



# Non-invasive Plaque Imaging using Multi-slice Spiral Computed Tomography

*Stephen Schröder, MD*

Associate Professor of Internal Medicine/Cardiology  
Interdisciplinary Section „Cardiovascular Imaging“  
Departments of Cardiology and Radiology  
Eberhard-Karls-University  
Tübingen, Germany



# Coronary imaging using MSCT

## -Improvements of technology-



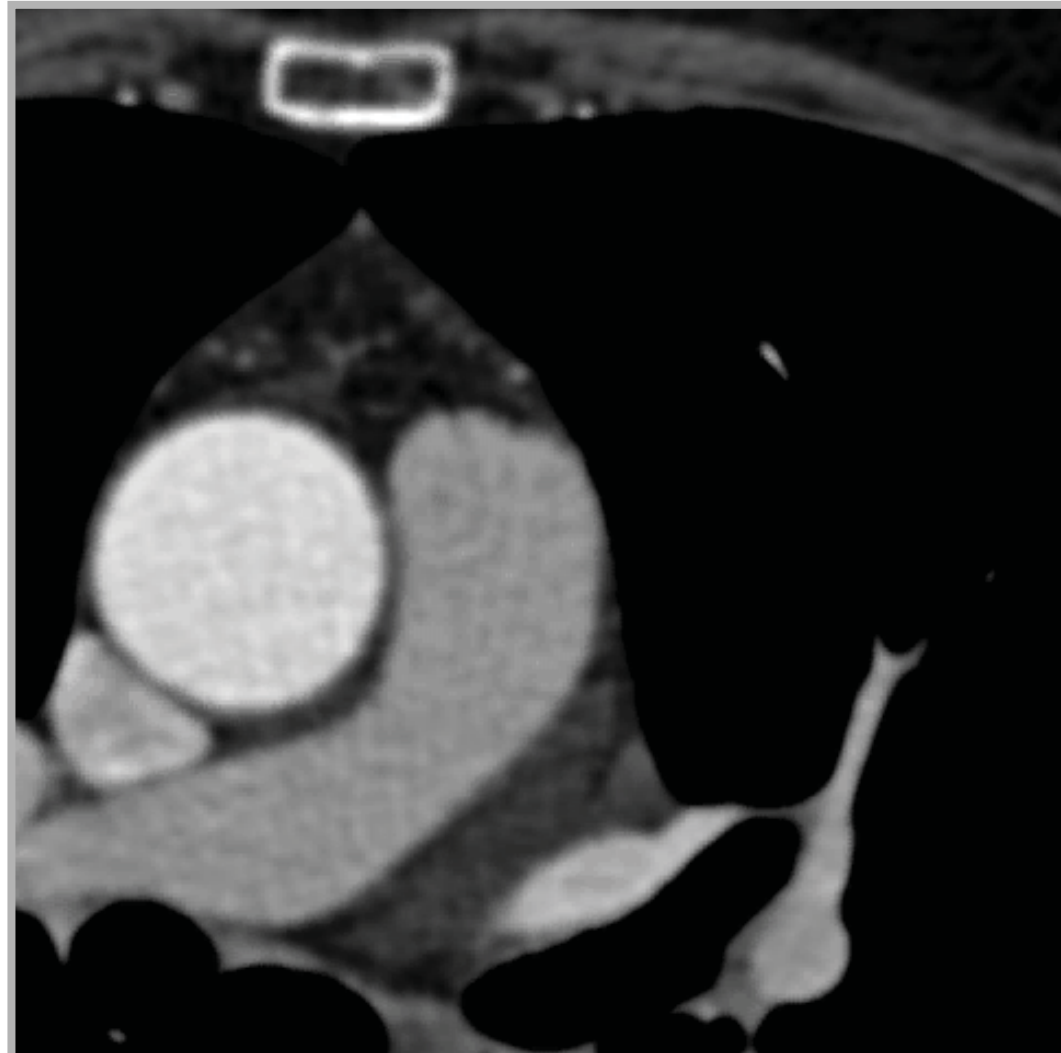
			<b>1999</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>
	<b>Konv. Angio</b>	<b>EBCT</b>	<b>MSCT (4-slices)</b>	<b>MSCT (12-slices)</b>	<b>MSCT (16-slices)</b>	<b>MSCT (64-slices)</b>
<b>Temporal resolution (ms)</b>	<b>20</b>	<b>100</b>	<b>Down to 125</b>	<b>Down to 105</b>	<b>Down to 92</b>	<b>&lt; 92</b>
<b>In-plane Res. lp/cm</b>	<b>50</b>	<b>5</b>	<b>8.6</b>	<b>10</b>	<b>10</b>	<b>&gt; 10</b>
<b>Z-Achse Res. lp/cm</b>	<b>-</b>	<b>2</b>	<b>7</b>	<b>9</b>	<b>9</b>	<b>&gt;10</b>
<b>Eff. SW (mm)</b>	<b>-</b>	<b>3</b>	<b>1.25</b>	<b>0.8</b>	<b>0.8</b>	<b>&lt;0.8</b>

