The new CT technology: what are the benefits?

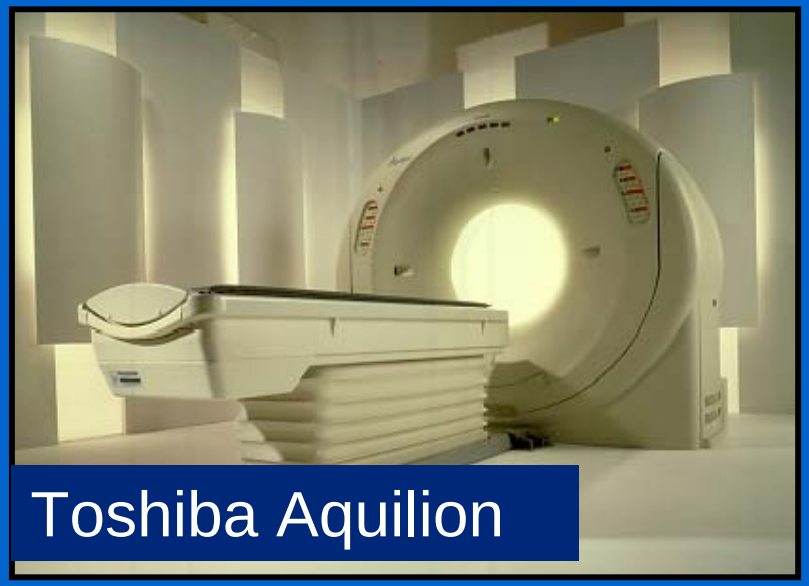
Julia Barrett

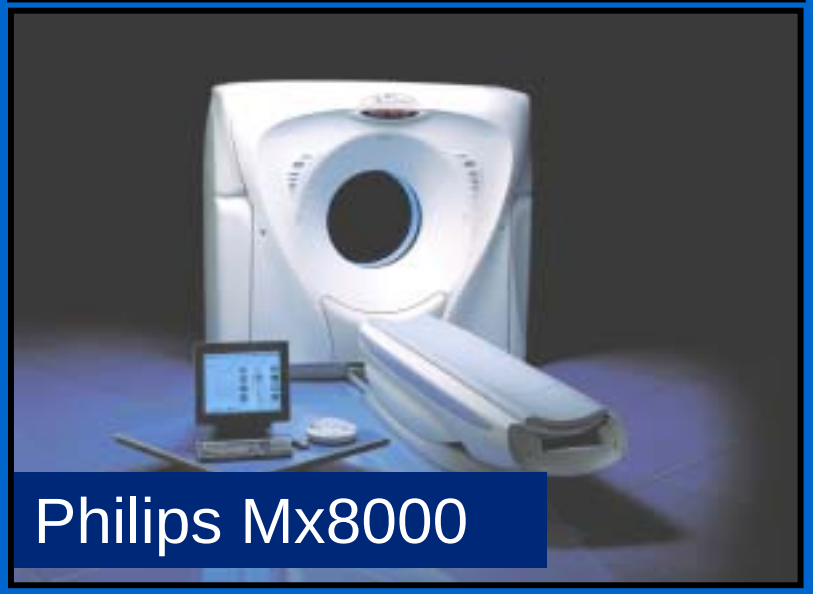
ImPACT*, St George's Hospital, London

*An MDA device evaluation group

www.impactscan.org

The new CT technology

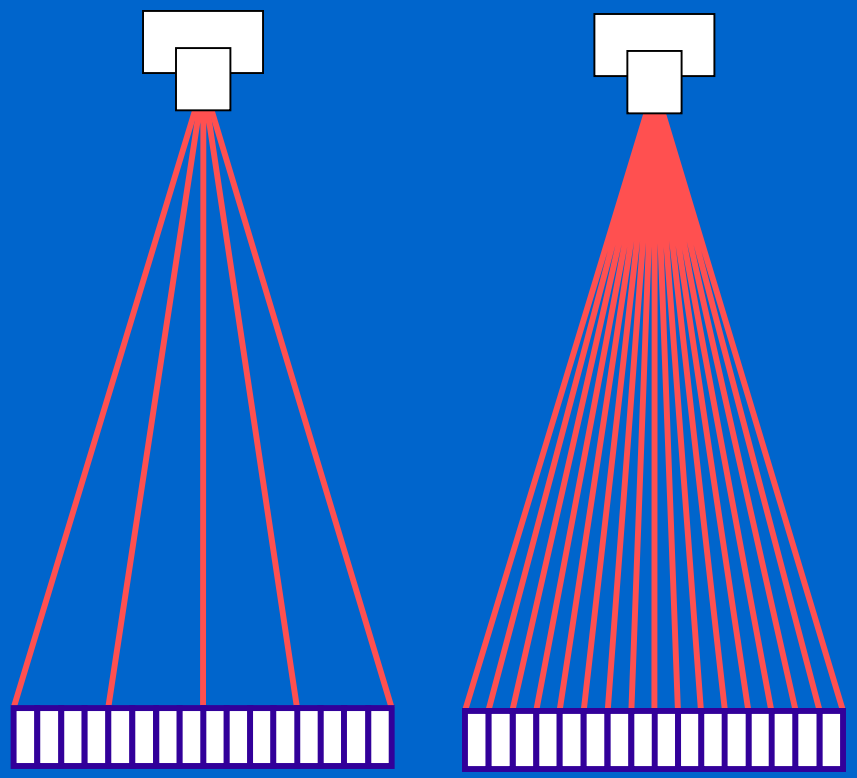




What is the “new technology”?

1. Hardware developments

- Multi-slice acquisition
  - 4-slice since 1999 (GE,Siemens, Toshiba, Philips)
  - 8-slice since 2001 (GE)
  - 16-slice since 2002 (GE,Siemens, Toshiba, Philips)
- Half-second rotation
  - 0.5 sec now standard on top models (all makes)
  - 0.42 sec cardiac option (Siemens, Philips)



4-slice acquisition

16-slice acquisition

What is the “new technology”?

2. Software developments

- Image reconstruction and display
- Applications packages
- Exposure control

3. Cost

- Multi-slice in 2002 v. top range single-slice in1998
  - Manufacturers A and B: “about the same”
  - Manufacturer C: “about £160k more”

How does the patient benefit?

- Are the images of greater diagnostic value?
  - better image quality?
  - improved imaging capabilities?
- Is patient comfort/compliance/safety improved?
  - formerly difficult procedures now more comfortable?
  - reduced risk of complications?
  - new CT techniques available that spare patient from more invasive diagnostic procedures?
- Are radiation doses any lower?
  - any different from single-slice scanning?
  - any dose reduction features?

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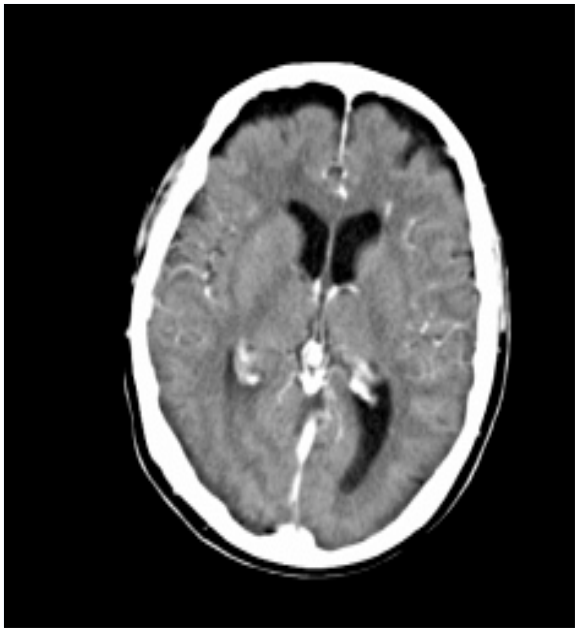
Axial image quality

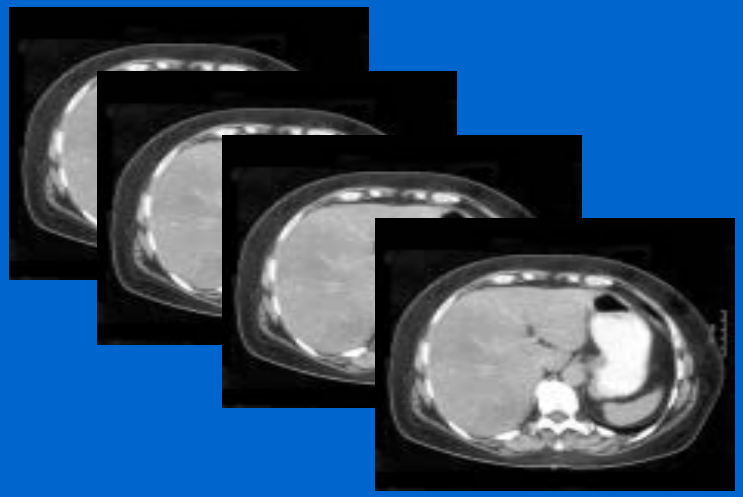
- Most design features are same for single and multi-slice.
- Transverse axial scan image quality similar for multi and single slice scanners, *for a given slice thickness.*

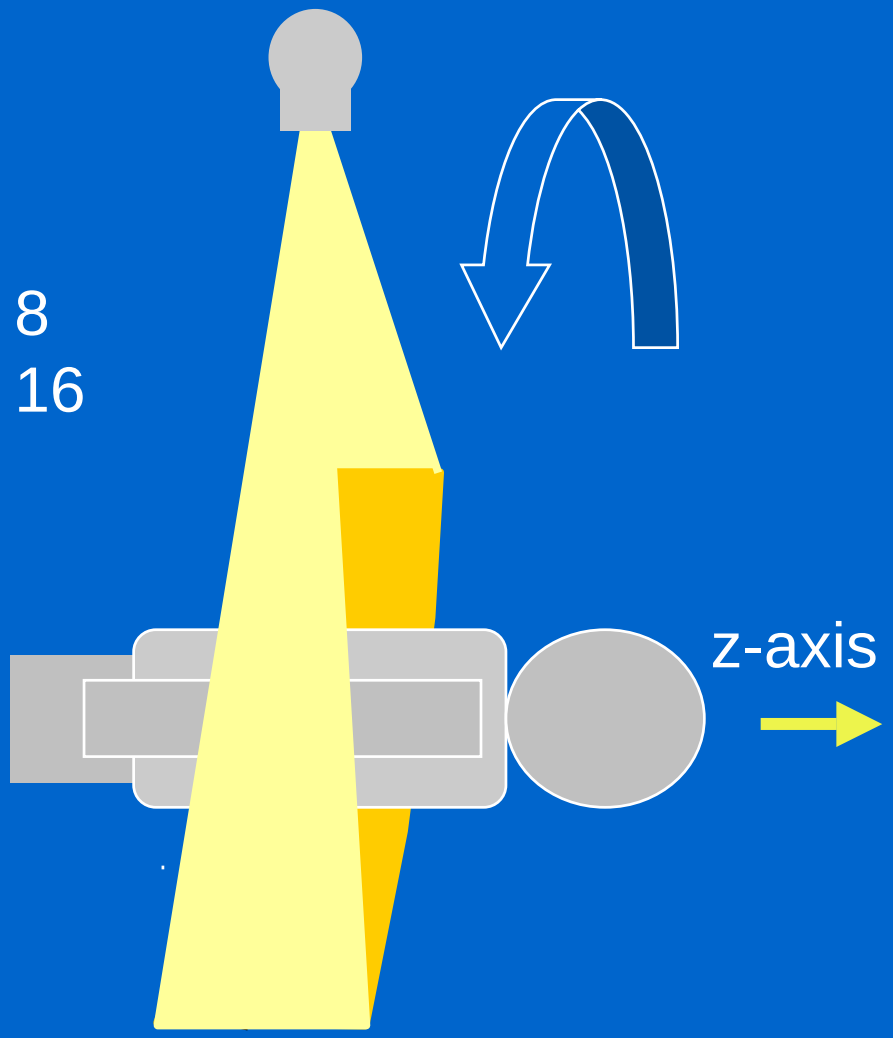


Multi-slice scanning

- multiple banks of detectors
- single irradiation width
- 4 data sets
  - 4 axial images
  - 4 helical sets of data

