Medical Imaging

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History of medical imaging

- X-rays - Roentgen, 1895
- Nuclear medicine - Cassen, 1951
- Ultrasound – Donald, 1962
- SPECT - Kuhl, Edwards, 1963
- PET – Ter-Pogossian, 1972
- MR - Lauterbur, Mansfield, Hutchison, 1972
- CT - Hounsfield, 1973

Planar X-ray

- Relies on contrast from electron density
- Radiation dose per view
  - limits number of images
- Spatial resolution ~ 0.1mm
- Temporal resolution ~ 10ms

Ultrasound

- Relies on differences in acoustic impedance
- No known side effects at diagnostic power
- Spatial resolution ~ 2-3mm
- Temporal resolution ~ 40ms

Nuclear medicine

- Requires radiolabel
- Radiation dose per administration
- Spatial resolution ~ 6-10mm
- Temporal resolution ~ 50ms

SPECT

- Requires radiolabel
- Radiation dose per administration
- Spatial resolution ~ 8-10mm
- Temporal resolution ~ 10min

PET

- Requires radiolabel
- Radiation dose per administration
- Spatial resolution ~ 3-5mm
- Temporal resolution ~ 5min
- On-site/nearby cyclotron (except F-18)

MR

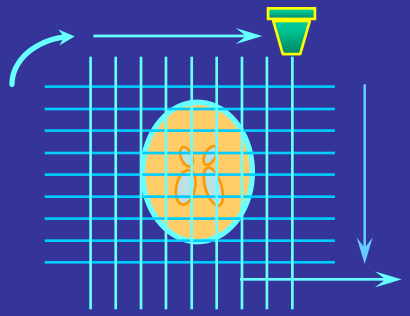
- Relies on proton density
- No known side effects at current field strengths
- Spatial resolution ~ 0.1mm
- Temporal resolution ~ 100ms

CT

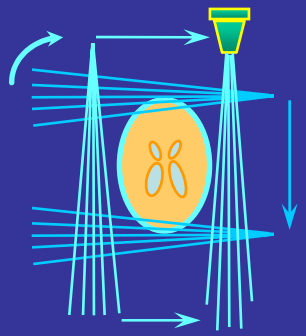
- Relies on contrast from electron density
- Radiation dose per view
- Spatial resolution ~ 0.1mm
- Temporal resolution ~ 0.5s

FOUR GENERATIONS OF CT SCANNER

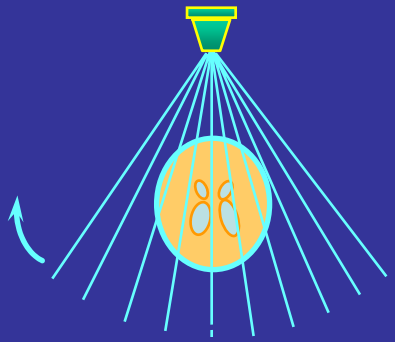
1st Generation



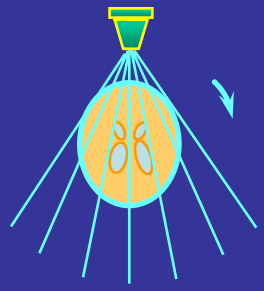
2nd Generation



3rd Generation

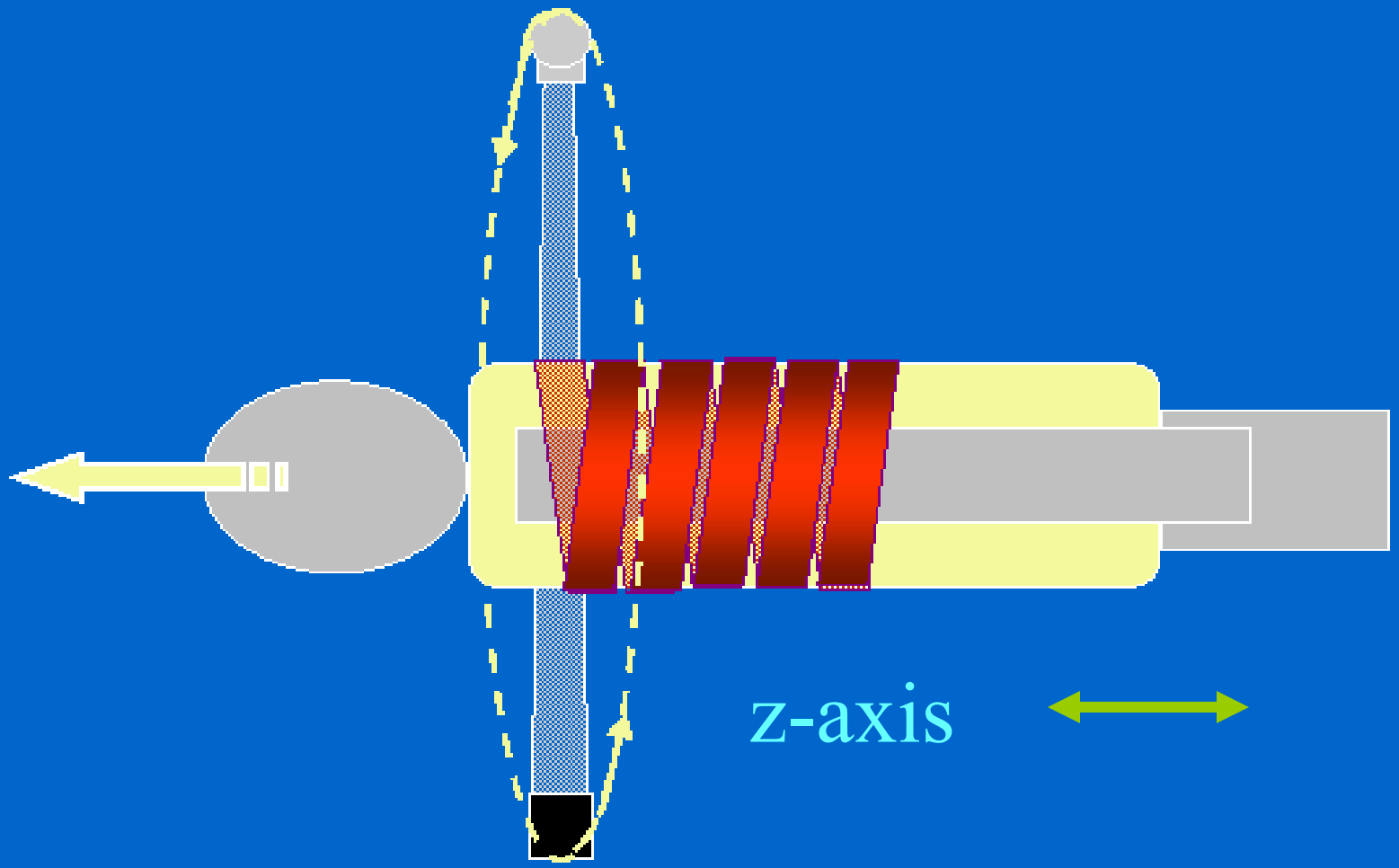


4th Generation

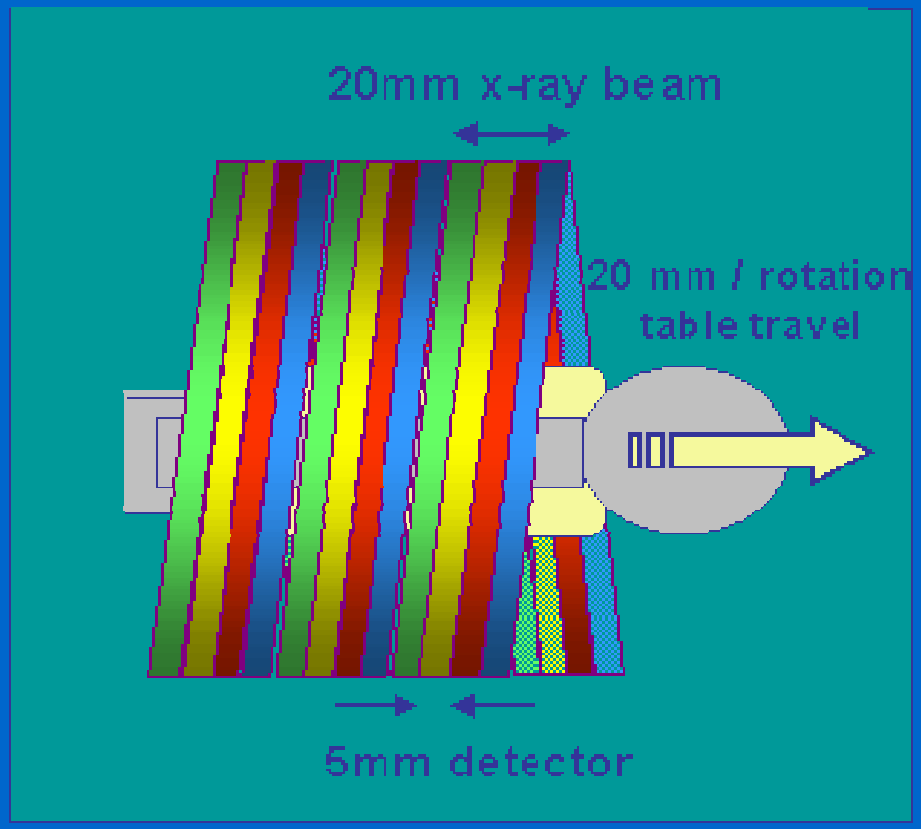


1st and 2nd	♦ no longer produced commercially for medical use
3rd	♦ ray sample spacing fixed by detector pitch ♦ sensitive to detector channel signal stability ♦ x-axis scatter collimation
4th	♦ may be not be practical as a multislice ♦ x-axis scatter collimation not practical ♦ sample spacing not restricted by ♦ sensitive to periodic modulation

Helical scanning

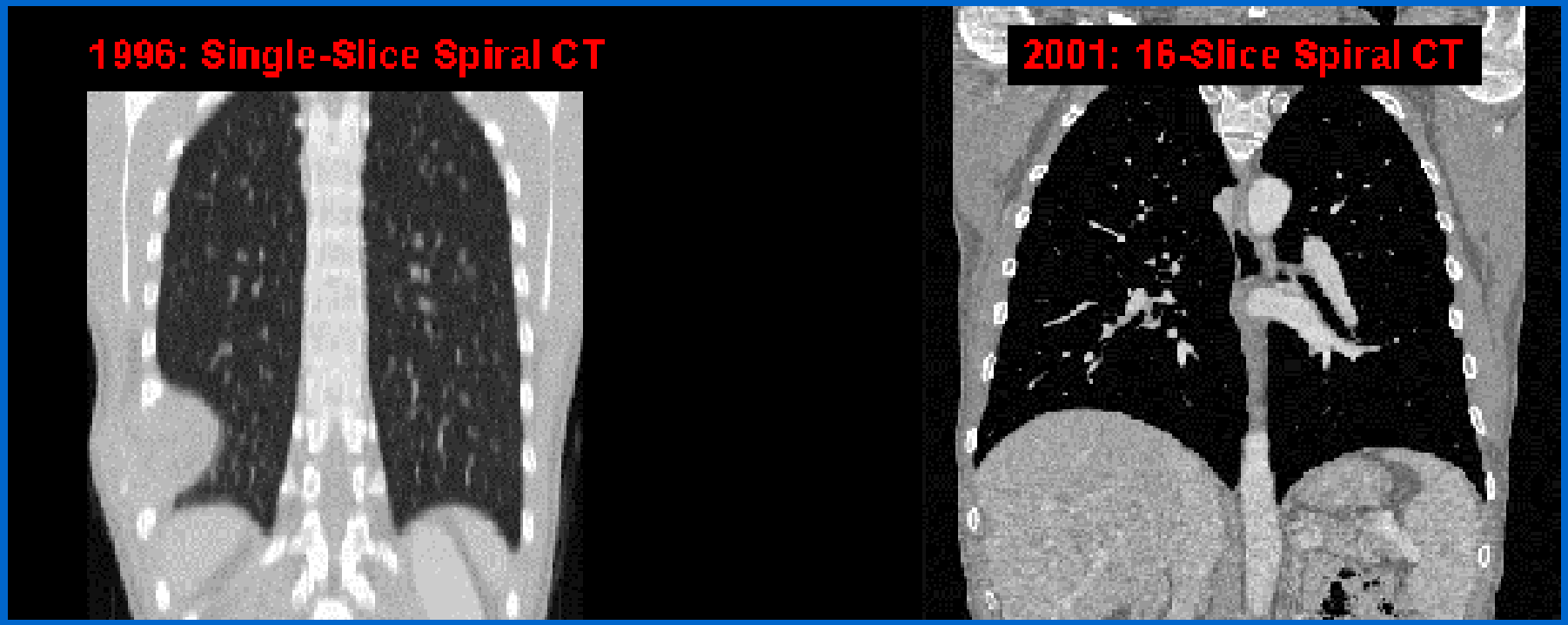


$Pitch_x$ and $Pitch_d$



- $Pitch_x = \frac{20}{20} = 1$
- $Pitch_d = \frac{20}{5} = 4$

Thinner slices → better z-axis resolution

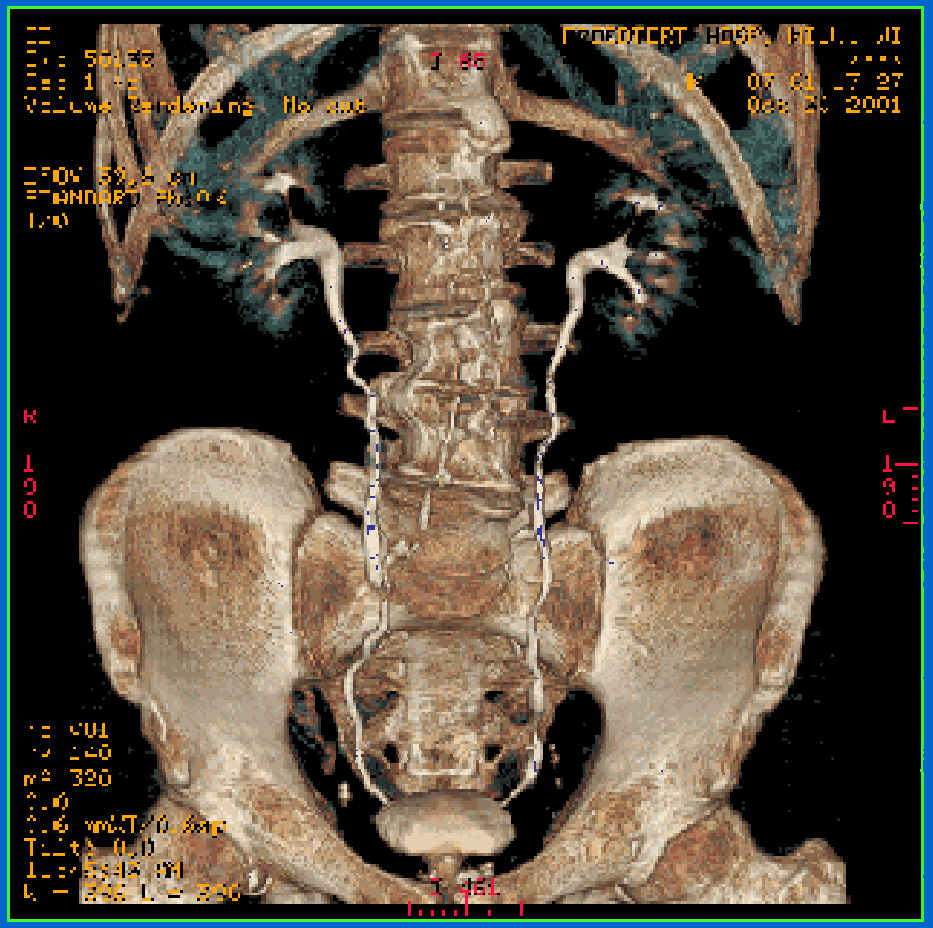


Courtesy: Prof. Kalender, University of Erlangen

- Near-isotropic imaging achieved using 0.5 mm slices
- Finer detail perceptible in multi-planar reformats

Thinner slices → better 3D images

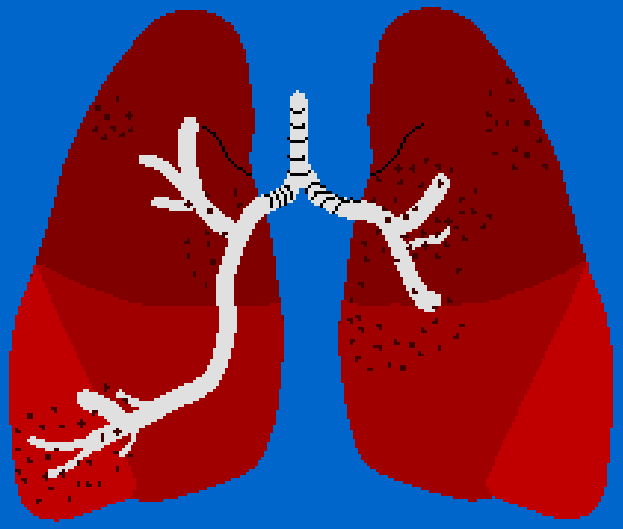
- Large numbers of narrow slices provide high quality volume rendering
- Stair-step artefacts virtually eliminated, edges well-defined



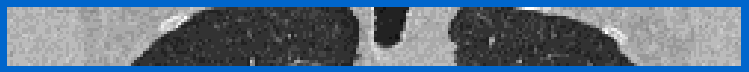
Courtesy: GE Medical Systems

Longer volumes → more useful scans

How many 1 mm slices in 30 sec scan time?



