THE INTRA-OCULAR FOREIGN BODY

In infants and young children the risk must be taken and it is the duty of the surgeon to take proper precautions personally, and not to delegate such an important responsibility. The eye should be examined immediately before the operation while the patient is on the table. If a general anaesthetic is to be given either to an adult or to a child administration should not be commenced until the surgeon is present.

The only infallible preventive, if any measure can be infallible, is the use of local analgesia. This method should be adopted in all adult cases in which the eye to be removed is not obviously and distinctly different in external appearance from the other.

A paragraph on this subject should be included in every text-book in which removal of the eye is mentioned.

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THE INTRA-OCULAR FOREIGN BODY
A Series of 72 Cases in the B.L.A.

BY

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LONDON

This paper is an account of 72 cases of penetrating wounds of the eye with retained intra-ocular foreign body which came to a field hospital in Normandy and a 2,000-bedded General Hospital in Belgium (B.L.A.) from July, 1944, to the end of hostilities in Europe in May, 1945. It is the sequel to a report of 102 such cases, treated from the beginning of General Cunningham's offensive in the Western Desert (M.E.F.) in November, 1941, to the end of

As the following statistics show, these cases include besides battle casualties accidental injuries in field workshops, and injuries inflicted by foolish and negligent handling of military weapons.

The majority of foreign bodies produced by the fragmentation of modern war missiles are so lowly magnetic that the importance of more accurate localisation than is necessary in civil practice soon became evident to us for it was essential to bring the terminal of a giant electro-magnet as near to the intra-ocular foreign body as possible in order to effect its extraction. When this was done in a number of cases in which the foreign body had been labelled as non-magnetic in other medical units it was extracted. Probably the fault in these cases lay in relying on the so-called "magnet test" in which pain is elicited on applying the magnet to the eye. Either the foreign body when attracted to the magnet moved a certain distance but did not quite reach the retina and choroid (a fact sometimes seen when the foreign body could be followed with an ophthalmoscope whilst the terminal of a giant-magnet was brought as near as possible to the sclera) or the impact was too gentle to elicit pain, or as it seemed in some cases the sensation of

<table>
<thead>
<tr>
<th>Route of extraction</th>
<th>M.E.F. 102 cases</th>
<th>B.L.A. 72 cases</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B.C.</td>
<td>Acc.</td>
</tr>
<tr>
<td>Posterior (Scleral) route</td>
<td>22</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>(21.5%)</td>
<td>(8.8%)</td>
</tr>
<tr>
<td>Anterior route</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>(4.9%)</td>
<td>(2.9%)</td>
</tr>
<tr>
<td>Total ...</td>
<td>27</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>(26.4%)</td>
<td>(11.7%)</td>
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</tbody>
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Table A shows the percentage of intra-ocular foreign bodies extracted by a giant electro-magnet through (1) the scleral route (2) the anterior route.

M.E.F.—Middle East Force.
B.L.A.—British Liberation Army.
B.C.—Battle Casualty.
Acc.—Accidental injury.
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the intra-ocular membranes was temporarily impaired by either contusion or concussion changes. An even more probable cause of failure was the use of a giant electro-magnet terminal at a distance too remote to move the intra-ocular foreign body to a position where it could be either felt or seen. Particularly was this so when attempts were made to bring forward a foreign body from the vitreous in the first stage of the anterior route technique for extraction.

Table A shows that with improved equipment and proper technique the successful extractions of intra-ocular foreign bodies were increased. Although the type of war missiles was much the same in both theatres of war the figures for Normandy and Belgium (despite working under crude field conditions in Normandy) are better than those of the Middle East Force.

It is possible that in future with an improved magnet the number of successful foreign body extractions by the scleral route might be increased.

Investigation

A reliable diagnosis can only be made with a good light such as either the Lister or scialytic operating lamp, surface anaesthesia with pantocaine 1 per cent., a Desnarres' retractor, binocular loupe, the slit-lamp and corneal microscope, ophthalmoscope, Schiötz tonometer (in some cases) and radiography. It is essential to examine carefully the adjacent anatomical structures bounding the orbit, the nose, face, and skull; particularly is this so in military surgery, where a missile in its course may have damaged the face, accessory nasal sinuses, eye, orbit, and intra-cranial contents. In one case a fine shell splinter had penetrated the occiput, traversed the intra-cranial contents, entered the orbit from behind and penetrated the sclera to come to rest in the vitreous. The small scalp wound had healed and the soldier was unaware of its existence. In another instance the intra-ocular foreign body had traversed the right eye (a through and through scleral wound) the right os planum, nasal septum, left os planum and through the sclera on the nasal side of the left eye. The general condition of the patient must be considered, haemorrhage from other wounds and shock requiring first attention. It is surprising how little the majority of eye wounds suffer from being left alone after simple cleansing of the eye and lids and covering with a pad and bandage. In the Western Desert and North African campaigns in 1941, 1942 and 1943, delay in evacuation of casualties through the field ambulances and casualty clearing stations amounted in some instances to 5 to 12 days before the soldier with an injured eye reached an eye
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surgeon. It was remarkable to see many such eyes with little or no clinical evidence of inflammation.

However, in the case of intra-ocular foreign bodies prompt surgical attention is desirable in principle. Delay may allow the foreign body to become entangled in a collection of fibroblasts, and a mass of surrounding exudate, possibly infective, may jeopardise other intra-ocular tissues by trailing the foreign body in the course of its extraction.

An entry wound in the sclera may be difficult to find when it is only a millimetre or so long and has healed by the time the patient is seen. In military surgery a guide to its position may be given by a snick in the lid margin, a wound in the eyelids and the skin adjacent to the orbit. With the slit-lamp and corneal microscope, the bulbar conjunctiva is seen adherent and puckered at the site of the scleral wound. In grosser cases a small knuckle of herniated vitreous covered with young fibrous tissue and conjunctiva is sometimes evident.

The scleral wound may be behind the equator and the reflection of the bulbar conjunctiva and so will not be seen until Tenon’s capsule is opened in surgical exploration of the injured site. In such cases the lens is often clear, unless the foreign body has passed obliquely forwards and struck it, and so ophthalmoscopic examination will reveal the site of the entry wound unless this is obscured by a severe intra-ocular haemorrhage.

Aluminium and some non-magnetic alloys give rise to no apparent signs of irritation inside the eye and when small are best left alone. Larger non-magnetic foreign bodies causing visual obstruction and likely to cause intra-ocular inflammation may be removed by an instrument introduced into the eye when the foreign body can be seen by means of the ophthalmoscope and the instrument thus guided to it under view. Small fragments of glass and bakelite may remain quiescent in the eye for years but some, particularly when situated in the filtration angle or on the iris, cause irritation and require removal by forceps, blunt hook or scoop. Copper and stone cause rapid intra-ocular inflammation in most cases and evisceration becomes necessary. There are, however, some cases of soldiers who retained multiple minute particles of stone on the iris and in the cornea and sclera following a land mine or booby trap explosion whose eyes settled down after several weeks’ or months’ irritation and have remained quiet. Possibly the fragments were rendered sterile in the explosion and so are unlike those seen in civil injuries, which often become infected.

