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Metallic Artifact Reduction Capabilities of Dual-Energy Computed Tomography (DECT)

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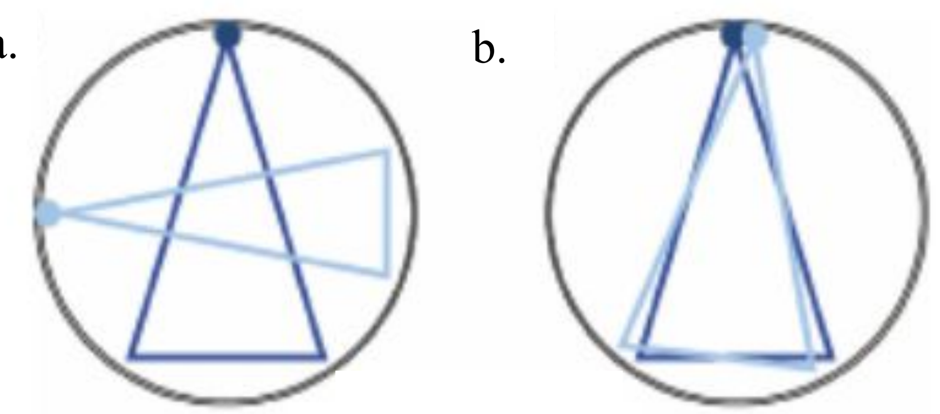
What is Dual Energy CT (DECT)?

- The utilization of two different energy spectra to acquire data in computed tomography imaging
- Generates a singular image by obtaining two data sets through imaging a patient with two differing kilovoltage (kV) values (one low, one high)

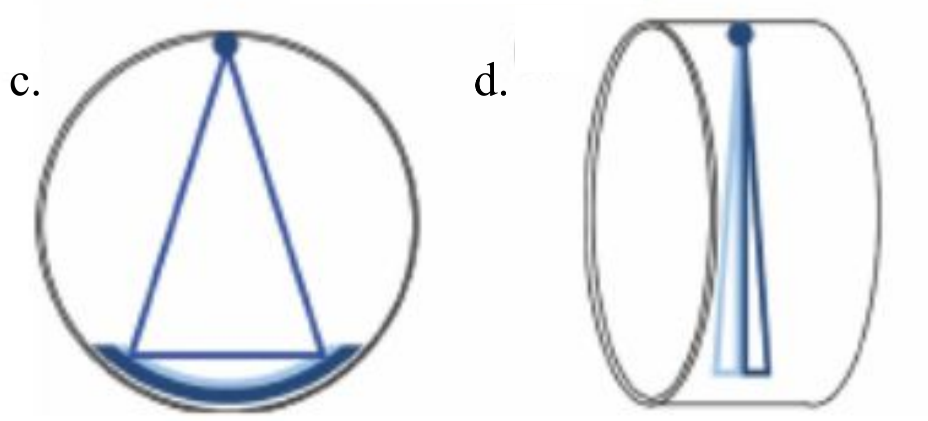
Data Can Be Acquired Through Several Methods

a. b.



(Light Blue = Low Energy Photons) (Dark Blue = High Energy Photons)

c. d.



(Samei, Peck, Siewerdsen, & Ritenour, 2019, p. 262)

a. Dual-source dual-energy CT
b. Single source fast kV switching dual-energy CT
c. Single-source, dual-layer, dual-energy CT
d. Single-Source, twin-beam, dual-energy CT

How does Dual Energy CT Combat Artifacts?

- DECT functions according to the fundamental that in the diagnostic energy range, a material's linear attenuation coefficient (fraction of attenuated incident photons in a monoenergetic beam per unit thickness of a material) could be broken down through basis material decomposition into two linearly independent components

1. Compton Scatter 2. Photoelectric Effect

- By obtaining images with two different spectra, and breaking the data down through basis material decomposition, data are able to be processed through monoenergetic extrapolation
- Monoenergetic extrapolation - virtually simulating images as if the patient was exposed to a monochromatic beam, (Beam with a single kV value) allowing for a significant reduction in beam hardening artifacts

(Samei et al., 2019, pp. 261-262)