or 8
or 16



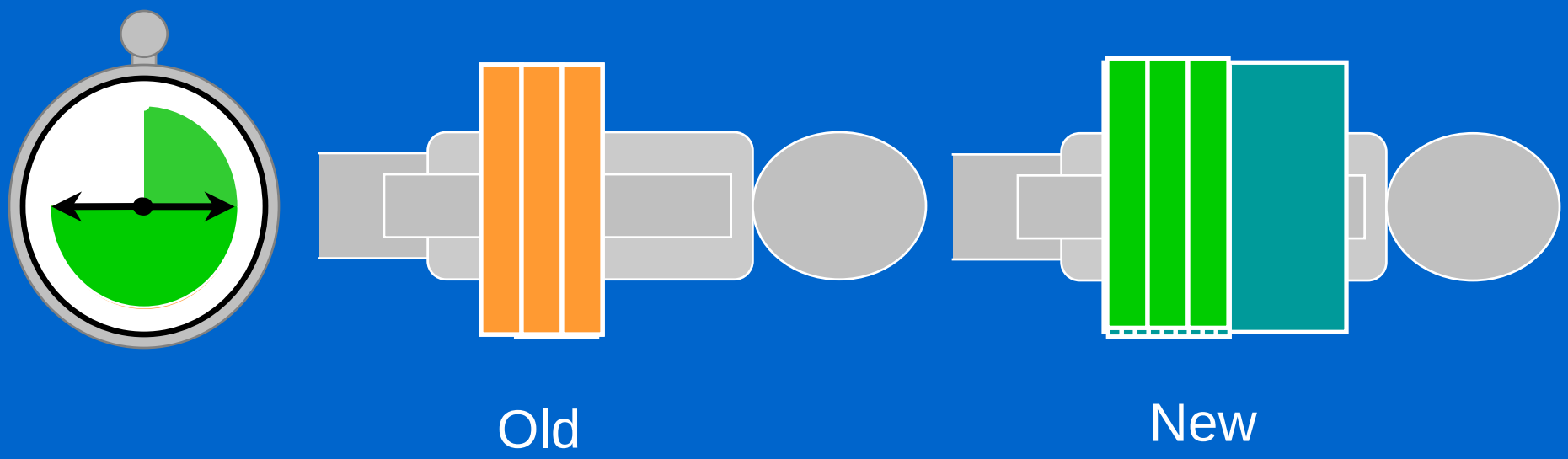


Advantages over single slice

Either same acquisition in shorter time

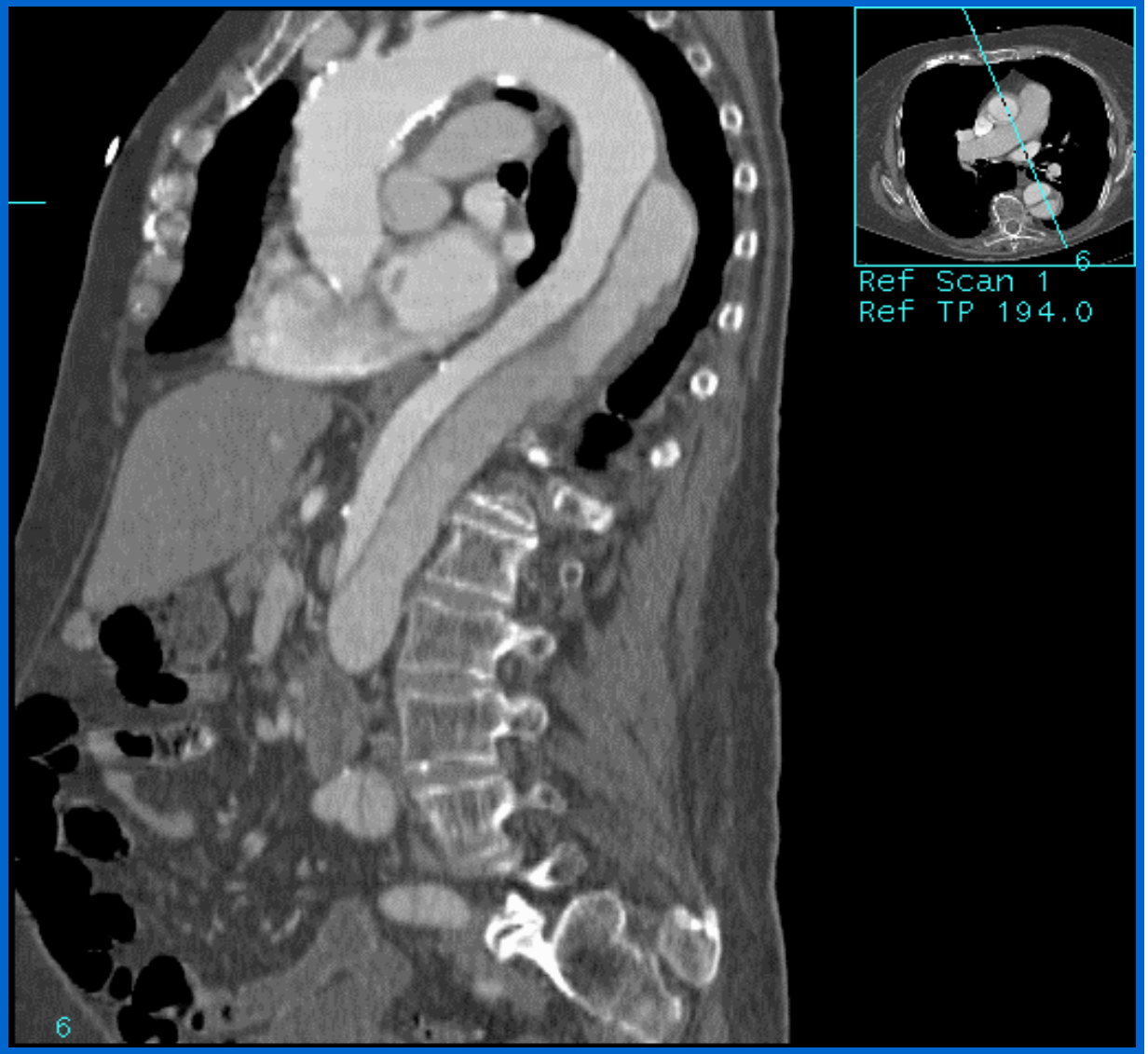
or thinner slices for better z-axis resolution

or scan larger volumes in the same time



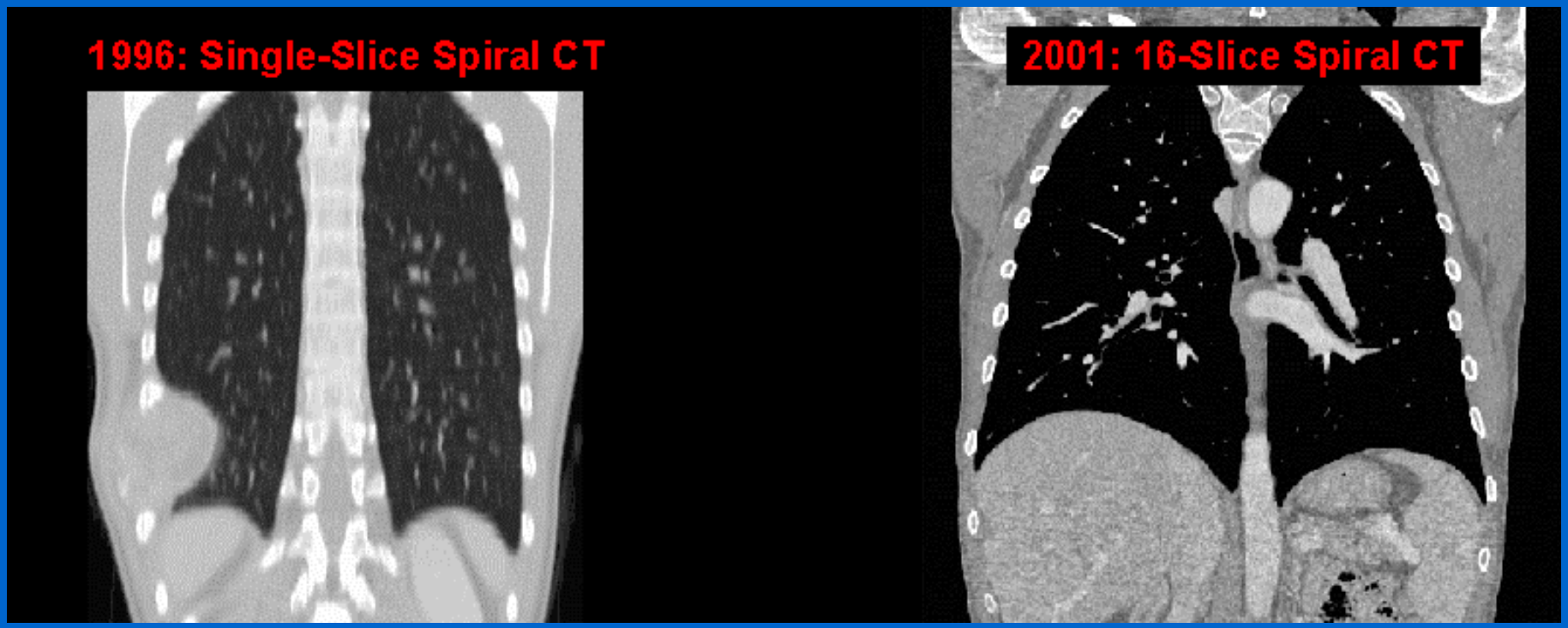
Shorter time → fewer motion artefacts

- e.g. aortic dissecton:
  - 500mm in 16 sec
  - 4 x 2.5mm slices
  - pitch 1.625



Courtesy: Dr. Baum, University of Erlangen

Thinner slices → better z-axis resolution

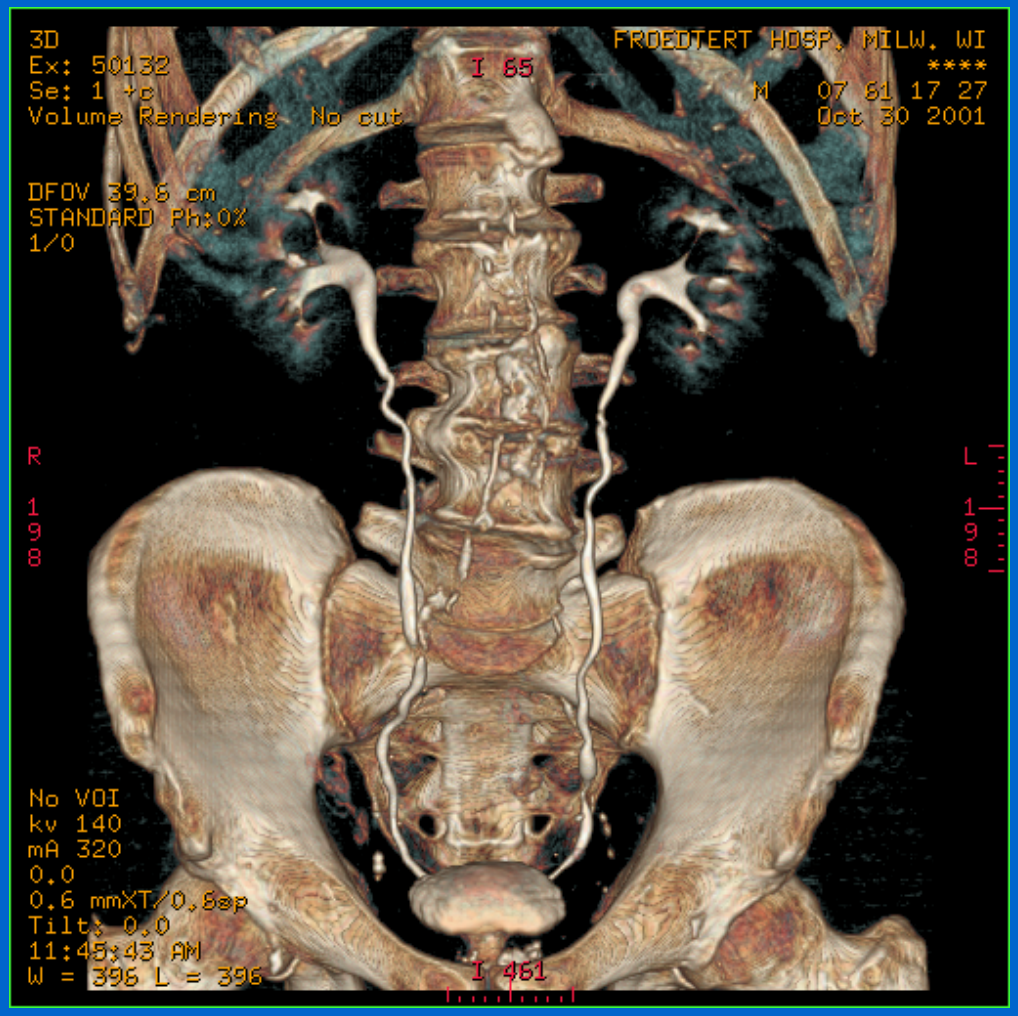


Courtesy: Prof. Kalender, University of Erlangen

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

Thinner slices → better 3D images

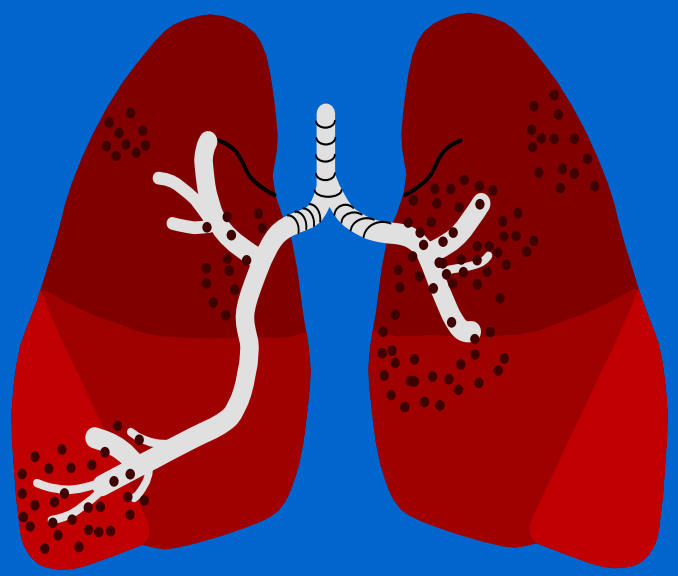
- Large numbers of narrow slices provide high quality volume rendering
- Stair-step artefacts virtually eliminated, edges well-defined



Courtesy: GE Medical Systems

Longer volumes → more useful scans

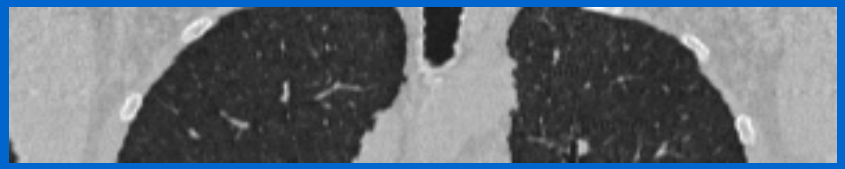
How many 1 mm slices in 30 sec scan time?



30

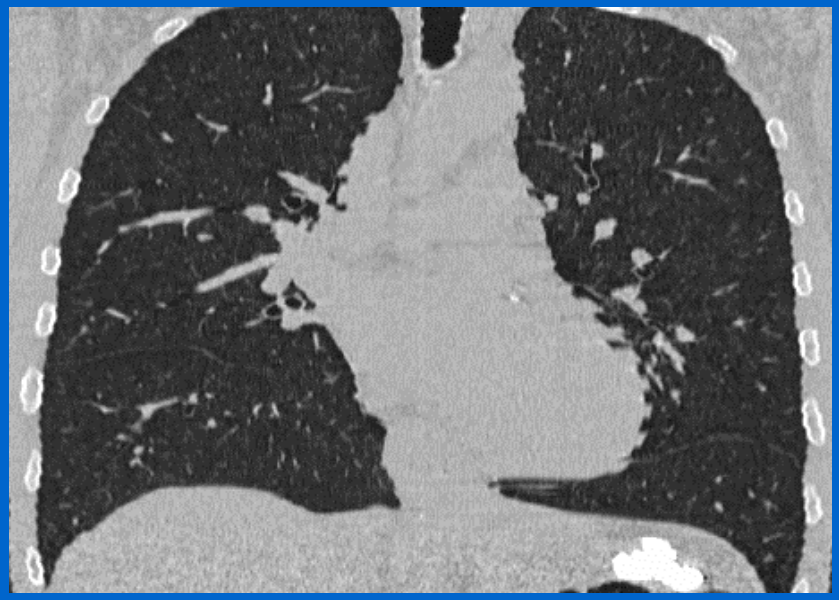
1 sec rotation, single-slice

60



0.5 sec rotation, single-slice

240



0.5 sec rotation, four-slice

Courtesy: Siemens

What evidence is there of improvements?