30

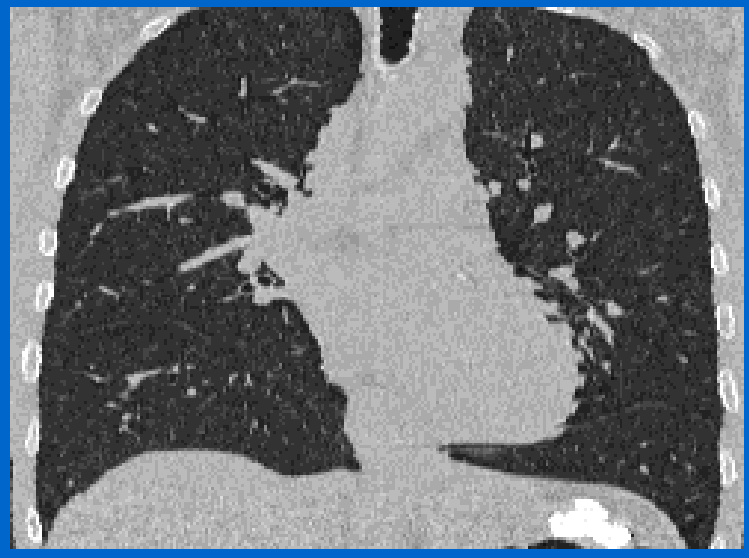


1 sec rotation, single-slice

60

0.5 sec rotation, single-slice

240

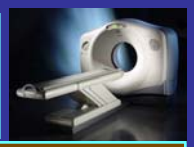


0.5 sec rotation, four-slice

Courtesy: Siemens

Detector development

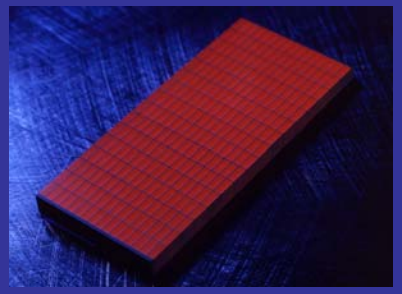
QX/i

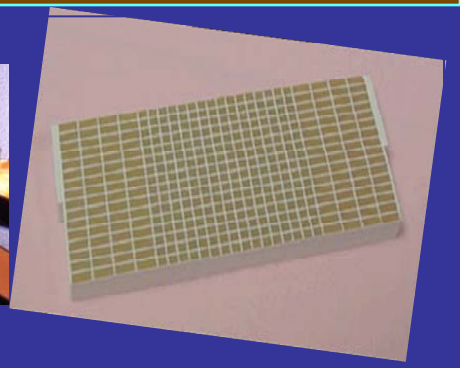


LightSpeed Plus

LightSpeed Ultra

LightSpeed & LightSpeed pro 16





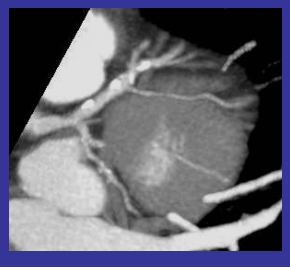
HiLight Matrix detector

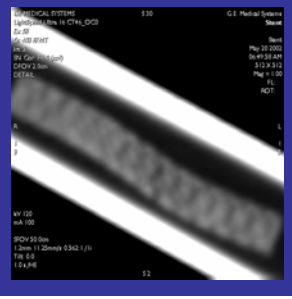
HiLight II Matrix detector

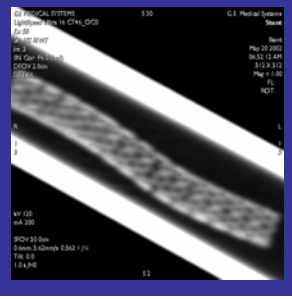
0.5 sec
4x 1.25 mm
30-40 sec
15 cm

0.5 sec
8x 1.25 mm
15- 20 sec
15 cm

0.5 sec
16x 1.25 mm / 16 x 0.6 mm





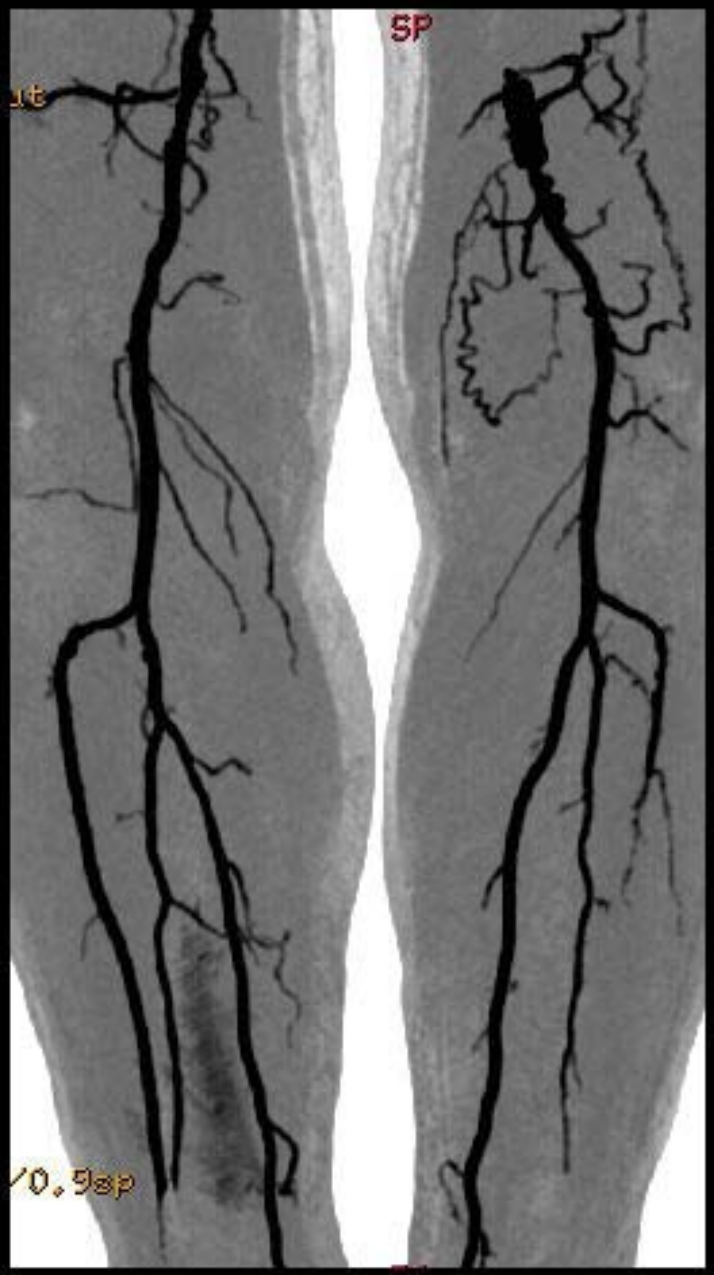


Performance Factors

Image Quality

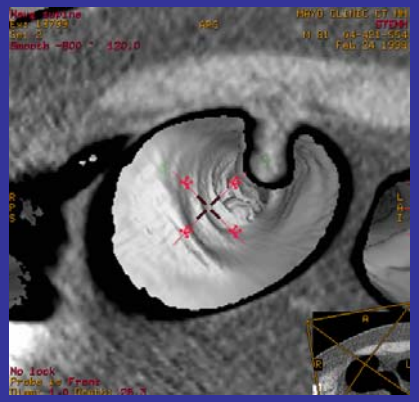
Dose

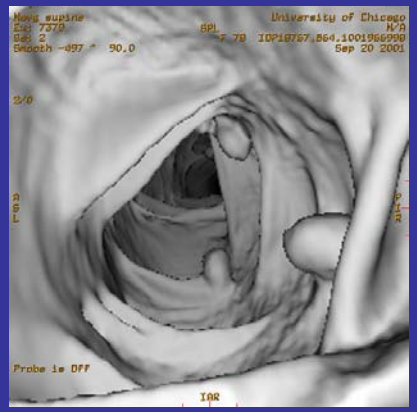
Speed



(Shut.)

CT Colonoscopy





- Colorectal cancer is the 2nd most common cause of cancer deaths
  → 135,000 new cases in 2001 (US)
  → 5-year life expectancy is 61%
- Key concept: Removal of precursor polyps diminishes cancer risk
- Current methods have significant barriers to early detection