Issue with relying solely on DECT for metallic artifact reduction

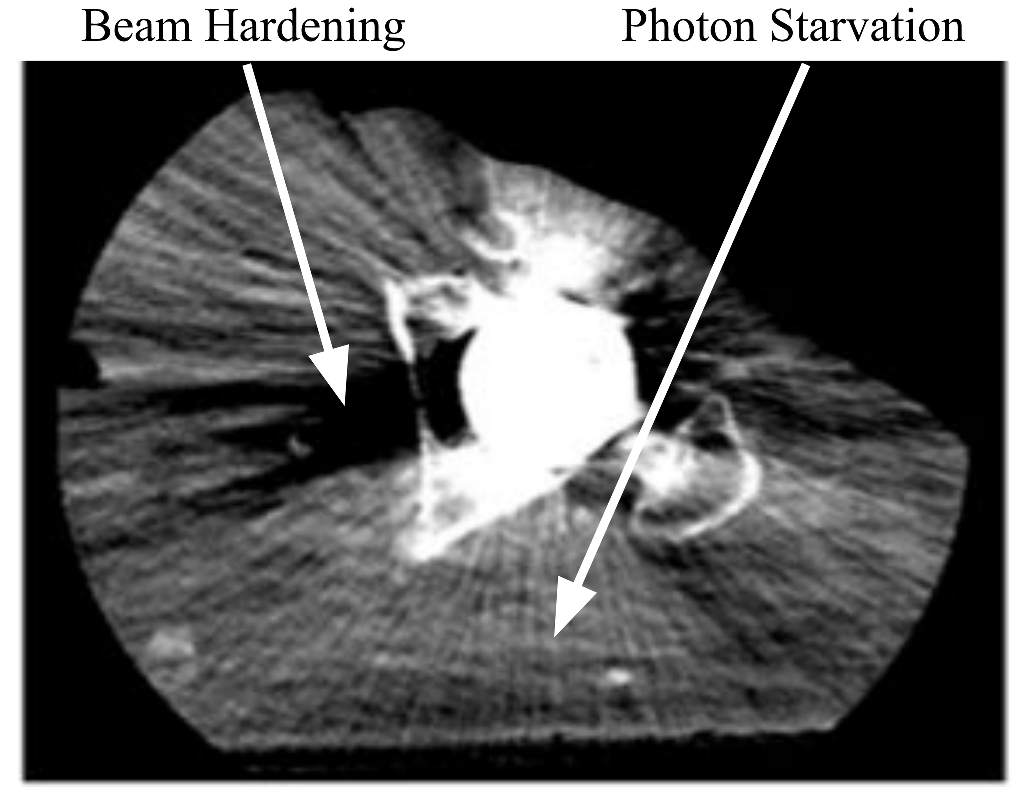
- Metallic artifacts in CT are mainly caused by beam hardening and photon starvation

Problem: DECT only combats beam hardening

- Beam Hardening - Low energy photons absorbed at a more significant rate than high energy photons (More prominent in materials with high atomic numbers)
  - Large area of darkness demonstrated near metallic implant on image below
- Photon Starvation - Significant attenuation of the x-ray beam as it passes through metallic hardware which results in insufficient amount of photons reaching the detector
  - Bright and dark streaks on a reconstructed image radiating in all directions from metallic implant on image below

(Katsura, Sato, Akahane, Kunimatsu, & Abe, 2018, pp. 451-452)

Beam Hardening Photon Starvation



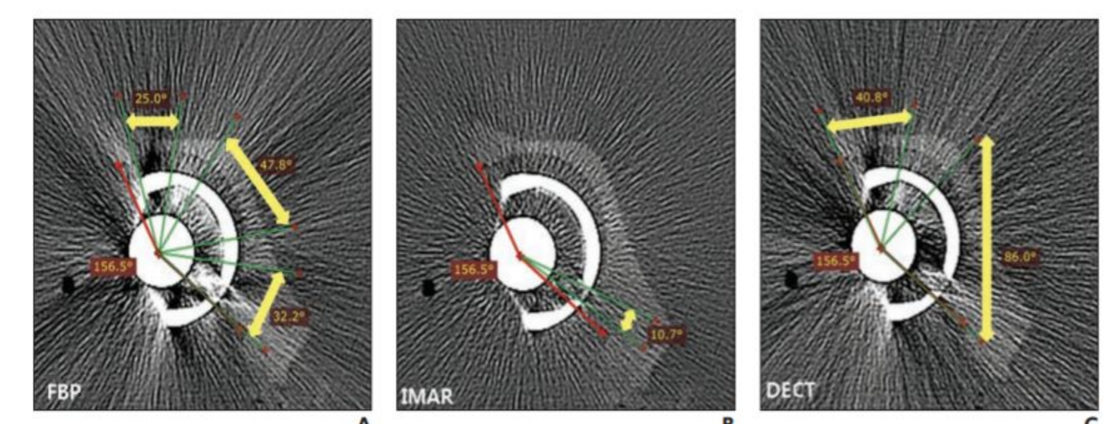
(Barreto et al., 2020, p. 5)

How DECT Compares to Other Artifact Reduction Methods in CT

A Loosening Hip Phantom Study:

- DECT was compared to two other artifact reduction methods in CT: Filtered Back Projection (FBP); and iterative Metal Artifact Reduction (iMAR) to determine which method allowed for greatest visualization of the acetabular cortex on patients with metallic hip implants
- Total hip replacement and bipolar hemiarthroplasty phantom were imaged with each artifact reduction protocol