- Abdominal imaging
  - improved tumour detection rate in liver
  - improved staging of pancreatic cancer
  - improved polyp detection in CT colonography
  - planning renal surgery
- Chest imaging
  - “the new gold standard for detecting pulmonary emboli”
  - pulmonary and systemic circulation
  - bronchial tree disorders
  - focal and diffuse lung diseases
  - quantification of thoracic lesions

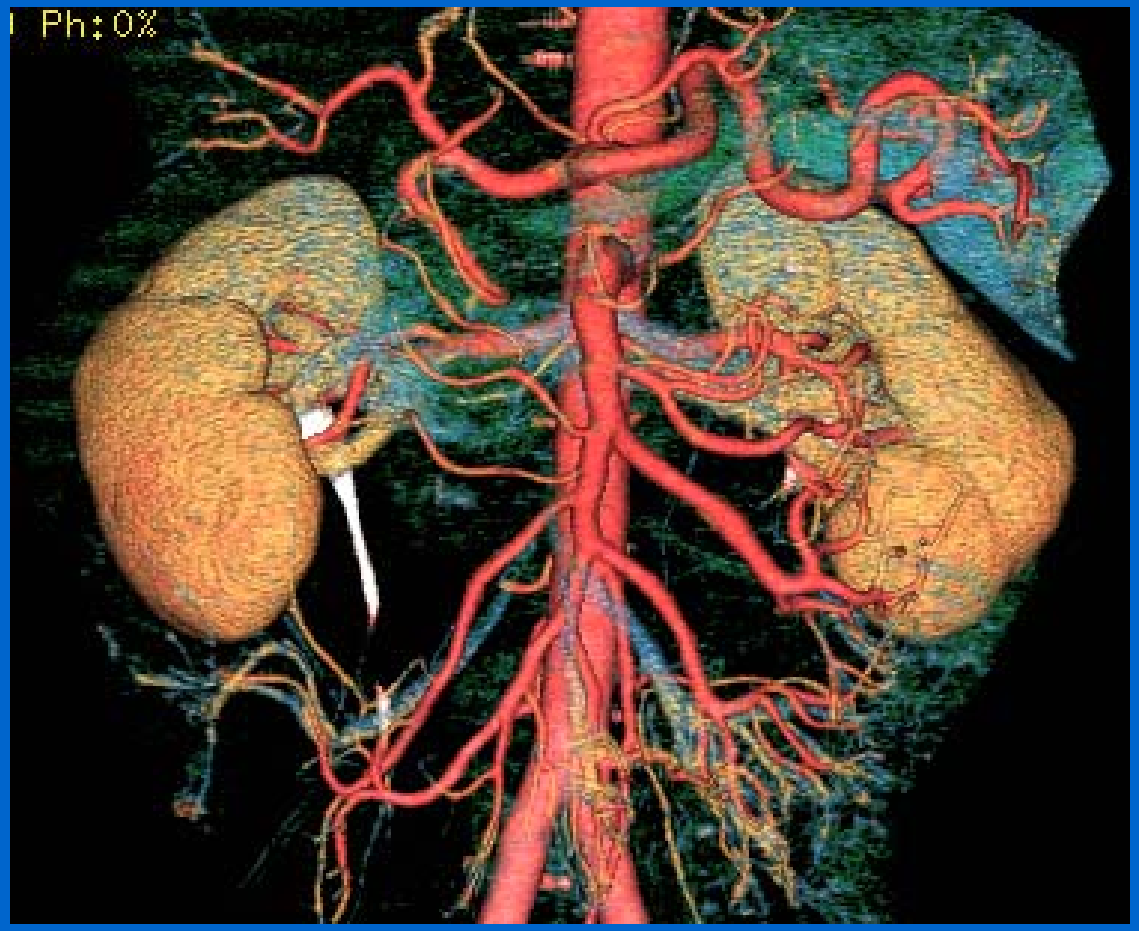
Advantages for CT angiography

- The more slices that can be acquired per rotation
  - the longer the volume that can be scanned
  - the higher the resolution possible
- e.g entire lower limbs scanned in single helical run
  - with 4-slice system, have to use ~3 mm slice
  - with 16-slice system, can perform high-resolution angiography using 1 mm slice

Courtesy: Siemens

Advantages for CT angiography

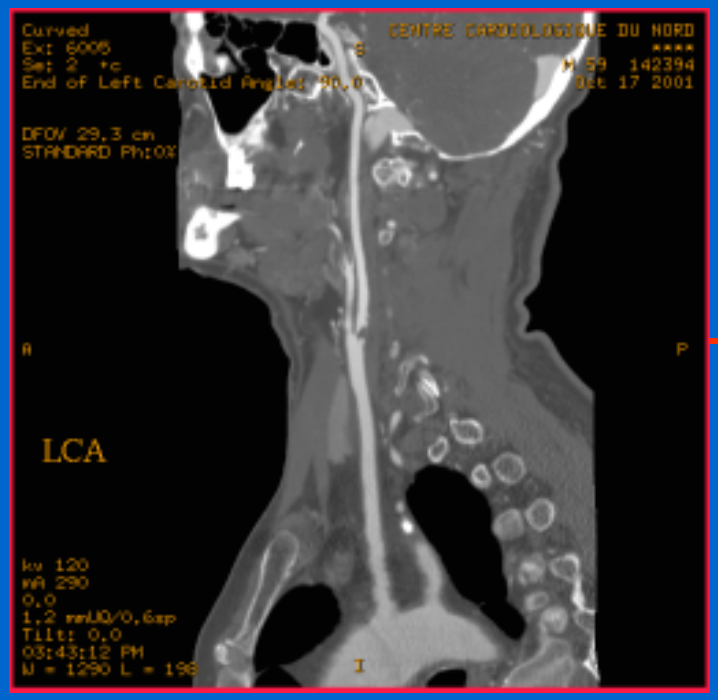
- e.g. kidney donor angiogram: choosing which kidney to harvest
  - 16 x 0.625 mm
  - pitch 0.938
  - volume rendered reconstruction
- choose kidney with only one renal artery, or one with longest artery

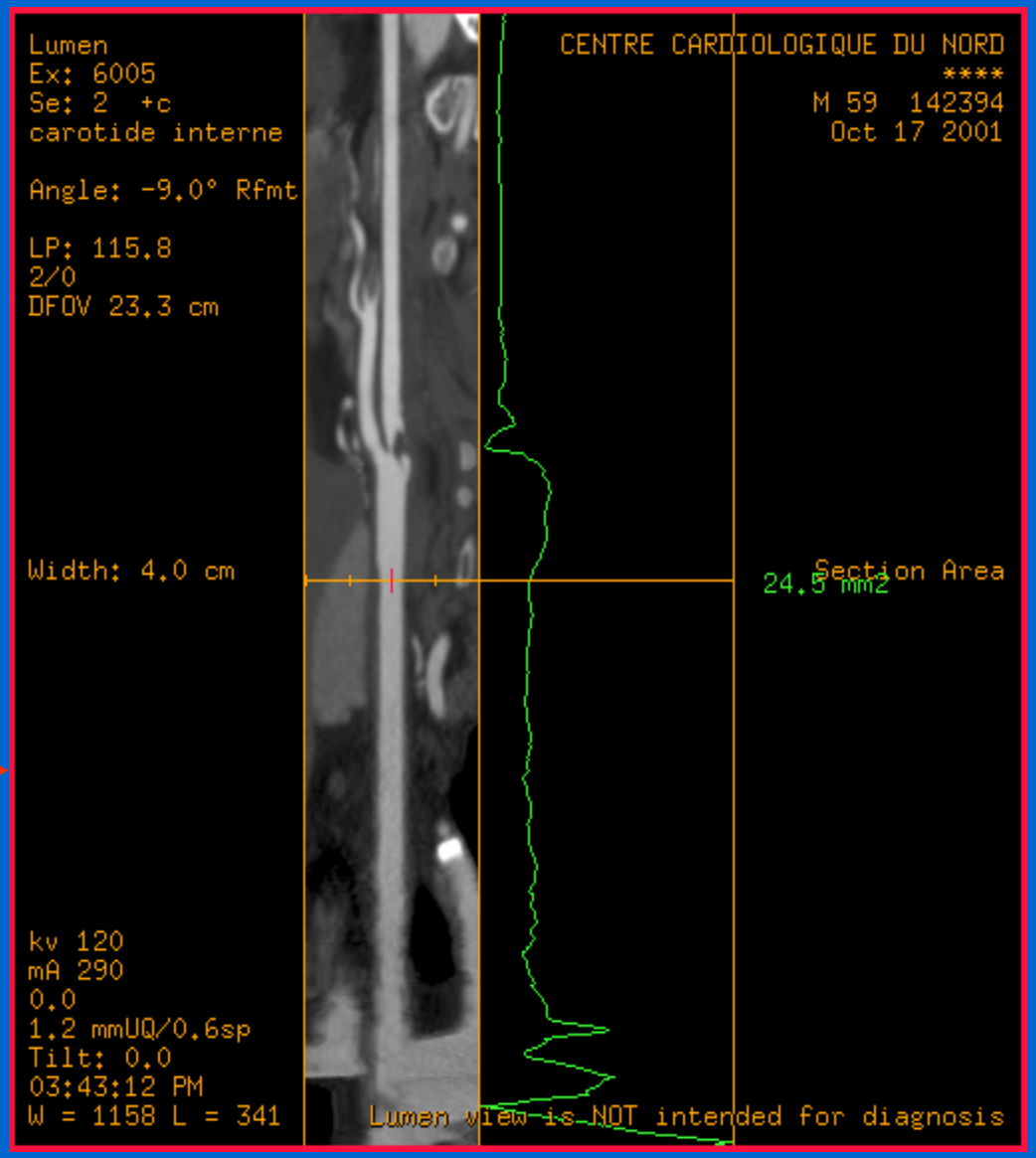


Courtesy: GE Medical Systems

Vessel analysis

- Software package:
  - straightens out vessel of interest
  - plots diameter of vessel lumen



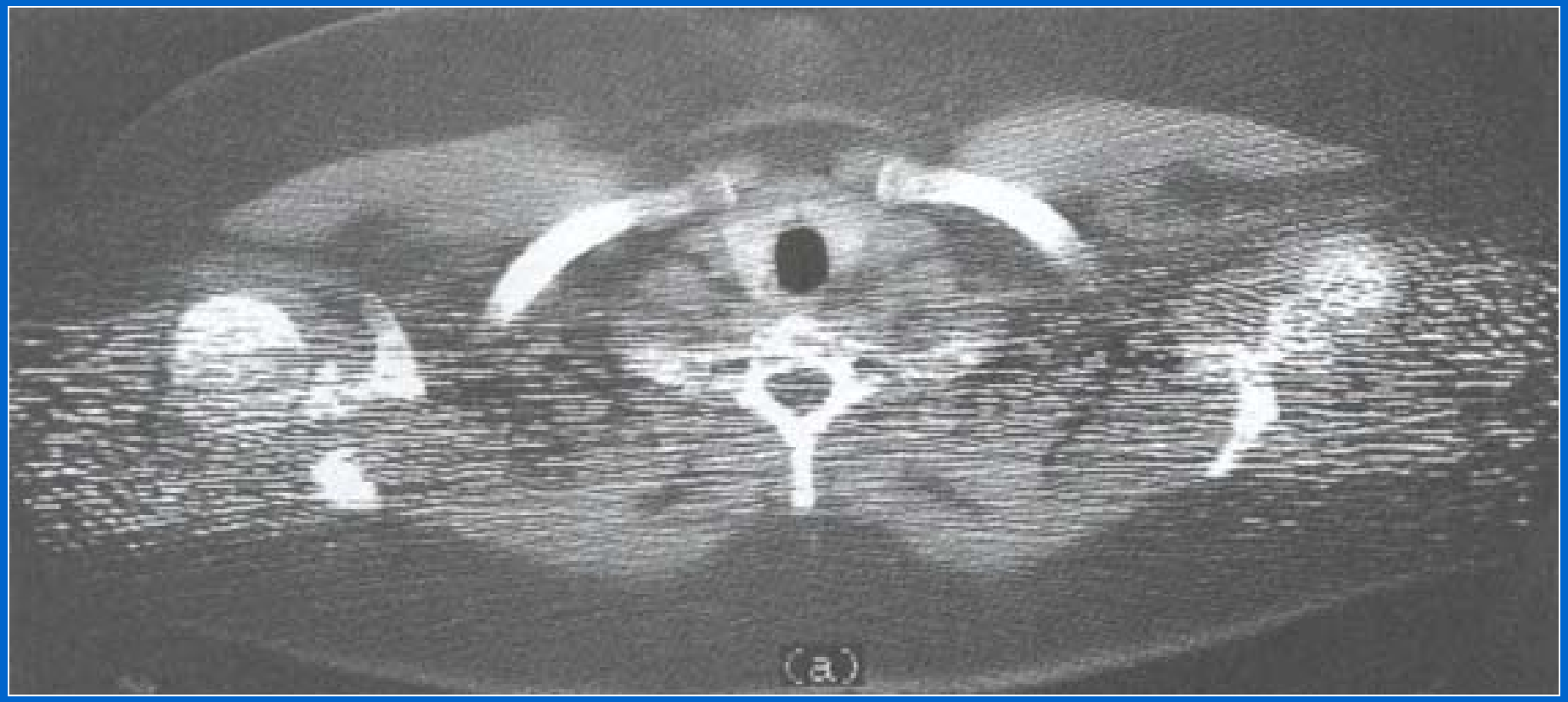


Courtesy: GE Medical Systems

Artefacts in multi-slice scanning

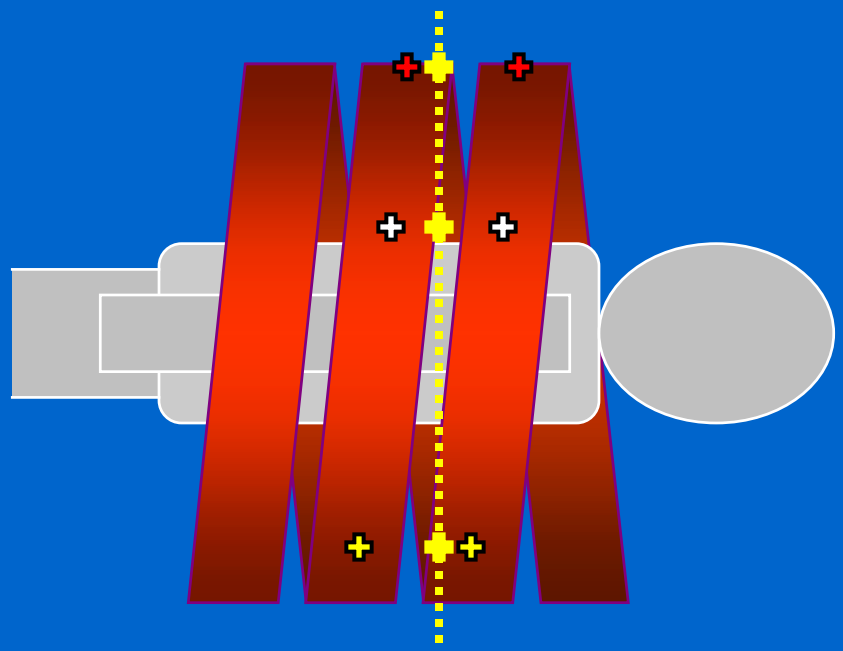
- Motion artefacts reduced by faster scanning
- Stair-step artefacts in 3D reconstructions reduced by using thinner slices
- Partial volume artefacts reduced by using thinner slices
- Streaking artefacts due to photon starvation more likely with thin slices. Can these be reduced?