A non-invasive test for early polyp detection

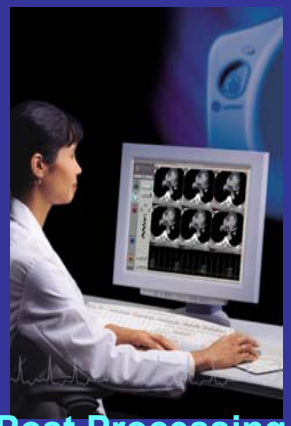
CT Imaging Workflow

Patient Prep

Acquisition

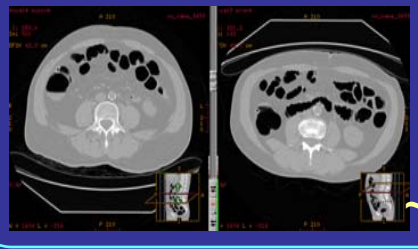
Recon
1~2 min

Auto transfer



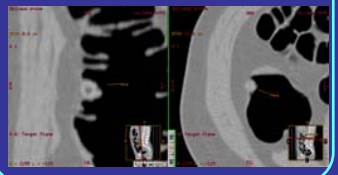
Post Processing
CT Colonography™

Review/Bookmark mode



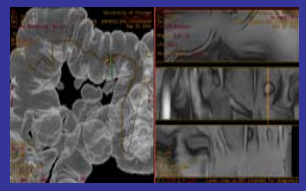
~6 min

Analyze



~3 min

Analyze: Nav+

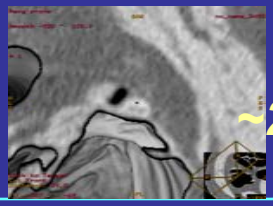


~3 min

Endoluminal view

~2 min

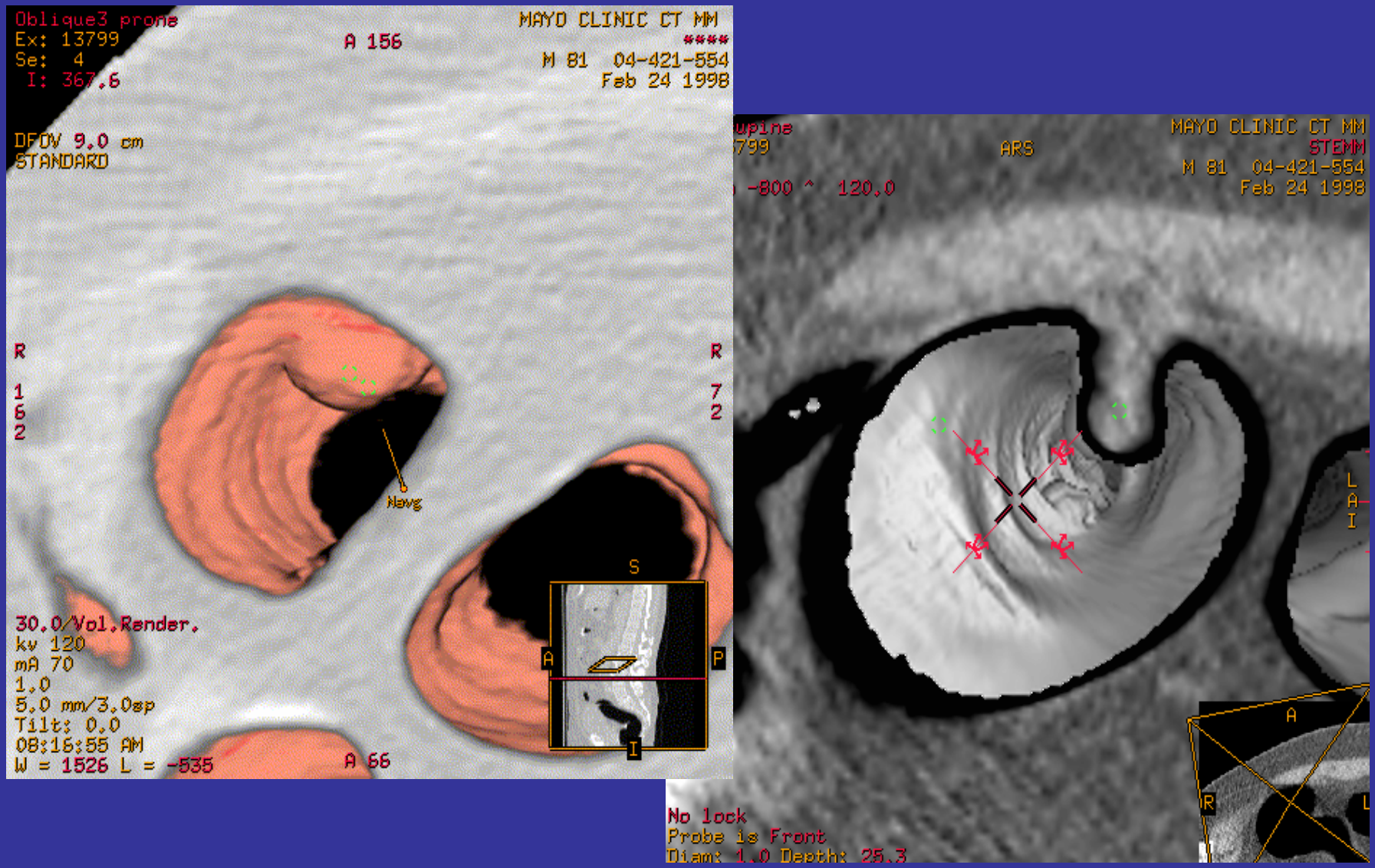
Cut



~2 min

VR

~2 min


Oblique3 prone
Ex: 13799
Se: 4
I: 367.6
A 156
MAYO CLINIC CT MM
****
M 81 04-421-554
Feb 24 1998
DFOV 9.0 cm
STANDARD
R
162
Navg
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72
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A
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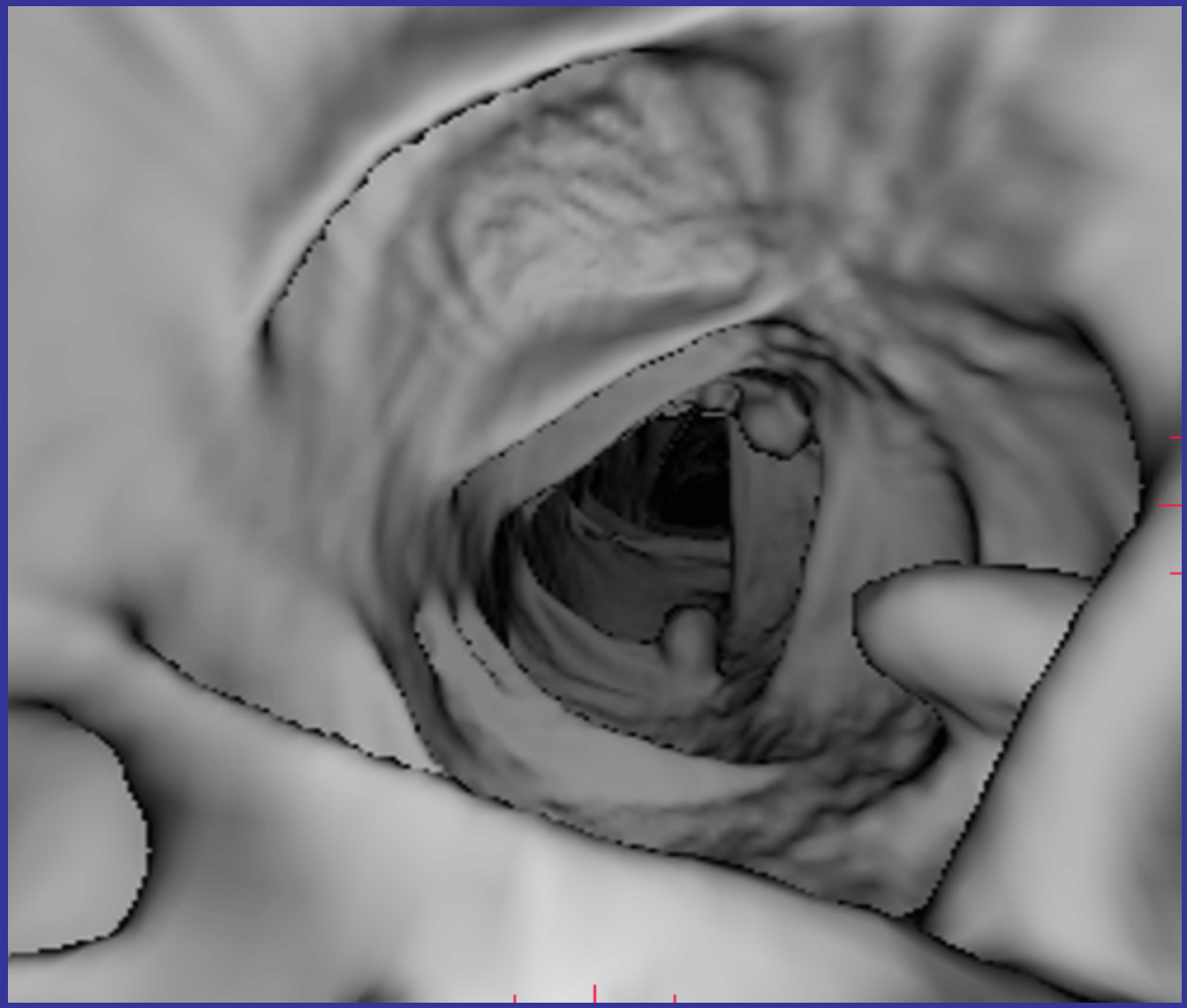
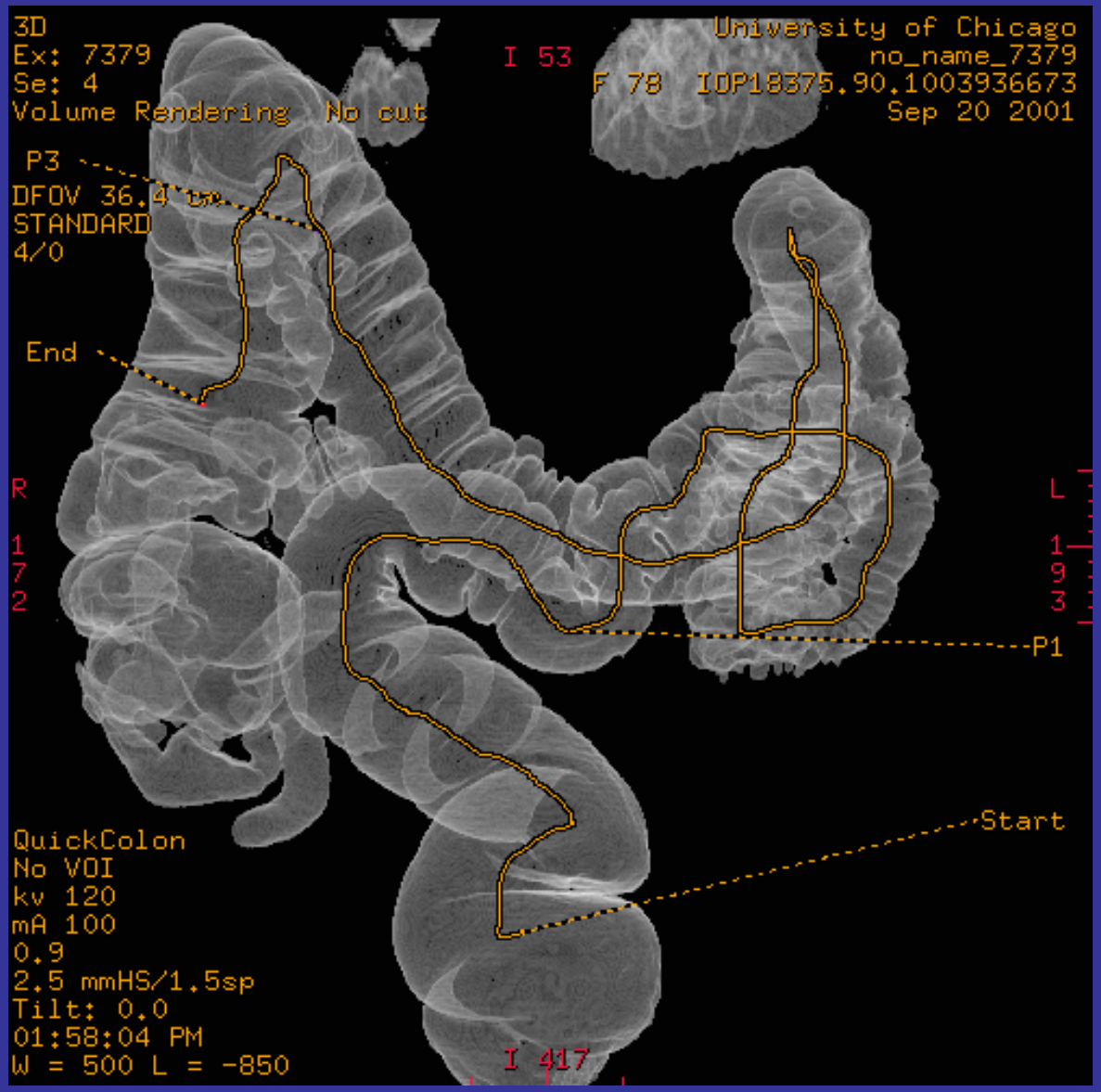
kv 120
mA 70
1.0
5.0 mm/3.0sp
Tilt: 0.0
08:16:55 AM
W = 1526 L = -535
A 66
upine
799
ARS
-800 ^ 120.0
MAYO CLINIC CT MM
STEMM
M 81 04-421-554
Feb 24 1998
L
A
I
A
R
L
No lock
Probe is Front
Diam: 1.0 Depth: 25.3

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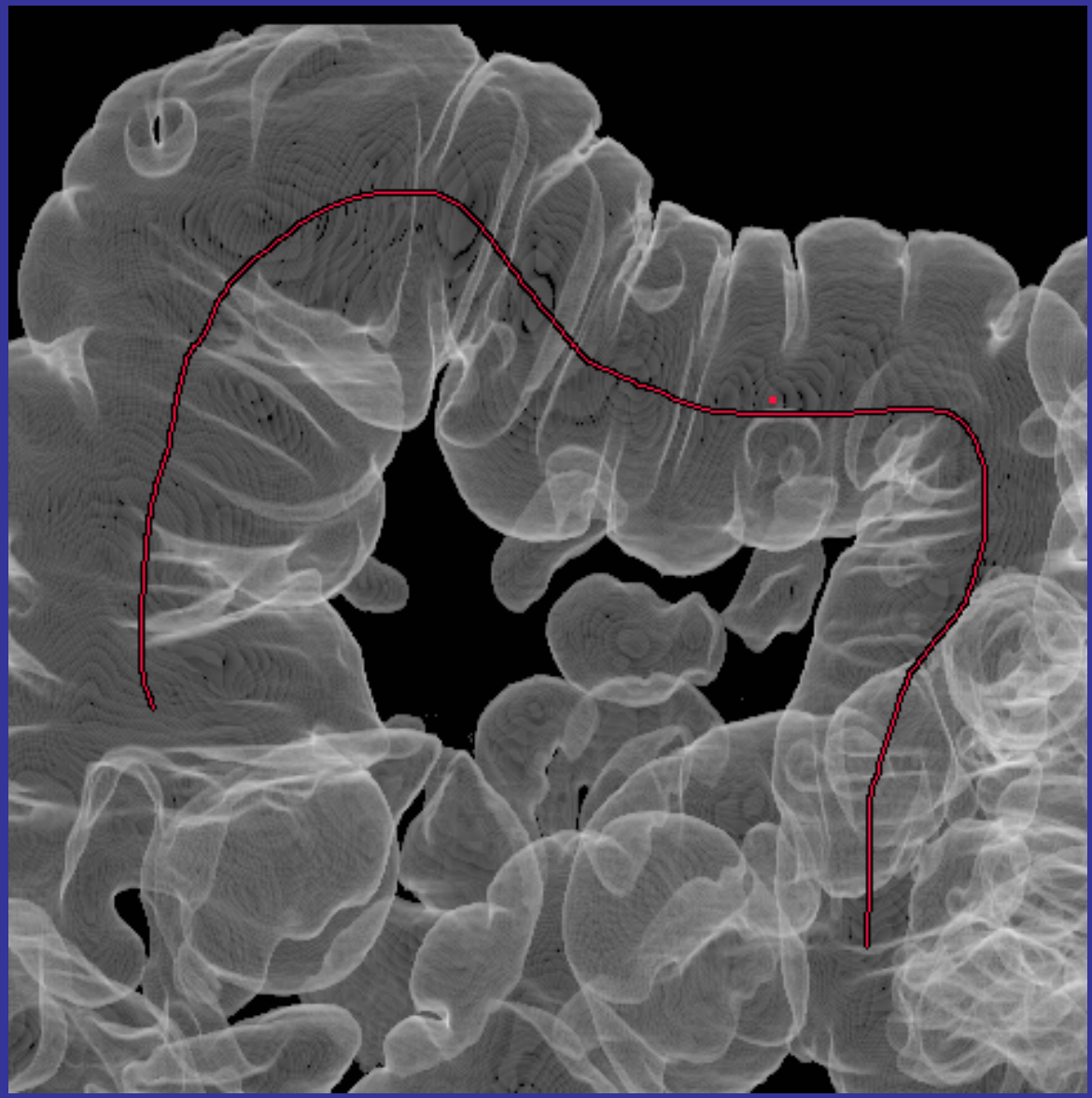
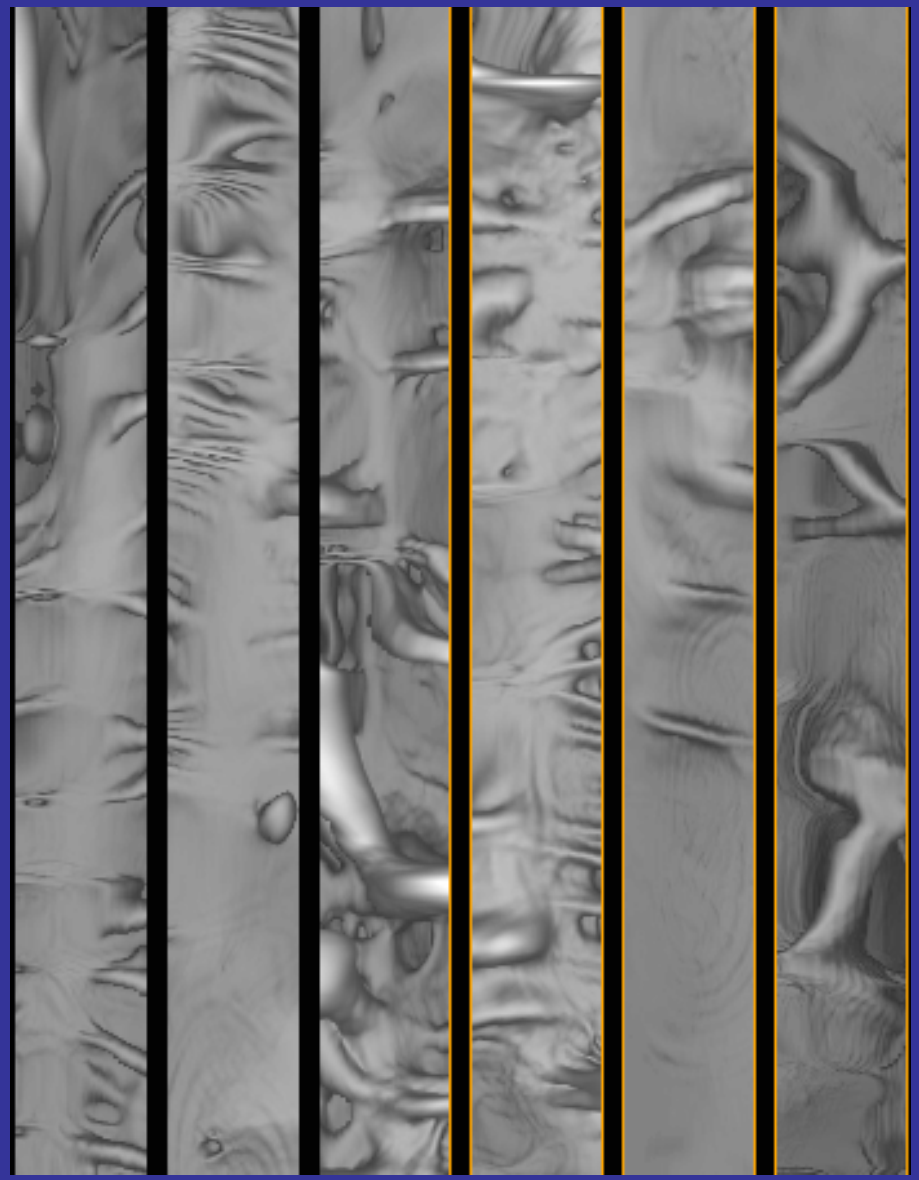
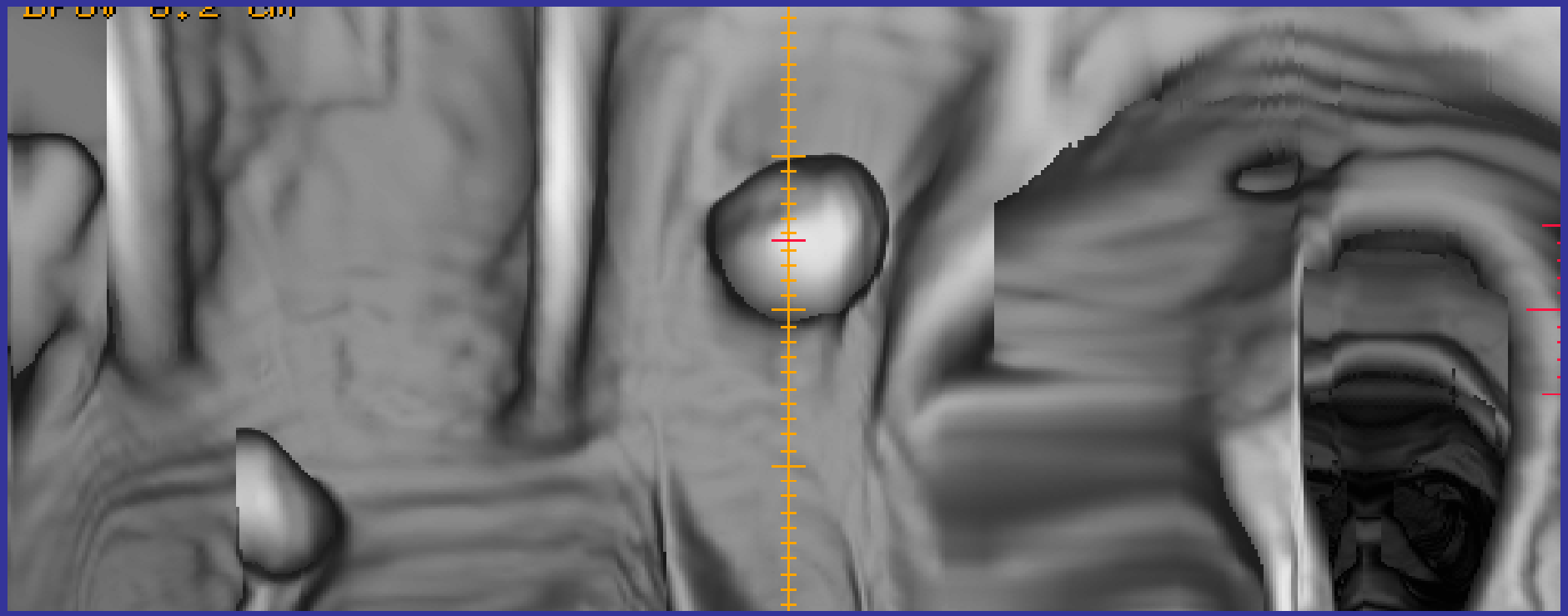
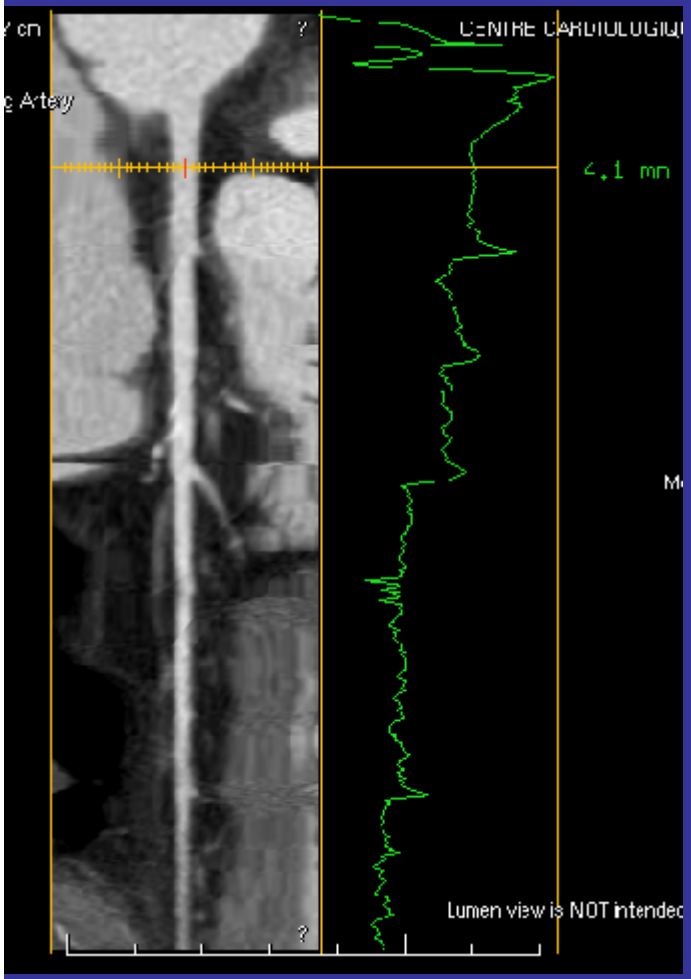
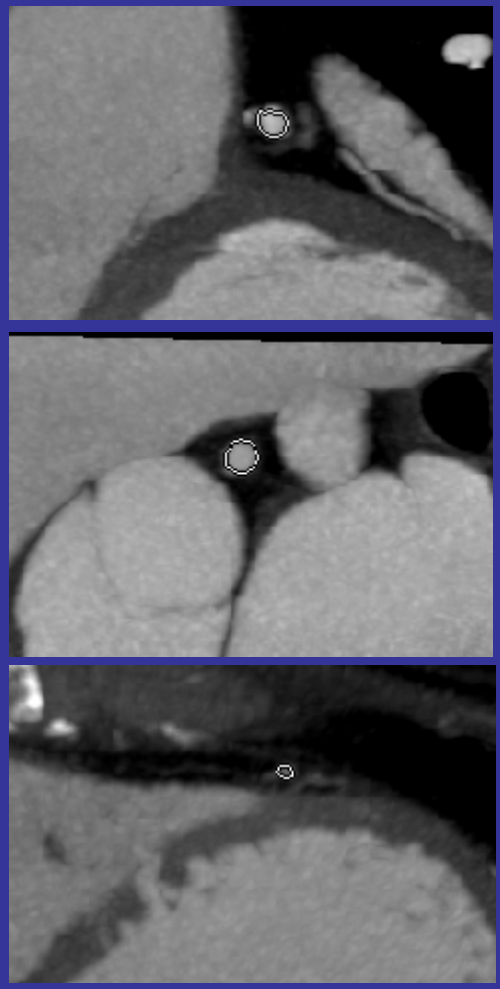






