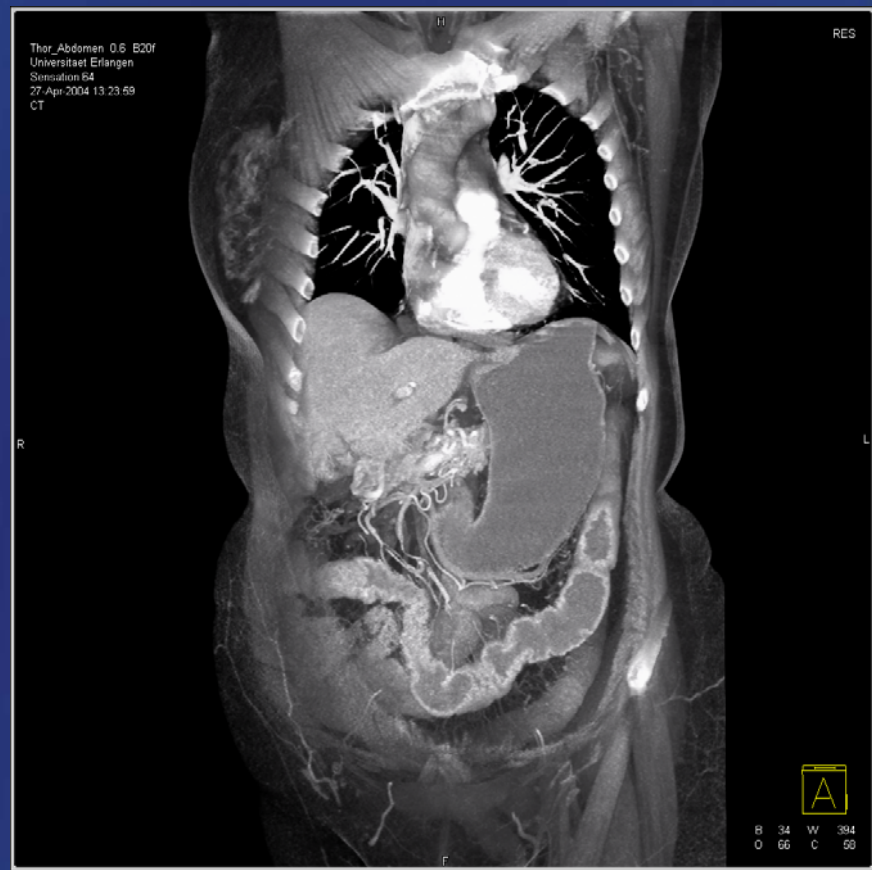
- CT Basics
- Principles of Spiral CT
- Dose



Who invented CT ?

- 1963 - Alan Cormack developed a mathematical method of reconstructing images from x-ray projections

Sir Godfrey Hounsfield

Nobel Prize - Medicine

(1919 – 2004)

- **Sir Godfrey Hounsfield worked** for the Central Research Labs. of EMI, Ltd in England f
- Invented 1st clinically CT scanner in 1971
- Nobel Prize Winner 1979

Before the Era of CT……...

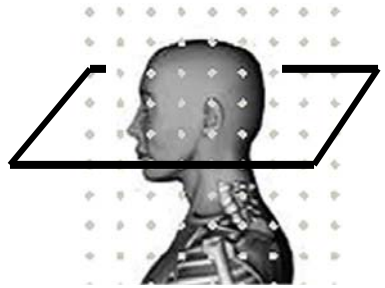
What is wrong with this image?

- Structures are superimposed
- 2D image (2 planes)

- Cannot differentiate subtle tissue densities

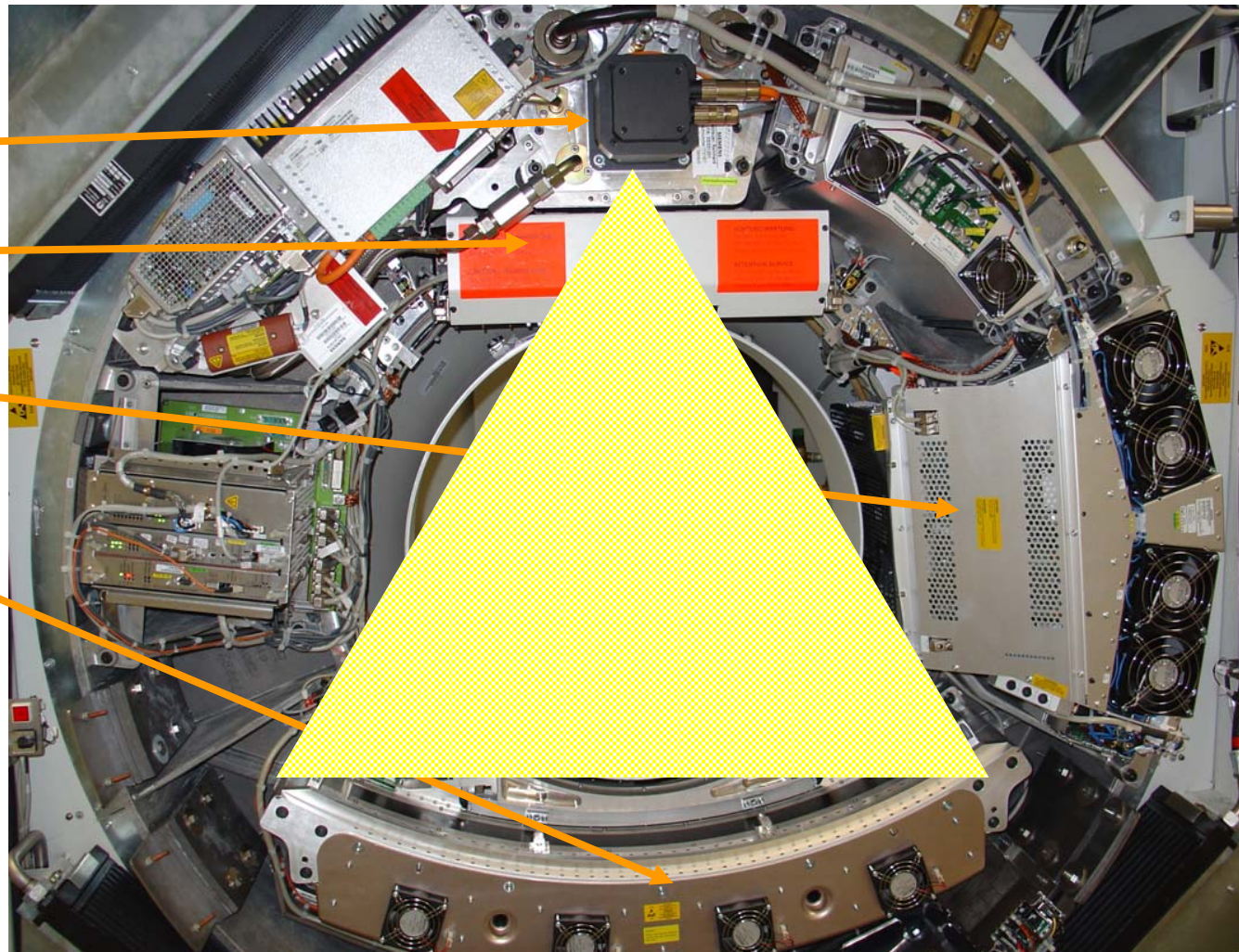
How is a CT scan made ?

- Cross-sectional imaging technique
- Uses x-rays from x-ray tube
- Detector Converts x-rays to light
- Light converted to electronic signal
- Electronic signal constructed to make image in a computer
- Density differentiation – grayscale / colour images



Inside a CT - Sensation 64

- Tube
- Collimator
- Generator
- Detector



CT : From x-ray to detailed image

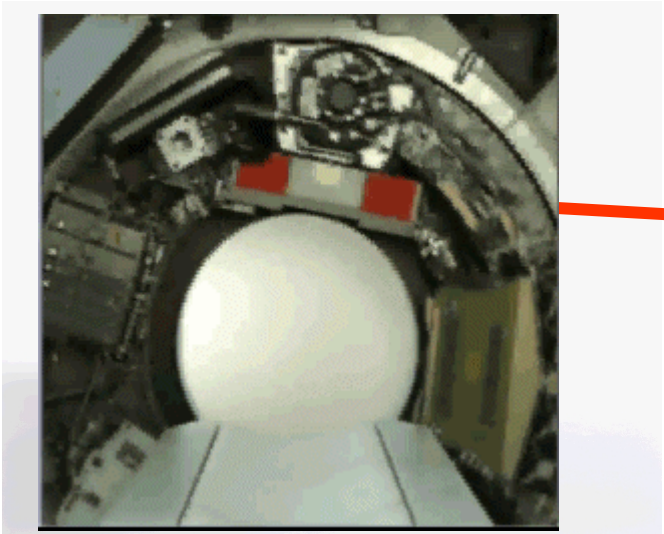
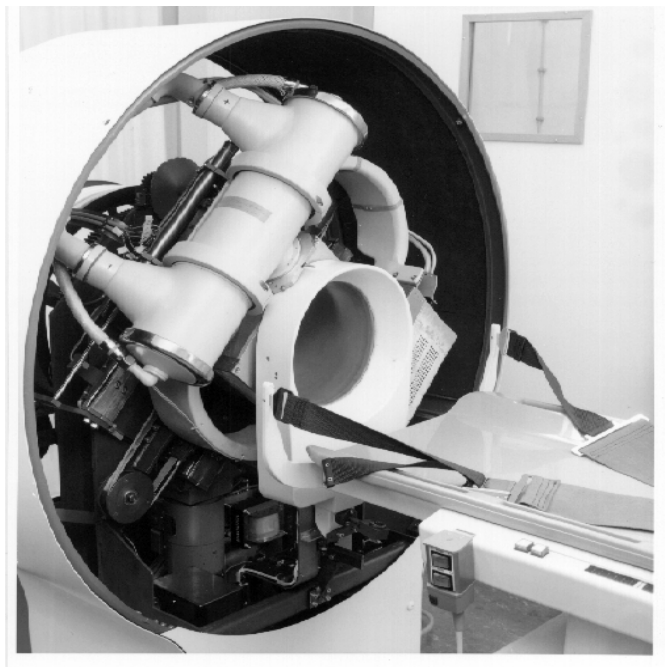


Image Recon. Computer

Diagnostic images

The FIRST Siemens CT Scanner



SIRETOM (1974)

Scan time 7 minutes, Image Matrix 80x80 Pixel,

Scan field 25 cm, spatial resolution 1.3 mm (4lp/cm)

Head scanner

Image acquisition – the “slice”

- X-ray beam is narrowed by an collimator
- Only one thin part of the body will be radiated

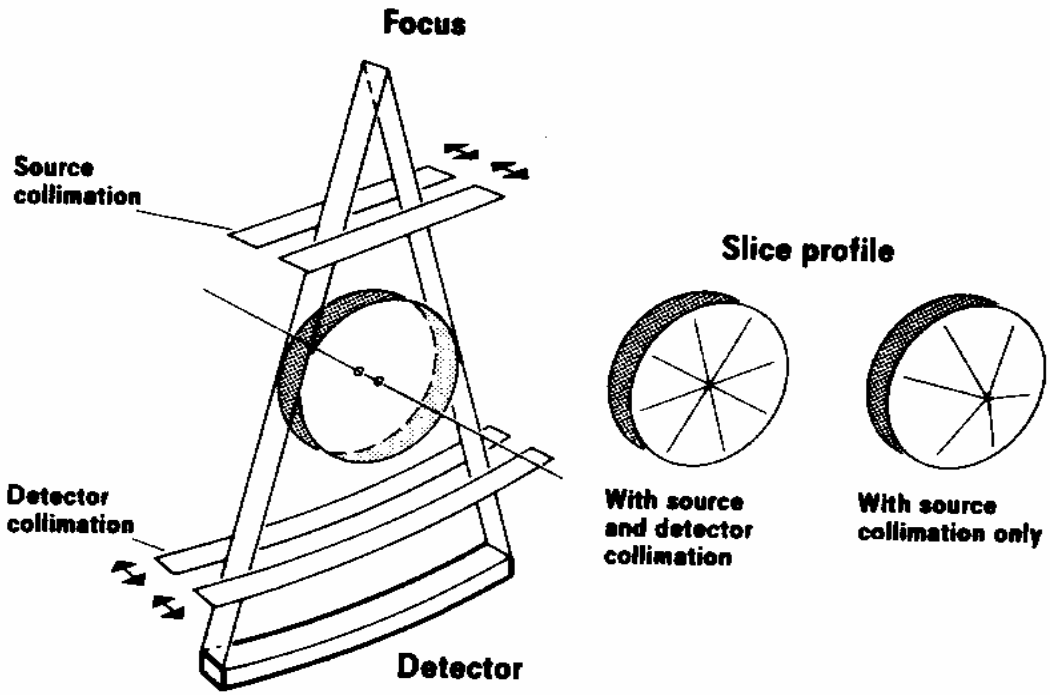
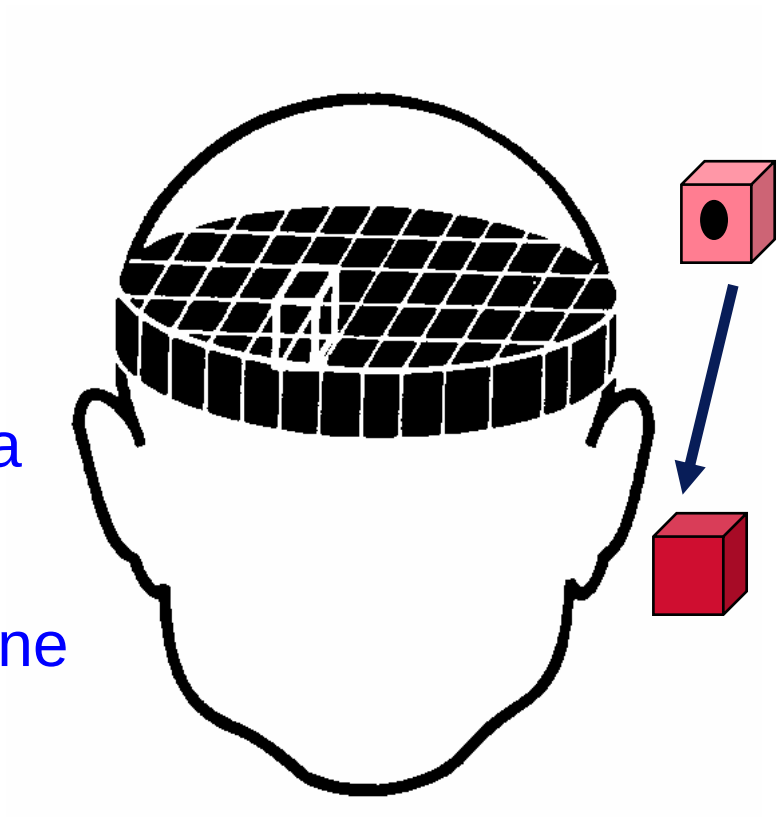


Image acquisition: the “Voxel”

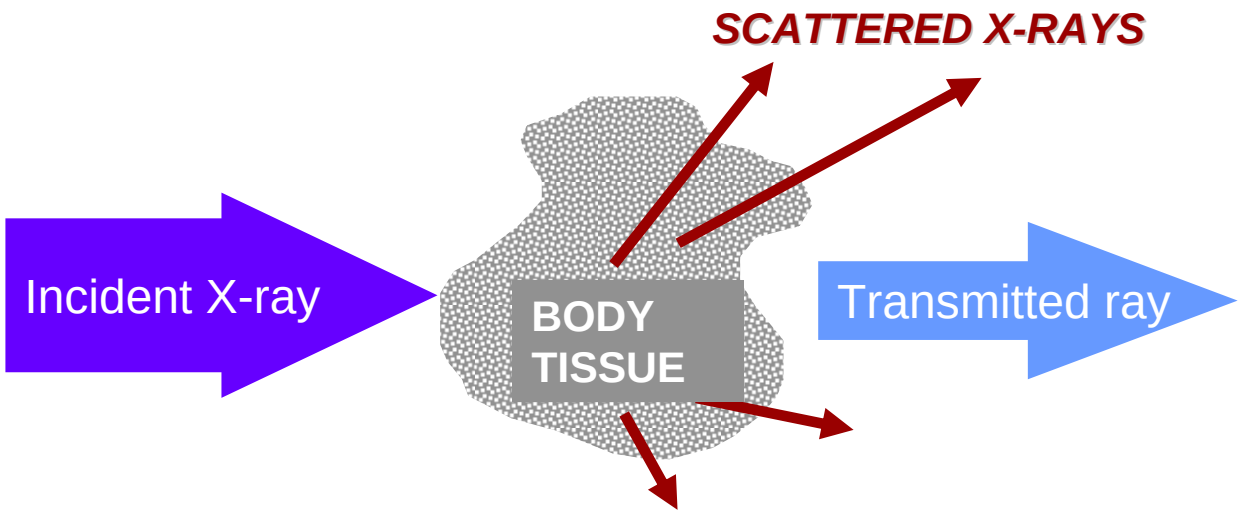
The slice will be partitioned mathematically into small Volume elements - “voxel”.

The attenuation will be measured in the voxels as a constant value

The image element in a plane is a “Pixel”



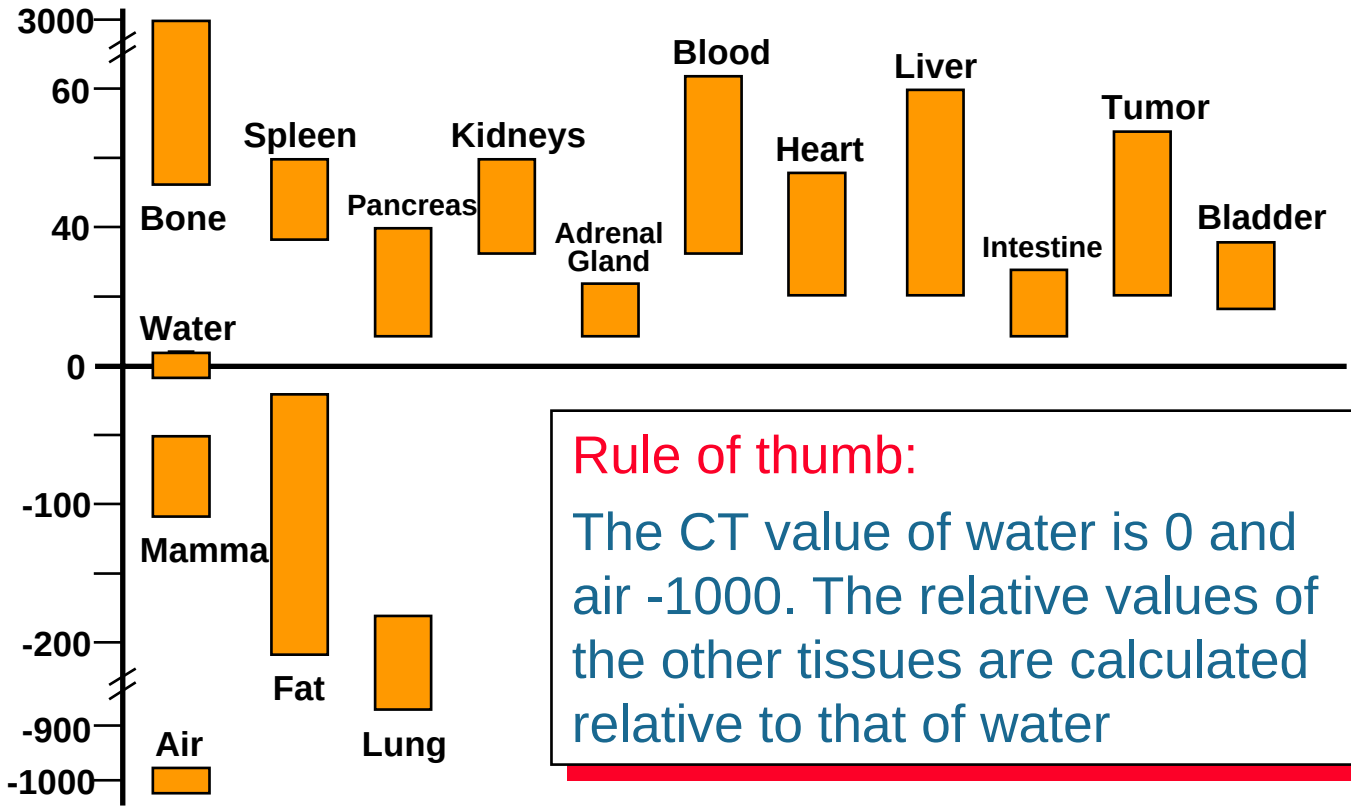
Concept of X-ray Attenuation



The degree of attenuation is measurable with CT and is expressed in HU (Hounsfield) unit

HU gives an indication of tissue density (CT Density)

