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A Comparison of Digital X-Ray Tomosynthesis, Radiography, and Computed Tomography For Orbital Metal Detection

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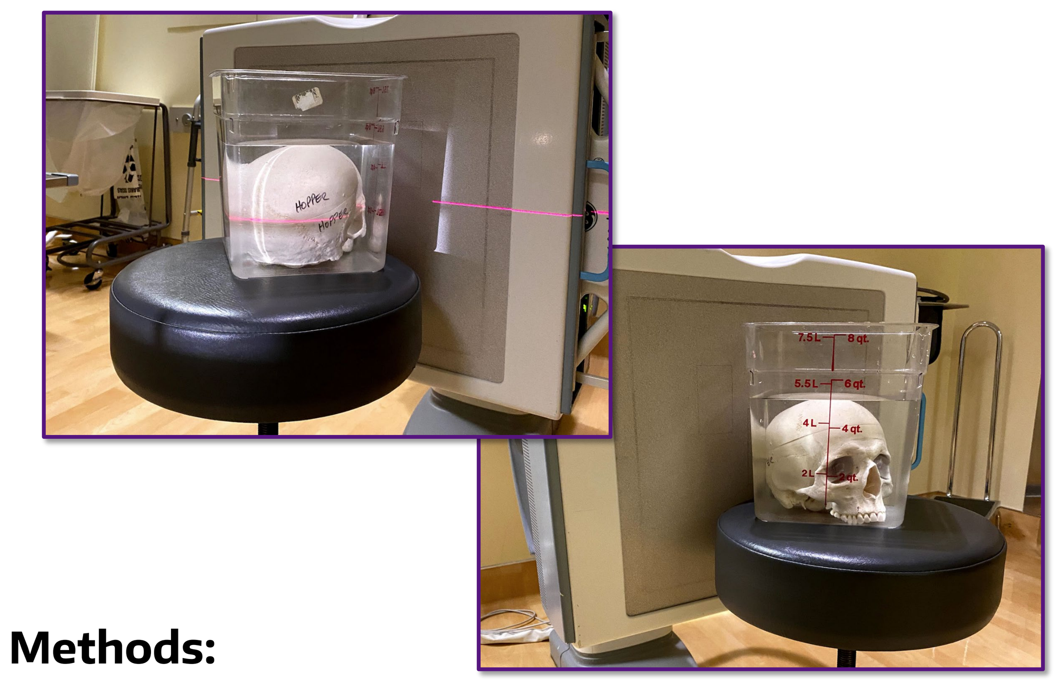
Background

Purpose:

Orbit metal screening is an essential component of patient safety screening prior to MRI. Patients who are identified to have previously performed metalwork or have any known metal fragments in the eye typically undergo imaging prior to MRI to confirm or rule out metal presence and determine location. The purpose of this work was to investigate and compare three candidate screening modalities for detecting tungsten carbide, steel, and aluminum fragments in the orbit. Recently, digital x-ray tomosynthesis (DT) has become more common on clinical x-ray systems, and detectability of metal fragments on DT was compared to that on 2-view radiography (DR) and computed tomography (CT).



Methods:

A semi-anthropomorphic head phantom was created by placing a human skull model into a water bath. Shaving fragments of aluminum, steel, and tungsten carbide were created. Varying sized fragments of aluminum (0.1-2.7mg, 0.04-1.0mm^3), steel (0.4-5.9mg, 0.05-0.75mm^3), and tungsten carbide (0.4-8.1mg, 0.03-0.52mm^3) were embedded in table grapes, with one fragment in each grape. For each metal type, four samples were used. The grapes were placed into the skull and images were acquired with our institution's orbit CT protocol, 2-view facial bone DR protocol (PA and lateral views), and with a facial DT protocol (PA view). Resulting images were reviewed by a radiologist to qualitatively evaluate comparative detectability on each modality. For each set of grapes with different fragments embedded, repeatability was investigated by acquiring repeat images after repositioning of the grapes, the skull, and/or no repositioning. The effect of different CT reconstructions was also investigated (**Table 1**).

Table 1: Acquisition and reconstruction details

Modality	Acquisition & reconstruction notes
DR	• Acquisition: PA and lateral
DT	• Acquisition: Single PA view • Reconstruction: 3mm slices with 3mm spacing
CT	• Reconstructions: 5mm contiguous slices, 0.625mm contiguous slices, 5mm thickness/2mm interval coronal and sagittal MIPs

Figure 1: CT reconstruction comparison (0.4mg steel)