Highlight of Study: Two radiologists evaluated images of the total hip replacement by each artifact reduction protocol to determine which protocol would provide best visualization of loosening of the implant



(Kim, Cha, Kim,Yi, & Kim, 2019, p. 1198)

Criteria for analysis

- Values each artifact reduction protocol presented for this task were associated numerical values according to how obstructed the cortical angle of the implant was. The cortical angle was established by measuring the total angle of the pelvic bone (156.5 degrees) with the center of the angle at the middle of the femoral head

A. FBP shows 67.1% obscured cortical angle
B. IMAR image shows 6.84% obscured cortical angle
C. DECT image shows 81.0% obscured cortical angle

(Kim et al., 2019, p. 1198)

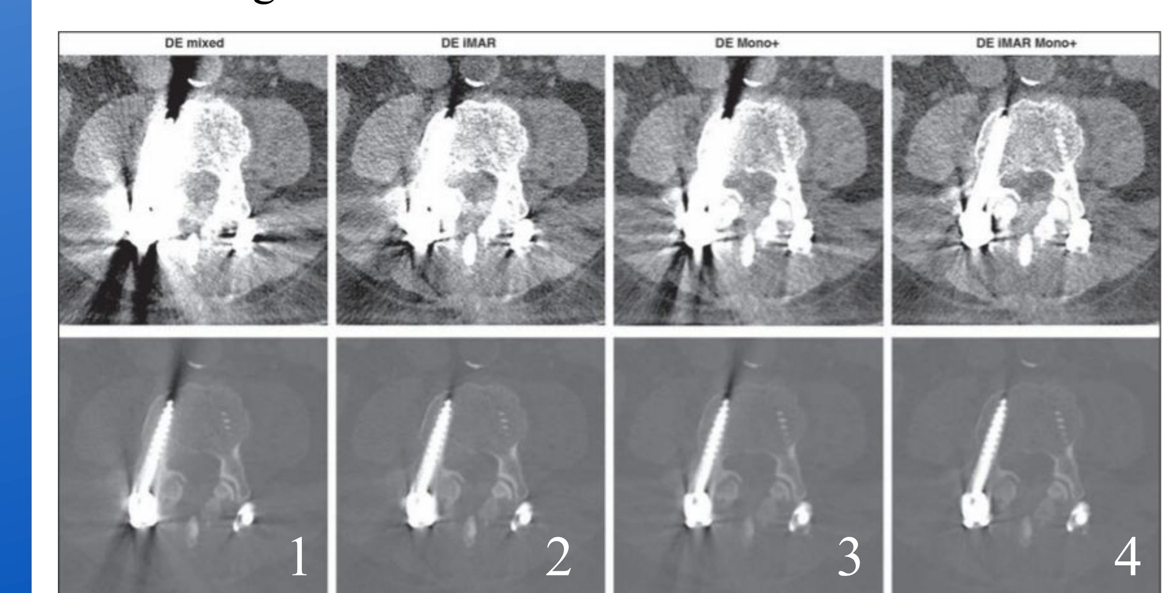
- iMar had the most significant impact on negating artifact produced by the beam's interaction with metallic implants. This protocol significantly reduced streaking artifact at a much greater level than the other two protocols under analysis: DECT; and FBP
- With an 81.0% obscured cortical angle from metallic artifacts, DECT recognizably performed very poorly on its own for reducing artifacts caused by metallic implants

Optimizing Artifact Reduction Capabilities of DECT

- It is essential that technologists optimize images acquired on dual-energy systems to combat both beam hardening and photon starvation. To achieve this, dual-energy data must be processed with other artifact reduction protocols available

Clinical Assessment of Metal Artifact Reduction methods in Dual-Energy CT Examinations of Instrumented Spines

- In this study, three artifact reduction protocols available in Dual-Energy CT where evaluated to determine which produced the most desirable images for diagnosis



(Long et al., 2018, p. 397)

1. DECT images reconstructed using only monoenergetic extrapolation (DE Mixed)
2. DECT images reconstructed with an iterative metal artifact reconstruction algorithm (DE iMAR)
3. DECT images reconstructed with a virtual monochromatic imaging algorithm (DE Mono+)
4. DECT images reconstructed with a combination of DE iMAR and DE mono+ (DE iMAR Mono+)

- This study concluded, DE iMAR Mono+ reduced metallic artifacts significantly greater than the three other protocols under evaluation. The authors did not note how many pixels of artifacts DE mixed images removed from images; however, it was noted that DE iMAR reduced a mean of 3592 artifact pixels, DE Mono+ 3611, and DE iMAR Mono+ 5769

(Long et al., 2018, p. 399)

Conclusion

The goal of CT technologists is to provide radiologists with highest quality images possible; therefore, when available, technologists should utilize a DE iMAR Mono+ algorithm to provide optimal images when imaging patients with large metallic implants