RADIOLOGY RESEARCH

Radiographic Tomosynthesis: Acquisition Parameters

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Detroit, MI

Learning Objectives

Learn ..

1. Appreciate the importance of scan direction ,
2. Understand how tomosynthesis (TS) images can have better resolution than CT images
3. Learn guidelines for performing TS examinations,

.. [with muskuloskeletal examples]

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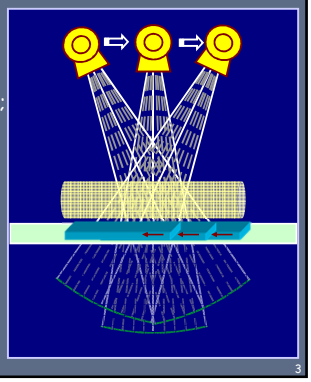
A - DR & Tomosynthesis (TS)

Digital Radiography (DR) detectors capable of rapid sequence acquisitions are effective for xray TomoSynthesis (TS) imaging;

- High resolution
- No geometric distortion
- High frame rate (pulsed)
- Minimal lag

Accurate mechanical movement of the detector and x-ray tube is required to achieve high detail from TS reconstruction.



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A – Shimadzu Sonialvision / Safire

- The Shimadzu Sonialvision / Safire system integrates the digital detector within a radiographic tilt table.
- Shown in the tilt position for a lateral knee tomosynthesis acquisition (60º), the detector translates up and the x-ray tube moves downward.
- The x-ray central beam is directed at the joint surface with an angle that varies from -20 to +20 degrees

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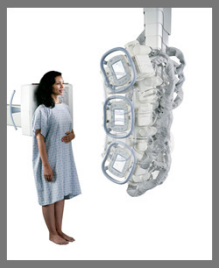
A – GE VolumeRAD



- For the GE VolumeRAD system, the tube angle changes as the tube mount moves linearly.
- The detector remains in a stationary position.

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B.1 – Acquisition lag

- Tomosynthesis requires the acquisition of many views acquired as a very rapid sequence.
- Minimal lag from frame to frame is required

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B.1 – Transient Response

Rapid Edge Movement Test
- 1.51 mm Cu edge
- High edge position
- Low central layer
- 74 frames
- 30 frames/second

Radiographic technique
- RQA5 'equivalent'
- 70 kVp, 1 mA-S
- .5 Cu, 2 mm Al

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B.1 – Transient Response

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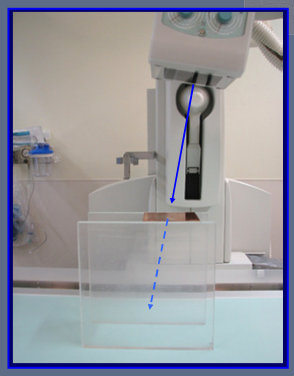

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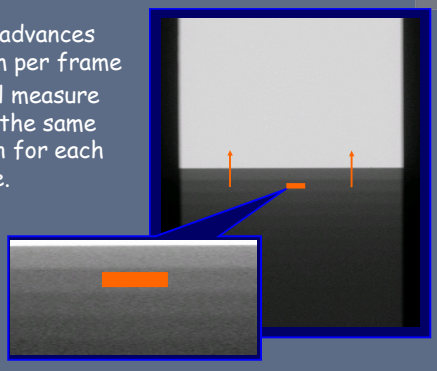
B.1 – Transient Response

- Edge advances ~ 1 cm per frame
- Signal measure from the same region for each frame.