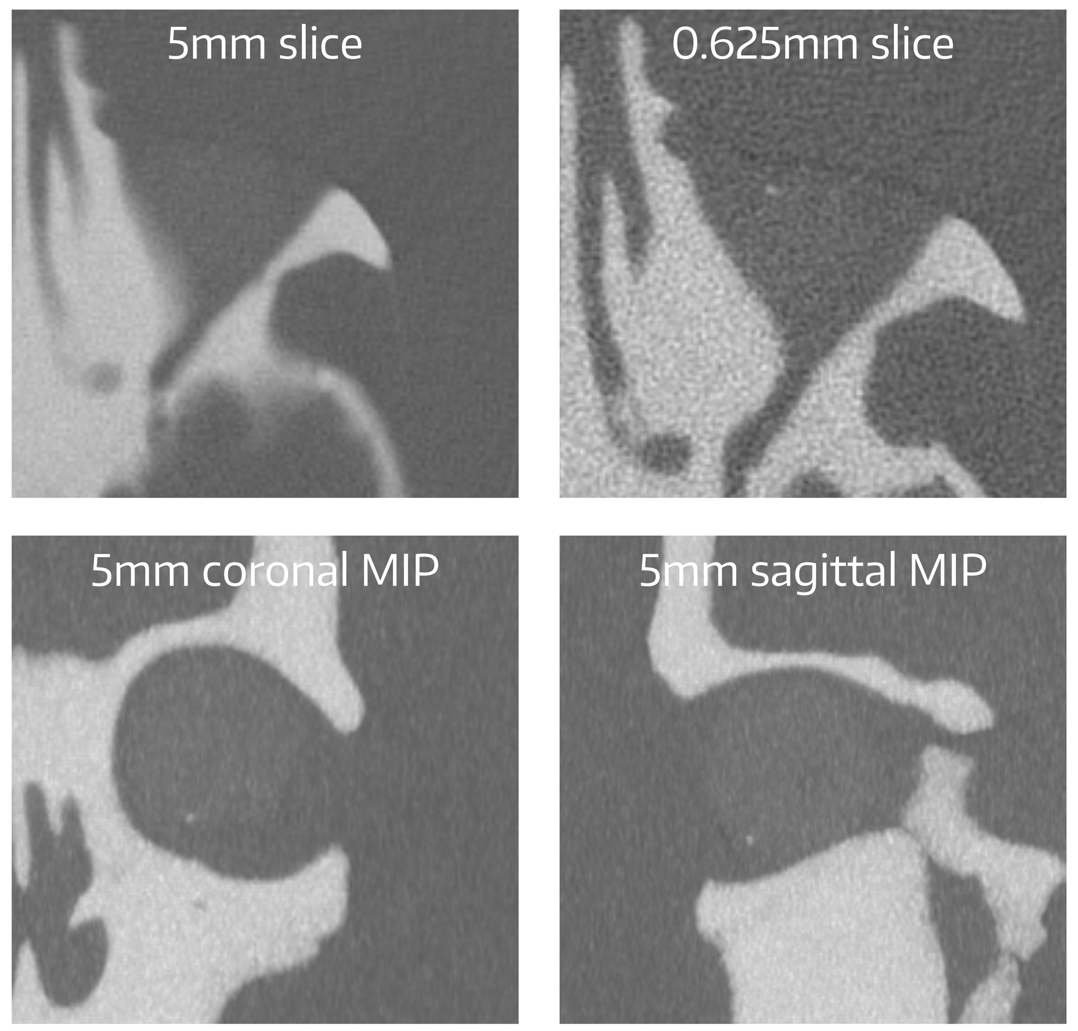


Table 3: Variability of detection at lower limit

Modality	Sample	Fraction of repeats where fragment was detected
DR	Steel 2.5mg	5/5
	Tungsten carbide 0.4mg	5/5
DT	Aluminum 2.7mg	2/4
	Steel 0.7mg	2/5
	Tungsten carbide 0.4mg	4/4
CT	Aluminum 0.7mg	3/5
	Steel 0.4mg	4/4
	Tungsten carbide 0.4mg	4/4

Table 2: Detection by fragment material, size, and modality

Material	Fragment Size	Modality		
		DR	DT	CT
Aluminum 2.7 g/cm^3	0.1 mg	–	–	–
	0.7 mg	–	–	✓
	1.2 mg	–	–	✓
	2.7 mg	–	✓	✓
Steel 7.85 g/cm^3	0.4 mg	–	–	✓
	0.7 mg	–	✓	✓
	2.5 mg	✓	✓	✓
	5.9 mg	✓	✓	✓
Tungsten Carbide 15.6 g/cm^3	0.4 mg	✓	✓	✓
	0.6 mg	✓	✓	✓
	1.3 mg	✓	✓	✓
	8.1 mg	✓	✓	✓

Table 2: Detectability of each fragment by material, size, and modality. ✓ indicates that the fragment was detected, – indicates that it was not detected.

