
Het Hart in Beeld
11 maart 2010
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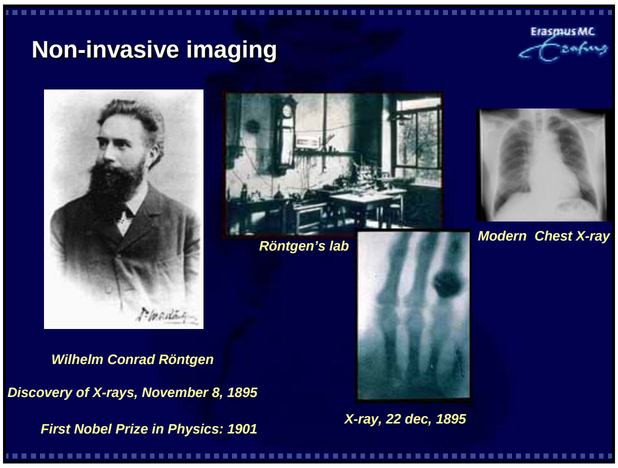
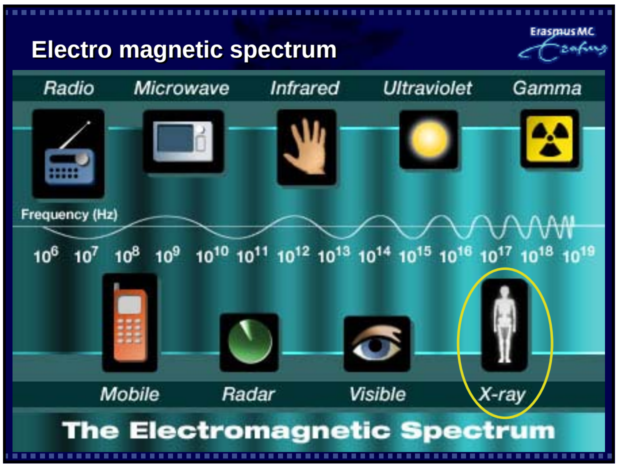
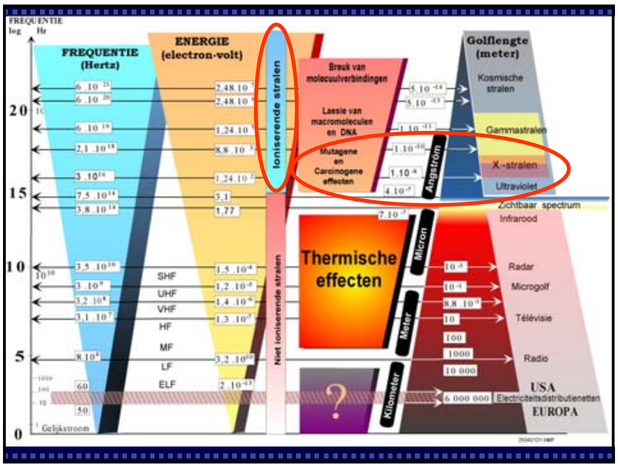
Erasmus MC


Invasive "imaging"
Andreas Vesalius
Humani corporis fabrica libri septem 1543


Non-invasive imaging
Erasmus MC
Röntgen's lab
Modern Chest X-ray
Wilhelm Conrad Röntgen
Discovery of X-rays, November 8, 1895
First Nobel Prize in Physics: 1901
X-ray, 22 dec, 1895

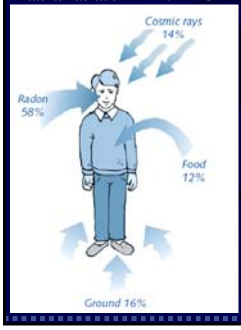

Electro magnetic spectrum
Erasmus MC
Radio
Microwave
Infrared
Ultraviolet
Gamma
Frequency (Hz)
10^6 10^7 10^8 10^9 10^10 10^11 10^12 10^13 10^14 10^15 10^16 10^17 10^18 10^19
Mobile
Radar
Visible
X-ray
The Electromagnetic Spectrum


First CT scan 1972:
G.N. Hounsfield & A.M. CormackNobel prize 1979


FREQUENTIE (Hertz)
ENERGIE (electron-volt)
Ioniserende stralen
Niet ioniserende stralen
Golflengte (meter)
Breuk van moleculuutverbindingen
Laesie van macromoleculen en DNA
Mutagene en Carcinogene effecten
Thermische effecten
Kosmische stralen
Gammastralen
X-stralen
Ultraviolet
Zichtbaar spectrum
Infrarood
Radar
Microgolf
Télévisie
Radio
USA
EUROPA
Angstrom
Micron
Meter
Kilometer
SHF
UHF
VHF
HF
MF
LF
ELF
Gelijkstroom

Natural radiation & risk estimation

Natural radiation NL: +/- 2mSv



Estimated risk by age

Age	Lifetime risk of death / mSv
Child (0-10y)	14 / 100.000
Adolescent (10-20y)	18 / 100.000
Adolescent (20-30y)	7,5 / 100.000
Adolescent (30-40y)	3,5 / 100.000
Adolescent (60y)	2 / 100.000
Adolescent (80y)	1 / 100.000
Average	5 / 100.000

Medical radiation dose

Diagnostic procedure	Typical effective doses (mSv)	Equivalent period of natural background radiation	Lifetime additional risk of fatal cancer per examination
X-ray examinations:			
Chest (single PA film)	0.02	3 days	1 in a million
Cervical spine (neck)	0.08	2 weeks	1 in 200,000
Hip	0.3	7 weeks	1 in 67,000
Thoracic spine	0.7	4 months	1 in 30,000
Pelvis	0.7	4 months	1 in 30,000
Abdomen	0.7	4 months	1 in 30,000
Lumbar spine	1.3	7 months	1 in 15,000
CT head	2	1 year	1 in 10,000
CT chest	8	3.6 years	1 in 2500
CT abdomen/pelvis	10	4.5 years	1 in 2000