Important facts are the likely nature of the missile striking the eye, the force and direction from which it came, and the position of the patient’s head when the foreign body struck him. In war
wounds fragments of metal removed from other parts of the body are tested by a magnet and so afford useful information as to the probable character of the intra-ocular foreign body.

Localization of the intra-ocular foreign body

1. Ophthalmoscopic.—In 17 out of 102 cases of intra-ocular foreign bodies from war missiles in the Desert Campaign 1941-43, in 28 out of 72 cases in the fighting in France, Belgium and Germany 1944-45, the foreign body was seen by the ophthalmoscope. In 21 of the latter it was extracted by the posterior route (through the sclera), 19 by the giant electro-magnet and 2 by forceps under ophthalmoscopic control. Three were extracted by the anterior route. In the remainder the foreign bodies were non-magnetic. These were less than 0-5 mm. in most instances, showed no evidence of adjacent inflammation, and so were left.

The ophthalmoscope is also of great use, in cases where the media are clear and the foreign body can be seen in the vitreous, for finding out whether it is magnetic or not and the excursion it will make on application of the magnet terminal to the sclera at the nearest accessible point to it. If the foreign body reaches the retina on applying the magnet then it may be extracted through a scleral incision. In some cases, particularly those of very small foreign bodies, 0-25 mm. or less, the foreign body may move only a few millimetres in the vitreous and not reach the retina. In some such cases postural treatment and repeated applications of the magnet may eventually make it accessible for removal. In 8 instances the foreign body moved between 1 and 4 mm. and did not reach the retina, and in 6 of these it was extracted by the magnet after opening the sclera, choroid and retina.

It is important not to be misled by the floating movement of a small particle of a light metal suspended in the vitreous which alters its position with movements of the eye on changing the position of the head. Before applying the magnet the position of the foreign body should be carefully noted for this may be different in the lying and sitting positions. The magnetic movement is quite unmistakable, it is a sudden jerk towards the magnet.

2. Radiographic.—Radiographic localisation of an intra-ocular foreign body is essential in every case of injury due to war missile even though the foreign body is evident on ophthalmoscopic examination, for X-rays may reveal the presence of other foreign bodies. It is, however, not an infallible test for in a number of cases X-rays failed to reveal small foreign bodies of less than 1 mm. which were seen with the ophthalmoscope, were magnetic and extracted through the scleral route.

There are about 30 methods of X-ray localisation of intra-ocular
foreign bodies. These have been classified into 6 groups in Vol. III of "A Textbook of X-ray Diagnosis" by British Authors and also are fully described in "La Radiographie en Ophtalmologie" by E. Hartmann.

Perfection in the radiographic localisation of an intra-ocular foreign body has not yet been reached. The technique selected often depends upon the nature of the case and the apparatus available.

Under ideal conditions there should be a device for keeping the head absolutely immobile, the provision of an occipital rest and a horse-shoe shaped bar covered with soft dental stent wax for the patient to bite achieves this purpose. Immobility of the eye during exposure to X-rays is effected by the provision of a suitable target, such as a black cross on a white background for the patient to look at. Several such targets are necessary when views are taken of the eye looking in front, up, down, to the nasal and temporal side. The patient is more comfortable either lying on his back or sitting up. Some positions such as lying face downwards and looking into a mirror at close range (Comberg's technique) are awkward and painful. Multiple wounds necessitate the dorsal position and the radiographic technique must be arranged accordingly.

The more elaborate and expensive instruments such as those devised by Sweet and Dixon have a radio-opaque indicator mounted at a known distance (10 mm.) from the centre of the cornea. Additional aids in other procedures where simple apparatus only is available are the attachment of radio-opaque markers to the surface of the eye; these, such as little silver clips or hooks, may be inserted into the conjunctiva or sewn into place such as the limbal ring described below. Skeoch's scleral ring and the corneo-scleral contact glass with either radio-opaque dots or a ring as used by Comberg and Wessely are placed free in the conjunctival sac. The disadvantage of the attachment of either clips or a limbal ring is that a surgical procedure is necessary to effect this. Skeoch's scleral ring and the contact glass are both liable to slip out of position and tilting and moving of these devices is appreciable when the eye is turned in different directions. An error in localisation is likely to occur in such cases. An opaque marker may obscure an intra-ocular foreign body in the antero-posterior view but the latter will be evident in the lateral view. The various methods employed in the localisation of an intra-ocular foreign body may be classified according to the main principle in the technique. These are six.

(1) Physiological.—In this method the head is fixed and the eyes are moved in prescribed directions. Some useful information may be obtained by calculations of the movement of a foreign body
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on movement of the eye. Two to four exposures may be made on the same film, the patient being directed to look up, down, to the nasal and temporal sides. The eye is sub-divided into 4 quadrants in front of the equator and 4 behind it. The movement of the foreign body will be with the eye in the anterior quadrants, and against it in the posterior quadrants. The centre of rotation of the eye is never a fixed point so that the theoretical assumption that a foreign body at this point would not move does not hold. The surgeon is chiefly interested in the relation of the foreign body to the sclera.

Belot and Fraudet centre the X-ray tube at a point they judge to be the centre of rotation of the eye and take three lateral views looking up, in front and down, and three anterior views looking in front, nasally and temporally.

The difficulties in this method of localisation lie in centring the X-ray tube accurately and in keeping the patient's head absolutely still during the movements of his eyes.

If the foreign body is well clear of the eye in the orbital tissues there is no movement. Displacement sometimes occurs in the orbital fat, a heavy foreign body such as a lead pellet being pressed to another position when the eye is moved.

Movement of an extra-ocular foreign body may also occur when it is situated in Tenon's capsule, an extra-ocular muscle and in the optic nerve. When it is in the bulbar conjunctiva it will of course move but it is visible unless obscured by a subconjunctival haemorrhage. Foreign bodies in the lids also move.

In war injuries the multiplicity of foreign bodies in the orbit make an accurate diagnosis of the number and site of those in the eye very difficult.

(2) Geometric.—In this method the head and the eye are immobile, the X-ray tube is moved and views are taken from several known angles with a radio-opaque indicator 10 mm. in front of the centre of the cornea. The calculations are plotted on a chart. Sweet and Dixon use this technique and probably it is the most accurate of all methods. The apparatus is elaborate and expensive, only a few hospitals possess it and it was never available in field medical units in a theatre of war.

Kraus and Briggs claim greater accuracy with their apparatus than any other, the essentials of which are (1) head rest with clamping devices for immobilisation of the head, (2) attached to the forehead cross-bar is a small unit designed to work to fine adjustment and carrying indicators which may be moved laterally, up and down and to and from the eye. These indicators are made partly of radio-opaque and partly of non-radio-opaque materials; (3) X-ray cassette holders and perimeter with spot-light.

The indicator, axis of the eye and centre of the X-ray tube must
be in one straight line. The tube (central ray) must not be tilted or distortion will occur. The best anode to indicator distance is probably one metre, at which the magnification will be negligible (1 : 20). Exposure depends on the X-ray apparatus used. For each exposure one of the indicators is placed in contact with the cornea at the centre of the pupil and the scale attached to it will show any magnification.

The calculation of the site of the foreign body is a complicated geometric problem and Stern comments that in this instance it is fallacious and that the simpler limbal ring method gives as accurate results.

