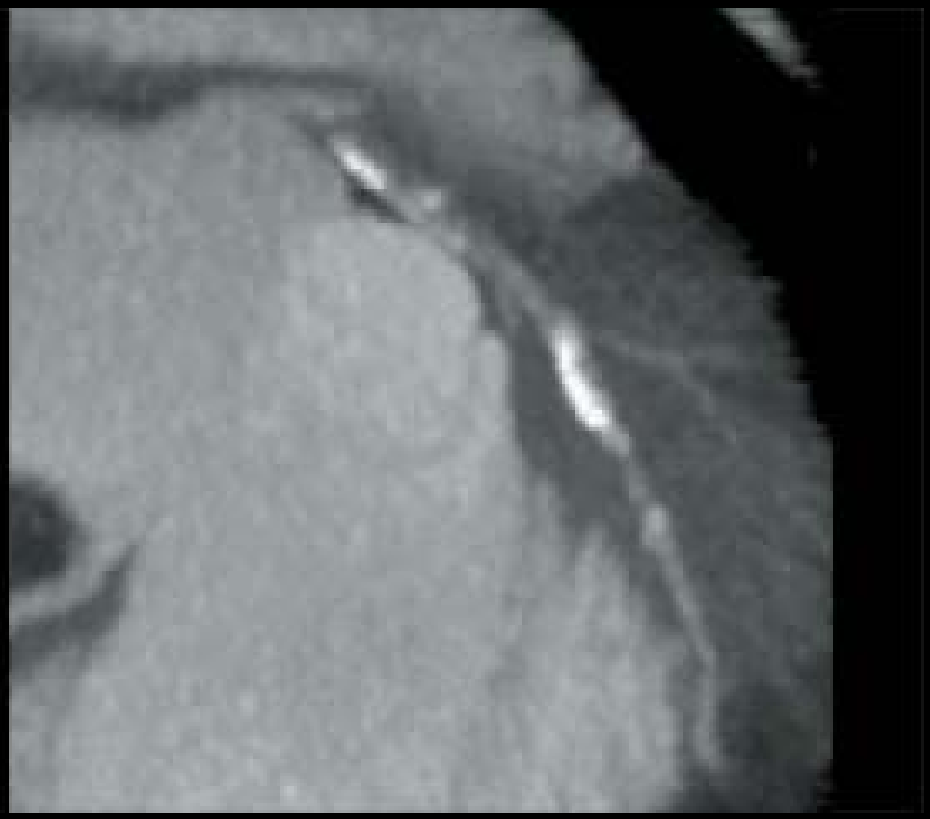
Which Questions may be answered

Advantages for Patient / Referral

Place in Diagnostic Algorithm

CT in the Clinical Diagnostic of Cardiac Disease





R. Rienmüller (1983) Thesis

EBT 2001

„CTCA is a valuable clinical tool, that has the potential to improve the investigation of cardiac patients.

CTCA will undoubtedly become both more prevalent and more useful as access and technology improves.“

A. Baumbach, M.CK.Hamilton: ESC, E-Journal – Vol 5. N 20, Feb. 2007

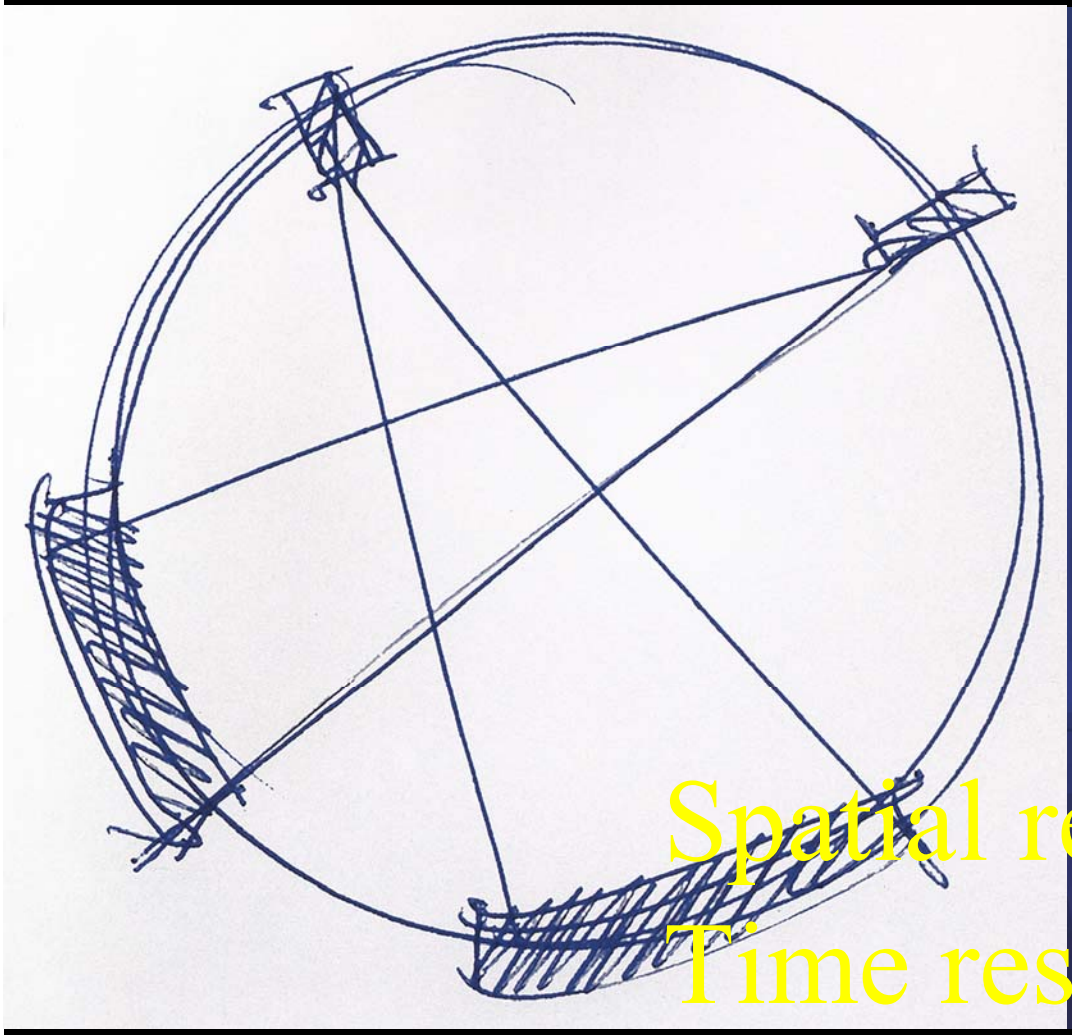
Spatial resolution 1.5 mm

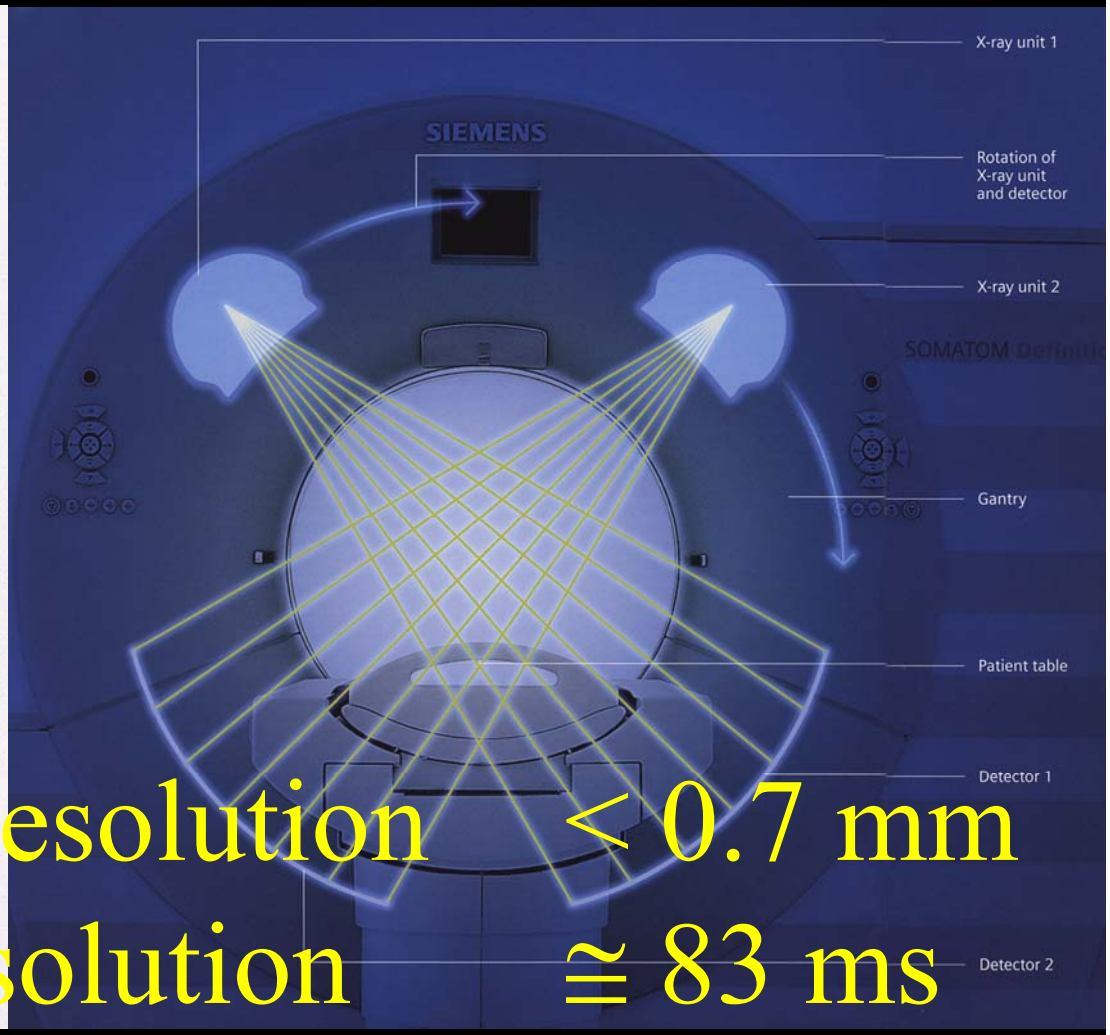
Time resolution < 50 ms

Spatial resolution < 0.7 mm

Time resolution $\cong 165$ ms

Dual Source CT





Spatial resolution < 0.7 mm

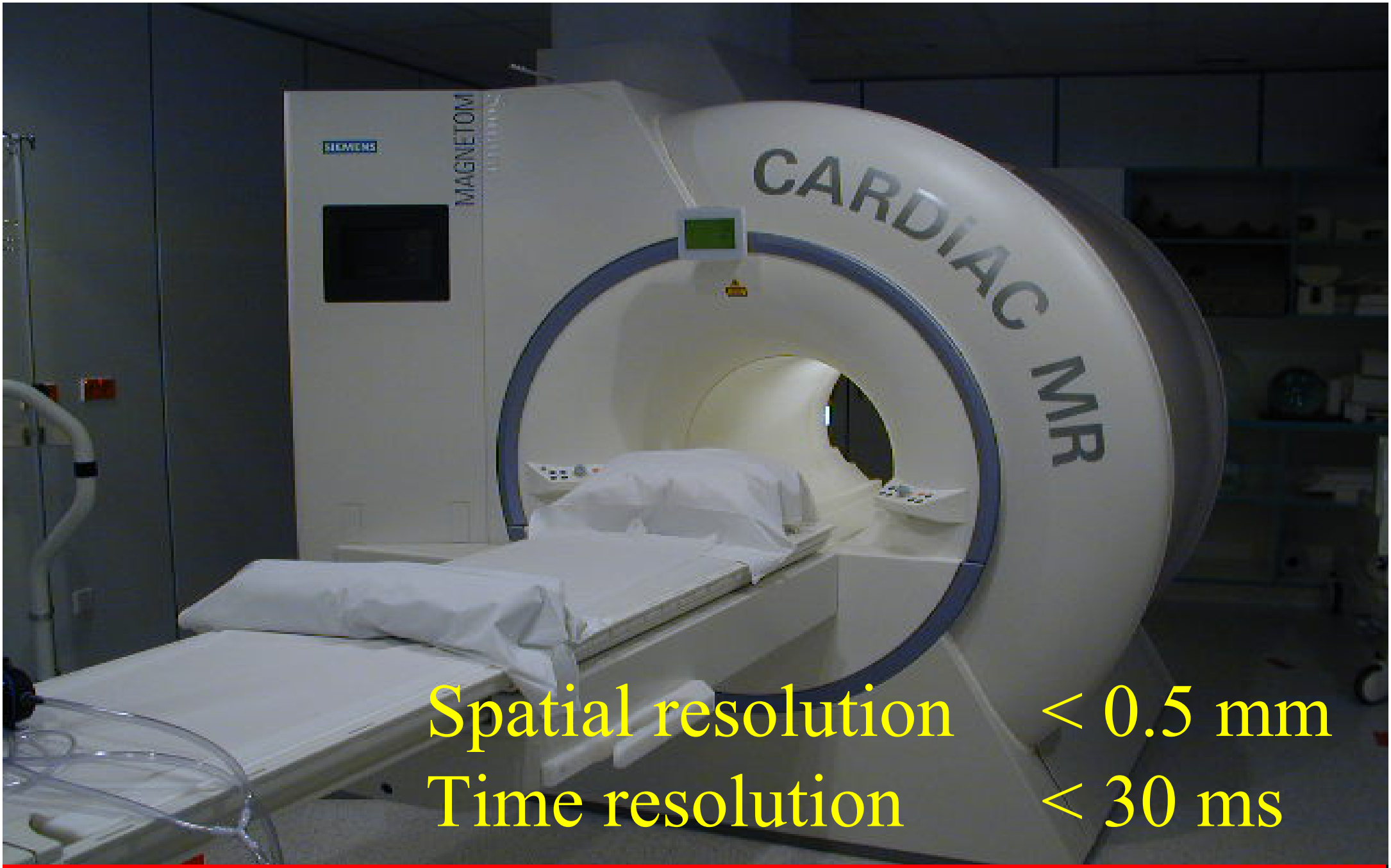
Time resolution $\cong 83$ ms

www.siemens.com/medical

CT– Technologien

Modalität	Scanzeit	Bemerkungen
Single Slice	ca 1000 ms	Schichtdicke ca 1mm
Spiral	ca 500-700 ms	
Multislice, Multidetector	ca 330-500 ms	Isotrope Bild Voxel
(16, 32, 64 - 256)	(165 ms)	
Dual Source	165 ms	Isotrope Bild Voxel
	(84 ms)	
EBT (UFCT)	50-100 ms	Schichtdicke 1,5 mm
(1. Multislice & Multidetector System)		

