Investigation of Extended HU Mode Using a Semi-Custom CT Phantom

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Purpose

- Metals in computed tomography (CT) scans often saturate image pixel values, making low- and high-density metals indistinguishable.
- The purpose of this work was to test the effectiveness of the extended HU mode on a GE Discovery RT16 CT scanner to distinguish between metals in the range of 2.7-18.1 g/cm³.

Methods

- Extended HU CT scans (single helical slice, 300 mA, 120 kVp) were taken of an acrylic phantom, containing single cylindrical (9- or 30-mm diameter) inserts of aluminum (2.7 g/cm³), titanium (4.5 g/cm³), stainless steel (7.9 g/cm³), brass (8.5 g/cm³), or tungsten (18.1 g/cm³).
- Figures 1, 2 and 3 show phantom modifications, experimental setup and an example CT scan.
- ROI analysis methods were compared to the mean (Figure 4) including: maximum pixel value and edge painting (Figure 5). Edge-painting here was defined as averaging the brightest pixels along the edge of the insert.
- Profiles across each insert, plotted in Figure 6, were acquired to quantify HU changes with material and size, as well as cupping effects.
- HU was plotted as a function of mass density in Figure 7 to assess distinguishability of metals.

Figure 1. Phantom modifications at BC Cancer Vancouver's Joint Engineering Center