Basic principle CT-scan

Measure the slice x-ray absorption profile under multiple angles

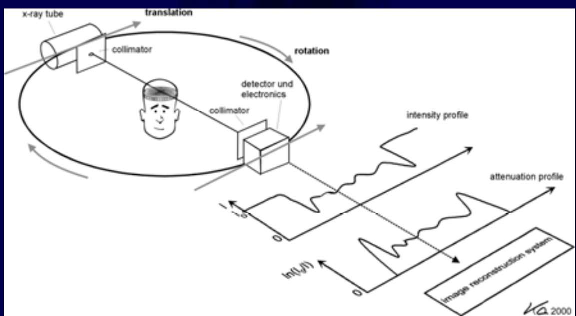
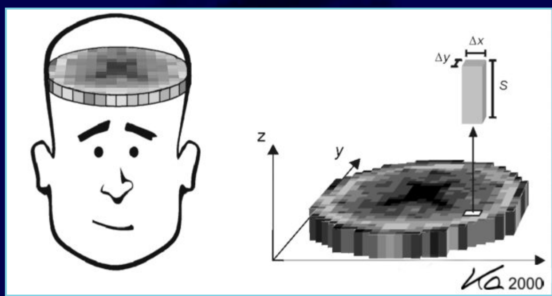


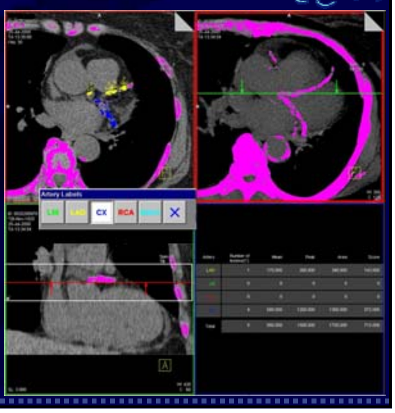
Image reconstruction

- Calculate x-ray absorption for small volumes in slice
- Image quality depends on: patient, scanner type, indication, protocol & radiation



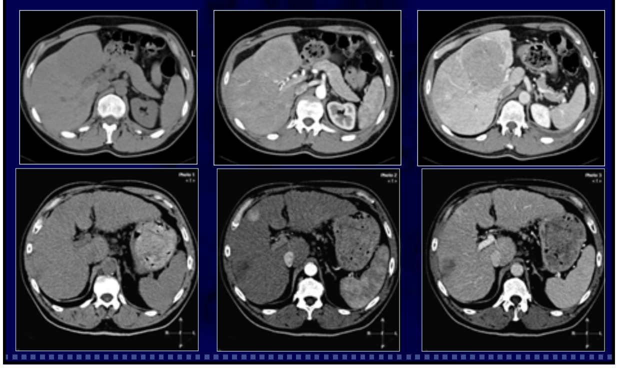
Calcium Score

- Scan without contrast
- Measures amount of calcium
- Powerful risk factor
  ! No diagnosis !
- Predictor of successful CCTA



Contrast resolution & intravenous contrast

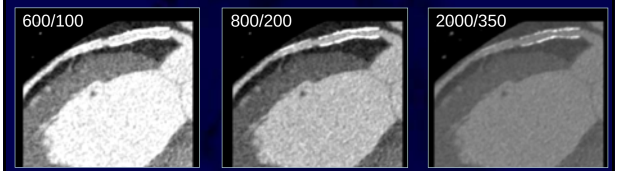
native | delay 30sec. | delay 80 sec.



Blooming of calcium and stents

- Wide window/greyscale reduces blooming
- Wide window/greyscale reduces image contrast

- High contrast flow rate's require large lumen venflon's
  ! Injector pressures up to 300 PSI = 15500mm Hg !

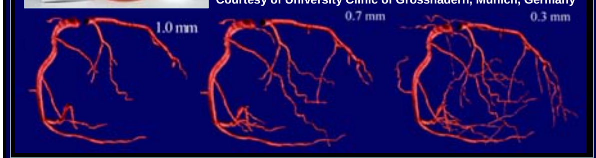


Spatial resolution

- Influence of slice thickness on image quality

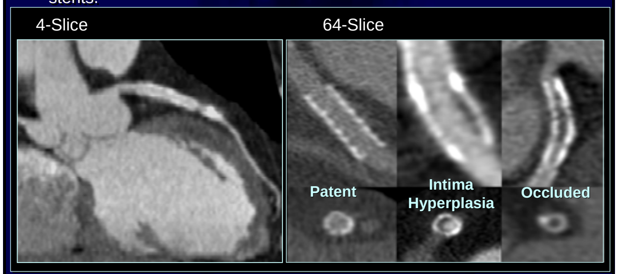
Less than 0.5mm resolution is needed for good evaluation of small coronary side branches. (resolution DSA 0.1mm)

Courtesy of University Clinic of Grosshadern, Munich, Germany



Developments in spatial resolution

- Limitations of spatial resolution in 4-Slice is clearly seen when evaluating stents.



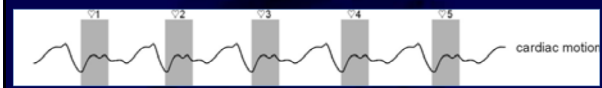
Motion in non ECG gated scans

4-slice

16-slice

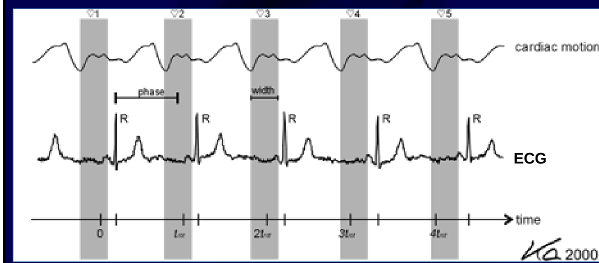
ECG-synchronization

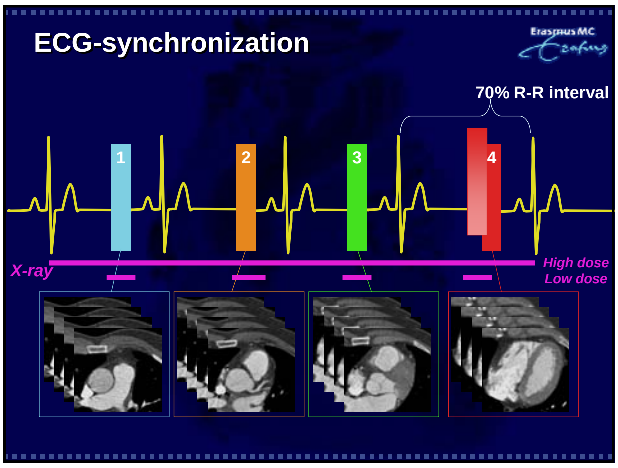
- We know the heart has periods of motion and rest.