(3) **Stereoscopic.**—The principle is the same as the geometric method. One exposure is made with the head in the prone position and inclined toward the affected eye so that the X-ray tube aimed at an angle tangential to the lateral orbital margin may obtain one exposure with the minimum of bone shadow. Another view is taken laterally with a contact glass and radio-opaque ring embedded at the limbus, then 3 successive photographs on 3 different films taken of the eye looking up, in front and down.

This method does not give precise measurements of the distance of the foreign body from the ocular tunics.

(4) **"Simple."**—Hartmann includes in this group X-ray measures which use a radio-opaque marker in contact with or close to the eye and require only simple X-ray apparatus. The circumstances of military surgery in the field necessitate the employment of such methods, for neither elaborate apparatus nor radiologists experienced in this special work are available.

It is therefore imperative to have some simple procedure which may be done expeditiously by the eye surgeon and the X-ray department staff operating under crude conditions in a tent.

A brief account of some of the radio-opaque markers has been given above. Of these the limbal ring, Comberg's and Wessely's contact lenses and Skeoch's scleral rings are worthy of mention. The chief advantage of these devices is that by their close contact with the eye they afford greater accuracy in measuring the distance of the foreign body from the known point where they lie against the eye.

The movement of Comberg's and Wessely's contact glasses containing 4 radio-opaque dots or a ring at the limbus and the tilting of Skeoch's scleral ring are causes of inaccurate calculations. Efforts have been made to secure immobility of the marker by suturing it to the conjunctiva. Thorpe (H. E.) had Comberg's contact lens drilled with 4 holes, 3 of these were placed near the periphery of the scleral part of the glass at 3, 6, and 9 o'clock respectively for the purpose of suturing to the bulbar conjunctiva. He made also a fourth hole at the limbus in the 1.30 o'clock
meridian so that air could reach the cornea. The bulbar conjunctiva more than 3 mm. from the limbus is mobile so that suturing here does not give absolute immobility to a contact glass.

Another authority has fashioned a projecting boss from the centre of the corneal part of the contact glass so that by seizing this with forceps he may adjust the position of the glass with the opaque limbal ring directly over the limbus immediately before X-ray exposure.

Yazujiam's combined limbal and scleral ring, is I think unnecessarily elaborate. It consists of the limbal ring of 12 mm. inside diameter, joined by 4 radiating bars of 6 mm. length with the scleral ring which has 22 mm. inside diameter and 24 mm. outside diameter. The cross bars may obscure the foreign body in both the lateral and antero-posterior views.

Skeoch's ring is made of stainless steel dental wire gauge 30 and welded with a lead bead. There are 3 sizes of internal diameter 24, 25 and 26 mm. respectively. The ring is slid into the upper and lower fornices with the lead bead just above the caruncle. The equatorial fit is checked by directing the patient to look to the right and then to the left.

Three X-rays are taken (1) lateral (2) oblique lateral. The ring tilts and the eye moves twice as far as the ring. (3) poster-o-anterior. The lead bead and ring afford shadows against which the density of the foreign body is compared.

The limbal ring.—Of all these marking devices the limbal ring, described by A. C. Norman in 1915, gives results which are reasonably accurate and of practical value in the majority of cases. The rings are made of silver wire 1 mm. in diameter and sizes varying in the internal diameter of the ring from 9 to 13 mm. are used. The ring which exactly fits the limbus is chosen and its immobility on the eye is assured by suturing it at 9, 12 and 3 o'clock to the conjunctiva at the limbus. For 3 mm. or so behind the limbus the bulbar conjunctiva is firmly attached to the episcleral tissues and does not ride easily over the sclera as is the case with the bulbar conjunctiva behind this zone.

A refinement which is, I think, helpful in the orientation of the eye is to fuse to the limbal ring 3 small silver loops at 9, 12 and 3 o'clock for the passage of the suture and the marking of these meridia, any deviation of which would be noted in the X-ray film and allowed for in assessing the meridian in which the foreign body lies. The technique is as follows:—

The eye is anaesthetized with pantocaine, and when much inflamed 2 or 3 minims of novutox are injected into the episcleral tissues at the limbus at 12, 9, and 3 o'clock. A silver ring of 1 mm. thickness and of a size chosen to fit exactly the corneo-scleral junction is stitched in position by sutures of 00 silk passing
through the conjunctiva at 12, 9 and 3 o'clock respectively. A drop of oil, paraloein is instilled into the eye and a pad moistened in the oil is applied to the closed lids and bandaged in position. When possible the patient sits during X-ray examination. In some cases other wounds prevent this. During the first exposure he is directed to look with his uncovered eye forward, and for the second to look downward. For this purpose conspicuous marks such as red crosses or lights 5 cm. in diameter are placed on the wall for a sitting patient and on the ceiling for lying cases at the two points in which fixation of the eye is necessary during exposure. Each exposure is half the normal. To obtain a postero-anterior view of the orbit free from the dense shadow of the petrous part of the temporal bone the head is tilted slightly so that the occiput is down and the face up; the petrous shadow then falls over the antra. In an accurate postero-anterior radiograph the silver ring shows as a perfect circle; and in the lateral as a linear shadow. To obtain a perfect linear shadow in the first position of the lateral view Captain V. Lees, R.A.M.C., suggested that a mirror be attached to the X-ray apparatus in front of the unaffected eye and exactly at right angles to the X-ray cassette holder. The patient is directed to look at the reflection of his eye in the mirror.

**Interpretation of radiographs.**—The diameter of the silver ring is known and its measurement is checked on the X-ray film. Any radiographic magnification is noted. This has never been more than 1 mm., and when present allowance must be made for this fact. When an anode film distance of 30 inches or more is used parallactic magnification of the ring is negligible, and a schematic eye of 24 mm. drawn on the film is accurate enough. In the lateral view a line is drawn posteriorly from the centre of the ring and at right angles to it for about 22 mm. The upper and lower limit of the ring is used in turn as the centre of a circle whose radius is 12 mm. (*i.e.*, half the average length of an eye 24 mm.); with a pair of dividers set at 12 mm. the horizontal line is intersected by arcs described from the above centres. The point of intersection on the horizontal line is now taken as the centre of a circle with 12 mm. radius and this is described on the radiograph. A similar procedure may be done with the silver ring in the second position, that is, looking down. Likewise in the postero-anterior view a circle of 12 mm. radius is described around the centre of the silver ring. The ring is known to be at the limbus and so measurements may be taken from this on both the postero-anterior and the lateral radiographs.

Movement of the foreign body is the essential diagnostic feature. If the relationship of the silver ring image to the foreign body is unaltered in the first and second positions it may be presumed that the foreign body is moving with the eye. The radiographs with
the schematic eye marked upon them will indicate also the position of the object with regard to the centre of rotation. If the foreign body is in front of this it will apparently move with the ring, if behind against it—that is, a foreign body in the posterior half of the eye will lie at a higher level in the second position where the ring has rotated downwards.