Photon starvation artefacts

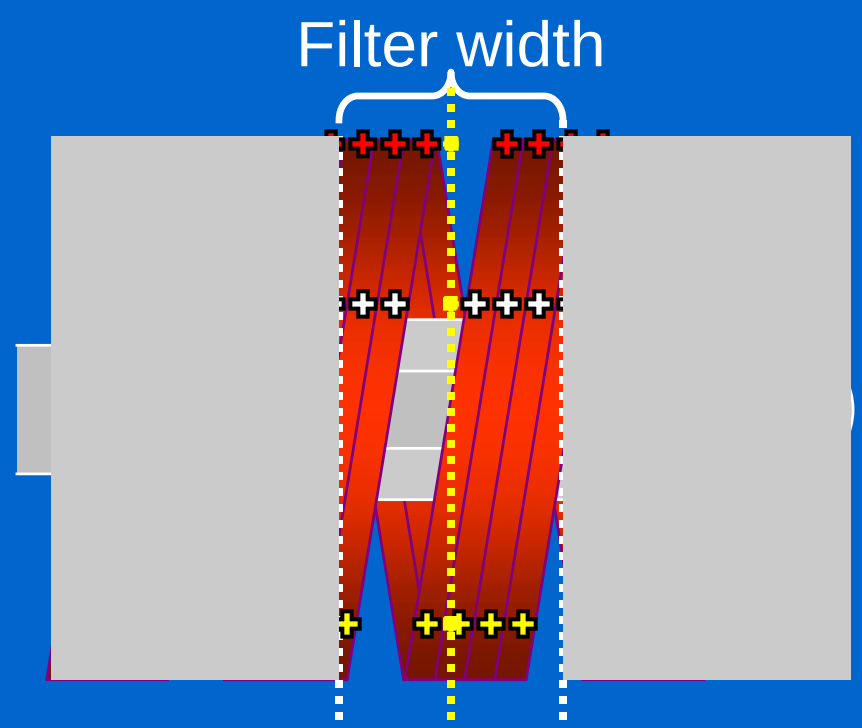


Methods of image reconstruction

2-point interpolation
as used on single-slice

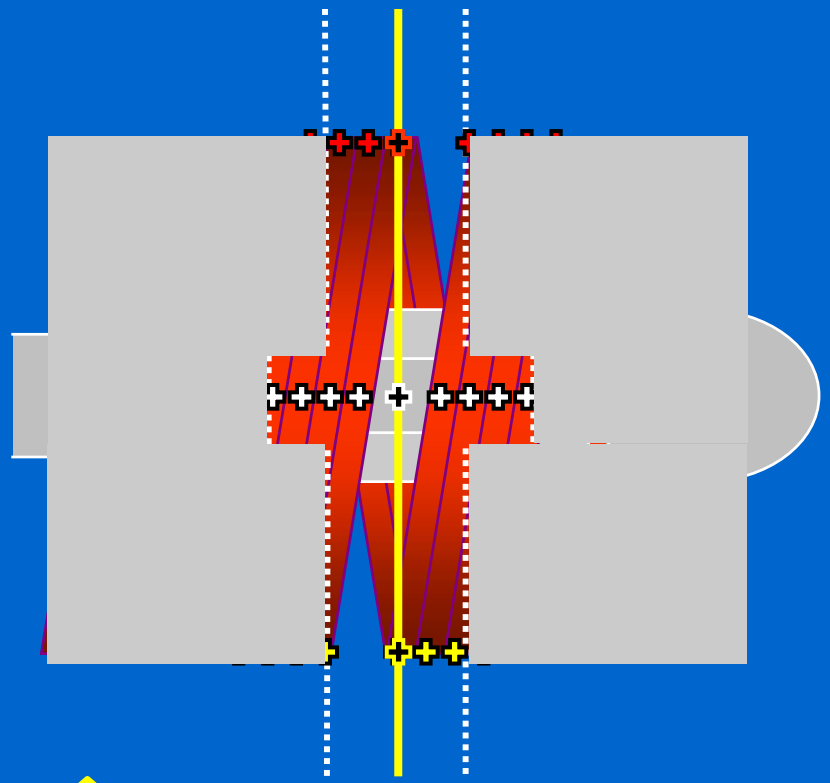


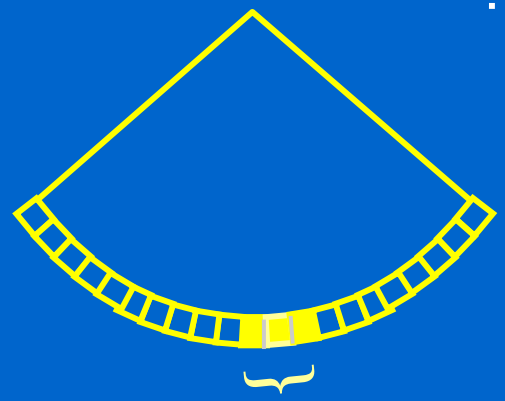
Filter interpolation
as used on multi-slice

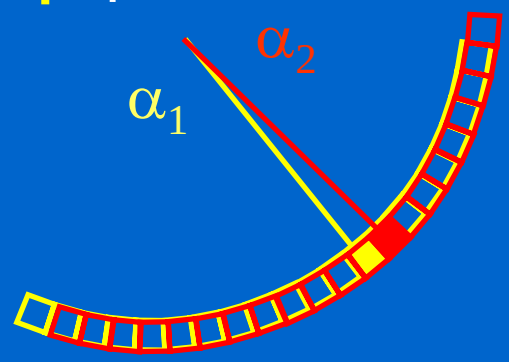


Multi-dimensional adaptive filtering (MAF)

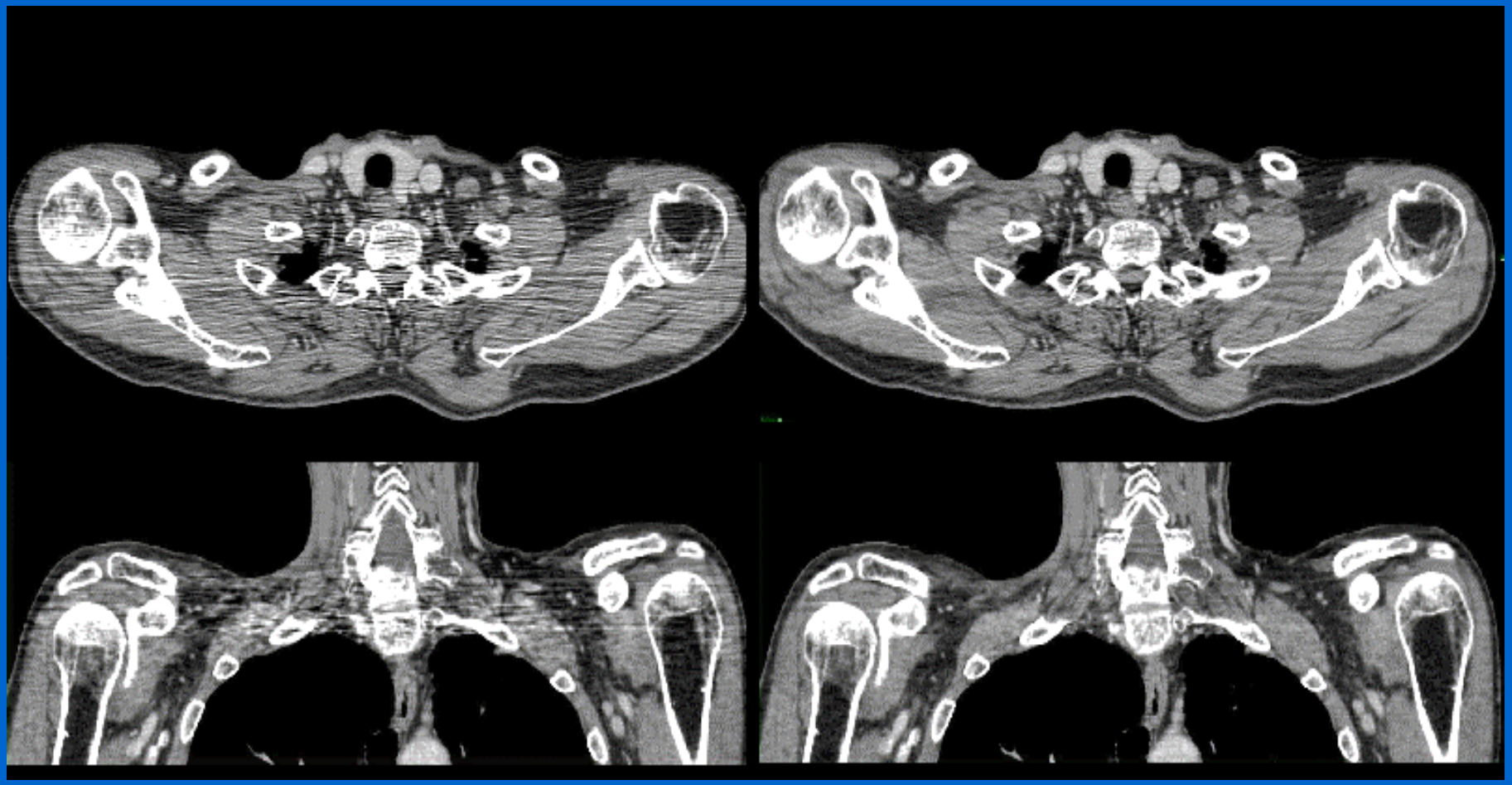
- For data points below selected attenuation threshold:
  - extra wide z-filter is applied for part of each rotation
  - for each projection, neighbouring detector channels are averaged
  - for each detector, signal is averaged between successive sampling angles
- To minimise blurring, <5% data points modified







Effects of 3D filtration

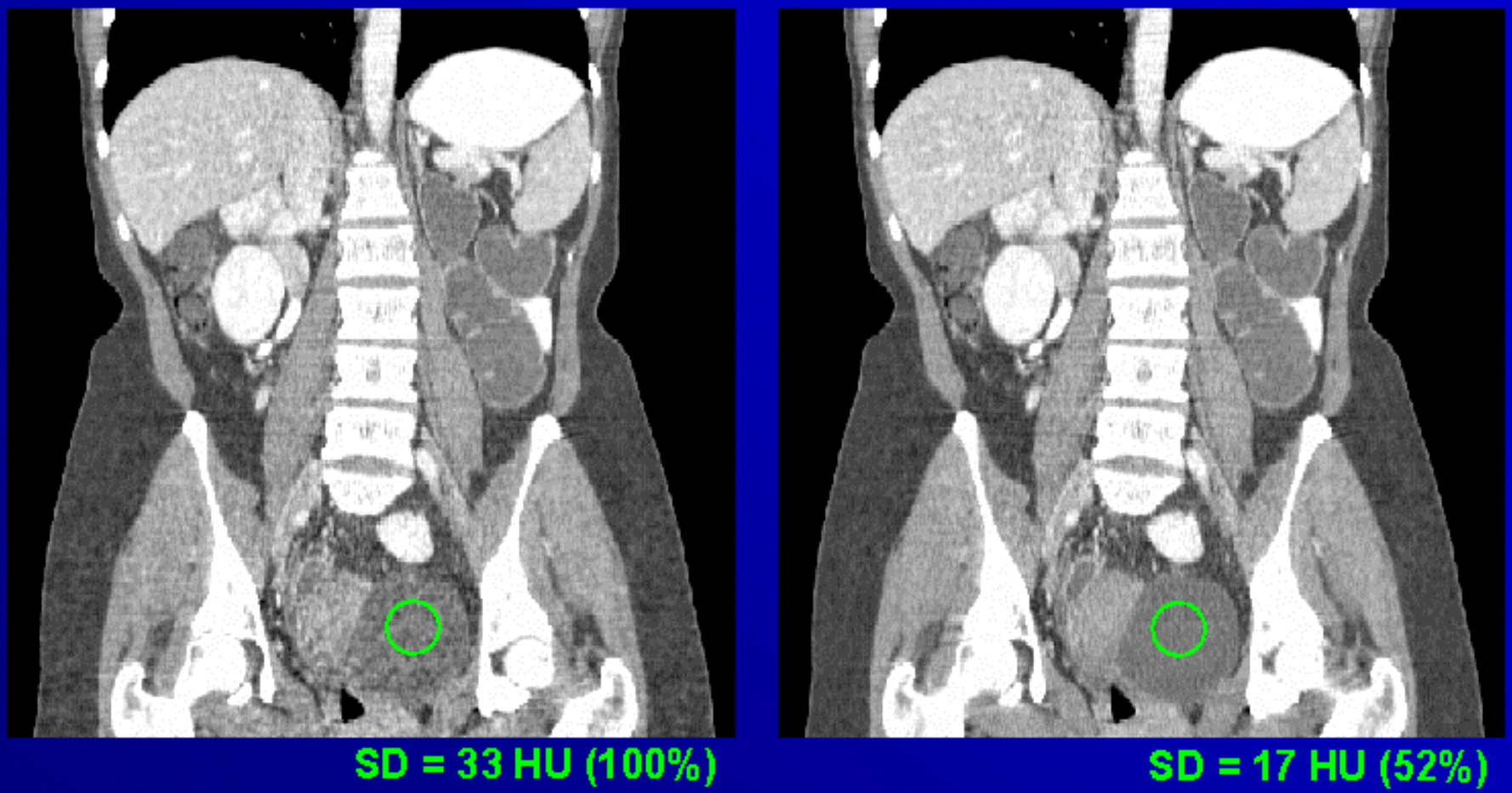


Standard

With MAF

Courtesy: Prof. Kalender, University of Erlangen

Noise reduction using 3D filtration



- “Noise in the pelvis typically reduced by 50% to 70%”

Courtesy: Prof. Kalender, University of Erlangen

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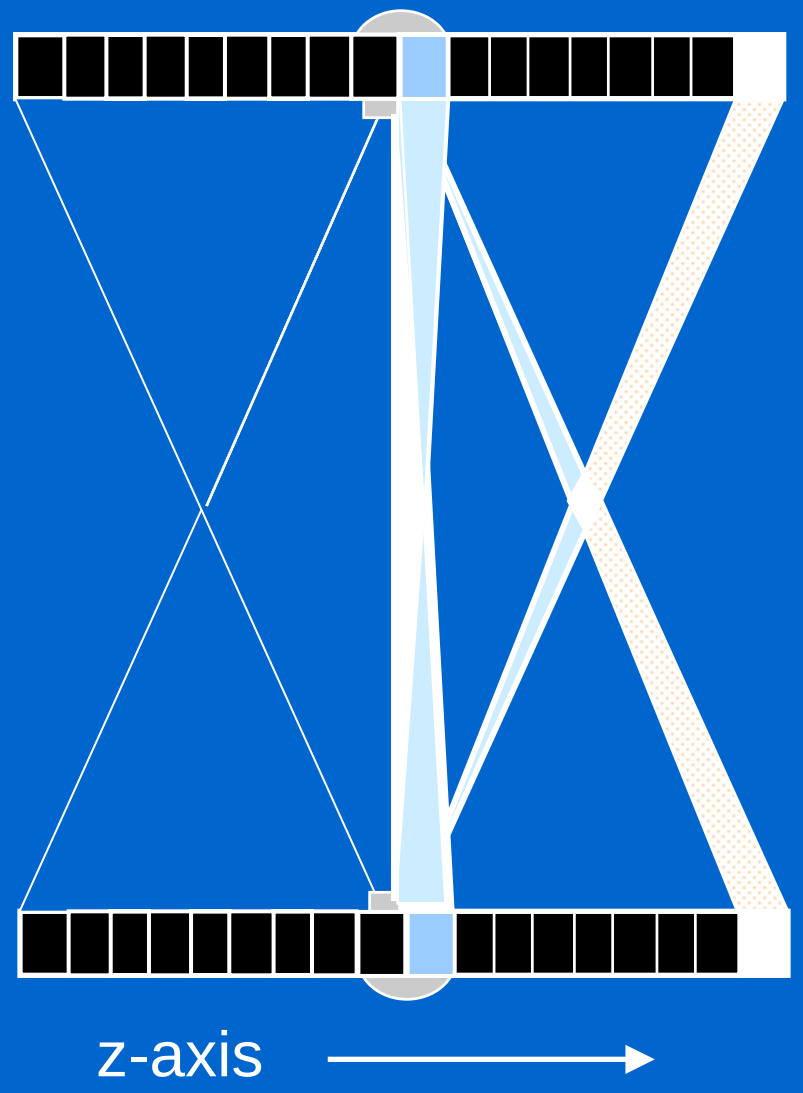
- Stair-step artefacts in 3D reconstructions reduced by using thinner slices
- Streaking artefacts due to photon starvation more likely with thin slices. Can these be reduced?
- Are there any artefacts specific to multi-slice scanning? Can they be overcome?