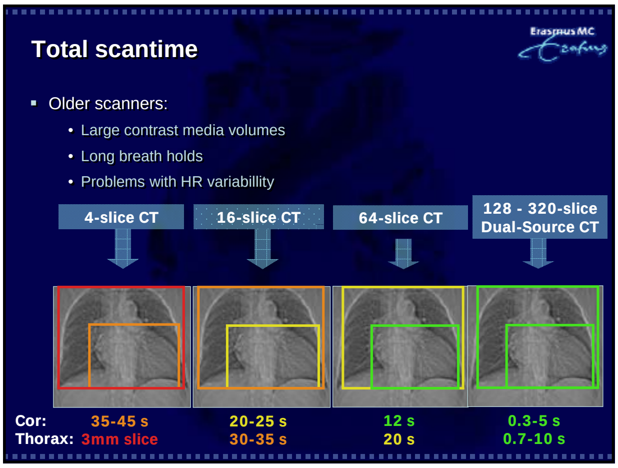


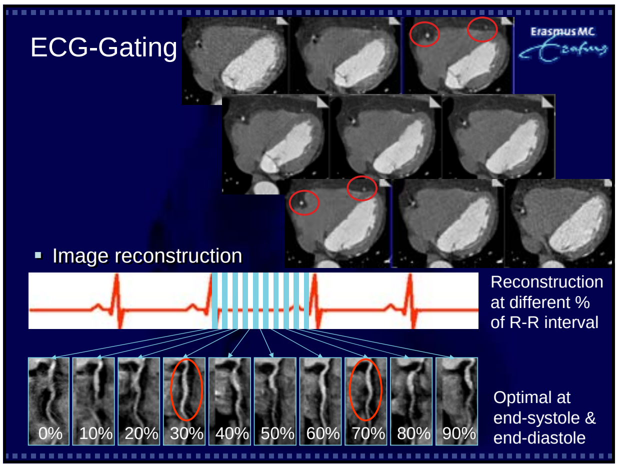
ECG-synchronization

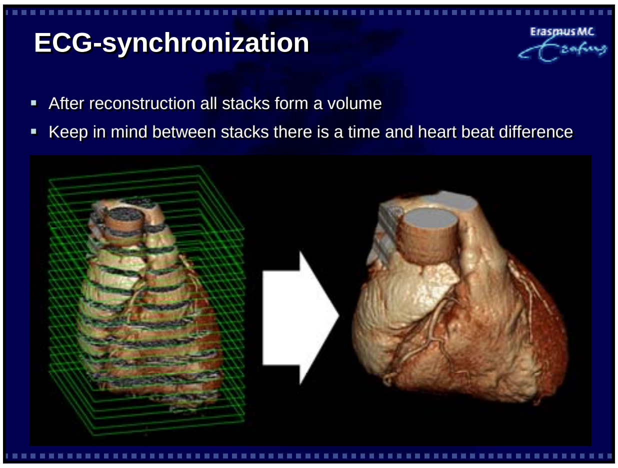
- We can measure the electric signal
- With the measured ECG we can <u>estimate</u> the rest period

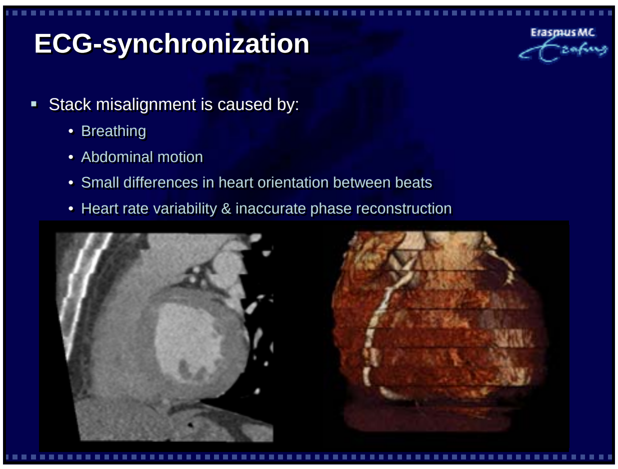


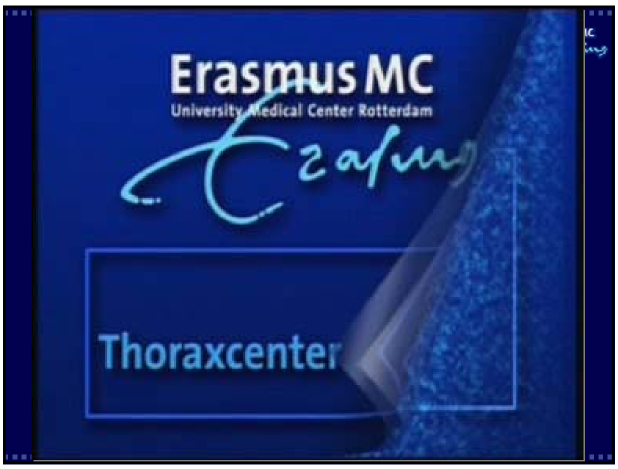

ECG-synchronization
70% R-R interval
1
2
3
4
X-ray
High dose
Low dose

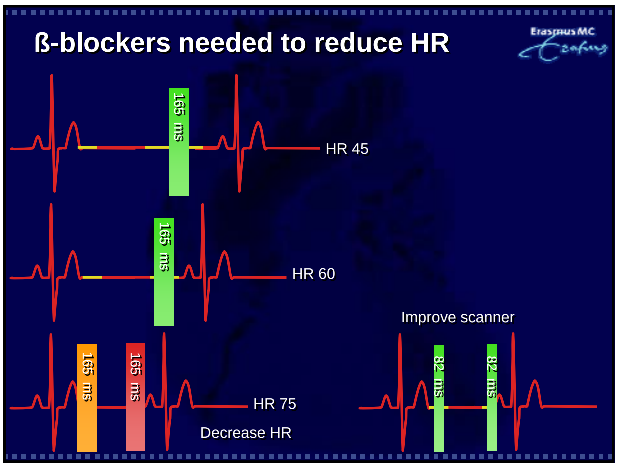

Total scantime
Older scanners:
Large contrast media volumes
Long breath holds
Problems with HR variabillity
4-slice CT
16-slice CT
64-slice CT
128 - 320-slice
Dual-Source CT
Cor: 35-45 s
Thorax: 3mm slice
20-25 s
30-35 s
12 s
20 s
0.3-5 s
0.7-10 s