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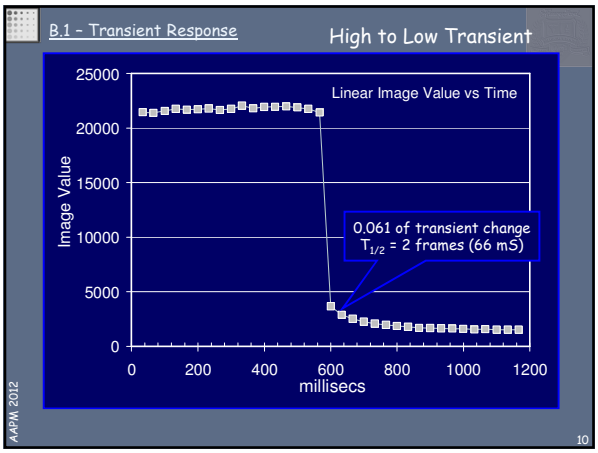
B.1 – Transient Response
High to Low Transient
Linear Image Value vs Time
Image Value
25000
20000
15000
10000
5000
0
0
200
400
600
800
1000
1200
millisecs
0.061 of transient change
T1/2 = 2 frames (66 mS)
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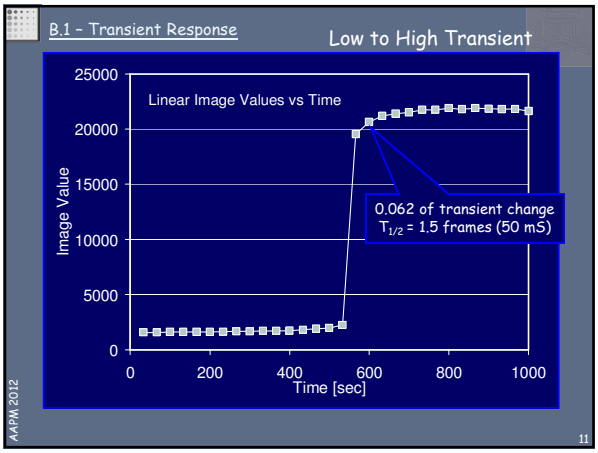
B.1 – Transient Response
Low to High Transient
Linear Image Values vs Time
Image Value
25000
20000
15000
10000
5000
0
0
200
400
600
800
1000
Time [sec]
0.062 of transient change
T1/2 = 1.5 frames (50 mS)
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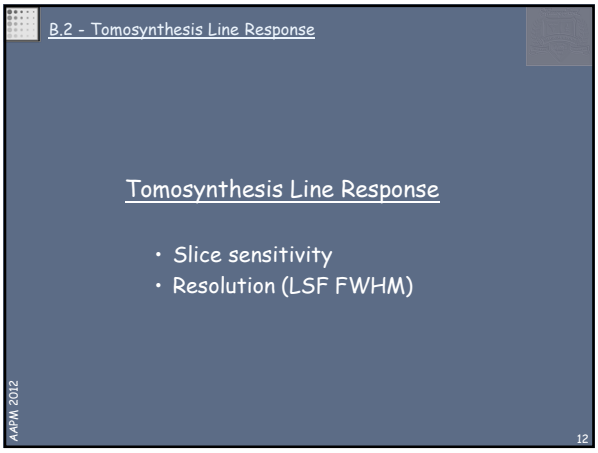
B.2 - Tomosynthesis Line Response
Tomosynthesis Line Response
• Slice sensitivity
• Resolution (LSF FWHM)
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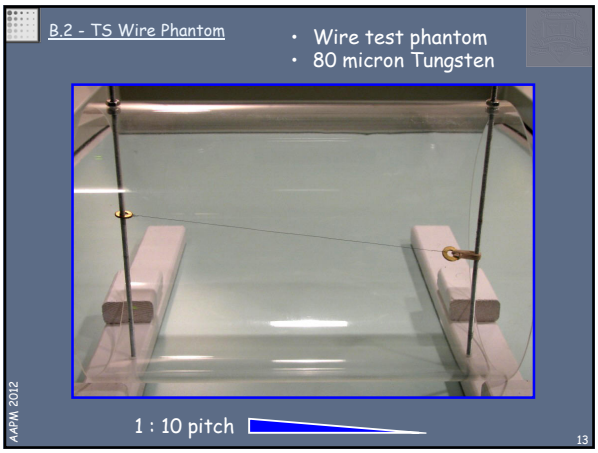
B.2 - TS Wire Phantom
• Wire test phantom
• 80 micron Tungsten
1 : 10 pitch
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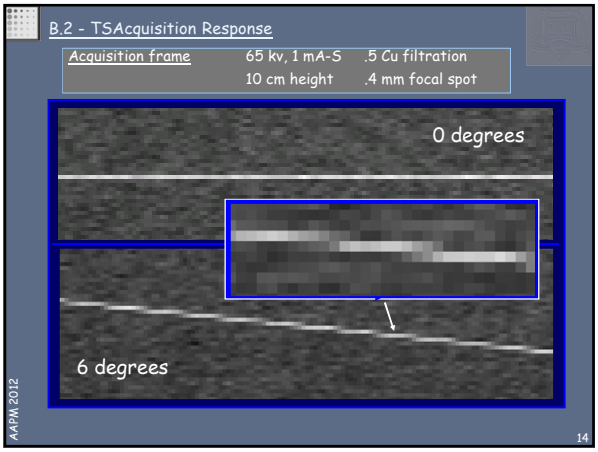
B.2 - TSAcquisition Response
Acquisition frame
65 kv, 1 mA-S
10 cm height
.5 Cu filtration
.4 mm focal spot
0 degrees
6 degrees
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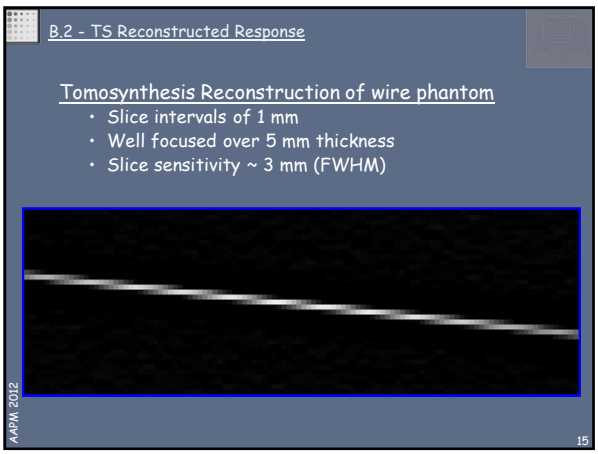
B.2 - TS Reconstructed Response
Tomosynthesis Reconstruction of wire phantom
• Slice intervals of 1 mm
• Well focused over 5 mm thickness
• Slice sensitivity ~ 3 mm (FWHM)
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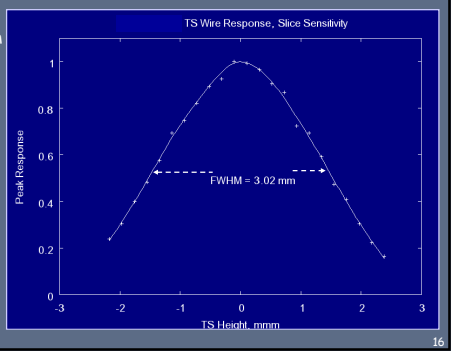
B.2 - TS spatial response