The shadow of the foreign body might fall within the circles described and yet be outside the eye. The point is settled by the movement of the foreign body, which is generally absent when it is extra-ocular. There is, however, an exception to this in the case of a foreign body in Tenon’s capsule, where slight movement may take place, but this is rarely as great as in the case of an intra-ocular foreign body. In such cases, therefore, if the foreign body shows a new relationship to the ring in the second position it is probably outside the eye. When the foreign body is clearly outside the limits of the circles described then it is certainly extra-ocular. The size of the foreign body is carefully measured on the radiograph. This will determine the length of the scleral incision necessary for its extraction.

Ahlbom’s method is also good and simple. A circle of 26 mm. diameter is placed in front of and projected on to the eye. He uses teleradiography. The distance between the anti-cathode and the film is 275 m. and the projection is practically cylindrical and the error in magnification so slight that it can be neglected. To show very small foreign bodies he uses an aluminium disc between the occiput and the cassette and also employs the “bone free” technique.

(5) “Bone-free” (Sans squelette).—The osseous shadows of the orbital walls and floor of the skull sometimes obscure the presence of small intra-ocular foreign bodies particularly fragments of 0·5 mm., and even 1 mm. when the material of the foreign body is of a kind which does not give a dense shadow.

“Bone-free” exposures of the eye anterior to the equator may be obtained by turning the head partly to the side away from the affected eye and placing the X-ray tube at a tangent to the lateral orbital margin and the film at the inner canthus.

This procedure although helpful in difficult cases has its limitations.

(6) Injections into Tenon’s capsule.—Efforts have been made to outline the sclera by the injections of radio-opaque substances into Tenon’s capsule.

Air has been used. In some cases it remains for a day or two and has had to be sucked out. There is an instance recorded in the literature of the death of a rabbit from air embolism after injection into Tenon’s capsule. Lipiodol has been used, and in the United States, diotrast.
Pirie has described the "subjective" method of localisation in a dark-adapted patient, the retina being stimulated by X-rays the shadow of the foreign body is projected. The fallacies of this procedure are that a retinal injury, such as the site of ricochet of the foreign body will produce a shadow and the shadow of the foreign body may fall upon the blind spot.

Biplane fluoroscopy is difficult and liable to inaccuracies and Thorpe's endoscope is a traumatic approach to localisation of an intra-ocular foreign body which is not justifiable in most cases.

Locators

In 1851 Aveling used a magnetised needle for the detection of the site of a steel foreign body such as a needle embedded in the soft parts of the body. The needle dipped and adhered to the skin at the exact point under which the foreign body lay.

Pooley and Pagenstecher in 1880 and 1881 working independently devised an apparatus also based on the principles of magnetic localisation. Their experiments showed that the depth of the foreign body might be inferred from the degree of deflection of the magnetised needle and a change in the position of the foreign body after the application of the magnet may be ascertained.

In 1894 Asmus added a mirror to such an apparatus to reflect the excursions of the magnetic needle on to a scale. Berman's locator described by Minsky (1944) is a rod in which are placed the equivalent of two transformers, one in the handle and the other at the tip, which is used to search for the foreign body. The primary coils are connected in series to a source of alternating current. Also in series, the secondary coils are connected through an amplifying unit to a voltmeter. When an alternating current is sent through the primary coils, a current is produced in the secondary coils by induction. The instrument has a means of equalising (balancing out) the voltages in the secondary coils so that the needle of the voltmeter will read approximately zero, since no current flows between them. If the coil in the tip of the rod approaches a magnetic metal (the foreign body), the balanced inductance is disturbed and a difference in potential takes place in the secondary circuit, which results in a flow of current. The amount of this current, shown by the deflection of the needle in the voltmeter, varies with the size of the metallic particle and with its distance from the tip. At the greatest point of deflection, therefore, the tip of the locator is immediately over the foreign body. Conversely, as the locator travels away from the foreign body, the deflection of the needle is lessened. Minsky states that he can estimate the depth of a foreign body, if its size and composition are known, by determining the distance necessary to give the
same reading, with the controls unchanged, in approaching a similar piece of metal. The instrument responds best to iron and steel, and less effectively to copper, brass, silver, aluminium, lead and their combinations. The differentiation of a non-magnetic from a magnetic foreign body is easily made when the needle of the voltmeter does not move at all.

Magnets

The best magnet is, I think, one shaped like a 6-inch shell with screw-in straight terminals; some are short and conical and others long and attenuated and about 2 to 3 mm. in diameter at the tip, the latter are more accurate and easily manipulated than the former which give a more diffuse field and may attract the foreign body to the side of the cone. This magnet is suspended over the head of the operating table. It should be so perfectly counter-balanced that the slightest move or tilt leaves it in place. The magnet itself should be so fitted on a ball-bearing setting that it may be tilted and turned easily to any angle, and fixed so by a clamp. A foot-switch is controlled by the surgeon to make and break the electric current. The patient’s head is immobilized between sandbags and covered with a dark green linen mask with an aperture for the eye to be operated on. The main body of the magnet is enclosed in a sterile dark green linen sleeve. The magnet terminals are sterilized in A.C.10, rinsed in saline, dried with a sterile cloth before being screwed into the socket at the end of the magnet.

The advantage of this magnet is that the terminal tip may be applied with greater precision and kept so as long as necessary. Also it permits ophthalmoscopic examination of a vitreous foreign body by the surgeon to ascertain the magnetic nature or not of the foreign body.

Such a magnet is obviously desirable in military surgery where multiple wounds are present and on account of these the patient must lie on the table. It is even so in civil injuries when the eye alone is affected.

Solus Magnet. This has been used in military surgery, particularly in eye units operating in the field. It was intended for use as a portable magnet, and supplied with a strap for slinging over the shoulder of a medical orderly. The orderly has great difficulty in maintaining the end of the magnet at the desired site, and this procedure is technically unsatisfactory. Lt.-Colonel A. Lister effected a considerable improvement in this respect by mounting the magnet on a portable X-ray stand (Fig. 1).

On the upright of the stand there is a rachet adjustment to lower the tip of the magnet to the eye. As the movement of this is somewhat coarse I found it best to stop when the tip of the terminal was
2 or 3 mm. from the cornea or sclera and then by gradually raising the operating table the magnet terminal could be brought into contact with the cornea or into the lips of a scleral wound.

An improvement could be effected in this magnet by making the collar and framework holding the magnet of non-magnetisable metal and providing a clamping device to keep the magnet fixed for, when placed in an oblique position, it kicked.

Fig. 2 shows another type of counter-balanced magnet set in a hinged frame. The magnet is swung over the head of the operating table and held inclined at an appropriate angle.

The force inside the ring of Mellinger's magnet—that is, the operative field—is homogeneous all over. There is no preferred point of force and no dispersion of lines of force in the operative zone. It is possible to make with Mellinger's magnet terminals more delicate manipulations than with Haab's magnet.

The terminal held in the surgeon's hand must never be introduced into the operative field without the current having been switched on. The danger of placing the terminal inside the ring and then turning on the current is that it may become dragged suddenly on to the eye.
Mellinger's magnet has several disadvantages. The patient complains of an oppressive and confined feeling when his head is within the ring. The surgeon has often to exert considerable manual strength to hold still the magnet terminal in the magnetic field. If this is protracted it may impair slightly the steadiness of his fingers for subsequent stages in the operation. It is sometimes difficult to tie the scleral suture with the head inside the ring after extraction of a foreign body by the scleral route. In such cases the ring has to be swung clear of the head before this stitch can be tied, thus causing a short delay in closing the wound.

