AAPM Imaging Education Course

Body Tomosynthesis: Image Features and Artifacts

Michael J. Flynn, PhD
Henry Ford Health System
Detroit, MI

Learning Objectives

Learn ..

1. Appreciate the importance of scan direction ,
2. Understand the nature of the artifacts associated with tomosynthesis scan acquisition and reconstruction.
3. Learn guidelines for performing TS examinations,

.. [with muskuloskeletal examples]

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 (60°), 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

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 to avoid streak artifacts

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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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6

B.1 – Transient Response

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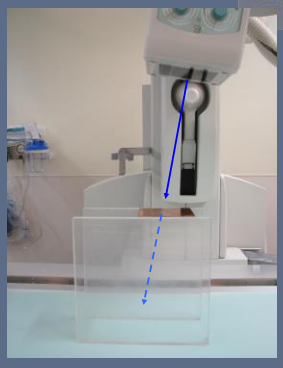

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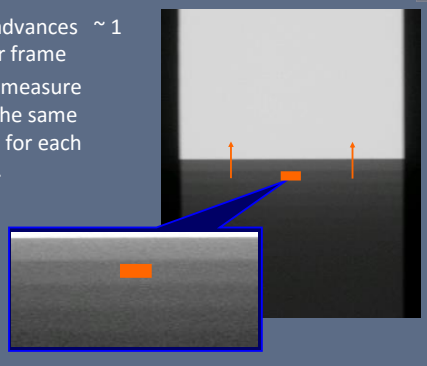
B.1 – Transient Response

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



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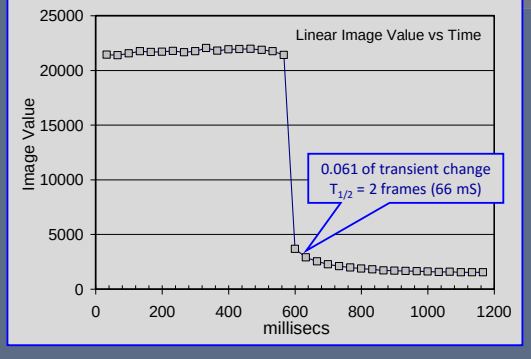
B.1 – Transient Response

High to Low Transient



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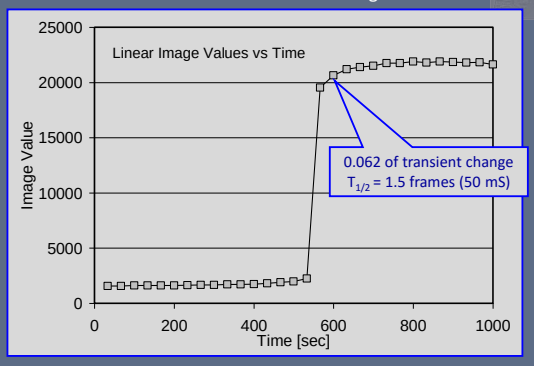
B.1 – Transient Response

Low to High Transient



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B.2 - Tomosynthesis Line Response

- The registration of each acquired projection must be accurately known to prevent blur.
- One method to measure the spatial response is to scan a thin wire tilted relative to the scan plane.
  - Slice sensitivity
  - Resolution (LSF FWHM)

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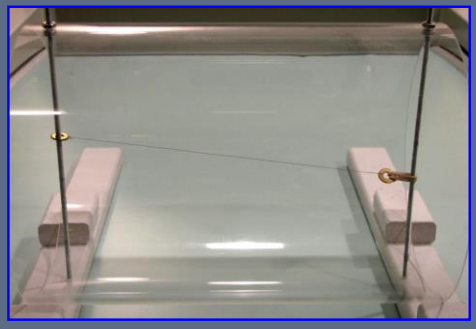
B.2 - TS Wire Phantom