Benötigt wird eine Scanzeit von ca 20 ms, ca 10 Mal während einer Herzaktion für die Dauer von ca 40 Herzaktionen als Volumenscan



Spatial resolution < 0.5 mm

Time resolution < 30 ms

34 y male with Known Coarctation of the Aorta

Present History: disorder of sleep with dyspnoe and episodes of choking, peripheral edema, acute cardiac decompensation

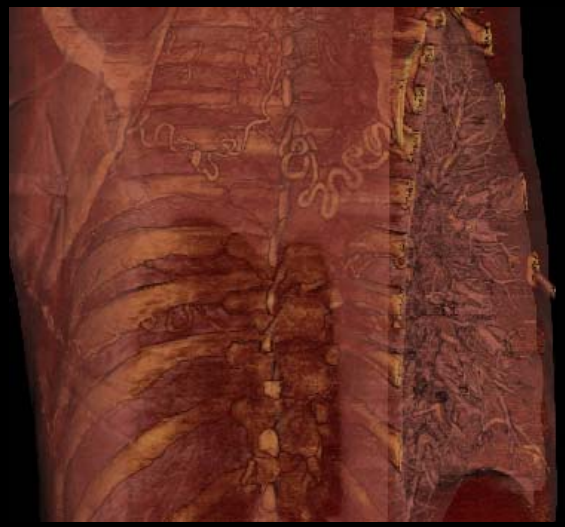
Risk factors: Hypertension (RR:r 150/60 mm Hg, RR:l 135/60 mm HG), Bicuspid valve, Aortic insufficiency, Nicotin,

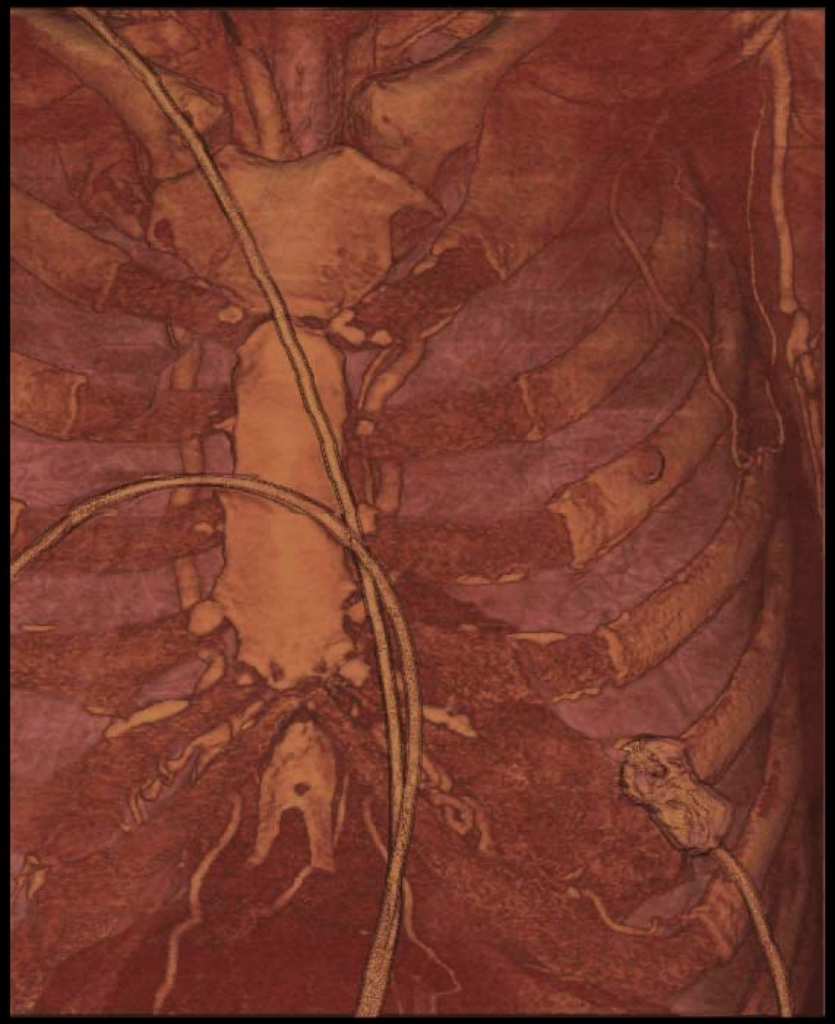
Medication: Seloken ret. plus, Lasix 20 mg