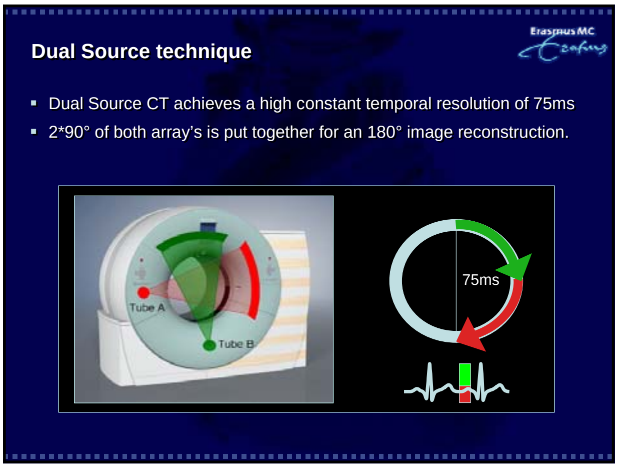

ECG-Gating
Image reconstruction
Reconstruction at different % of R-R interval
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
Optimal at end-systole & end-diastole

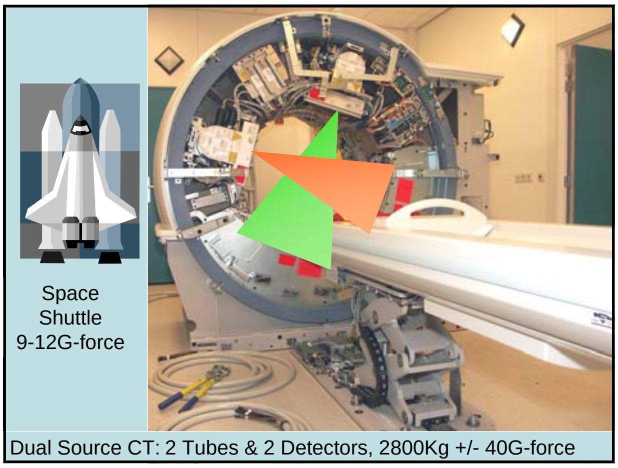

ECG-synchronization
After reconstruction all stacks form a volume
Keep in mind between stacks there is a time and heart beat difference

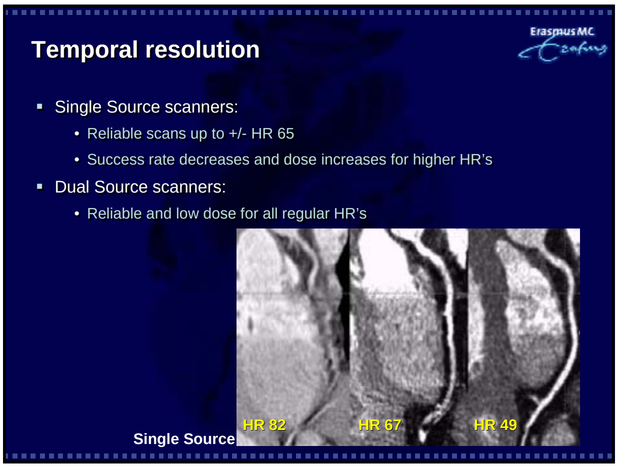

ECG-synchronization
Stack misalignment is caused by:
Breathing
Abdominal motion
Small differences in heart orientation between beats
Heart rate variability & inaccurate phase reconstruction

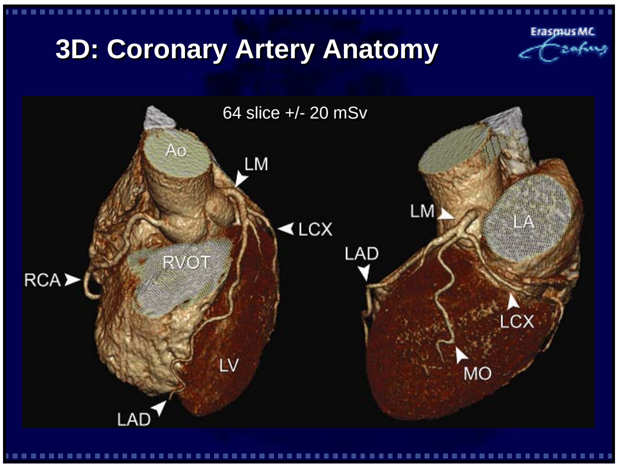

Erasmus MC
University Medical Center Rotterdam
Thoraxcenter

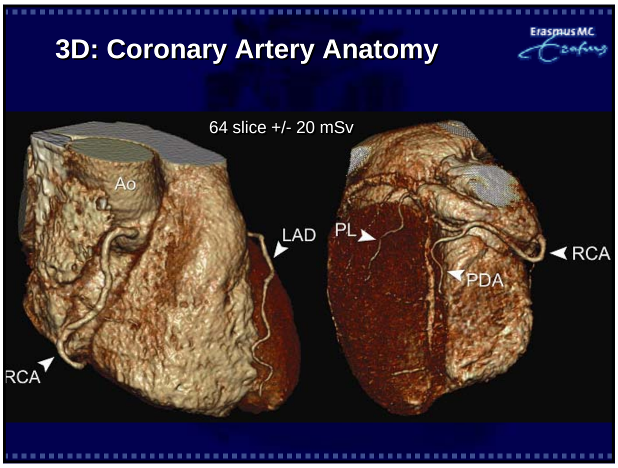

ß-blockers needed to reduce HR
165 ms
HR 45
165 ms
HR 60
Improve scanner
165 ms
165 ms
HR 75
82 ms
82 ms
Decrease HR