- Wire test phantom
- 80 micron Tungsten



1 : 10 pitch

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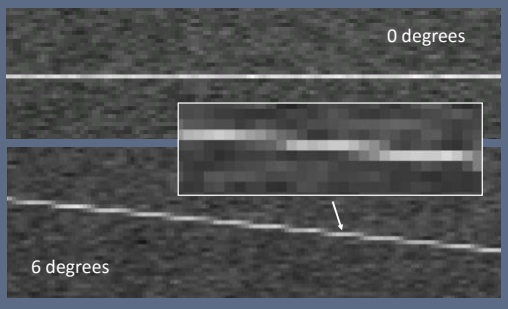
B.2 - TSAcquisition Response

Acquisition frame 65 kv, 1 mA-S .5 Cu filtration
10 cm height .4 mm focal spot



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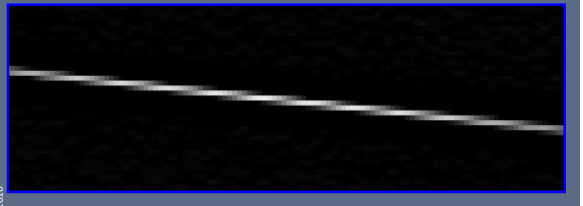
B.2 - TS Reconstructed Response

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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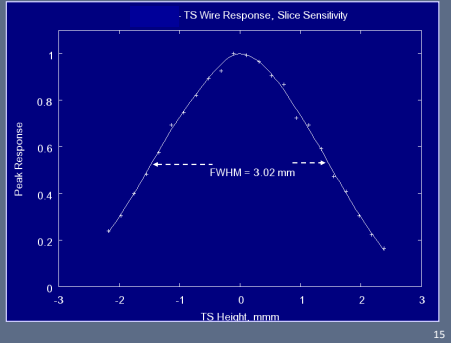
B.2 - TS spatial response

SliceThickness (Sensitivity):

Peak contrast of a thin line vs height

FWHM = 3.02 mm

(rsna 2007)



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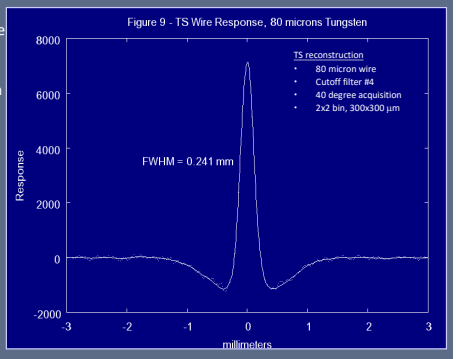
B.2 - TS response

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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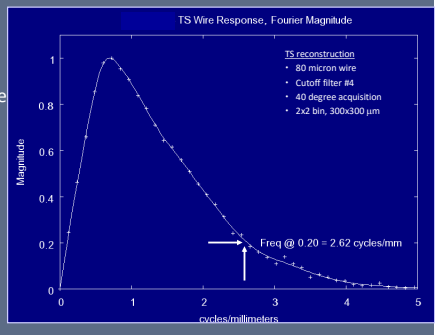
B.2 - TS line response

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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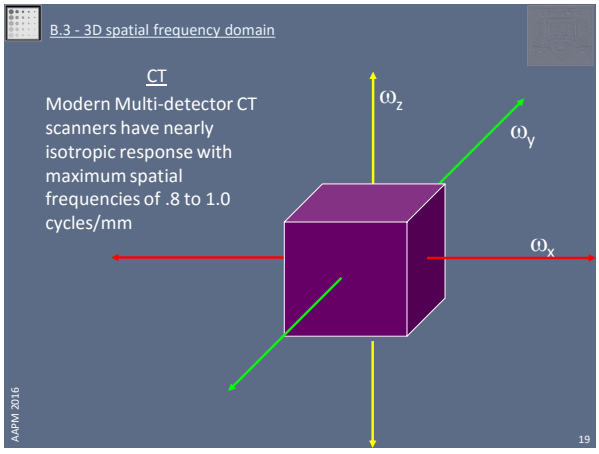
18


