Foreign bodies in orbits

Review article – X Radiation dose implications in screening patients with ferromagnetic IOFBs prior to MRI: a literary review

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ABSTRACT

Patients scheduled for a magnetic resonance imaging (MRI) scan sometimes require screening for ferromagnetic Intra Orbital Foreign Bodies (IOFBs). To assess this, they are required to fill out a screening protocol questionnaire before their scan. If it is established that a patient is at high risk, radiographic imaging is necessary. This review examines literature to evaluate which imaging modality should be used to screen for IOFBs, considering that the eye is highly sensitive to ionising radiation and any dose should be minimised.

Method: Several websites and books were searched for information, these were as follows: PubMed, Science Direct, Web of Knowledge and Google Scholar. The terms searched related to IOFB, Ionising radiation, Magnetic Resonance Imaging Safety, Image Quality, Effective Dose, Orbits and X-ray. Thirty five articles were found, several were rejected due to age or irrelevance; twenty eight were eventually accepted.

Results: There are several imaging techniques that can be used. Some articles investigated the use of ultrasound for investigation of ferromagnetic IOFBs of the eye and others discussed using Computed Tomography (CT) and X-ray. Some gaps in the literature were identified, mainly that there are no articles which discuss the lowest effective dose while having adequate image quality for orbital imaging.

Conclusion: X-ray is the best method to identify IOFBs. The only problem is that there is no research which highlights exposure factors that maintain sufficient image quality for viewing IOFBs and keep the effective dose to the eye As Low As Reasonably Achievable (ALARA).

INTRODUCTION

Magnetic Resonance Imaging (MRI) is a method of sectional assessment that provides excellent differentiation of many tissues types in different areas of the body with the advantage of using non-ionizing radiation. It is essential for medical diagnosis and has evolved very quickly, providing valuable advances in clinical practice[1-2].

The main principle of MRI is the interaction of atoms which have a magnetic moment within an applied magnetic field[3]. Magnetic susceptibility defines the extent to which a material becomes magnetized when placed in a magnetic field. Materials with positive magnetic susceptibility are called paramagnetic; those with negative magnetic susceptibility are called diamagnetic. Ferromagnetic materials, such as iron, cobalt and nickel, are superparamagnetic and so are highly likely to be affected by magnetism. The most common Intra-Ocular Foreign Bodies (IOFB) are iron particles[2,4].

MRI is contraindicated if there are any ferromagnetic foreign bodies present, as the magnetic force emitted may result in movement of the metal, causing serious injuries[1]. In relation to the orbits, movement of any metal fragments can cause very serious damage, and even blindness in extreme cases[5]. To prevent damage to the eye, strict pre-assessment protocols have been advocated prior to any MRI scanning, however this is not a legal requirement, only a recommendation1.

Patients are asked to fill in a questionnaire that helps determine whether they have, or are at high risk of having, any ferromagnetic IOFBs[6-8]. If a high risk is determined, the patient may be referred for further imaging. There are several imaging options available to confirm the presence or absence of any IOFB including plain film orbital X-ray, CT and ultrasound[6]. The most commonly used method is X-ray of the orbits. However, the lens of the eye is particularly sensitive to ionising radiation. A late onset consequence of ocular radiation exposure is clouding of the lens, known as cataracts[9]. Therefore, it is crucial to ensure that any imaging is justified and radiation dose to the eye is kept ALARA[10].

METHODOLOGY

Eight investigators searched several online databases and websites for literature. The searches took place on PubMed, Science Direct, Web of Knowledge and Google Scholar. The search terms used were as follows and were searched both alone and in combinations; Radiation Dose, Eye, Orbits, Ocular, X-Ray, Ultrasound, Sonography, MRI, MRI Safety, CT, Epidemiology, Cataracts, Foreign Body, Image Quality, IOFBs, Radiology and Metal. The language searched was English. The years searched ranged from 1986 to the present, due to lack of very recent publications. The inclusion criteria for the selection of the articles for the construction of this literature review were: 1) Comparison between multiple image-related methods for detection of IOFB; 2) Identifying several reports about MRI incidents regarding ocular IOFB. The exclusion criteria applied to articles that referred to use of film in radiography rather than CR, except an article from 1986 that reports the first case of ocular injury on an MRI site. These searches yielded 35 papers, several of which were rejected due to age, irrelevance to the review, and language. This left 28 papers and books that were relevant to the study and were subsequently used.