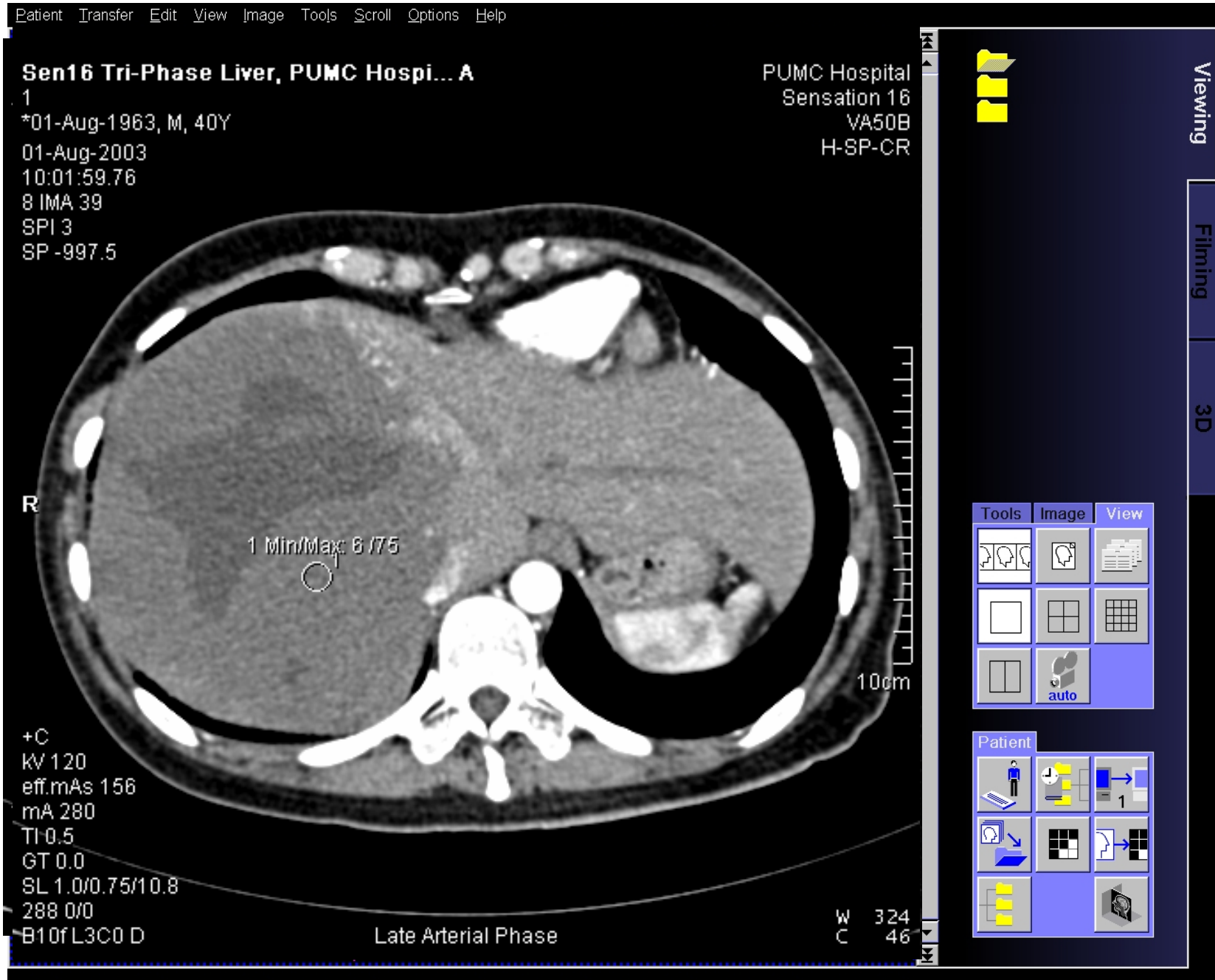
Hounsfield Unit Scale



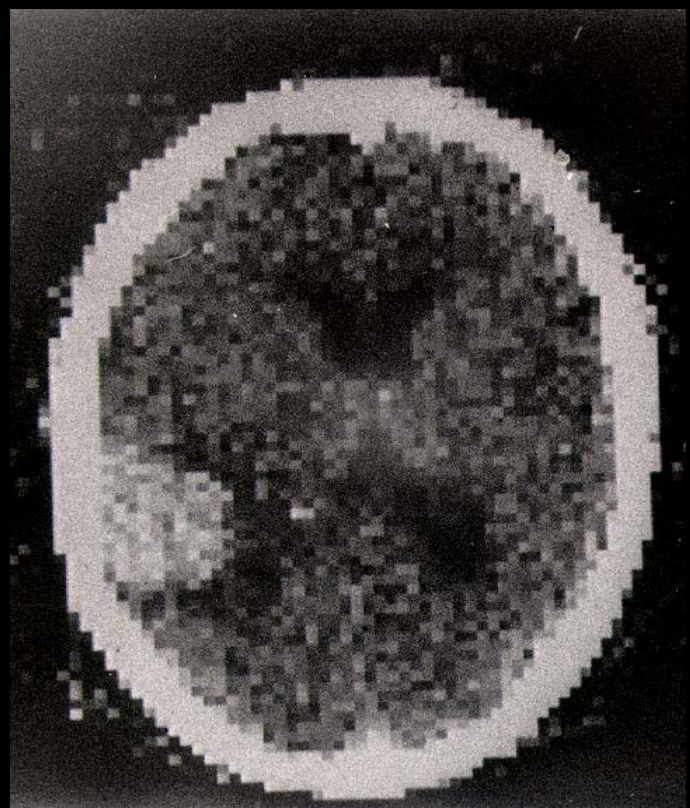
Rule of thumb:

The CT value of water is 0 and air -1000. The relative values of the other tissues are calculated relative to that of water

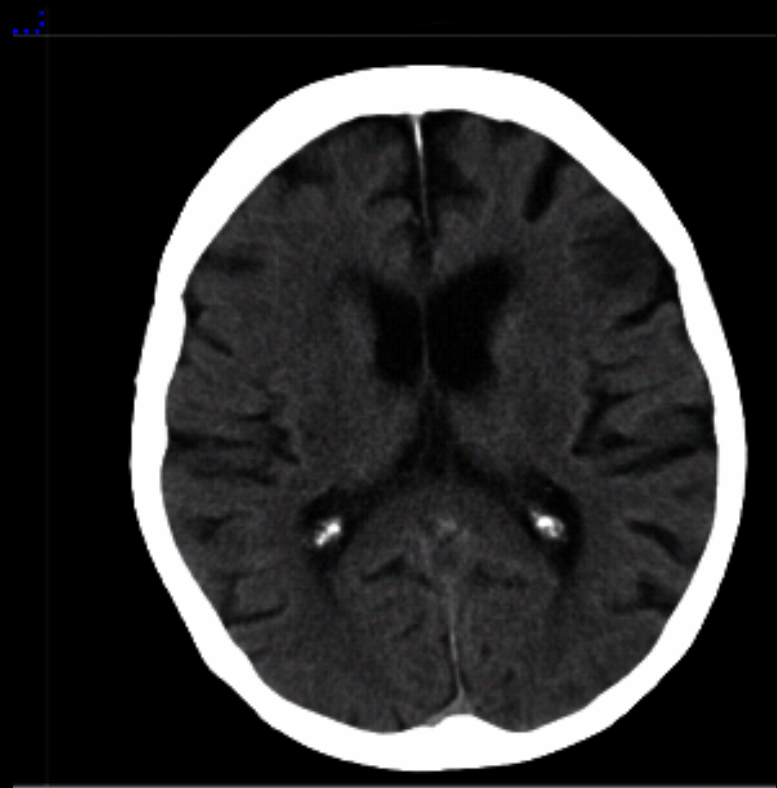
This is the CT number or Hounsfield unit (HU)


Patient Transfer Edit View Image Tools Scroll Options Help
Sen16 Tri-Phase Liver, PUMC Hospi... A
1
*01-Aug-1963, M, 40Y
01-Aug-2003
10:01:59.76
8 IMA 39
SPI 3
SP -997.5
PUMC Hospital
Sensation 16
VA50B
H-SP-CR
R
1 Min/Max: 6 /75
10cm
+C
kV 120
eff.mAs 156
mA 280
TI 0.5
GT 0.0
SL 1.0/0.75/10.8
288 0/0
B10f L3C0 D
Late Arterial Phase
W 324
C 46
Viewing
Filming
3D
Tools
Image
View
auto
Patient

CT then……CT now……..



SIRETOM 1974



Spirit 2004

CT Basics: Sequential scanning

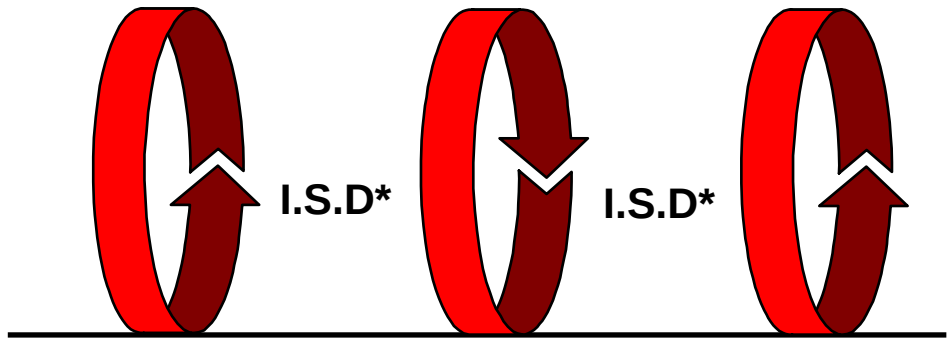
- In 1970's , CT worked only using a sequential scan
  - One Scan - First rotation (2 seconds per rotation !!)
    - Rotation of tube and detector around 360° + Radiation exposure
    - After each scan a table movement was performed
  - The tube and detector system moved back to the initial position
    - Because of cables !
  - Table moves
  - Second rotation (2 seconds per rotation !!)
  - Table moves etc etc

- Problem:
  - Long examination time
  - The lung could not be scanned in one breath hold

Conventional sequential CT...

Sequence-Scan:

- long cycle time

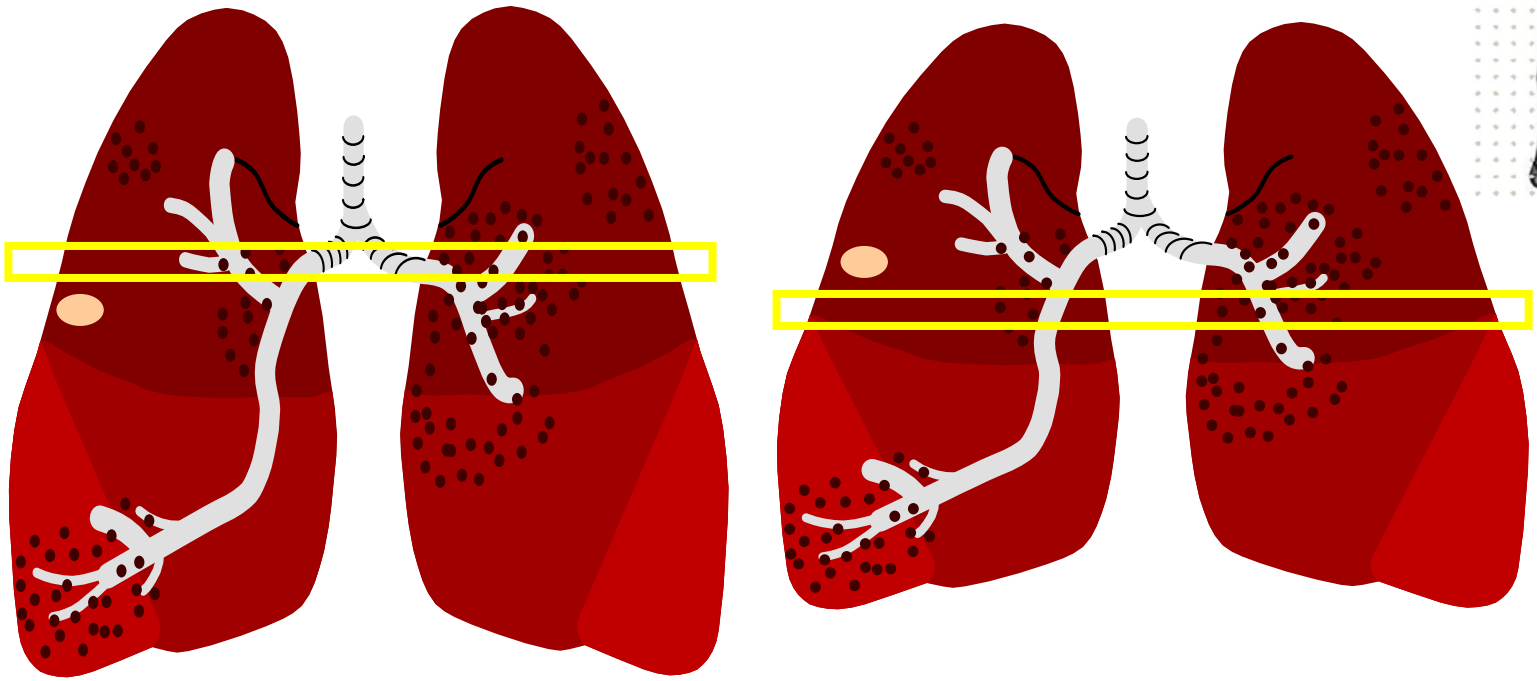


•Inter scan delay
- time between 1st slice to 2nd slice
-Gantry rotation, gantry stop,
-patient moves,
-gantry rotates, gantry stop etc.

Please note that conventional sequential CT still used today for some head scans (however, gantry does not require to return anticlockwise to start position due to slip rings)

CT Basics

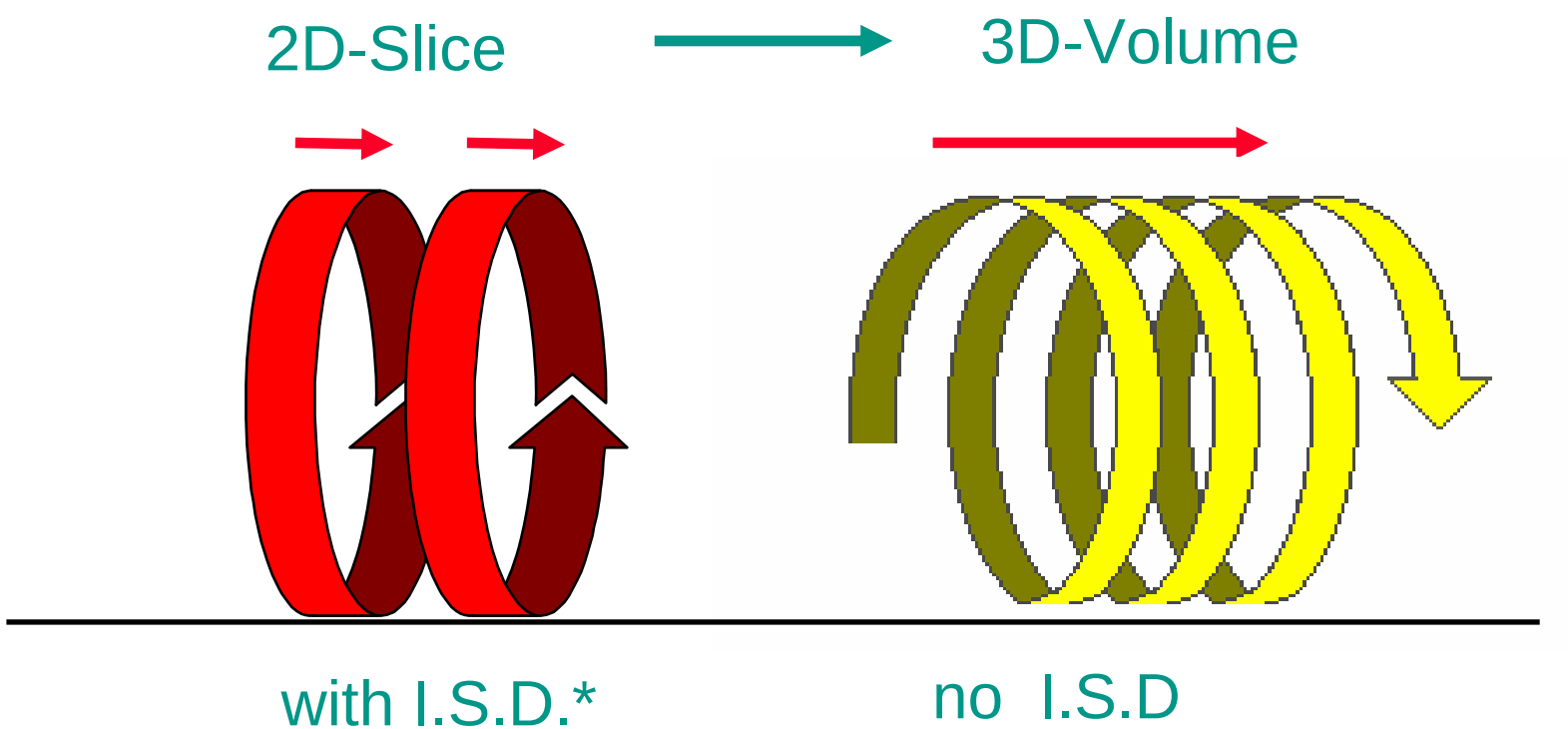
Lungs – like a sponge !



- Mis-registration due to different levels of respiration between slices

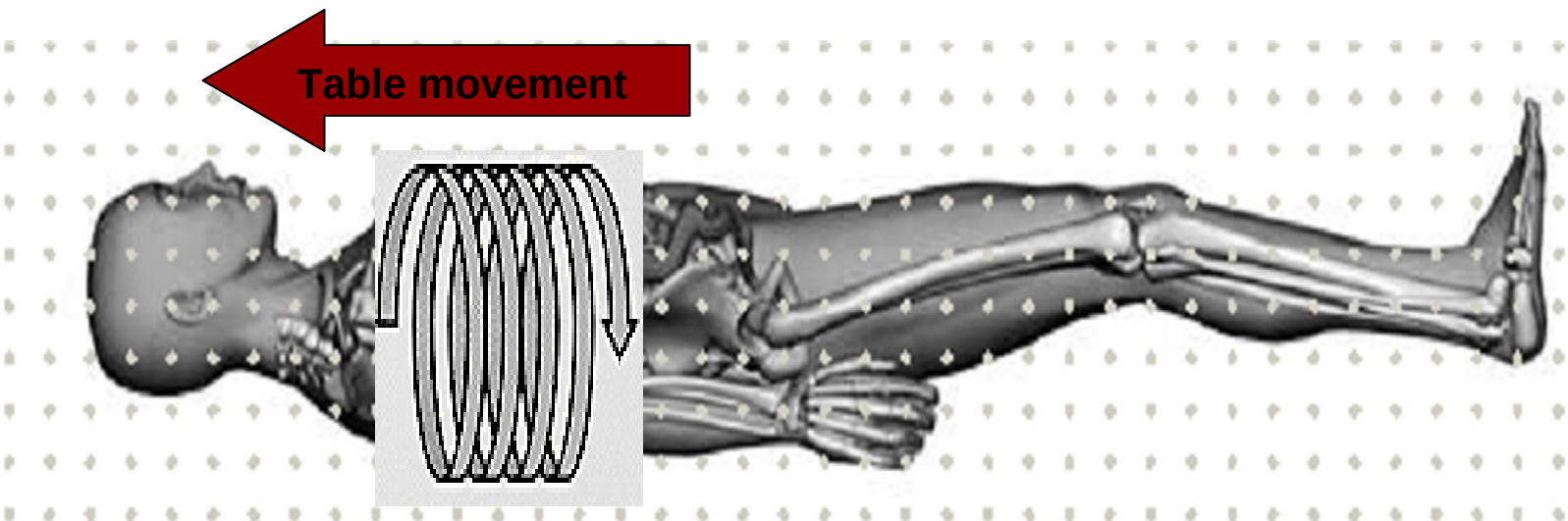
1990: The Spiral CT Era……..

Conventional CT versus Spiral-CT ...