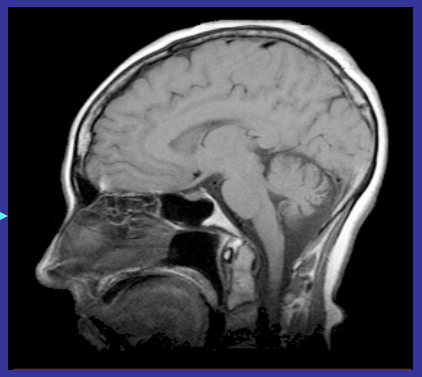
Coronary arteries

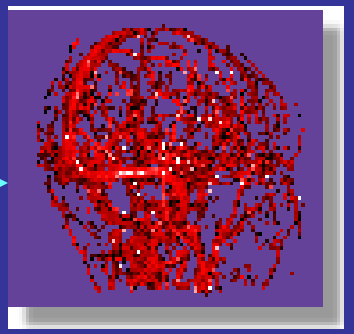


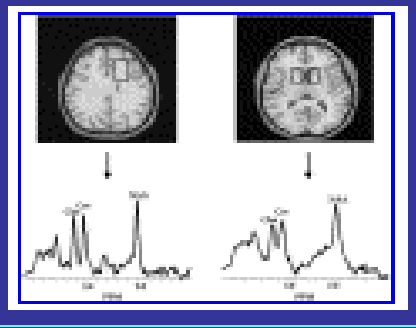


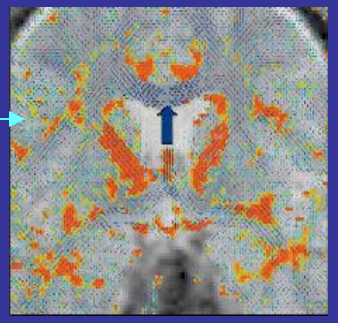
MRI: Buy one, get four free.

- MRI imaging
- MRA angiography
- MRS spectroscopy
- fMRI functional
- DTI diffusion tensor

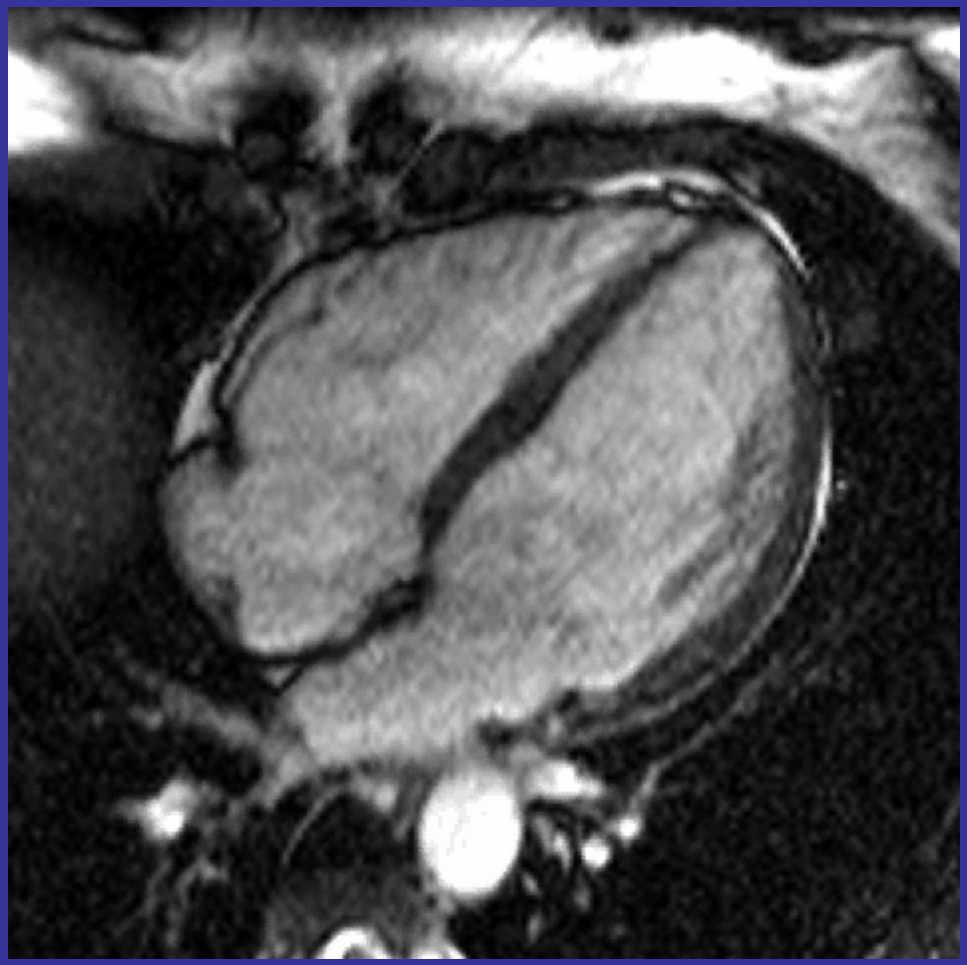




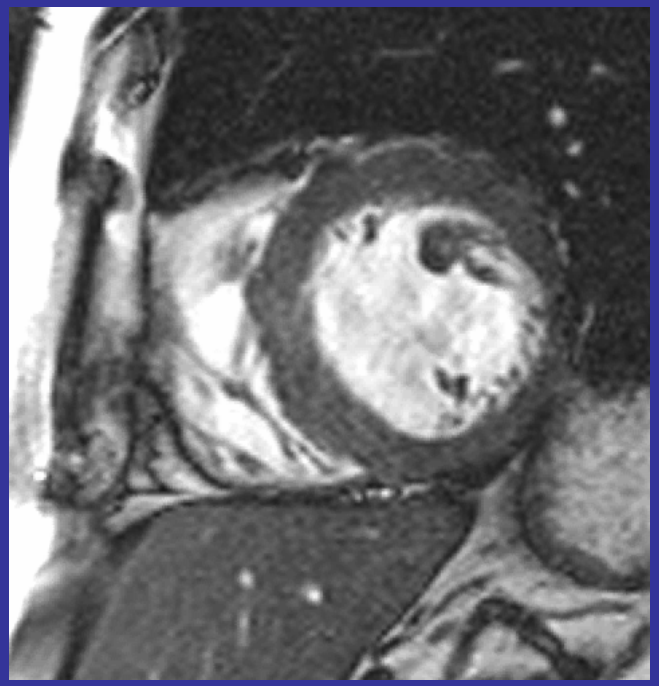


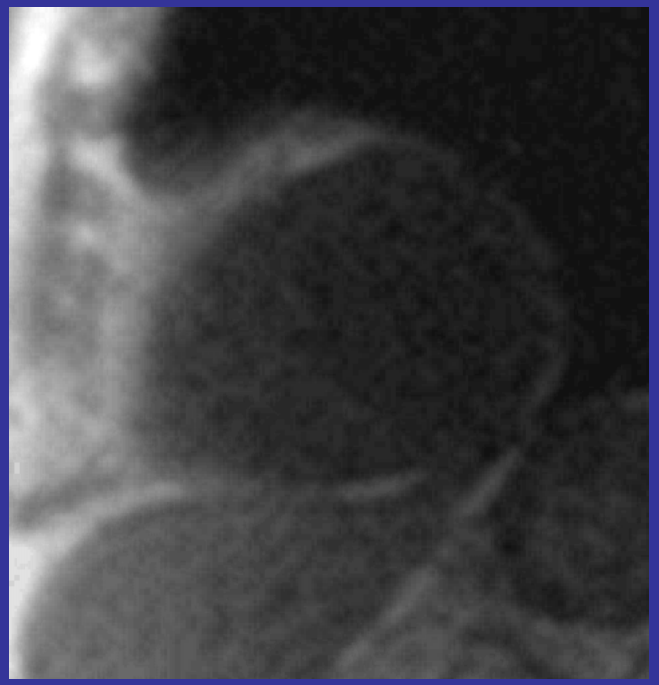


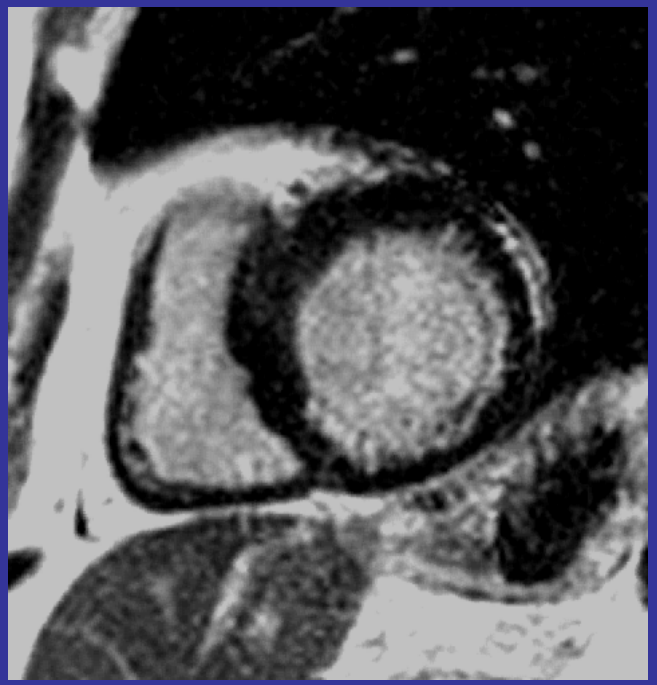
Normal 4 chamber (4ch)



Normal short axis (sa)

