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Magnetic resonance imaging and computed tomography in the detection and localization of intraocular foreign bodies

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Abstract. In this experimental study, various foreign bodies were inserted into fresh bovine eyes, in different localizations. Twenty-one magnetic and non-magnetic foreign bodies, dimensions of which varied from $1.5 \times 1.5 \times 2$ mm to $3.5 \times 6 \times 7$ mm, were tried to detect by computed tomography (CT) and magnetic resonance imaging (MRI) scanning. In addition, further dissections were applied to check the ocular damage attributable to movement of the foreign bodies. Ferromagnetic foreign bodies have been shown to move in the eye and the risk of torsional forces being applied to the ferromagnetic foreign body seemed to cause intraocular complications during MRI scanning. All of the foreign bodies that were implanted in bovine eyes were recognized on CT scanning, except intraocular lenses. As a general rule, metallic foreign bodies produced beamhardening artifacts, but these artifacts did not cause any problem in detecting the localizations of foreign bodies.

Introduction

In the evaluation of patients who sustain penetrating injuries of the orbit, particularly those injuries in which the eye itself is involved, two questions must be answered. Is there a foreign body present? If so, what are its characteristics? The answers to those questions are crucial in deciding the optimum management of such injuries.

The purpose of this study was to determine how various magnetic and non-magnetic foreign bodies could be detected in ocular tissue by computed tomography and magnetic resonance imaging and to evaluate the possible ocular damage attributable to movement of the foreign bodies during an MRI examination.

Materials & Methods

Twenty-one organic and metallic foreign bodies in different sizes were placed in and around the eye of the 16 fresh bovine eyes (Figs. 1 & 2). Two

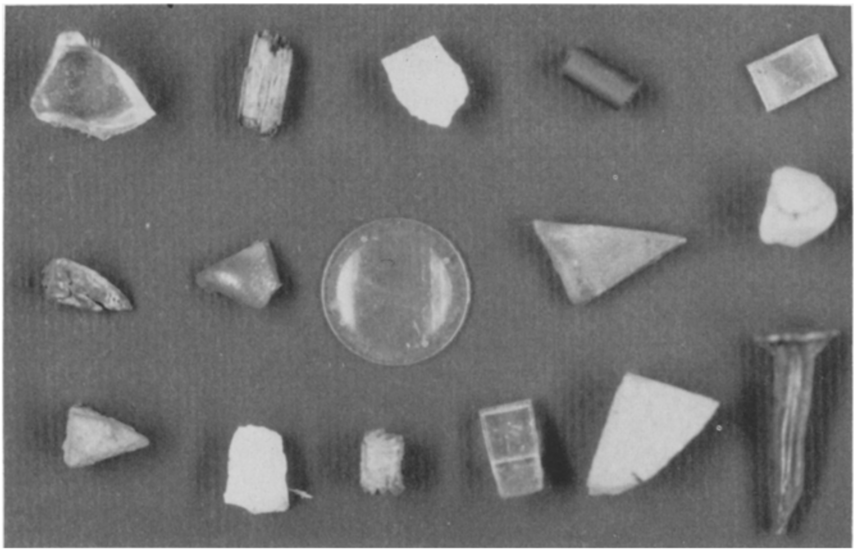

Fig. 1. Foreign bodies placed in and around the fresh bovine eyes.

control eyes were similarly operated but without the insertion of foreign bodies to determine whether any scanning artefact was induced by the wound itself or by the presence of healon.

The sizes of the foreign bodies varied from 1.5 × 1.5 × 2 mm to 3.5 × 6 × 7 mm. (Table 1). The foreign bodies were inserted into fresh bovine eyes through a triangular scleral flap at the posterior pole with microforceps to place the fragments in the suprachoroidal space or the vitreous gel. Some insertions were made through the cornea to place the fragment into anterior chamber and the others were placed subconjunctivally and intrasclerally. To avoid the introduction of air, the foreign bodies were inserted into the suprachoroidal space, vitreus and anterior chamber under sodium hyaluronate (healon).

