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# An investigation into the accuracy of orbital X-rays, when using CR, in detecting ferromagnetic intraocular foreign bodies

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## ABSTRACT

**Purpose:** The aim of this study is to determine the accuracy of orbital X-rays, when using computed radiography (CR), in detecting ferromagnetic intra-ocular foreign bodies (IOFBs) prior to magnetic resonance imaging (MRI).

**Methods:** A total of 64 orbital X-rays of an anthropomorphic head phantom were acquired using CR. For each image 1, 2, 3, or 4, large, medium, or small IOFBs were fixed to the anterior surface of the left or right orbit. Each of the acquired images with an IOFB was duplicated in order to increase the sample size. A further 16 normal images (no IOFB) were also included in the sample. Observers were invited to review the images and were permitted to manually magnify and window the images to detect any IOFBs present on each image.

**Results:** 10 observers (4 radiographers; 4 reporting radiographers; 2 consultant radiologists) independently reviewed the images. The mean (SD) sensitivity and specificity were 72.1% (7.3%) and 99.2% (0.8%) for all observers, respectively. According to size the sensitivity in detecting small, medium and large IOFB were 46%, 76% and 93%, respectively. According to location, the lower lateral quadrants had the lowest sensitivity (53%) whereas the upper medial had the greatest (88%).

**Conclusion:** Findings from this study using CR support previous conclusions that conventional X-rays fail to detect metallic IOFBs in all cases. Diagnostic performance is governed by IOFB size and location.

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## Introduction

Ferromagnetic materials are considered as contraindications for MRI because there is a potential for them to move or become displaced.<sup>1</sup> In 1986, Kelly et al. first reported a case where a patient who had a clinically occult 2.0 × 3.5 mm metallic intra-ocular foreign body (IOFB) underwent an MRI examination which subsequently resulted in a vitreous haemorrhage and unilateral blindness.<sup>2</sup>

Since then, radiographic examinations of the orbit are used as a screening test prior to MRI examinations to rule out possible IOFBs in patients who are deemed high risk following completion of screening questionnaires. Previous studies have concluded that radiographic examinations are a useful method to exclude ferromagnetic IOFBs prior to MRI.<sup>3</sup> However, Bryden et al.<sup>4</sup> and Bray, &

Griffiths<sup>5</sup> found the sensitivity of film/screen for detecting metallic IOFBs to be 69% and 90%, respectively. Furthermore case reports of ocular injury despite apparently normal orbit radiographs have led to concerns regarding the sensitivity and specificity of film/screen radiographs used for this purpose.<sup>6</sup>

The aim of this study was to determine the accuracy of orbital X-rays, when using computed radiography (CR), in detecting ferromagnetic IOFBs prior to Magnetic Resonance Imaging (MRI).

## Materials and methods

## Image acquisition

An adult anthropomorphic head phantom was positioned for a posteroanterior (PA) projection of the orbits in keeping with key radiographic positioning texts.<sup>7,8</sup> The phantom's chin was then raised in order to lower the petrous ridge below the inferior aspect of the orbit. A Woverson Acroma X-ray unit (high frequency generator with VARIAN 130 HS standard X-ray tube, total filtration of 3 mm Aluminum equivalent and a 0.6 mm focal spot) was used to

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acquire the images. The tube voltage and mAs were manually selected (70 kVp and 20 mAs) as this mimicked local clinical practice. The source-to-image distance was fixed at 100 cm and the primary X-ray beam was collimated to include the lateral skull margins and the whole of the orbits ( $21.5 \times 8.5$  cm). This also followed recommendations within the literature.<sup>7,8</sup>

Images were acquired using the same  $18 \times 24$  cm Agfa CR image receptor (IR) which was placed in the vertical Bucky. Acquisitions made use of a secondary radiation grid and images were processed using an Agfa 35-X digitizer (Agfa-Gevaert Corp, Mortsel, Belgium) using a skull look up table.

#### IOFB simulation

A preliminary study was conducted to select suitable sizes and compositions of ferromagnetic materials in order to mimic IOFBs. Four large ( $>1.0$  to  $0.6$  mm) sized IOFBs, four mid-sized ( $0.5$ – $0.1$  mm) IOFBs and four small (iron filing) IOFBs were subsequently selected. For each image it was planned to have 1, 2, 3, or 4 IOFBs in either the left or right orbit across the four quadrants (Fig. 1). The IOFBs were fixed to the anterior surface of the orbit

with a random distribution but with a minimum of 20% distribution for each size per quadrant (Table 1). Across the 24 images with IOFBs present there was a dedicated image with small, medium and large IOFBs for each of the eight eye quadrants. All of the 24 acquired images with an IOFB were duplicated in order to increase the sample size. A further 16 normal images (no IOFB) were also included in the sample; this gave a total of 64 images (Fig. 1).

#### Image assessment

Ten observers (four radiographers, four reporting radiographers and two consultant radiologists) reviewed each of the images independently. Observers were provided with 64 diagrams of the orbits and asked to place a cross on the diagram to indicate the location of any IOFB they identified on the corresponding image (Fig. 2). The same instructions were provided to each observer and images were randomised but presented to each participant in the same order. Observers had no prior knowledge of the IOFB simulations.