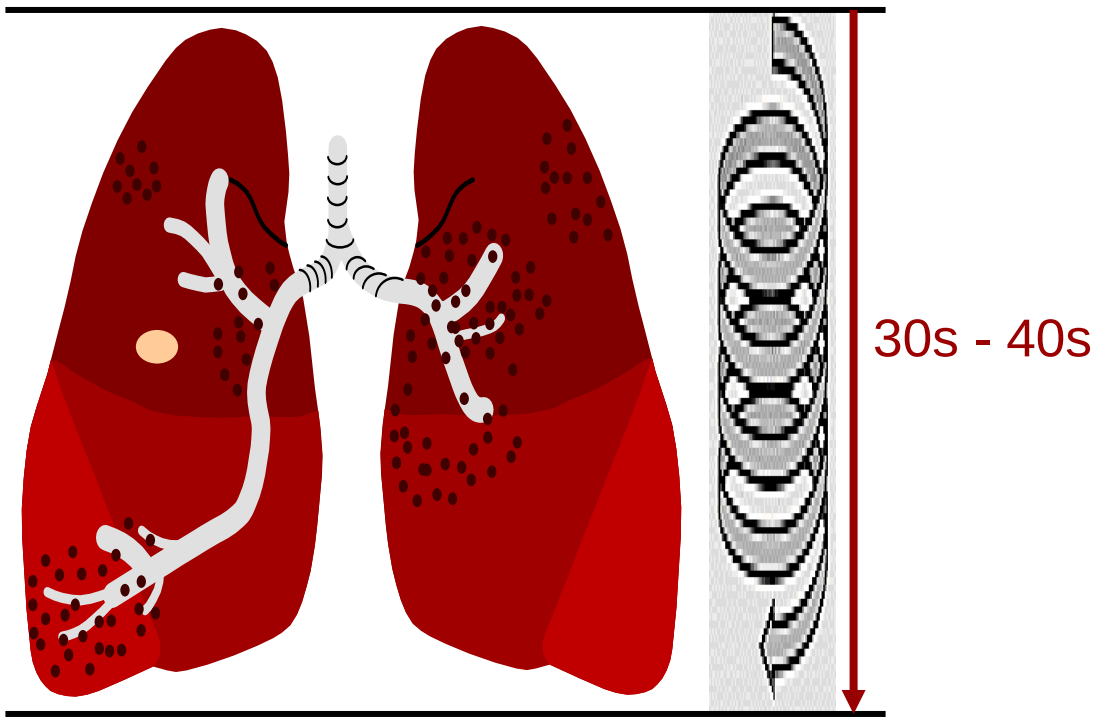


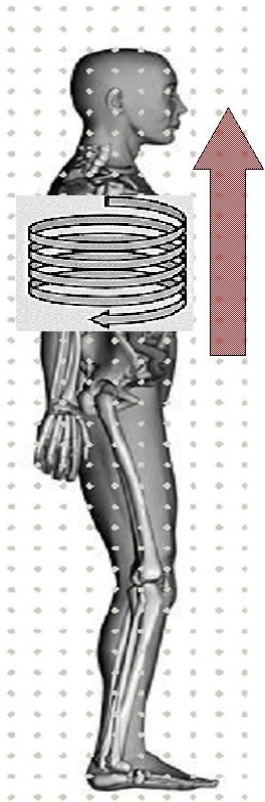
Principles of Spiral CT

- **C**ontinuous gantry rotation
- **C**ontinuous table feed (head or foot direction)
- **C**ontinuous radiation
- **C**ontinuous volume acquisition



Principles of Spiral CT

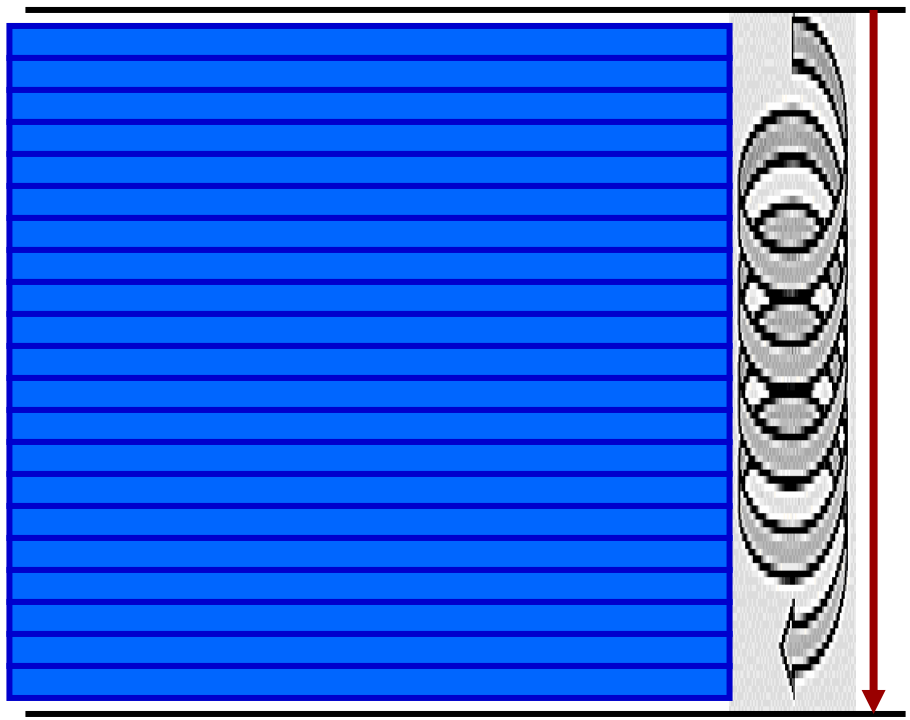


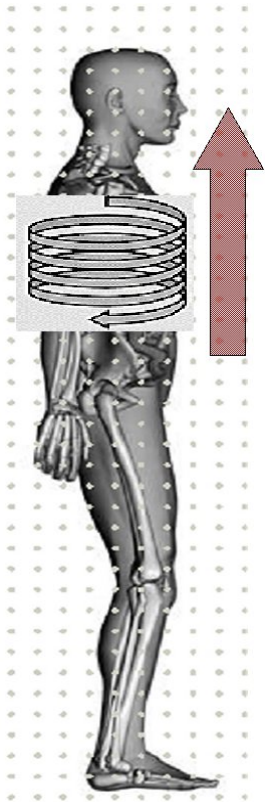


Volume scanning in a single breath hold

Raw data (CT computer data) is created, then image (picture) data is processed using CT computer

Principles of Spiral CT

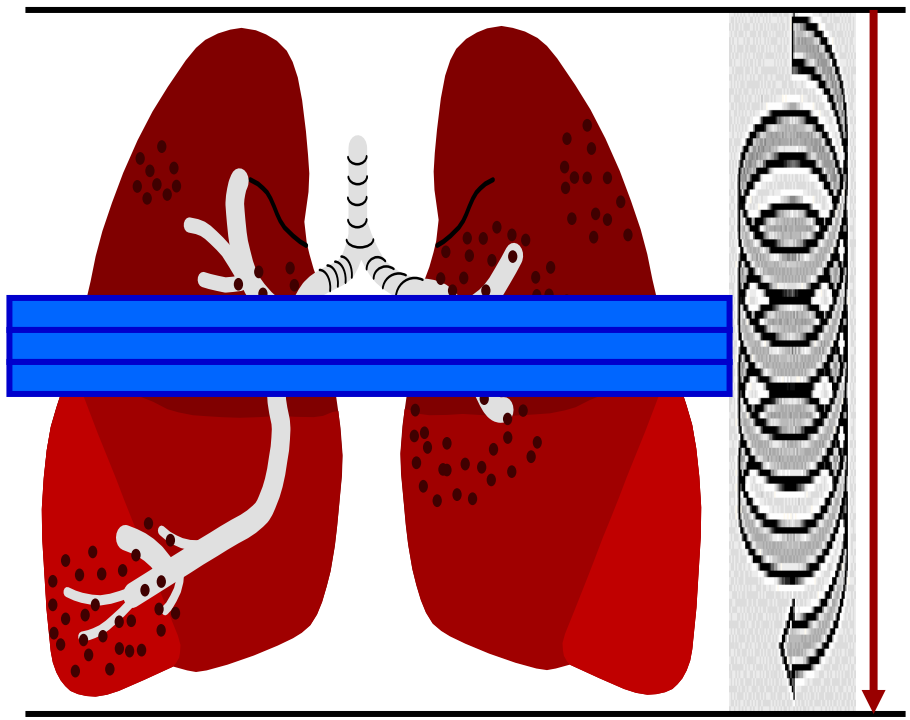




Continuous Slices

Concurrent Image Reconstruction during the spiral acquisition
or
Retrospective Image Reconstruction

Principles of Spiral CT



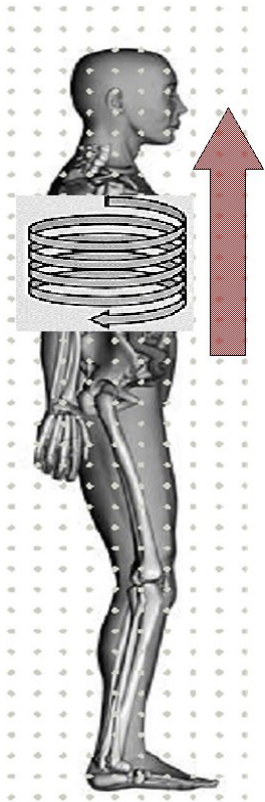
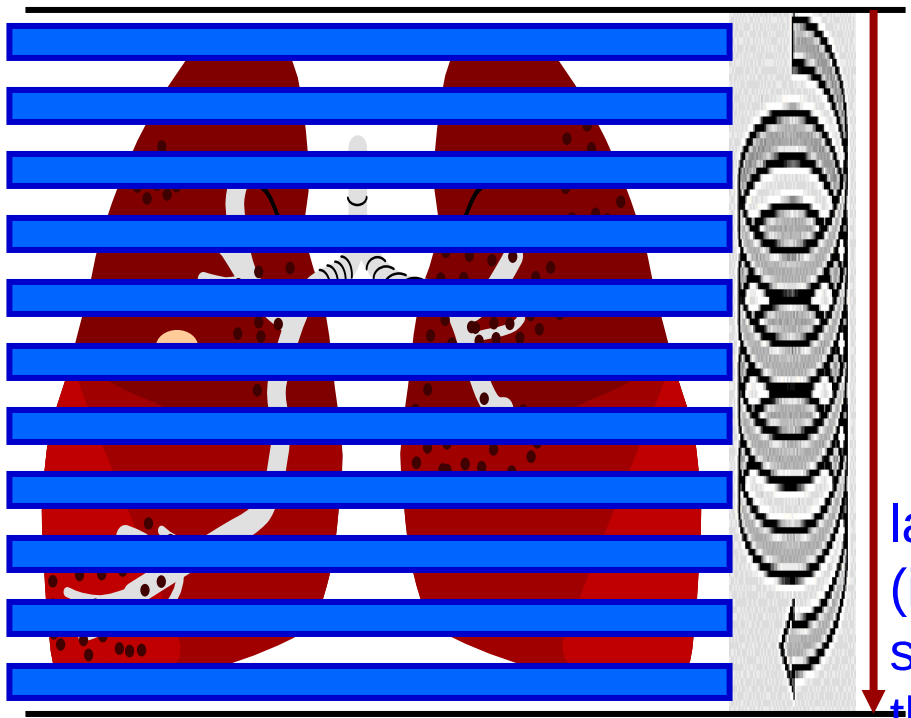


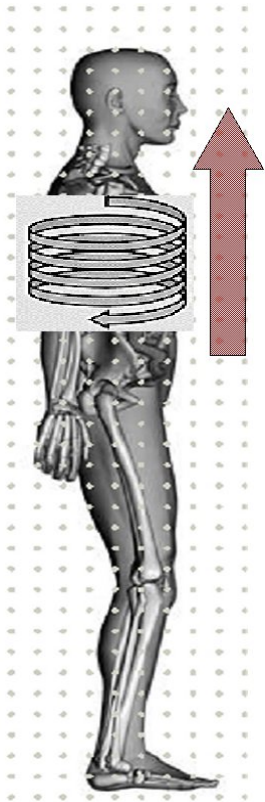
Image Reconstruction at arbitrary slice position over a limited volume

Principles of Spiral CT



larger distance (increment) between the slices than the slice thickness

Image Reconstruction with gaps



Principles of Spiral CT

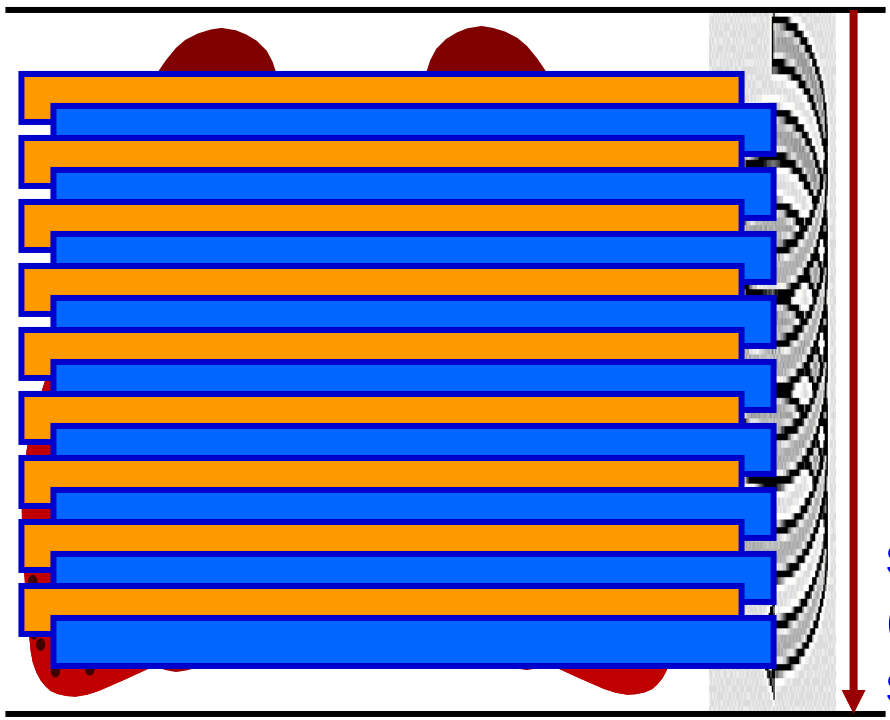
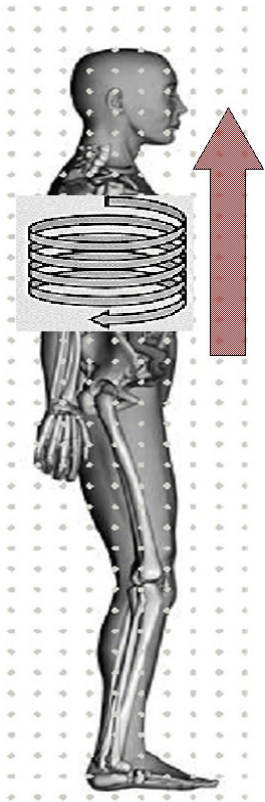


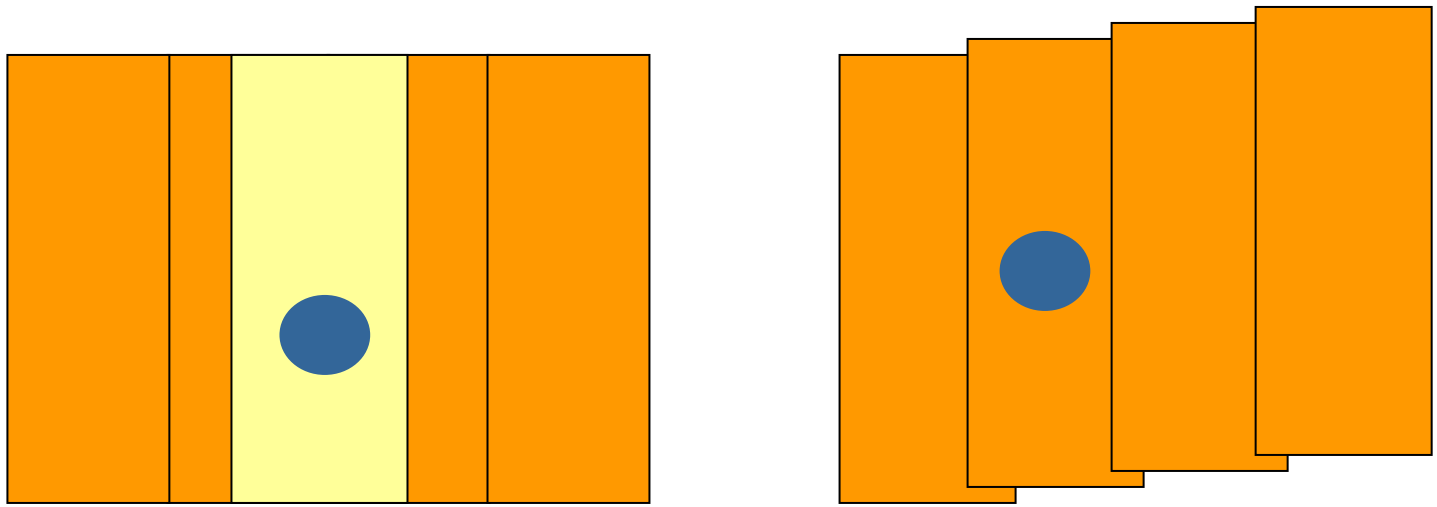
Image Reconstruction with overlap



smaller distance (increment) between the slices than the slice thickness

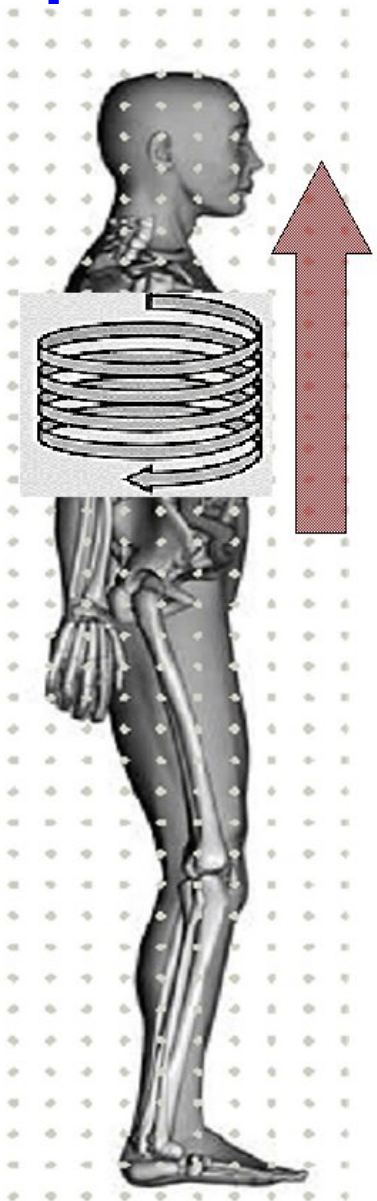
Principles of Spiral CT

Problem: Partial Volume Artifact



- Partial Volume Artifact:
  - Suspicious lesion is covered *partially* in one slice
- Overlapping axial slices
  - Reduces Partial Volume Artifacts by centering the lesion within the slice
  - No additional radiation dose

Spiral CT benefits



- Complete Volume coverage
- Faster data acquisition
  - More patient comfort
  - Data acquisition in one breath hold
  - Less movement artifacts
  - Less contrast media
  - Less patient dose
  - Higher patient throughput

New Concept with Single Slice Spiral

Spiral Scanning can be done at variable speed relative to the collimation

$$\text{Pitch} = \frac{\text{Table Feed per Rotation}}{\text{Collimation}}$$

Examples for Collimation = 5.0 mm

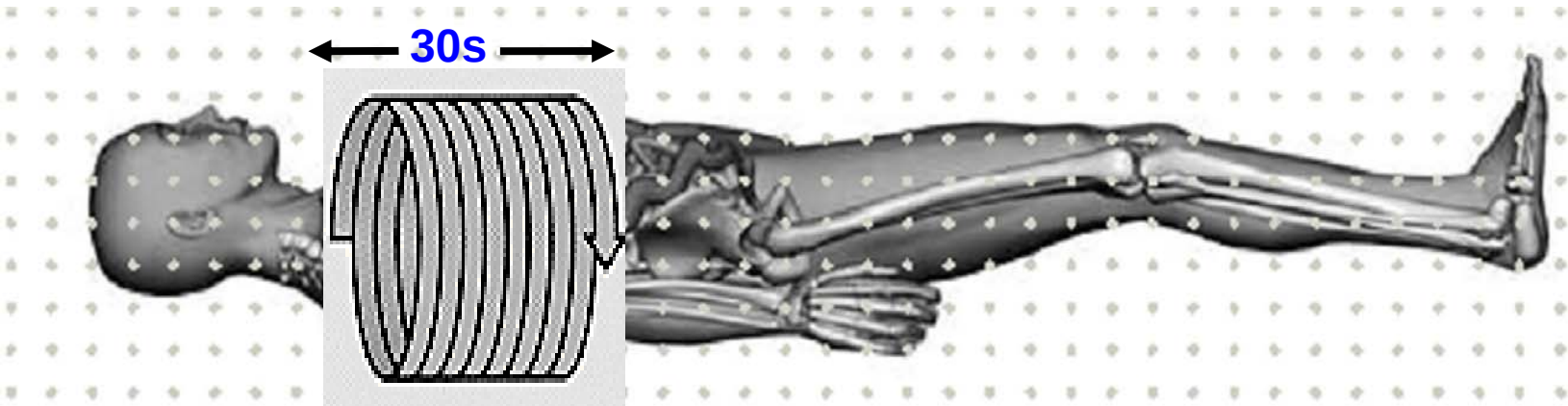
Table feed per rotation = 5.0 mm	Pitch 1.0
Table feed per rotation = 7.5 mm	Pitch 1.5
Table feed per rotation = 10.0mm	Pitch 2.0

- Freely selectable from 1.0 to 2.0
  [Emotion (single slice)]