The eyes were immersed in paraffin liquid in a perspex container. After solidification of paraffin, first computed tomography scanning, and than magnetic resonance imaging scanning were performed. Computed tomograms were performed on a Toshiba TCT 6005 scanner using 2 to 5 mm slice thickness, 250 mÅ, 4 sec, 120 V doses. We used FC-1 filtration with S-2

Table 1. The real sizes and the localizations of the foreign bodies and their sizes on computed tomography (CT) & magnetic resonance imaging (MRI) scannings

No. of eyes	Foreign body	Location			Size [mm]		
		Real	CT	MRI	Real	CT	MRI
1	Aluminium	suprachoroid	+	+	3 × 3 × 3	5 × 5	3 × 3
2	Iron	suprachoroid	+	gd	1.5 × 2 × 2	5 × 5	gd
3	Lead	suprachoroid	+	+	2 × 2 × 3	4.5 × 5[bh]	2.5 × 2.5
4	Copper	intrascleral	+	+	1.5 × 1.5 × 2	2 × 2	2 × 2
5	Glass	subconjuctiv.	+	+	1 × 2 × 2	2 × 2	2 × 2
6	Chromium	intravitreal	+	gd	2 × 2 × 3.5	3 × 4.5[bh]	gd
7	Glass	subkonjuctiv.	+	+	1.5 × 2 × 2	2 × 2	2 × 2
8	Glass[a]	intravitreal	+	+	5 × 5 × 7	5 × 6	5 × 5
9	Wood	intrascleral	+	+	3 × 3 × 5	4 × 5	6 × 7
10	Stone	suprachoroid	+	+	4 × 5 × 5	5 × 5	4 × 5
11	Pmma[b]	intravitreal	–	–	1 × 9 × 9	–	–
12	Mica	suprachoroid	+	+	2 × 2 × 5	3 × 4	3.5 × 4
13	Graphite	intrascleral	+	art	2 × 2 × 4	2 × 4	art
14	Brick	suprachoroid	+	+	3 × 3 × 5	3.5 × 5	5 × 7[art]
15	Bakelite	suprachoroid	+	+	3 × 3 × 5	4 × 5	3.5 × 4.5
16	Iron	"+ intravit.	+	gd	2 × 2 × 13	4.5 × 9[bh]	gd
17	Pmma	ant. chamber	–	+	1 × 9 × 9	–	7 × ?
18	Porcelain	suprachoroid	+	+	3 × 4 × 5	3 × 5	3.5 × 4.5
19	Ceramic	suprachoroid	+	+	3.5 × 6 × 7	5 × 7	5 × 7
20	Solder	suprachoroid	+	art	2.5 × 3 × 4	5 × 6[bh]	art
21	Glass	ant. chamber	+	+	3 × 4.5 × 5	4 × 5	4.5 × 5

[a]Windscreen; [b]Polymethylmethacrylate

[+]: detected in real localization; [–]: could not be detected; gd: globe distortion; art: artifact; bh: beamhardening artifact.

and S-3 section parameters to increase the soft tissue resolution in sections.

Magnetic resonance images were acquired using a 1.0 Tesla superconducting magnet (Siemens Magnetom 1T) and a Helmoltz's head coil. Four to six mm slice thickness was used with 256 × 256 pixels. On T1 weighted images 500 msec of repetition time and 15 msec of echotime (lasted 4 minutes), on T2 weighed images 2500 msec of repetition time and 22 to 90 msec of echo time (lasted 10 minutes) were used respectively.

After being imaged, the eyes were dissected by removal of the anterior globe by incision through the pars plana. The location of the foreign body and any change in its position or damage to the intraocular structures were noted.