Slice Thickness (Sensitivity):

Peak contrast of a thin line vs height

FWHM = 3.02 mm

(rsna 2007)



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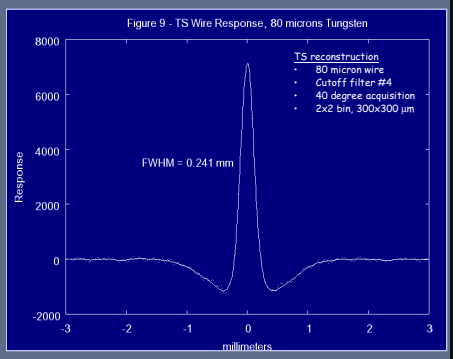
B.2 - TS response

TS Resolution:

- Thin wire response at maximum contrast.
- Re-projection with 1/10th sub-pixels

FWHM = 0.24 mm

(rsna 2007)



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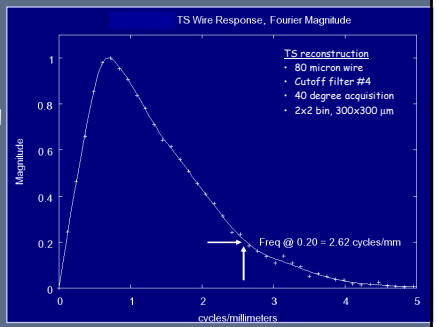
B.2 - TS line response

Fourier transform (magnitude) of LSF

Extended spatial frequency response but no low frequency, DC, information.



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B.3 – TS vs CT resolution

- In the x direction, TS resolution is about 3 times better than current CT scanners.
- In the x direction, TS slice thickness about 3 time worse than thin slice CT scans.