It is most important not to assume that because the application of the magnet causes no pain in the eye the foreign body is therefore non-magnetic. Had I believed this I would have lost 20 foreign bodies in the M.E.F. series of 102 cases and 19 in the B.L.A. series of 72. All gave rise to no pain on testing, and all (39) were extracted by the giant magnet, 36 by the scleral route and 3 by the anterior route.

The low magnetic quality of certain foreign bodies will be increased when placed in the field of a giant electro-magnet, but only to a certain extent, saturation being reached very quickly. For this reason many applications of the magnet are unnecessary for when this is done heat is generated in the wiring and the pulling power of the magnet becomes less. I have extracted a small magnetic foreign body on the fourth application of the magnet.
Kraus and Briggs recommend up to 50 applications for 2 seconds duration at 2 seconds interval. They comment that if it is not extracted with 50 applications it is useless to go on.

In one case in the B.L.A. series—Pt. J.—a metallic foreign body 10 x 4 x 3 mm. entered the sclera in the upper temporal quadrant of the right eye in front of the equator. The foreign body traversed the vitreous and part of it had perforated the sclera about the equator and beneath the internal rectus muscle. When the magnet terminal was placed over the wound on the temporal side the eyeball rotated temporally. The scleral wound on the temporal side was closed by sutures and covered with a conjunctival flap. The internal rectus muscle was then exposed, mattress sutures inserted in the muscle belly and its tendon divided. Diathermy was applied around the scleral wound through which part of the foreign body was projecting. Three scleral sutures were inserted on either side of the projecting part of the foreign body, the scleral wound was enlarged and the foreign body extracted by the magnet.

In one case of traumatic cataract when a magnetic foreign body 0.25 mm. was brought forward by the anterior route it became arrested in a fold of the torn lens capsule and would move no further. It was extracted by Arruga's forceps passed through a keratome section.

**Surgical exploration**

In some cases where it is doubtful from the radiographs whether the foreign body is just inside the eye, impacted in the sclera or in Tenon's capsule surgical exploration is indicated. The diathermy apparatus and the instruments necessary for incising the sclera and extracting the foreign body by a giant electro-magnet are available.

A tongue-shaped flap of conjunctiva and Tenon's capsule convex towards the limbus is cut and reflected posteriorly on its base, the axis of the flap being in line with the site of the foreign body and its apex 7 mm. or more in front of the site of the foreign body. The flap is held reflected by two sutures of 00 black silk clamped to the head towels.

Tenon's capsule is dissected from the sclera with a few strokes of a small muslin swab held in forceps. Adhesions of Tenon's capsule to the sclera, bands and nodules of fibrous tissue are guides to the site of the foreign body. The sclera is dimpled where it is cut tangentially or penetrated by the foreign body. The foreign body may be found inside a fibrous nodule on the sclera or it may be partly embedded and transfixing this structure. If the foreign body has passed into the eye the entry wound is circumvallated with diathermy and the sclera opened between sutures taking
care not to press the foreign body into the vitreous as it lies in the choroid or deeper layers of the sclera. Extraction is effected either by forceps or the electro-magnet. After closure of the scleral wound penicillin powder is lightly dusted in its vicinity and the conjunctival flap sutured with a continuous key pattern stitch.

**Operation**

The scleral (posterior) route was used in 45 cases in this series. In 37 of these the foreign body was extracted, in one it was removed with special forceps, and in the remaining 7 the foreign body was not attracted to the tip of the magnet. I have a feeling that in some of these with a better magnet and more accurate X-ray localisation the foreign body might have been extracted. Most of the cases in which the foreign body was not extracted occurred at a time when conditions were particularly crude and the field electrical generating set full of vagaries and inconsistent in its behaviour. The technique of the posterior route is fully described in the account of the M.E.F. series of 102 cases (*Brit. Jl. Ophthal.*, Vol. XXVIII, p. 105, 1944).

Technical essentials are a tongue-shaped conjunctival flap convex anteriorly, the application of diathermy to the site on the sclera nearest to the foreign body and over an area of sufficient length to cover an antero-posterior linear incision 1 mm. longer than the greatest diameter of the foreign body, the insertion of a mattress scleral suture on either side of the scleral incision when about two-thirds of the thickness of the sclera had been cut through, and turning the head and operated eye so that the scleral wound lies uppermost before incising the choroid. The latter point is important in the prevention of vitreous presentation in the scleral wound. In no case was any vitreous lost. Nor did the diathermized area of the choroid and retina embarrass the extraction of a foreign body. Some surgeons believe that the foreign body may become entangled in the coagulum and so circumvallate the scleral incision with diathermy, leaving the area of incision untreated.

It was necessary to introduce the tip of the giant electro-magnet terminal into the lips of the wound so that its point touched the face of the vitreous but did not enter it. This was done by fine adjustment in the height of the magnet terminal.

The scleral suture was tied immediately after extraction of the foreign body and penicillin powder was lightly dusted into the wound.

Fifteen foreign bodies were extracted by the anterior route, 13 of them by the magnet and 2 by forceps.

In 12 instances there was no movement of the foreign body on applying the giant electro-magnet.
In some cases the foreign bodies were 0·5 mm. in size and impacted in the lens where they had produced a localised opacity near the equator and no appreciable visual disturbance. In these it was probable that they were magnetic for similar fragments removed from the face were so. It was decided to leave the fragments alone and to review the eye from time to time. It was undesirable to draw these through the lens capsule, and in any case it was improbable whether a magnet terminal placed on the cornea would have moved such minute particles of an alloy.

I do not believe that the bogey of retinal detachment after the scleral route extraction is any more probable and indeed less so than the risk of vitreous loss which is also quoted as a contra-indication to the scleral route method of extracting intra-ocular foreign bodies. With careful technique neither of these serious events is likely to happen.

If a retinal detachment occurs as a sequel to a foreign body it is due to the nature of the penetrating wound and the pathological changes this has caused inside the eye rather than any operative intervention of a careful and properly planned character.

**Cases**

Table D gives the units to which the wounded and injured men belonged. As might be expected the infantry and armoured troops were prominent in the battle casualties and R.E.M.E. and R.A.S.C. in accidental injuries in field workshops.

Table E shows the type of missile which penetrated and was inside the eye in the two groups of casualties (1) battle and (2) accidental.

It will be seen from this table that as in the M.E.F. series shell fragments accounted for the largest number of eye wounds with retained intra-ocular foreign body. Land-mine injuries were next common whereas in the M.E.F. series these were third in the order of frequency, hand grenade wounds being second. In Normandy the orchards and verges of the roads were heavily mined. The "shoe" mine was particularly difficult to detect. The charge was encased in a wooden box, a trip wire projected above the surface of the ground and was difficult to see. Soldiers walking or running over such mines often had a foot blown off, the line of traumatic amputation being at the ankle, and had an injury to an eye. In the case of one officer a fragment of the rubber boot which covered his amputated foot was blown into his right orbit and lay on the sclera, producing a severe concussion of the intra-ocular membranes on the temporal side.