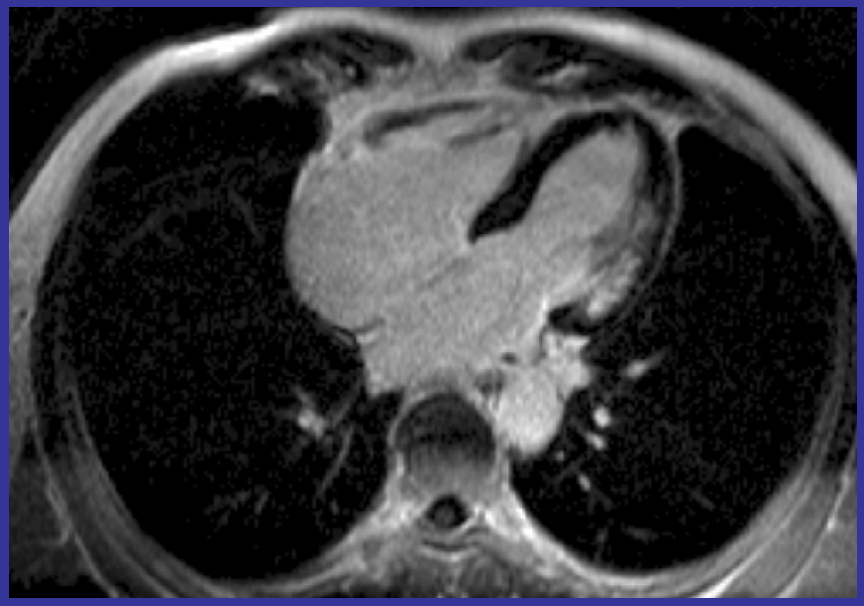


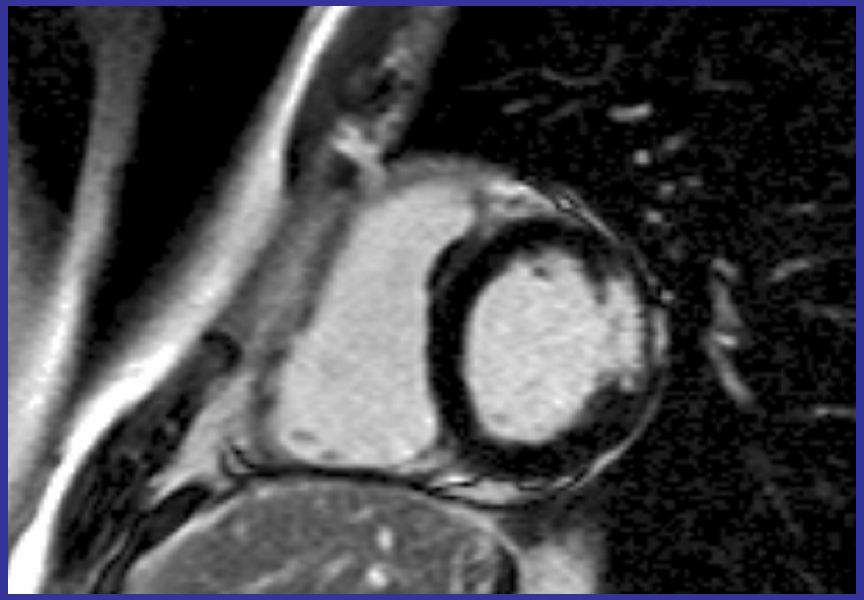




Series of SA images at the same slice position. 1: CINE, 2: First-pass, 3: Late Gd (subendocardial infarction)

“Silent” myocardial infarction

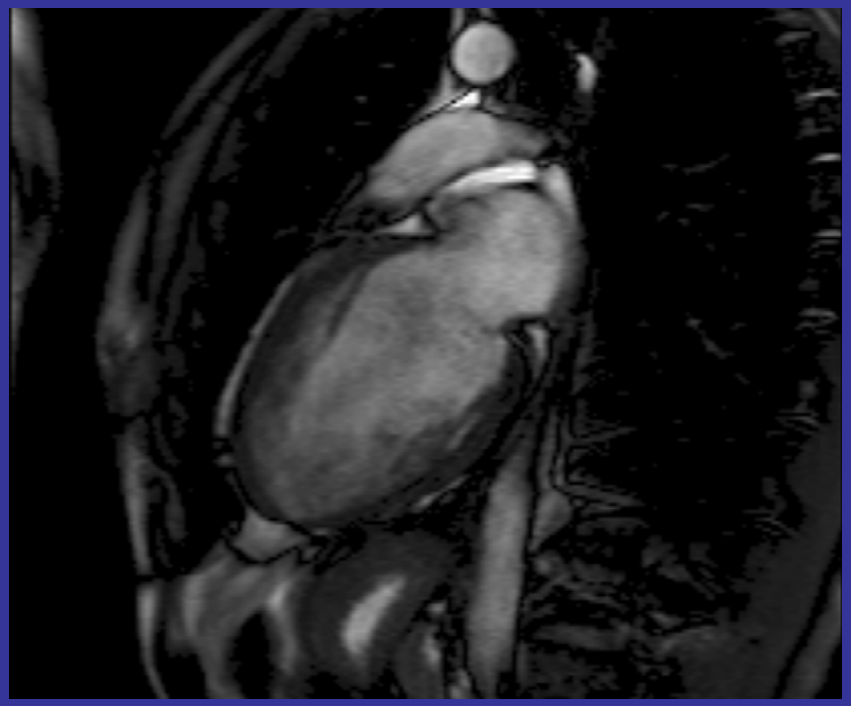


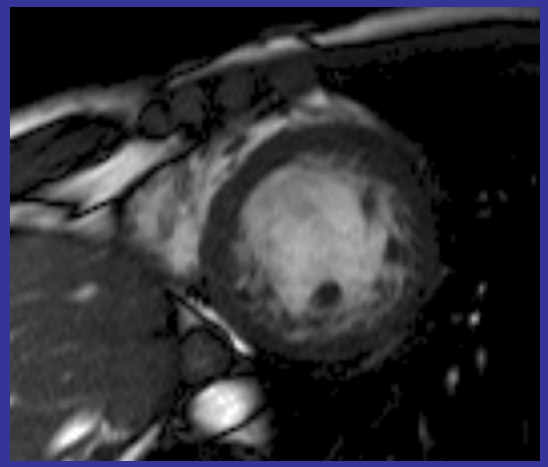


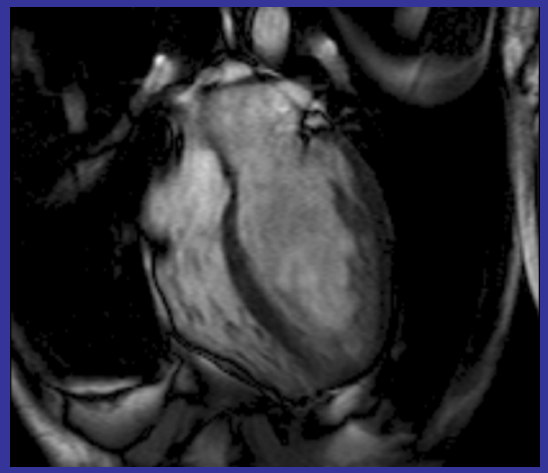
“Silent” myocardial infarction

In a preliminary study on patients attending the Heart Failure clinic with a diagnosis of idiopathic cardiomyopathy 34% (8/25) have evidence of a previous myocardial infarction without any history of chest pain.

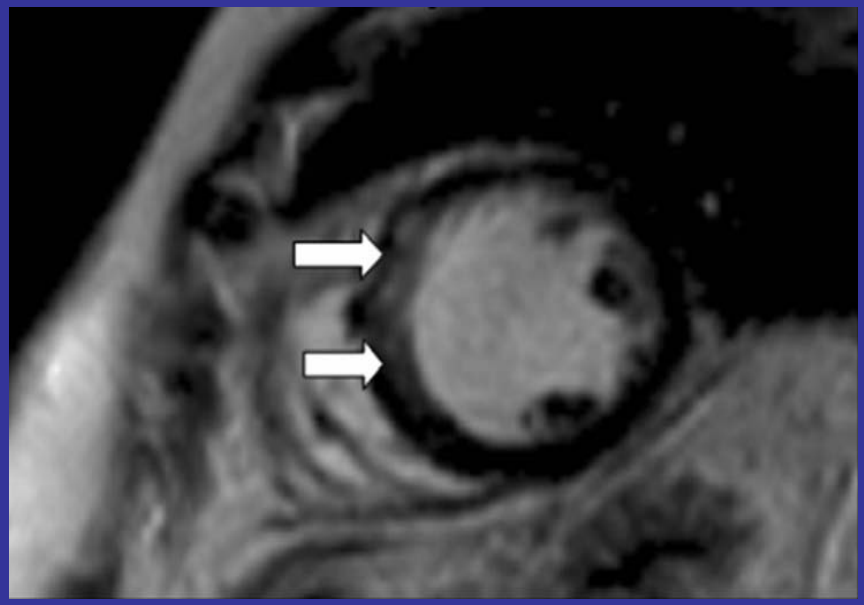
LV non compaction

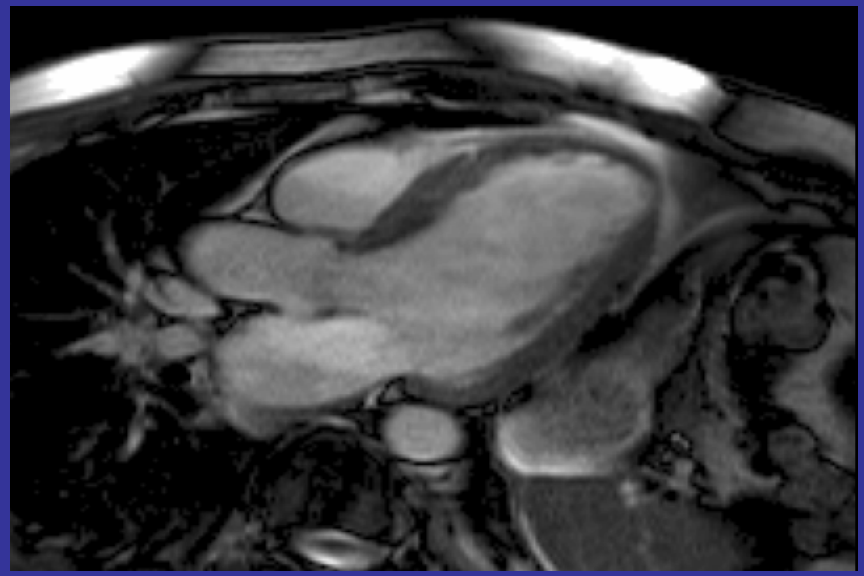






Contrast enhanced CMR shows anterior myocardial infarction with associated akinesis





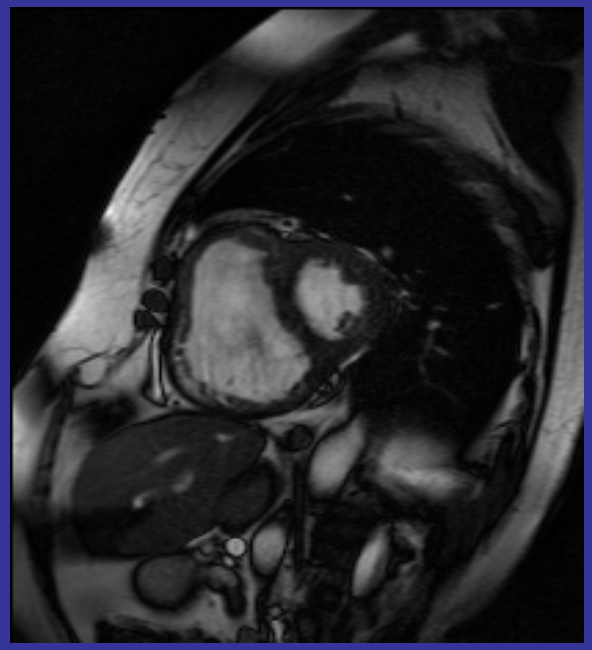
Pulmonary Hypertension

- Rare
- Poor prognosis (mean survival 2 yrs from Dx)
- Diagnosis and Monitoring Difficult
- Diagnosis requires Invasive Assessment
- Therapies experimental and need to be targeted appropriately

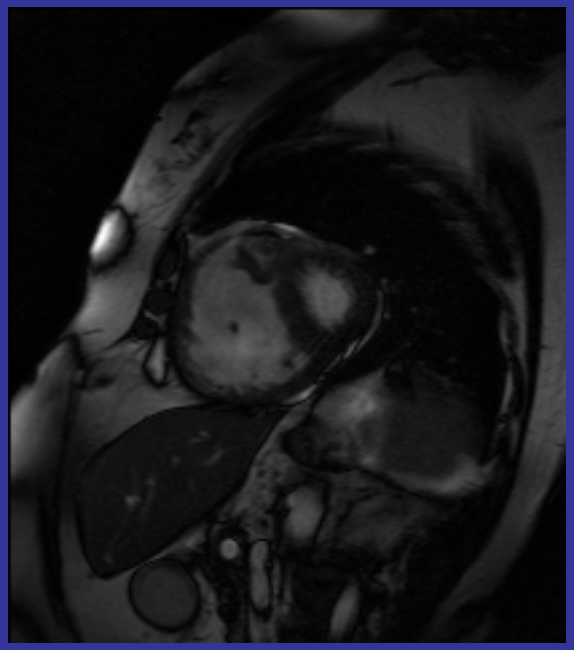
The Advantages of Cardiac MRI

- Non-invasive, Eliminates unnecessary risk
- Can be performed under stress (using IV Dobutamine) increasing sensitivity
- Allows assessment of consequences of disease on Cardiac Function