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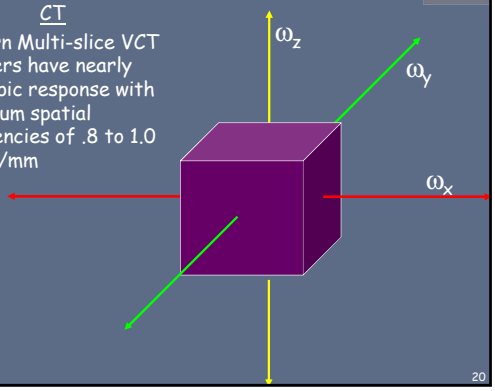
B.3 - 3D spatial frequency domain

CT

Modern Multi-slice VCT scanners have nearly isotropic response with maximum spatial frequencies of .8 to 1.0 cycles/mm



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B.3 - CT Resolution

(2006 SPIE)

Clinical Multi-slice scanners

- 64 slice scanners
  - GE Lightspeed VCT 64
  - Siemens Sensation 32x2
- PISF FWHM
  - Transverse 1.14 +/- .05 mm
  - Axial 0.87 +/- .11 mm
- 10% MTF Freq.
  - Transverse 0.74 +/- .02 cycles/mm
  - Axial 0.92 +/- .12 cycles/mm

For purposes of comparison, we express typical VCT performance as;
- 1.00 mm (FWHM PISF)
- 0.83 cycles/mm (10% MTF)

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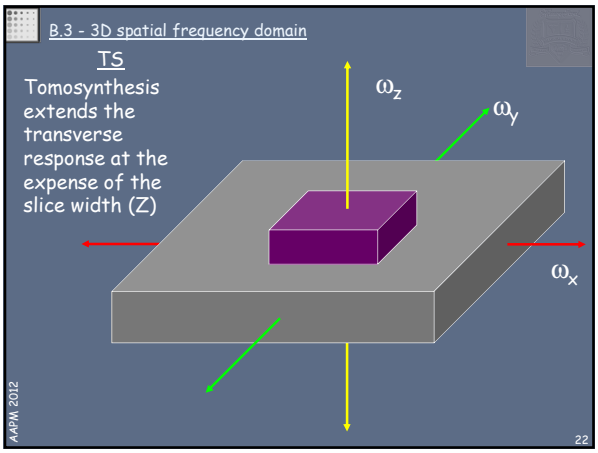
B.3 - 3D spatial frequency domain
TS
Tomosynthesis extends the transverse response at the expense of the slice width (Z)
ω_z
ω_y
ω_x
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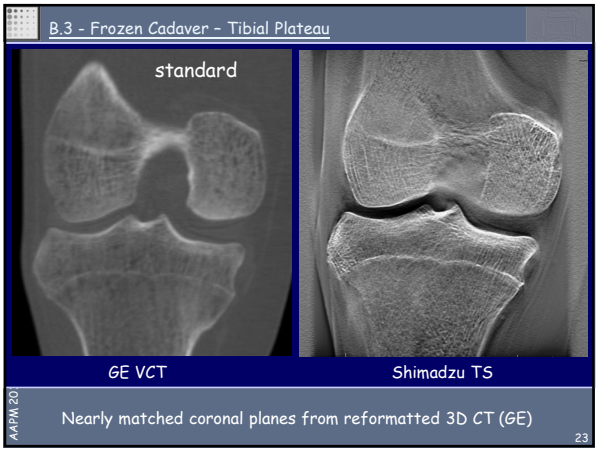
B.3 - Frozen Cadaver – Tibial Plateau
standard
GE VCT
Shimadzu TS
Nearly matched coronal planes from reformatted 3D CT (GE)
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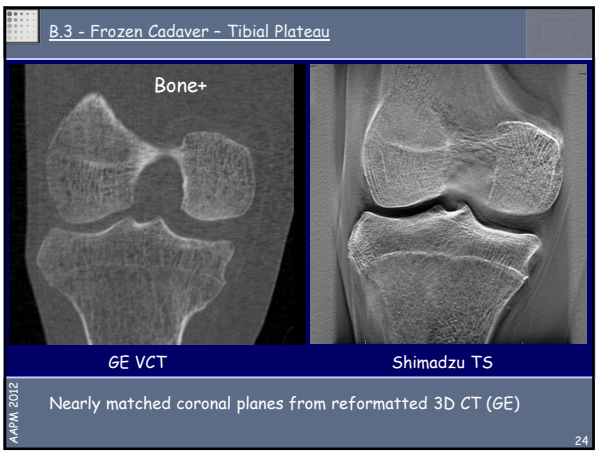
B.3 - Frozen Cadaver – Tibial Plateau
Bone+
GE VCT
Shimadzu TS
Nearly matched coronal planes from reformatted 3D CT (GE)
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B.3 - 3D spatial frequency domain