Results

The comparison of the real localizations and sizes of the foreign bodies with the sizes and localizations that were detected on computed tomography and magnetic resonance imaging scans were shown on Table 1.

Two intraocular lenses (PMMA) could not be detected on CT scans. Thirteen of 19 detected foreign bodies had the same dimensions on CT scans (68.4%), the other 5 of 6 foreign bodies sized approximately 2 mm more than their true sizes, and one of them sized approximately 4 mm less than its true size. Four of these 6 foreign bodies (lead, chromium, iron and solder) had 'beam hardening' artifacts. Beam hardening artifact did not seem to cause any problem in detecting localizations of the foreign bodies (Fig. 3).

One intraocular lens could not be detected on MRI scans. Ferromagnetic and paramagnetic foreign bodies such as iron, chromium, solder and graphite created local magnetic field changes, thereby we could not visualize the foreign bodies because of the globe distortion (Figs. 4–7). Eleven of the 15 detected foreign bodies had the same dimensions on MRI scans. The other 2 of 3 foreign bodies (brick & wood) sized approximately 2 mm more than their true sizes, one of them (PMMA intraocular lense) sized approximately 2 mm less than its true size.

The attenuation coefficient (density measurement) of the foreign bodies were detected on CT in Hounsfield Units (Table 2). As a general rule, metallic foreign bodies produced more Hounsfield artifacts than did non-metallic foreign bodies, thus providing a clue to their composition. It was so significant that the foreign bodies which had magnetic field changes and causing globe distortion on MRI scanning (iron, chromium and solder) had more than 3000 Hounsfield Units (Table 2).

When the eyes were dissected by removal of the anterior globe by incision through the pars plana, it was noted that iron and solder foreign bodies had changed their position by 7 to 8 mm in the suprachoroidal space and the chromium foreign body in the vitreus had changed its position approximate-

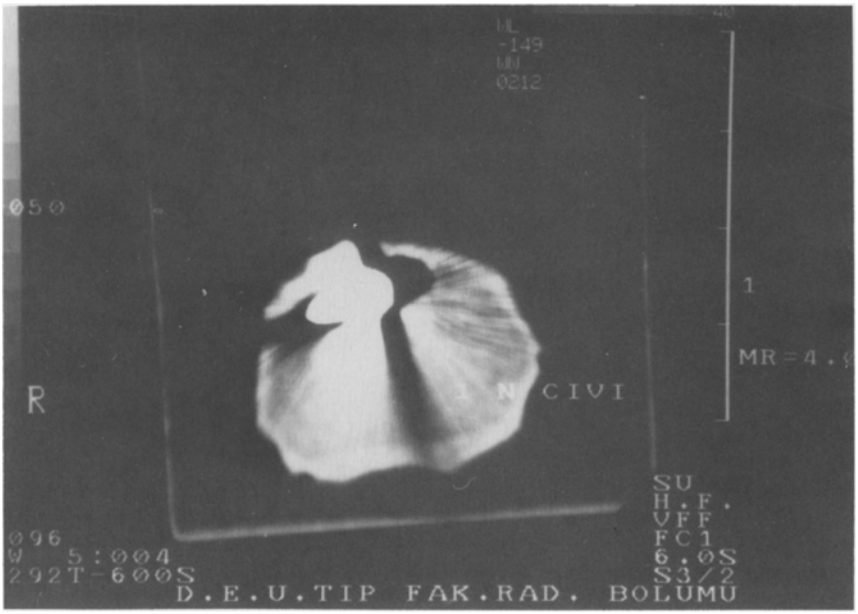

Fig. 3. The beam hardening artefact of the iron fragment on CT scanning.

