Impact of Novel Reconstruction and Metal Artifact Reduction Algorithms on Metal Electron Density Curve for KVCT Simulator

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INTRODUCTION

- CT-ED conversion assumes a unique relationship between CT Number and Electron Density (ED).
- In metal prostheses, this assumption is invalidated because beam hardening creates artifactual variability in the apparent CT Number[1,2,3].
- Modern algorithms for tomographic reconstruction and metal artifact reduction may reduce the severity of beam hardening artifacts.

OBJECTIVES

1. Measure CT# variability for a wide range of metals
2. Evaluate impact of novel reconstruction and metal artifact reduction algorithms on CT# variability
3. Determine how to uniquely identify metals to facilitate density “overrides” in radiotherapy planning.

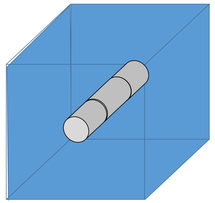
METHODS – METAL PHANTOM

- 6 metal alloys were evaluated:

Metal	Density [g/cm3]	ED / water
Aluminum 6061	2.7	2.34
Titanium	4.51	3.72
Stainless Steel 304	7.93	6.65
Stainless Steel 316L	8.00	6.70
Brass C360	8.50	6.99
Copper C110	8.96	7.36

- Metals were cut into 3” x 1” solid rods

- Rods suspended in water tank



METHODS – TISSUE PHANTOM

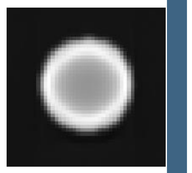
- A Tomotherapy™ Cheese Phantom was included for reference.
- This phantom is constructed from solid water, and contains inserts representing various soft-and hard-tissues.

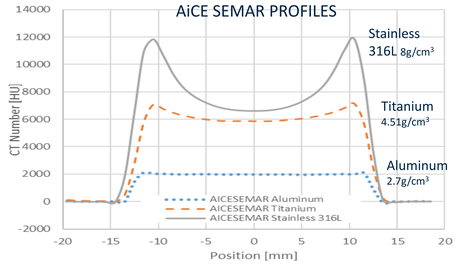
METHODS - CT SCANNING

- **The Metal Phantom and Tissue Phantom were imaged using two scanners:**
- **<u>Aquilion Exceed LB</u> (Canon Medical Systems Corporation, Japan):**
  - Acquisition: 120 kVp ; 400 mA ; 1x1x3mm voxels
  - Reconstruction: AIDR: Adaptive Iterative Dose Reduction Reconstruction, with and without Single Energy Metal Artifact Reduction (SEMAR) ; AiCE: Advanced intelligent Clear-IQ Engine, with and without SEMAR
- **<u>Tomotherapy</u> (Accuray Incorporated, Sunnyvale, California):**
  - Acquisition: 3.5 MV ; 0.76x0.76x3mm voxels ; Reconstruction: Filtered Backprojection
- **Data were analyzed in MATLAB (MathWorks, Natick, Massachusetts)**

RESULTS - CT SCANNING

- <u>Aquilion</u> Reconstructions (120kVp):
- Beam-hardening artifact identified on metals ρ>2.7g/cm^3 . Artifact severity increases with metal density, as previously reported[3].

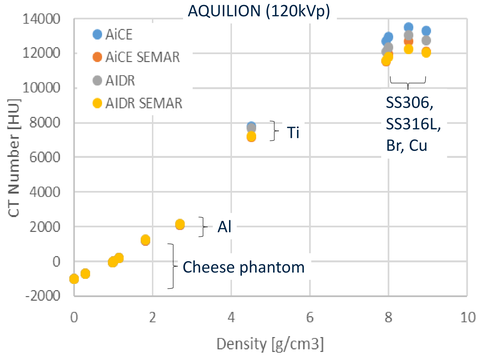




- <u>Tomotherapy</u> Reconstructions (3.5MV): no cupping visualized (not shown).

QUANTITATIVE ANALYSIS

- Metal and Tissue phantoms: Perimeter pixel CT Numbers plotted against material density.
- <u>Aquilion:</u> metals ρ<7.93g/cm^3 can be differentiated.



- <u>Tomotherapy:</u> metals ρ<8.50g/cm^3 can be differentiated (not shown).

DISCUSSION

- Developing a CT-ED conversion requires identifying an appropriate CT Number to assign uniformly to the pixels within the demarcated boundary of the metal.
- Previous authors[2] assumed CT Numbers along the outermost perimeter of metals as being “correct”; that is, least affected by beam hardening. We found this approach can be used to establish a direct CT-ED curve.
- At 120 kVp, the CT-ED curve plateaus for metals with densities greater than 7.93 g/cm^3. This limits the validity of a CT-ED curve beyond 7.93 g/cm^3.
- At 120 kVp, metals with densities ≤ 7.93 g/cm can be uniquely identified based on CT Number, despite beam-hardening artifacts. Metals with greater densities cannot be differentiated.
- Choice of reconstruction and metal artifact reduction algorithms influenced magnitude of CT Numbers on object boundaries, but did not improve identification.
- A limitation of our study is the sparsity of metals with densities between aluminum and titanium, and between titanium and stainless steel. Between these densities, we speculate the shape of the CT-ED curve to be piece-wise linear.

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