Diagnostic evaluation: Catheterisation, CTA, MR

34 y male with
Coarctation
of the Aorta

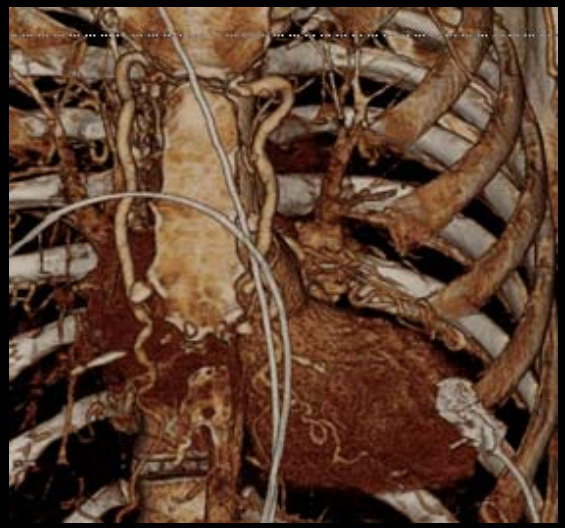
MSCT 64

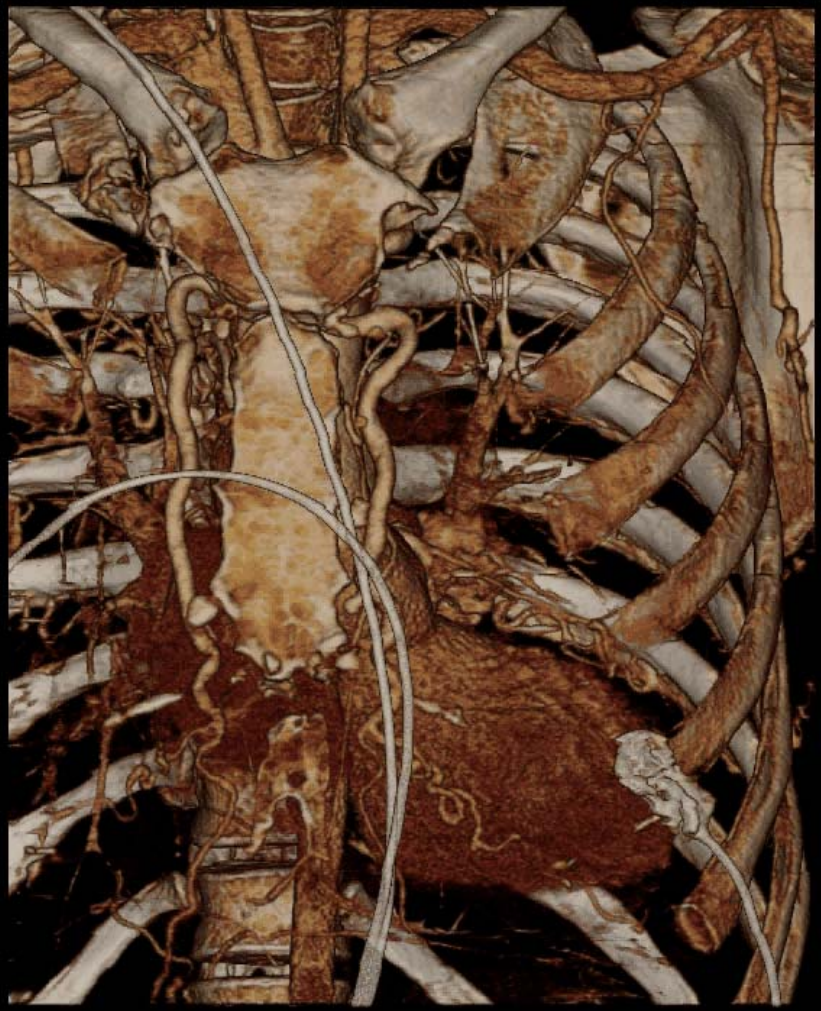




34 y male with Coarctation of the Aorta

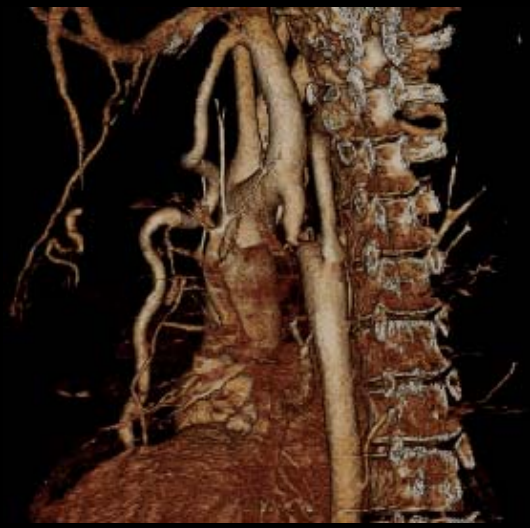
MSCT 64

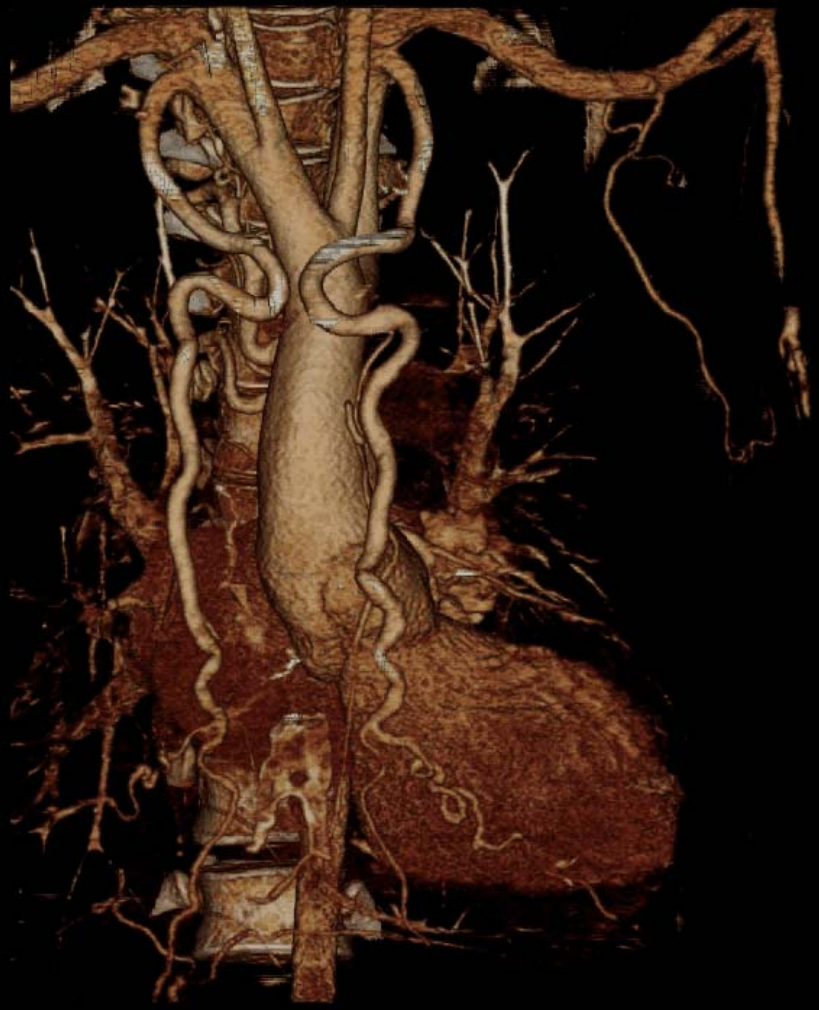




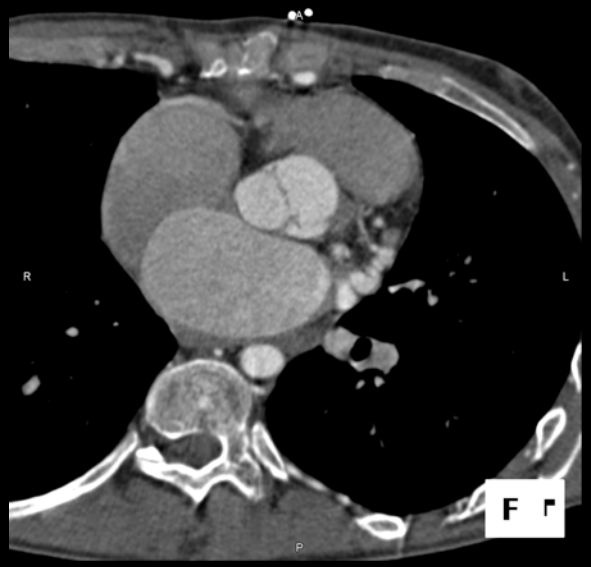
34 y male with Coarctation of the Aorta

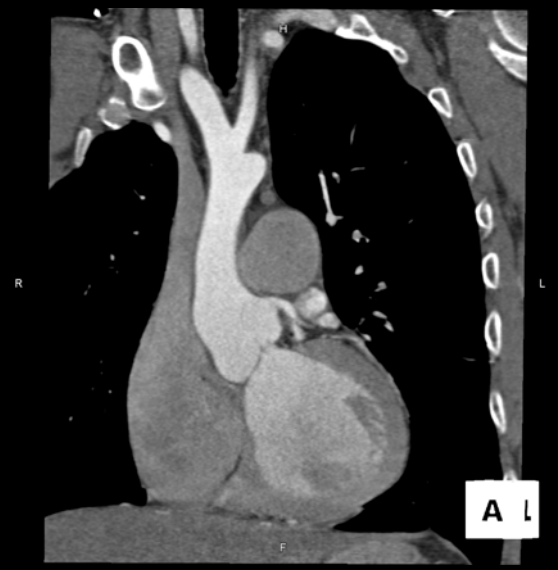
MSCT 64

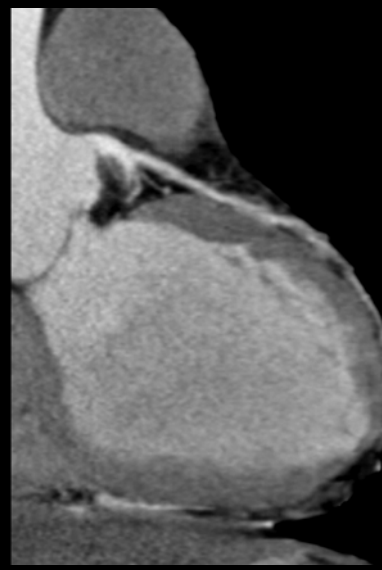


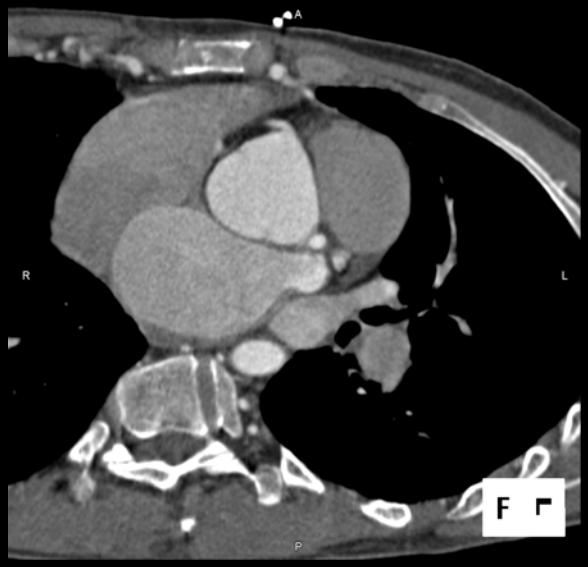


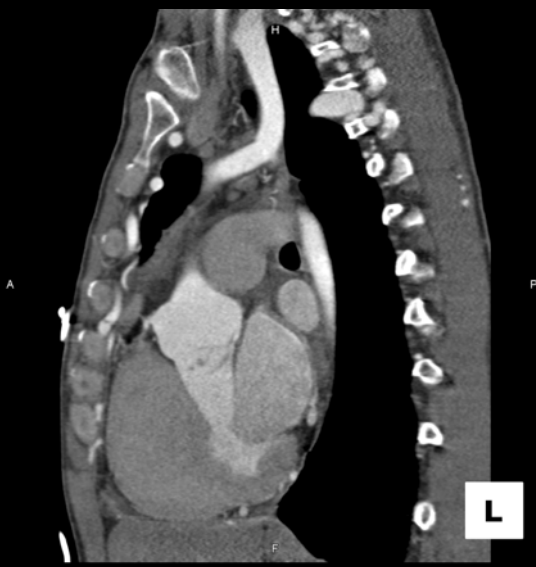
W.S., ♂, 37 YO

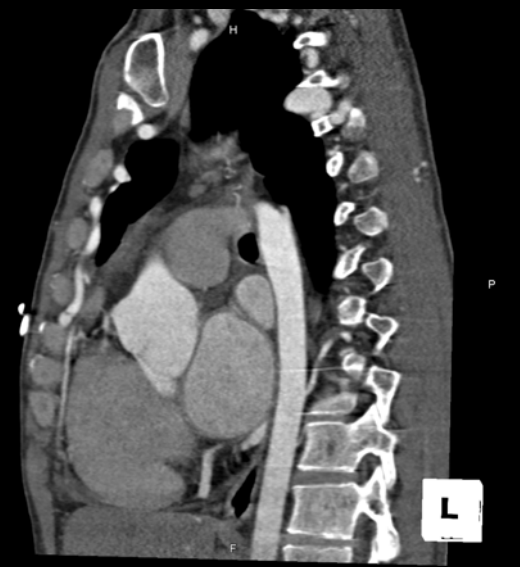












34 y male with Known Coarctation of the Aorta

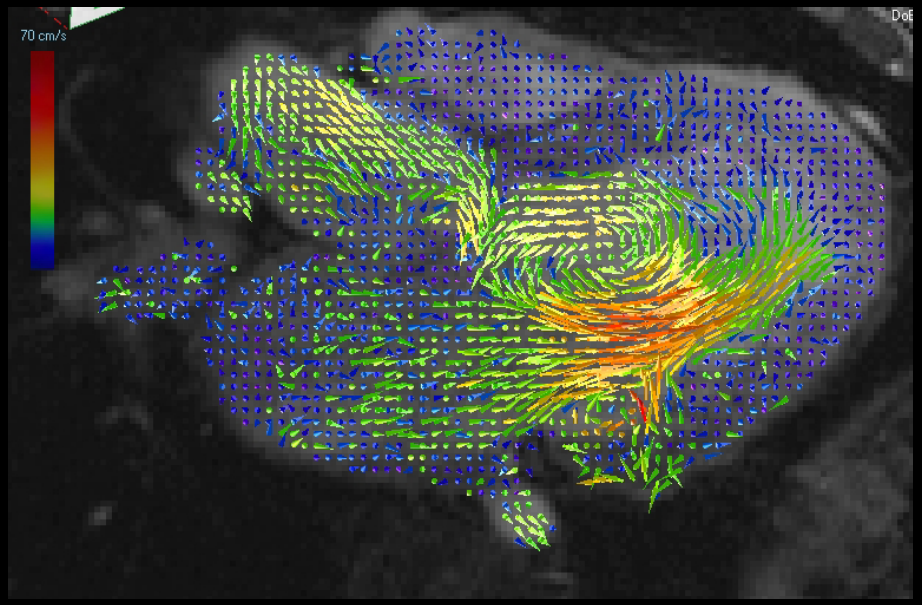
Findings

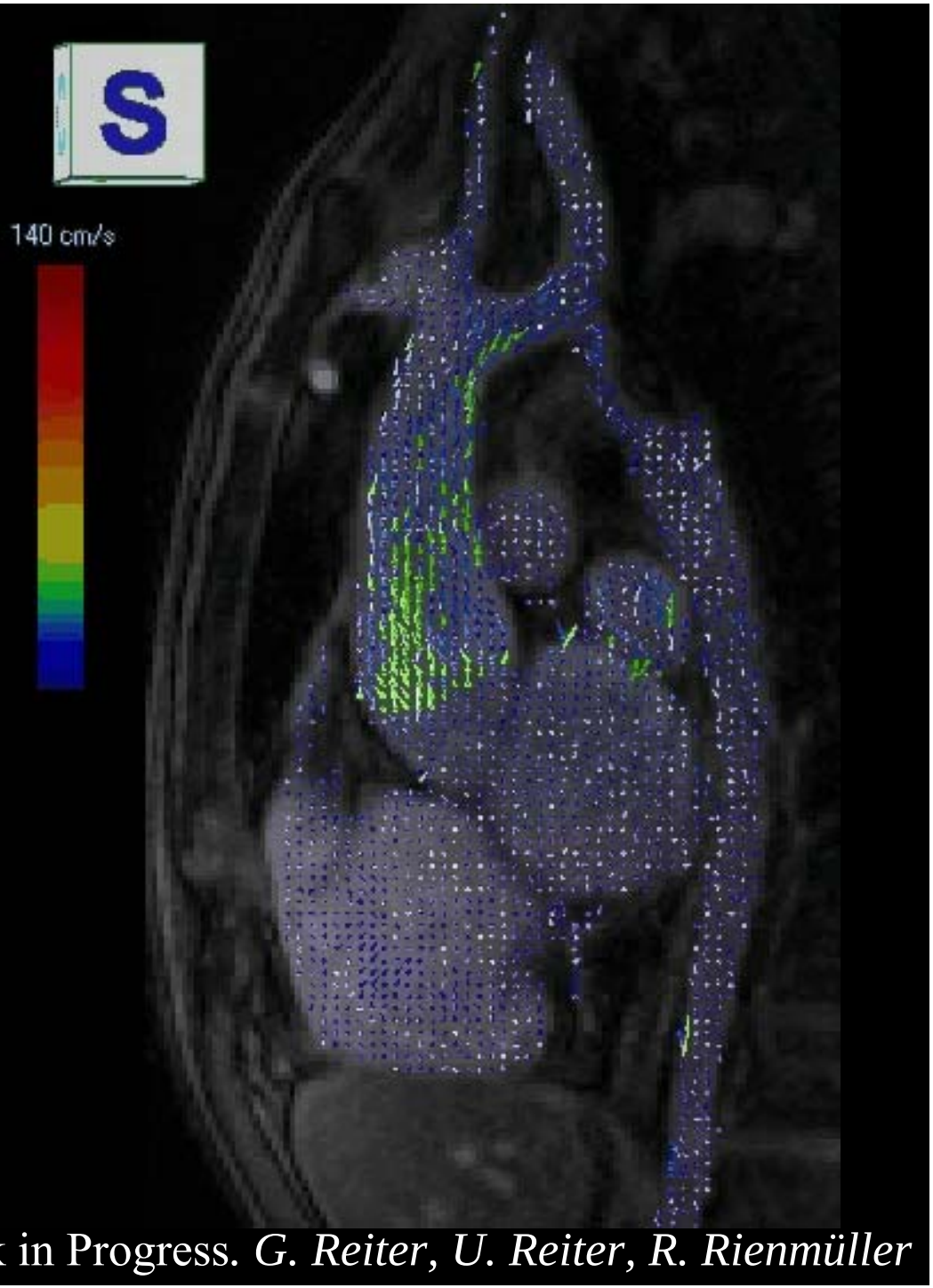
MSCT 64: Bicuspid valve, Dilatation of ascending aorta and of the anomalous supraaortic vessels, Severe (afew mm) stenosis, Bypassing circulation by dilated internal thoracic arteries, by dilated intercostal arteries (III), by dilated lateral thoracic arteries, by dilated rete scapulare
Normal origin of LCA and RCA,thin LAD, CX and RCA

EBT: (Borderline) myocardial perfusion of 63 ml/100g/min at HR of 78 min^{-1}, RR 180/80 mm HG

34 y male with Coarctation of the Aorta

Cardiac MR





Work in Progress. *G. Reiter, U. Reiter, R. Rienmüller*

34 y male with Known Coarctation of the Aorta

MR:	EDV – 232 ml,	ESV – 138 ml,	SV – 93 ml,
	EF – 40,3%,	LVMM – 176 g	
	Asc. Aorta:	Forward-Flow	80 ml
		Reverse-Flow	35 ml
		Net Forward-Flow	45 ml
	Poststenotic Desc. Aorta		0,078 ml
	r. Intercostal artery		5 ml
	l. Intercostal artery		8 ml
	Desc. Aorta prox.		15 ml
	Desc. Aorta dist.		14 ml

Suggested therapy:

short term: interventional treatment of the stenosis

long term: aortic valve and ascending aorta surgery

Coronary Heart Disease

„... is the Manifestation of Atherosclerosis in the Coronary Arteries. As the Disease is a Multifactorial Process Leading to Myocardial Ischemia, it may Appear as Angina Pectoris, Myocardial Infarction, Cardiac Dysrhythmia, Sudden Death or Cardiac Insufficiency. The Course of the Disease may be Silent."