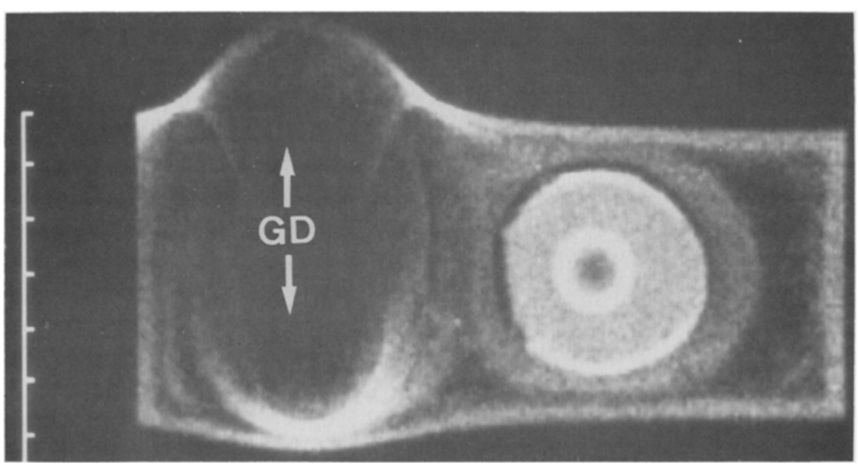

Fig. 4. The distortion of the bovine glob, containing iron fragment, because of the torsional forces being applied to the ferromagnetic foreign body during the MRI scanning.

ly 10 mm because of the torsional forces being applied to the ferromagnetic foreign bodies during the magnetic resonance image scanning.

Control eyes showed no significant artifact from the wound site or the injection of viscoelastic matter.

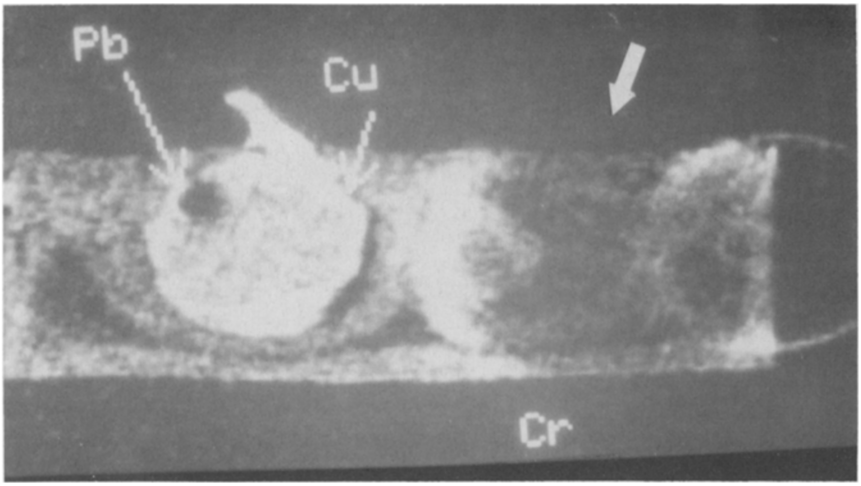

Fig. 5. The MRI scanning of the eye (left) in which lead and copper inserted, the excessive image distortion of the right eye containing chromium.

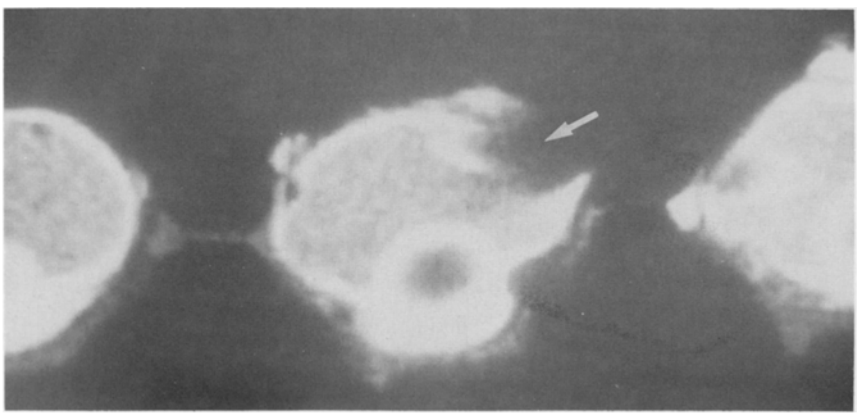

Fig. 6. The quadranal distortion of the glob, containing graphite, caused by the local magnetic field changes on MRI scanning.