Figure 2: Visualization of metal fragments by modality

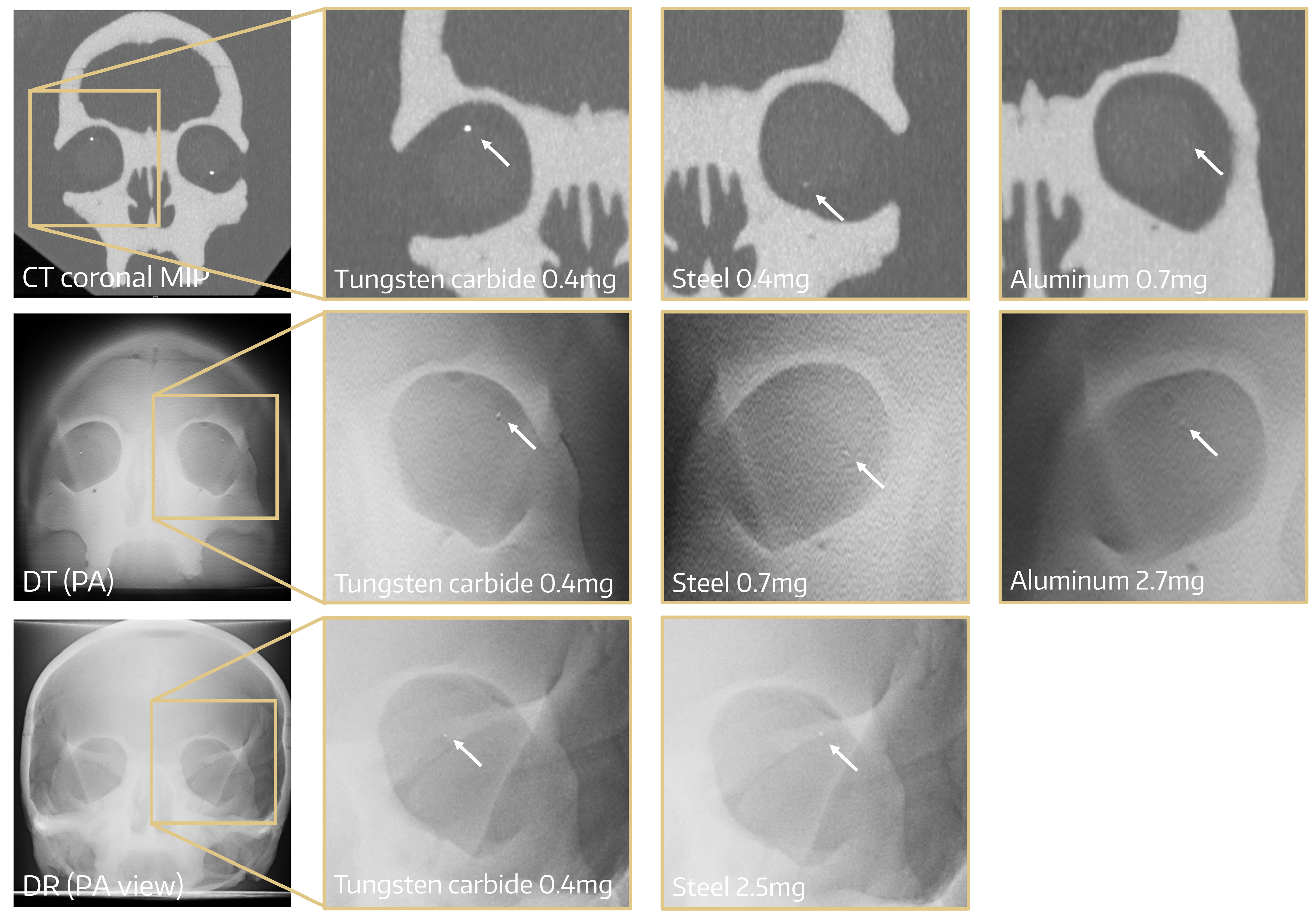


Figure 2: Smallest detectable fragment on each modality (CT, DT, and DR, from top to bottom). Images from fragments that could not be detected by a modality (for example, aluminum on DR) are excluded.

Results and Conclusions

Results:

Detectability of each fragment by material, size, and modality is indicated in **Table 2** with examples in **Figure 2**.

- For the fragment sizes investigated, tungsten carbide was detectable on all modalities.
- Steel fragment detectability was variable with size and modality, with detection of all fragments on CT, three of four on DT, and two of four on DR.
- Aluminum fragments were the most challenging to detect; three of four were visible on CT reconstructions and only the largest was just detectable on DT.

Observation of repeat acquisitions indicated more consistency in detectability of fragments on CT and DR, while detection of fragments on DT was less consistent (**Table 3**).

For fragments that were near the limit of detection on CT, thin slice reconstructions and MIPs aided in increasing contrast between metal fragments and background (**Figure 1**)

Conclusions:

Based on these results, the limit of detection of aluminum fragments was estimated to be approximately 1 mg on CT, 3 mg on DT, and could not be established on DR. The limit of detection of steel fragments was estimated to be <0.5 mg on CT, 1 mg on DT, and 2.5 mg on DR. smaller tungsten carbide fragments All tungsten carbide fragments could be seen on all modalities, therefore the lower limit of detection of tungsten carbide could not be established. (Creating and imaging was not feasible.)

With respect to detectability of orbital metal fragments, DT performance was found to lie in between that of DR and CT. DT may be an appropriate modality for orbital metal screening, providing a balance between the radiation dose, detection capabilities, and relative costs of DR and CT.

This work will continue with a radiologist reader study to more meaningfully evaluate the sensitivity and repeatability of these orbit screening approaches. Prevalence and potential for safety concerns of different metal fragment materials and sizes will also be considered when selecting a screening approach.