B.3 - 3D spatial frequency domain
CT
Modern Multi-detector CT scanners have nearly isotropic response with maximum spatial frequencies of .8 to 1.0 cycles/mm
ω_z
ω_y
ω_x
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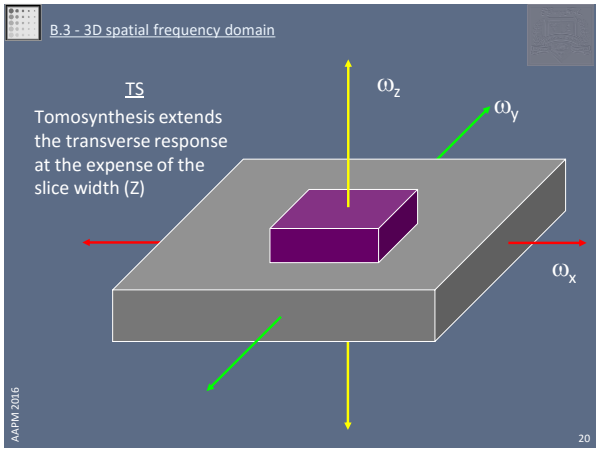
19


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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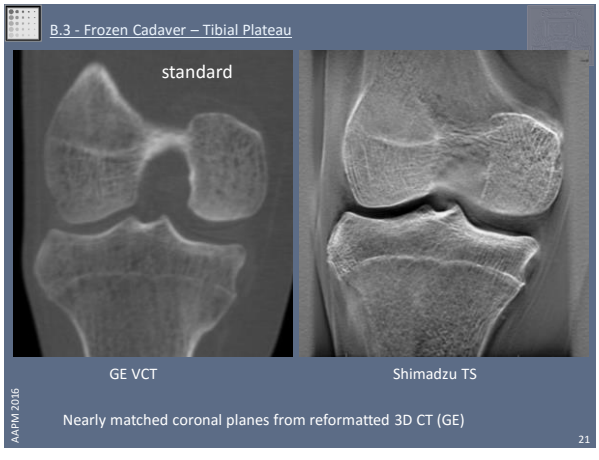
20


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

GE VCT | Shimadzu TS

Nearly matched coronal planes from reformatted 3D CT (GE)

B.3 - 3D spatial frequency domain

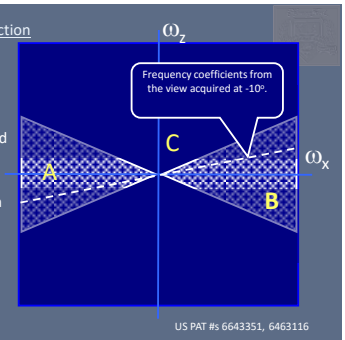
- In the x direction, TS resolution is about 3 times better than current CT scanners.
- In the x direction, TS slice thickness about 3 time worse than thin slice CT scans.
- HOWEVER,