Workflow

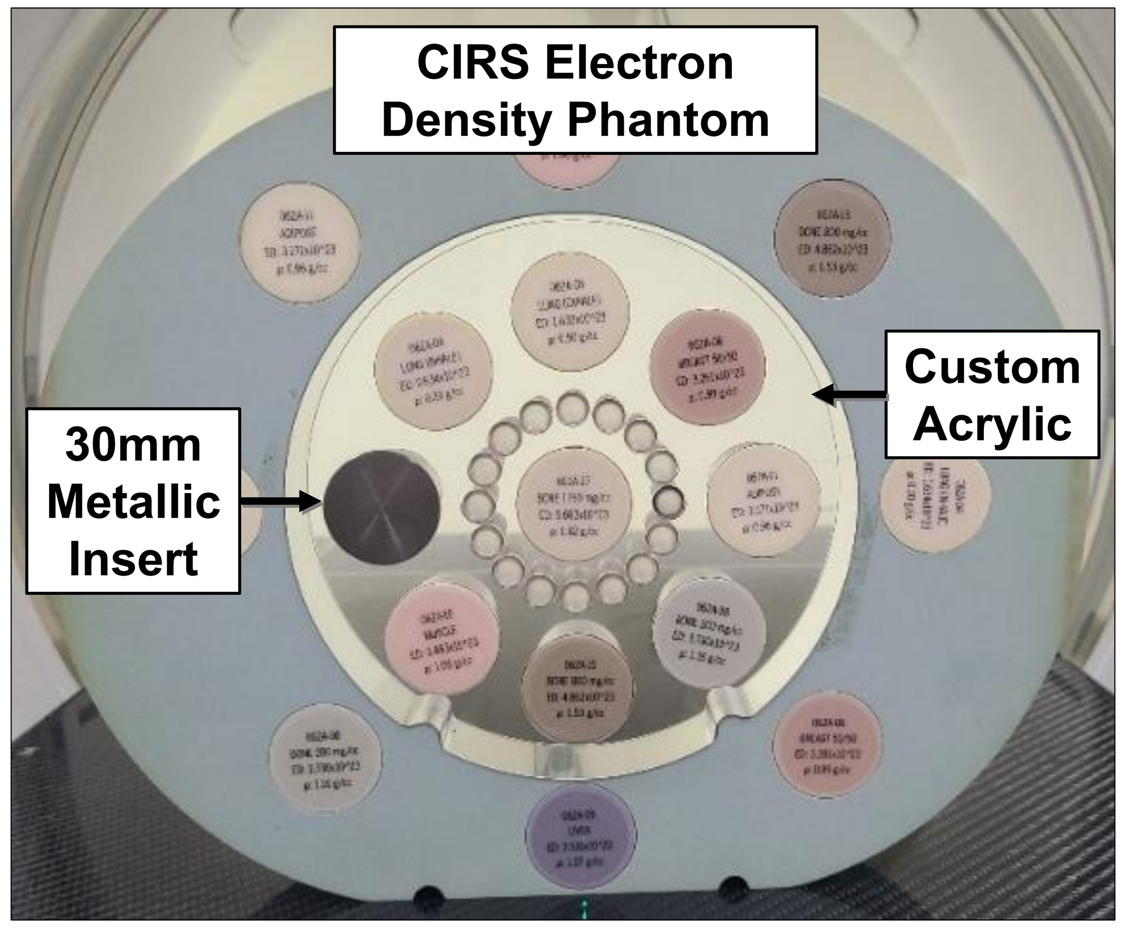

Figure 2. Experimental setup. The materials of the 30mm or 9mm inserts at the 9 o'clock positions were changed for each CT scan

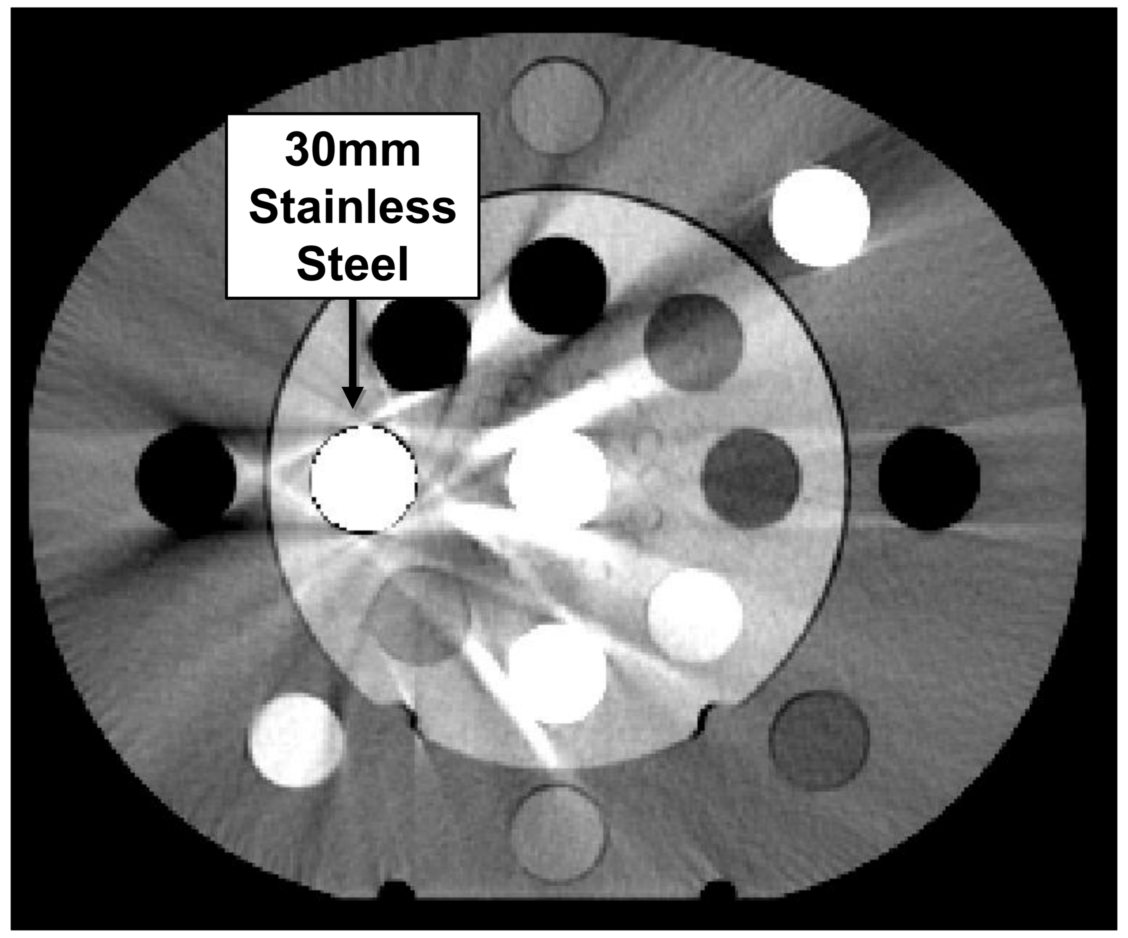

Figure 3. CT scan example. Windowed and leveled before next step.