- In the x direction, TS resolution is about 3 times better than current CT scanners.
- In the x direction, TS slice thickness about 3 time worse than thin slice CT scans.
- HOWEVER,

  the TS image is NOT a tomogram in that large segments of the volumetric spatial frequency domain are un-sampled.

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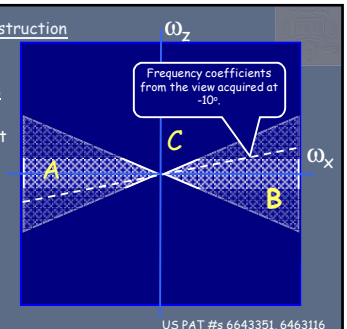
B.3 -Tomosynthesis Reconstruction

Filtered Backprojection

- The reconstruction is similar to cone beam CT but with a limited acquisition angle.
- The tomosynthesis image quality can be understood from the Fourier representation of the acquired data.



US PAT #s 6643351, 6463116

A. High signal frequencies in the x,y directions provide in-plane detail.
B. Varied filter cut-off frequencies vs angle limit Z signal resolution.
C. Flat surfaces are not sampled along the ω_z direction

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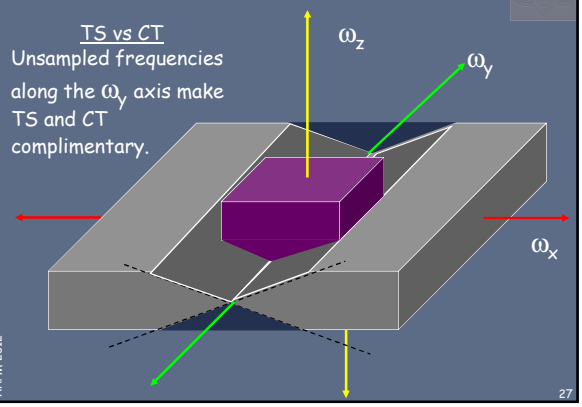
B.3 - 3D spatial frequency domain

TS vs CT

Unsampled frequencies along the ω_y axis make TS and CT complimentary.



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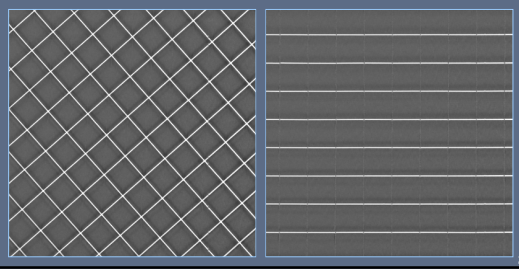
B.3 Orientation effect

Grid phantom made from a the grid of a fluorescent ceiling light;
- 1 cm aluminum louvers
- 14 mm spacing

12 cm x 12 cm
- 45° to scan
- 0° / 90° to scan



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B.4 – MultipleTS views

- Because of the large slice thickness and anisotropic spatial resolution, multiple TS view are needed to examine organs in different orientations.
- This is an important distinction relative to CT where sagital, coronal, and transverse views are obtained from the same acquisition.

AAPM 2012, SU-C-218-1
1 or 2 View Chest TS
Y. Zhong, MD Anderson

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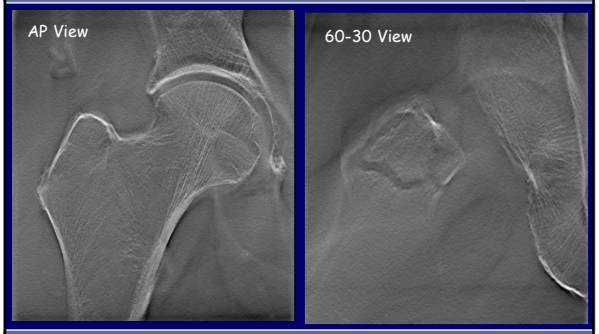
B.4 – MultipleTS views