# *Coronary imaging using MSCT*

## *-Comprehensive view on anatomy-*



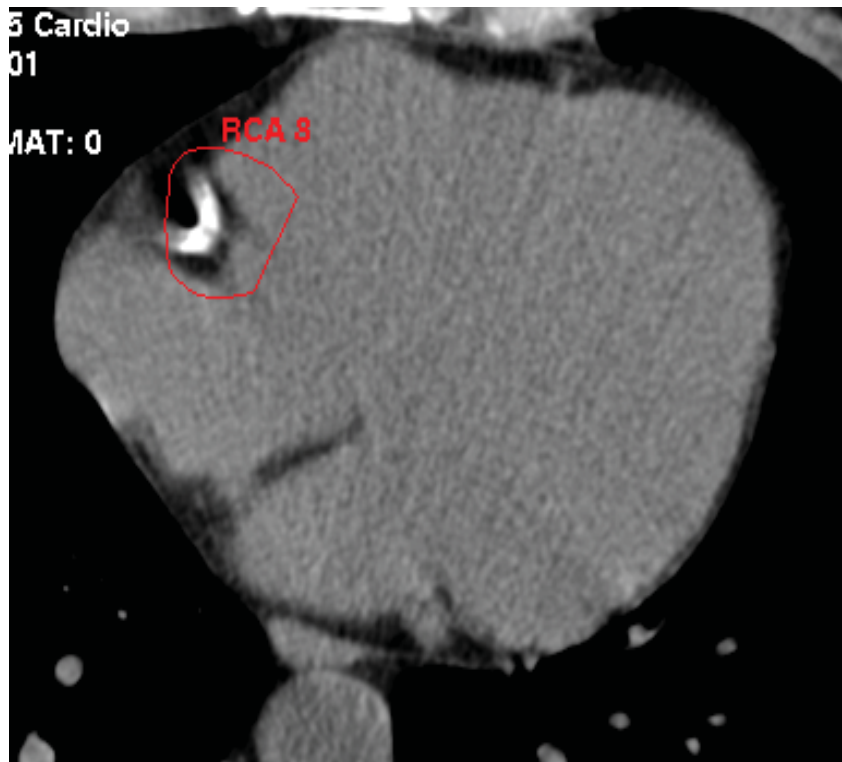
- **~200 axial images**
- **submillimeter resolution**





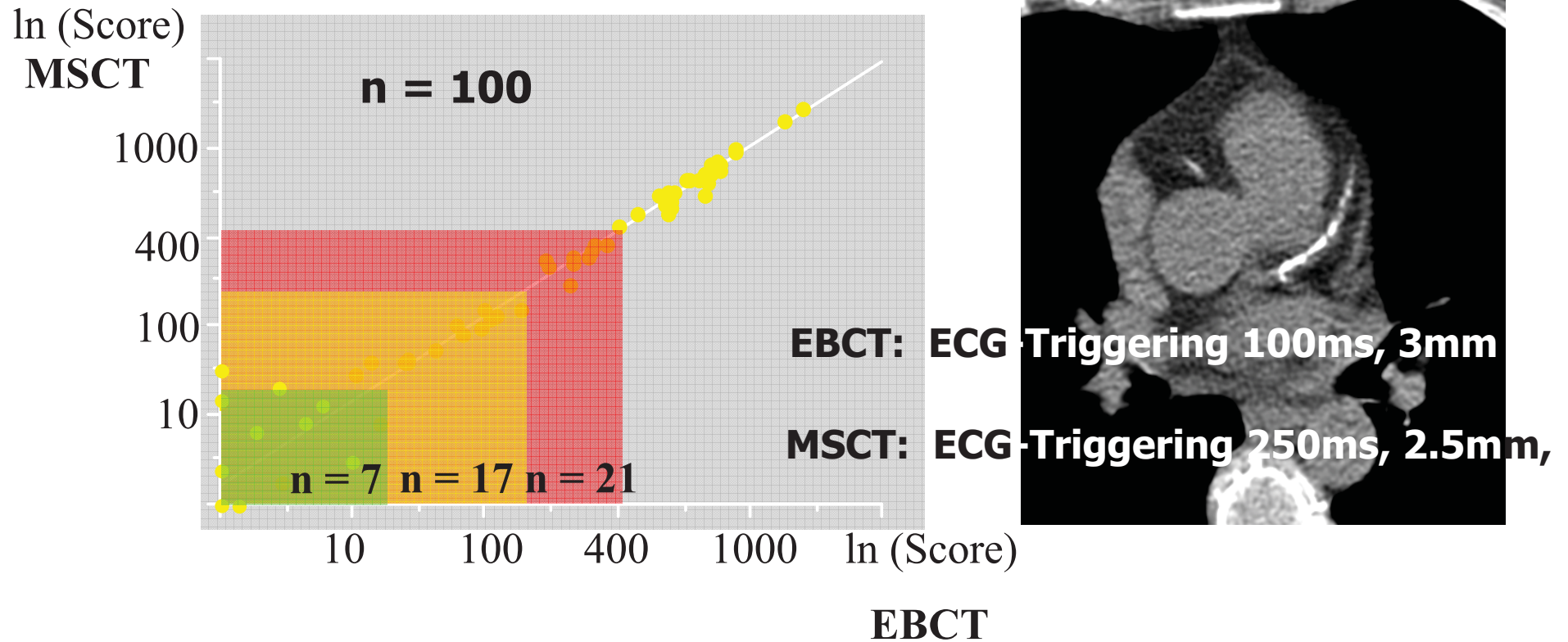
# Plaque imaging using MSCT

## -Calcium scoring-



# Plaque imaging using MSCT

## -Calcium scoring-



**Correlation  $r=0.985$  for EBCT/MSCT (Agatston-Score)**

**C.R. Becker et al. AJR 2001; 176:1295-1298**

# Plaque imaging using MSCT

## -Calcium scoring-



	<b>EBCT</b> Prosp. Trigg (3 mm)	<b>MSCT</b> Prosp. Trigg (4x2.5 mm)	<b>MSCT</b> Retros. Gating (4x2.5 mm)	<b>MSCT</b> Retros. Gating (4x1.0mm)
<b>Agatston Score</b>				
<b>MV</b>	35.5	20.8	21.8	28.0
<b>SD</b>	3.3	5.8	6.1	1.6
<b>Var.Coeff (%)</b>	9.3	27.9	28.3	<b>5.9</b>
<b>Calcium-Mass</b>				
<b>MV (mg<sup>3</sup>)</b>	6.3	3.9	4.2	4.9
<b>SD (mg<sup>3</sup>)</b>	0.3	0.9	1.0	0.2
<b>Var.Coeff (%)</b>	5.3	22.2	23.9	<b>4.1</b>

