Metal Artefact Reduction in CT

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- Metal Artefact
- Clinical Indications for MAR
- SEMAR and How It Works
- Technical Considerations
- Case Studies utilising SEMAR
Metal Artefact in CT

• Polychromatic Beam
  - Wide spectrum of energies, linear attenuation coefficient very dependent on energy of x-ray beam

• Beam Hardening Artefact
  - Attenuation on lower energy photons, increased effective energy of beam and tissue reflected by lower value of $\mu$
  - Violation of linear superimposition of attenuation values once back projected

• Photon Starvation
  - Statistical error of low photon counts
  - Dark and bright streaks preferably in direction of greatest attenuation
Figure 1: Beam hardening artefact from bilateral hip replacements
Figure 2: SEMAR applied to reveal anatomy normally obscured by beam hardening.
Clinical Indications for MAR

- Diagnosis of Post Operative Complications
  - Prosthetic Loosening
  - Polyethylene Wearing
  - Periprosthetic Fractures
  - Post Operative soft tissue masses/lesions
  - Aneurysm Clips, Lumbar fusions, Billiary clips, anywhere metal will impede surrounding structures and accurate diagnosis.
SEMAR (Single Energy Metal Artefact Reduction)

- Toshiba based MAR technique
- Uses Data Segmentation, Forward Projection, and Interpolation
- Can uncover bone and soft tissue structures normally obscured by beam hardening effects

- I know what it is but how does it work!?"
Figure 3: SEMAR algorithm. BPJ; Back Projection. FPJ; Forward Projection.
• A sinogram of a lemon with a metal rod inserted.
• The horizontal direction of the sinogram corresponds to the ray data in each projection.
• The vertical axis represents the projections acquired at different angles through the lemon.
• The bright region corresponds to the high attenuation of the metal rod and shows as an obvious sine wave.

Figure 4: Sinogram of lemon with metal rod and FBJ image
Figure 5: A complete 360 degree sonogram of an abdominal cross section is compared with the reconstructed image using FBP.
**SEMAR**

- Raw data is forward projected to create a sinogram
  - Same data is reconstructed using filtered back projection (FPB)
- Metal is segmented in this image and then forward projected creating a metal only sinogram
- Metal only sinogram subtracted from original sonogram
- Linear interpolation used to calculate missing data
Original Projection Data → Metal Only Sinogram → Extraction of Metal from Sinogram and Interpolation

Original Image → Segmentation of Metal
SEMAR

- Interpolated sinogram reconstructed using FBP
- Image segmented again to further exclude residual metal artefacts
- This data is again forward projected into a sinogram and linear interpolation used to fill in the gaps
- Image volume is reconstructed and original metal segmentation is reintroduced
BPJ after first pass interpolation

Further elimination of metal objects and corrected sinogram

BPJ of corrected sinogram

AIDR

Final Image

Original Metal Segmentation Reintroduced
Technical Considerations

- Toshiba 160 Slice
- 40mm detector width with .5mm slices (ability to do .25mm)
- Version 6 Software - 10 volume blocks of 40mm making total scan coverage of 400mm (40cm)
- Most recent software (Version 7) and scanners have 16cm detector coverage and can be applied retrospectively to any region
- Version 7 can be applied prospectively and retrospectively to region of interest – can be applied to longer scan ranges
- 120kv and AIDR standard protocol - how can we change technical parameters?
Figure 6: SEMAR 6 block volume acquisition scout of bone with metal hardware
Figure 7: Axial 0.5mm slice through bone demonstrates beam hardening artefact and associated photon starvation. The acquisition protocol used 120kV, max of 250 mA (modulating), and AIDR standard.
Figure 8: Demonstration of how increasing kv decreases metal artefact in addition with SEMAR
Figure 9: Demonstration of how increasing AIDR from standard to strong decreases noise associated with metal artefact with SEMAR
Figure 10: Demonstration of how lowering the standard deviation and increasing mA values can reduce metal artefact.
Case Study 1

Clinical History

• Periprosthetic fracture right knee post mechanical fall? Assess position and extension. (1st presentation)

• Right TKR periprosthetic fracture? Please perform fine slice CT with artefact reduction and 3D recons? stable vs unstable prosthesis. May require long stem TKR revision if unstable. (2nd presentation)
CONVENTIONAL AXIAL

SEMAR AXIAL
Conclusion

• Study of better diagnostic quality than CT performed a day prior
• Periprosthetic fracture of the lateral femoral condyle
• Vertical fracture line extending from supracondylar region to lateral margin of prosthesis
• Approximately 5mm of lateral and superior displacement
• Moderate sized lipohaeamarthrosis noted
Case Study 2

Clinical History

66F L3 pathological fracture D3 post posterior instrumented fusion. For CT lumber spine on 21/4/15 for picture of bony morphology ?residual tumour.
Conclusion

- Pedicle screws been placed at L1-L2 and L4-L5 with posterior rods
- L3 laminectomy has been performed with resection of most of the posterior aspect of the L3 vertebral body
- L3 body demonstrates extensive bone destruction extending into both pedicles.
- Soft tissue density material extending posteriorly in the spinal canal is identified at the L3 level
- Most likely represents residual soft tissue tumour or haematoma
Summary

- SEMAR plays a critical role in reducing metal artefact to diagnose post operative complications
- Should be used for a range of anatomy where metal may affect an accurate diagnosis
- Important to understand how relevant technical parameters can influence a SEMAR image
- Applying SEMAR can be vital to a patient’s diagnosis and future management