Multiple TS acquisitions are required to get detail in planes of different orientation

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B – TS vs CT summary

- TS advantages
  - Much improved in plane detail.
  - More tolerant of metal devices.
  - Limited angle acquisition improves the radiographic technique.
    - Low kV due to reduced thickness.
    - Reduced irradiation from cone views.
    - Reduced overall patient dose
- CT advantages
  - Quantitative tissue property value.
  - Isotropic response
  - Multiple orientations from one acquisition

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C – Knee Tomosynthesis

TS Knee examination

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C - Standing PA Views

- Weight bearing examination of the knee permits assessment of cartilage loss, an early indicator of OA.
- Biomechanical studies have shown that the tibia-femur contact stress is greatest with the knee flexed.
- Standing views are obtained with the knee moved forward to press on the table pad.
- A table tilt of 70° with a waist restraint is used for safety reasons.
  - Messieh et. al., J of Bone & Joint Surgery, Vol 72-B, No 4, 1990.

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C - Standing Lateral Views

- Lateral views of individual knees are obtains by placing the opposite foot on a ledge associated with the standing table accessory.
- A table tilt of 60 degrees places a load on the single leg similar to that of normal standing on two legs.
- The lateral view is of interest with respect to the patellar gap. Thus a flexed position is not used.

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C - Coronal views - example

- Coronal images are reconstructed from the PA standing acquisition views.
- Each image corresponds to a slice thickness of about 2.5 mm at intervals of 1.0 mm.
- Typically about 80 images are reconstructed.
- Reconstruction takes about 1.5 minutes using a post processing work station (PPWS).

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C - Sagittal views - example

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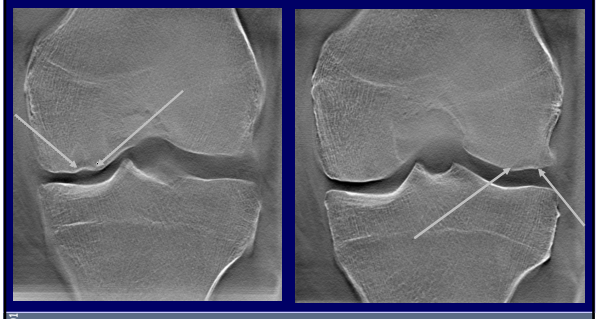
C.2 - Knee Case – Femoral Insufficiency Fractures

Tomosynthesis Demonstrates Bi-condylar Insufficiency Fractures



Coronal Tomosynthesis – Insufficiency Fracture of Medial Femoral Condyle

Coronal Tomosynthesis – Insufficiency Fracture of Lateral Femoral Condyle

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C.2 - Knee Case – Femoral Insufficiency Fractures

Tomosynthesis shows bi-condylar femoral insufficiency fractures with greater resolution of bone detail than MRI

ORS, 2009

"In a report on 18 patients, TS supported our concept that the initiating cause of subchondral "insufficiency fractures" and SONK is a rapidly progressive form of degenerative arthritis."

2008 JAAOS

"tomosynthesis is a powerful tool that can be used to define the relationships of metabolic changes in cartilage those in bone as well as the relationship of bone changes to cartilage. This will be particularly true in circumstances where both magnetic resonance and tomosynthesis images are concurrently available."

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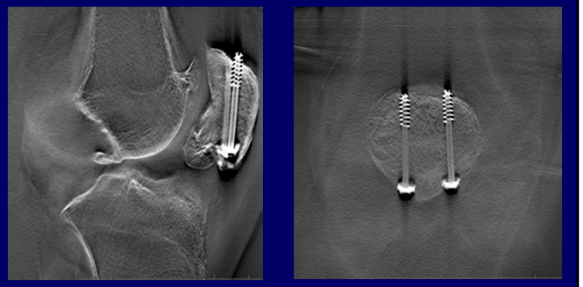
C.5 - Knee Case – Occult fracture

Patient presented with continued knee pain following a traumatic injury while out of state which was repaired with patellar screws.



Sagittal and coronal views obtained by scanning parallel to the screws minimize overshoot from the high absorption in the metallic material.