The importance of screening before MRI

Several published cases of injuries as a result of ferromagnetic IOFBs in MRI scanners exist. The first, in 1986, involved a sheet-metal worker with an occult IOFB. He experienced severe pain as a result of a vitreous hemorrhage. This resulted in subsequent unilateral blindness when he was removed from the 0.35T scanner[10-12]. Williamson et al performed various MRI scans with a 0.08T scanner on bovine eyes containing ferromagnetic IOFBs. They concluded that the particles did not move, however they proposed that using a higher field strength may cause intraocular damage[12-13]. This was confirmed by Gunenc et al when they used a 1.0T scanner. The IOFBs inserted in bovine eyes were shown to move by 7 to 10mm[12,14].

Table 1: Range of questions in 78 UK sites[6]

Questions pertaining to IOFBs	Number of sites asking this question
Have you ever had metal in your eyes?	45
Do you have any metal in your eyes?	11
Have you ever had any embedded metal requiring treatment?	3
Have you had an injury to eye involving metal?	8
Have you ever had an intra-orbital foreign body (of any kind)?	4
Have you ever worked with metal?	28
Have you ever worked with metal at speed?	3
Have you ever worked in the iron or steel industry?	1
Have you ever worked in a shipyard?	2
Have you ever had an eye injury?	1
Have you ever attended an eye department?	1

Due to the 1986 report, several measures were recommended to screen patients for MRI examinations before they entered into the MRI controlled area. To decide whether screening is necessary, the patients are asked to complete a written questionnaire. An example of this form can be accessed through www.mrisafety.com[7]. Table 1 provides a list of examples of questions asked to patients at different imaging sites across the UK with regards to IOFB safety. This is provided courtesy of Bailey et al, which they took from a 1996 newsletter published by the British association of MR Radiography[12].

However, the safety questionnaire is not always able to accurately identify patients with IOFBs. According to Bowman et al, a 63 year-old male metal worker requiring a brain MRI denied any history of an IOFB. After MRI he complained of pain and developed hyphema[12]. Bailey et al give several reasons why this could happen: "(a) Situations where the patient has no recollection of history of IOFB or occupational exposure to penetrating metallic fragments, (b) the patient forgets a previous history of a metallic penetrating orbital injury, (c) the condition of the patient might inhibit their abilities in answering the screening questionnaire, and/or (d) the patient could fail to disclose relevant information regarding an orbital injury"[6].

The American College of Radiology (ACR) state that "all patients who have a history of orbital trauma by a potential ferromagnetic foreign body for which they sought medical attention are to have their orbits assessed by either plain X-ray orbit films (2 views) or by a radiologist's review and assessment of contiguous cut prior CT or MR images, obtained since the suspected traumatic event, if available."[6]. However, Shellock and Kanal have a different opinion to the ACR and believe only certain patients should be considered "high risk" and should be categorized by size and location of the fragment. Specifically they say that not every metal worker is to be considered a "high risk" patient; only the ones who have a history of eye injury should have radiographic screening prior to MRI. Although, they do consider it important that MR sites have a standardized policy and set guidelines for screening patients with suspected ferromagnetic IOFBs[15].

In summary, it is important that patients who are at "high risk" of ferromagnetic IOFBs must have some form of radiographic screening of which a range of options are available[6]. However, it is essential to consider the radio-sensitivity of the eye and the effects ionizing radiation has on the lens.

The use and optimisation of X-ray

According to the Safety Committee of the Society for Magnetic Resonance Imaging "the use of plain radiography is considered to be an acceptable technique for identifying or excluding intraorbital metallic foreign bodies that represent a potential hazard to a patient about to undergo MRI"[5].

Imaging protocols for orbital X-ray acquisition vary from hospital to hospital, however the images produced are fairly standardised and usually consist of Postero-anterior (PA) skull radiography[16-17].

The great debate in radiography remains the question of balance between image quality and radiation dose to the eye. Even different textbooks used worldwide differ in their opinions of the positioning technique, kV, mAs and Source to Image receptor Distance (SID) ranges. For example, Bontranger et al says that by using 75kVp, 18mAs and a SID of 100cm, with a PA axial 30° caudal angle and resting the forehead and nose on the Image Receptor (IR) (Caldwell's method) the petrous ridge will be projected onto the inferior orbital floor, or even under it, allowing clear visualization of the orbits[17]. Ballinger et al. says that for the localization of IOFBs using radiography it should be performed using two perpendicular projections – lateral and PA axial with a 30° caudal angle. This author also says that some physicians prefer to use a modified Waters positioning (25°-37° caudal beam angulation and central ray directed to the nasion instead of the acanthion) instead of Caldwell´s method[18]. Richards et al defends that the Parallax motion method can determine if an IOFB is located within the eyeball by acquiring two lateral and two PA modified Waters exposures; one exposure is acquired with the patient looking to the extreme right, and the other one to the extreme left[19]. Clark´s textbook (12th edition) says that the parameters should be 70-85kVp, but does not specify mAs or SID. It goes on to say that the patient should rest the chin and nose on the IR and the orbito-meatal line should be positioned at a 35° to the central ray, which is perpendicular to the IR. Clark's recommends this positioning to ''exclude the presence of metallic foreign bodies in the eyes before MRI investigations''[16].