# *Plaque imaging using MSCT*

## *-Calcium scoring-*



<b>Investigator</b>	<b>Number</b>	<b>Age</b>	<b>FU (years)</b>	<b>Gender (% male)</b>	<b><i>Risk Ratio</i></b>
<i>Georgiou</i>	192	53	4.2	54	<b><i>13.1</i></b>
<i>Detrano</i>	491	57	2,5	64	<b><i>10.8</i></b>
<i>Keelan</i>	288	56	6.9	77	<b><i>3.2</i></b>
<i>Arad</i>	1173	53	3.6	71	<b><i>20.2</i></b>
<i>Agatston</i>	367	52	6.0	68	<b><i>16.9</i></b>
<i>Detrano</i>	1196	66	3.4	89	<b><i>2.3</i></b>
<i>Park</i>	967	67	6.4	91	<b><i>4.9</i></b>
<i>Raggi</i>	632	52	2.7	51	<b><i>15.4</i></b>
<i>Wong</i>	926	54	3.3	79	<b><i>8.8</i></b>
<i>Arad</i>	5585	59	4.3	70	<b><i>10.7</i></b>
<i>Kondos</i>	5635	51	3.1	74	<b><i>10.5/2.6</i></b>

**Budoff et al, JACC 2003;42:1867-1878**



## ***Non-invasive MSCT imaging*** ***-Plaque imaging: Risk stratification?-***



### Qualifiers:

Note that total CVD risk may be higher than indicated in the chart:

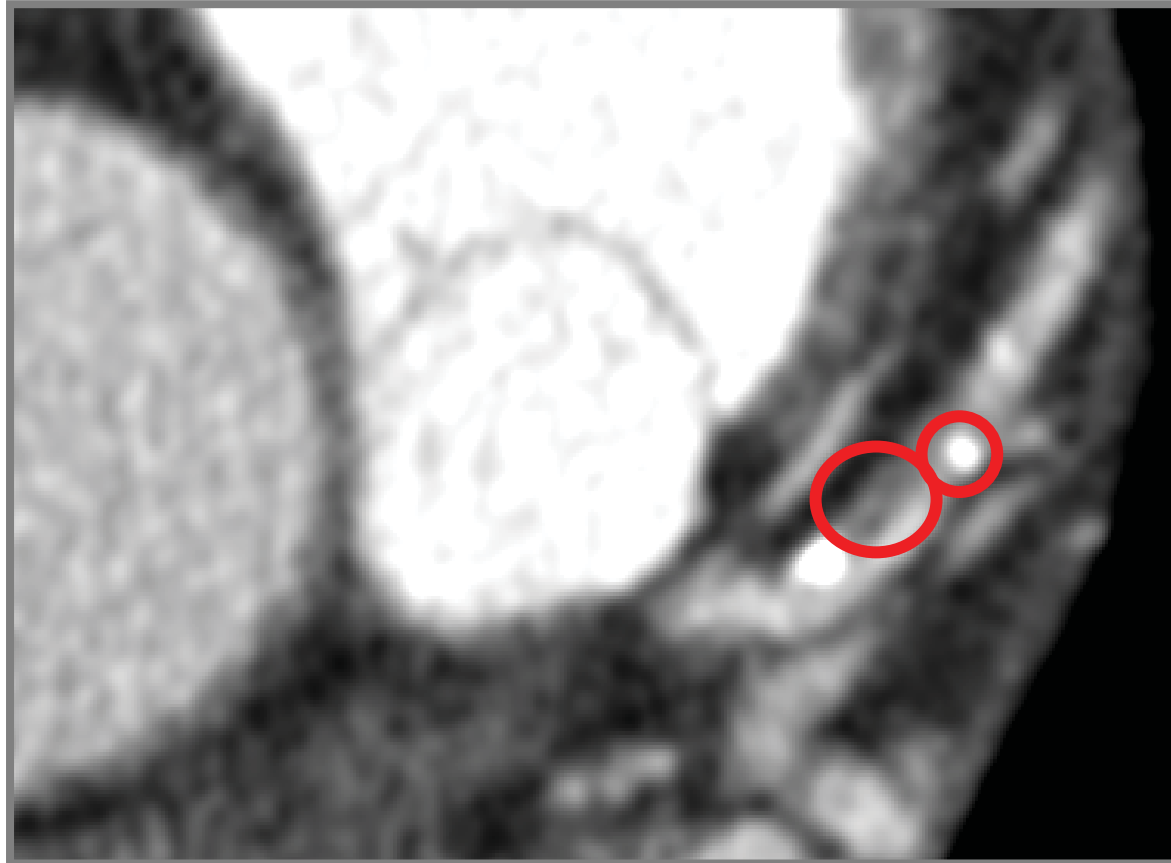
- In subjects who approach the next age category
- In asymptomatic subjects with pre-clinical evidence of atherosclerosis (e.g. CT scan, ultrasonography)
- In subjects with a strong family history of premature CVD
- In subjects with low HDL cholesterol levels, with raised triglyceride levels, with impaired glucose tolerance, and with raised levels of C-reactive protein, fibrinogen, homocysteine, apolipoprotein B or Lp(a)
- In obese and sedentary subjects