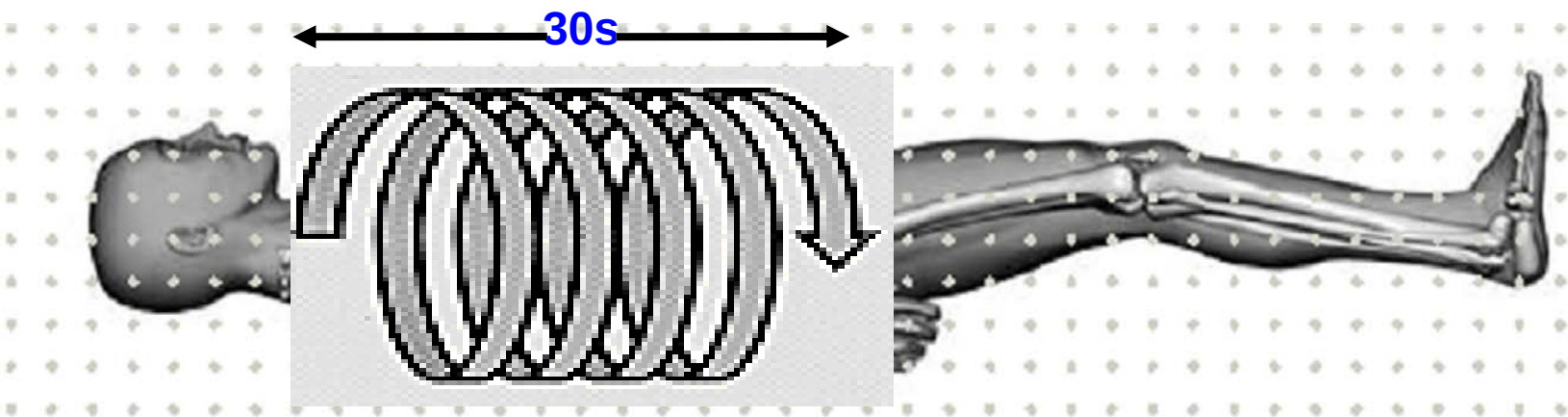
Clinical Benefits of Increased Pitch

More coverage in the same time

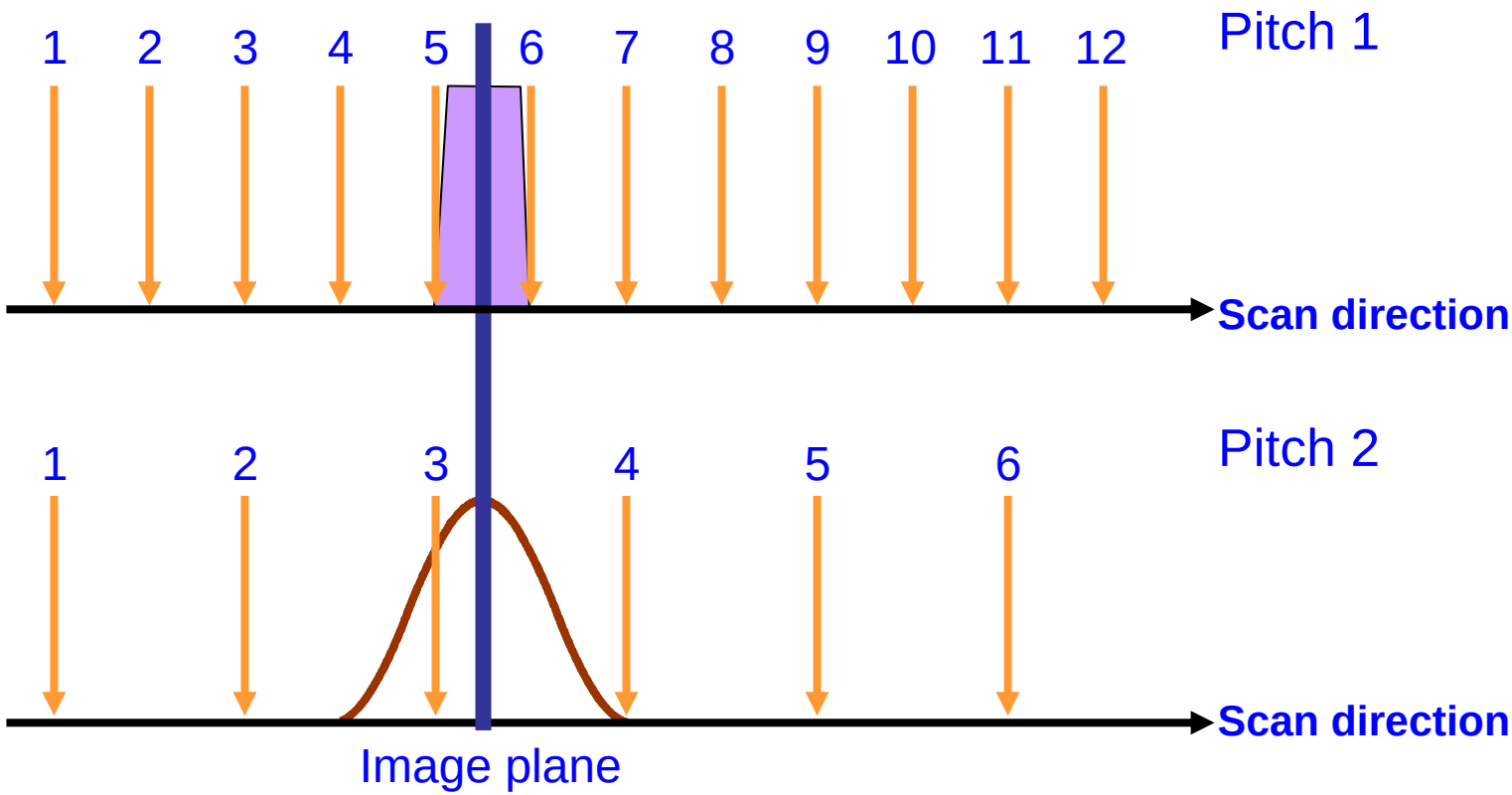
Pitch 1



Pitch 2



Pitch & Image Quality



Data points are stretched with increasing Pitch causing slice profile broadening

Slice Profile (SP)

- Effective slice thickness of an image

Slice Profile Resolution

Factors influencing Slice Profile

- Collimation
- Pitch
- Interpolation algorithm (360° or 180°)

In the worst case scenario……

Example

5 mm collimation, Pitch 1.0 → 5.0 mm Slice Profile

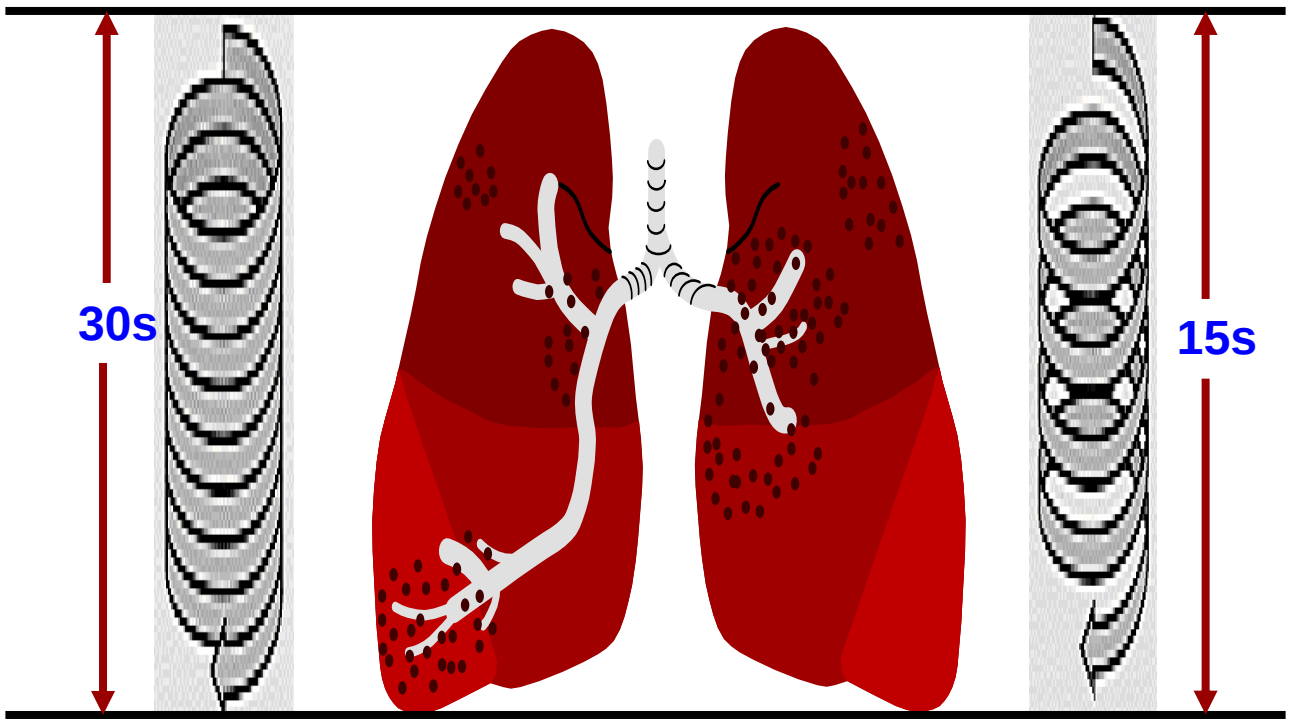
5 mm collimation, Pitch 2.0 → **6.5 mm** Slice Profile

Scanning at Pitch 2 leads to *decrease in image quality* *on single slice CT & other vendors MSCT*

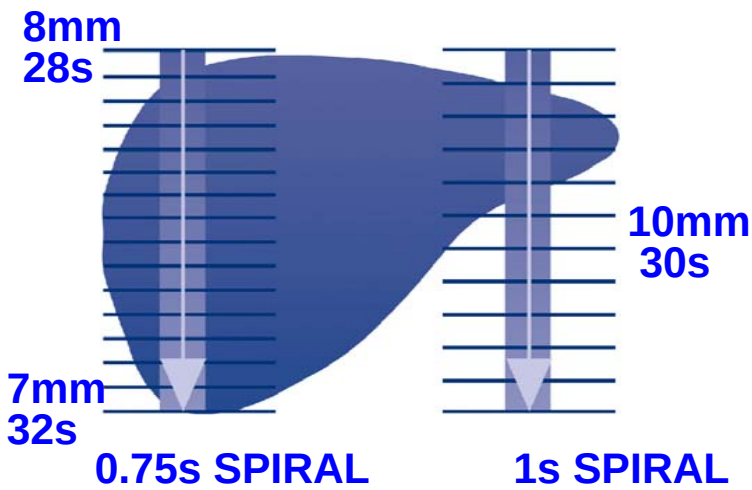
Clinical Benefits of Increased Pitch

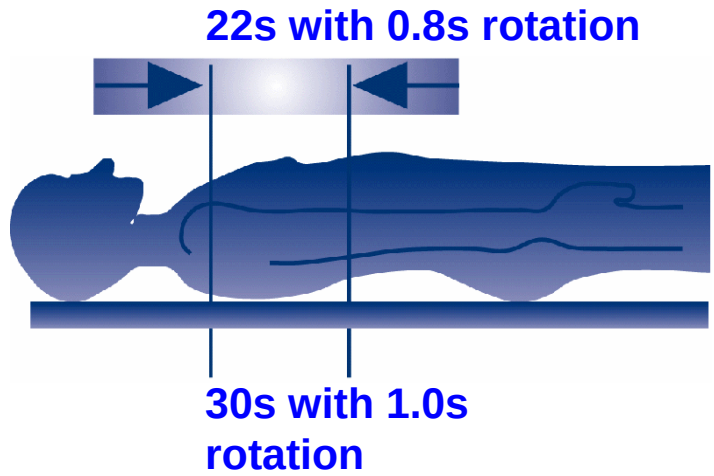
Reduced scan time & dose for the same coverage

assuming same slice size

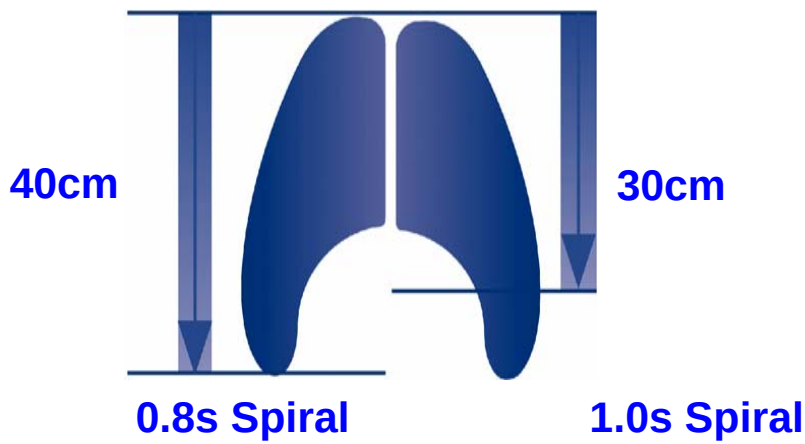


Clinical Benefits of Subsecond Spiral





- Reduced scan time & dose
- Improved resolution
- More coverage
- Improved Temporal Resolution
  - Less motion artifacts
  - New applications – Cardiac CT



Chest Imaging Protocols Comparison

Sequential CT

- Slice Imaging
- ~ 2s per slice
- 100 -150 ml contrast
- 8 - 10 mm collimation

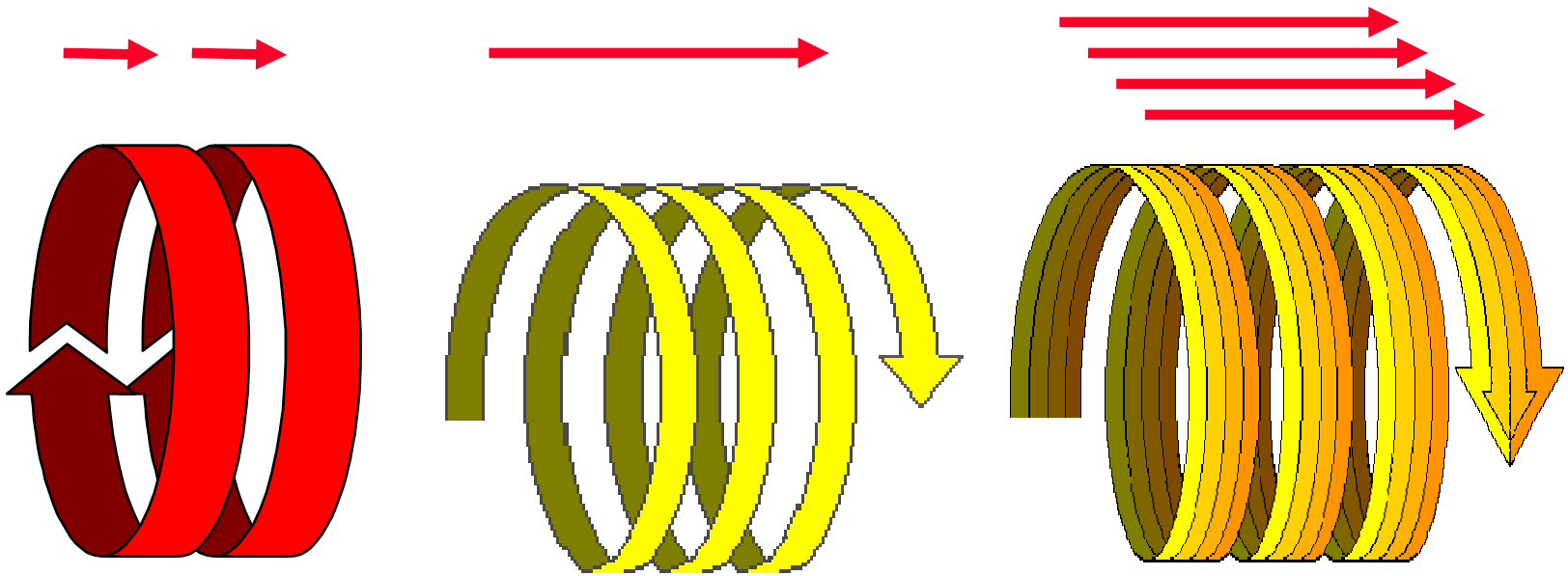
Single Spiral CT

- Volume Imaging
- 25s - 40s per volume
- 50 - 80 ml contrast
- 3 - 5 mm collimation

- Eliminates respiratory mis-registration
- Faster with improved spatial resolution
- Reduced contrast dosage

Conventional vs. Single-Slice Spiral vs. Multi-Slice Spiral

Single Slice → Single Volume → Multi-slice Volume

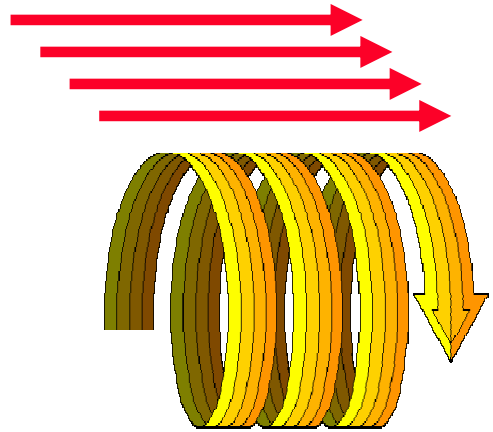


I.S.D*

no I.S.D

* Inter Scan Delay

Multi-Slice CT Scanning



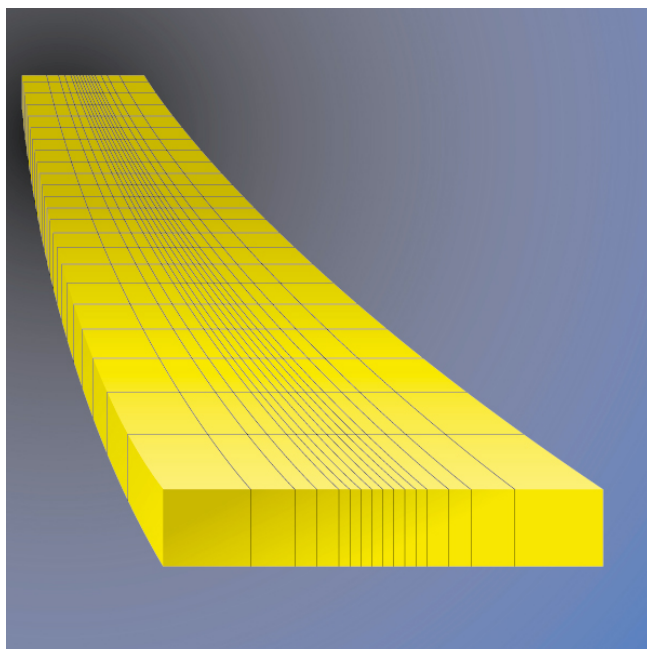
- Multi-Slice CT
  - Multiple slices are acquired for each rotation.
  - With the currently available multi-slice scanners, either 2, 4*, 6, 10, 16, 24**, 40 or 64 slices can be acquired per rotation.

• Refurbished Volume Zoom / Sensation 4

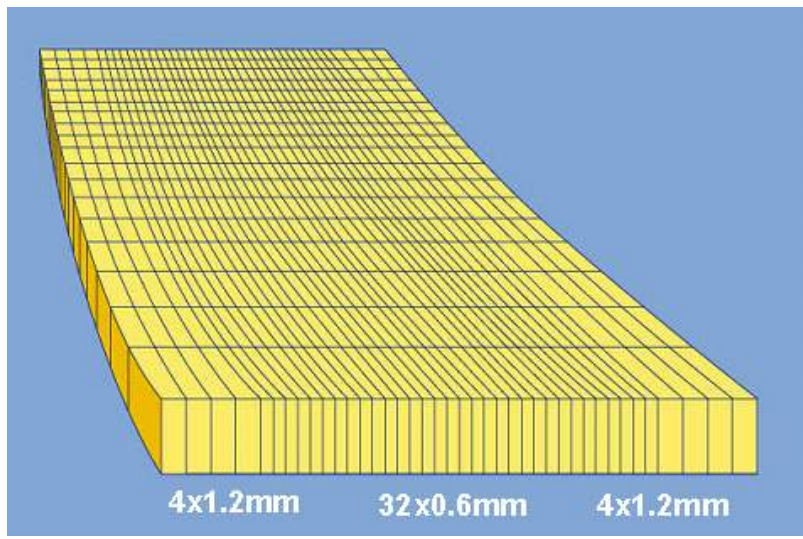
** Sensation Open

Multi-slice Detector Designs

Single slice CT's have one detector row,while multi-slice CT's have multiple detector rows.