The cone beam problem

- Data collected for each detector acquisition corresponds to volume between two cones, not a flat plane

- Worse for data collected by outer detectors than by inner detectors



Cone beam artefact

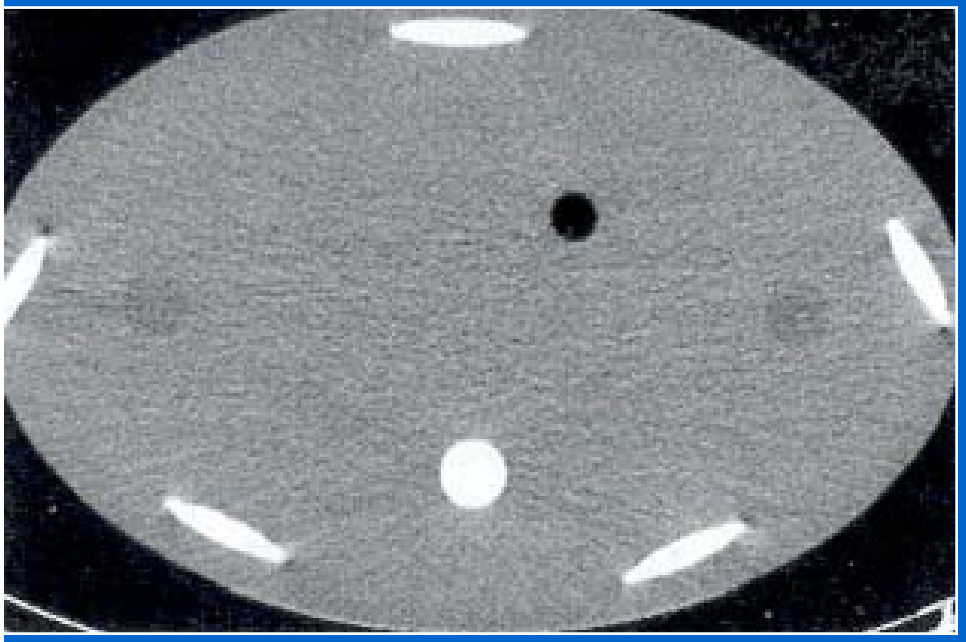


Image from centre detector row

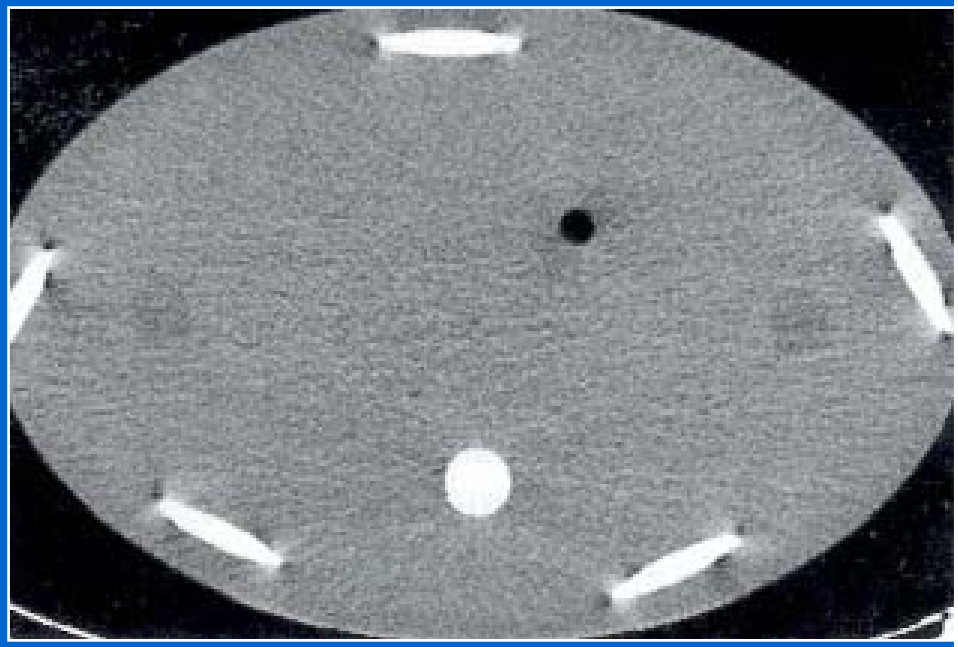
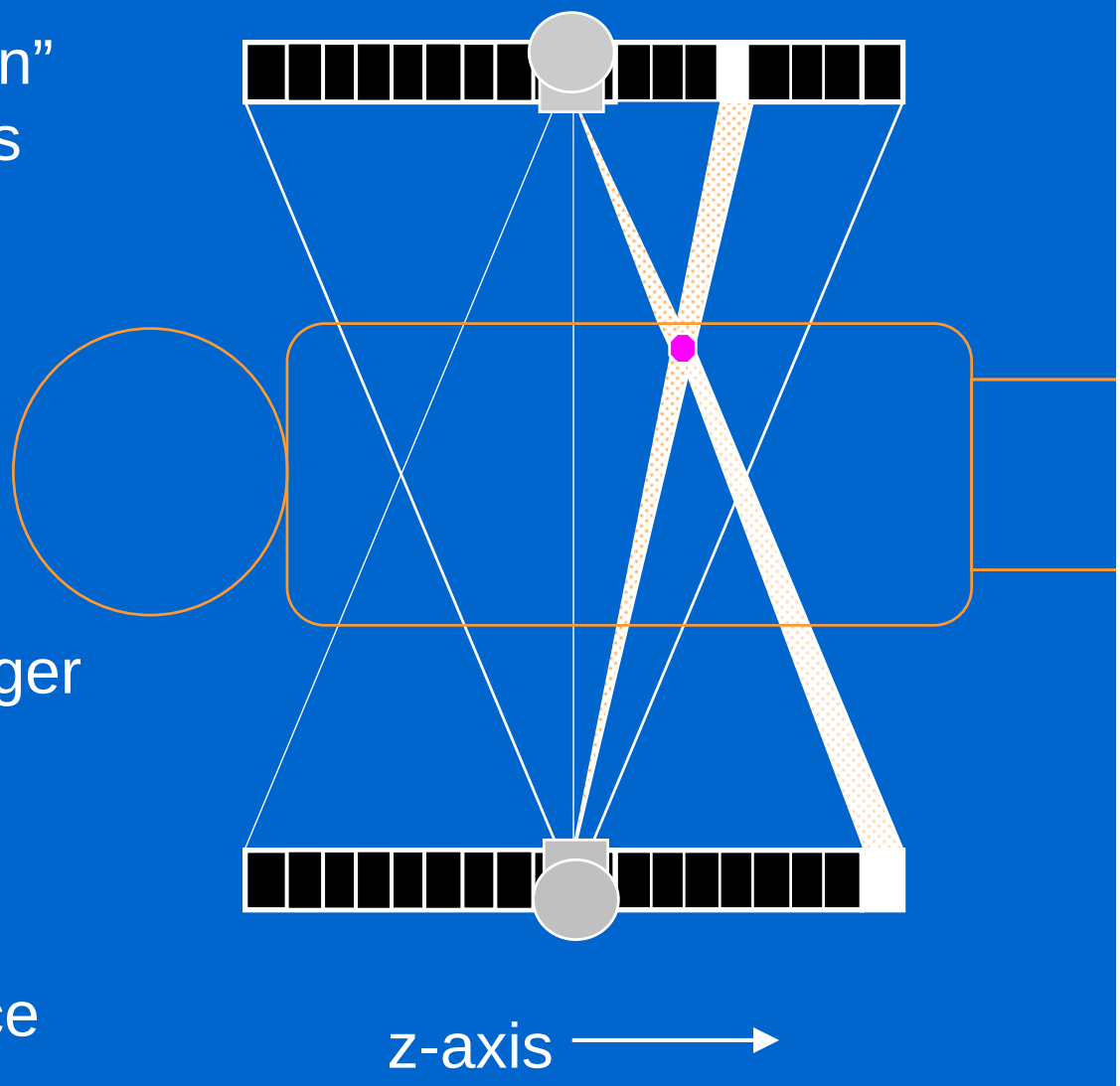


Image from outer detector row

Cone beam effect

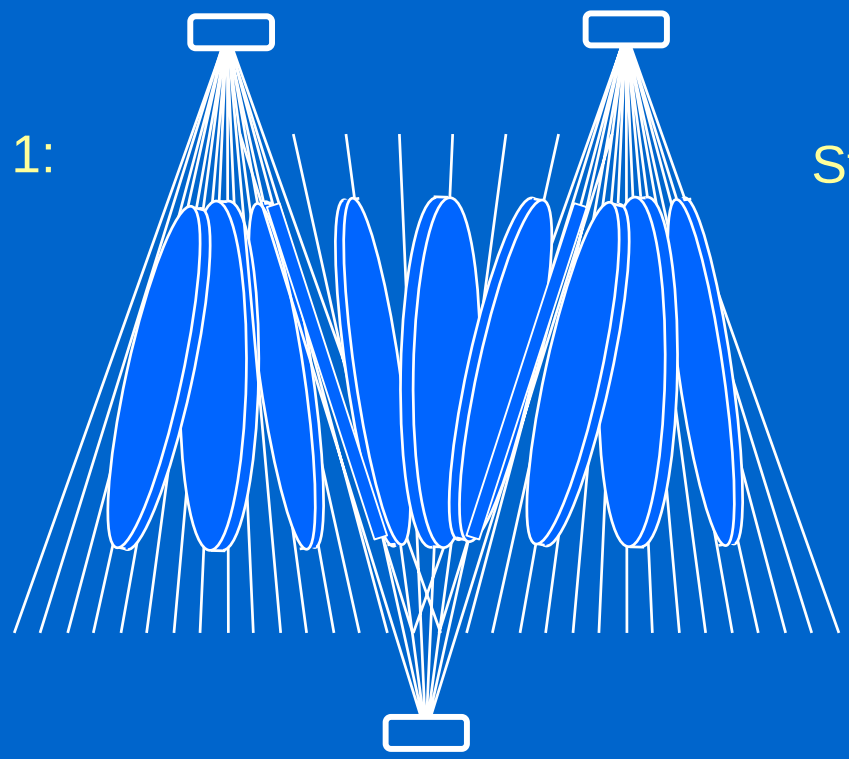
- Off-axis objects are “seen” by different detector rows for different tube angulations
- Mis-registration of data leads to artefacts in the image
- Effect gets worse the larger the cone angle and the thinner the slice
- ∴ 16-slice scanners affected more than 4-slice



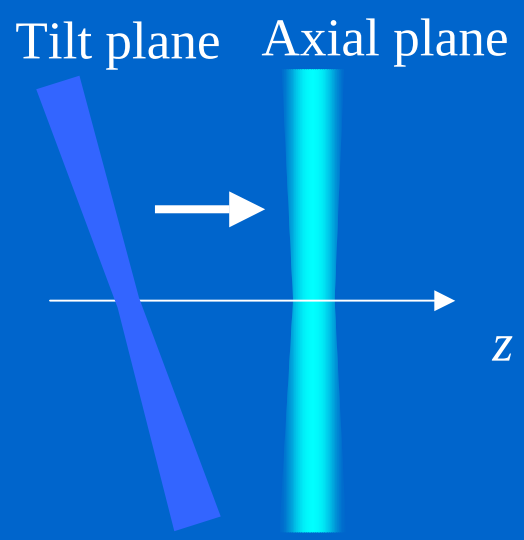
Solving the cone beam problem

- For 8- and 16-slice scanners, manufacturers employ various forms of cone beam reconstruction instead of standard z-filter interpolation
- e.g. ASSR:

Stage 1:

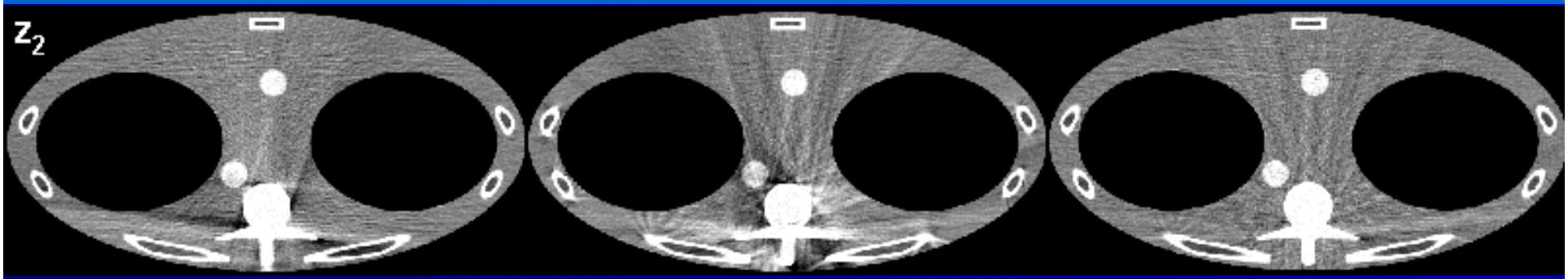


Stage 2:



Effects of using cone beam algorithm

Single-slice 1 x 1.5 mm	8-slice 8 x 1.5 mm	8-slice 8 x 1.5 mm



180°LI **180°MFI** **ASSR**

Courtesy: Prof. Kalender, University of Erlangen

How does the patient benefit?

- Are the images of greater diagnostic value?
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  - improved imaging capabilities?
- Is patient comfort/compliance/safety improved?
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  - new CT techniques available that spare patient from more invasive diagnostic procedures?
- Are radiation doses any lower?
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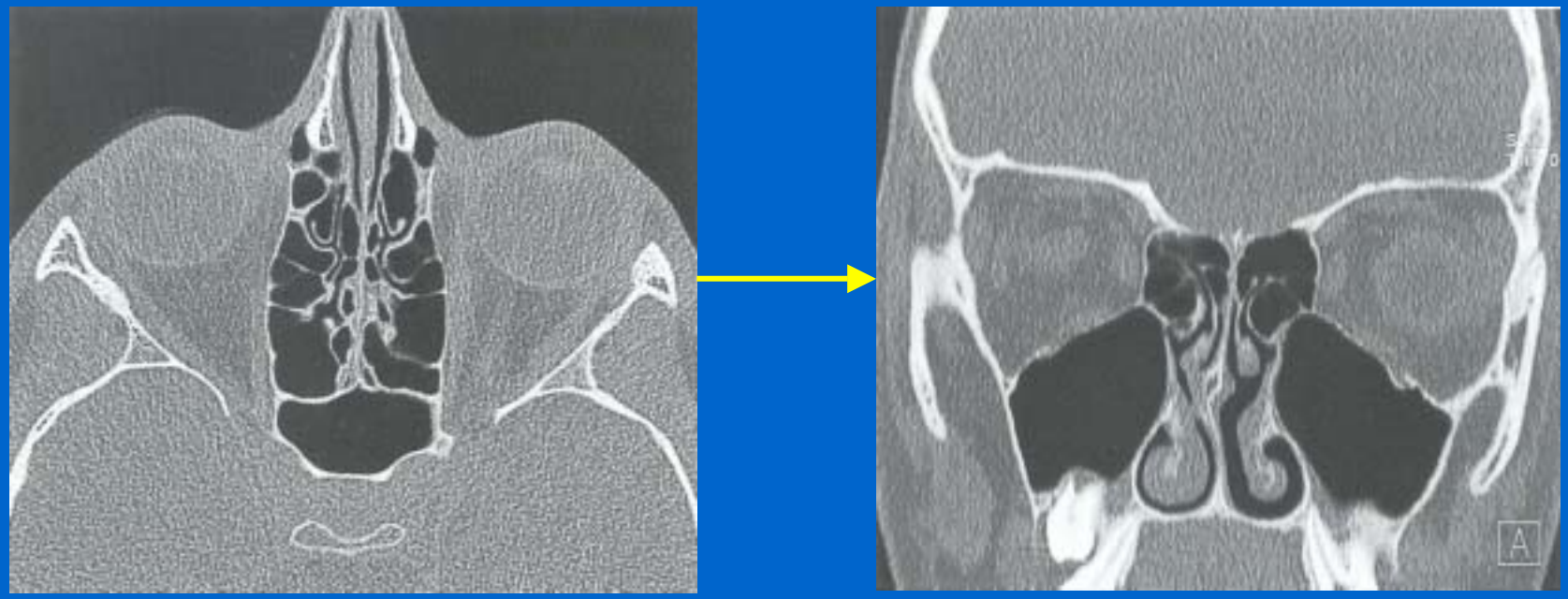
Improved patient comfort and compliance