***European Task Force on CHD Prevention***

***Eur Heart J 2003;24:1601-1610***

# *Plaque imaging using MSCT*

## *-Non-calcified plaques-*



*Different stages of atherosclerosis  
or  
artifacts?*

# ***Plaque imaging using MSCT*** ***-Reference-Standard: Histology-***



**I- Isolated Macrophages**

**II- Foam Cell Layers**

**III- Extracellular Lipid Pools**

**IV- Extracellular Lipid Core**

**V- Fibromuscular layers formed**

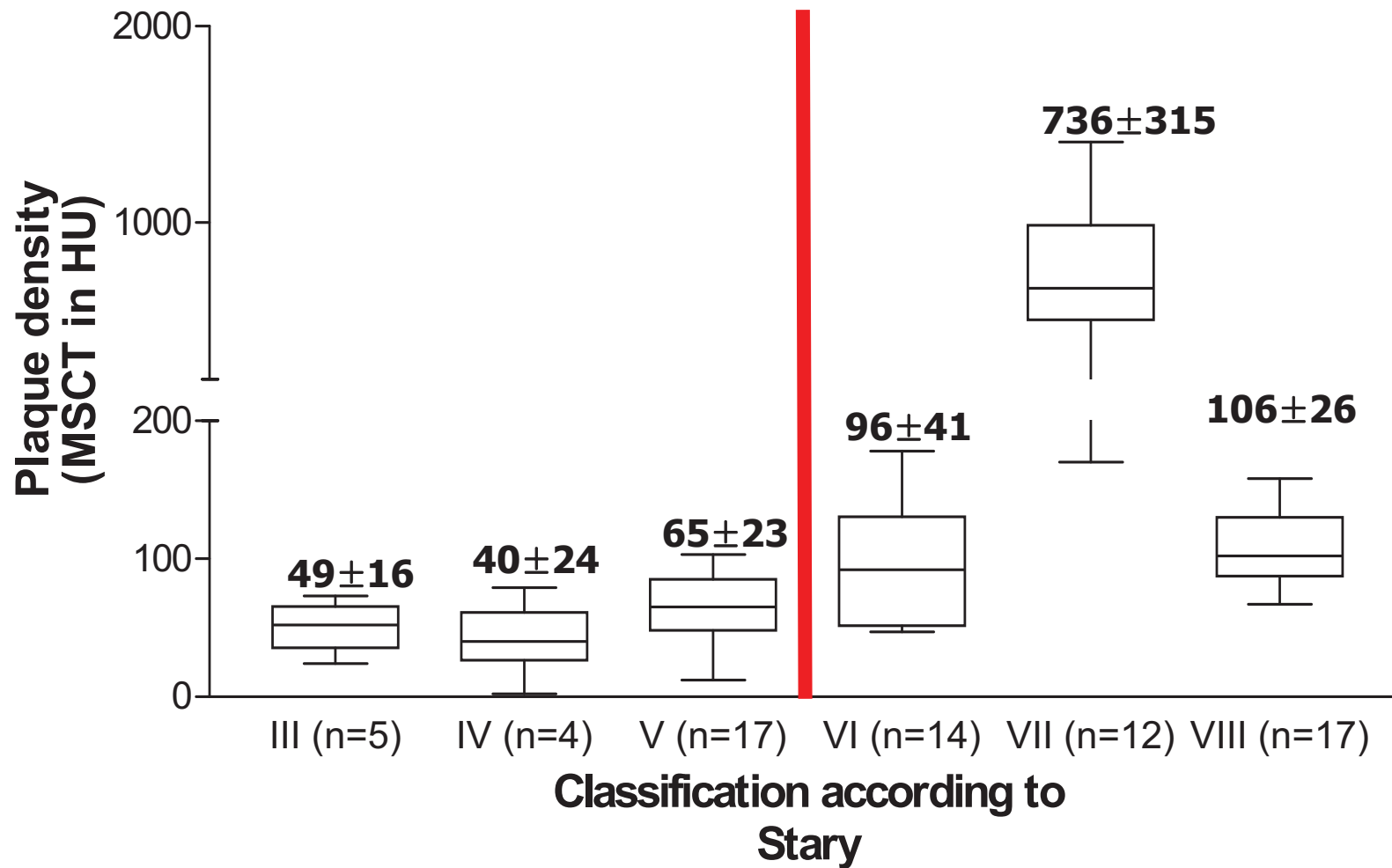
**VI- Intravascular Thrombi**

**VII- Calcification predominates**

**VIII- Fibrous tissue predominates**

# Plaque imaging using MSCT

## -Non-calcified-plaques: EX-vivo results-



*Schröder et al. 2004; under submission*

# Plaque imaging using MSCT

## -Non-calcified-plaques: EX-vivo results-



**A:** H&E-stained cross section of a Stary V atherosclerotic plaque



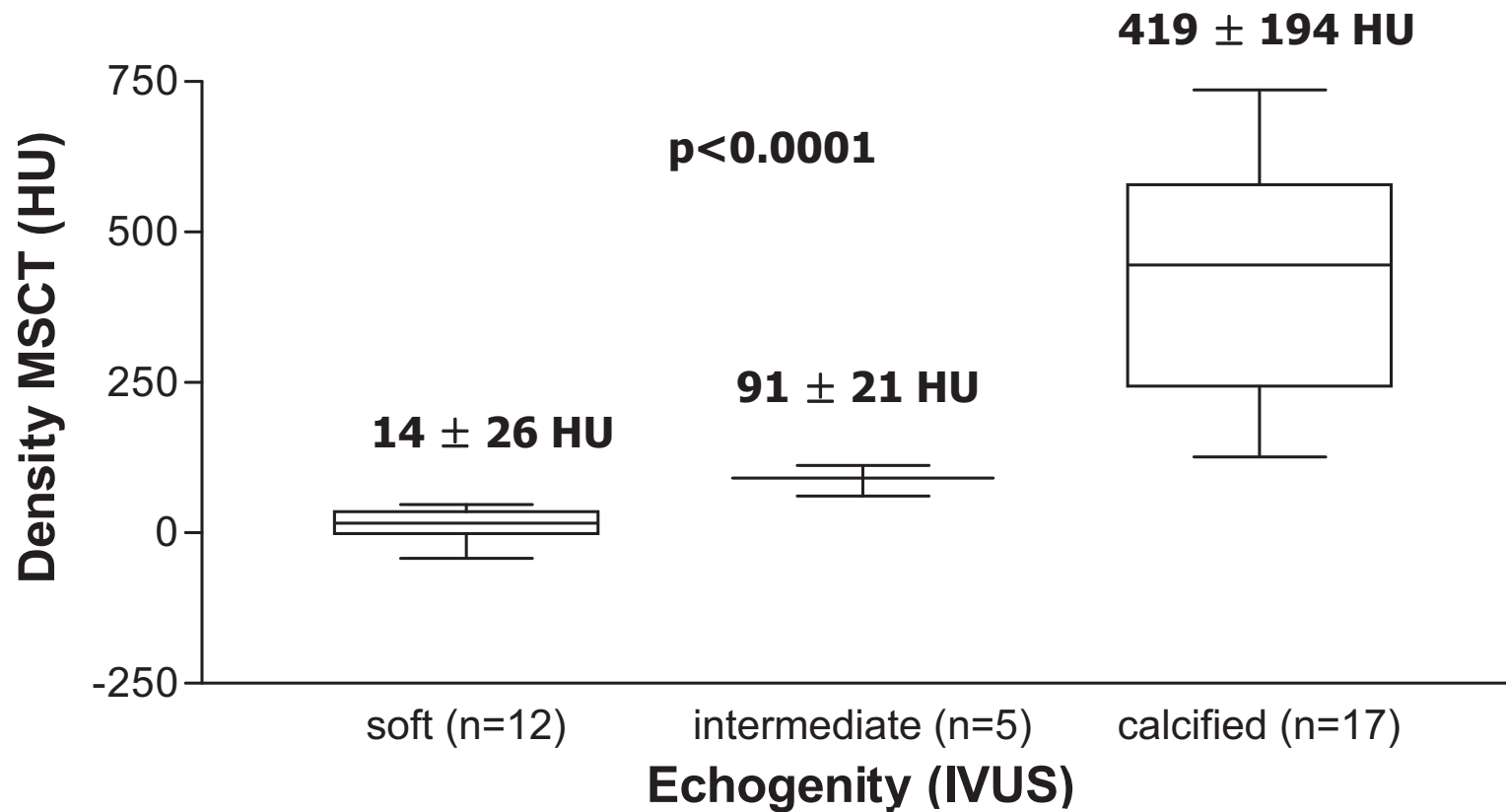
**B:** Scheme demonstrating the parts of the lesion in figure A