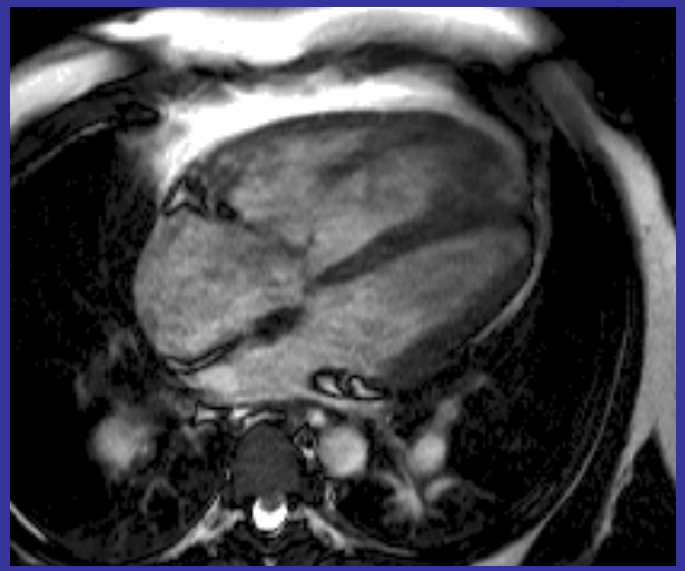
NORMAL SA VIEW



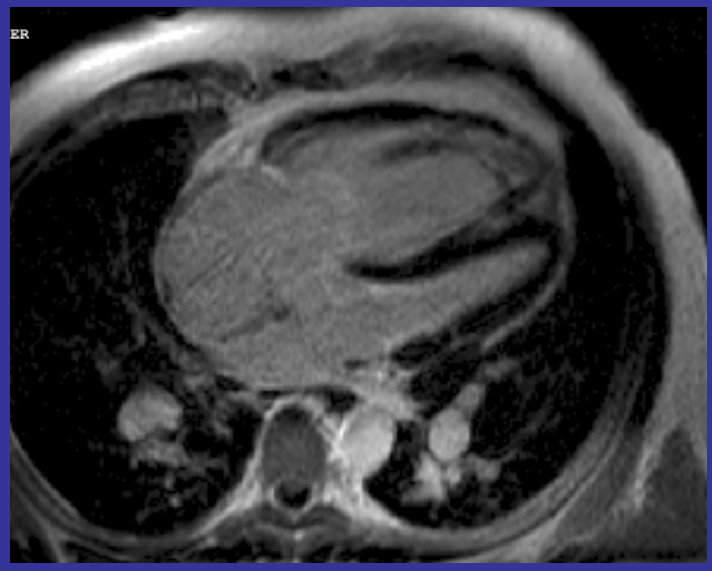
PHT AT REST



PHT AT STRESS



4 CHAMBER - PHT



SEPTAL AND RV WALL LGE IN PHT

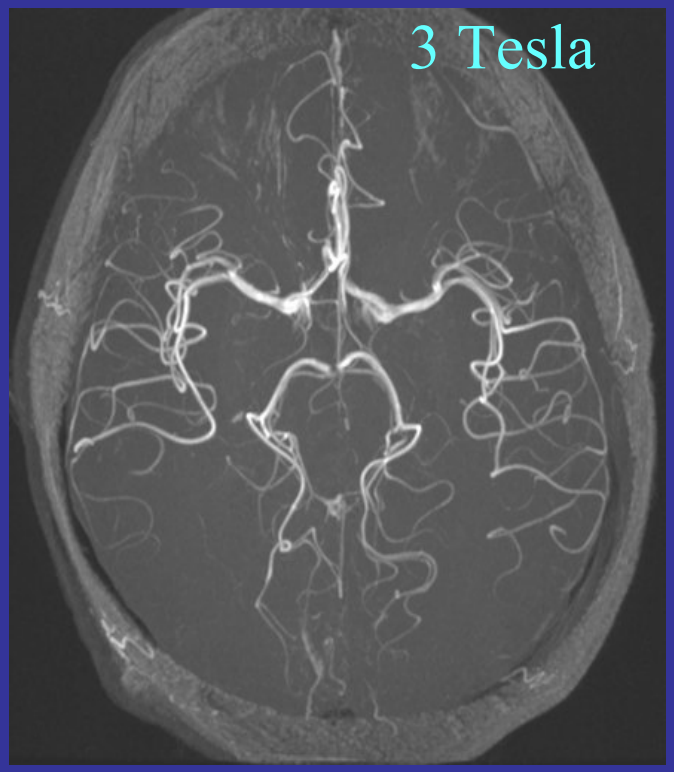
MR brain

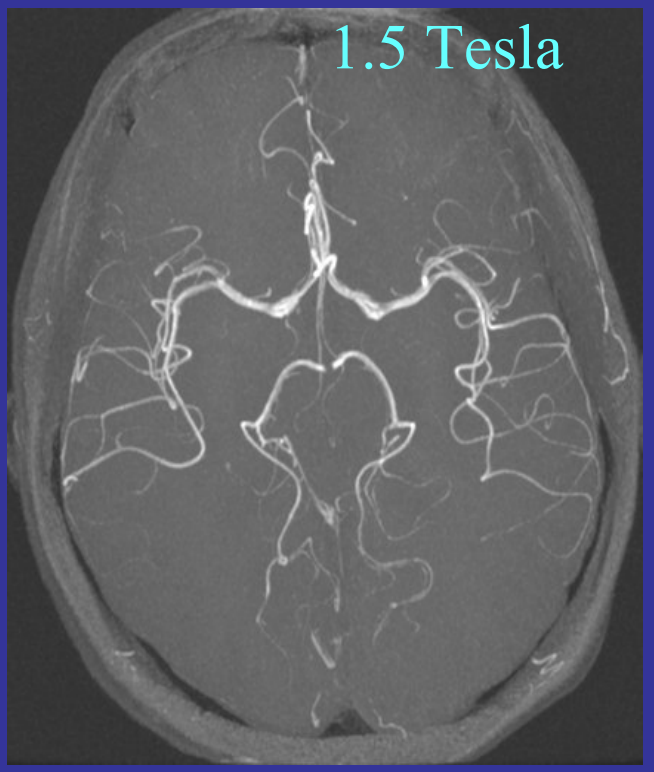
- MRI can image brain structures in living brain with detail of 0.1mm.
- MRI is free of risk.
- MRI impacts on almost all human brain research

Magnetic resonance imaging

- Magnetic resonance angiography can study blood vessels in the brain
- This is important in stroke
- Subarachnoid haemorrhage can occur without warning

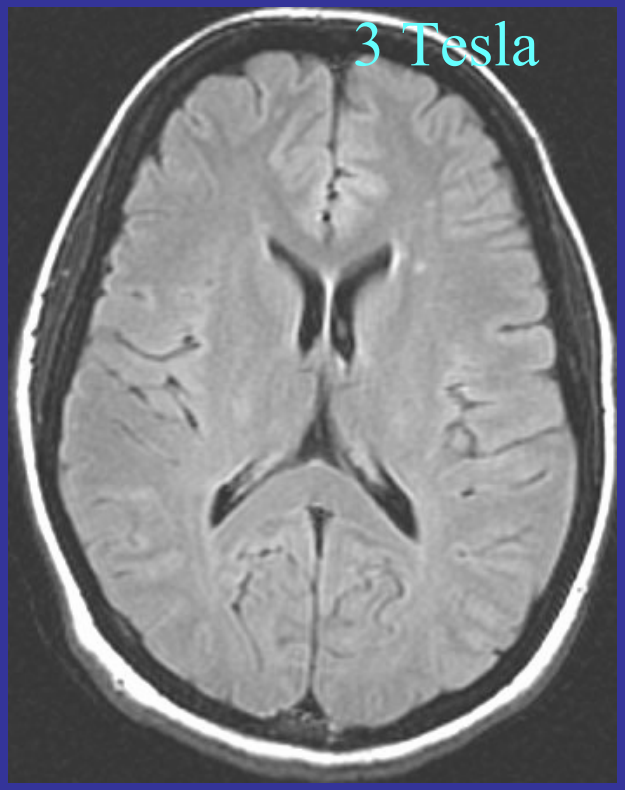
3T: Better definition of blood vessels

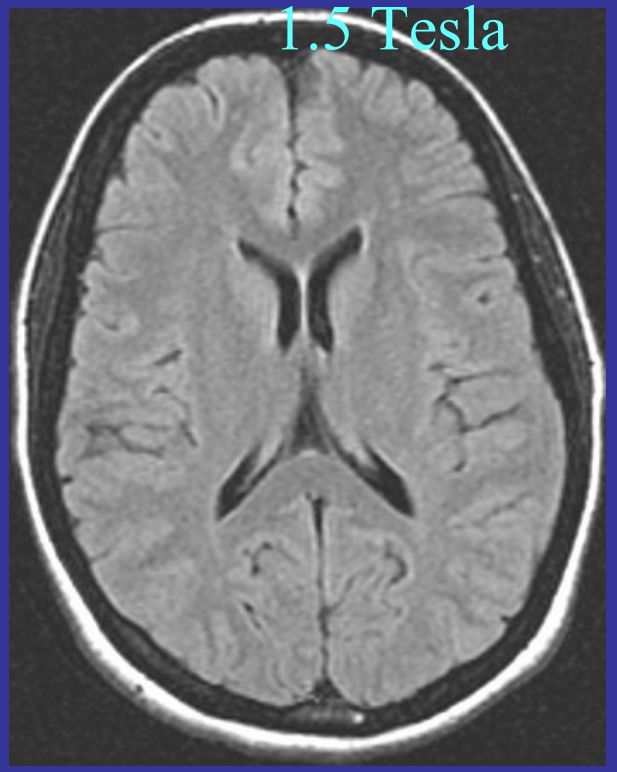




Important in stroke

3T: Better for white matter



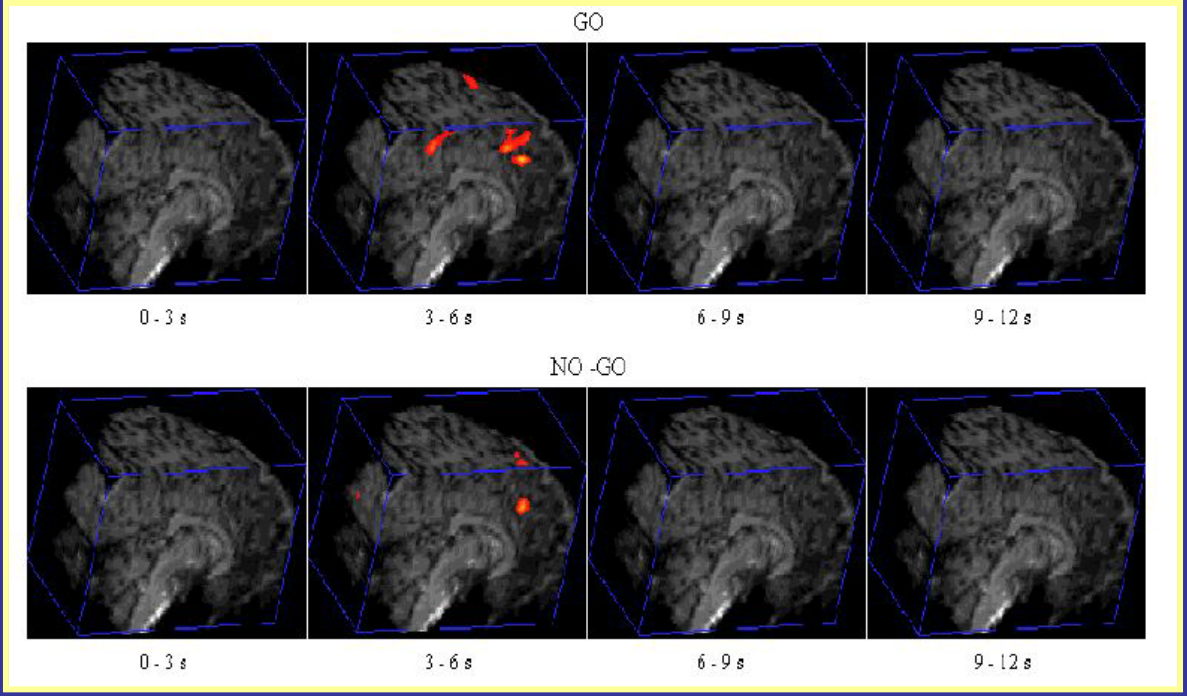


Important in MS

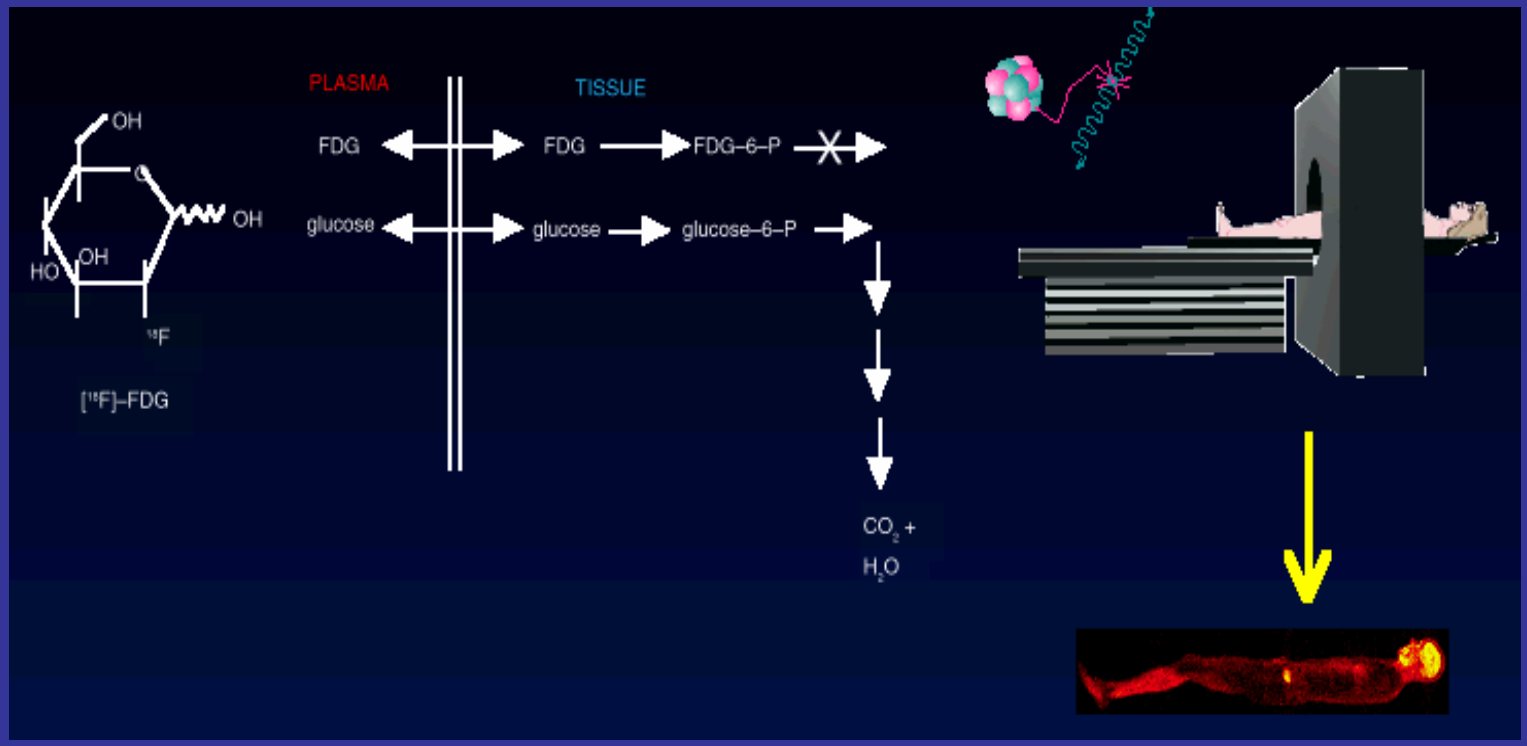
functional MRI of motor function

Paradigm: * stimulus every 12 seconds

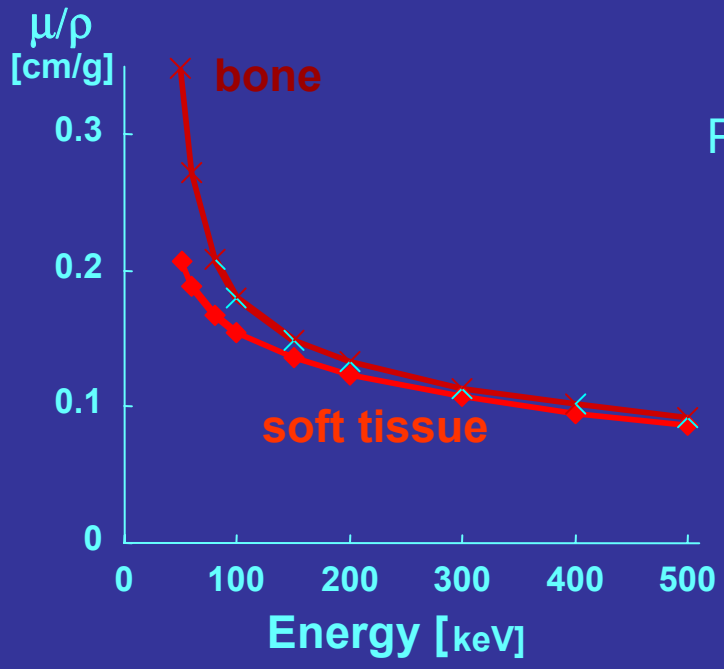
* if ‘2’ press; if ‘5’ don’t press



The PET procedure



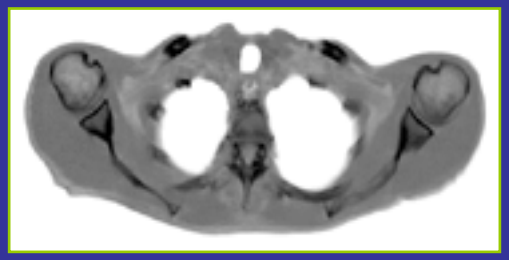
Attenuation Correction with CT



Photoelectric effect is higher in bone

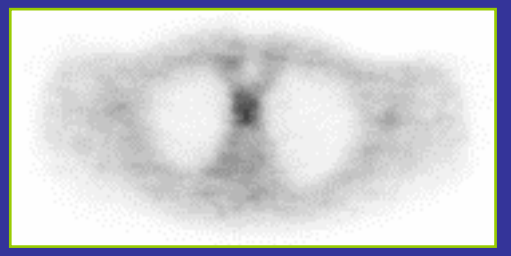
Hybrid method:

