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Intraorbital foreign body detection and localisation by radiographers: A preliminary JAFROC observer performance study

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ABSTRACT

Introduction: The purpose of this study was to run a preliminary investigation to establish if a short course of learning would increase radiographers' performance in intraorbital foreign body (IOFB) detection and localisation on pre-magnetic resonance imaging (MRI) orbital computed radiographs (CR).
Method: A multi-reader multi-case (MRMC) human observer study was performed. Fifteen radiographers from 5 hospitals participated. Each radiographer reviewed a pre- and post-training image bank and was instructed to identify the presence or absence of IOFBs, indicating the lesion location on each case whilst scoring the detection using a confidence index on a 5-point scale, for 30 orbital radiographs. The results were analysed using a Jackknife free-response receiver operating characteristic (JAFROC2 equal weighted) methodology.
Results: The performance of the radiographers demonstrated a statistically significant difference after a short period of training in the detection of IOFBs on orbital radiographs (F (1,14) = 12.99, df = 14.0, p = 0.0029). The JAFROC2 analysis averaged figure of merit (FOM) for the radiographers was 0.818 (95% CI 0.769, 0.867) pre-training and 0.920 (95% CI 0.891, 0.950) post-training.
Conclusion: These results suggest that with a short programme of learning in image interpretation for IOFBs in orbital radiographs, radiographers should be able to achieve a high level of accuracy in the identification and localisation of IOFBs prior to MRI examination.

Introduction

Since the first reported cases of serious eye injuries from metallic intraorbital foreign bodies (IOFBs) by Kelly et al.[1] The risk from injuries such as rupture, haemorrhage or blindness have formed the basis for stringent screening protocols for pre-magnetic resonance imaging (MRI) examinations. There has since been numerous reported cases[2–5] that have helped develop health and safety protocols to screen patients with suspected metallic IOFBs before they enter the controlled area of the MRI department. Current policies applied in National Health Service (NHS) practice conform to recent guidelines by the Society and College of Radiographers (SCoR) and the British Association of Magnetic Resonance Radiographers (BAMRR),[6] the Medicines and Healthcare products Regulatory Agency (MHRA),[7] the European Union Physical Agents Directive (EUPAD)[8] and the Ionising Radiation (Medical Exposure) Regulations IR(ME)R Schedule 1.[9,10] All of which aim to ensure no individual (patient, staff, or visitor) enters an MRI controlled area with a metallic IOFB. This process involves verbal screening, written questionnaires, review of previous imaging (if available) and in uncertain cases pre-MRI orbital radiographs.

MRI radiographers have the potential to role extend and develop their clinical practice in a service improvement capacity to streamline their diagnostic imaging pathways. Under IR(ME)R[10] legislation MRI practitioners have the capacity through local level agreement to develop a scope of entitlement to identify themselves through departmental protocols, referral criteria, job descriptions and appropriate continuing profession development (CPD) training and audit activities to be recognised as the referrer for pre-MRI orbital radiographs. The relevant skills and knowledge to extend radiographers' scope of practice for the rationale to refer patients for orbital radiographs and the interpretation of imaging for the purposes of excluding the presence of metallic IOFBs are contained as part of the protocols in the employers' procedures under IR(ME)R.[10] The demonstrable knowledge would need to show an awareness of the circumstances leading to a penetrating injury resulting

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in a retained IOFB, with regular audit of the suitability and impact of referrals.[11] Whilst documenting a record of a sufficient amount of test film viewings from a bank of suitable radiographs, and a period of clinical image interpretations to demonstrate a level of competence. Specifically IR(ME)R[10] advises that each medical exposure has a clinical evaluation of the image, which is recorded for audit purposes.

Radiographers have previously evidenced the ability to interpret a wide range of current radiographic investigations.[12–18] Role extension into referral and interpretation of pre-MRI orbital radiographic imaging would benefit the workflow practice of busy MRI departments and waiting time initiatives, as well increasing radiographer responsibilities in a modern radiology service.

Aims and objectives

The purpose of this study was to run a preliminary investigation to establish if a short one day intensive course of lectures, question and answer sessions and interactive case reviews would increase radiographers' performance in IOFB detection and localisation on pre-MRI orbital computed radiographs. The training reviewed orbital and facial bone anatomy, physiology, pathology, image interpretation and search strategies. Whilst reviewing published cases of IOFB injuries, and discussing the current legal perspectives and NHS polices and guidelines to prevent IOFB injuries.

Methodology

The study followed a multiple reader multiple case (MRMC) retrospective preliminary study of 15 radiographers from 5 hospitals using a Jackknife free-response receiver operating characteristic (JAFROC2) methodology.[19] The observers reviewed a pre- and post-training image bank and were instructed to identify the presence or absence of IOFBs, recording the lesion location (LL) on each case and scoring the detection using a confidence index on a 5-point scale for 30 orbital radiographs. The study was approved by an ethics and governance panel, and all observers gave informed written consent.