**C:** Contrast-enhanced MSCT -image of the atherosclerotic lesion shown in figure A

# Plaque imaging using MSCT

## -Non-calcified-plaques: In-vivo results-

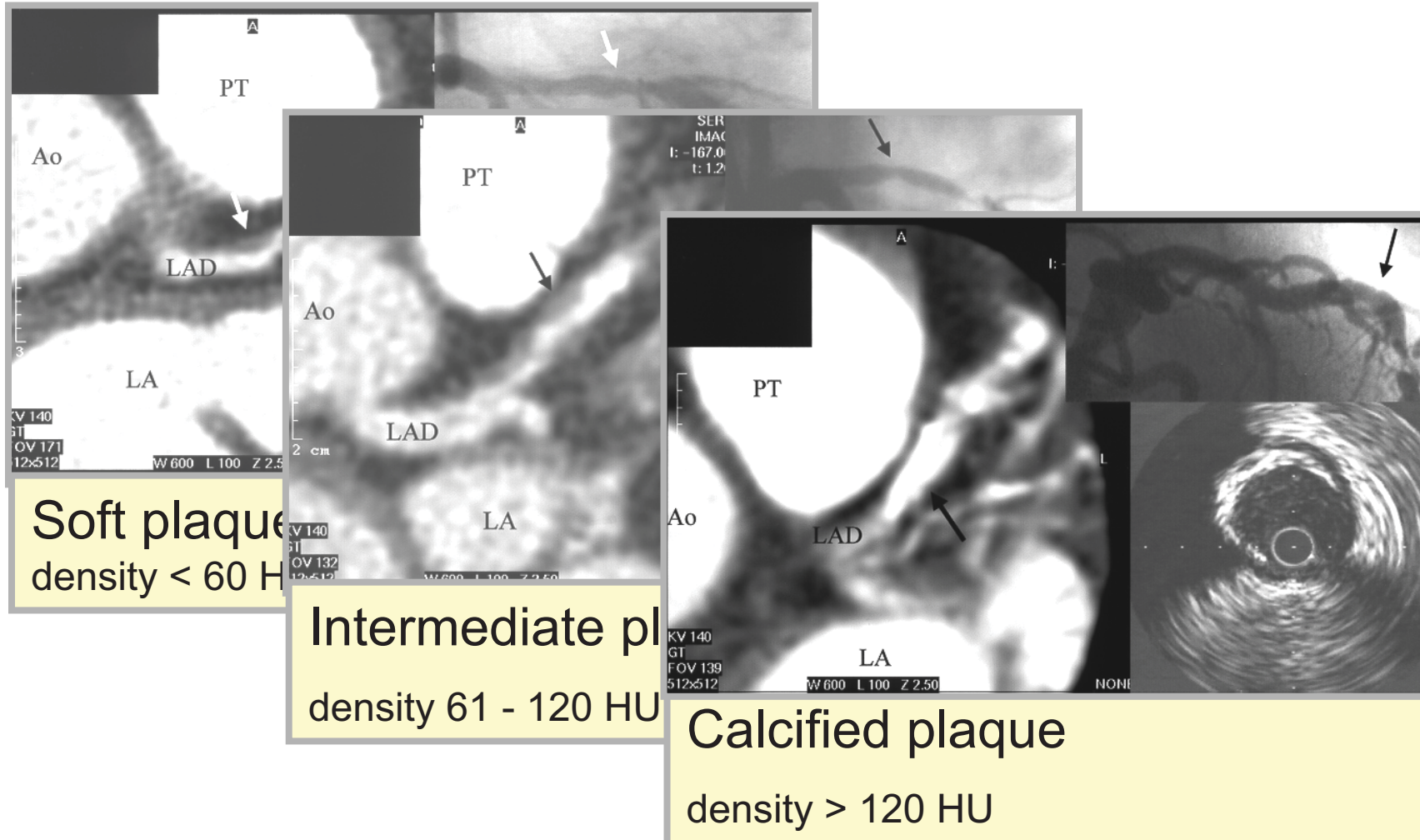


*Schröder, Kopp et al. JACC 2001;37:1430-5*



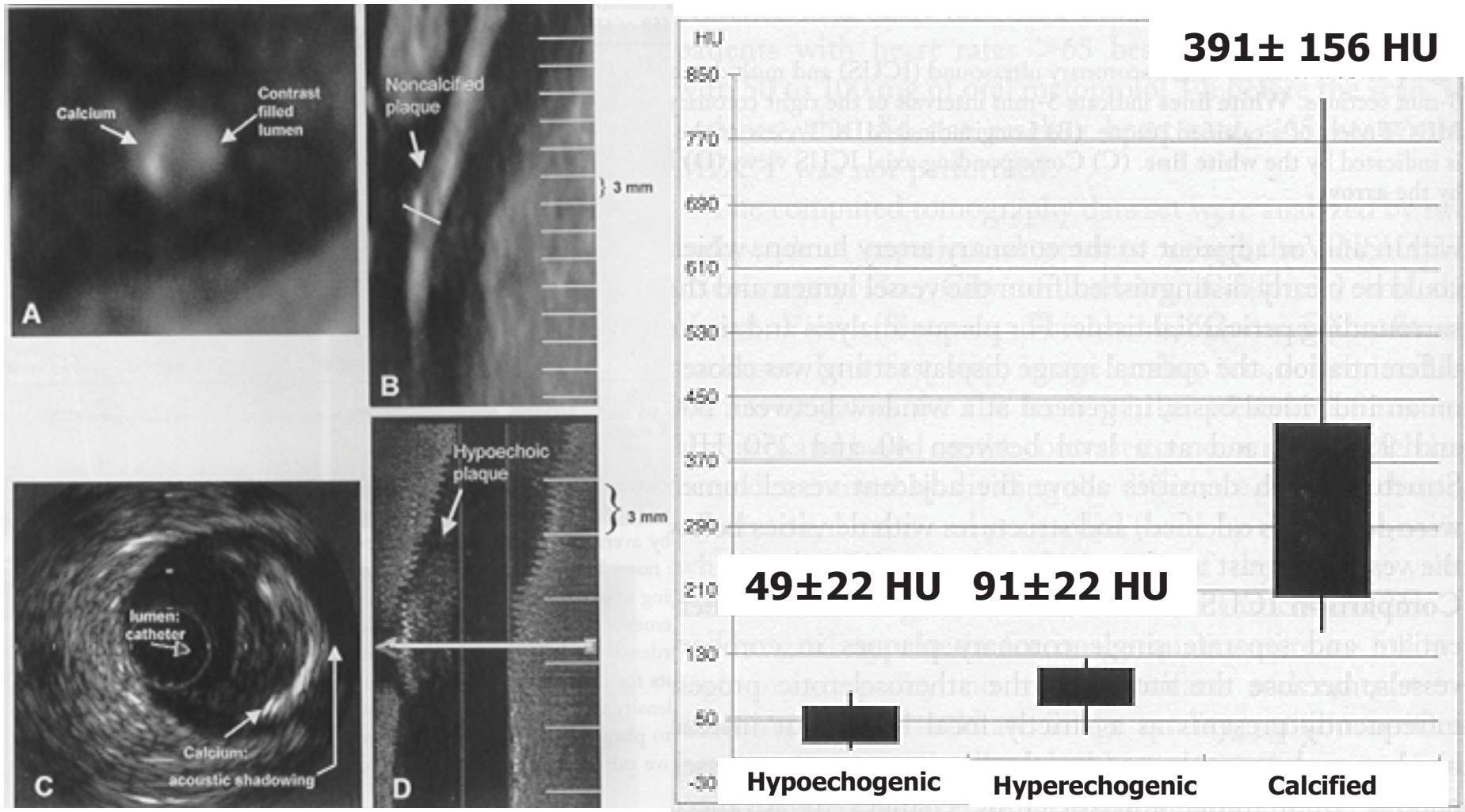
# Plaque imaging using MSCT

## -Non-calcified-plaques: In-vivo results-



# Plaque imaging using MSCT

## -Non-calcified-plaques: In-vivo results-



Leber et al. JACC 2004;43:1241-1247

# Plaque imaging using MSCT

## -Non-calcified-plaques: In-vivo results-



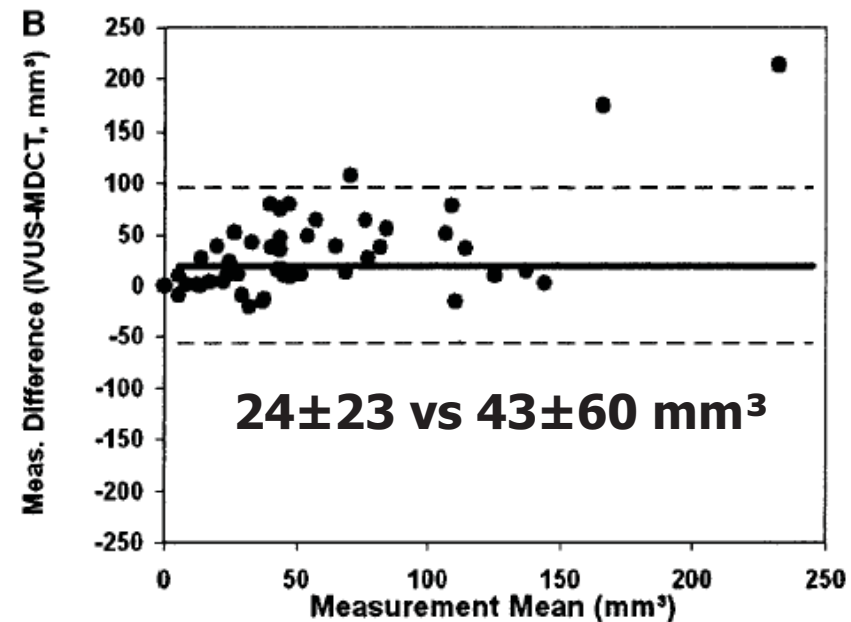