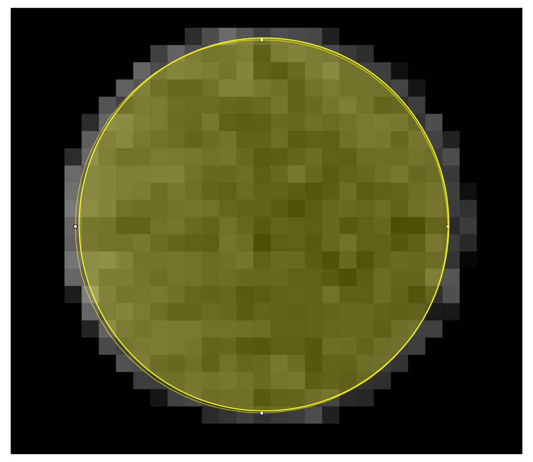

Figure 4. For low density metals, like aluminum, a circular mean ROI adequately distinguished HU.

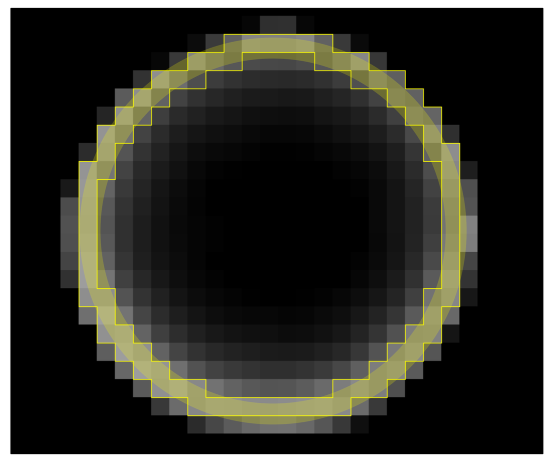

Figure 5. For high density metals which exhibit cupping effects, like steel, an "edge-painted" ROI better distinguished HU.

Results

How Did Material and Size Impact Cupping Effects?

- Cupping effects were more pronounced for larger-diameter inserts and denser metals.