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

B.3 -Tomosynthesis Reconstruction

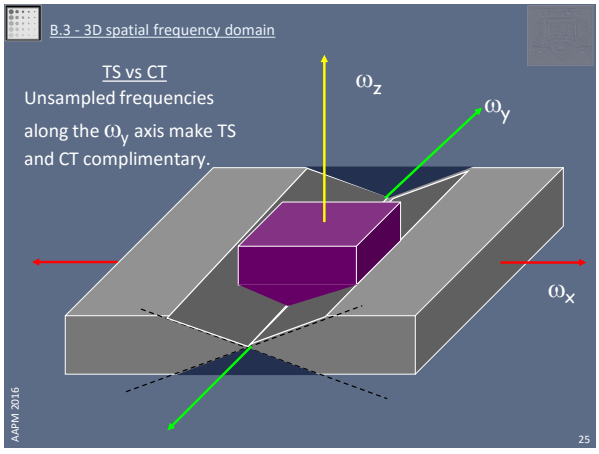
Filtered Backprojection

- 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


B.3 - 3D spatial frequency domain
TS vs CT
Unsampled frequencies
along the ω_y axis make TS
and CT complimentary.
ω_z
ω_y
ω_x
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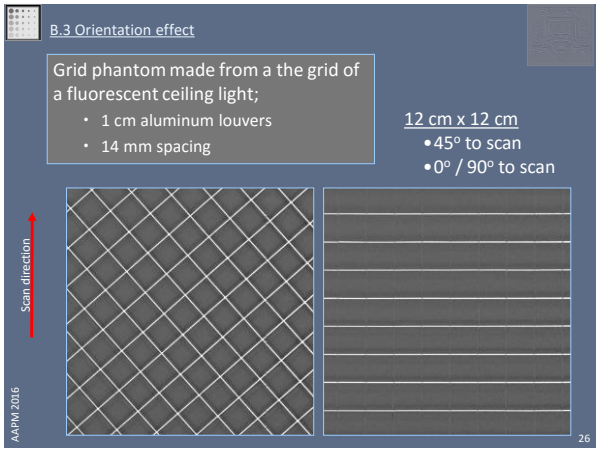
25


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
Scan direction
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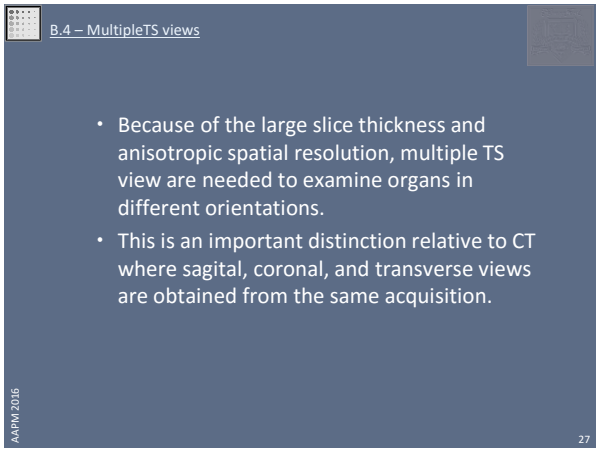
26


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.
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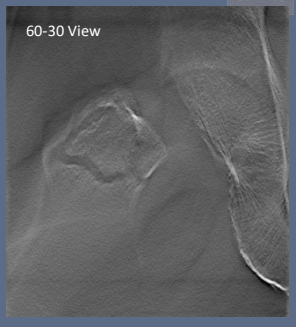
B.4 – MultipleTS views



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

B – TS vs CT summary

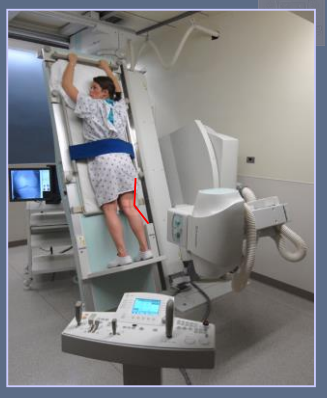
- TS advantages
  - Much improved in plane detail.
  - More tolerant of metal devices.
  - Limited angle acquisition improves the radiographic technique.
    - Low kV due to reduced thickness.
    - Reduced irradiation from cone views.
    - Reduced overall patient dose
- CT advantages
  - Quantitative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

C – Knee Tomosynthesis

TS Knee examination

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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32

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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33

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34

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35

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36

C - Sagittal views - example

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37

C - Sagittal views - example

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38

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39

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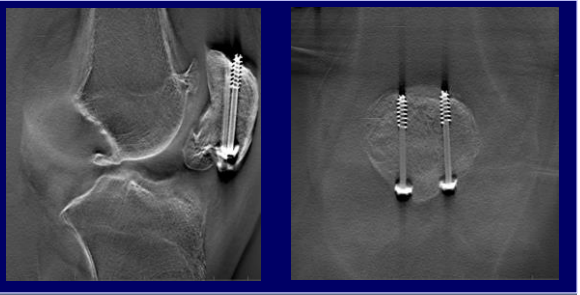
C - Knee Case – Occult fracture

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



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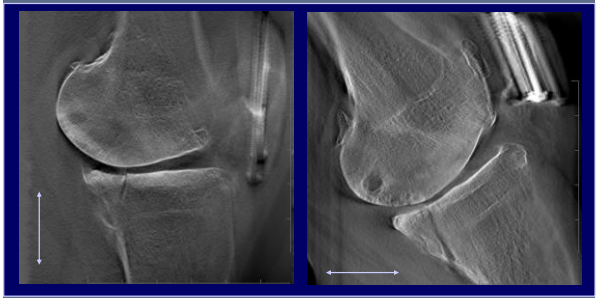
Sagittal and coronal views obtained by scanning parallel to the screws minimize overshoot from the high absorption in the metallic material.