Discussion

The present study has shown that computed tomography is capable of detecting small metallic (Fig. 8) or glass foreign bodies in ocular tissues and it is a safe way of detecting intraocular foreign bodies. On the other hand the main disadvantage of CT scanning is the beam hardening artifacts created by metallic objects such as iron (Fig. 3), chromium and lead. But these artifacts did not cause any problem in detecting the localizations of

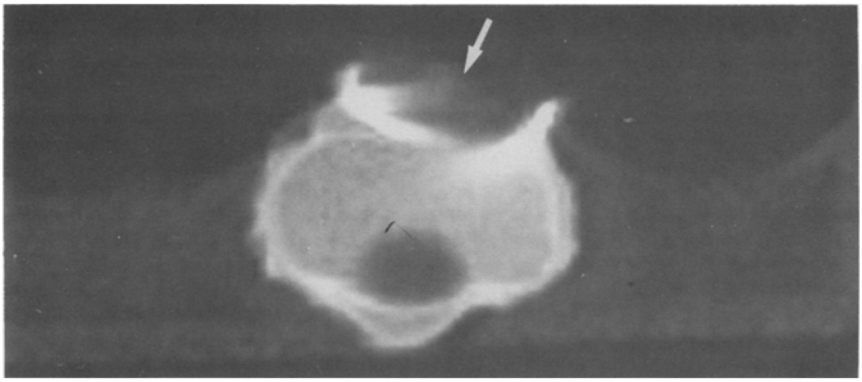

Fig. 7. The quadranal distortion of the bovine globe in which solder inserted.

Table 2. The attenuation coefficient of the foreign bodies that were detected on CT (glasses, ceramic and metallic foreign bodies had more than 1100 HU values, other non-metallic foreign bodies had below 600 HU values)

No of eye	Foreign bodies	Attenuation coefficient [Hounsfield Units (HU)]
1	Aluminium	1150
2	Iron	3800
3	Lead	11600
4	Copper	1600
5	Glass	1400
6	Chromium	6000
7	Glass	1100
8	Glass	2100
9	Wood	5
10	Stone	500
11	Mica	25
12	Graphite	260
13	Brick	400
14	Bakelite	400
15	Iron	20600
16	Porcelain	600
17	Ceramic	2000
18	Solder	6500
19	Glass	2800

foreign bodies [1]. In this study we detected the dimensions of metallic objects 1–3 mm more than their real dimensions because of the beam hardening effect, however in order to overcome this problem filtration procedures can be used.

As a result, one can assume that the foreign body may be a metallic object or a glass if the HU value is more than +1100 (iron, aluminum, lead, copper, chromium, solder), on the other hand if the HU value is below

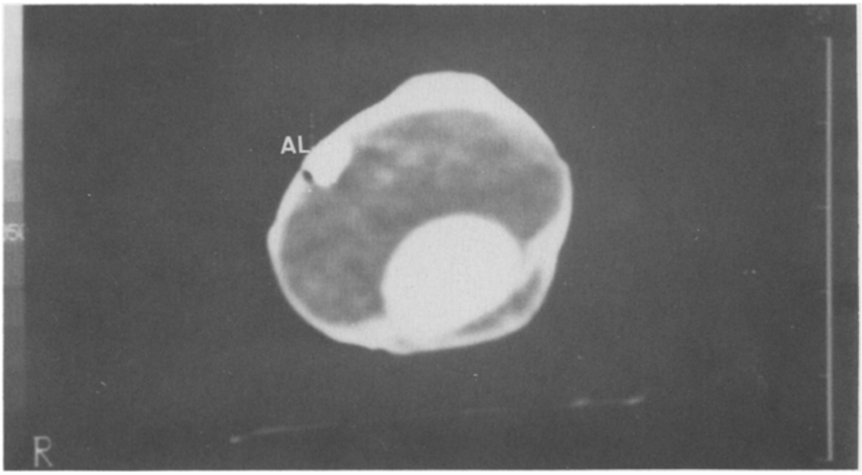

Fig. 8. The CT scanning of the aluminium fragment placed in the suprachoroidal space.