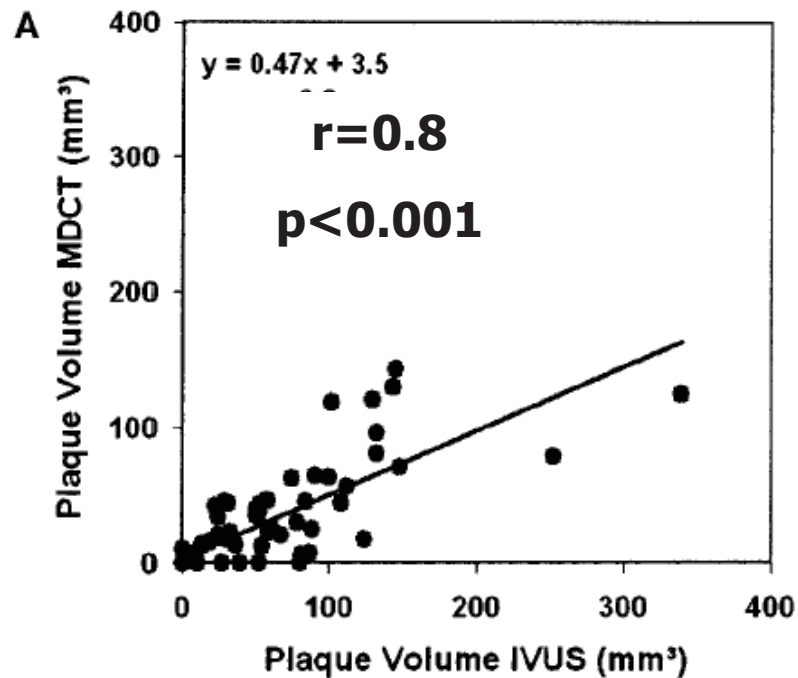
N=37 pts, 68 vessels, Sensation 16, 12\* 0.75 mm, 120 kV,  
450 mAS, 100 ml CM

	Soft Sensitivity	Fibrous Sensitivity	Calcified Sensitivity	Total Specificity
<b>RCA</b>	12/16 75%	27/34 79%	49/49 100%	94/102 92%
<b>LAD</b>	44/54 81%	47/62 76%	76/83 92%	294/315 93%
<b>LCX</b>	6/10 60%	13/16 82%	25/26 96%	96/108 89%
<b>Total</b>	<b>62/80</b> <b>78%</b>	<b>87/112</b> <b>78%</b>	<b>150/158</b> <b>95%</b>	484/525 92%

# ***Plaque imaging using MSCT*** ***-Non-calcified-plaques: In-vivo results-***



- **N=22 pts, 22 vessels**
- **Segmental detection + evaluation of plaque volume**