- segment bone in CT
- scale bone by 0.44
- scale other by 0.54



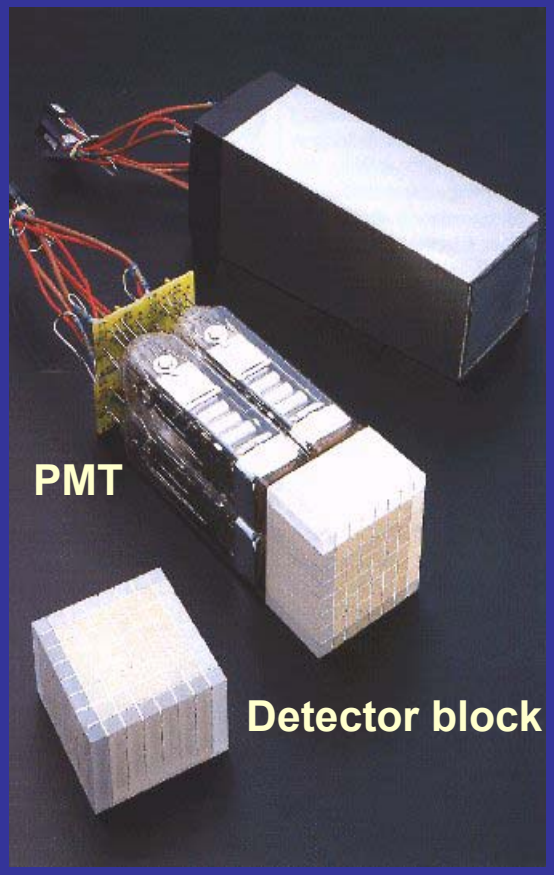
Original CT scan

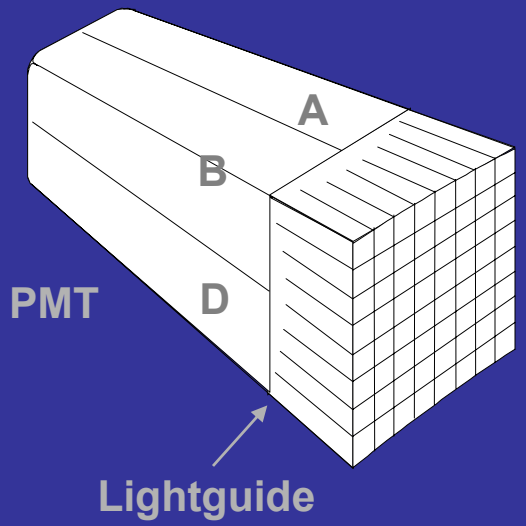
Scaled CT scan

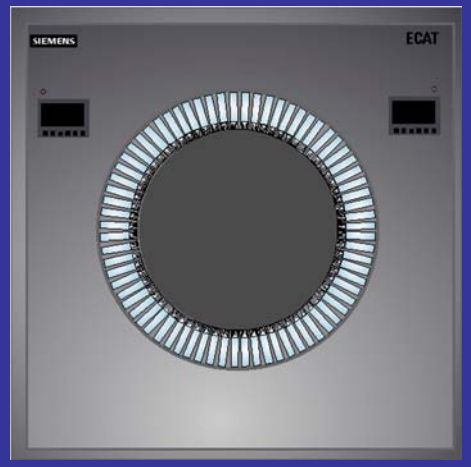


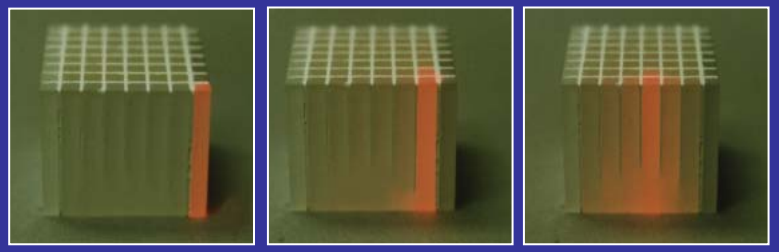
PET emission scan

Scanner Detectors









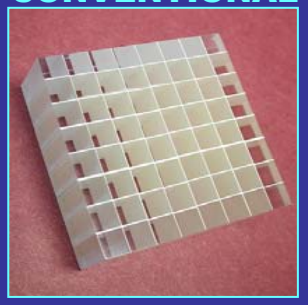
Channeled scintillation light

Crystal Characteristics

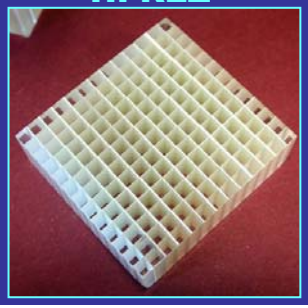
	LSO	BGO	GSO	NaI
Density (g/cc)	7.4	7.1	6.7	3.7
Effective atomic number	65	75	59	51
Hygroscopic?	No	No	No	Yes
Rugged?	Yes	Yes	No	No
Decay Time (nsec)	40	300	60	230
Relative Light Output	75	15	25	100

LSO HI-REZ Detector Technology

CONVENTIONAL

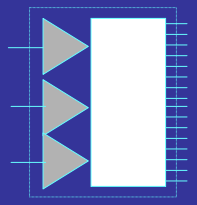


HI-REZ

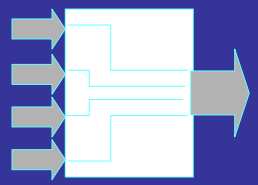


Detector material	LSO	LSO
Block matrix	8 x 8	13 x 13
Crystal size	6.4 x 6.4 mm	4.0 x 4.0 mm
Crystal thickness	25 mm	20 mm
Total number of crystals	9,216	24,336
Number of image planes	47	81
Plane spacing	3.4 mm	2.0 mm
Spatial resolution	6.3 mm	4.6 mm
Volumetric resolution	250 mm^3	98 mm^3

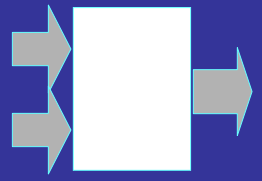
Pico-3D Means Faster Electronics!!



ANALOG TO DIGITAL ASICs*



DIGITAL SIGNAL ASICs



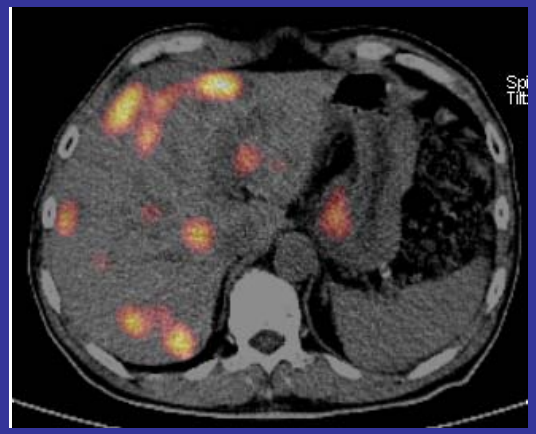
COINCIDENCE ASICs

PICO ELECTRONICS	**500 picosecond** digital resolution **10-bit** analog to digital conversion	**15.6** million samples/second/ channel **~15%** energy resolution	**5** nanosecond coincidence window **128** nanosecond clock sync **58% < randoms** **Low** deadtime
TYPICAL ELECTRONICS	2 nanosecond digital resolution 6 bits analog to digital conversion	7.8 million samples/second/ channel 25% energy resolution	12 nanosecond coincidence window 256 nanosecond clock sync High deadtime

**ASIC = application specific integrated circuit*

Key Benefits

- Combine functional (PET) and anatomical (CT) imaging for highest accuracy coregistration and fusion
- PET and CT components can be operated independently
- Short duration, low noise CT-based attenuation correction (also used for scatter correction)
- Faster overall scanning time
- Fully quantitative, whole-body images for SUV calculation
- Applications in improved disease localization, biopsy guidance, therapy monitoring, and radiation therapy planning



Automatic Image Registration & Fusion

Easy

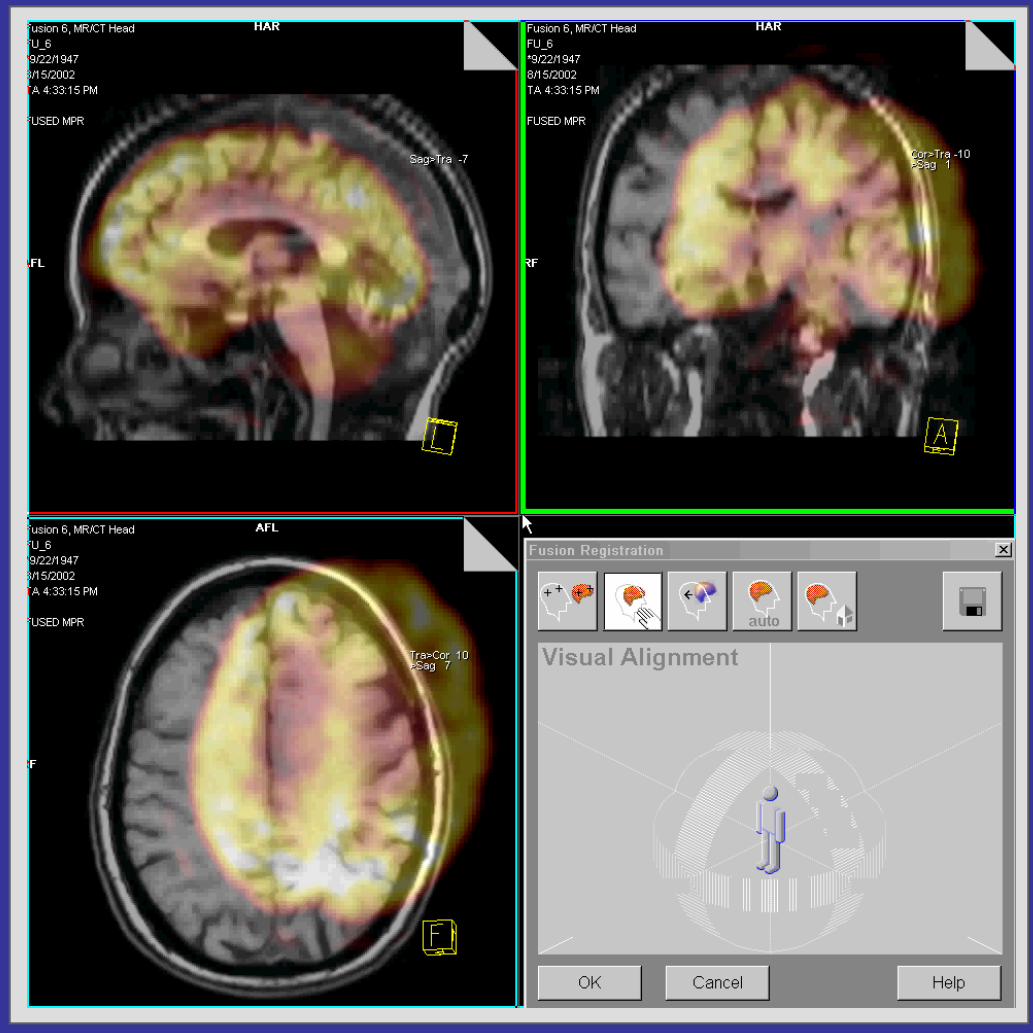
Fast

Precise

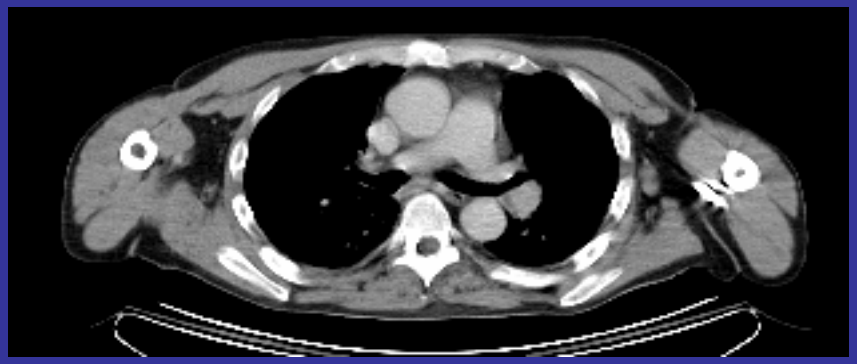
Flexible

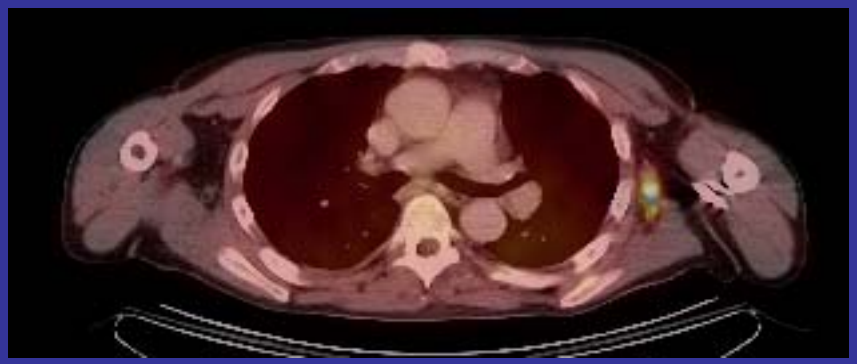
Multi-Modality

Multi-Vendor



PET/MR



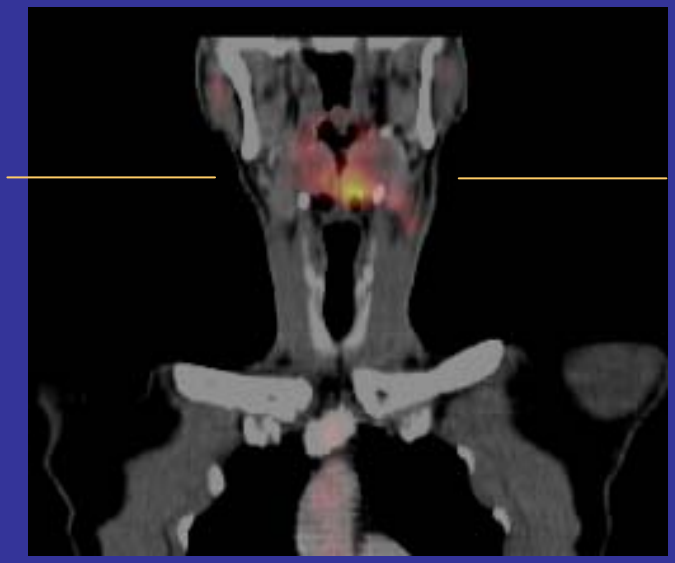


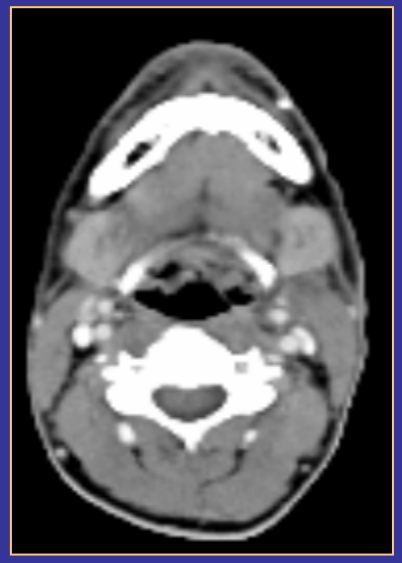
Lymphoma

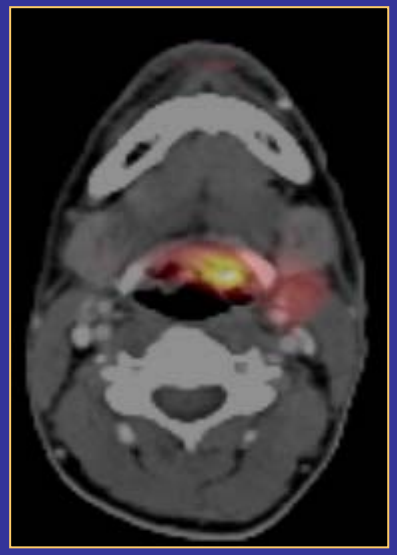
Case: 51 year old male with Lymphoma. S/p chemotherapy. Complete remission.
Scan protocol: CT 125 mAs, 130 kV_p, pitch 2, 5mm slice width
PET 360 MBq FDG, 1h p.i., 5 min/bed, 7 beds

Findings: PET/CT positive for axillary LN.