There was a higher incidence of eye injuries from fragments of machine-gun bullet casing than in the M.E.F. series. This may
have been due to the severe fighting at close quarters in villages (Tilley, Villers-Bocage, Hottot, Caumont and others) where machine and Sten gun fire was used liberally in house to house attacks, fragments of bullet casing produced by ricochets spattered the exposed faces of the combatants.

### Table D

<table>
<thead>
<tr>
<th>Unit</th>
<th>Battle Casualty</th>
<th>Accident</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>British Infantry</td>
<td>21</td>
<td>1</td>
<td>22</td>
</tr>
<tr>
<td>Canadian Infantry</td>
<td>5</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>R.A.C.</td>
<td>7</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>Canadian Armour</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>R.A.</td>
<td>3</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>R.E.</td>
<td>3</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>R.E.M.E.</td>
<td>3</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>R.A.S.C.</td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Royal Marines</td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>R.A.F.</td>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>U.S. Engineers</td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Polish Infantry</td>
<td>5</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Polish Armour</td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Polish Medical Corps</td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Dutch Infantry</td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Yugo-Slav Infantry</td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>German Infantry</td>
<td>4</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>German Navy</td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>60</strong></td>
<td><strong>12</strong></td>
<td><strong>72</strong></td>
</tr>
</tbody>
</table>
### Table E

<table>
<thead>
<tr>
<th>Missile</th>
<th>Battle Casualty</th>
<th>Accident</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shell</td>
<td>...</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>Hand Grenade</td>
<td>...</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Machine gun bullet casing</td>
<td>8</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>Land mine</td>
<td>...</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Booby trap</td>
<td>...</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Mortar bomb</td>
<td>...</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Bazooka bomb</td>
<td>...</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Aerial bomb</td>
<td>...</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Phosphorus bomb</td>
<td>...</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Hammer and chisel</td>
<td>...</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Tank track</td>
<td>...</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Glass</td>
<td>...</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>...</td>
<td>60</td>
<td>12</td>
</tr>
</tbody>
</table>

In the attack on Caen the German mortar fire was exceedingly heavy and so were the British casualties. Booby-traps were left in the breaches of abandoned German weapons and in vehicles and houses. The "bazooka" bomb was used against the armoured units and casualties from this missile also occurred in the infantry and engineers.

In the Western Desert Campaign we believed that an improved steel helmet of the German coal-scuttle pattern with side-pieces protecting the temporal region on each side would have saved a number of penetrating wounds of the sclera. There is no doubt that the number of serious head injuries would have been appreciably reduced. N.C.O.'s ordered the men to tighten the lace inside the British steel hat. This procedure raised it an inch or more on the head and so increased the exposure of the temporal fossa and the lateral side of the orbits.
THE INTRA-OCULAR FOREIGN BODY

As in the Western Desert engineers clearing mine-fields did not or would not wear a protective device over their eyes. Many severe injuries of both eyes from blast, burning and the spatter of gun-powder, earth and stone fragments could have been prevented by wearing thick salvoc goggles. Later in the campaign the eye pieces of captured German respirators were used to good prophylactic advantage.

The hammer and chisel provided the highest incidence of accidental penetrating wounds with retention of an intra-ocular foreign body.

Evacuation of wounded

In Normandy the tented field hospitals were about 8 miles behind the line during the battles for Caen and Caumont. We operated most of the time as a Casualty Clearing Station. The wounded came to us from the field and generally reached us within a few hours, or at the most within a day, of being hit. We could not hold them for more than a few days and as soon as they were fit to travel they were evacuated either by air or sea to the United Kingdom. At times it was possible to keep some patients until the injured eye was out of immediate danger. At first the conditions of work were crude, operating tables stood at odd angles on an uneven field, water was limited to one enamel bowl shared by four surgeons and changed once every two hours, gloves and gowns were reserved for intra-abdominal work, fitful illumination depended on the vagaries of a field generating set, primus stove sterilizers had irregular habits and unseasoned theatre orderlies slowed down the rate of dealing with a large number of casualties.

It was surprising how quickly matters improved, and efficiency and good order became established.

I do not think that any eye casualty suffered from an operation under these conditions and during the 10 weeks we worked thus all the eyes which received conservative surgical attention settled down well after operation, none became infected and in none did removal of the eye seem likely to be necessary at a later date. This was just the fortune of war.

After the break-through at Falaise and the advance across the Seine, Picardy and Flanders I was transferred to the 108 (General) Hospital (2,000 beds) which was working on the outskirts of Brussels in a bottle-neck on the line of evacuation of casualties. Here in a separate pavilion there were 90 ophthalmic beds, treatment rooms and operating theatre suite. The volume of work was immense and until the lull that followed von Rundstedt's advance in the Ardennes we operated as a C.C.S. I was, however, allowed at times to hold seriously wounded eye cases for 2 or 3 weeks and
this was so after the Rhine crossing and until the end of the war in Europe.

In May, June and July, 1945, repatriated prisoners of war of many European nationalities, "displaced persons" and enemy prisoners required surgical attention for neglected wounds and were held until fit for discharge from hospital.

Clinical Facts

An enquiry was made about the distance of the explosion from the soldier. Whilst the majority of wounded were able to assess this some were unable to appreciate which of many missiles bursting near them caused the wound.

One man was wounded by an aerial bomb explosion 200 yards away whilst he was lying down and in 7 per cent. of shell wounds this missile burst more than 20 yards from the soldier. The majority were within this range.

Fifty per cent. of grenades and 34 per cent. of mines and booby traps exploded within a yard of the soldier.

The men were asked their position when hit and the direction from which the missile came. In some, but not all cases, such information was helpful.

Size of the missiles.

<table>
<thead>
<tr>
<th>Maximum diameter</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>less than 1 mm.</td>
<td>...</td>
</tr>
<tr>
<td>1 to 2 mm.</td>
<td>...</td>
</tr>
<tr>
<td>2 to 3 mm.</td>
<td>...</td>
</tr>
<tr>
<td>3 to 4 mm.</td>
<td>...</td>
</tr>
<tr>
<td>4 to 5 mm.</td>
<td>...</td>
</tr>
<tr>
<td>5 to 6 mm.</td>
<td>...</td>
</tr>
<tr>
<td>6 to 7 mm.</td>
<td>...</td>
</tr>
<tr>
<td>7 to 8 mm.</td>
<td>...</td>
</tr>
<tr>
<td>10 mm.</td>
<td>...</td>
</tr>
<tr>
<td>11 mm.</td>
<td>...</td>
</tr>
</tbody>
</table>

There were 6 cases of multiple foreign bodies in the eye and in 3 of these all the foreign bodies were removed by a single operation through the scleral (posterior) route. In the fourth case the foreign bodies were not magnetic. In one case there were two foreign bodies in the vitreous measuring 4 x 2-5 x 1 mm. and 4 x 1 x 1 mm. respectively; in another case 3 foreign bodies all measuring 0-5 x 0-5 mm., the third case 2 foreign bodies 1 x 1 mm. and 1 x 1 mm., the fourth 2 foreign bodies 5 x 4 mm. and 2-5 x 1 mm., the fifth 2 foreign bodies 3 x 0-5 and 0-25 x 0-25 mm. and the sixth 2 foreign bodies less than 0-25 mm. both situated in the lens cortex.
THE INTRA-OCULAR FOREIGN BODY

As in the M.E.F. series foreign bodies between 2 to 3 mm. in their maximum diameter were common and the majority were under 3 mm.