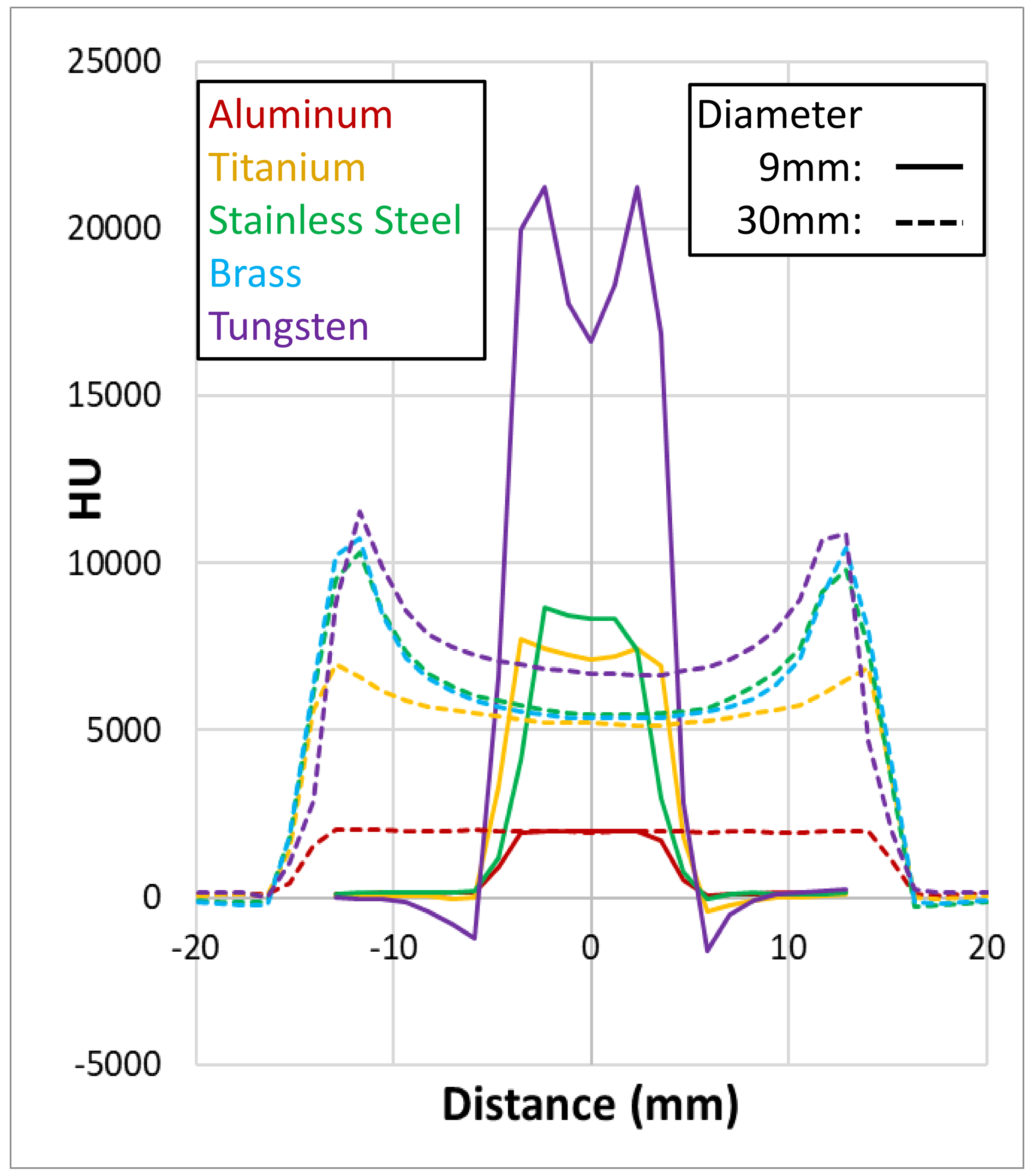

Figure 6. Profiles across 9-mm and 30-mm diameter metal inserts. "Cupping" artifacts are visible where the center of the insert has a lower HU than its edges due to photon starvation in the dense metals. Smaller diameter inserts produced less cupping than large diameter inserts.

How Well Did Extended CT Distinguish Metal Types?

- For metals with density > 4.5 g/cm³, (stainless steel, brass, and tungsten): 9mm diameter inserts were distinguishable, but 30mm inserts were not. ("distinguishable = clearly unique HU")