+600 this foreign body may be a non-metallic object (wood, stone, mica, brick, plastic, bakelite, porcelain). In the latter situation magnetic resonance image scanning can be used effectively and safely [2].

Foreign bodies such as iron, chromium, solder, graphite can cause intraocular damage on MRI by resonance and heat. For that reason if there is a metallic foreign body history or a metallic foreign body suspicion on computed tomography scans, magnetic resonance image is useless, and also harmful for the eye and must be avoided [3].

In our study, on magnetic resonance imaging, not only the metallic foreign bodies (iron and chromium) could not be detected, but also the globes themselves containing them could not be visualized due to excessive image distortion (Figs. 4 & 5).

Although Williamson et al. reported that graphite gave a small artifact which did not obscure detail of the globe significantly [4], graphite (Fig. 6) and solder (Fig. 7) created a quadrant globe distortion in our study. He has also reported no change in position of foreign bodies or damage to the surrounding ocular structures, and the technique, used in their study, at low field strength (0.08T) is considered to be safe [4].

Williams et al. used high field strength (2 Tesla) MRI on rabbit eyes and reported that the foreign bodies smaller than $0.5 \times 0.5 \times 0.5$ had no change in their position [5].

On the other hand, vitreous hemorrhage caused by a ferromagnetic foreign body was reported on a 0.35 Tesla MRI scanning [6].

If the nature and the magnetic properties of the foreign body are not known clearly, magnetic resonance image scanning may be dangerous. It was shown that ferromagnetic fragments move in the rabbit vitreous and cause retinal dialysis and detachment [7].

However the plastic and organic (wood) foreign bodies have a low HU value and may not be readily apparent on CT scan. MRI scans in this case delineates the foreign body from surrounding tissues, distinguishes it from air, and localizes it for surgical removal. Wooden fractures can easily be mistaken for air, particularly in the presence of fractures and sinus communication [2].

In our study, we hardly differentiated wood (+5 HU) from air (−540 HU) on CT scanning. Whereas, it was easy to detect location and to determine its dimensions on MRI scanning. Review of previous reports suggests that wood particularly dry wood, is not detected on plain X-rays or CT scans unless it is associated with a radioopaque substance such as metallic paint [8].

Platinum or titanium intraocular lens (IOL) loops, and tantalum or cobalt-nickel retinal tacks have been shown to produce no ill effect [9, 10].

Heavy metal particles, used in the pigment base of mascara and eyelining tattoos, have a paramagnetic effect that causes alteration of the local magnetic field in adjacent tissues. These changes in normal signal result in distortion of globes. In some cases, the distortion may mimic actual ocular disease such as a ciliary body melanoma or cyst [11]. For this reason, woman who have an intraocular foreign body must be examined on MRI scanning after her make up cleared away.

We concluded that, it was not possible to distinguish the different materials by computed tomography and magnetic resonance imaging techniques as reported previously [4, 12, 13].

As a result, in intraocular foreign bodies ultrasound must be the first step after the clinical examination. If there is a globe perforation or a suspicion in the diagnostic criterias of ultrasound, CT can be suggested. If it is difficult to localize the foreign body on CT scanning, or the foreign body seems like a non-metallic fragment and if it has to be done because of the associated pathology (retinal detachment, granulation tissue, infection) MRI scanning can be more helpful.

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