J. Meyer. Klinische Kardiologie, Edd. *E. Erdmann, G. Riecker*. Springer Verlag 1996

Clinical Question

1) Does the patient have coronary atherosclerosis?
   (Stage, Localization, Kind of sclerosis, Degree of stenosis)
2) Does the patient have myocardial ischemia?
3) How big is the individual myocardial perfusion (ml/100g/min)?
4) Which mechanism may prevent or reduce myocardial ischemia?
5) Does the patient have myocardial infarction?
6) Which parts of the myocardium are viable?
7) How big is the individual coronary reserve?

74 y anxious female with CAD and Hypertension

Present History:

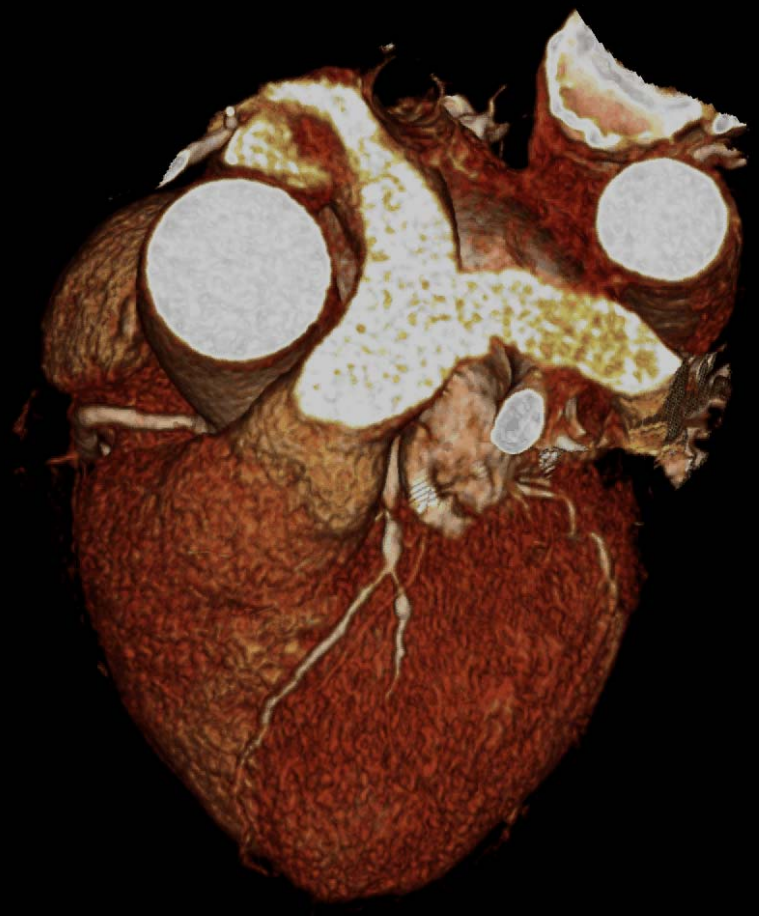
Angina at night for two years

Past History:

3 y ago: suspected MI and stroke,
Non-conclusive CA

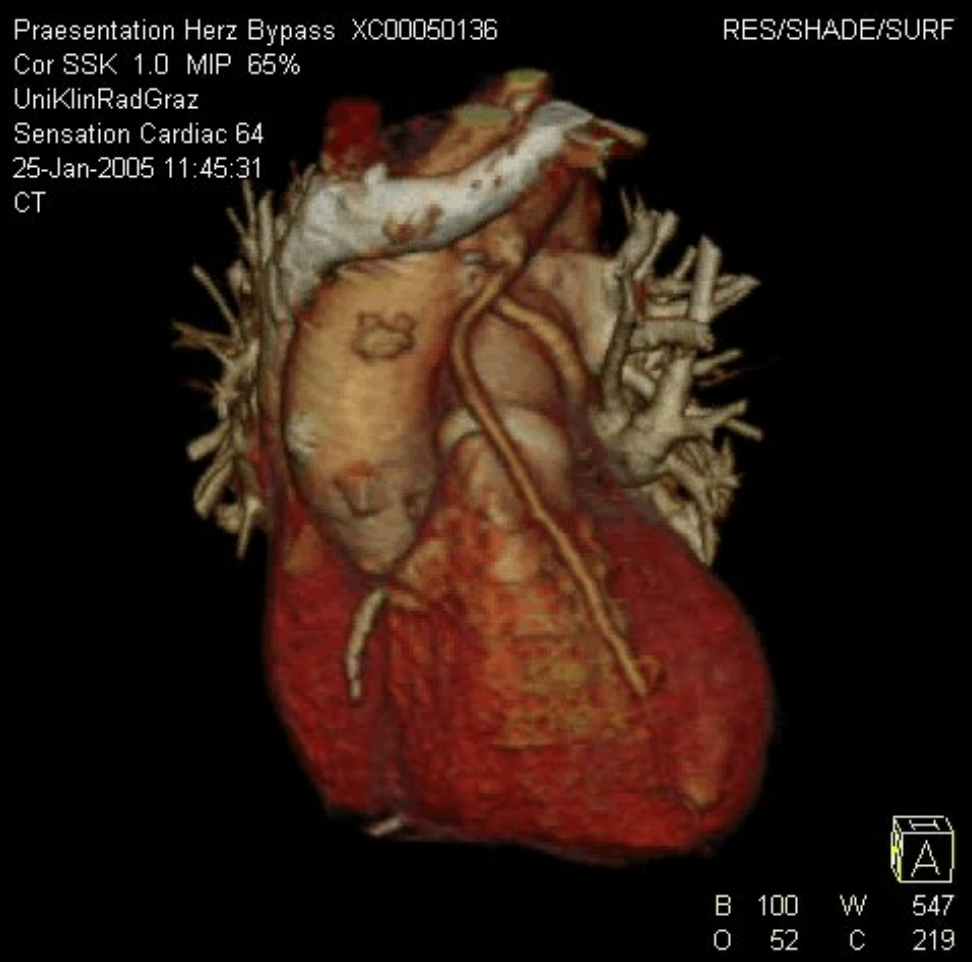
Medication: TASS 100 mg, Plavix,
Nomexor, Iterium, Dancor, Temesta,
Plendil ret., Tebonin ret.

Hospitalisation: July 6-11, 2005
Coronary Angiography rejected
Ergo- and Tl-Scint. not done
CT-Angiography recommended
Blood pressure allways in „lower normal range“



Traditional approach in patients with suspected CHD

- Patients history
- Physical findings
- Chest X-ray
- ECG
- Echocardiography
- Cardiac Scintigraphy
- Labor parameters
- Coronary angiography



Traditional approach in patients with suspected CHD

Chest X-ray
ECG
Echo
SPECT
Labor parameters

} Indirect methods, No visualization of coronary arteries and No measuring of myocardial perfusion in (ml/100g/min)

Coronary angiography ≃ Luminography No visualization of coronary walls and myocardial perfusion

No relationship between extend of luminal stenosis and myocardial perfusion

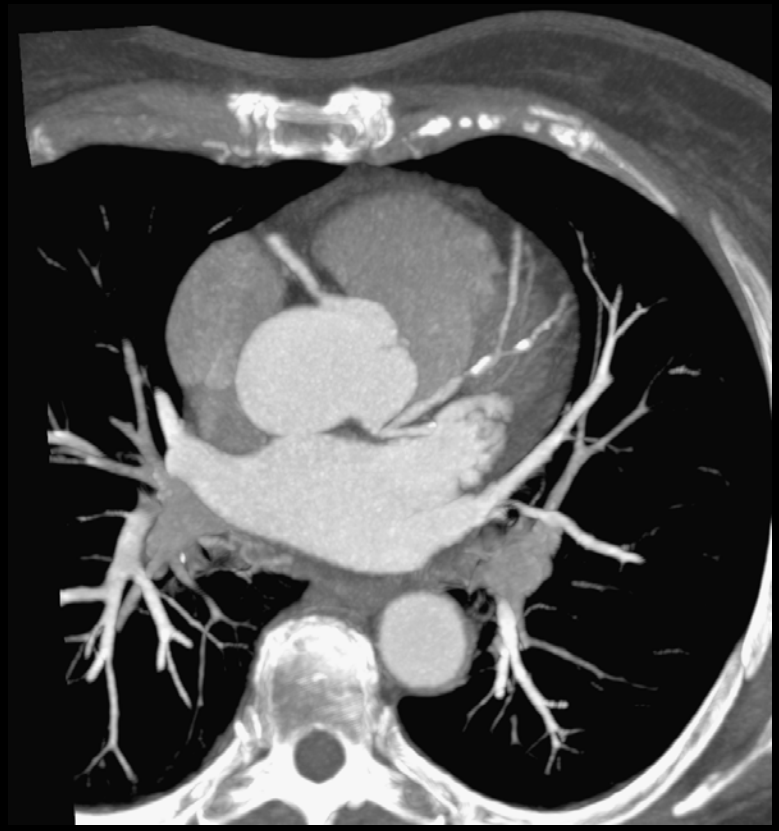
„Angiographic Evidence of The Severity of Coronary Stenosis is not Correlated with Physiological and Clinical Effects.

„There is no Apparent Relation between the Severity of Coronary Lesions and their Propensity to Cause Future Cardiac Events. Most Lesions Resulting in Cardiac Events are not Severely Stenotic.“

As cited by *G. Levine et al.* N Engl J Med, 1995; 332:512-521

74 y anxious female with CAD and Hypertension

EDV	100	[105 ± 10] ml
ESV	29	[30 ± 5] ml
EF	71	[>70] %
CO	3,6	[5 ± 0.5] l/min
LVMM	70	g
HR	54	min-1
RR	120/75	mm Hg
Ca^{++} Score	67	[0]



Myocardial Perfusion global = 54 [75 ± 10] ml/100g/min

ant.wall = 49 [75 ± 10] ml/100g/min

Perf/HR = 1.00 [1 ± 0.3]

Perf/RPP = 0.0083 [0.009]

LAD > 90 % → 3,5 cm

> 50 % → 5-7 cm

Diagonal > 50 % → 0,5 cm

74 y anxious female with CAD and Hypertension

Procedure after CTA:

→ Referring physian informed by phone + letter

→ Patient referred to EBA (Emergency)

→ Patient came to Radiology

→ Patient referred to Dep. of Cardiology

→ ECG – Stress test negative

→ Patient send home

→ Patient continues to complain

→ Cardiology LKH-West

→ Coronary angiography – CTA-Diagnosis confirmed and by Drug eluting Stents dilatation performed, and antihypertensive therapy adapted to present Hypotension