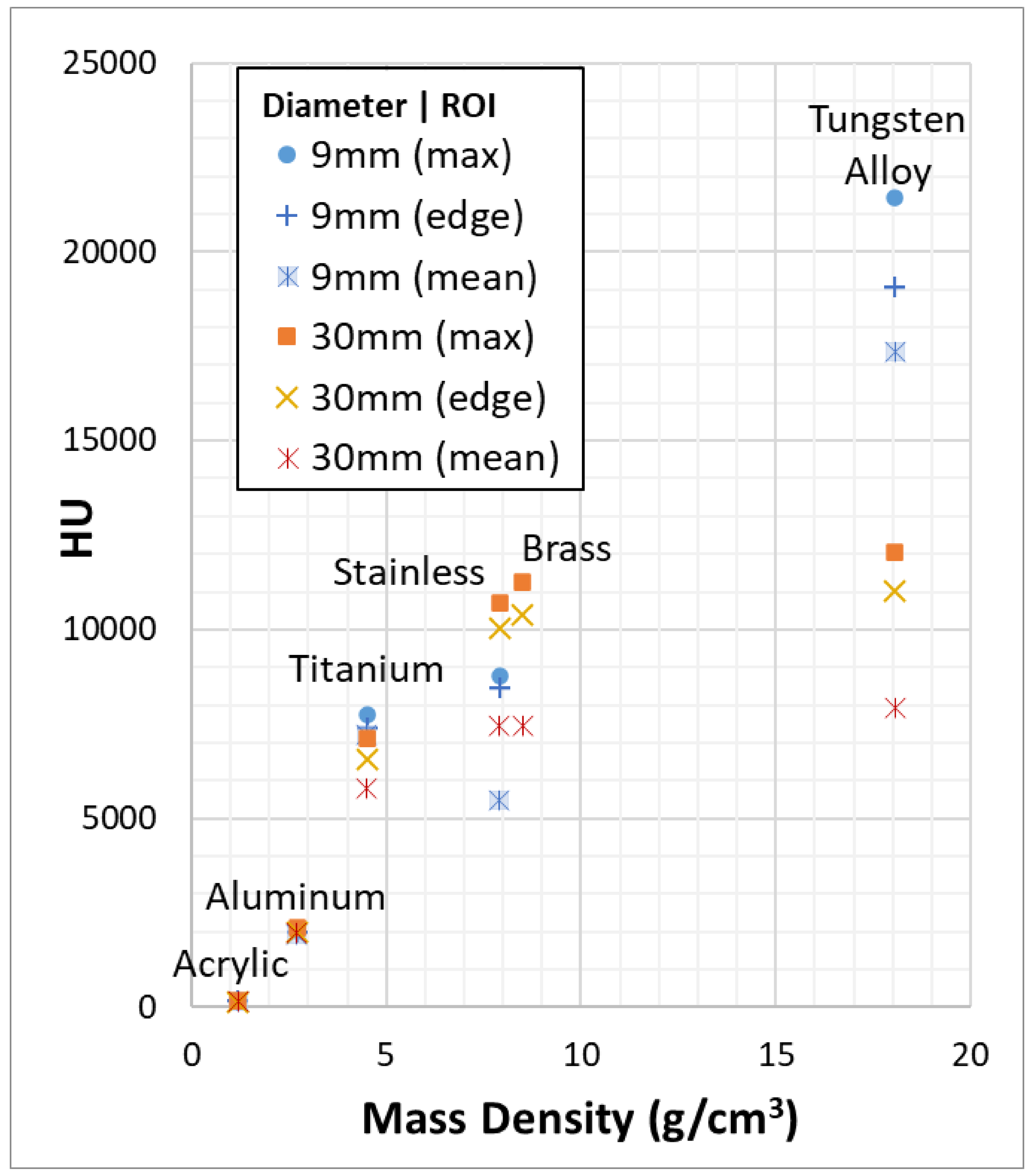

Figure 7. HU as a function of mass density for a range of metals and ROI strategies. Max uses the max pixel value. Edge-painting uses an average of the pixels along the edge of the insert. Mean uses the mean of the pixel values within a circular ROI defined as 1 pixel smaller than the insert.

Discussion

- The mean pixel value ROI method did not distinguish titanium from stainless steel for 9-mm inserts or titanium, stainless, brass, and tungsten for 30-mm inserts.
- The maximum pixel value ROI method more clearly distinguished between metal types. It distinguishes all metal types for 9-mm inserts but failed to clearly distinguish brass from tungsten for 30-mm inserts. (The edge-painting ROI method performed similarly).

Conclusions

- The extended HU range distinguished metal types independently of insert size for objects ≤ 4.5 g/cm³, above which the HU value of the metal becomes size-dependent, and no longer reliable.
- An alternative method for HU value analysis for identifying high-density metals exhibiting "cupping" artifacts was introduced and shown to work better than simple ROI averaging.
- This work could allow an extended HU CT scan to identify these materials, enabling more accurate external beam radiotherapy dose calculations in the presence of metal bodies.

References:

1. Gnanasambandam A, N ANR, K SS. Effects of metal implants and validation of four treatment planning methods used for radiotherapy dose calculation. Rep Pract Oncol Radiother. 2022;27(5):821–31