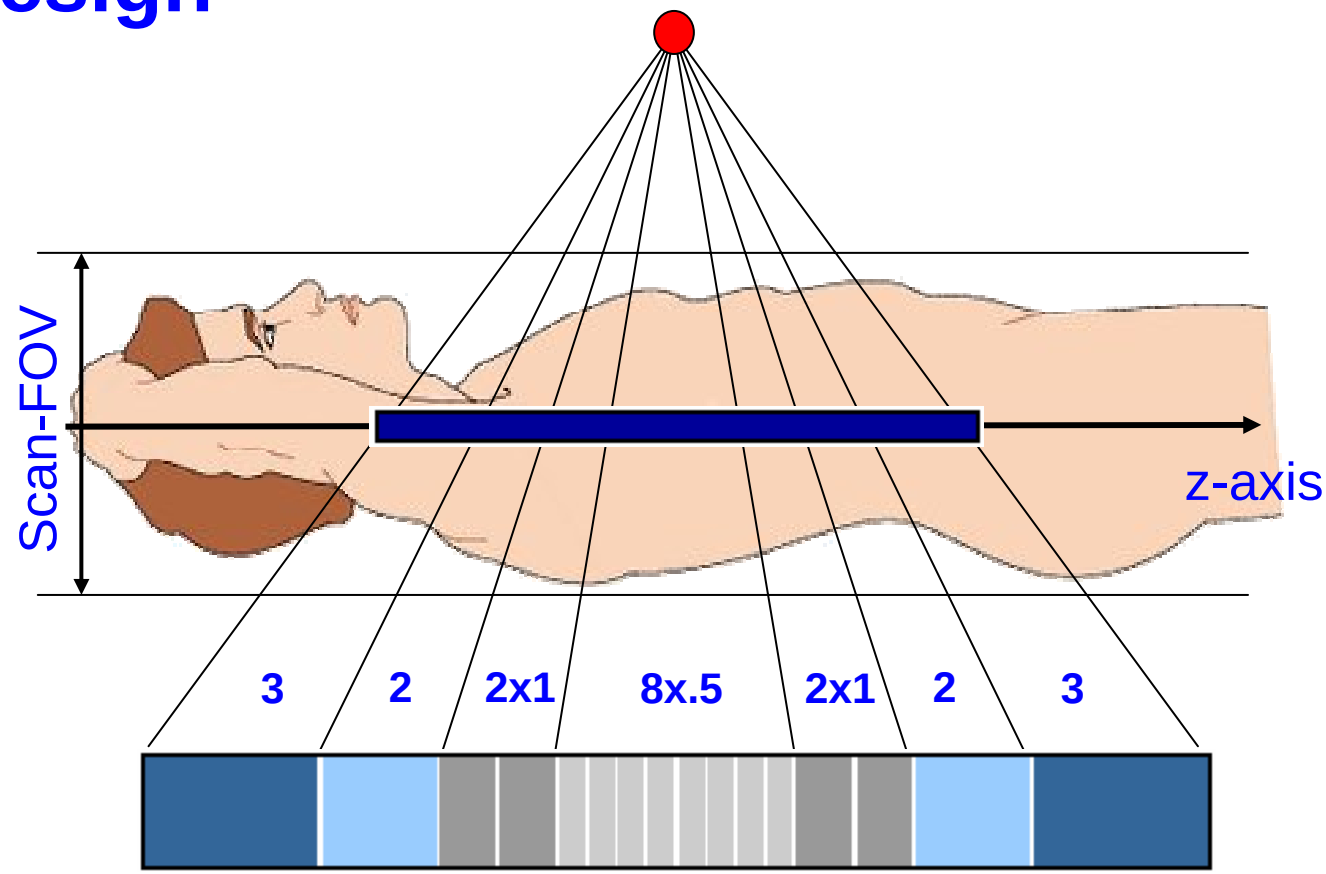


Emotion 6



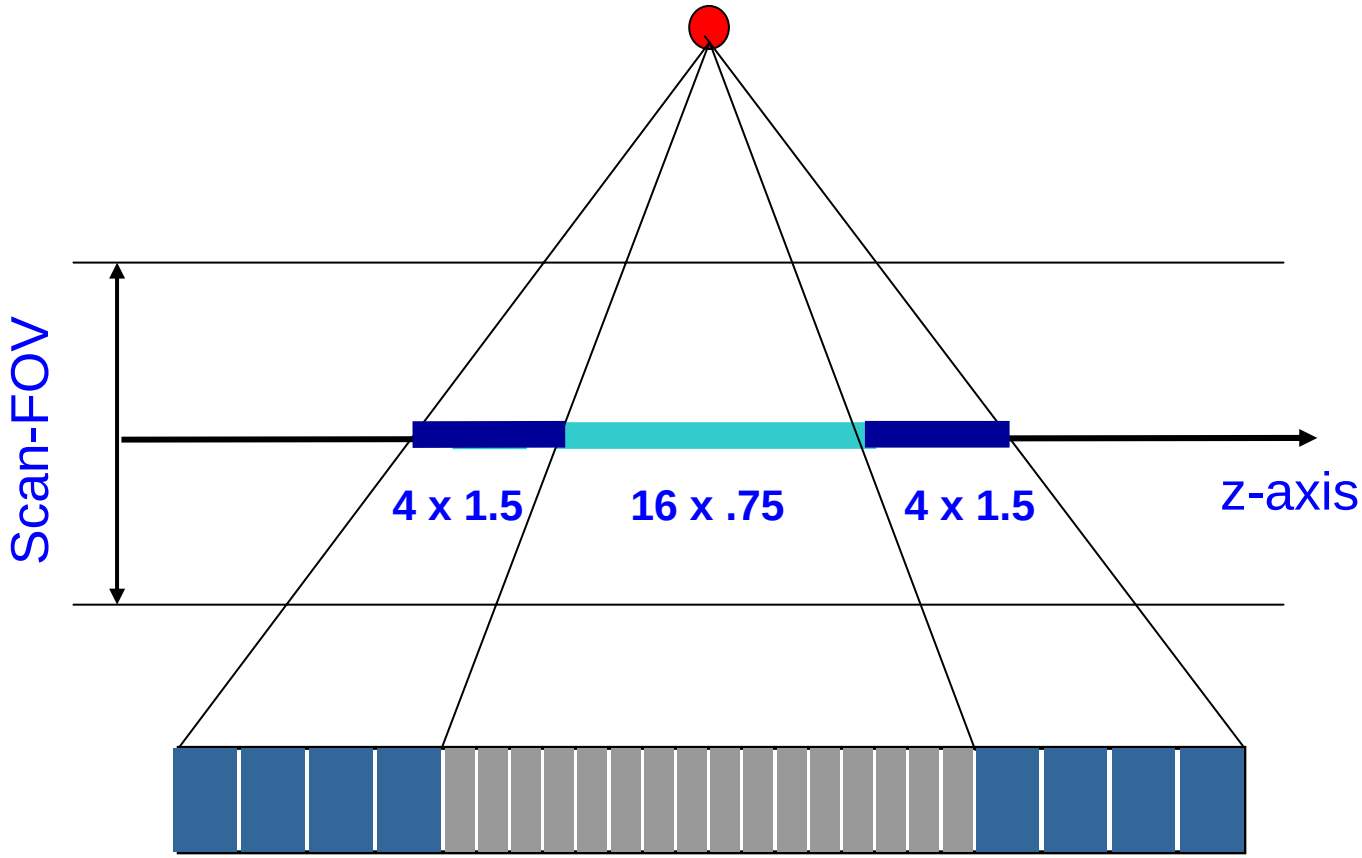
Sensation 64

Multi-Detector Adaptive Array Design

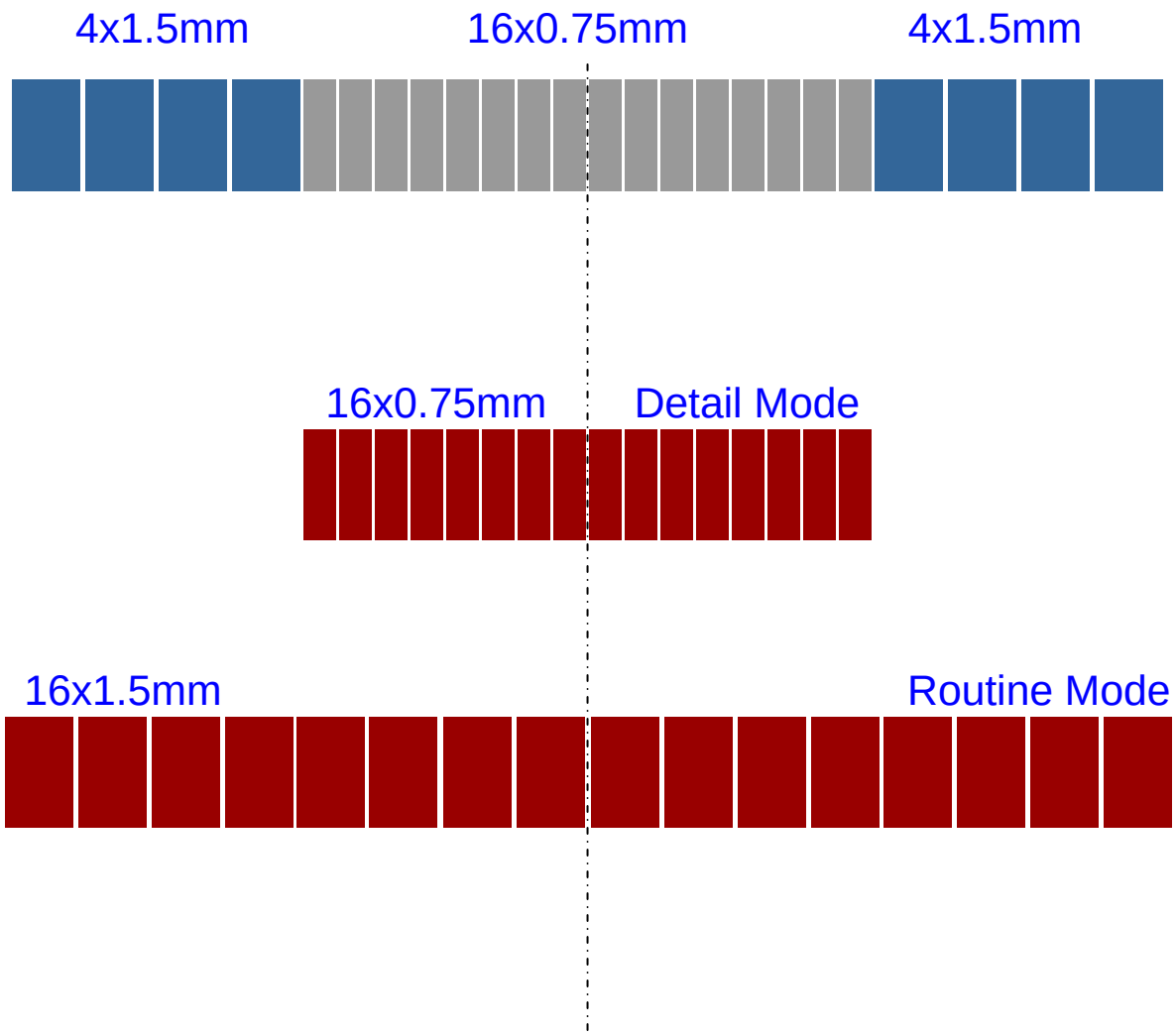


Emotion 6 adaptive array detector

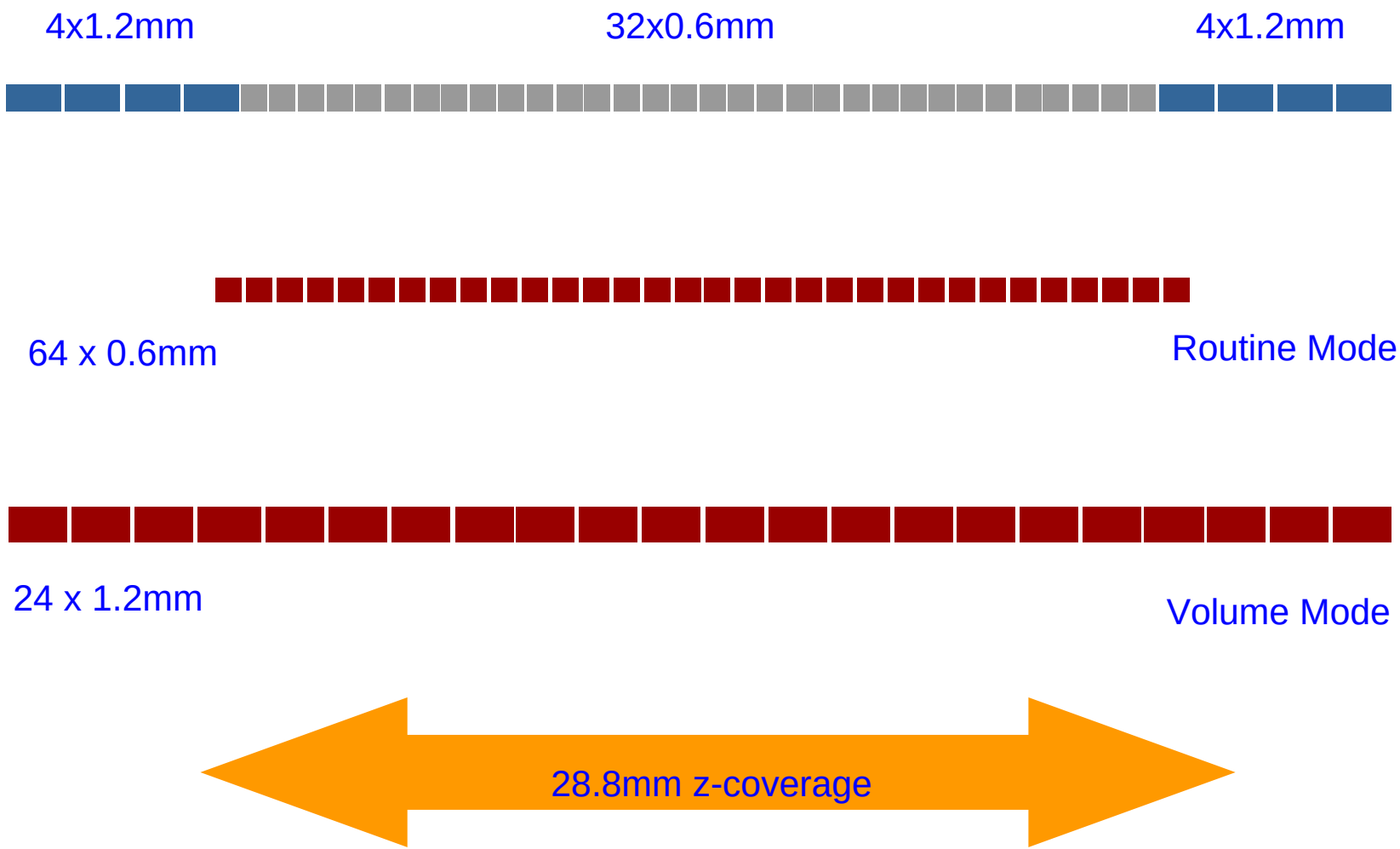
Adaptive Array Design – S16



Detector Configuration Sensation 16



Detector Configuration Sensation 64



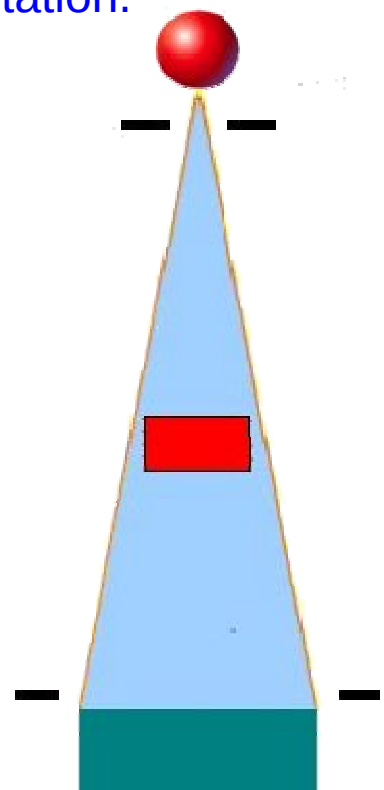
Slice Collimation & Width...

- For all Siemens MSCT´s a combination of *Collimated slice* and *reconstructed slice thickness* have to be selected
- The slice width is the true width of a Siemens CT reconstructed slice (unlike other vendor's MSCT systems who have slice broadening)
- Slice width can only be thicker than slice collimation…cannot be thinner
- The slice thickness can be changed retrospectively

Slice collimation...

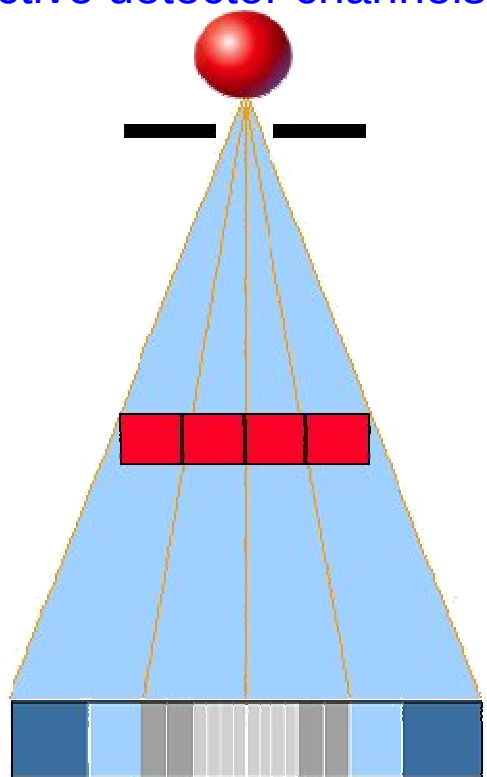
Single Slice CT

Slice collimation is the slice thickness collimated by the tube collimator determining the Z coverage per rotation.



Multi Slice CT

Slice collimation is the total slice thickness collimated by the tube collimator and then divided by the number of active detector channels.



Two different definitions for pitch

- Pitch Factor: table ... by the ... distance ... collimation
- Volume Pitch: table ... by the ... collimation
- Selection ... abdomen scan

be careful!

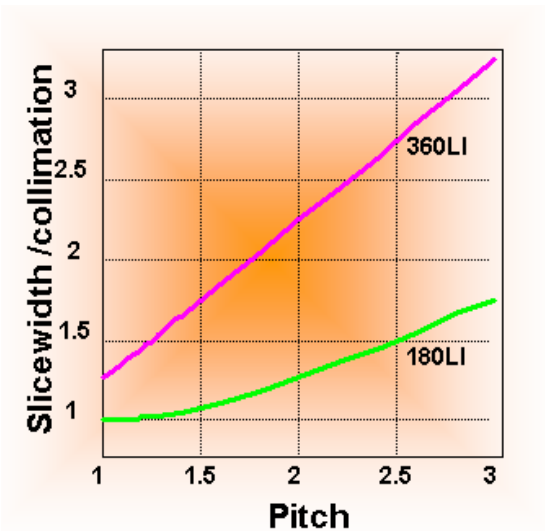
$$\text{Pitch Factor:} \quad \frac{\text{18mm per rotation}}{\text{16 rows x 0.75 mm}} = \text{Pitch 1,5}$$

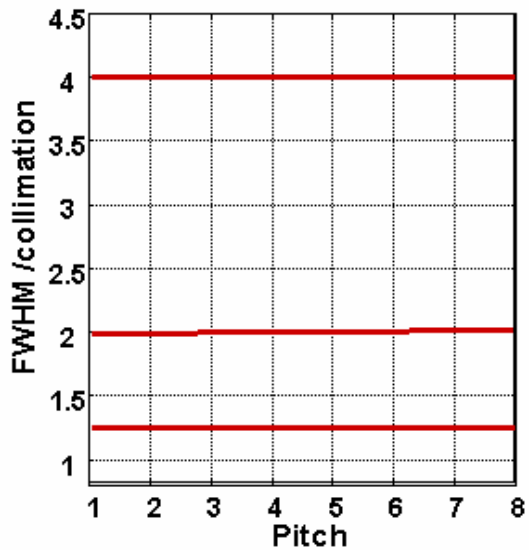
$$\text{Volume Pitch Factor:} \quad \frac{\text{18mm per rotation}}{\text{0.75 mm}} = \text{Pitch 24}$$

Pitch...

In multi-slice spiral with the Emotion Duo / 6 and the Sensation, you select the slice collimation together with the slice width, and the slice width is not affected by the pitch or the algorithm.

No slice Broadening
What you ask for is what you get!





Clinical Applications of Spiral CT

- Routine Volume Acquisition (in a breath hold)
- Routine Neuro Spiral Imaging
- Multiphasic Spiral Contrast Studies
- CT Angiography's
- Musculoskeletal 3D Imaging

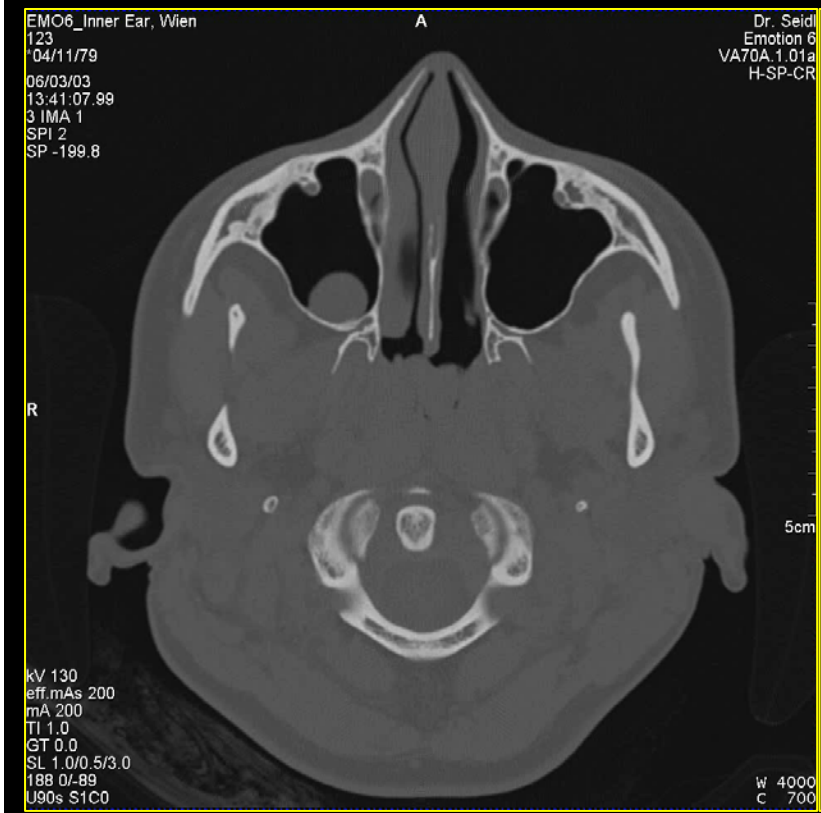
Routine Applications

- Bone and lungs

- Soft tissue

Bone & Lungs

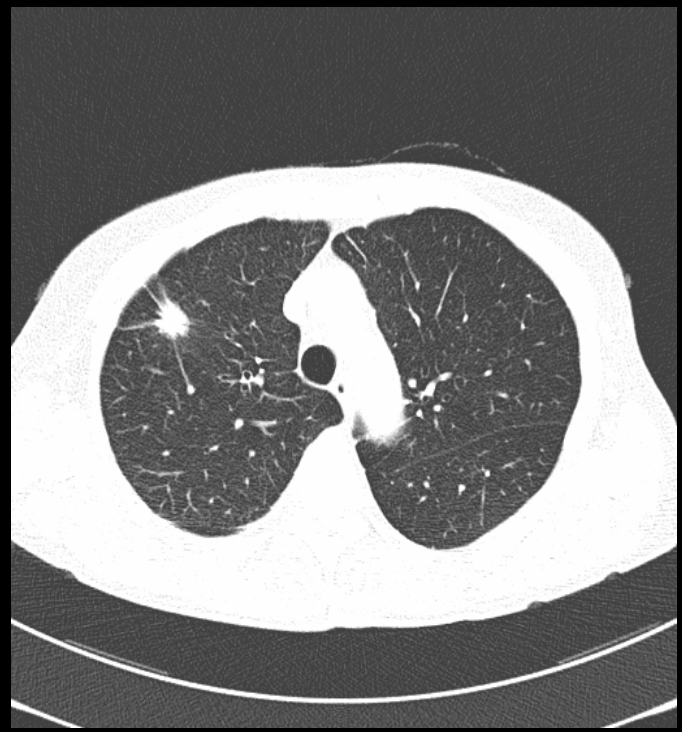
“Black & White” - High Contrast



Bone and lungs

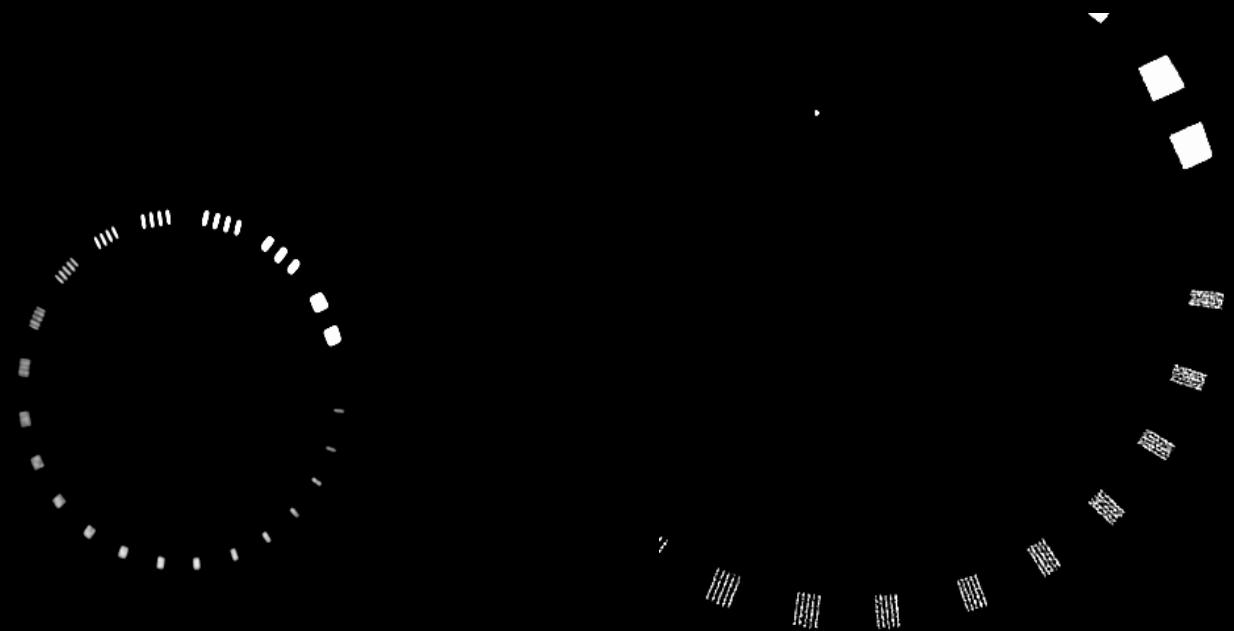
- Big differences in the tissue densities
- High contrast resolution is needed
- High images noise – less dose is needed
- No differentiation of small tissue density differences