Age incidence.

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>18 to 19 years</td>
<td>3</td>
</tr>
<tr>
<td>20 to 30 years</td>
<td>57</td>
</tr>
<tr>
<td>31 to 40 years</td>
<td>8</td>
</tr>
<tr>
<td>Over 40 years</td>
<td>4</td>
</tr>
</tbody>
</table>

Eye affected.

<table>
<thead>
<tr>
<th>Eye</th>
<th>Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right</td>
<td>35</td>
</tr>
<tr>
<td>Left</td>
<td>27</td>
</tr>
<tr>
<td>Both</td>
<td>10</td>
</tr>
</tbody>
</table>

Site of penetrating wound.

(1) Through the cornea.

- Upper temporal quadrant: 5
- Upper nasal quadrant: 6
- Mid-line between these quadrants: 3
- Centre of cornea: 2
- Corneo-scleral junction on nasal side: 1
- Lower nasal quadrant: 6
- Lower temporal quadrant: 11
- Mid-line between these quadrants: 2

(2) Through the sclera.

- Upper temporal quadrant: 10
- Upper nasal quadrant: 4
- Mid-line between upper and lower nasal quadrants: 1
- Lower nasal quadrant: 6
- Lower temporal quadrant: 5

(3) Multiple—2. In one of these two penetrating wounds were in the lower nasal quadrant of the sclera and in the other there were three wounds in the cornea, 2 in the lower nasal and 1 in the upper temporal quadrant of this structure.

(4) Wound of entry not seen—9. In the majority of these exploration showed that the foreign body had entered the orbit and penetrated the sclera behind the reflection of the bulbar conjunctiva.

In this, the B.L.A. series it is evident that the site of the penetrating wound was commoner on the temporal side than the nasal, both in the cornea and the sclera, whereas in the M.E.F. series there was a high incidence of wounds in the nasal half of the cornea, particularly the lower nasal quadrant, and in the lower quadrants of the sclera.
Uveal Prolapse—7 cases. The nature and size of the missiles which caused the penetrating wound and prolapse is set out below.

Iris.

Shell
- 3 x 1.25 x 0.75 mm. ... ... ... ... 1
- 5 x 4.5 x 1.5 mm. ... ... ... ... 1
- 2 x 1.25 x 0.25 mm. ... ... ... ... 1
- 3 x 2 x 0.25 mm. ... ... ... ... 1

Iris and Ciliary Body.

Phosphorus bomb
- 6 x 4 x 0.5 mm. ... ... ... ... 1

Land-mine
- 10 x 4 x 3 mm. ... ... ... ... 1

Ciliary Body.

Bullet casing
- 2 fragments 5 x 4 and 2.5 x 1 mm. ... 1

Choroid.

Aerial bomb
- 2.5 x 1.75 mm. ... ... ... ... 1

The two eyes in which there was prolapse of the ciliary body from a large fragment which traversed the vitreous and stuck partly through the sclera on the opposite side of the globe became quiescent for a few weeks but ultimately required excision. The others were saved.

Traumatic cataract.—34 cases. In 24 of the 34 cases the penetrating wound was in the cornea. In 7 of these the damage to the lens was slight. The size of the intra-ocular foreign body in these cases varied from 0.12 to 1.5 x 1 x 0.25 mm. In one instance it was 0.12 mm. and in another there were 2 fragments of aluminium alloy about 0.25 x 0.25 mm. deep in the lens.

The ultimate visual result in these cases was on the whole good. Two had 6/6 vision, one 6/9, another 6/24 before leaving hospital and no information about the others was forthcoming from the hospitals to which they were evacuated in the United Kingdom.

The remaining 17 cases had severe damage to the lens.

In 6 instances the lens was damaged where the foreign body passed through the sclera. Two of these showed a slight degree of cataract and in 4 it was severe.

The wound was not seen in 3 cases of traumatic cataract and cataract was bilateral in one case, one eye had a scleral wound and in the other eye the wound was not seen.

Vitreous haemorrhage.—The incidence of vitreous haemorrhage in the B.L.A. series was 44.4 per cent., that in the M.E.F. 48 per cent. and the proportion of slight and severe cases was nearly alike in the two series, the severe cases being slightly more in the B.L.A. casualties. Table H shows the incidence of slight and severe vitreous haemorrhage in relation to a corneal or scleral penetrating wound.
The intra-ocular foreign body

Table H

<table>
<thead>
<tr>
<th>Vitreous Haemorrhage</th>
<th>Corneal wound</th>
<th>Scleral wound</th>
<th>Wound not seen</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slight</td>
<td>...</td>
<td>4</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Severe</td>
<td>...</td>
<td>3</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>...</td>
<td>7</td>
<td>23</td>
<td>2</td>
</tr>
</tbody>
</table>

As might be expected, severe vitreous haemorrhage occurred when the site of the entry wound was near the exit of a vena vorticosa, in the line of a long ciliary artery and in some cases when it traversed obliquely the pars plicata of the ciliary body. In such cases the sizes of the foreign bodies were from 2.5 to 6 mm. in their longest diameter.

Vitreous prolapse.

On arrival at hospital vitreous prolapse was present in 5 cases. In 4 of these it was through a scleral wound inflicted by foreign bodies 1, 2.5, 3 and 5 mm. in their longest diameter and in 2 of these cases the foreign body had also perforated the upper lid. In one case vitreous prolapsed through a penetrating wound of the cornea made by a 2 mm. foreign body.

Retinal detachment.

Retinal detachment was present in 2 cases. In both of these the entry wound was in the lower half of the sclera, in front of the equator and the retinal detachment and vitreous haemorrhage were in the vicinity of the wound.

In two instances when the vitreous haemorrhage was too severe to see the retina, some dark brown blood-stained inter-retinal fluid escaped when the choroid was incised for magnet extraction of the foreign body. So it is probable that retinal detachment was present in these cases.

I have no knowledge of the incidence of late retinal detachment in this series for it has been impossible after the war to trace more than a small number of them.

(Follow-up cards were sent with the notes of every soldier in this series. Out of 72 I received only 1 reply, and that from a general house-surgeon in a small north country hospital, and this contained no details. This was a similar experience to the Middle East series.)
Visual result.

It was impossible in this series to obtain facts about the ultimate visual result. During 1944 we operated as a casualty clearing station and as soon as a man was fit to be moved he was evacuated to the United Kingdom. As stated above neither follow-up cards nor letters about the wounded were answered.

Whenever it was possible for a patient to have his vision tested before evacuation this was done (in the Normandy campaign this examination was made in a tent). It is possible that in many cases the visual acuity improved later. Such records as were taken at the time of evacuation are as follows:

<table>
<thead>
<tr>
<th>Vision Acuity</th>
<th>Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/5</td>
<td>2</td>
</tr>
<tr>
<td>6/6</td>
<td>5</td>
</tr>
<tr>
<td>6/9</td>
<td>5</td>
</tr>
<tr>
<td>6/18</td>
<td>1</td>
</tr>
<tr>
<td>6/24</td>
<td>1</td>
</tr>
<tr>
<td>6/36</td>
<td>2</td>
</tr>
<tr>
<td>Counting fingers</td>
<td>2 cases</td>
</tr>
<tr>
<td>Hand movements</td>
<td>8 cases</td>
</tr>
</tbody>
</table>

Perception of light:
- Accurate projection: 2 cases
- Inaccurate projection: 5 cases
- No perception of light: 2 cases

In the remaining 37 cases visual acuity was not tested because of evacuation at short notice and the impossibility of doing an accurate refraction on a patient with multiple wounds lying on a stretcher.