- ***IVUS*- N=83 sgts- 50 sgts with plaques [31 cp & ncp, 4: cp, 15: ncp)**
- ***MSCT (Sensation 16)*- 41 sgts with plaques  
(Sensitivity: 82/92%, Specificity: 86/88%)**



**IVUS-characteristics of plaques missed by MSCT (n=9 sgts)**  
**Volume  $47 \pm 11$  mm<sup>3</sup>, area  $8 \pm 3$  mm<sup>2</sup> (vs  $76 \pm 10$  mm<sup>3</sup>, area  $11 \pm 4$  mm<sup>2</sup>)**



## **Prerequisite for accurate detection of non-calcified plaques**

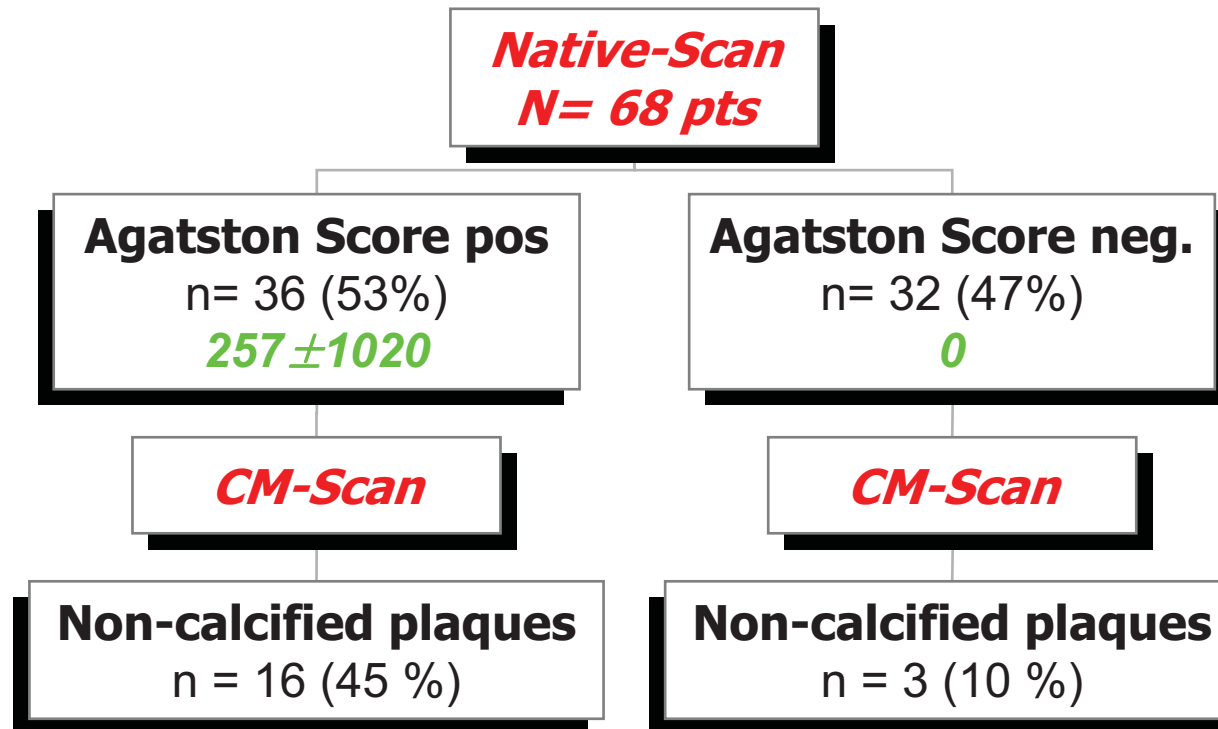
- **Larger vessel (>2 mm)**
- **Sufficient plaque thickness (>~0.9 mm)**
- **Sufficient plaque volume**