Inner ear



Lung

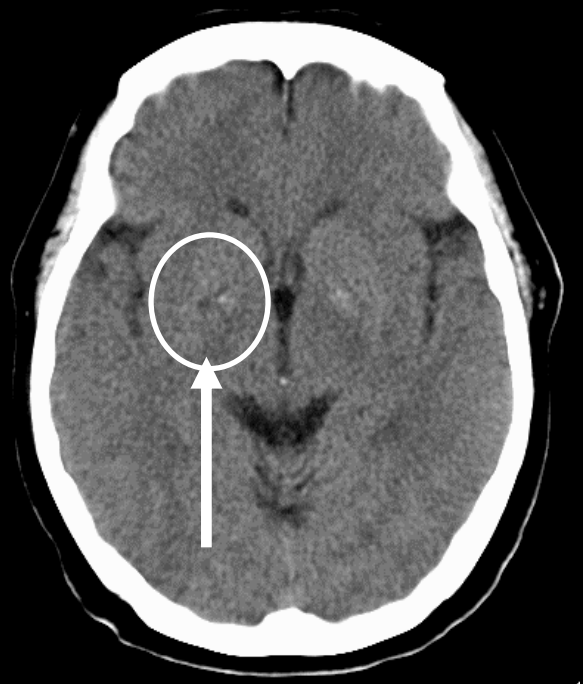
MTF: Catphan HC-insert with kernels H30s, U95u



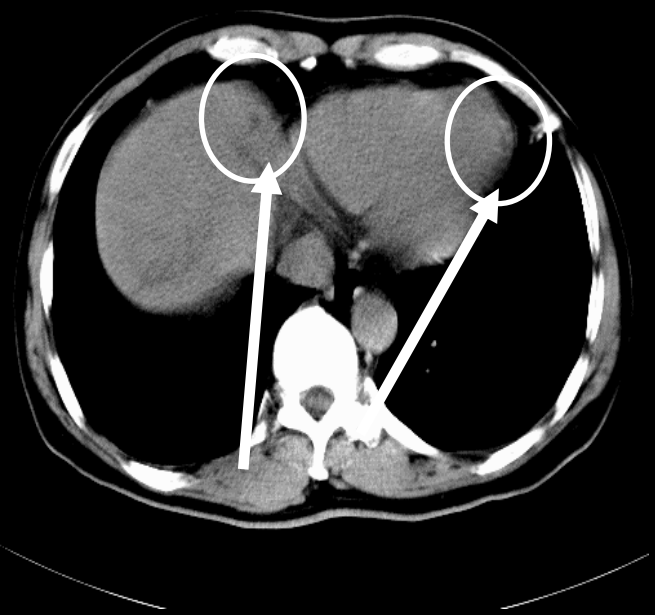
H30s , FOV = 200 mm , 7lp /cm U95u ,FOV = 100 mm , 20lp /cm

Soft Tissue - Low Contrast Resolution

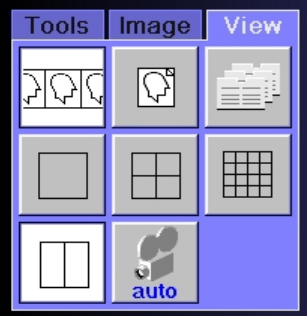
- Possibility to visualize different tissue densities, which are close together
- No image noise – you need a higher dose

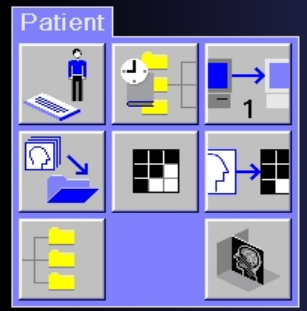


Head



Abdomen/Liver

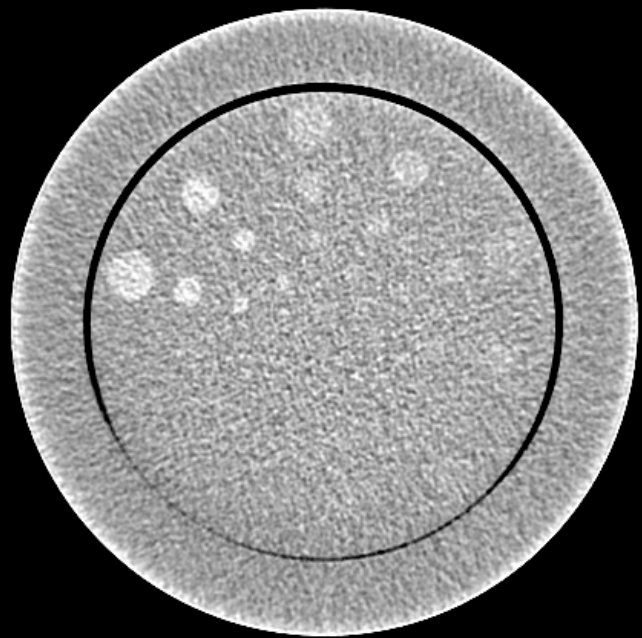


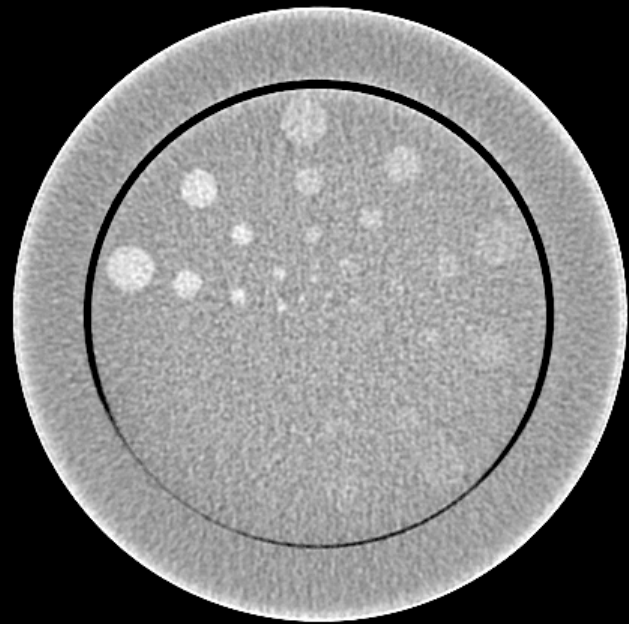


Low Contrast Resolution

- To visualize small density differences, a good Low Contrast resolution is needed
- Specification of Low Contrast Resolution
  - Phantom: CATPHAN (16mm)
  - Object size: 3mm
  - contrast diff.: 3HU
  - Dose at the surface: 19.7 mGy at 100/104 mAs
  - Technic: 1.0 sec; 10mm, 120kv

Low-contrast: Emotion (B30s,130 kV, 10 mm)





73 mAs

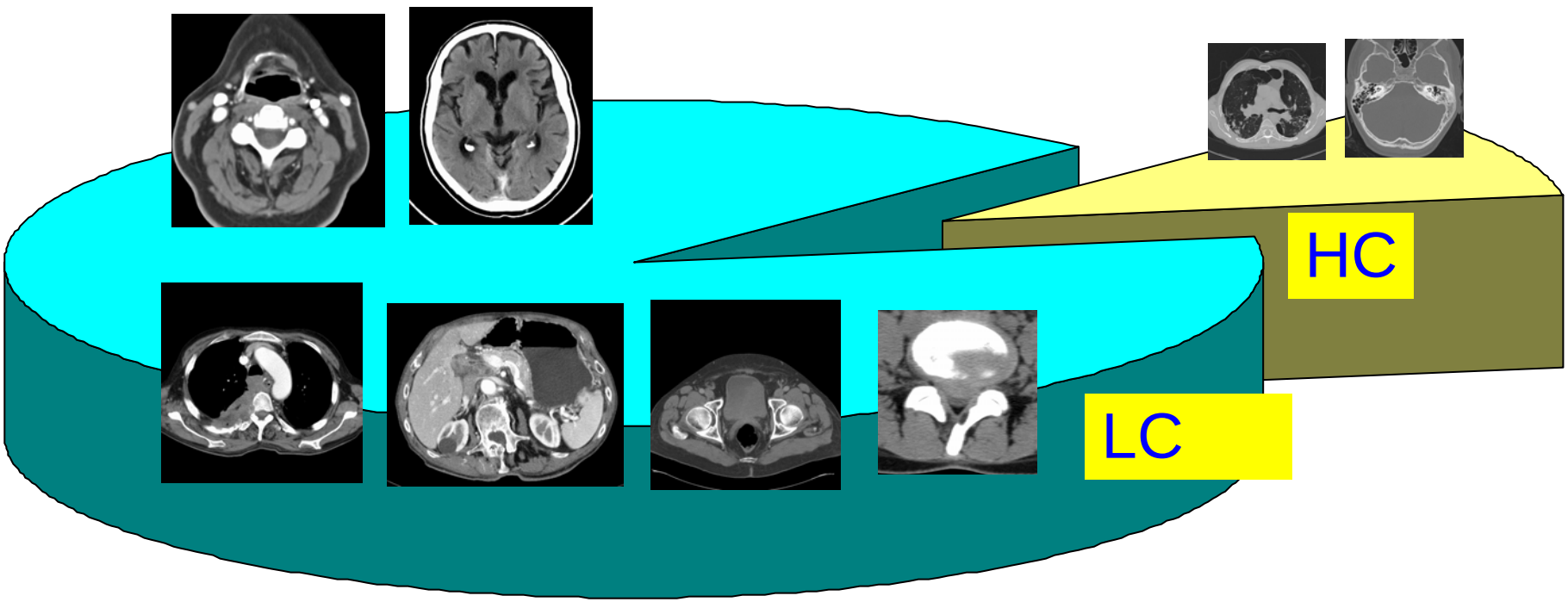
20 cm Catphan

FOV = 250 mm

225 mAs

Routine Mix of CT Examination

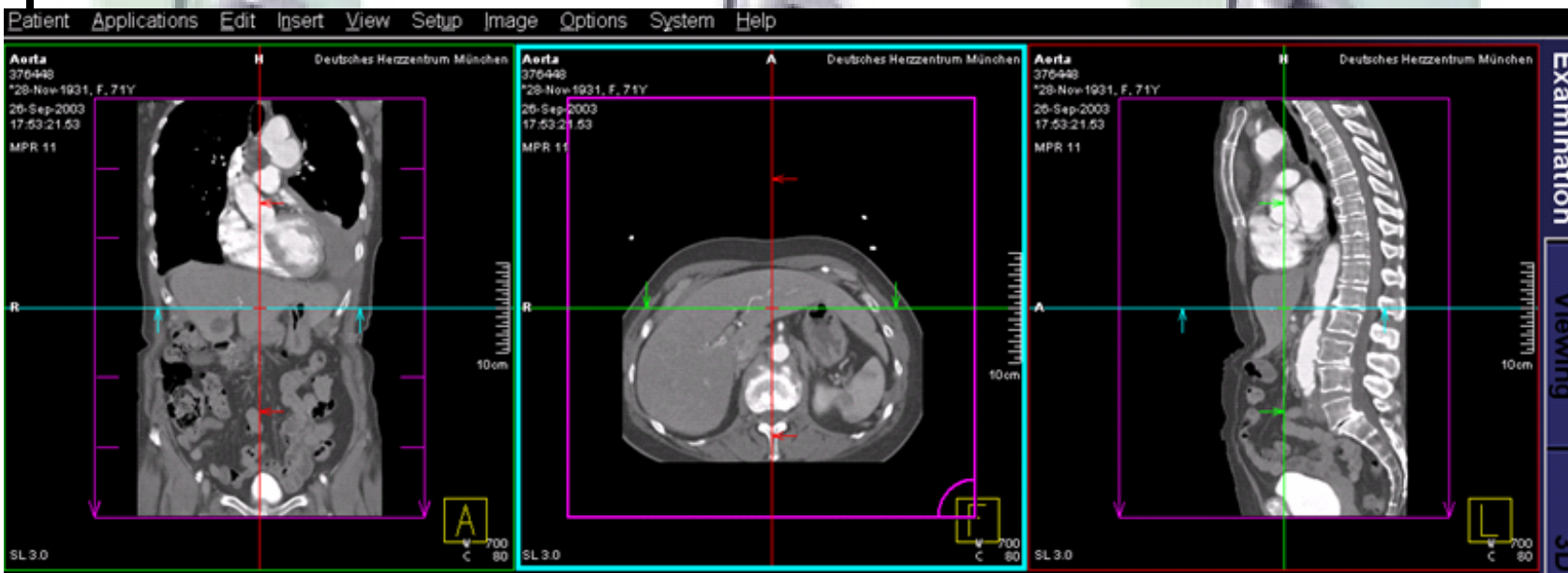
- Only 10% are High Contrast Studies



3D Imaging - Abbreviations

- MPR – Multi Planar Reconstructions
  - Transaxial images are combined to volume. The volume can be reformatted to secondary images in selected planes (sagittal, coronal or oblique)
- SSD – Shaded Surface Display
  - Surface images of tissue structure are created out of the volume dataset. A three dimensional object is calculated from voxels, whose threshold values are within a specific density range
- VRT – Volume Rendering Technique
  - Possibility to render different tissues, which have a different densities, as a 3D object in different colors and with different brightness and opacity
- MIP – Maximum Intensity Projection
  - Possibility to render different tissues, which have high density and show them as a 3D object in different grey scales

Reconstructions Orientations



coronal axial sagittal

Patient Transfer Edit View Image Tools Scroll Options Help

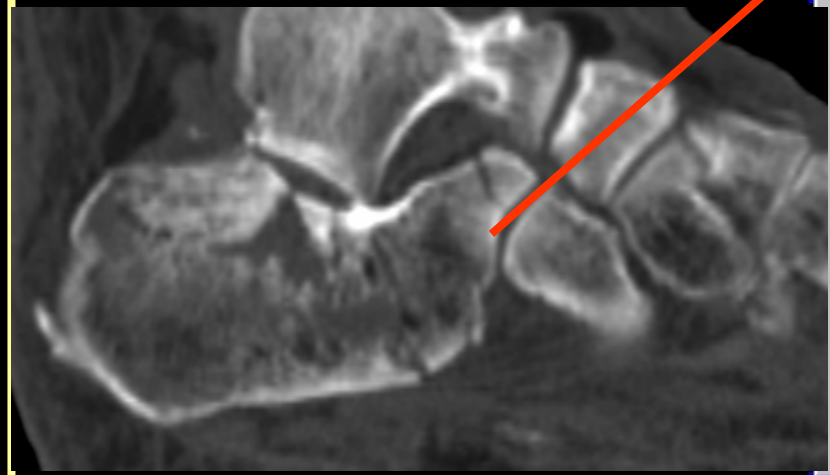
High-Resolution Ankle Study

Axial Imaging with Multiplanar Results

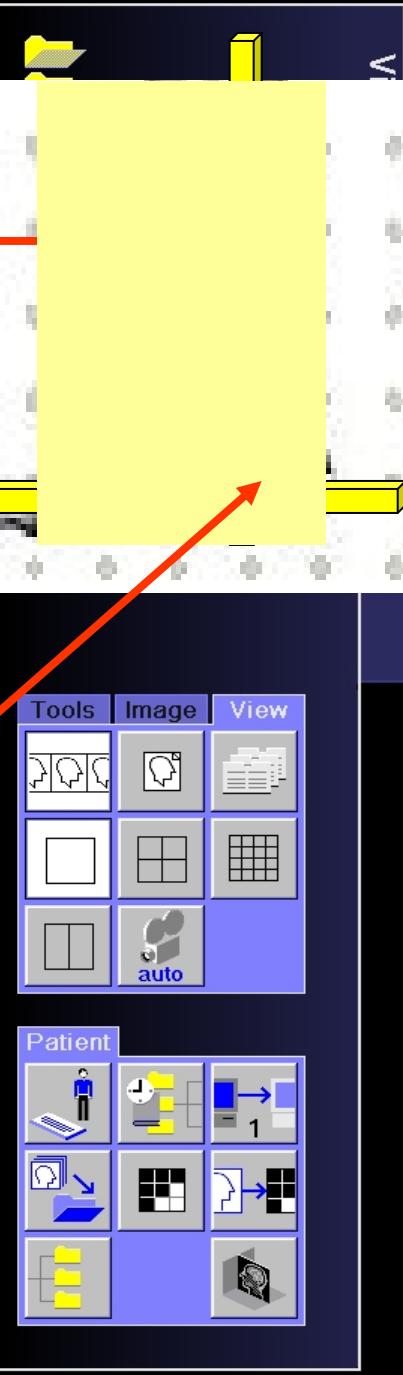
Axial Image

1 mm, Pitch 2, Emotion

Coronal Reformat

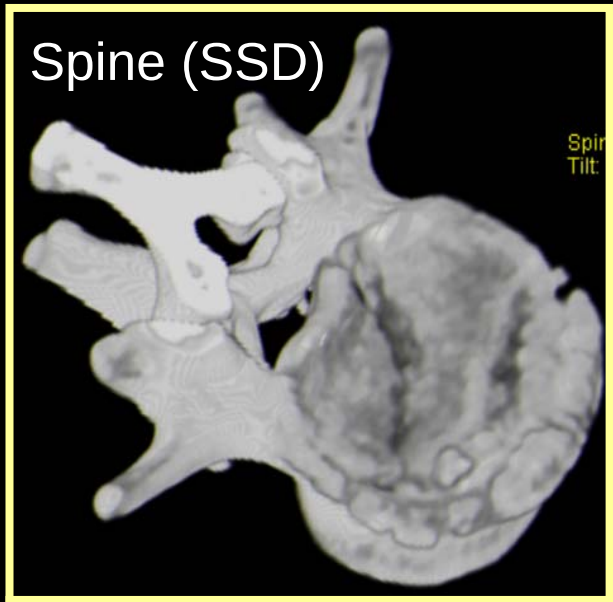


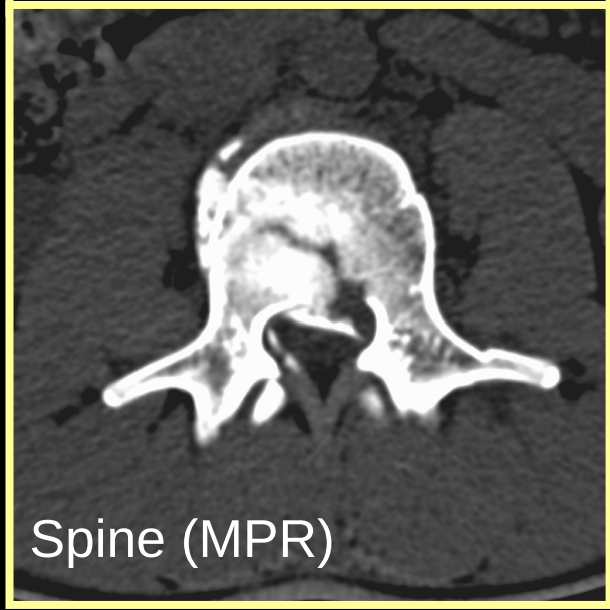
Sagittal Reformat



3D Trauma Imaging – Fractures

Spine (VRT)

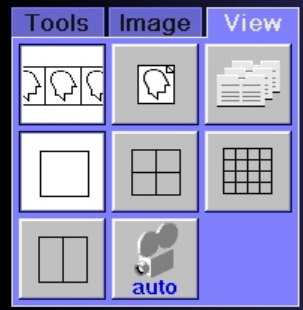


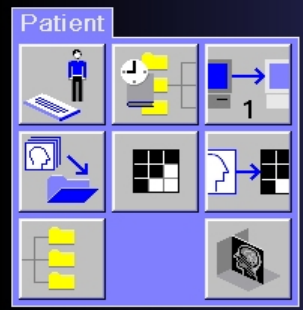


Musculo-Skeletal 3D Imaging (VRT)