- Paediatric: faster imaging requires less sedation
- Trauma: larger single scan volumes
- High quality MPRs can mean more comfortable patient positioning
  - e.g. sinus images reconstructed from axial scans:



Courtesy: Siemens

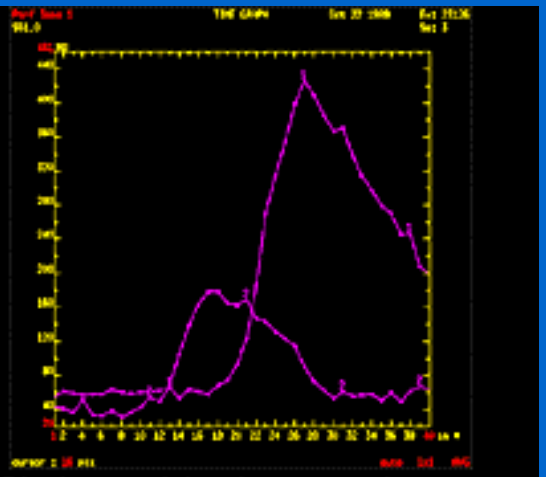
Reduced risk of complications

- Less contrast required with faster scanning
- Advantages for CT perfusion studies
  - e.g. stroke assessment

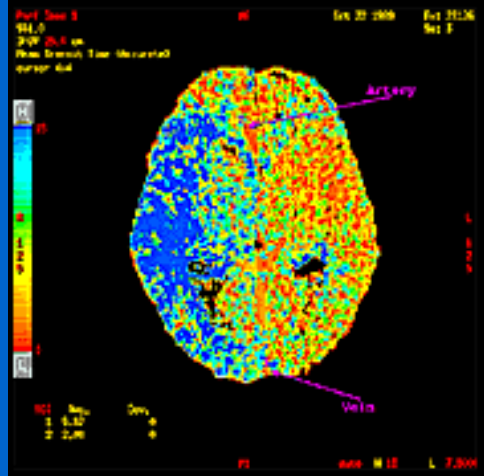
CT Perfusion

- xenon gas previously used
  - patients not very tolerant
  - scans taken over 5 - 10 minutes at 1 minute intervals
- faster scanning means ionic contrast can now be used
  - continuous scanning of the brain during contrast injection
  - scan time < 1 minute

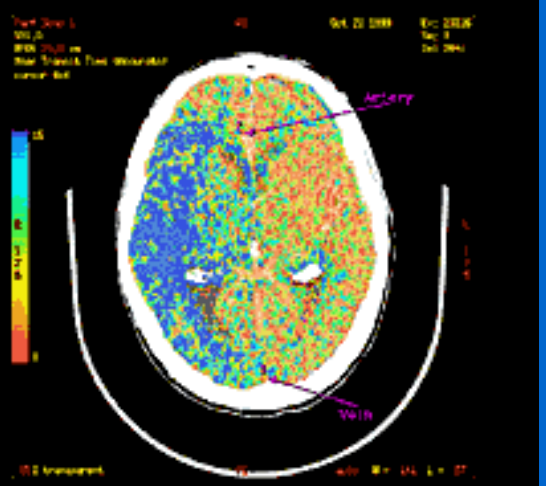
Select input artery and output vein automatically or manually.



Display arterial and venous enhancements to verify usage of right input and output curves.



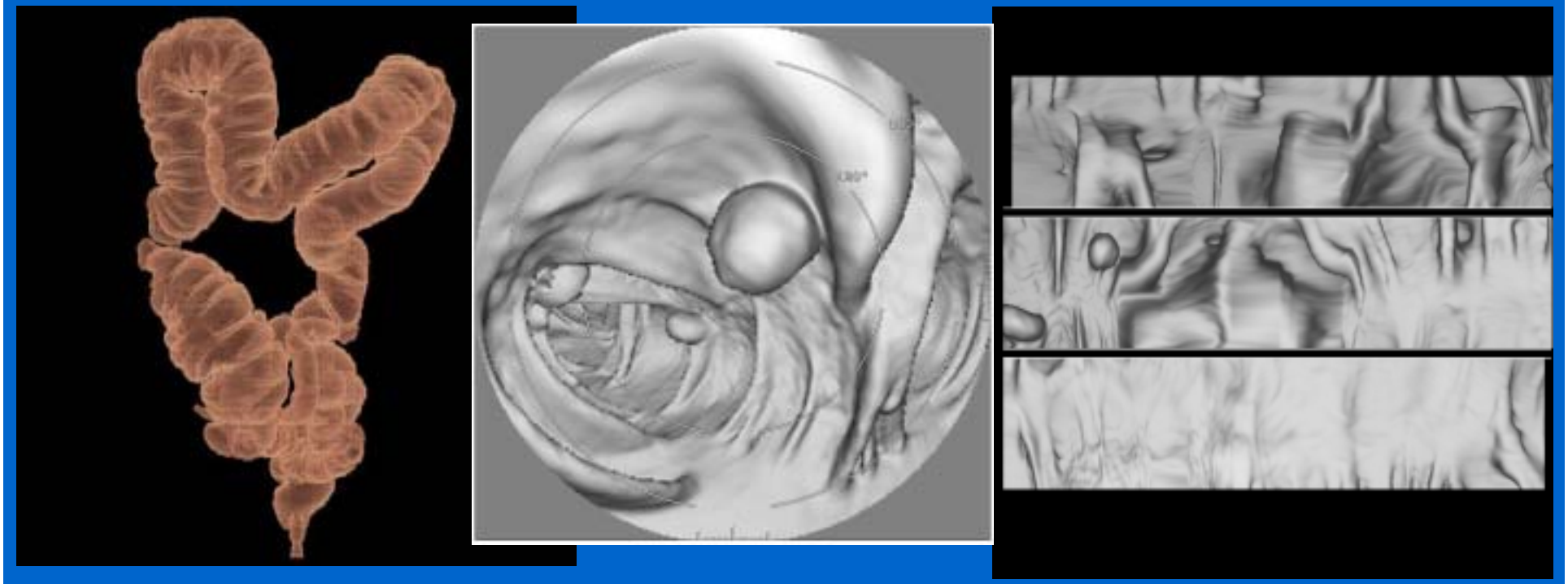
Functional image (MTT, CBV or CBF) appears for fast, accurate measurement.



Transparency provides an overlay of the parametric or functional image on a reference image.

Sparing invasive procedures

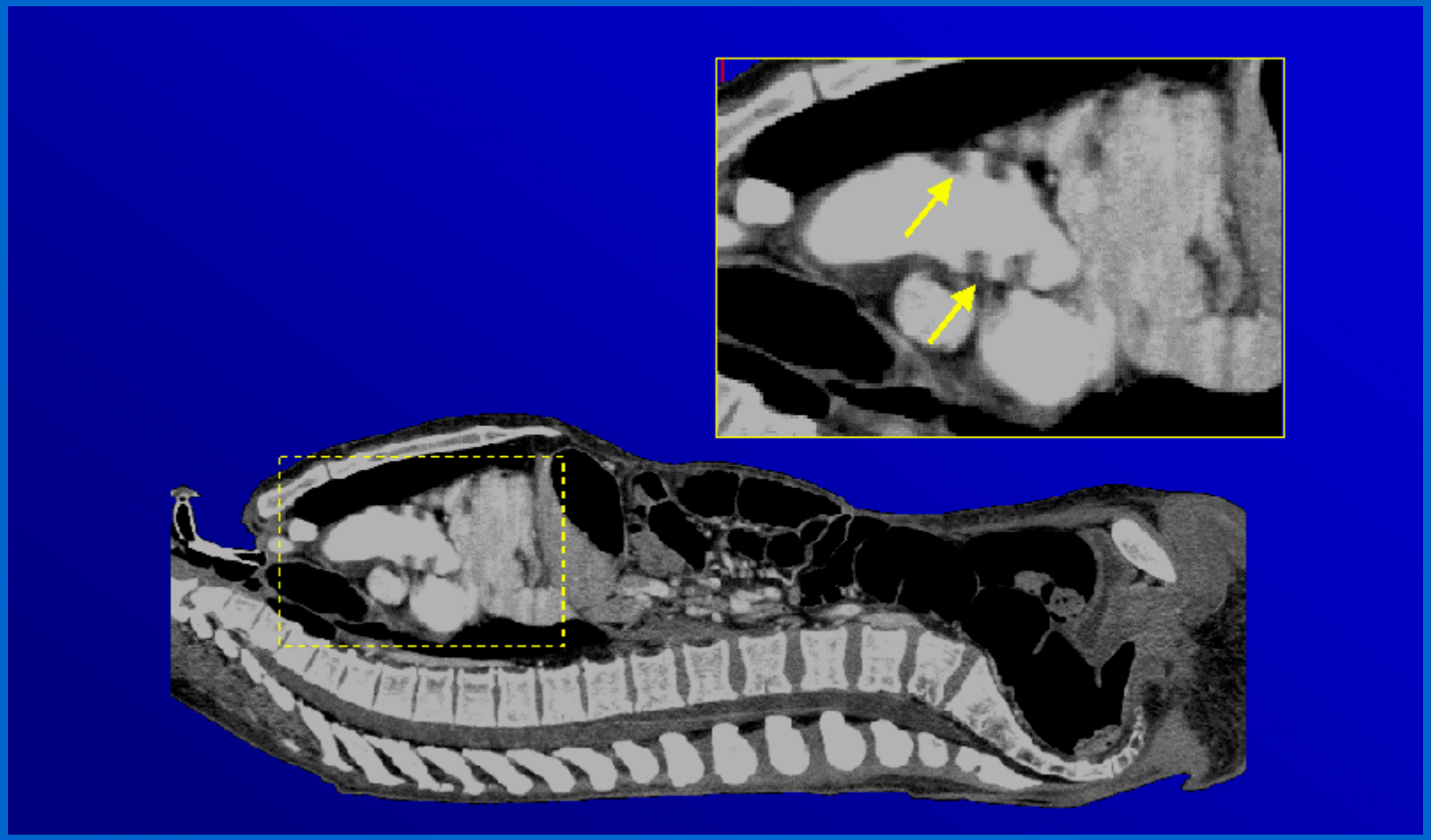
- e.g. colonography:



Courtesy: GE Medical Systems

Cardiac CT with earlier technology

- Cardiac movement caused blurring and severe motion artefacts

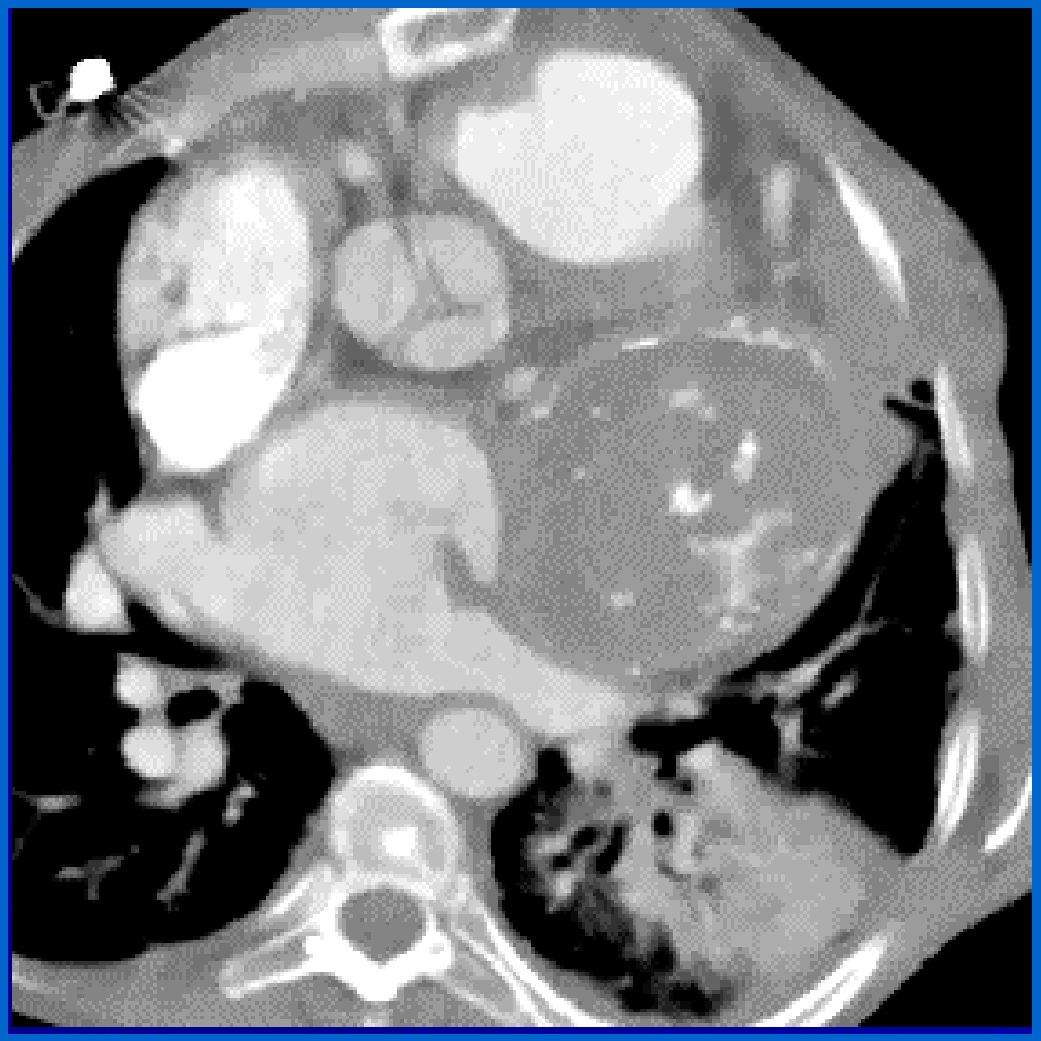


Courtesy: Prof. Kalender, University of Erlangen

Cardiac CT now

Compared with MRI and EBCT:

- Temporal resolution now almost comparable because of:
  - sub-second rotation times
  - ECG gating
  - multi-slice technology
- Better spatial resolution
- Advantages in cost, availability and patient comfort