The use of CT in ocular investigation for ferromagnetic IOFBs.

Pinto et al regard CT very highly in terms of IOFB detection, and believe that it is the most sensitive method in IOFB detection, as it can accurately detect and localise many different foreign bodies in the eye including metallic objects[20]. Saeed et al argue that CT provides better fragment localisation than X-ray and if the IOFB is too small to be seen on X-ray it will be seen on CT[21]. Cullen et al disagree with Saeed et al. Cullen et al conducted research using eyes of rabbits which showed that 3mm x 0.72mm fragments demonstrated some movement but caused no damage. From this, they concluded the much higher level of radiation dose required during CT imaging is unnecessary if the previous X-ray assessment cannot detect the IOFB. If the IOFB is too small to be affected by the electromagnetic field it will not move and cause any damage to the eye; this is particularly true in scanners of 1.5T and below[21-22]. It must be considered that these studies were done in dead animals, so there is no blood flow or pressure in the eye, so this may have affected their results.

Although CT is widely regarded by many studies as a good detection tool for IOFBs, the ionising radiation dose to the eye is considered by others to be unreasonably high. This is especially true when considering that Otto et al say that if the particles are so small that they cannot be detected on X-ray, when the patient is submitted to an MRI scan the movement of the IOFBs will not be sufficient to penetrate far enough into the eye to cause any resultant damage[23].

The effect of radiation on the eye

Absorbed ionising radiation can cause biological changes, depending on the area of anatomy exposed. Biological changes vary from stochastic to deterministic. Stochastic effects are changes that are possible when the anatomy is exposed to any amount of ionizing radiation, whereas deterministic effects will occur for certain, once the area has been exposed to a specified amount of radiation. In considering the eye, radiation effects are deterministic. Cataract formation begins after a dose of around 2Gy, and will have become fully opaque after an accumulation of 5.5Gy[9].

A cataract is a clouding of the lens and is associated with visual impairment. Anatomically, cataracts can be classified into three categories: nuclear sclerosis, cortical cataracts and posterior subcapsular cataracts[24]. According to numerous studies, which have investigated the association between the formation of cataracts and genetics, hereditary factors play a role in age-related cataract formation in around 50-70% of cases[24-25]. Additionally, ionizing radiation is known to be cataractogenic[26-27] and the International Commission on Radiological Protection (ICRP) (2012) recognises cataracts are a late stage deterministic effect of radiation exposure[28].

The ICRP recommend a reduction in planned exposure to the lens of the eye and so any ionising radiation exposures should be justified and kept ALARA, therefore ruling out use of CT[28].

Radiation free alternatives for IOFB identification

Radiation free alternative imaging techniques exist to identify IOFBs, and therefore should be investigated thoroughly. One study compared X-ray, CT and ultrasound of the eye, and their respective detection rates for IOFBs. X-ray was shown to be able to correctly identify size and shape of any metallic IOFBs, CT identified all IOFBs and provided information regarding the relationship to the globe wall. Sonography provided the same detail as CT but gave no ionising radiation dose[29]. However, a different study has discredited ultrasound in IOFB detection due to its unacceptable negative predictive value (85.2%)[30] and due to false detection of IOFB the patient may be denied a scan that could, possibly provide important diagnosis information.

On the whole there is not enough evidence to credit ultrasound as a first line imaging modality, however, for the time being, it can only be used in conjunction with other imaging modalities when looking for IOFBs[29].

CONCLUSION

Ferromagnetic IOFBs can be very dangerous for a patient who is undergoing MRI. They need to be identified prior to the MRI scan and there are several imaging modalities that provide varying levels of information on the location, size and shape of the fragments. The lens of the eye is highly radio-sensitive and therefore this needs to be considered when requesting imaging. Ultrasound gives no ionising radiation dose but there is a lack of evidence to use it as a first line modality. CT provides detailed information and detection of the ferromagnetic fragments but the radiation dose is unnecessarily high when X-ray can provide sufficient information using a lower dose. However, there is still controversy regarding the optimal technique and exposure factors that are appropriate and effective for this method of imaging. Further investigations are required to identify the optimal exposure factors to use to provide a diagnostic image whilst keeping the radiation dose ALARA.

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