41

C - Knee Case – Occult fracture

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



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sagittal (longitudinal)

sagittal (transverse)

42

D. Metal Artifacts

- With FBP tomosynthesis reconstruction, significant overshoot artifacts occur on edges perpendicular to the scan direction.
- These can be confused with device loosening
- New reconstruction methods offer significant improvement.

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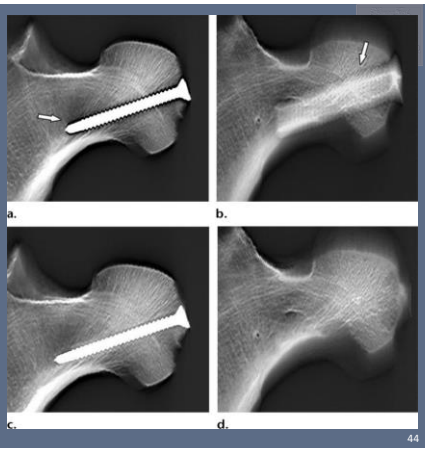
D. Metal Artifacts

Machida, Radiographics; 36:735 (2016)

a , c
GE FPB MAR algorithm

b , d
GE standard FBP



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D. Metal Artifacts

Machida, Radiographics; 36:735 (2016)

Iterative Reconstruction

T-smart, Shimadzu

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E – Hip Tomosynthesis

TS Hip examination

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E – 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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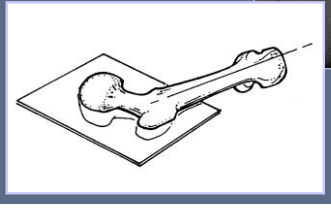
E – AP view

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



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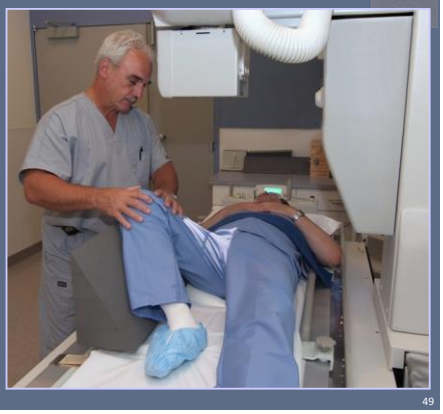
E – 6030 view

6030

- 60° up
- 30° out

The neck is rotated by bringing the knee up and out



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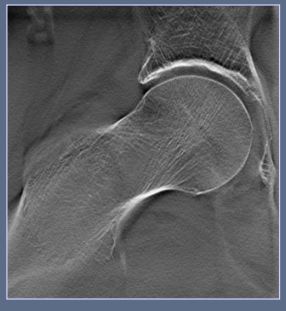
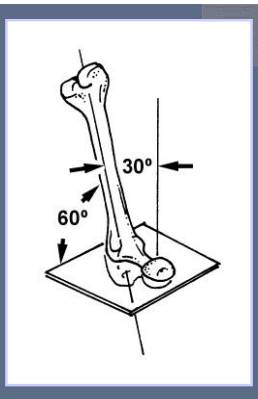
49

E – 6030 view





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

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E – 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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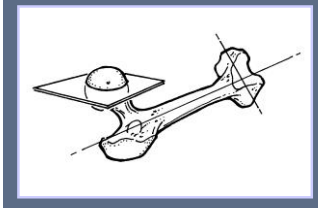
E– faux profile view