*Leber et al. JACC 2004;43:1241-1247*

*Achenbach et al. Circulation 2004;109:14-17*



# Plaque imaging using MSCT -Clinical significance?-



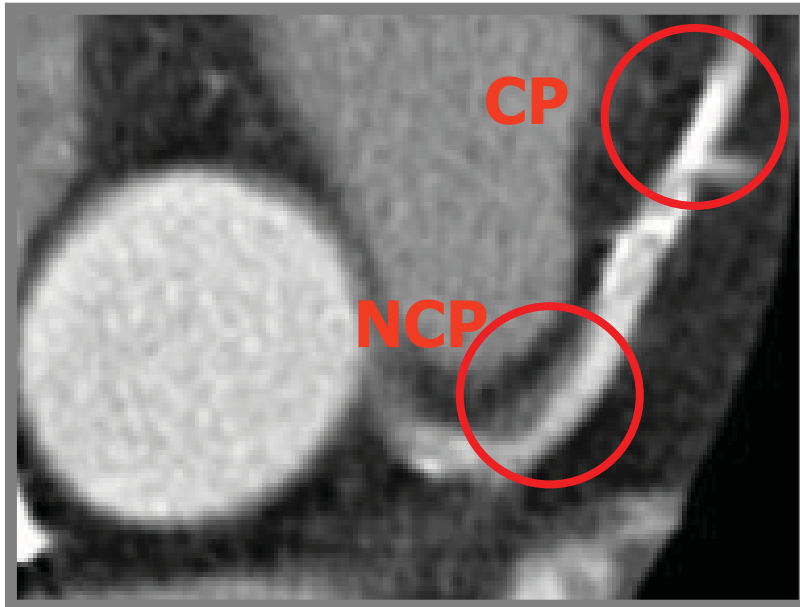
*Schröder, Küttner, Kopp et al. Int J Cardiol 2003; 92:151-155*

# Plaque imaging using MSCT

## -Clinical significance?-



n = 40 pat, age: 64 ± 8 years, „matched“ for CVRF



	AMI n= 21	SAP n=19	p-value
NCP	<b>2.4</b>	<b>0.74</b>	<b>&lt; 0.001</b>
CP	<b>3.2</b>	<b>7.1</b>	<b>&lt; 0.05</b>
CS	<b>322</b>	<b>631</b>	<b>&lt; 0.05</b>
TPB	<b>9.7</b>	<b>12.1</b>	<b>n.s.</b>

*Leber et al, Am J Cardiol 2003; 91:714-718*

# Plaque imaging using MSCT

## -Current limitations-



Dose measurement using an Alderson-Rando-Phantom  
(thermoluminescence dosimetry)

	[1]	[2]	[3]	[4]
Protocol	CaSc	CaSc	CTA	CTA
ECG-pulsing [+/-]	-	+	-	+
scan range [mm]	120	120	100	100
U [kV]	120	120	120	120
$I_{eff}$ [mAs]	133	133	400	400
gantry rotation time [s]	0,42	0,42	0,42	0,42
collimation [mm]	12 × 1,5	12 × 1,5	12 × 0,75	12 × 0,75
table feed [mm]	5,7	5,7	2,8	2,8
pitch-factor	0,32	0,32	0,31	0,31
CTDI <sub>w</sub>	10,45	10,18	37,56	37,56
Total mAs	1287	794	5322	2947
DLP	164	160	451	451

**Trabold, Schröder et al, Fortschr Röntgenstr 2003; 175: 1051-1055**

# *Plaque imaging using MSCT* *-Current limitations-*



Dose measurement using an Alderson-Rando-Phantom  
 (thermoluminescence dosimetry)

	<i>protocol</i>	<i>effective dose male [mSv]</i>	<i>effective dose female [mSv]</i>
[1]	CaSc	2,9	3,6
[2]	CaSc + ECG-pulsing	1,6	2,0
[3]	CTA	8,1	10,9
[4]	CTA + ECG-pulsing	4,3	5,6

*Trabold, Schröder et al, Fortschr Röntgenstr 2003; 175: 1051-1055*



## Detection of (early) atherosclerosis

- Calcified as well as non-calcified plaques can be detected by the use of MSCT with good diagnostic accuracy
- MSCT can provide information on morphology, not on biology
- Combination with other imaging modalities useful?
- Specific contrast media useful?
- *Clinical relevance of MSCT „plaque-imaging“ is currently unclear and subject of ongoing studies*

# ***Interdisciplinary Section „Cardiovascular Imaging“***



***PD Dr. Schröder***

**Dr. Beck**

**Dr. Burgstahler**

**Dr. Franow**

**Dr. Helber**

**PD Dr Herdeg**

**Dr. Pflumm**



***Dr. Kopp /***

***PD Dr. Miller***

**Dr. Fenchel**

**Dr. Heuschmid**

**Dr. Kramer**

**Dr. Küttner**

**Dr. Stauder**

**[Stephen.Schroeder@med.uni-tuebingen.de](mailto:Stephen.Schroeder@med.uni-tuebingen.de)**