varying from 13 to 77; 3 of these died, their ages being 20, 65, and 72 respectively. A group of 5 patients had had their primary vaccination in infancy and had been vaccinated later—one in 1910 and 1920, two in 1920, one in 1929, and one in 1940 without success. This last patient (Case 6), a woman of 37, was again revaccinated unsuccessfully on June 2; she contracted small-pox three weeks later and died. Thus the city patients who sickened of small-pox were either unvaccinated or had not been vaccinated or revaccinated successfully for upwards of 13 years prior to the present outbreak. Among these 25 cases 4 were contacts and had been vaccinated accordingly, with successful reactions. Their eruptions appeared from 9 to 12 days later, an experience similar to that already met with in those members of the crew who had been vaccinated successfully during the early days of the incubation period.

No link between the ship cases and the city cases was ever discovered in spite of the most careful search. It is possible that the city cases were infected from an independent source, such as a missed case from another ship from the East; but as there was no evidence of any such origin it must be presumed that they received their infection from the ship either directly or indirectly in some unknown manner. The occurrence of a group of cases in separate districts of the city, all infected within a few days of each other, suggests the presence of a mild unrecognized case as the most likely cause. Case 23, for example, had not been outside the mental hospital, of which he was an inmate, for some years, and he had had no visitors and no parcels during the weeks preceding his illness. All visitors to the hospital were checked up, with completely negative results.

Past Outbreaks of Small-pox

Major outbreaks of small-pox in the past have always been protracted. That of 1920 was introduced from the East in February, lasted till November, and was at its height in May, June, and July, amounting to 542 cases, with 113 deaths. The invasion of 1900 caused 397 cases between April and December, with its peak in June and July; this was followed in 1901 by a severe outbreak with 1,389 cases, which was again succeeded by a recrudescence in 1901-2, with 469 cases. Still earlier there was a large epidemic which lasted from 1871 to 1874, and sharp outbreaks occurred in Scotland and Glasgow in 1893, 1894, 1895, and 1897. In the bigger outbreaks, general vaccination was practised mostly by house-to-house visitation. In 1920, when centres were also set up, 225,000 persons were vaccinated during the several months when the outbreak was at its height. The present experience is in strong contrast; and it may be said that the people themselves, by taking timely advantage of the advice given and the facilities provided, stopped the outbreak at its start.

Lessons of the Outbreak

It is apparent from the above description that complete reliance cannot be placed upon vaccination unless performed successfully before the date of exposure. Also, immunity from vaccination diminishes after a few years. These two facts render it essential that everything possible should be done to protect ships' crews and passengers sailing from the East. Prevention of the spread of infection depends on the success of the two principal prescribed measures—vaccination and subsequent surveillance. If vaccination is not carried out promptly, surveillance becomes a matter of great importance; but adequate surveillance of contacts is more difficult to exercise in time of war because the destinations of passengers and crew are more uncertain, and may, in fact, be merely temporary or accommodation addresses. Had the case on board been accurately diagnosed and precautions taken, the subsequent story would have been very different. It would have been still better had vaccination of the susceptible members of the crew and passengers been carried out when the ship left Bombay, a port known to be infected. Attention to the vaccination of all who sail from Eastern ports, both passengers and crews, should be enforced as a routine precaution; otherwise there is grave danger of small-pox being introduced into this country. In the case of passengers, this would mean vaccination of those who had not been recently protected, as a condition of travel. In the case of crews, it would require the co-operation of members of the Merchant Navy, the great

majority of whom would no doubt be willing to be vaccinated from time to time if the need for such a precaution were made clear to them. Even the most careful attention to the provisions of the Port Sanitary Regulations, including conscientious surveillance of crew and passengers after arrival in this country, leaves loopholes for the entry of small-pox. Therefore adequate vaccination of all who travel from infected places is the only true safeguard.