W.S., m 63y

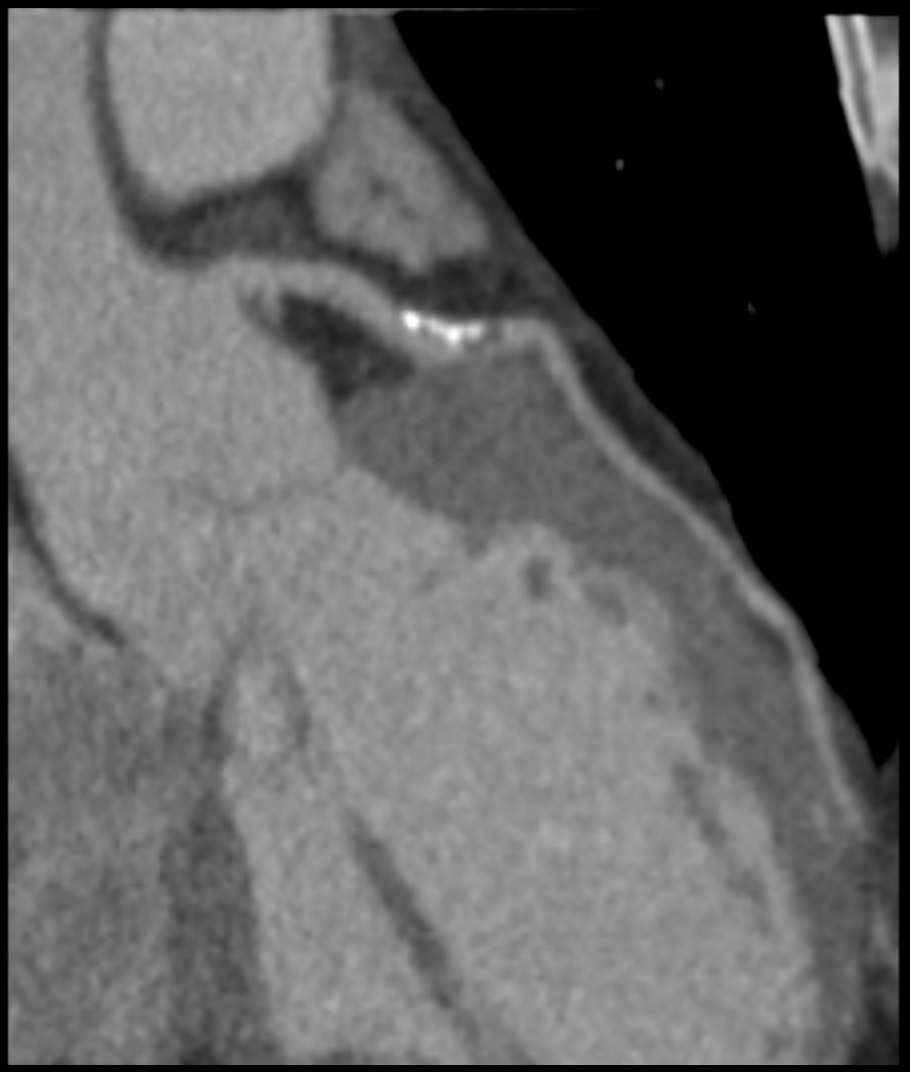
Symptoms: Chest pain

Findings: LAD – hard & softplaques,
Stenosis > 50%
RCA – hypoplastic

Ca Score: 110

Perfusion: globally reduced
to 41ml/100g/min
at HR of 52 /min,
RR of 119/76 mmHg

Morphology
& Function: EDV – 162 ml,
LVMM – 169, EF – 65%



Calcium Scoring

"Increased Calcium Score adds to the risk profile and can trigger preventive treatment"

De Bacher G, et all: Eur Heart J. 24 (17): 1601-10; 2003

"The routine assessment of the Coronary Calcium Score is still under debate"

Hamilton MCK, et all: BMJ 2003; 326: 1045-1046

Clinical Question

- What is the smallest soft and calcified plaque to be identified by CT?

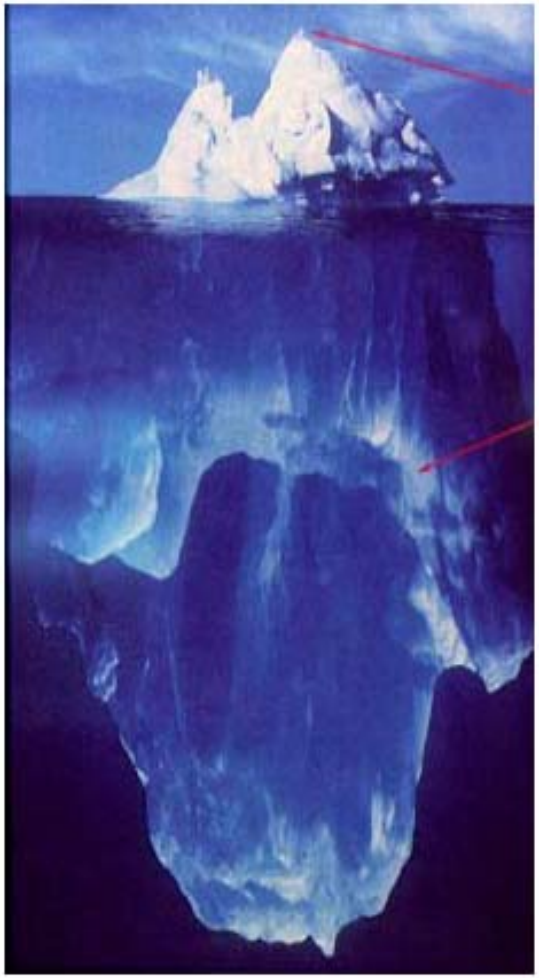
- How does Ca^{++} score correlate

  with soft plaque?

  with stenotic lesions?

  with age?