Excision.—Two eyes were ultimately excised. In each of these the foreign body had passed through the limbus of the upper nasal quadrant, traversed the vitreous and was impacted in the sclera of the lower nasal quadrant, the foreign body being partly inside the eye and part of it projecting through Tenon's capsule. In each case the foreign body was large, in one case it was 10 x 4 x 3 mm. and in the other 5 x 4.5 x 1 mm. In both cases after wound toilet, extraction of the foreign body and suture of the scleral wounds the eye settled down and remained so for a few weeks. I heard indirectly that the ophthalmologist in the Canadian Hospital to which these men were transferred considered excision proper on account of no perception of light, a soft eye and a wound in the ciliary region.

Endophthalmitis.—There were 2 cases of endophthalmitis which settled down. These received parenteral and subconjunctival penicillin.

There were no cases of panophthalmitis. How much this was due to penicillin powder dusted on to the exposed sclera around...
THE INTRA-OCULAR FOREIGN BODY

the sclerotomy wound in the scleral route extractions it is impossible to say. The surgical team wore gloves and a non-touch technique was adopted. The post-operative course was uncomplicated by inflammation in all cases of scleral route extractions.

Associated with wounds in other parts of the body.—Wounds were present in other parts of the body in 51.4 per cent. in the B.L.A. cases. Multiple wounds included severe injuries such as open fractures of the femur, haemothorax, amputations, burns and serious head injuries. The nature of these is recorded briefly in the appendix.

The variety of multiple injuries due to hand grenades, land mine explosions, and booby traps conformed closely in both the M.E.F. and B.L.A. series.

Incidence of penetrating wounds of the eye with retained intra-ocular foreign body

In both the M.E.F. and B.L.A. series it has been difficult to obtain accurate statistics of the incidence of penetrating wounds of the eyes with retained intra-ocular foreign bodies in relation to eye casualties and to all battle casualties. Security measures often prevented a publication of numbers of casualties particularly in the M.E.F. When the German-Italian forces reached Alamein in June, 1942, many records at H.Q. Medical Services were destroyed. The transfer of wounded through several hospitals and the collection of cases requiring magnet work at three of these (the majority of such cases went to the 15th Scottish and the 8th General Hospitals and a few to the 6th General Hospital) made the keeping of accurate statistics impossible.

In the M.E.F. series there were 102 cases of a penetrating wound of the eye with retained intra-ocular foreign body out of 328 men with wounds within the circumference of the orbit and 110 with intra-cranial wounds affecting the visual pathways. In some of the latter the orbit and the eye were also injured.

Scott and Michaelson collected statistics of the terminal phase of the Western Desert campaign and found 78 cases of intra-ocular foreign bodies out of 301 eye battle casualties, 190 of which had penetrating wounds of the eyes. In 58 of this series both eyes were injured.

Dansey-Browning in the Italian campaign had 24 cases of intra-ocular foreign body out of 129 eye casualties in whom 148 eyes were injured. He considers that eye casualties were 25 per cent. of the total battle casualties.

In this B.L.A. series there were 72 cases of retained intra-ocular foreign body in 335 battle casualties and 62 accidental injuries of the eyes.
The statistics given by Lt.-Colonel A. Lister in his Summary of Ophthalmic work in 21 Army Group from June 5 to September 30, 1944, are 2,188 eye casualties of which 1,440 were due to direct enemy action, 480 (about 30 per cent. of battle casualties) had a penetrating eye wound, 157 had intra-ocular foreign bodies, 51 (about 30 per cent.) were removed.

From October to December, 1944, eye casualties due to direct enemy action were 595, and were 3·8 per cent. of all casualties in October, 3·1 per cent. in November, and 0·8 per cent. in December. There were 215 "battle accident" casualties in this same period. Twenty per cent. of the eye casualties had penetrating wounds of the eye and 33 per cent. of these had intra-ocular foreign bodies, only 25 per cent. of which were removed.

Whiting and Goulden comment that in July, 1916 (during the 1914-18 war) they had 30 cases of retained intra-ocular foreign body in this month, 5 cases occurring on one day and 13 in a week. They also remark that in France at this time a considerable number of intra-ocular foreign bodies were non-magnetic.

Cridland gives the incidence of penetrating wounds of the eye with retained intra-ocular foreign body in civil practice in 3 large industrial areas as 1 in 977·9 of all eye cases and 1 in 299 of accident cases.

Summary

The clinical facts of 72 cases of penetrating wounds of the eye with retained intra-ocular foreign body in the B.L.A. are surveyed. Methods of X-ray localisation and types of giant electro-magnet are discussed. In military surgery under field conditions such apparatus has to be simple for the former has to be used expeditiously by men with no special knowledge or training. There is indeed little time for such work when dealing with almost daily convoys of several hundred wounded. Our average time for a case was three minutes for suturing a limbal ring in place, about 10 minutes for the X-ray and 7 to 12 minutes for the operation of extraction of the foreign body by the scleral route.

The scleral route for extraction is indicated in the majority of cases and is simpler and less traumatic than the anterior method. With careful technique the danger of vitreous loss is negligible. This complication did not occur in this series. Retinal detachment is mentioned in the literature as a complication of the scleral route operation. I think this catastrophe is unlikely to occur as a direct result of the operation when diathermy has been used around the incision in the sclera and intra-ocular membranes. It may have happened in cases where diathermy was not used but there is no comment on this point in the literature. Retinal detachment is
more likely to be due to the pathological changes induced inside the eye at the time of injury.

In this series 69·3 per cent. of foreign bodies were extracted, 51·3 per cent. by the scleral route and 18 per cent. by the anterior route. Other authors including 21 Army Group Medical H.Q. state that about 30 per cent. of modern war missiles are extracted by a giant electro-magnet but they do not differentiate the incidence of success by either the anterior or posterior route. Many reported failures by the anterior route might not have been so if the scleral route had been properly tried.

With better X-ray facilities for localisation and a better magnet I feel that the figure of successes in this B.L.A. series might have been higher. For extraction of the feebly magnetic alloys of war missiles it is essential to bring the terminal of a very powerful electro-magnet into the lips of a scleral incision placed as near as possible to the foreign body.

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"BLUE HALOES" IN ATEBRIN WORKERS

by

IDA MANN

OXFORD

I am deeply indebted to Dr. H. Wyers for having called my attention to this condition and for the opportunity of examining the cases described.

Since the introduction of atebrin* for the treatment of malaria and its consequent manufacture on a large scale, certain pathological conditions consequent on handling it in bulk have become known.

* Atebrin is 2-chloro-5-[(4-diethylamino-α-methylbutylamino)-7-methoxyacridine dihydrochloride and is also known as Mepacrin (B.P.) and Quinacrin (U.S.P.).