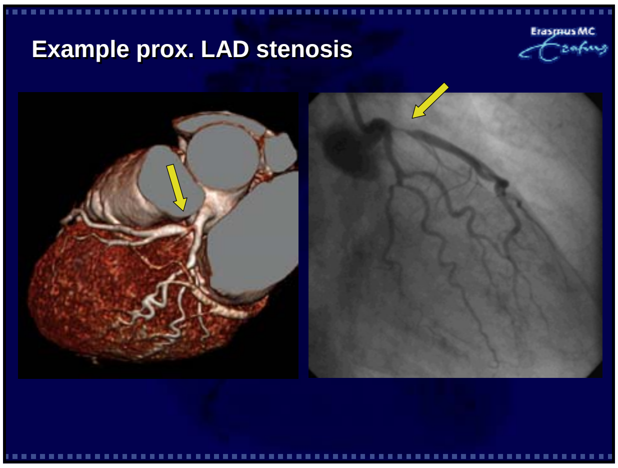

Dual Source technique
Dual Source CT achieves a high constant temporal resolution of 75ms
2*90° of both array's is put together for an 180° image reconstruction.
Tube A
Tube B
75ms

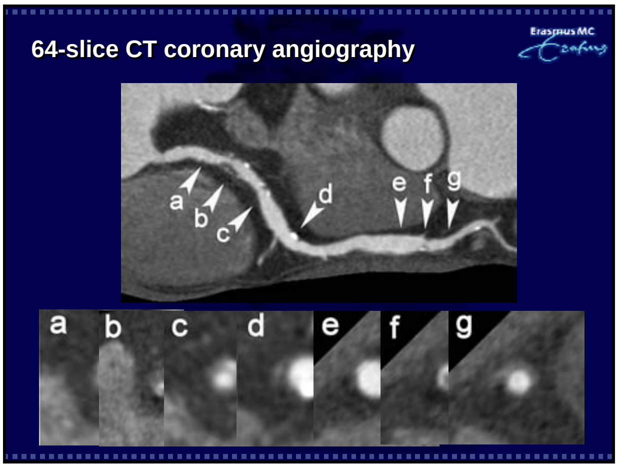

Space
Shuttle
9-12G-force
Dual Source CT: 2 Tubes & 2 Detectors, 2800Kg +/- 40G-force

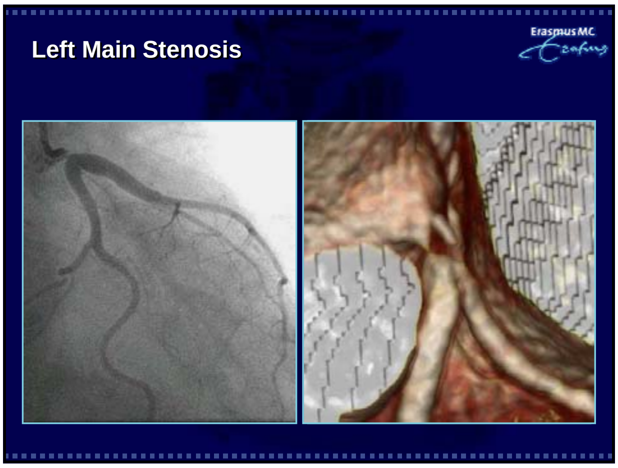

Temporal resolution
Single Source scanners:
Reliable scans up to +/- HR 65
Success rate decreases and dose increases for higher HR's
Dual Source scanners:
Reliable and low dose for all regular HR's
Single Source
HR 82
HR 67
HR 49

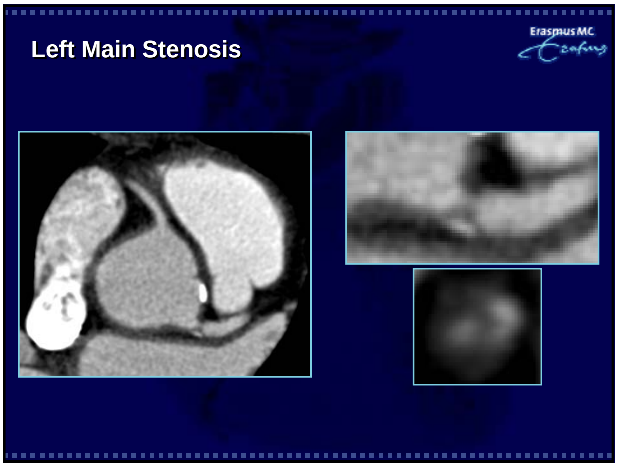

3D: Coronary Artery Anatomy
64 slice +/- 20 mSv
Ao
LM
LCX
RVOT
RCA
LV
LAD
LM
LA
LAD
LCX
MO