Coronary calcium and plaque burden



20%

Calcified

80%

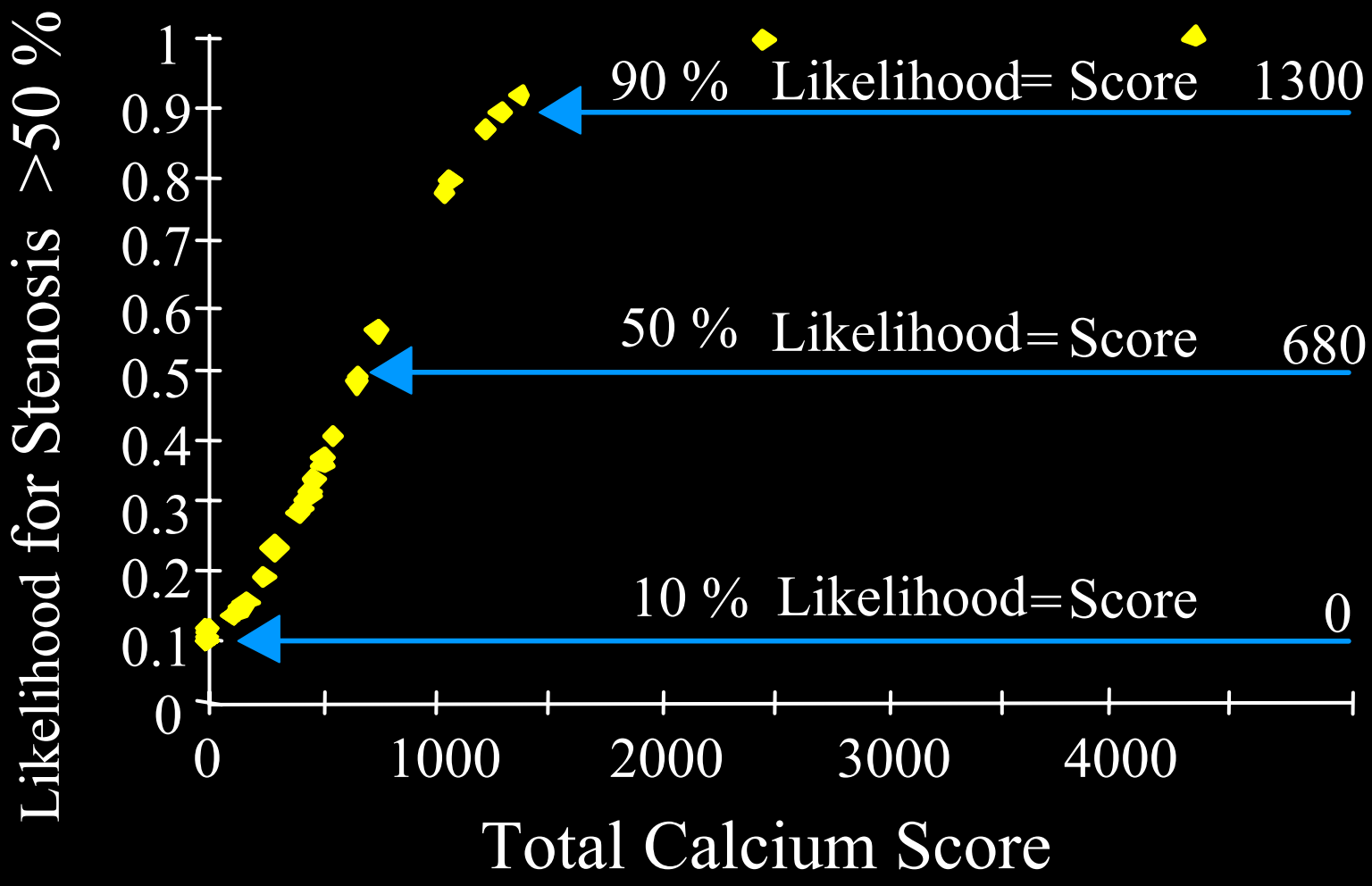
Fibrotic

Lipid Rich

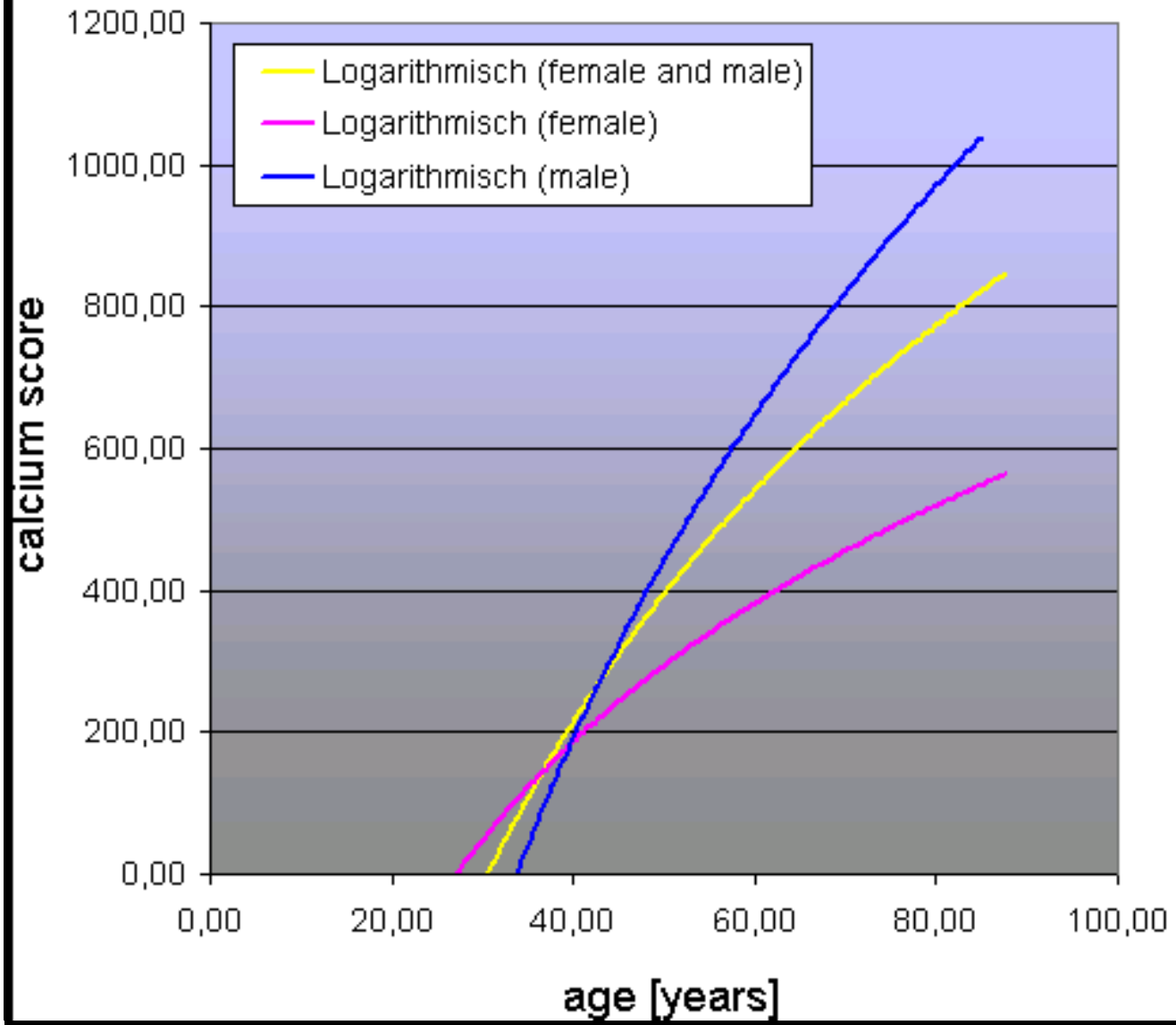
Plaque Detectable by IVUS, Pathology

Courtesy of R.Vliegenthart PhD
Lecture at ESCR Meeting Berlin 2004

Logistic Regression Analysis in Patients with Suspected Coronary Heart Disease



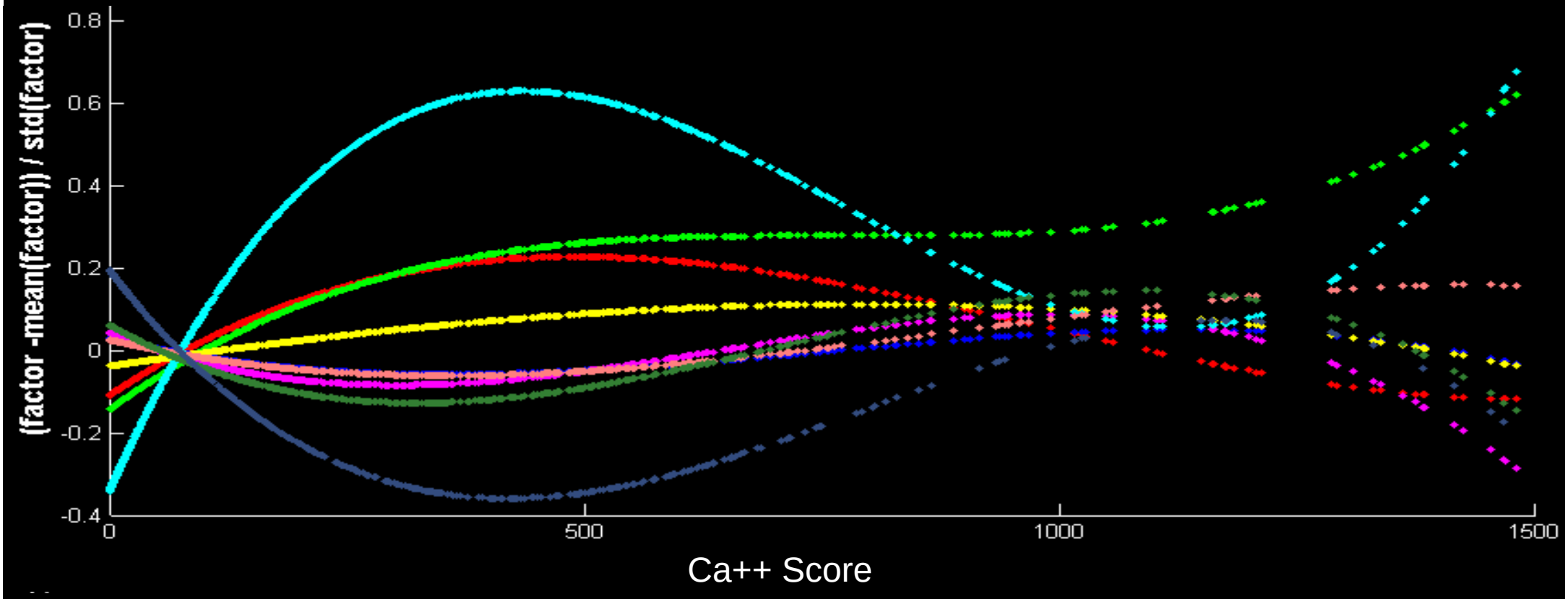
Calcium Score vs Age



f and m	female	male
n = 1541	n = 549	n = 991
r = 0,2039	r = 0,164	r = 0,25
p = 0,0001	p = 0,0001	p = 0,0001
score	**score**	**score**
mean = 529	mean = 393	mean = 604
sd = 1031	sd = 840	sd = 1116
min = 0	min = 0	min = 0
max = 7854	max = 7310	max = 7853
age	**age**	**age**
mean = 61	mean = 63	mean = 59
sd = 13	sd = 13	sd = 12
min = 16	min = 18	min = 16
max = 88	max = 88	max = 85

95% ci for r = 0,1555 to 0,2513 (f and m)
95% ci for r = 0,0822 to 0,2451 (female)
95% ci for r = 0,1939 to 0,3105 (male)

Co-factors of Ca^{++} Score



	Age	lvmm	Syst.	RPP	CO	SV	HR	Perfusion	Aortic Compliance
n	1472	1410	1462	1459	1308	1311	1474	1412	805
r	0.25	0.15	0.08	0,04	0,02	0	-0,01	-0,02	-0,13
r^2	0.14	0.03	0.02	0	0	0	0	0	0.04
p	0	0	0	0.12	0.02	0.94	0.6	0.44	0

M.S., m 73y

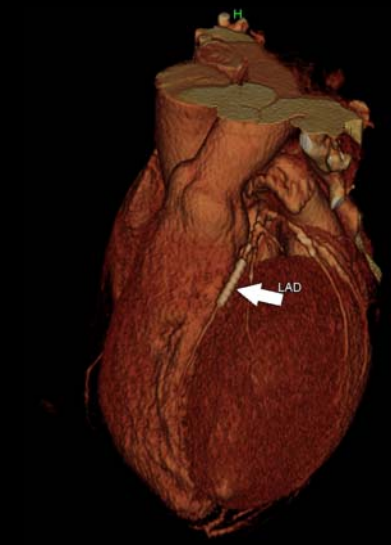
Symptoms: post Stent, occlusion?

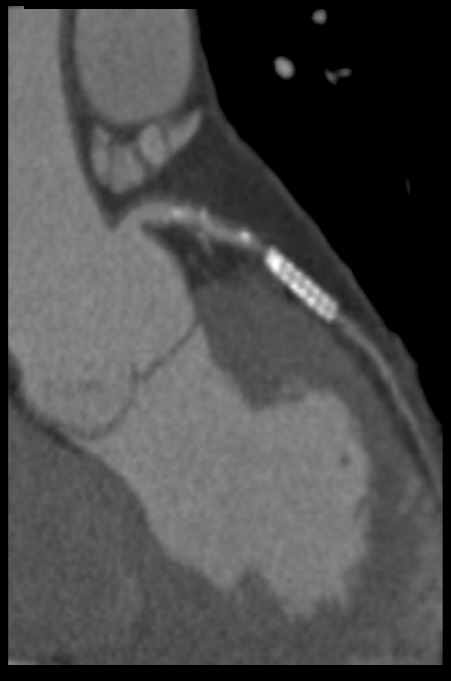
Findings: LAD – hard & softplaques,
with stenosis > 50% before
open stent,
R.intermedius – multipl.stenosis > 50%

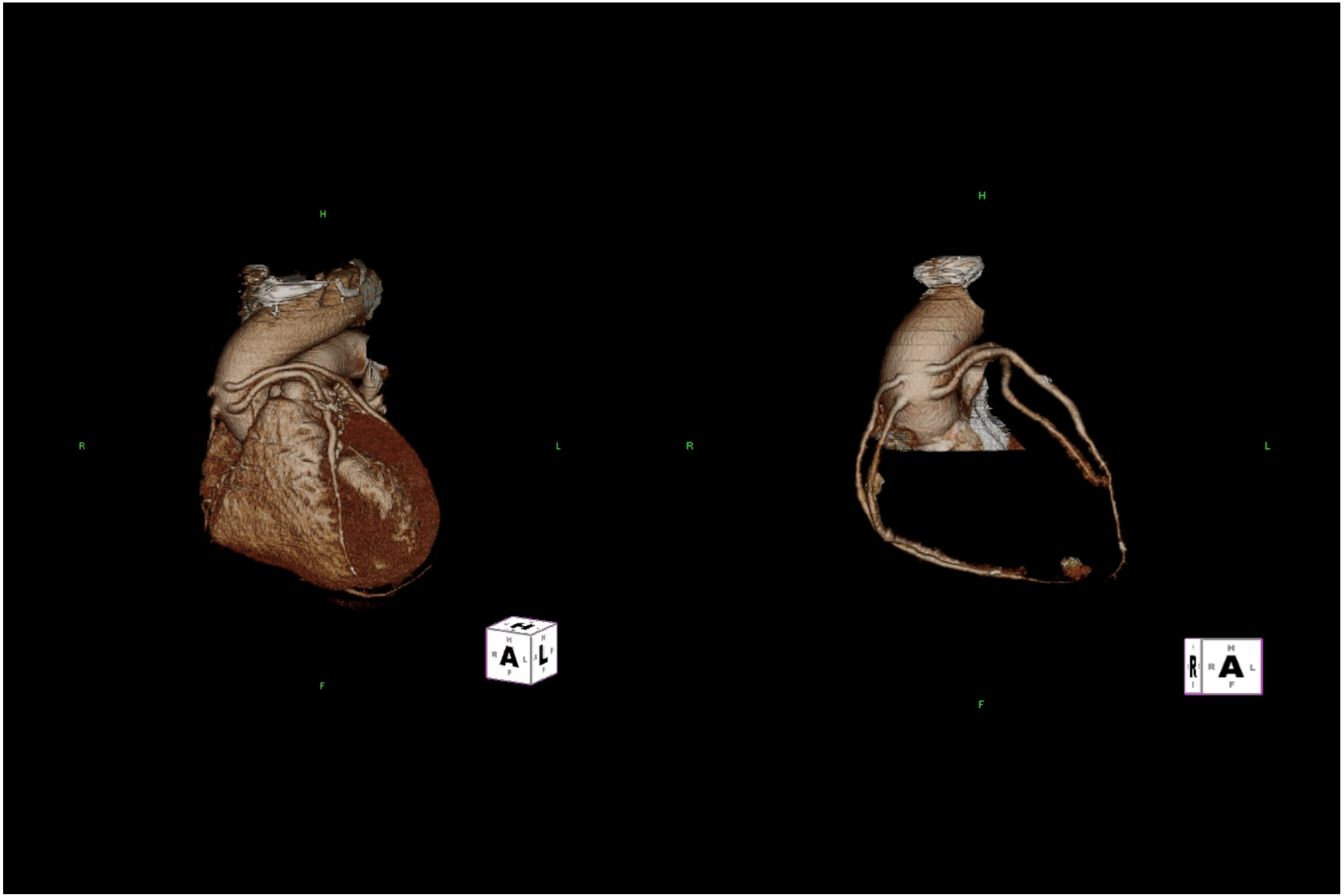
Ca Score: 673

Perfusion: globally reduced – 47 ml/100g/min
at HR of 49 /min,
RR of 164/95 mmHg

Morphology
& Function: EDV – 120 ml, LVMM – 98 g,
EF – 66%



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CT – Coronary Angiography (CTCA)

CTCA	tends to overestimate coronary stenosis compared to invasive coronary angiography pos. pred. value – ca.80% neg. pred. value – ca.95% *Achenbach et al. Eur J Radiol 2006*
CT Bypass	Sensitivity for occlusion up to 100% Sensitivity and specificity for stenosis ca. 95/ 89% (Cave Metal clip) *Pache et al. EHJ 2006*
CT Stent	Specificity and sensitivity ca. 98/ 83% (Cave geometry ∅ should be above 2 mm, right reconstruction Kernel) *Cademartiri et al. AJC 2005*

Diagnostic Accuracy of EBT / MSCT vs. Angiography for Stenotic Lesions > 50%

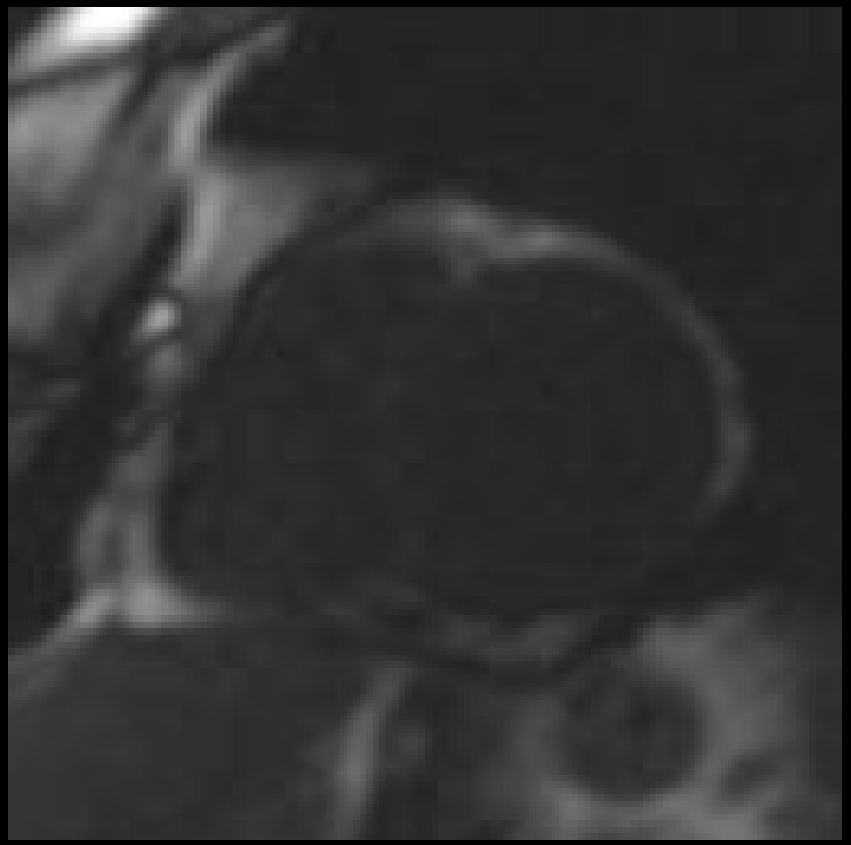
	n = 222 patients, 2220 segments, disease prevalence 45%	n = 20 patients, 200 segments, disease prevalence 10%
	All segments	All segments
Sensitivity (%)	67	73
Specificity (%)	74	96
PPV (%)	23	73
NPV (%)	92	96