The sample of participants recruited conformed to the criteria of band 5 and 6 radiographers working within MRI departments of southern United Kingdom (UK) hospitals, all had MRI experience ranging from 3 to 9 years, and some had previous postgraduate training in MRI, but no radiographers had any plain film reporting experience. The sample size for this preliminary study followed Obuchowski[21,22] tables for receiver operating characteristic (ROC) studies of observers sampled in medical imaging studies, and for external validity purposes[23] would not be representative of being proportional to the general population.

The images were obtained by permission of local NHS trusts from an anonymised retrospective digital teaching library (DTL) used by the university for research and teaching that conformed to section 33 of the UK Data Protection Act,[24] the Cosson and Willis[25] guidance from the National Information Governance Board for Health and Social Care, and the General Medical Council.[26]

Orbital radiographs used included letter box collimated under tilted occipito-mental (OM) with orbitomeatal baseline raised 10° less than for a standard OM (to provide a circular appearance of the orbits, unlike the oval OM standard view). Some of the images used included secondary supplementary views of eyes up or down or lateral side to side.

Images rejected from the study bank included those with the petrous ridge superimpositioned upon the lower orbital margin, poor positioning or rotation of the facial bones, over tilted projections, and the presence of artefacts on the imaging plate.

A sampling bias of pathology was reduced as near as possibly by using an appropriately wide range, amount and size of IOFBs as was feasible that conformed to textbook examples and conspicuity. A suitable range of subtle IOFBs as discriminatory examples ensured a fair process of image interpretation.[22,27] Where there were multiple IOFBs on an image each lesion was given equal weighting factor for the JAFROC2 analysis, as each lesion was deemed to have an equal importance and risk factor for potential injury. JAFROC2 methodology compares the performance of readers interpreting the same bank of cases at two different intervals (pre-testing was at the start of the study day, post-testing at the end of the study day). The methodology was intended to investigate questions such as whether or not teaching image interpretation improves diagnostic performance in the detection and localisation of IOFBs on orbital radiographs.

Each case had a triple reader retrospective approach of interpretation by three independent and blinded reviewers[27] (a consultant radiologist and two reporting radiographers) to determine concordance for the reference standard, and reduce potential bias (internal validity) of inter-rater disagreement of same case reviews.[28–30]

The images were evaluated on Liquid Crystal Display (LCD) image monitors with a resolution of 1280 × 1024, calibrated to the Digital Imaging and Communications in Medicine (DICOM) part 14 Greyscale Standard Display Function (GSDF) with VeriLUM software.[32] Quality checks were performed on the monitors prior to each test with a standard diagnostic imaging Society of Motion Picture and Television Engineers (SMPTE) reference pattern for spatial uniformity of luminance and temporal luminance stability complying with Royal College of Radiologists (RCR) guidelines.[31] The cases were viewed using commercially available software (K-PACS[33]) intended for displaying DICOM images. This allowed the observers to alter the computed radiograph (CR) window width and window level, pan and zoom the image, and measure region of interests (ROI) with the ability to display multiple images from a case for comparison views. An observing environment was chosen specifically for this study that reduced the possibility of disturbance of concentration, by controlling the lighting, noise and interruptions.[27]

The JAFROC2 (equal weighted) methodology allowed the readers to make as many or as few responses per images, and the paradigm allowed multiple IOFBs per case if required. When the observer reviewed each case they labelled the LL ROI (or quadrants in JAFROC2 terminology) and rated the degree of suspicion using a confidence index score, in this study 1–5. A score of 1 equated to high confidence that the ROI in question did not have a lesion (normal), with grading up to a score of 5 inferred the reader was highly confident the ROI in question did have a lesion (similar to a Likert scale).

The reader's scores were marked as either LL i.e. the mark of a lesion was within an acceptance region to the real lesion, or a non-lesion location (NLL). Acceptance regions of lesions are varied in peer review literature, this study has followed the Chakraborty[34] recommendation of a maximum diameter of a lesion or 3 mm. Acceptance radiuses are a controversial topic in observer performance studies and Chakraborty[20,34] considers the question of what is the maximum inaccuracy with no clinical impact that would be acceptable in a study scenario.

The JAFROC2 (equal weighted)[19] analysis produces a figure of merit (FOM) metric which determines the measure of the observer's detectability, using the number of LLs compared to the total known number of lesions (lesion localisation fraction (LLF)), and NLLs relative to the total number of cases in the image bank (non-lesion localisation fraction (NLF)). Specifically JAFROC2 (equal weighted)[20] methodology was used as NLL on non-diseased cases