TS planes are oblique to the axis of the neck

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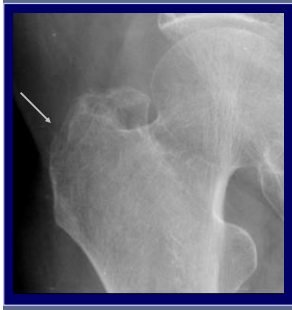
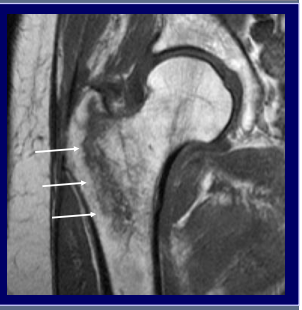
E- Hip Case #1 Trochanter fracture





- 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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E- 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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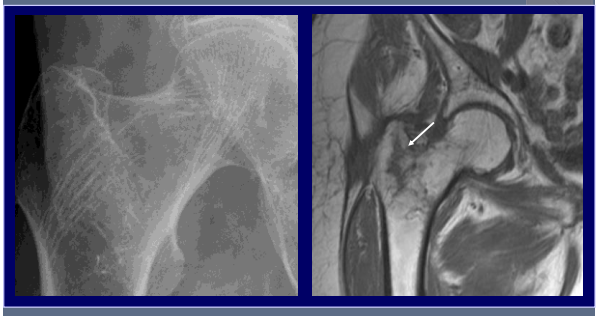
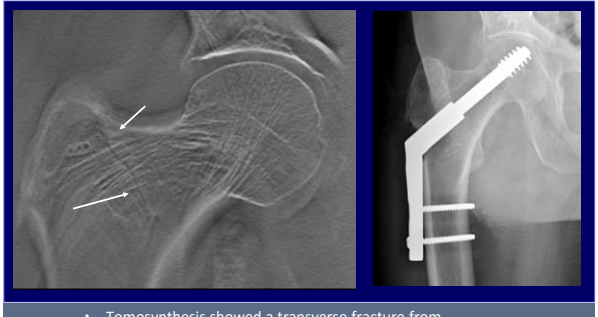
E - Hip Case #2 Trochanter fracture



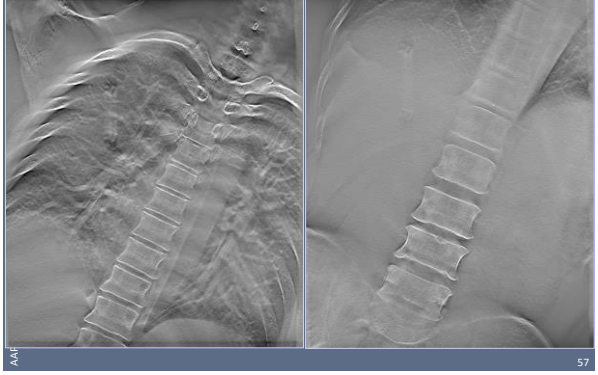
- Patient presented in the EM Dept with possible hip fx
- CR - 'there is no definite fracture line seen'
- MR- 'Nondisplaced intertrochanteric fracture'.

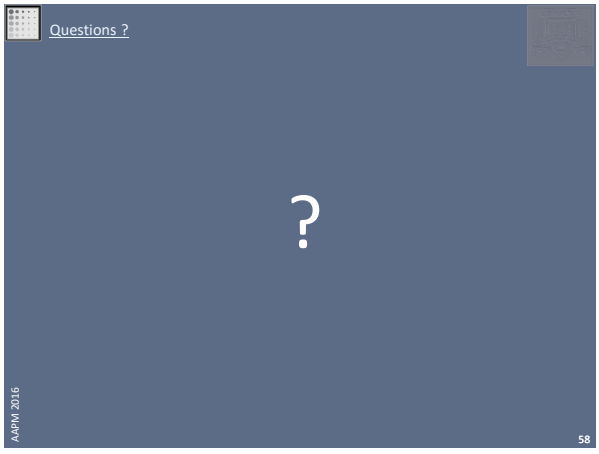
E - Hip Case #2 Trochanter fracture



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

F - #5 Spine AP, Metabolic Bone Survey




Questions ?
?
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58