Standard MR Protocol: Suspected CHD

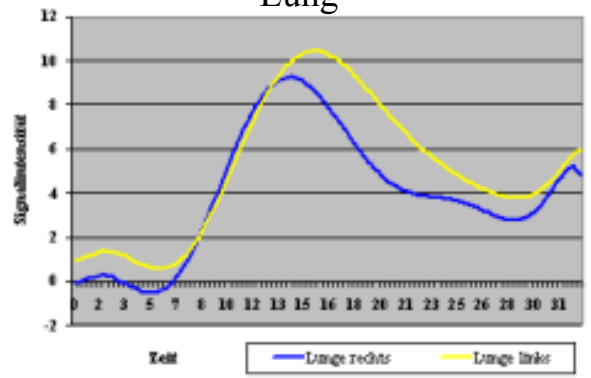
1. Planning and Overview
2. Function
3. Morphology
4. Coronary Arteries
5. Perfusion

   TrueFISP breathhold

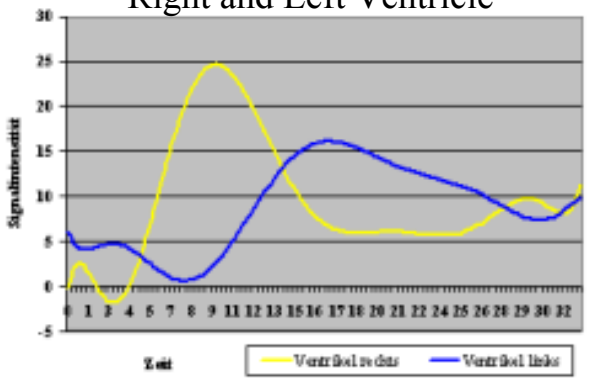
6. Cine Short Axes
7. Aortic Flow
8. Late Enhancement



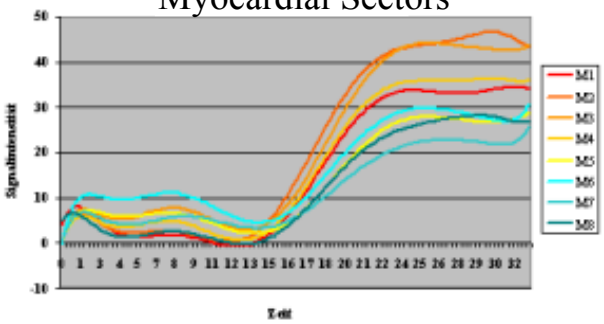
Lung

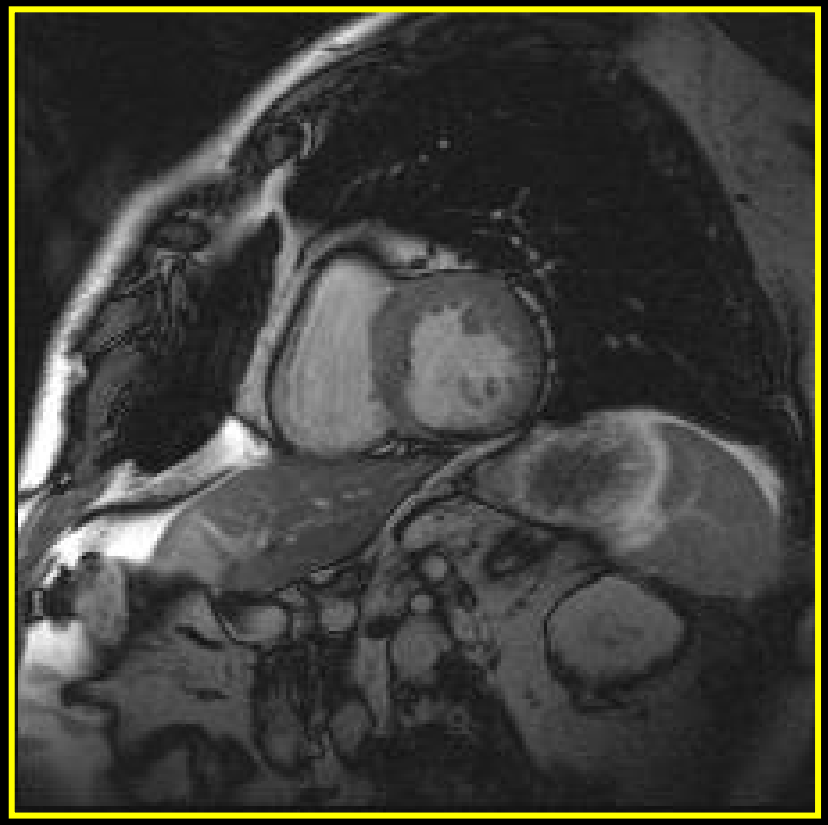


Right and Left Ventricle

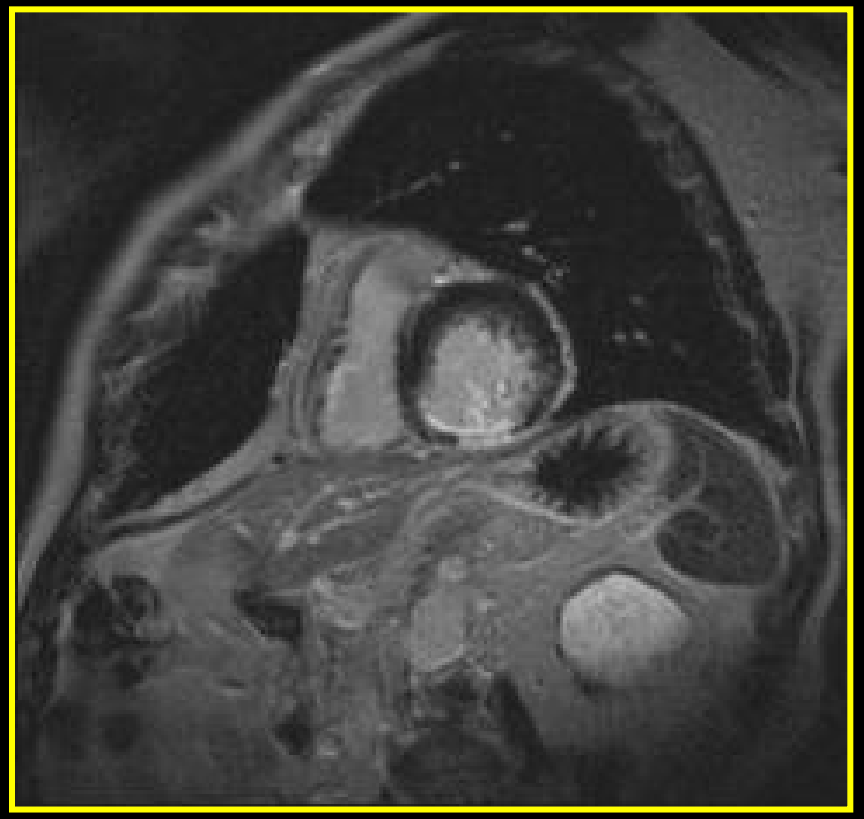


Myocardial Sectors



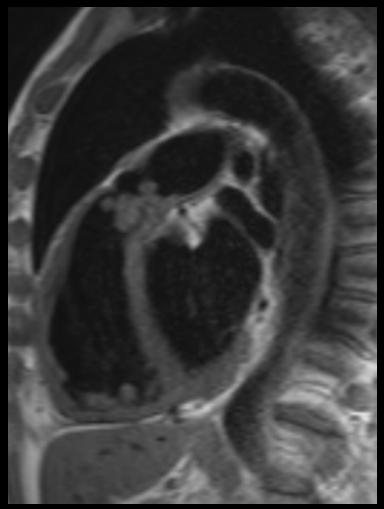


Cine SA True-Fisp

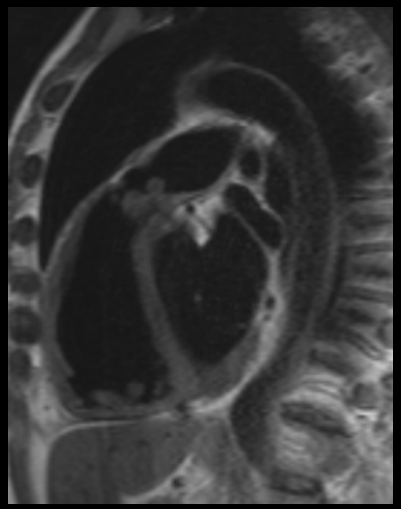


Late Enhancement: Flash 2D

Intima Sarcoma



T1



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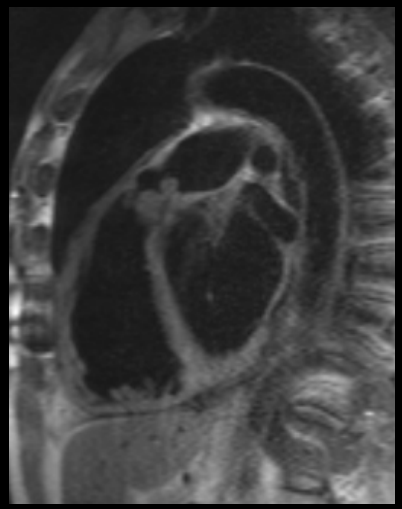

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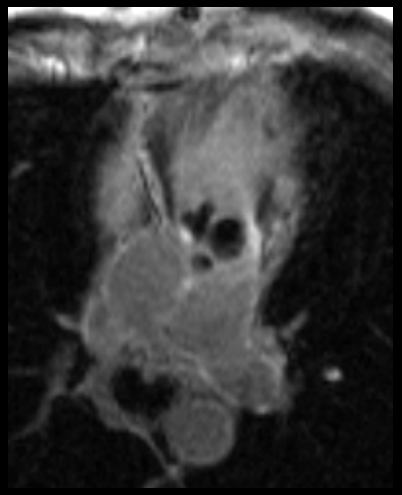
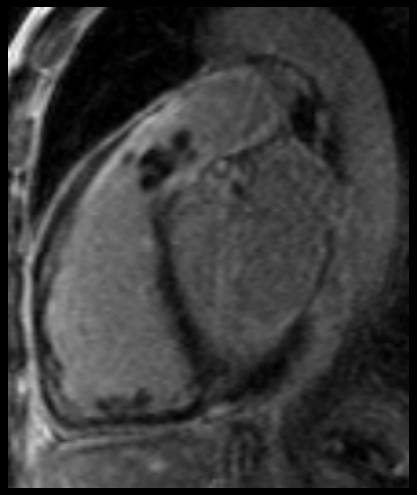
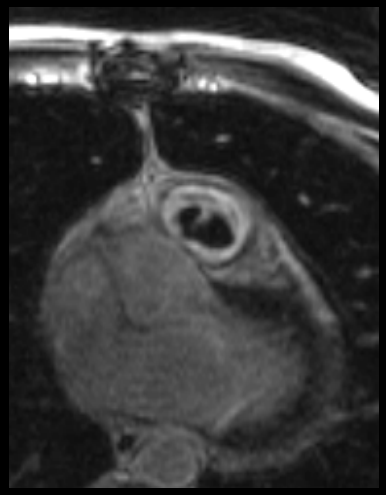
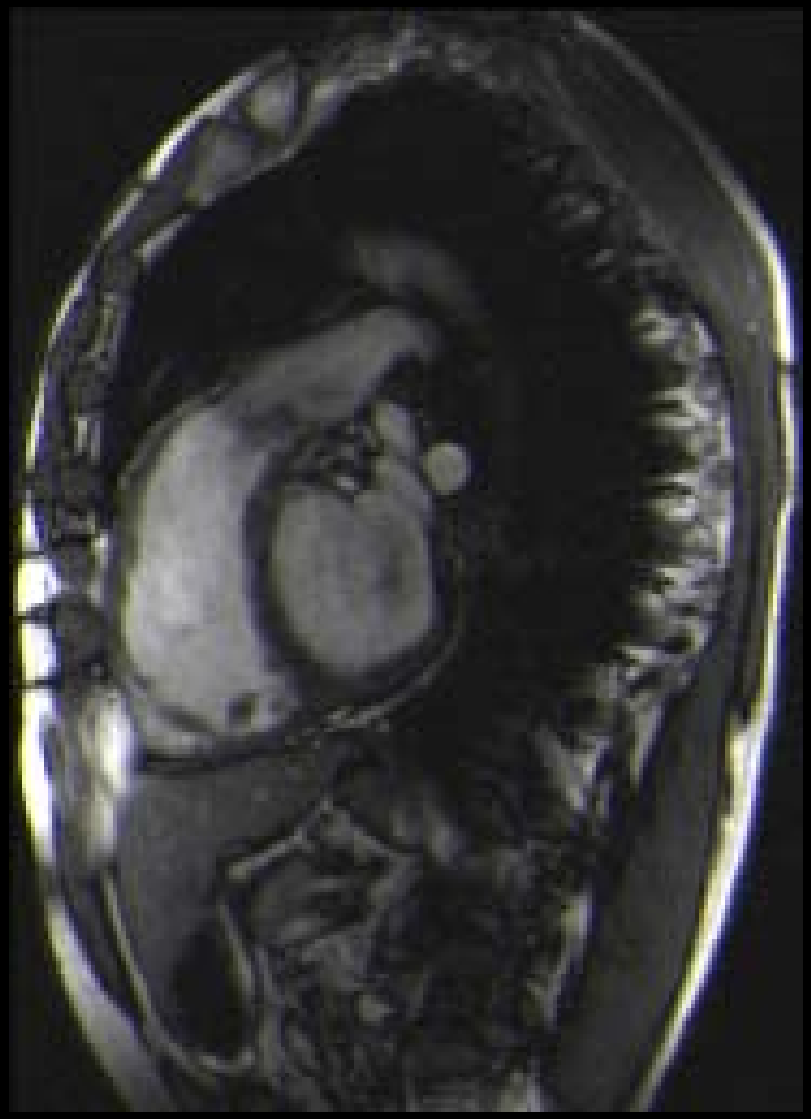