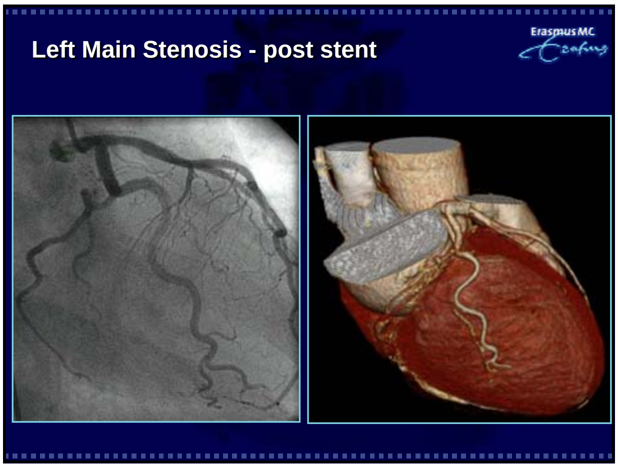

3D: Coronary Artery Anatomy
64 slice +/- 20 mSv
Ao
LAD
RCA
PL
RCA
PDA

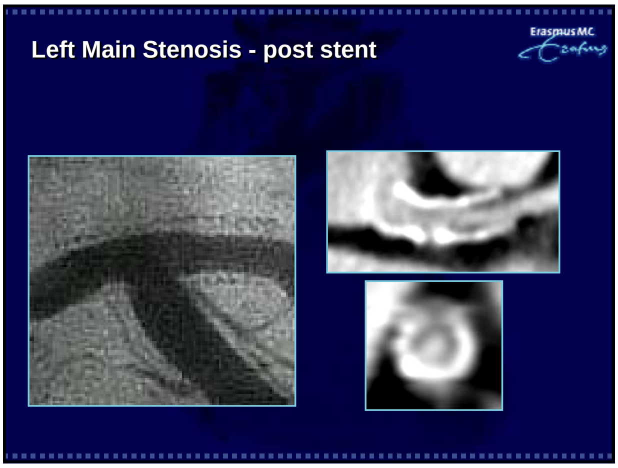

Example prox. LAD stenosis

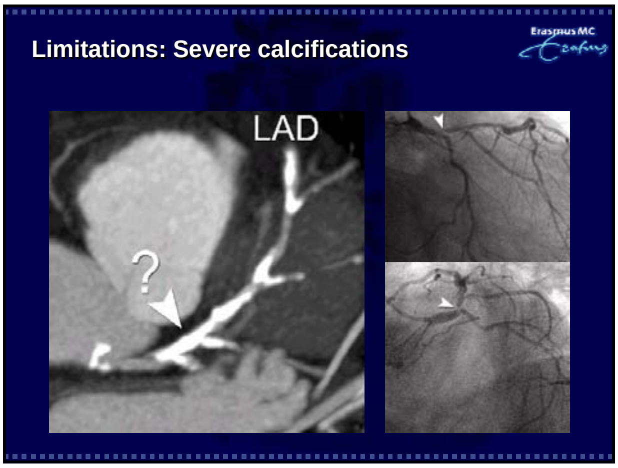

64-slice CT coronary angiography
a
b
c
d
e
f
g

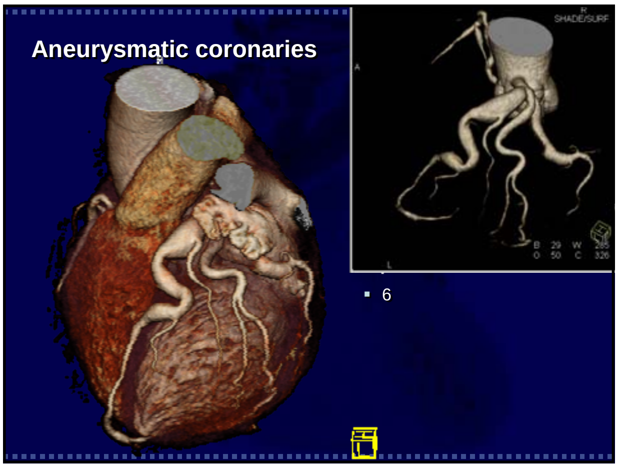

Left Main Stenosis

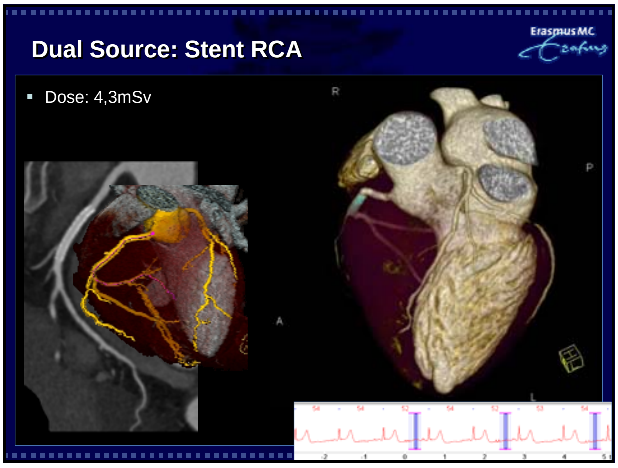

Left Main Stenosis

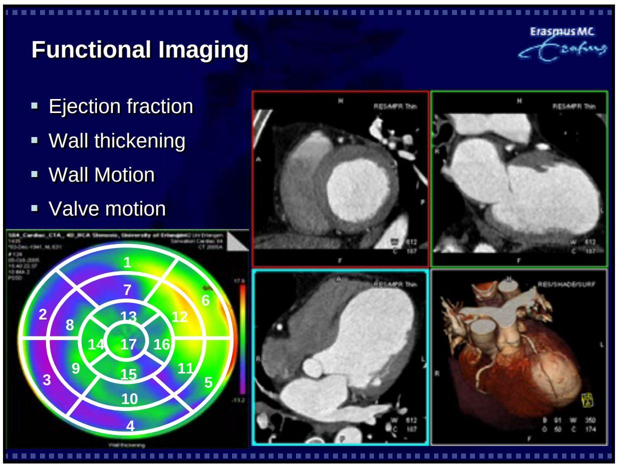

Left Main Stenosis - post stent

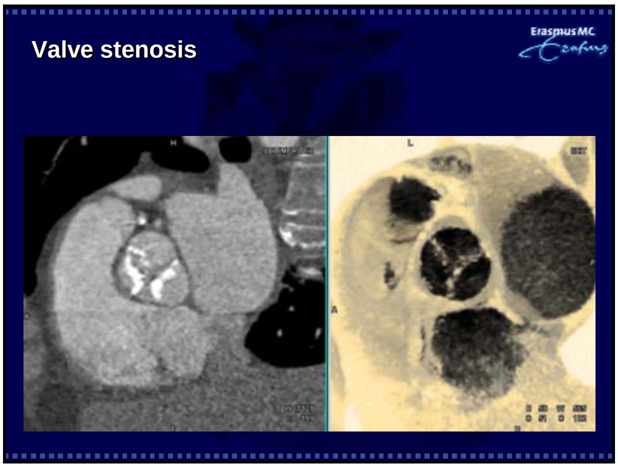

Left Main Stenosis - post stent

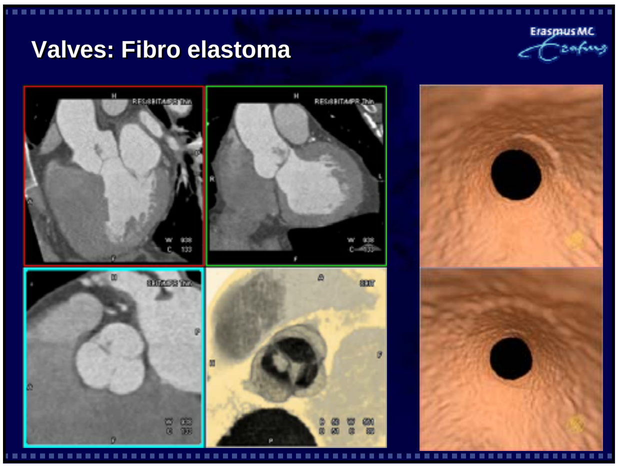

Limitations: Severe calcifications
Erasmus MC
LAD
?