Osteosacroma Left Pelvis

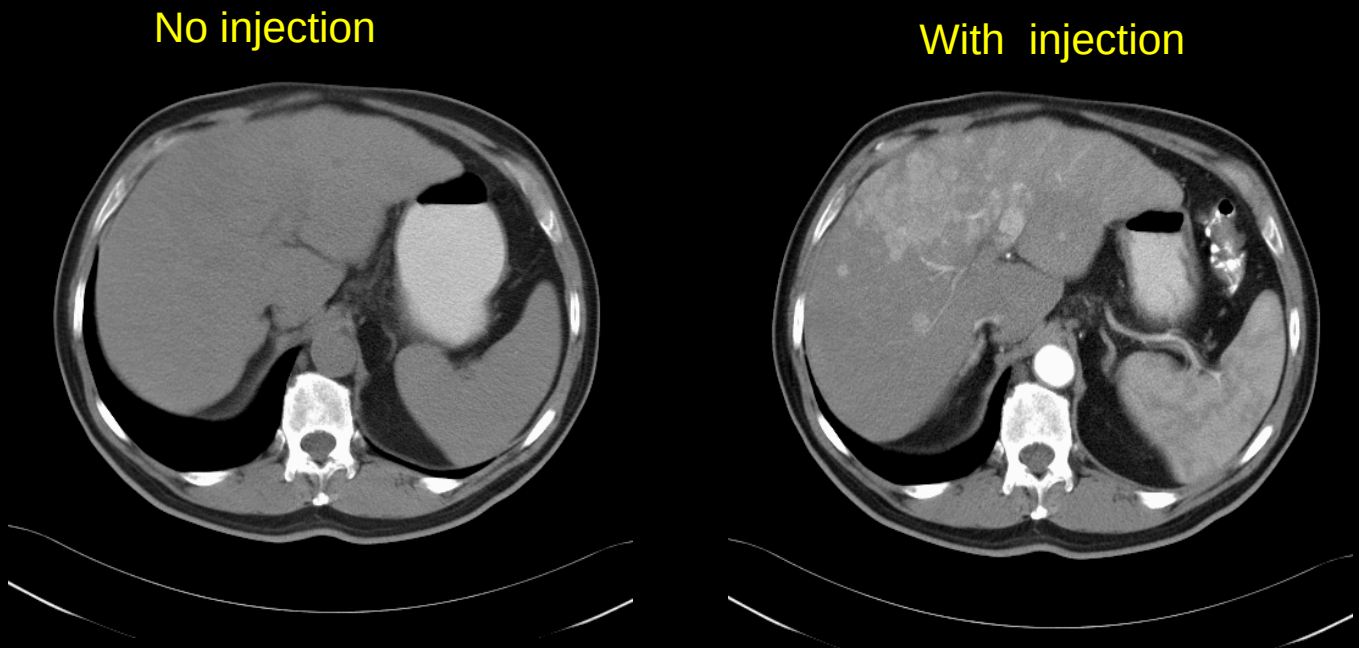
2 mm, Pitch 1.5, Emotion





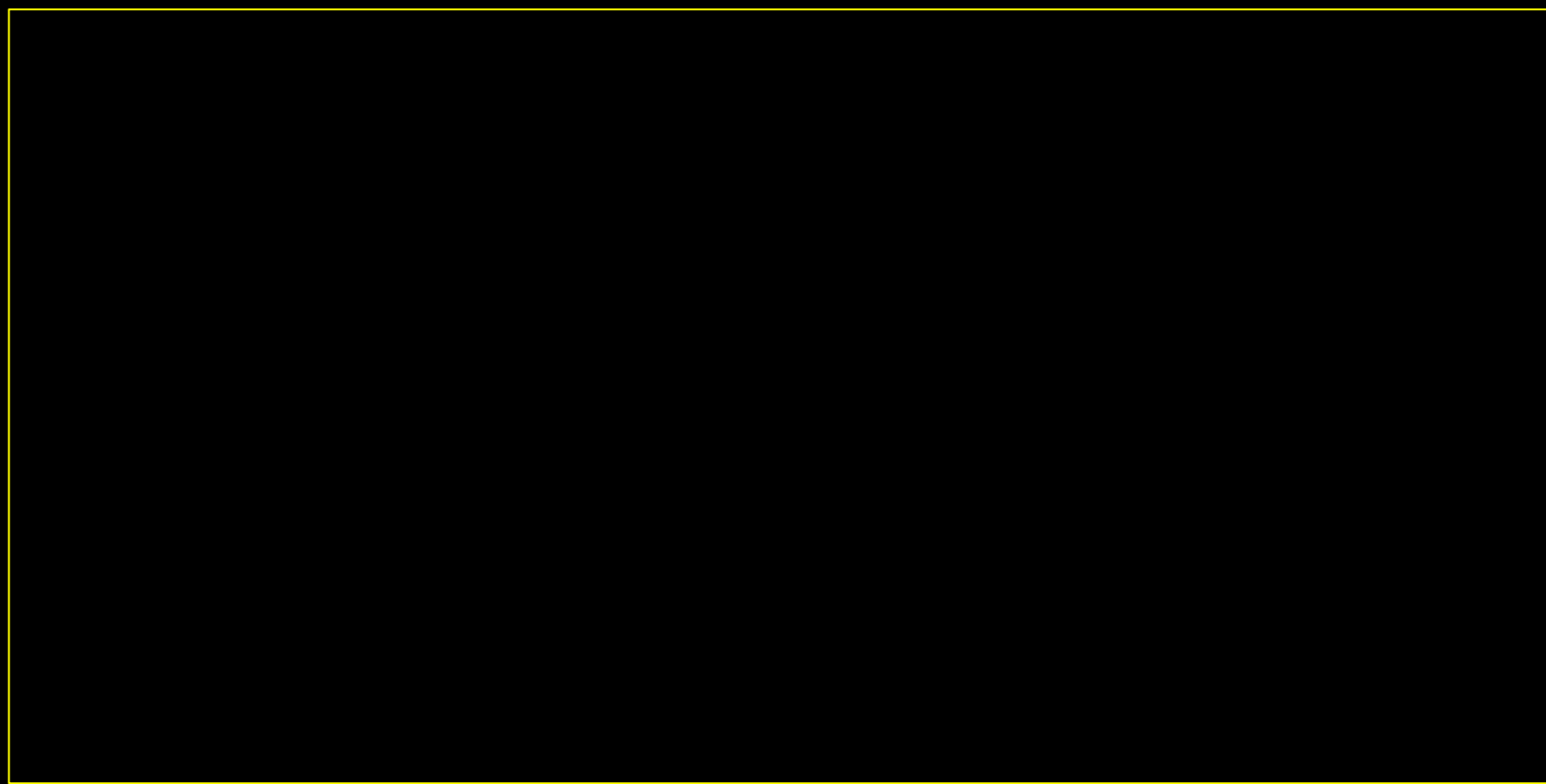
Why use an injector with contrast media for an examination ?

- Images with contrast media injection helps by the diagnosis and by the differential diagnosis



Multiphase Liver examination

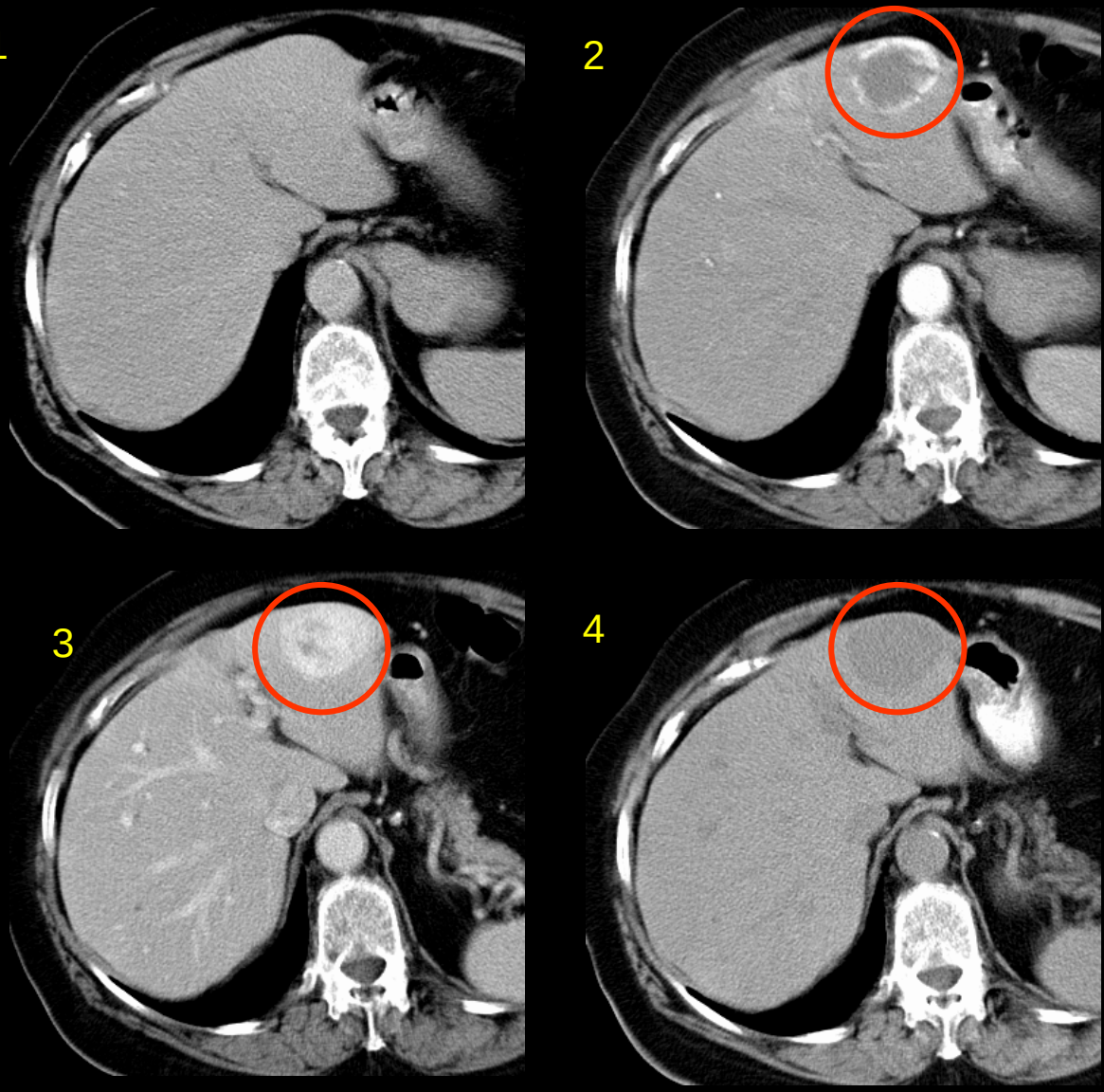
Liver Study with Contrast Medium



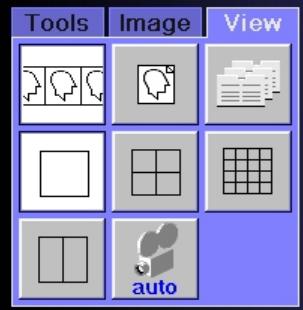
Arterial

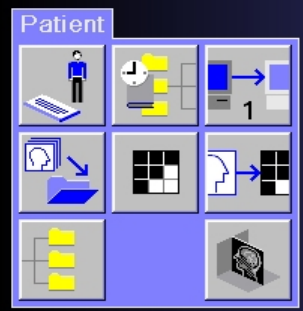
Venous

4-phase Liver Hemangioma (Emotion)

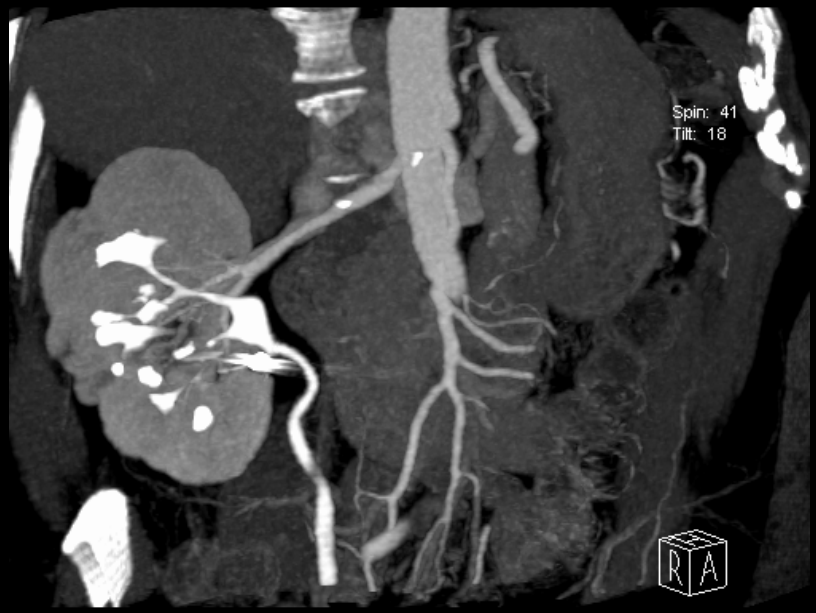


1 Pre-contrast
2 Arterial
3 Portal-venous
4 Delayed phase





Contrast media injection for CT Angio´s

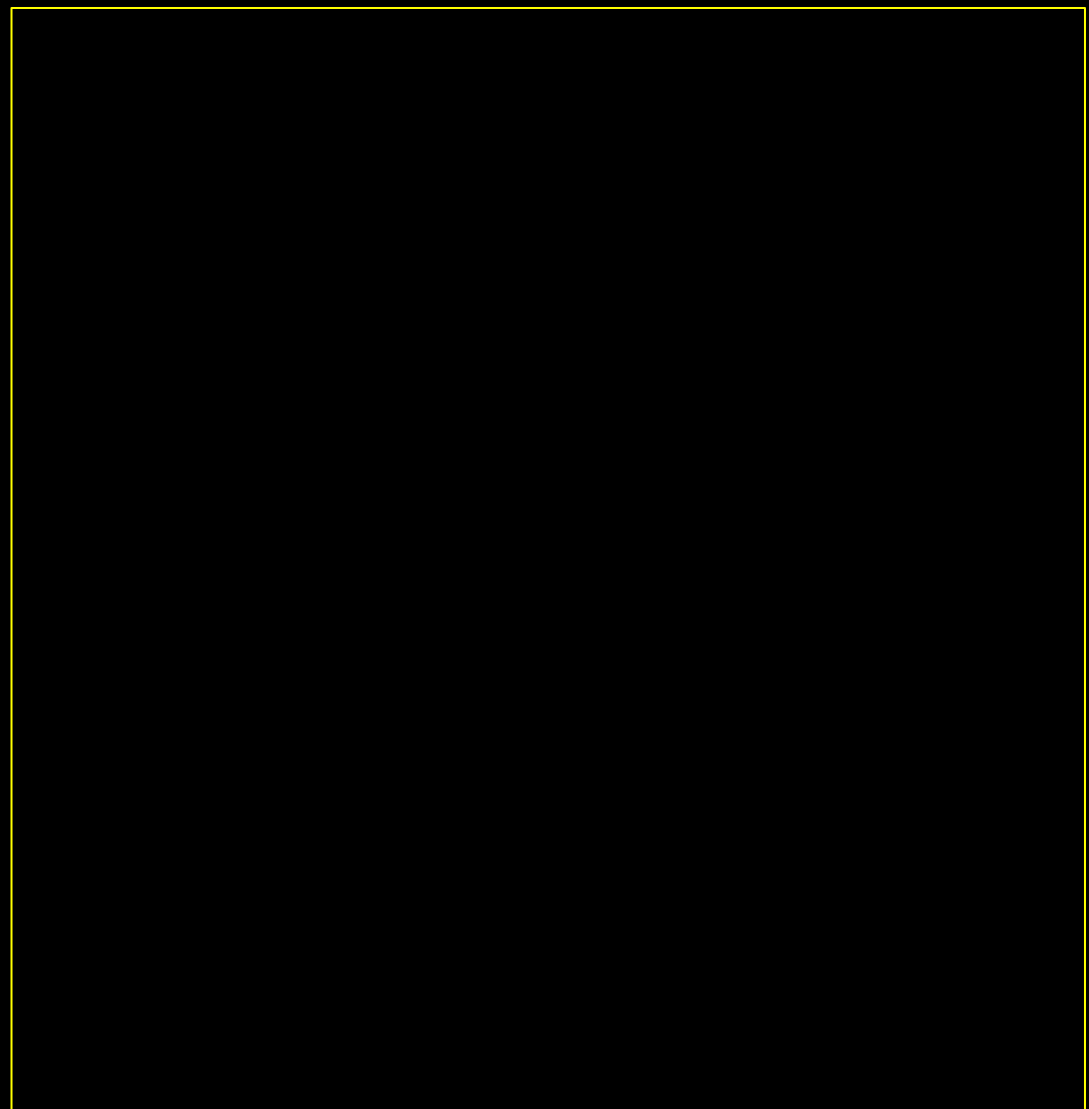


Angio study of Kidney (MIP)

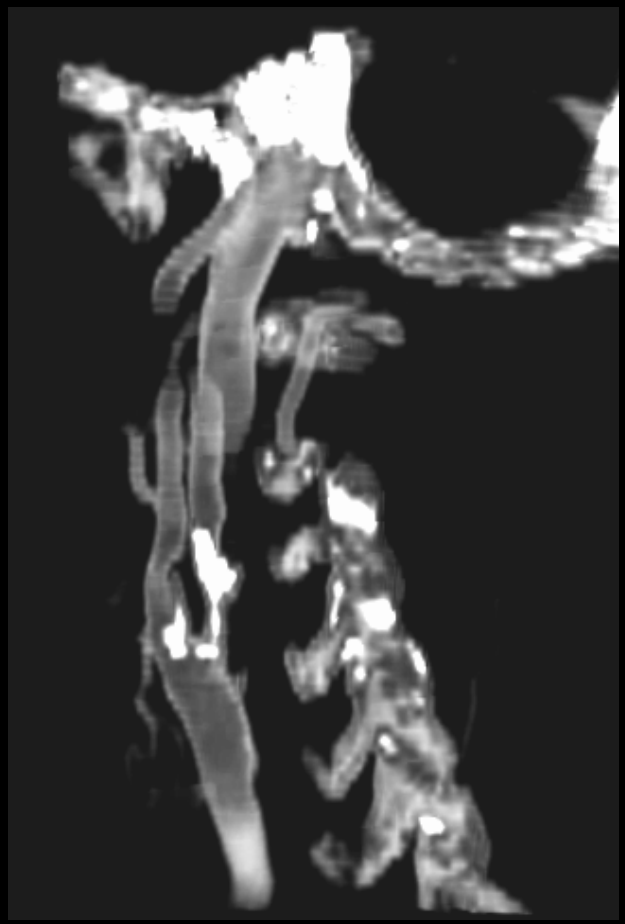
- CT Angiography
  - Visualization of vessels without catheter

Leg – femoral runoff (MIP)

Advanced Contrast Studies
VRT (InSpace)