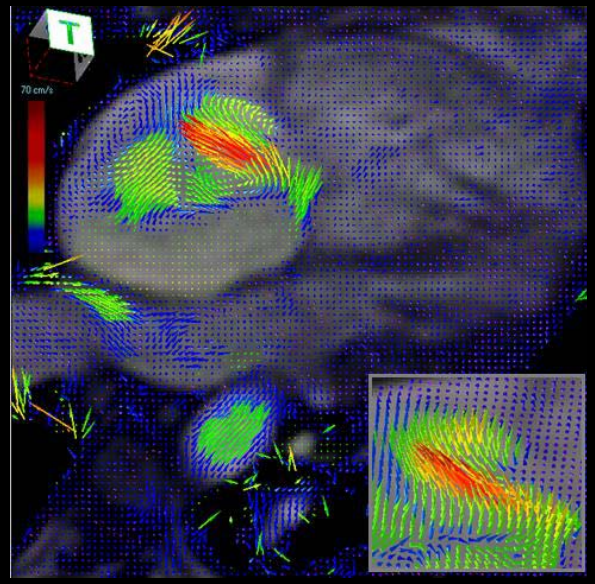


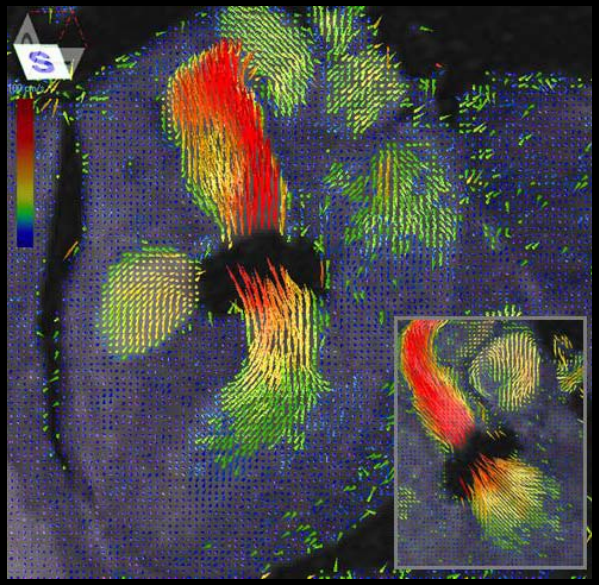
Late Enhancement



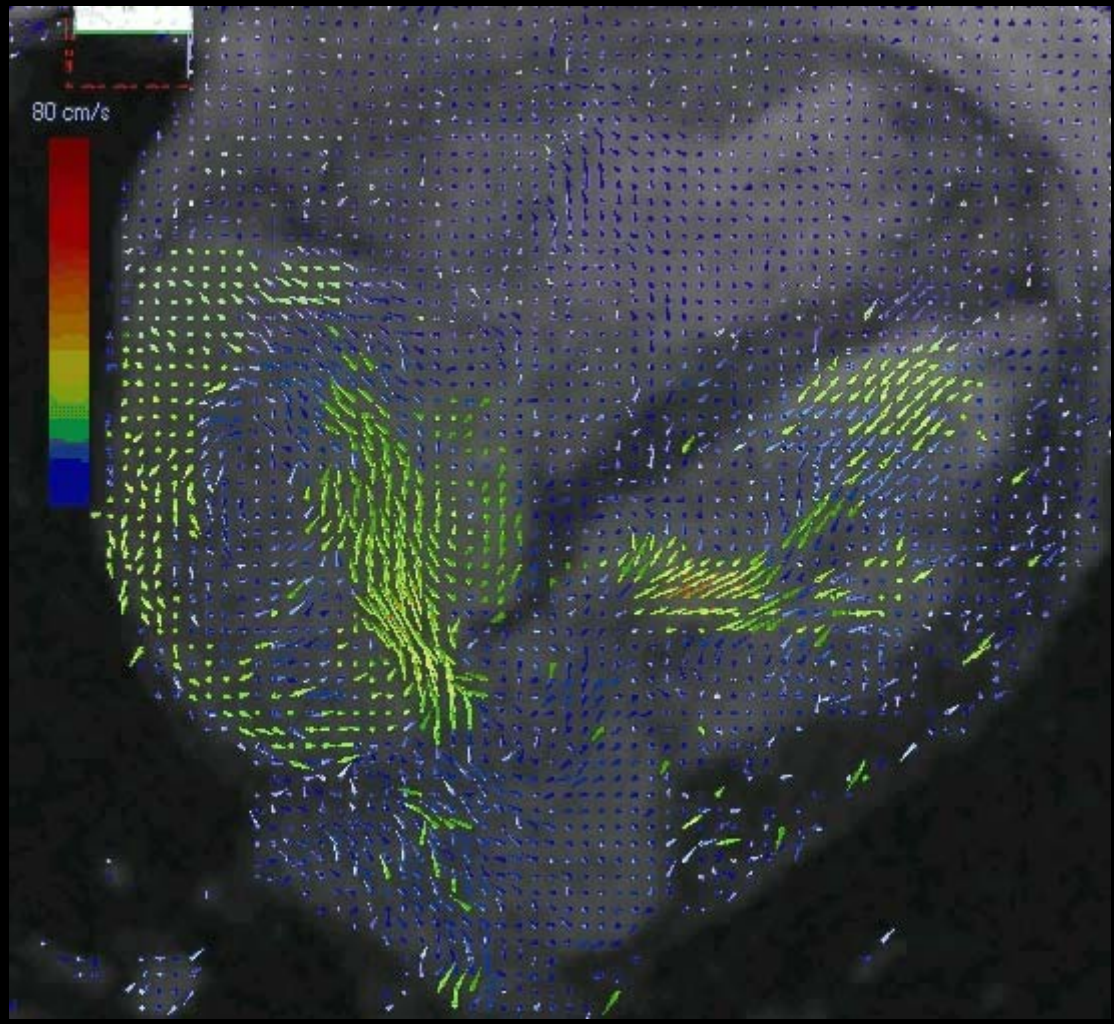
Cine TrueFISP

TI





Aortenklappenersatz



ASD

Change of Diagnostic Workflow by Cardiac CT and MR

[IC]² Berlin

Clinical Examples

Which Questions may be answered

Advantages for Patient / Referral

Place in Diagnostic Algorithm

Indication for Cardiac CT/MR- studies?

CT	MR
1) „Subclinical“ CHD	Infarction/ „Vitality“
2) Chronic Coronary Syndrom	Myocardial scare
3) Coronary stenosis > 50%	Myocarditis
4) Myocardial infarction	Valve vitium
5) Myocardial ischemia	Pericardial Constriction
6) Pericardial diseases	Cardial Thrombus/ Tumor
7) Anomaly of coronary vessels	ARVD
8) Bypass-stenosis/-occlusion	Shunt
9) Stent-occlusion	

Change of Diagnostic Workflow by Cardiac CT and MR

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Clinical Examples

Which Questions may be answered

Advantages for Patient / Referral

Place in Diagnostic Algorithm

Benefit for the Patient

Objective, non invasive, reproducible, fast method for exclusion or for early recognition and staging of coronary, cardiac and pulmonary diseases as One Stop Shop.

Benefit for the Referrals

Objective, non invasive, quantitative, reproducible, fast method for exclusion or for early recognition and staging of coronary, cardiac and pulmonary diseases as One Stop Shop.

Therapy recommendation and control of its individual effectiveness (evidence based medicine).

Benefit for Cardiologists

Reduction of unnecessary coronary catheterization.

Increase capacity for interventional procedures.

Objective, non invasive, quantitative, reproducible, fast method for exclusion or for early recognition and staging of coronary, cardiac and pulmonary diseases as One Stop Shop.

Therapy selection and control of its individual effectiveness (evidence based medicine).

Change of Diagnostic Workflow by Cardiac CT and MR

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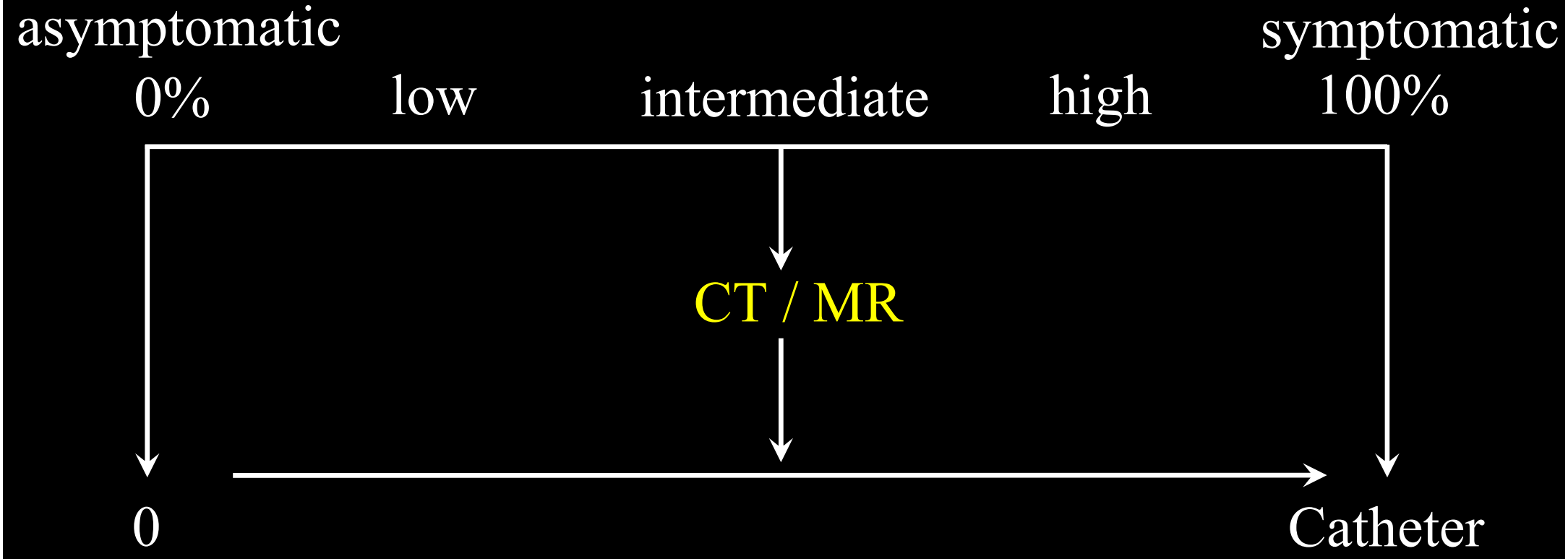
Clinical Examples

Which Questions may be answered

Advantages for Patient / Referral

Place in Diagnostic Algorithm

Risk Profile of CHD



CT enables noninvasive direct visualization of soft- and calcified coronary arterial plaques – "The potential of this information for risk stratification has sparked intense interest in plaque imaging to identify patients at high risk of a coronary event"

S. Achenbach 2007

New Concept for Evaluation of patients with suspected or known CHD

1. Step: Visualization of micro-pathology and patho-physiology by

MSCT, (DSCT, EBT) and MR

2. Step: Evaluation of etiology and accompanying individual health issues as history, physical findings, HR and RR, laboratory parameters, ECG – Arhythmia (Sympath./Para-sympath.), Echo – Valvular disease

(Cyclotron-PET) – Metabolism, Perfusion (ml/100g/min)

Conclusion I:

Non-Invasive In Vivo Visualisation Of Organ Micro-Pathology and Patho-Physiology

Will create new diagnostic work-up → new work-flow:

- "First look Doctor" in whole body One-Stop-Shop with Computed assisted diagnostic devices (pattern recognition) with therapeutical options
- Target history taking and target physical examination with additional tests dependent on individual patient's situation

Conclusion II:

Non-Invasive In Vivo Visualisation Of Organ Micro-Pathology and Patho-Physiology

Will demand for:

- New match of the (imaging) diagnostician and (therapeutic) clinicians
- Reform of medical education (radio-patho-anatomy and radio-patho-physiology)
- Implication of "autopsy" by CT/MR technologies with target biopsy and adequate evaluation.

Conclusion III:

Non-Invasive In Vivo Visualization Of Organ Micro-Pathology and Patho-Physiology

Will result in:

Effective, science-based, transparent, economic, individual patient orientated

new Health-Care System

open for genetic and molecular biology implementation

Change of Diagnostic Workflow by Cardiac CT and MR

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Thank you for your attention!

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