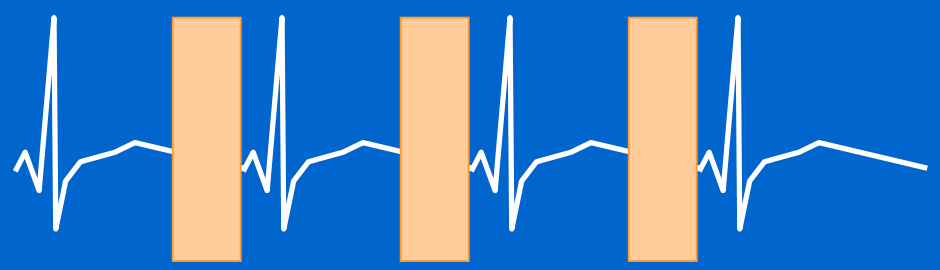


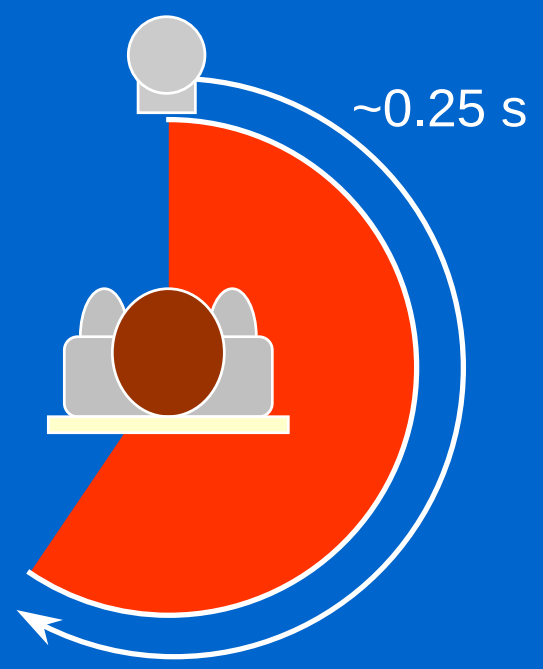
Heart rate 90 beats/min

Courtesy: Kalender, University of Erlangen

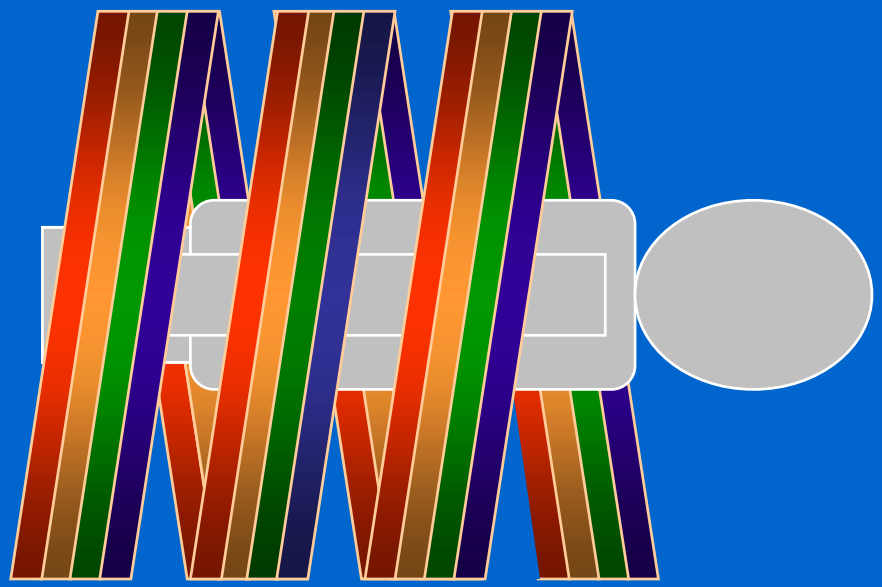
Prospective ECG gating

- Start of each axial scan triggered by ECG signal to coincide with heart phase with least motion
- Can produce partial rotation scan in ~0.25 sec





Retrospective ECG gating

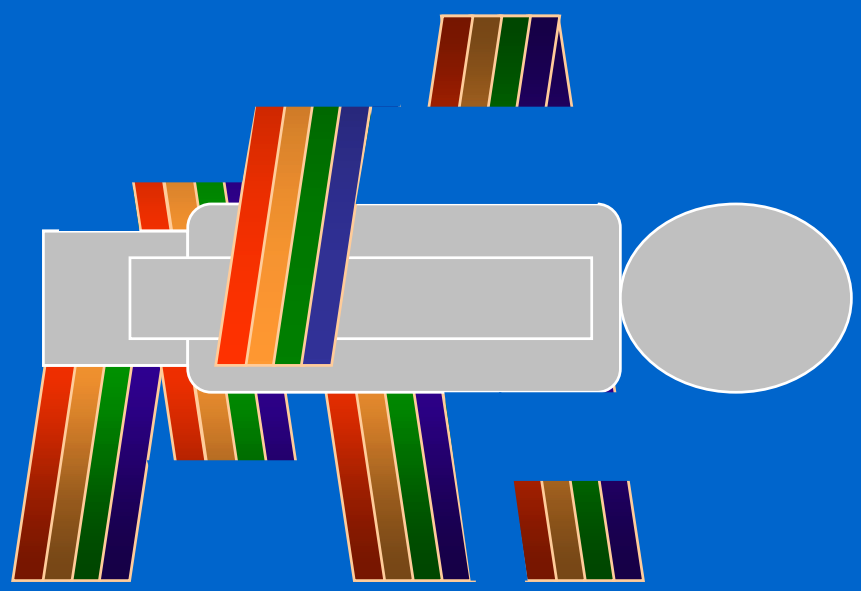


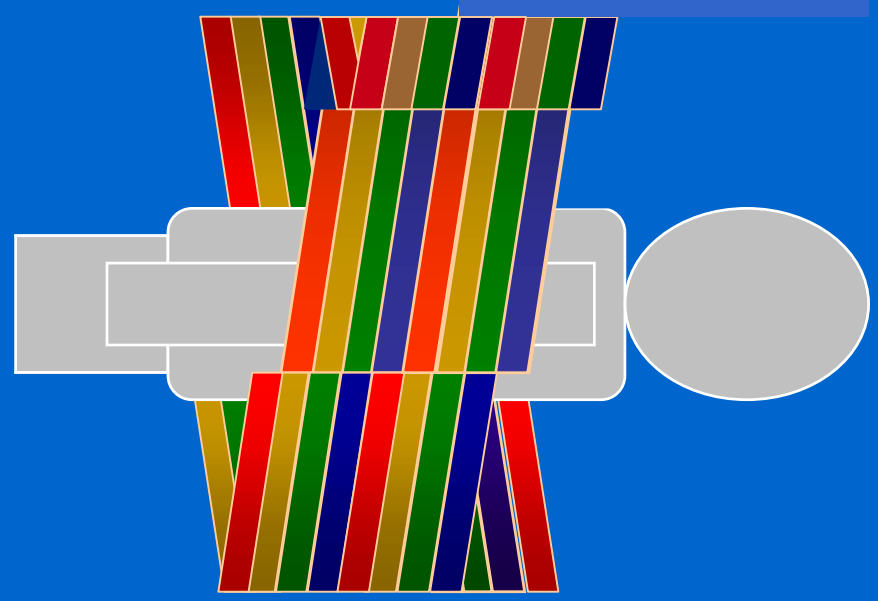
Retrospective ECG gating

- Image reconstructed using only portions of helical data collected during diastole

- Need pitch ~0.3

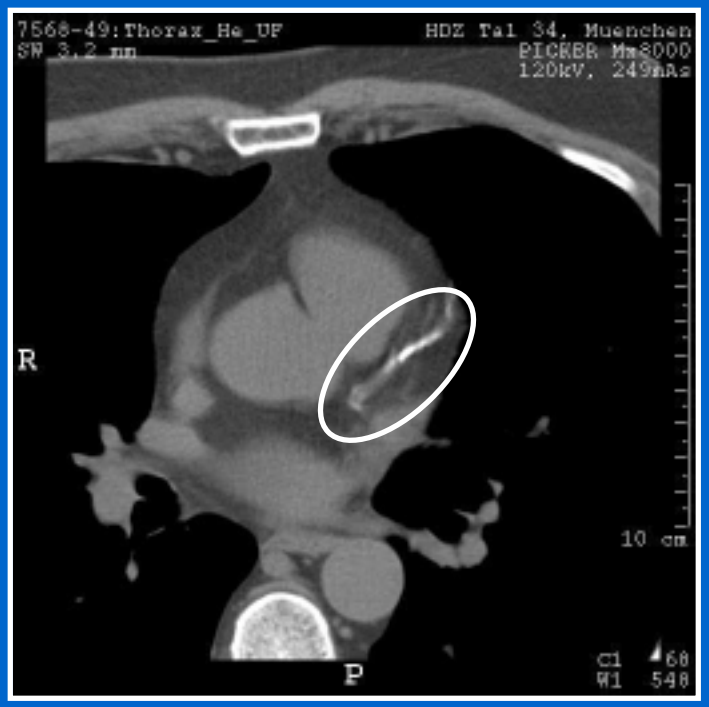
  ∴ high dose

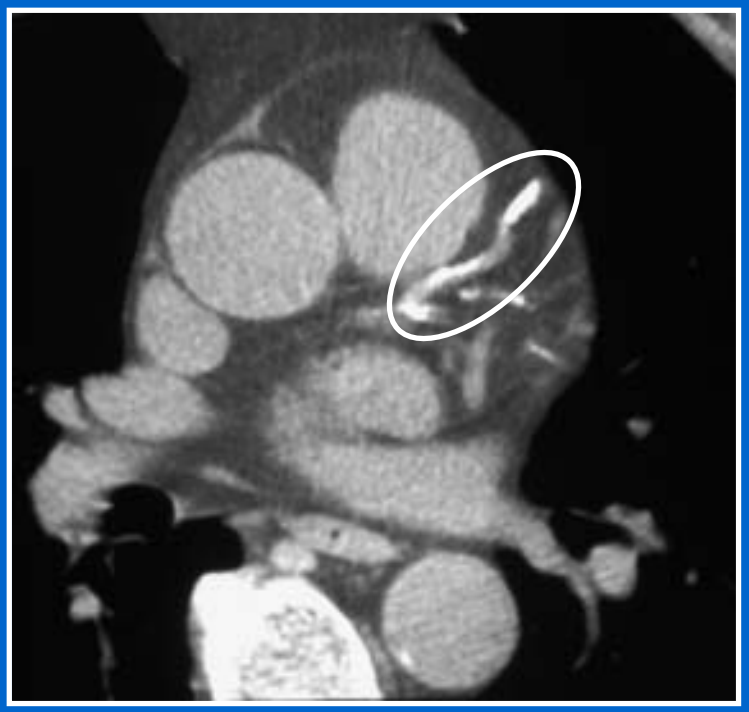




Cardiac calcification scoring

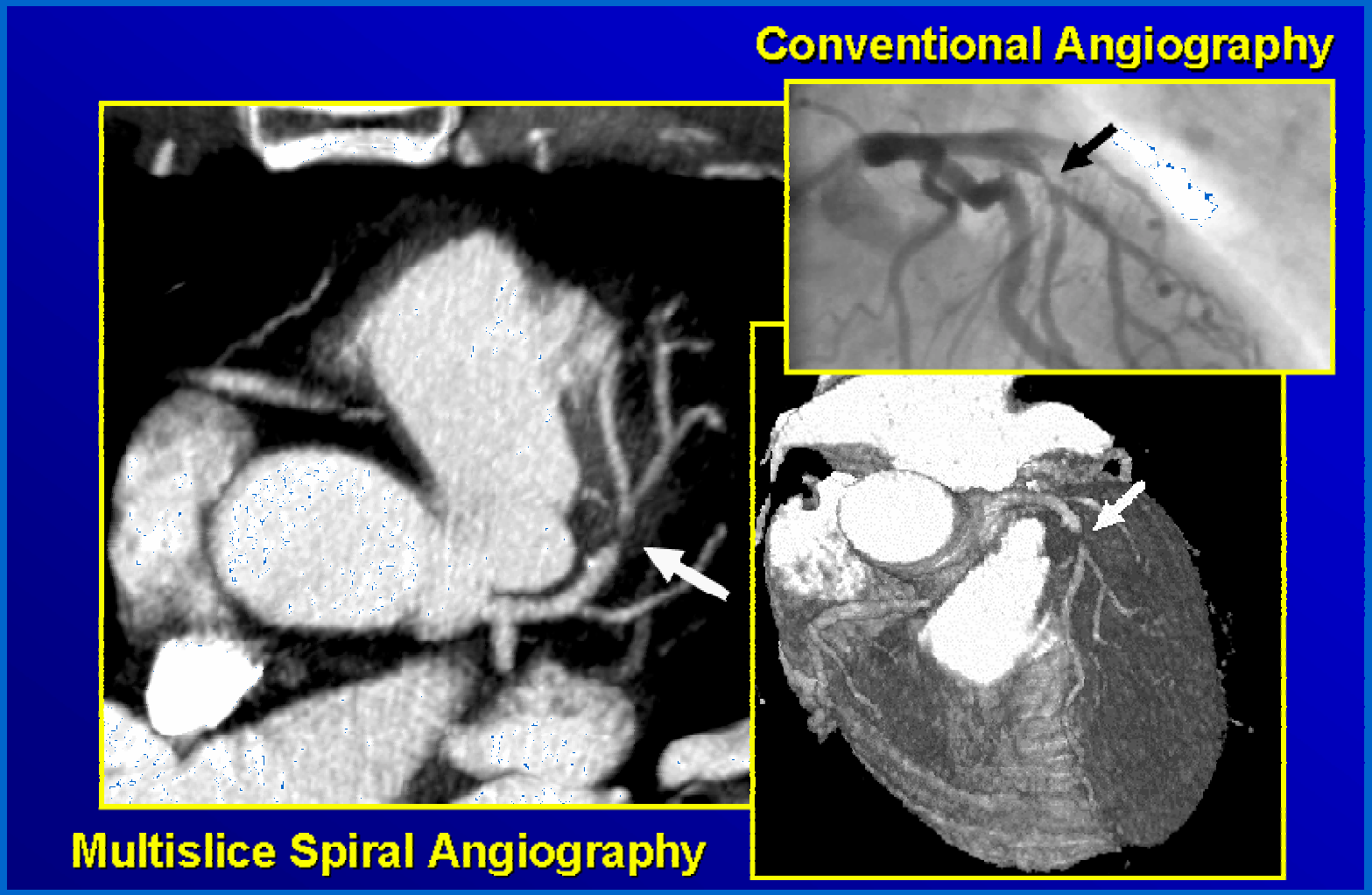
- Analysis of calcified coronary plaque used in diagnosis of coronary artery disease