Aneurysmatic coronaries
SHADE/SURF
6

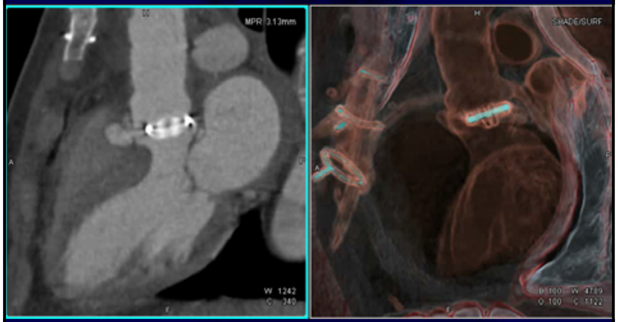

Dual Source: Stent RCA
Erasmus MC
Dose: 4,3mSv


Functional Imaging
Erasmus MC
Ejection fraction
Wall thickening
Wall Motion
Valve motion
1
7
2
8
13
12
6
14
17
16
9
15
11
3
10
5
4


Valve stenosis
Erasmus MC

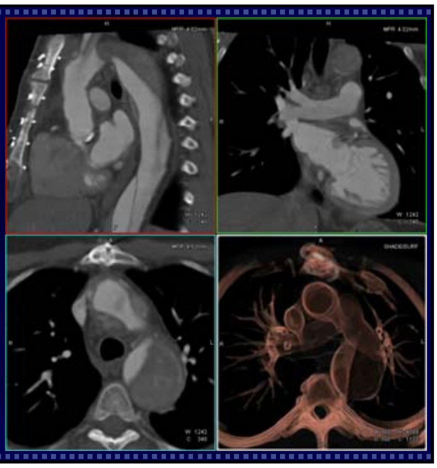

Valves: Fibro elastoma
Erasmus MC

Pericarditis with valve dislocation



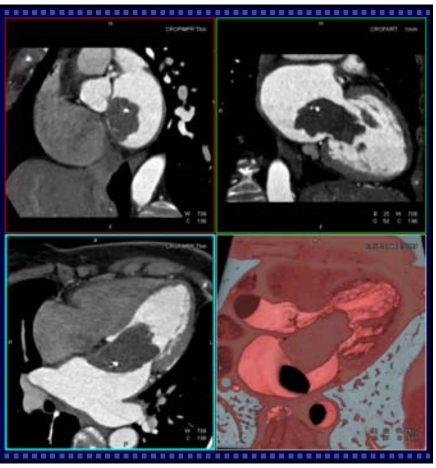
Dissection

- +/- 20 mSv



Mixoma

- Dual Source
- +/- 15 mSv



Diagnostic image quality

- Diagnostic performance of 64-slice CCTA versus conventional coronary angiography.
  - Good results are achieved with low exclusion %.
  - However results are achieved in HR controlled patient groups.

64-slice	N segments	Sens (%)	Spec. (%)	PPV (%)	NNP (%)	Excl. (%)
Leschka, Eur	1005	94	97	87	99	0
Heart	1065	86	95	66	98	12
Raff, JACC	725	99	95	76	100	0
Mollet,Circulation	725	76	97	75	97	0
Leber, JACC	1083	93	97	56	100	4
Ropers, AJC	842	85	98	82	99	1.2
Schuijf, AJC						

Diagnostic image quality

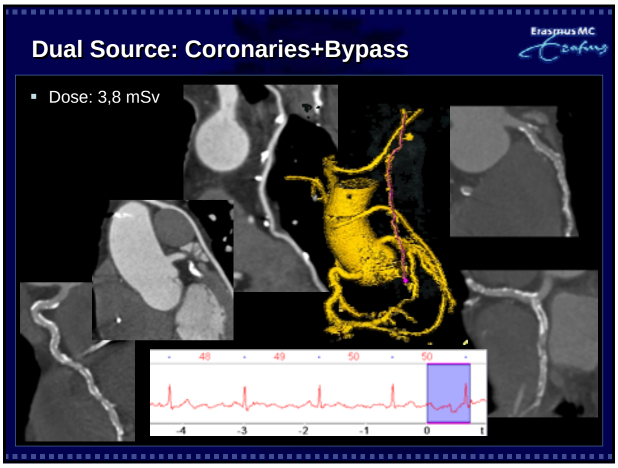
- Diagnostic performance of 64-slice Dual Source CCTA versus conventional coronary angiography.
  - Results are achieved without heart rate control.

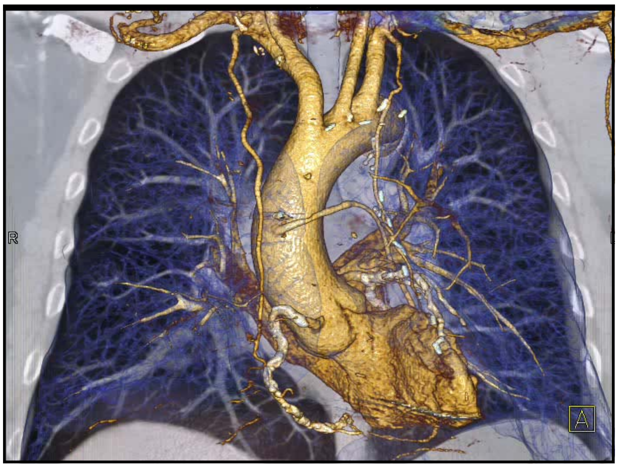
Dual Source	N	Sens. (%)	Spec. (%)	PPV (%)	NNP (%)	Excl. (%)
Weustink et al,	1489*	95	95	75	99	0
J Am Coll Cardiol.	100*	99	87	96	95	0
Scheffel et al,	420*	96	98	86	99	1,4
Eur.Radiology						