Data Courtesy of University Essen







Head and Neck cancer: Unknown Primary

Case: 48 year old man status post excision of a malignant left neck lymph node. Clinical work-up failed to reveal primary lesion.

Findings: PET/CT reveals focal uptake of FDG in left base of the tongue consistent with the primary malignancy.

Data Courtesy of PET Facility, University of Pittsburgh Medical Center, Pittsburgh, PA

Metastatic Melanoma

71-year-old male with metastatic melanoma on left shoulder discovered 12/94.

CT performed on 7/10/95 demonstrated tumor of the distal femur with negative findings in the abdomen. Bone scan on 7/13/95 showed an abnormal femur and four spine lesions.

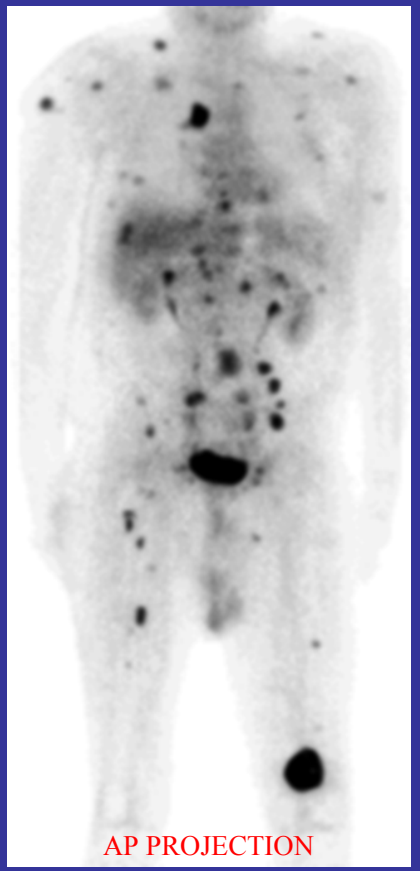
Whole-body FDG PET scan demonstrates numerous lesions throughout the body.

Patient was scheduled for an amputation and total knee replacement based on CT and bone scan results.

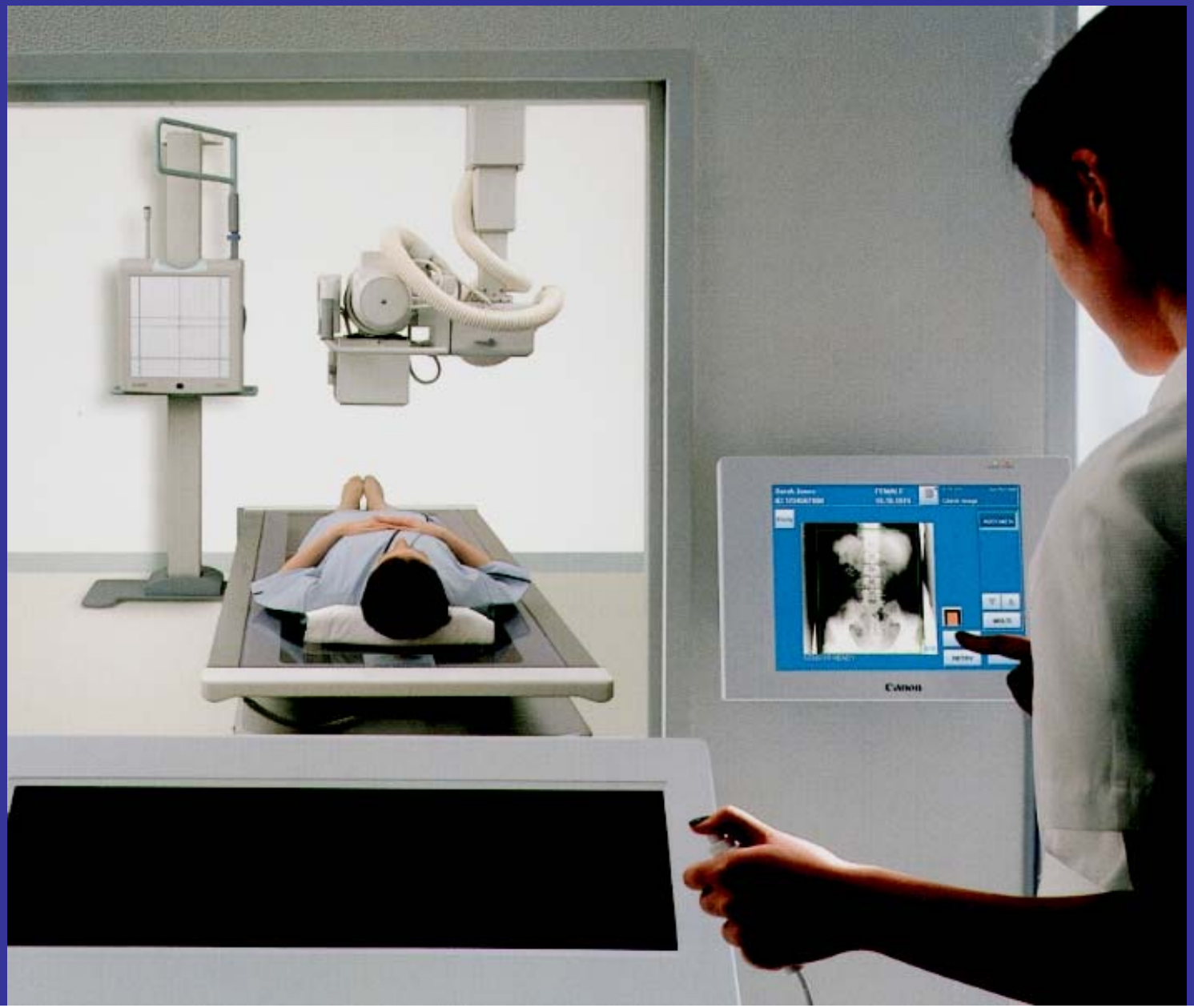
After PET found multiple lesions, surgery was cancelled, avoiding both the cost and the trauma of an operation that would not be effective.

Courtesy of Amjad Ali, M.D.

Rush-Presbyterian - St. Luke's Medical Center



Typical DR room




Canon
CXDI-31

Sequence of events - CR

1. Reception – Demographics onto RIS
2. Form collected by Radiographer /Assistant
3. Patient changed (if needed)
4. Room prepared – CR plate(s), exposure
5. Patient into room – ID check, projection(s)
6. Examination finish – cubicle or table
7. CR read …

CR reading stages

7. RIS link for demographics
8. Barcode read of label
9. Barcode scan of cassette(s)
10. Cassette into reader(s)
11. Preview > QA review station
12. Accept image(s) > Exam finish

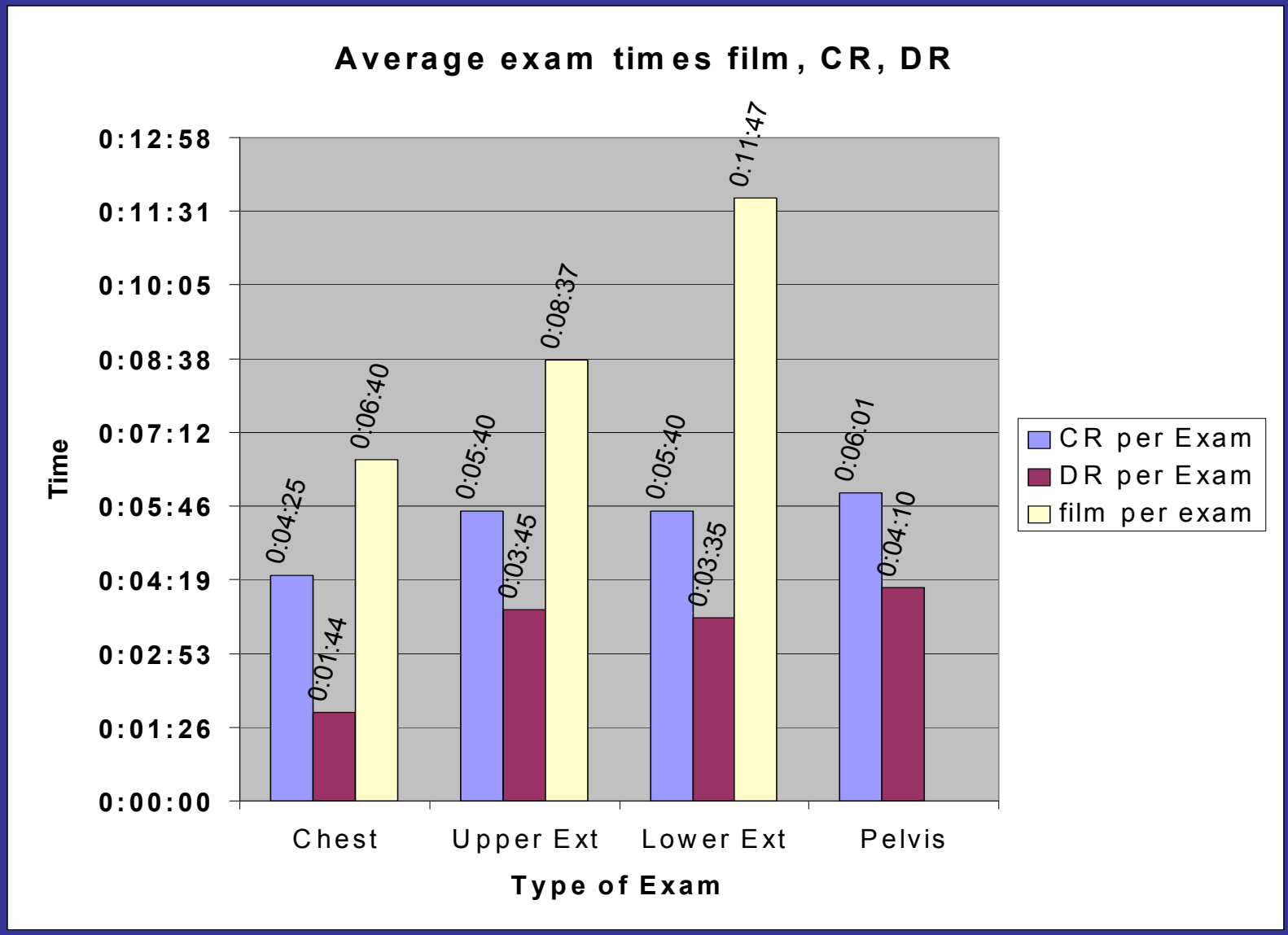
Sequence of events - DR

1. Reception – Demographics onto RIS
2. Form collected by Radiographer /Assistant
3. Patient changed (if needed)
4. Room prepared – Patient demographics, exposure
5. Patient into room – ID check, projections(s)
6. Image(s) QA review station
7. Accept image(s) > Exam finish

Missing stages in DR sequence

1. Barcode read of label
2. Barcode scan of cassette
3. Cassette into reader …
4. Preview

Results

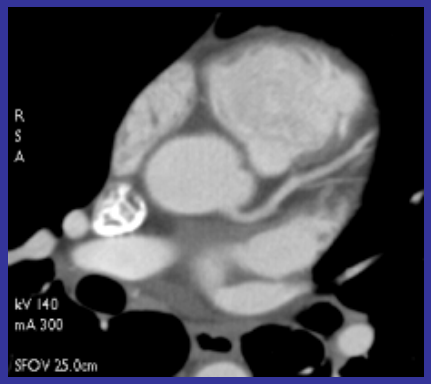

Average exam times film, CR, DR
Time
0:12:58
0:11:31
0:10:05
0:08:38
0:07:12
0:05:46
0:04:19
0:02:53
0:01:26
0:00:00
0:04:25
0:01:44
0:06:40
0:05:40
0:03:45
0:08:37
0:05:40
0:03:35
0:11:47
0:06:01
0:04:10
Chest
Upper Ext
Lower Ext
Pelvis
Type of Exam
CR per Exam
DR per Exam
film per exam

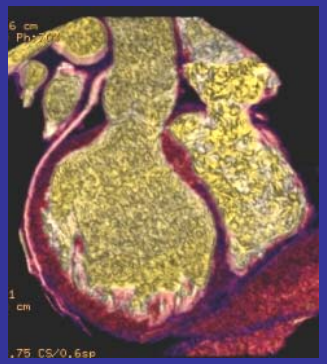
1 Direct Radiography

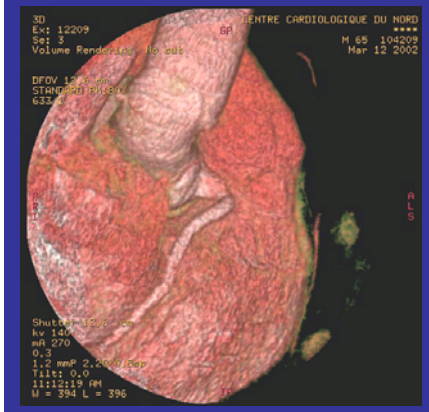
=

2.5 Computed Radiography rooms

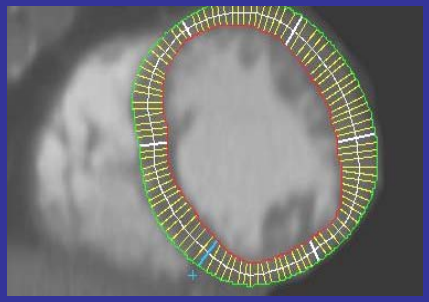
Almost

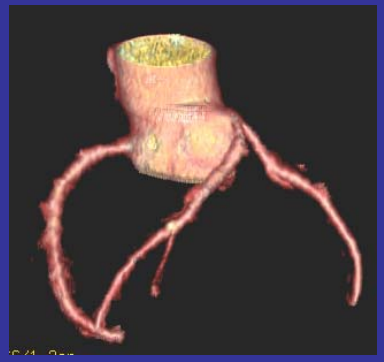

R
S
A
kV 140
mA 300
SFOV 25.0cm

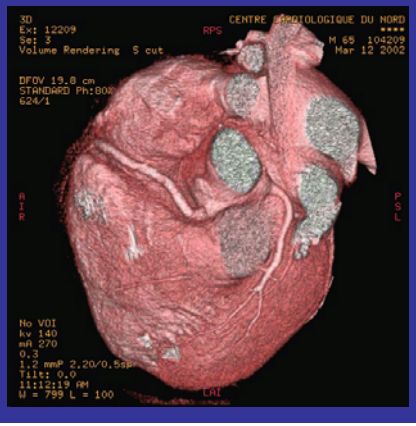



3D
CENTRE CARDIOLOGIQUE DU NORD
M 65 104209
Mar 12 2002

Thank you






3D
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M 65 104209
Mar 12 2002
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