CT coronary angiography

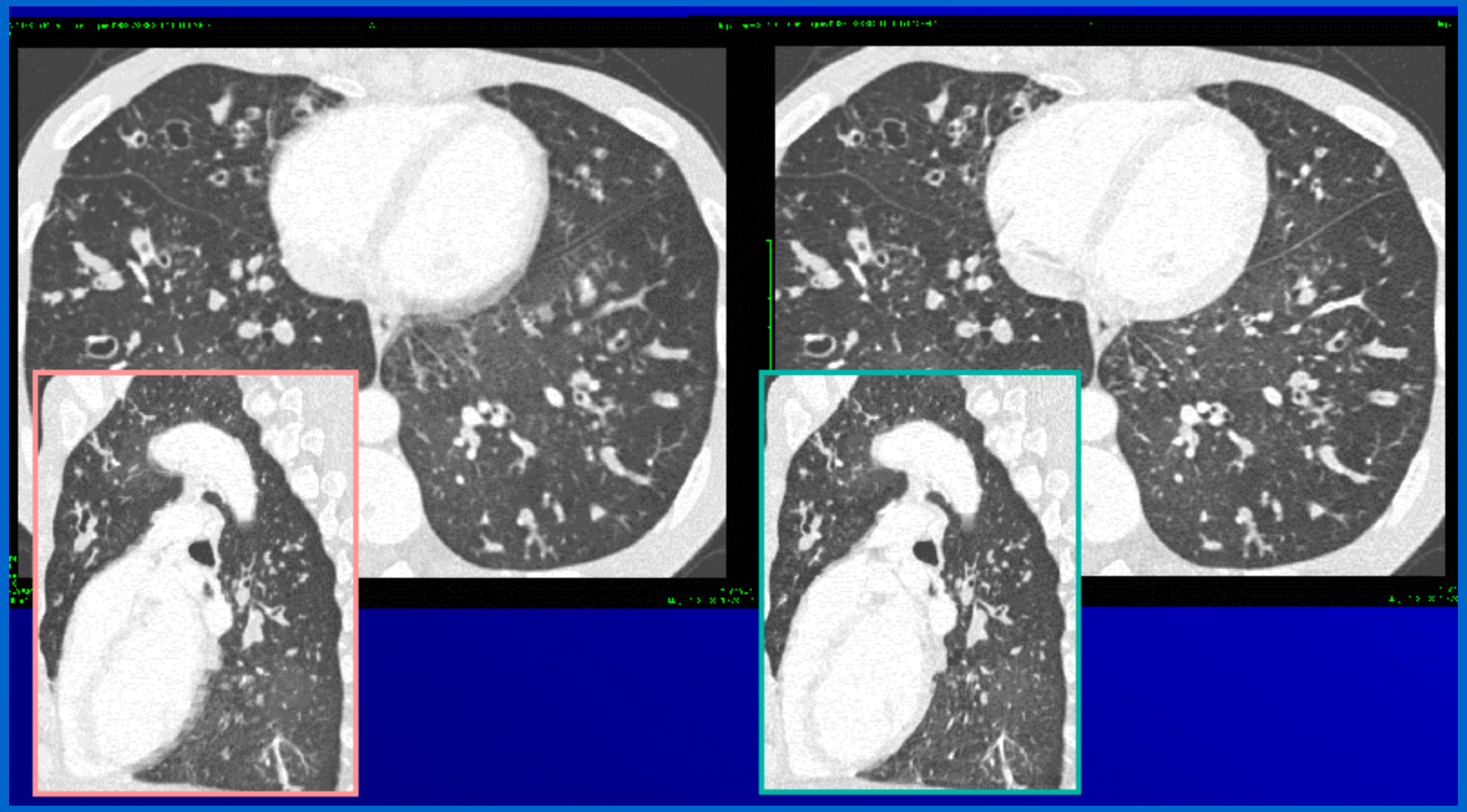
- Stenosis detectable in vessels down to 1.5 mm diameter



Courtesy: Prof. Kalender, University of Erlangen

Phase-selective reconstruction

- Determine heart motion function instead of ECG
- Use as basis for phase-selective reconstruction



ECG-gated reconstruction

Motion-correlated reconstruction

Courtesy: Prof. Kalender, University of Erlangen

How does the patient benefit?

- Are the images of greater diagnostic value?
  - better image quality?
  - improved imaging capabilities?
- Is patient comfort/compliance/safety improved?
  - formerly difficult procedures now more comfortable?
  - reduced risk of complications?
  - new CT techniques available that spare patient from more invasive diagnostic procedures?
- Are radiation doses any lower?
  - any different from single-slice scanning?
  - any dose reduction features?

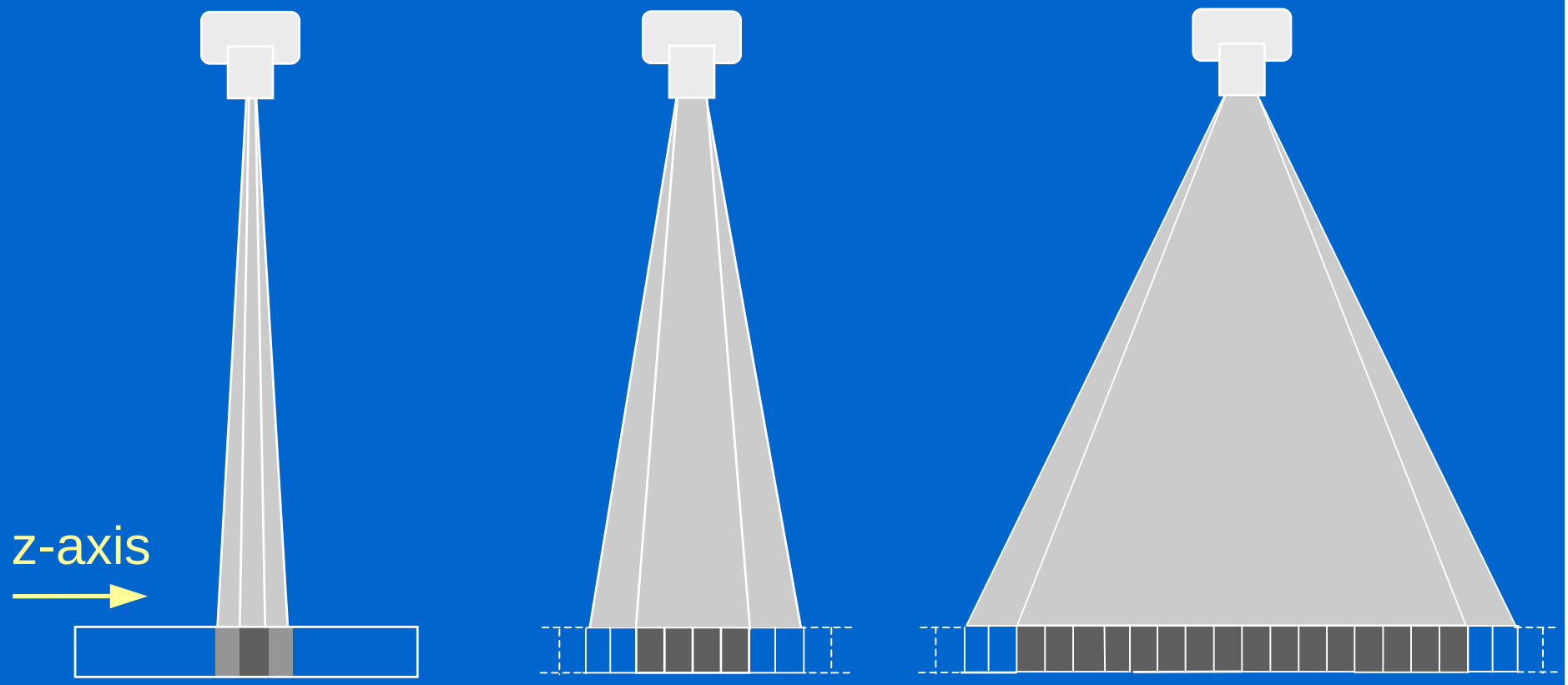
Multi-slice v. single-slice doses

- For wide slices, doses are similar on single- and multi-slice scanners in axial mode
- Effect of helical pitch on noise is different on multi-slice than on single-slice
  - To keep noise the same, mA increases automatically with increasing pitch on multi-slice
  - mA kept the same with pitch on single-slice because noise does not vary

How might doses be higher with multi-slice?

- More CT scans likely to be performed because of the greater range of scanning capabilities
  - ∴ increase in overall dose burden
- Use of CT for screening
  - e.g. lung cancer and colon cancer screening in high-risk groups
- Greater use of narrow slices
  - need higher mA to keep noise acceptable (partly offset by improved contrast due to less partial volume effect)
  - doses higher for narrow collimations because of beam penumbra

Thin slices: contribution of penumbra



Single-slice detector: penumbra contributes to image, ∴ no wasted dose

4-slice acquisition: penumbra contributes significant unused radiation dose

16-slice acquisition: unused penumbra constitutes much smaller proportion of total dose

Geometric efficiencies

Manufacturer	Scanner	Collimation	Geometric efficiency
GE	LightSpeed Plus	4 x 1.25	63%
	LightSpeed Ultra	8 x 1.25	76%
Philips	Mx8000 Quad	2 x 0.5	48%
	Mx8000 Quad	4 x 1	68%
	Mx8000 Infinite	16 x 0.75	93%

How might doses be lower?

- “Two-for-one” scanning
- e.g. high-res. lung + mediastinum
  - single scan using 4x1 mm collimation:

1.25 mm reconstructions,
0.5 mm intervals

5 mm reconstructions,
2.5 mm intervals

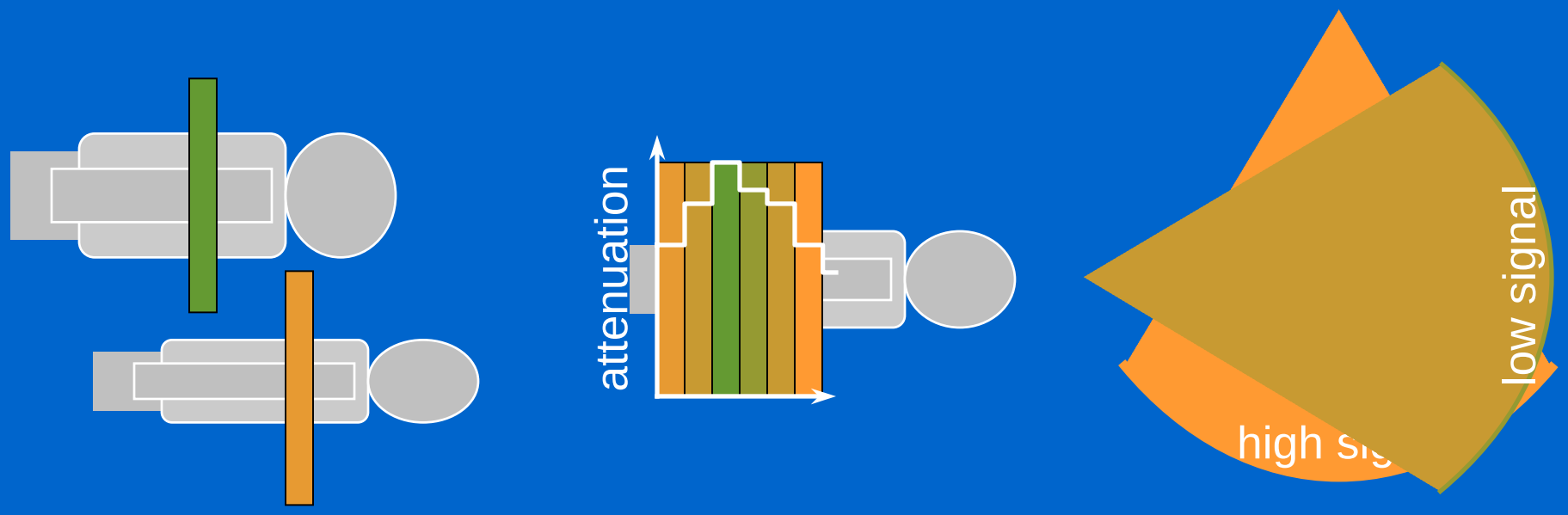
Courtesy: Siemens

Dose reduction features

- Tube current modulation
  - varies mA to match variations in attenuation
- Paediatric protocols
  - chose mA and kV appropriate to child's size

Matching tube current to attenuation

- Problem: different patient diameters and attenuation
  - from patient to patient
  - along patient length
  - in AP and lateral directions

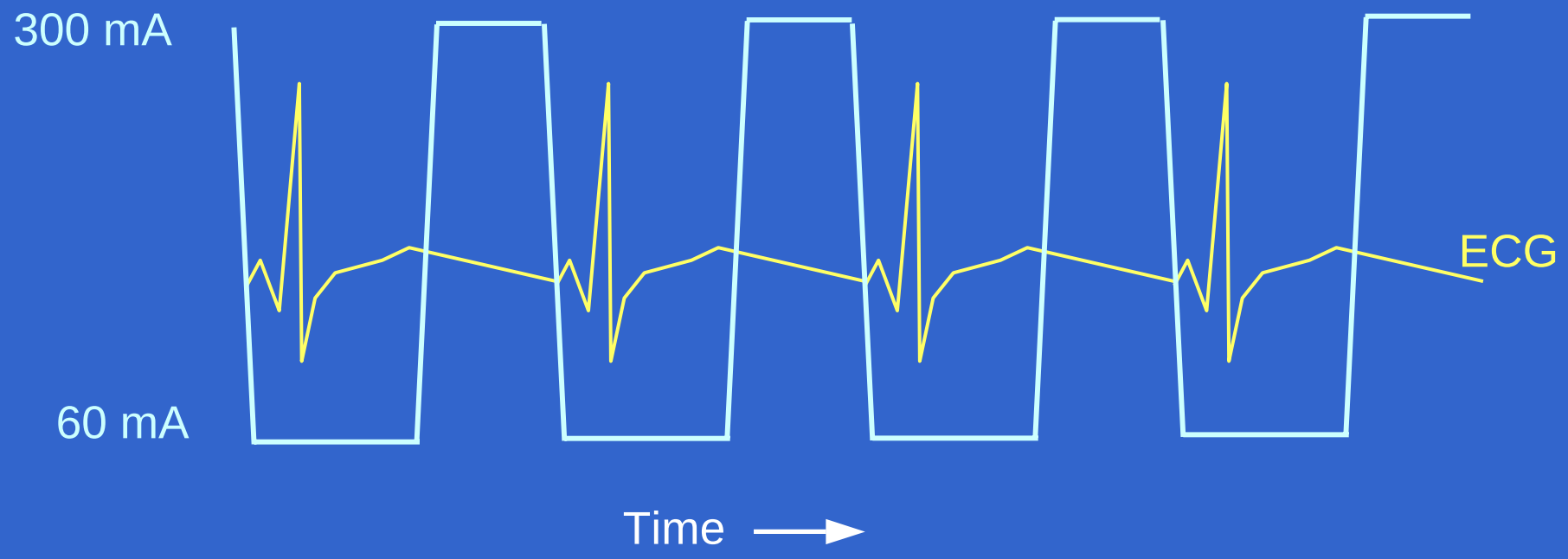


- Solution: automatic control of tube current (mA)

Tube current modulation

- Method 1: use one or more SPRs to assess attenuation along patient length
  - vary overall mA according to patient size
  - vary mA slice by slice during scan (e.g. GE's Auto mA)
- Method 2: use feedback mechanism
  - adjust mA based on signal to detectors during previous rotation (e.g. Siemens CARE Dose, Philips DoseRight)
- Advantages
  - lower dose (e.g. mean mAs reduction of 28% with CARE Dose)
  - image quality is constant, with fewer artefacts
  - tube heat capacity conserved

ECG-gated mA modulation



- ~50% dose reductions reported using this technique
- Further significant dose savings possible by using 80 kV rather than 120 kV without compromising image quality

Paediatric protocols

- GE's colour coded system
  - assigns scan parameters according to child's weight and height
  - ties in with hospital-wide Rainbow System which covers drug doses, needle sizes etc
- Philips and Siemens systems
  - protocols specific to weight and age

Conclusions

- New technology proving its worth:
  - in routine scanning
  - in more specialised fields
- CT scanning procedure may:
  - be more comfortable for the patient
  - carry fewer risks of complications
  - sometimes replace more invasive procedures
- CT doses:
  - likely to increase overall for the population
  - higher for some exams but could be lower for others
  - thin slice doses on 8- and 16- slice lower than on 4-slice
  - are being addressed by dose reduction features