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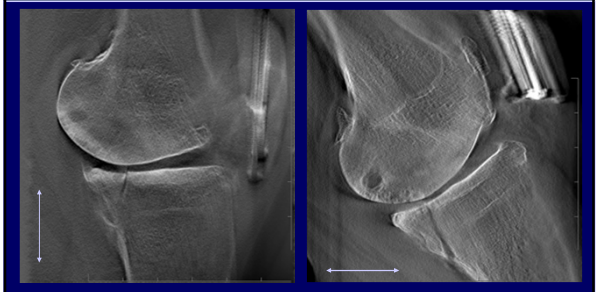
C.5 - Knee Case – Occult fracture

A displaced fibial fracture was clearly demonstrated on the tranverse scan.



sagittal (longitudinal) sagittal (transverse)

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D – Hip Tomosynthesis

TS Hip examination

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D – AP view

Gazeille, Flynn, Page et.al.
Skeletal Radiology
07 Aug 2011 (online)

AP view obtained with toe in and hip elevated with a boomerang filter.

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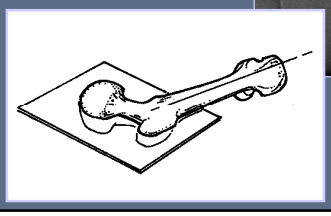
D – AP view

TS images are in a plane through the head, neck, and shaft.



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D – 6030 view

6030

- 60° up
- 30° out

The neck is rotated by bringing the knee up and out

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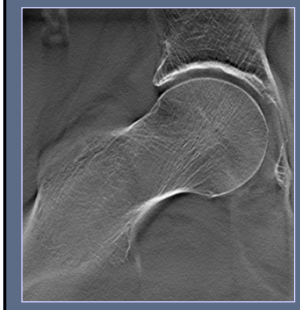
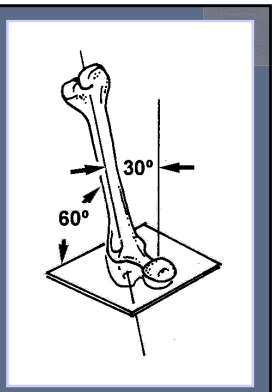
D – 6030 view





TS image are in a rotated plane througth the head and neck.

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D – modified 'faux profile'view

Similar to the standing faux profile radiographic view, the opposing hip is rotated forward by 60 degrees.

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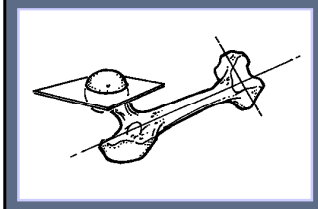
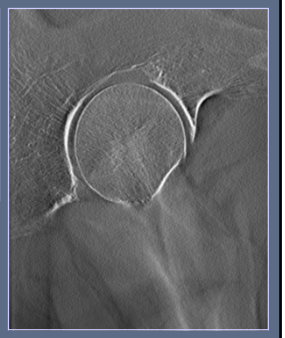
D – faux profile view





TS planes are oblique to the axis of the neck

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D - Hip Case #1 Trochanter fracture

- Patient presented in the EM Dept with possible hip fx
- Radiographs were inconclusive
- MR edema suggested a near complete fx that requires surgery.

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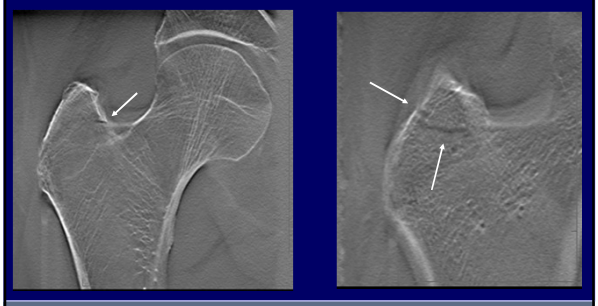
D - Hip Case #1 Trochanter fracture



- Tomosynthesis showed the fracture was restricted to the non weight bearing head of the trochanter.
- The patient was sent home without surgery.