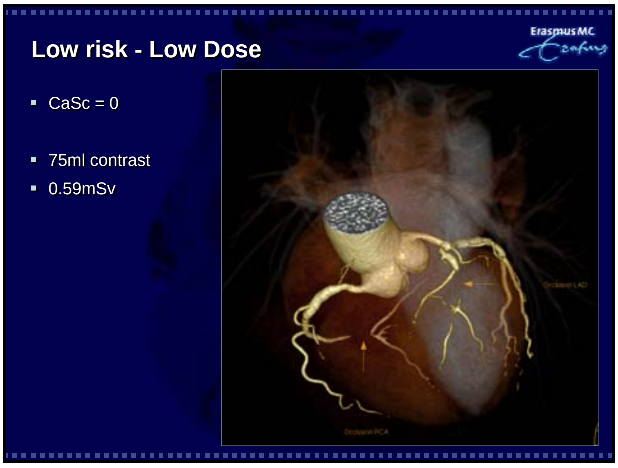
* segment based
* patient based

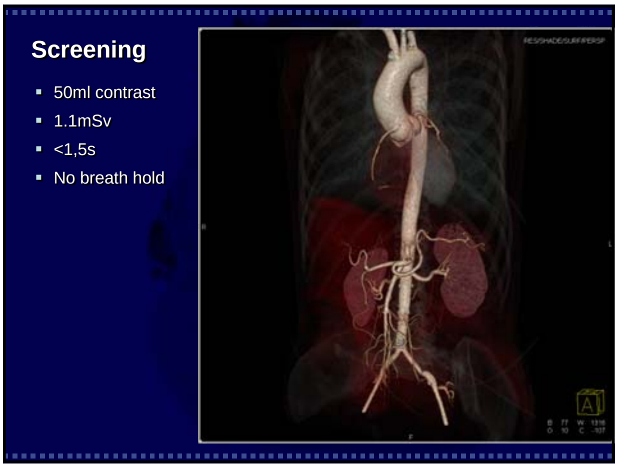
Dose overview

	E range in mSv (mean)	ECG tube modulation
Average background radiation (United States)	1.0–10 (3.6)	-
Conventional coronary angiography	3.1–21.8 (5.6)	-
Nuclear MPI studies	2.2–31.5	-
Ca scoring (retrospectively gated helical)	1.0–6.2	-
Ca scoring (prospectively gated axial)	1.0–3.0	-
CTCA (retrospectively gated helical)		
16-slice	5.7–13	No
16-slice	2.9–5.6	Yes
64-slice	9.4–21.4	Yes
64-slice dual source	7.8–16.9	Yes
320-slice	10.1–18.1	No
CTCA (prospectively gated axial)		
64-slice	0.75–6.7 (2.8)	-
320-slice	4.9–16.5	-
128-slice Dual Source		
low stable heart rate (prospective hight pitch spiral)	**0.5-1.8mSv**	**no**
medium & high heart rate (prospective axial)	**1.2-5mSv**	**yes**

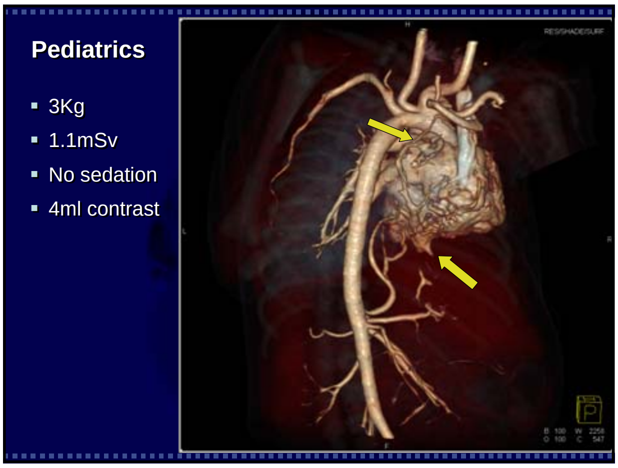

Dual Source: Coronaries+Bypass
Erasmus MC
Dose: 3,8 mSv




Low risk - Low Dose
Erasmus MC
CaSc = 0
75ml contrast
0.59mSv


Screening
50ml contrast
1.1mSv
<1,5s
No breath hold


Pediatrics
3Kg
1.1mSv
No sedation
4ml contrast


Pediatrics
3Kg
1.1mSv
No sedation
4ml contrast

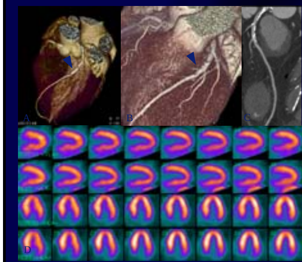
Pediatrics

- 3Kg
- 1.1mSv
- No sedation
- 4ml contrast

Myocardial Perfusion

Only 45% of patients with an abnormal CTCA have abnormal myocardial perfusion imaging (MPI) compared to SPECT. Of patients with obstructive coronary artery disease (CAD) on CTCA, 50% still have normal MPI

Schuijf JD et al (2006), JACC

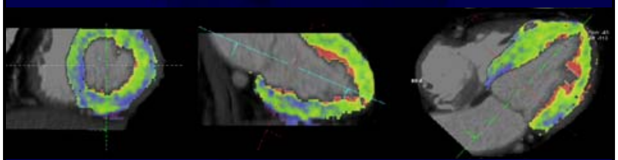


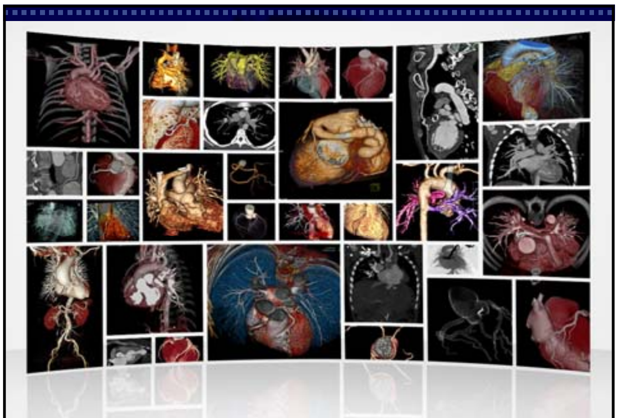
Discrepancy between CTCA and SPECT.

Myocardial perfusion imaging (MPI) and CTCA provide different and complementary information on CAD: detection of atherosclerosis versus detection of ischemia

Future developments

- CT myocardial perfusion
  - Anatomy and (stress) function
  - Fast
  - Non-invasive
  - Low radiation





Cardiac CT: Diagnostic modality of the future !