Images were viewed on a 24 inch NEC MultiSync EA243WM monitor (NEC Corp, Tokyo, Japan). Each display had been previously calibrated to digital imaging and communications in medicine (DICOM) grayscale standard display function (GSDF) and had a resolution of 2.3 megapixels. The LCD luminance was consistently above  $170 \text{ cd m}^{-2}$  which satisfied the minimum specification for primary diagnostic display devices used for image interpretation. The ambient lighting conditions were dimmed and kept constant for all observers in order to standardise the viewing conditions. Observers were permitted to manually magnify and window the images to detect any IOFBs present on each image.

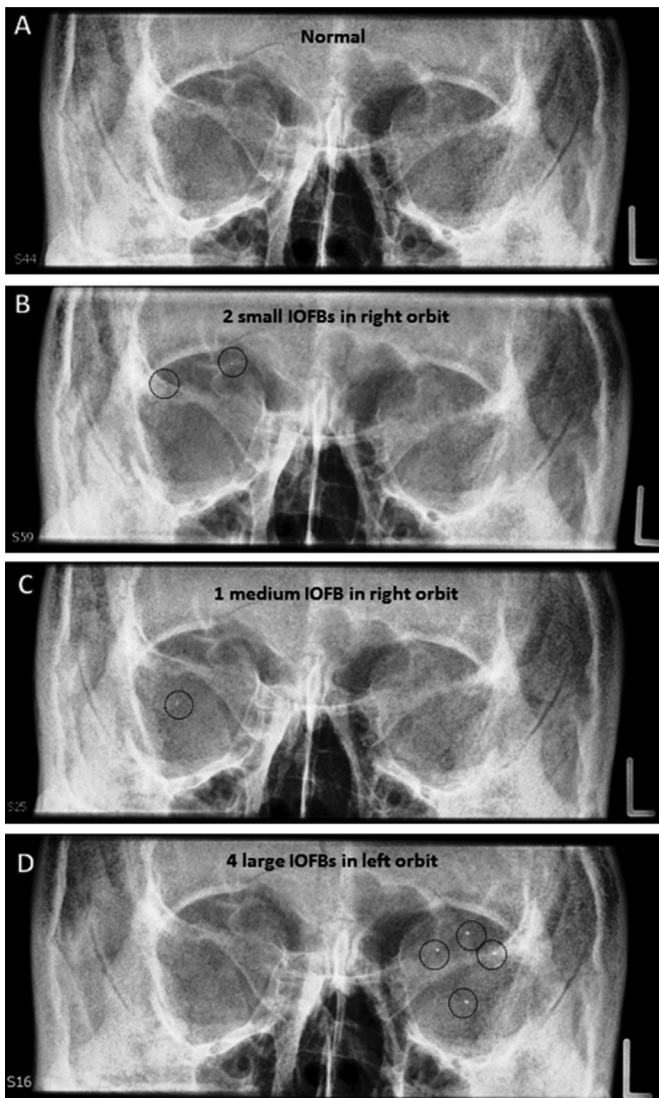
#### Statistical analysis

All data were transferred to Excel 2013 (Microsoft Corp, Redmond, WA) for statistical analysis. Sensitivity, specificity, and accuracy values were calculated for each observer. According to Altman (1999) the sensitivity of a test can be calculated  $a/(a + c)$  by the number of cases with a true IOFB correctly detected by CR ( $a$ ) divided by the sum of this number combined with any true cases of IOFBs missed by CR ( $c$ ).<sup>9</sup> The specificity of the test was calculated in a similar manner  $d/(b + d)$  where ( $d$ ) is the number of cases without an IOFB correctly identified by CR and ( $b$ ) is the number of positive IOFB cases determined by CR which were in fact not present. Accuracy refers to the true positives plus the true negatives divided by the true and false positives and the true and false negatives. For sensitivity, specificity and accuracy values generated using the above equations were multiplied by one hundred in order to provide percentage values. Sub-analyses were undertaken to evaluate the diagnostic accuracy of CR for different IOFB sizes and locations. In order to achieve this, IOFBs were graded as small, medium and large and the eye was split into four quadrants as previously demonstrated. Performance data were expressed as mean values plus and minus their respective standard deviations (SD). Data was also assessed according to observer type (radiographer, reporting radiographer or radiologist).

**Table 1**  
Distribution of IOFBs across the four eye quadrants.

|        | UM       | UL       | LM       | LL       |
|--------|----------|----------|----------|----------|
| Small  | 10 (25%) | 8 (20%)  | 10 (25%) | 12 (30%) |
| Medium | 10 (25%) | 8 (20%)  | 10 (25%) | 12 (30%) |
| Large  | 8 (20%)  | 16 (40%) | 8 (20%)  | 8 (20%)  |

Percentages are displayed in the parentheses. UM, upper medial; UL, upper lateral; LM, lateral medial; LL, lateral lower.



**Figure 1.** Image with a no IOFB (A), small IOFB (B), medium IOFB (C) and a large IOFB (D).

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