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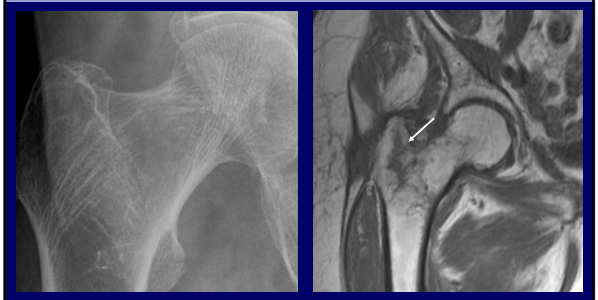
D - Hip Case #2 Trochanter fracture



- Patient presented in the EM Dept with possible hip fx
- CR - 'there is no definite fracture line seen'
- MR- 'Nondisplaced intertrochanteric fracture'.

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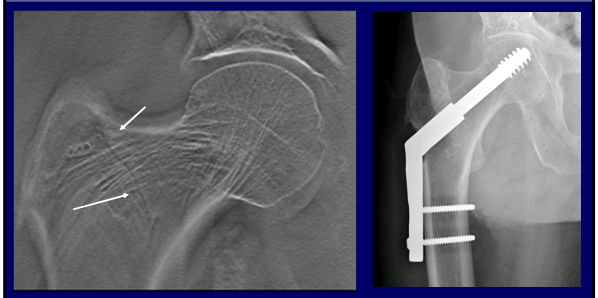
D - Hip Case #2 Trochanter fracture



- Tomosynthesis showed a transverse fracture from thetrochanter through the base of the neck.
- The patient was sent to surgery for a hip screw.

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D – TS Dose, Hip Exam

Gazeille, Flynn, Page et.al.
Skeletal Radiology
07 Aug 2011 (online)

Tomosynthesis Dose, Hip Exam

- 82 kVp – Average kV, varies amongst patients.
- 5.87 mGy - Entrance Skin Air Kerma (ESAK)
- 0.24 mSv - Effective dose for one view (ICRP103)

  Monte Carlo computation of organ doses.
  (PCXMC, Stuk, Helsinki, Findland)
- 0.72 mSv – Effective dose for 3 view examination

Mettler 2008
- 0.7 mSv – Radiographic hip exam
- 6.0 mSv – CT pelvis exam.

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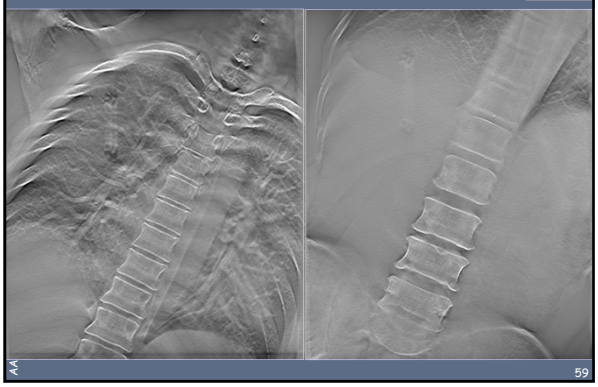
E - #5 Spine AP, Metabolic Bone Survey



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E - #5 Spine AP, Metabolic Bone Survey

Tomosynthesis Effective Dose

- Monte Carlo computation of organ doses. (PCXMC)
- ICRP 103 organ weights

	Median kV (N=30)	ESAK, mGy	Eff. Dose, mSv
Pelvis	80	5.48	0.57
L Spine	82	5.87	0.96
T Spine	76	4.76	0.86

Mettler 2008
- 6.0 mSv – CT spine exam
- 6.0 mSv – CT pelvis exam

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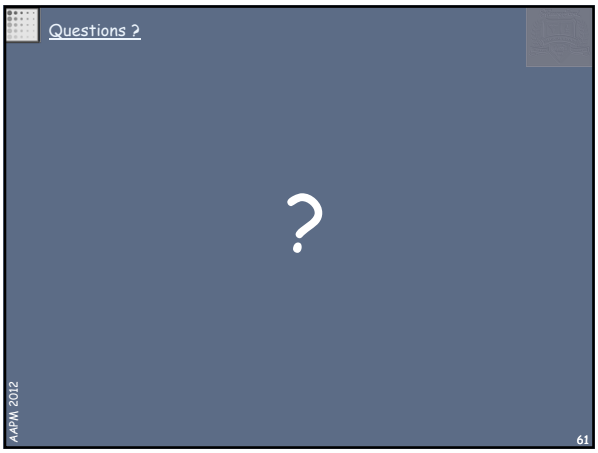
Questions ?
?
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