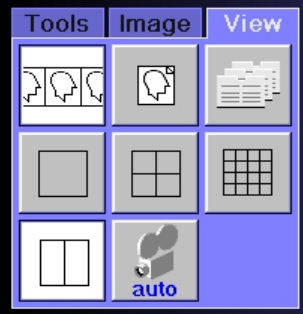


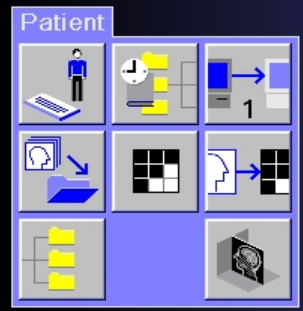
Neuro CTA – Carotid Arteries



2 mm, Pitch 2, Emotion MIP

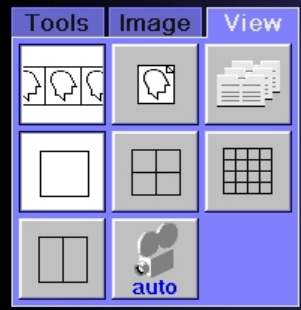
2 x 1mm, Emotion Duo VRT

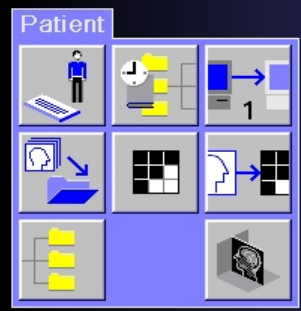


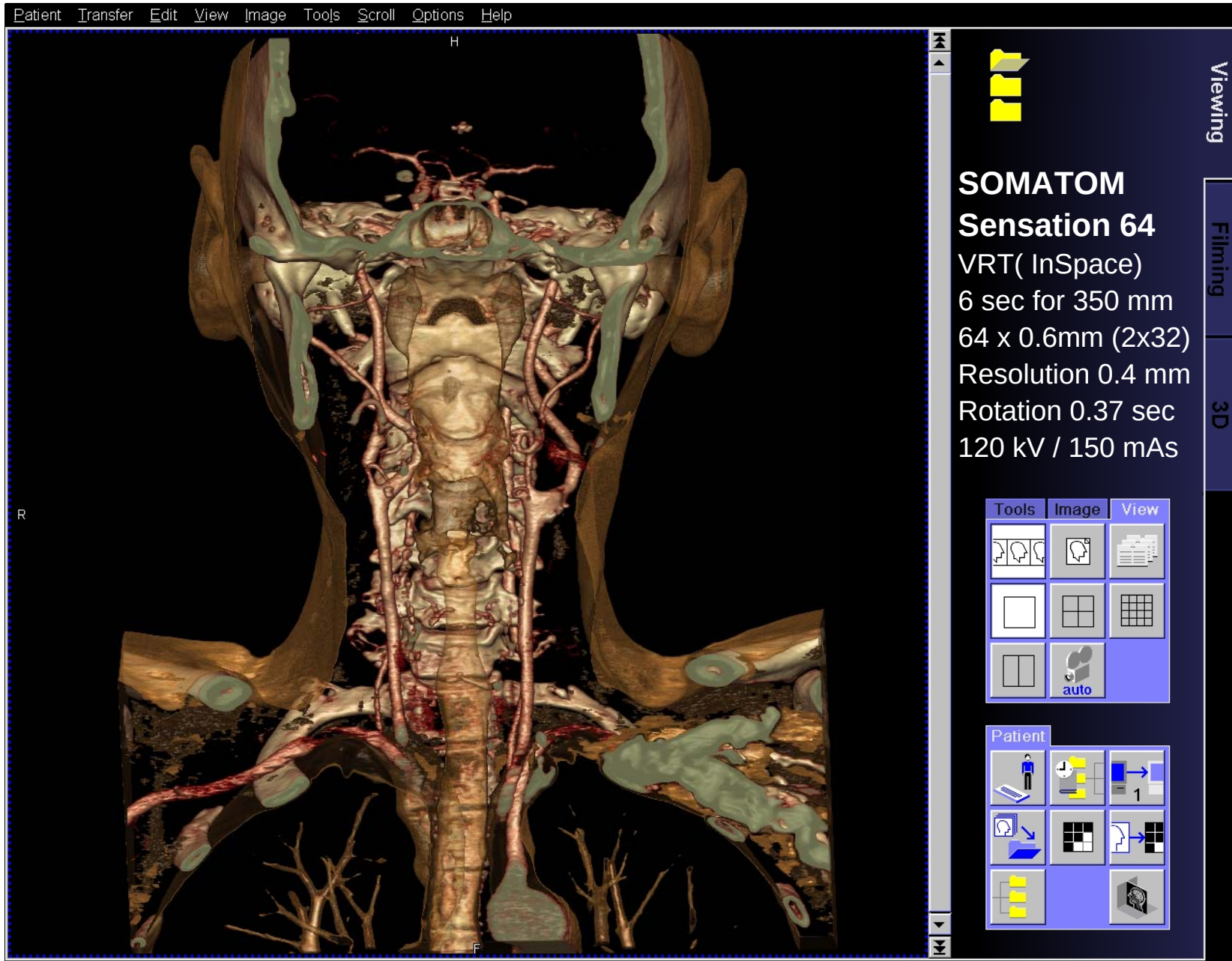


Abdominal CT Angiography – Aortic Stent

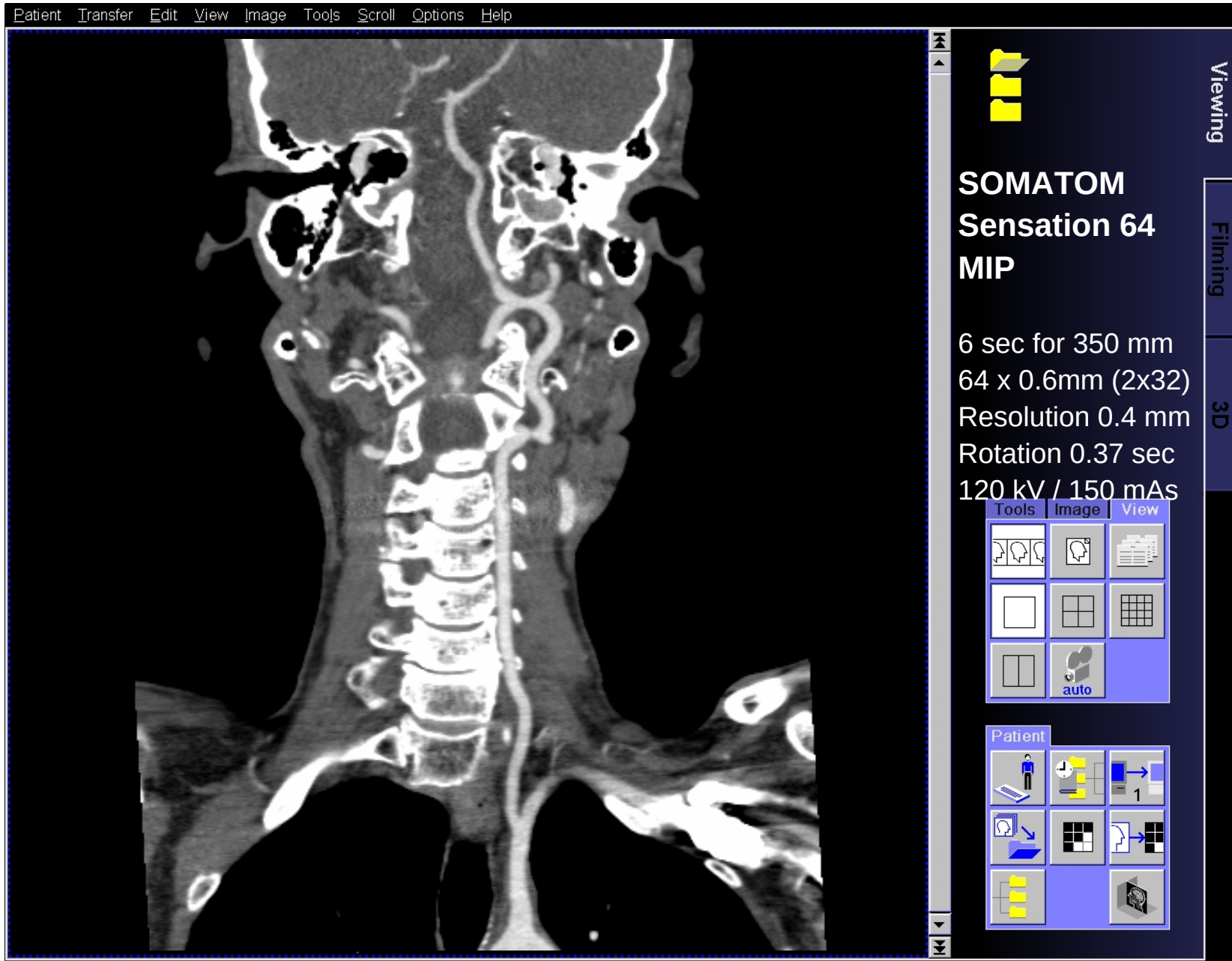
2 x 1mm, Emotion Duo VRT



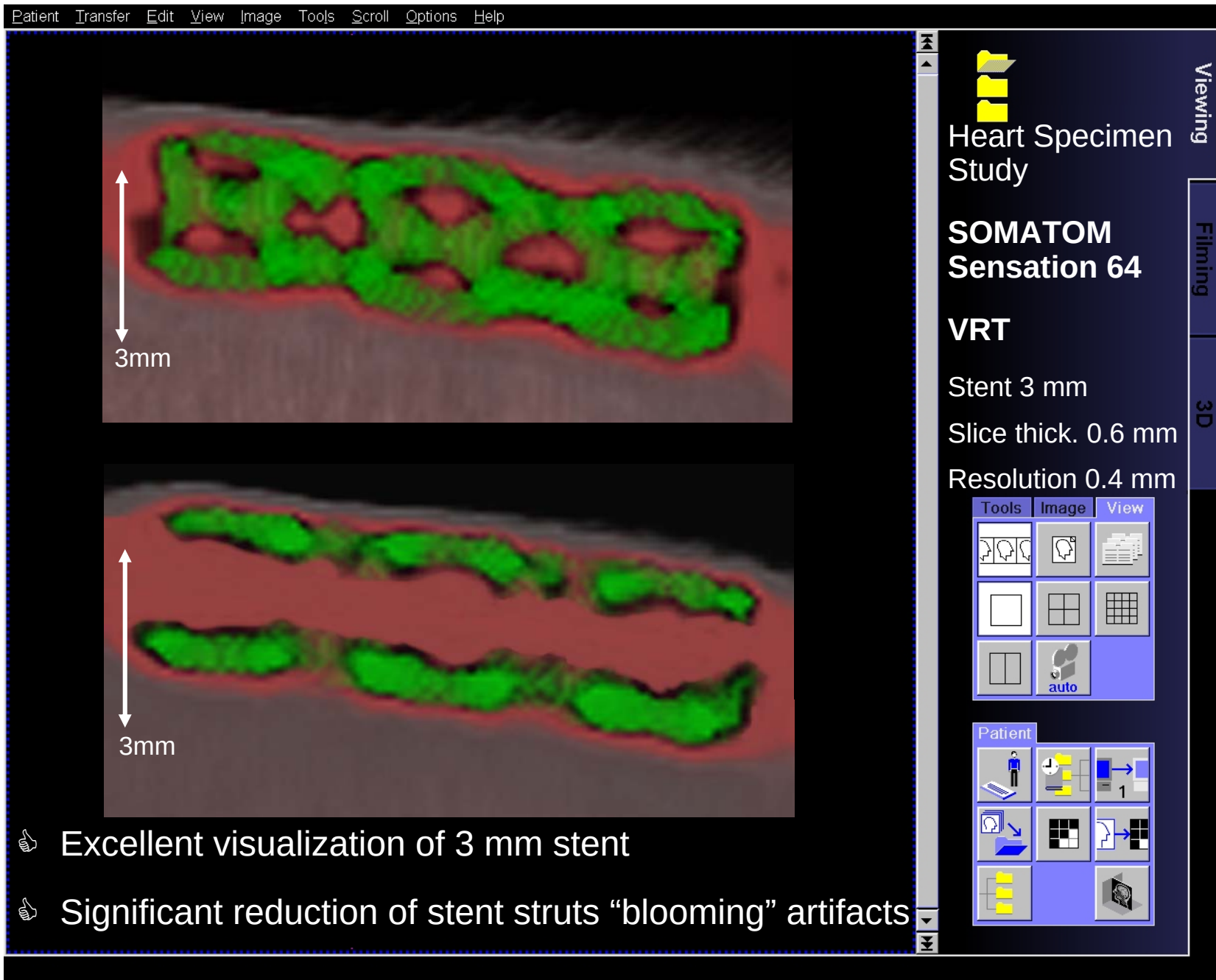


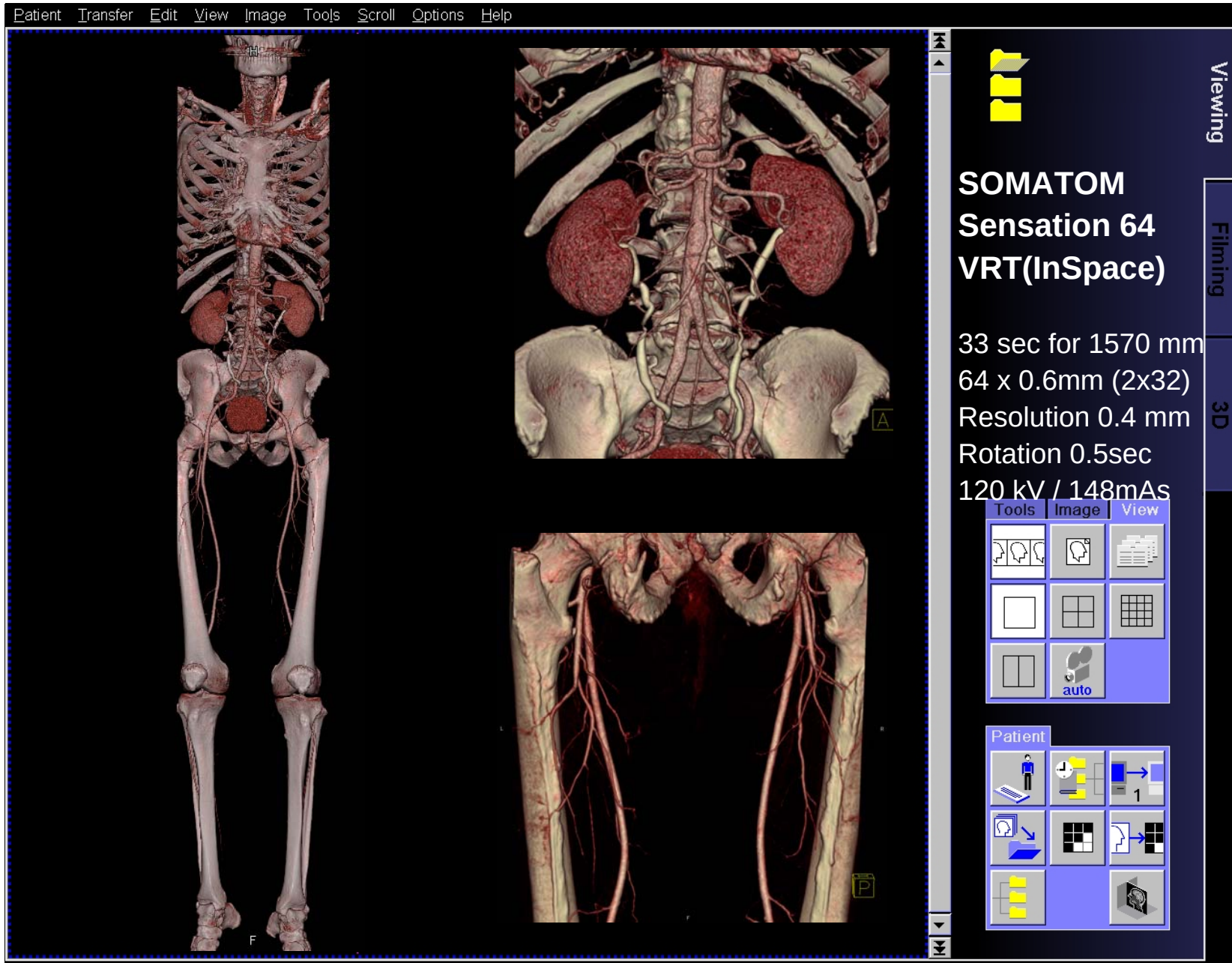


Courtesy of University of Erlangen, Department of Radiology and Institute of Medical Physics

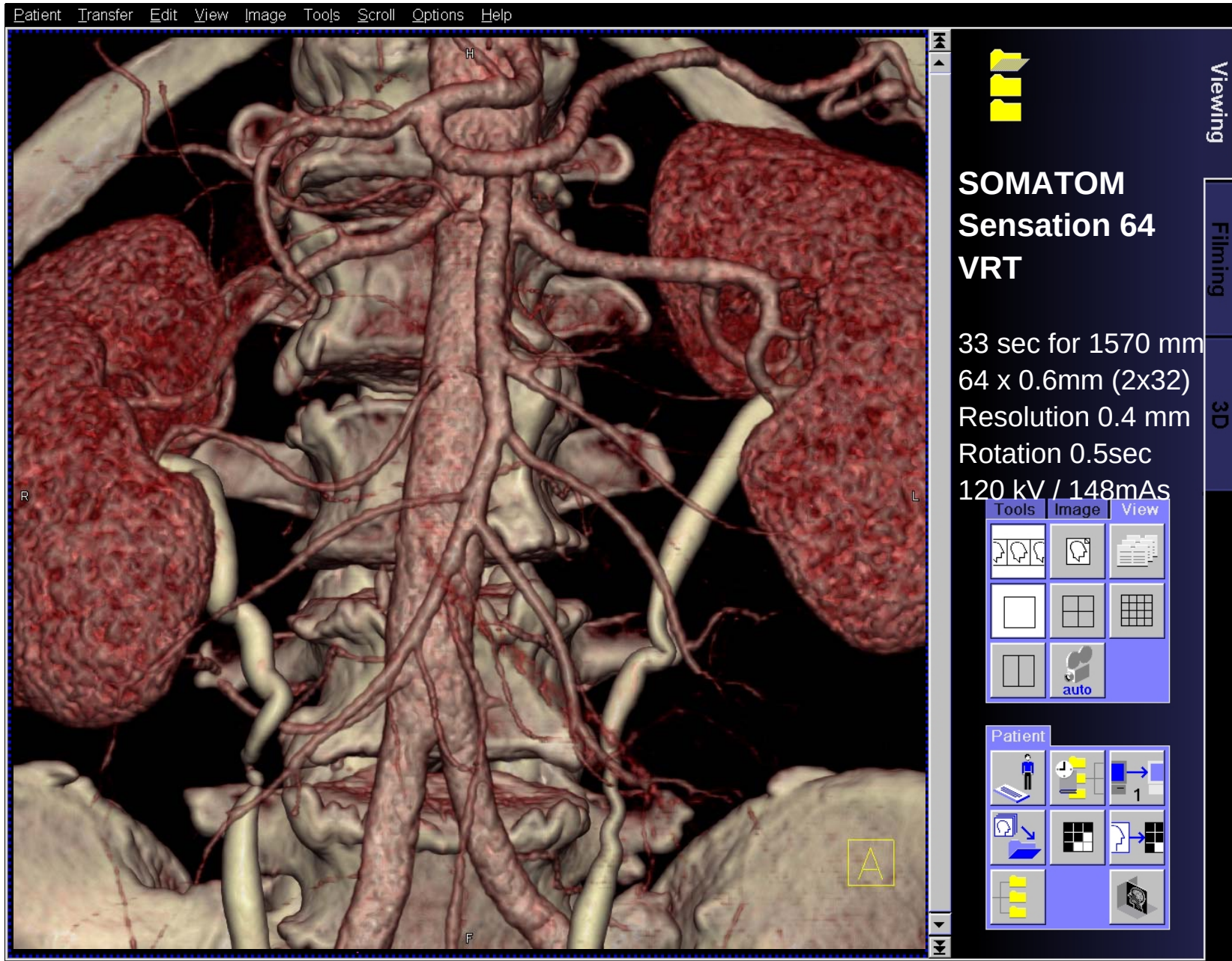


Courtesy of University of Erlangen, Department of Radiology and Institute of Medical Physics


Patient Transfer Edit View Image Tools Scroll Options Help
3mm
3mm
Heart Specimen Study
SOMATOM Sensation 64
VRT
Stent 3 mm
Slice thick. 0.6 mm
Resolution 0.4 mm
Tools
Image
View
auto
Patient
Viewing
Filming
3D
Excellent visualization of 3 mm stent
Significant reduction of stent struts “blooming” artifacts



Courtesy of University of Erlangen and University of Tübingen



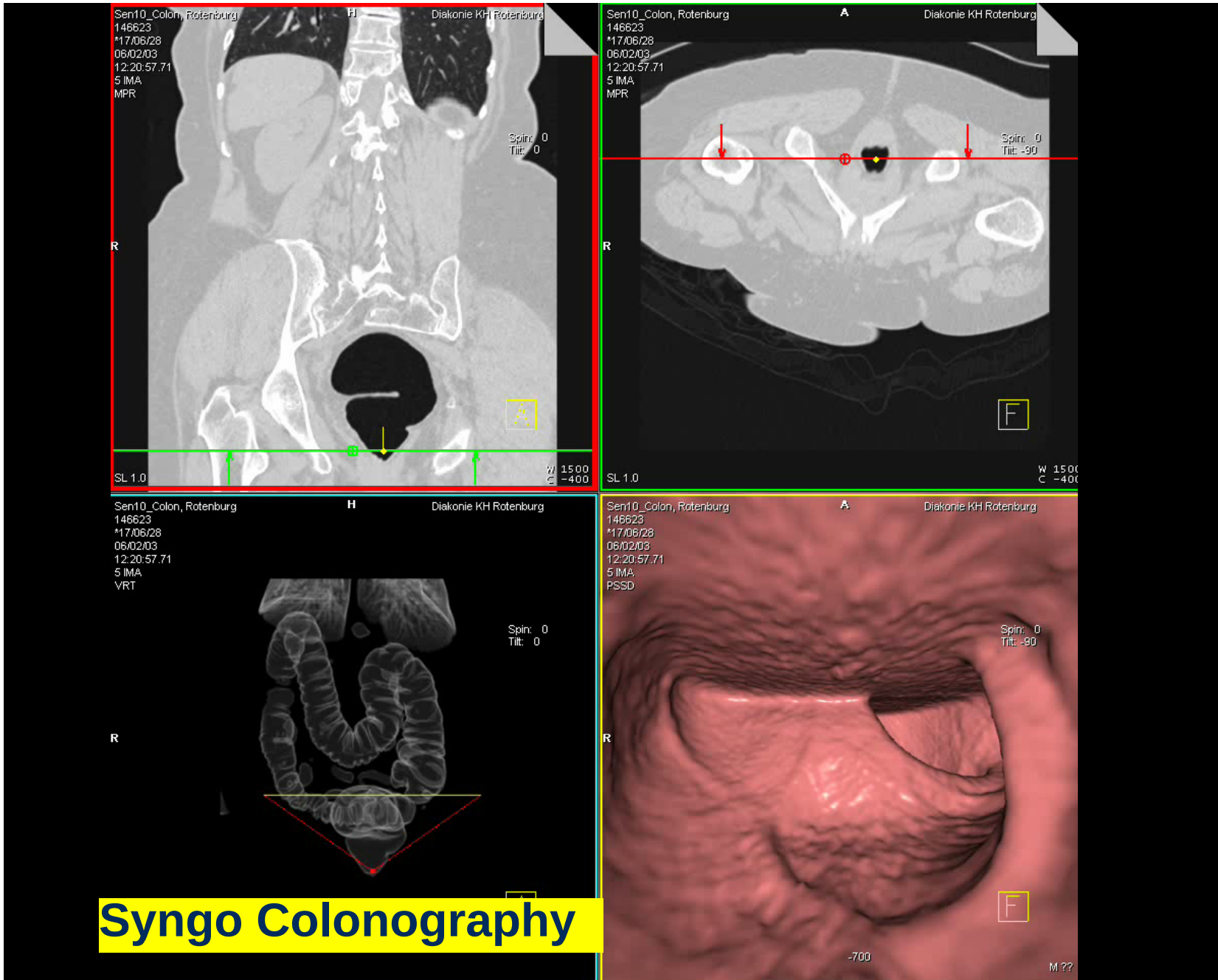
Courtesy of University of Erlangen and University of Tübingen

Real-time Color VRT with InSpace 4D

Emotion 6 – Blocked Venous Stent

Courtesy Klinikum Nord,Nürnberg,Germany

Real-time Color VRT with InSpace 4D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Sen10_Colon, Rotenburg
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06/02/03
12:20:57.71
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MPR
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Diakonie KH Rotenburg
Spin: 0
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