WAR SURGERY OF THE EYE

REMOVAL OF MAGNETIC INTRA-OCULAR FOREIGN BODIES BY THE POSTERIOR ROUTE

BY

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Intra-ocular foreign bodies possessing magnetic properties may be removed by one of two routes: (1) The anterior route, in which the foreign body is attracted forwards by a giant electro-magnet, through the suspensory ligament into the posterior chamber, then, by changing the direction of the magnetic force, is drawn between the iris and lens into the pupil and anterior chamber, whence it is extracted from the eye through a keratome section by a small electro-magnet guided by the operator's hand. (2) The posterior route, which necessitates exposure of the sclera by turning back a conjunctival flap either at some site of election or over the penetrating wound in this structure, if such is obvious or unclosed. An incision is made through the sclera, and the entry wound is enlarged to a size just adequate for the extraction of the foreign body. A magnet terminal is placed into the lips of the scleral wound.

Advantages of the Posterior Route

The advantages of this method of extracting intra-ocular foreign bodies, caused by the fragmentation of war missiles, are several. These bodies are rough irregular pieces, which if drawn forward by the giant electro-magnet in the anterior-route technique of extraction would inevitably damage the ciliary body and iris and might also injure the lens. The metals which compose the casing of shells, grenades, mines, and booby-traps are alloys with either low magnetic properties or none at all. In many instances it is essential to place the giant magnet terminal as near to the foreign body as possible on account of its low magnetic properties.

It happened by chance that all the penetrating wounds of the eye treated at the Scottish General Hospital during the Western Desert battles from Nov., 1941, to Aug., 1942, associated with a metallic magnetic intra-ocular foreign body, had the wound of entry through the sclera, and 80% of these were in the lower temporal quadrant in front of the equator, the lens being undamaged. The point of this is that exploration of the entry wound, its toilet, and closure are generally necessary, and it seems reasonable to save further surgical intervention by using the entry wound for the exit of the foreign body. However, in some cases, particularly high-velocity fragments of 2.5 mm. diameter and under from aerial bombs, the scleral wound had healed without complication during delayed transit through a field ambulance and casualty clearing station. In such cases a scleral incision of appropriate length was made at a site of election.

Another advantage of the posterior route is that in cases in which the foreign body proves to be non-magnetic the opening may be used for the passage of an instrument such as a thin pair of straight iris forceps or a fine wire snare placed in the lumen of a hypodermic needle (Brigadier C. W. Graham's technique), with which, under ophthalmoscopic view, the foreign body is seized and extracted. This was done successfully in the case of Corporal B., in which a 2 by 2 by 1 mm. rectangular fragment of a Breda shell detonator cap had penetrated the sclera in the lower nasal quadrant about 2 mm. in front of the equator, and after tearing a ragged hole in the retina lay in the vitreous in the upper nasal quadrant behind the equator. It seems that the posterior-route operation

disturbs an eye less than the anterior-route procedure does. After the former operation the eye regains its normal appearance more quickly, and ciliary injection is certainly not increased, as is sometimes the case after the anterior-route extraction.

Procedure in the Western Desert

The foreign bodies were ragged-shaped pieces of metal with rough granular surfaces. Their size varied from 3.5 by 2 by 0.5 mm. to 1.5 by 1 by 1 mm. Some were cubes 2.5 by 2.5 by 2.5 mm. or slightly less than this, but the majority were rectangular flakes, with an average thickness of 1 mm. They consisted of fragments of shells, air-cannon shells, and bombs in equal incidence. In no case was there any associated gross intra-ocular infection, and in only one was there a clot of opaque yellow fibrin adherent to the foreign body on extraction. It is doubtful whether the administration of sulphonamides at irregular intervals during evacuation from the forward areas could have played an appreciable part in the prevention of infection during the 6 to 14 days taken in evacuating men in the 8th Army's advance to Benghazi in Nov. and Dec., 1941. In the withdrawal into Egypt in June, 1942, as the enemy advanced, the wounded arrived at progressively shorter intervals of time after being hit, and at one period they came straight from the battlefield, circumventing field ambulances and casualty clearing stations, and were operated upon within 12 hours of being wounded. The delay of 6 to 14 days in giving appropriate surgical treatment to those hit in the early phases of the campaign did not seem to have jeopardized the future safety of the eye.

In a few instances the battalion and field ambulance medical officers, aware of the dangers of vitreous loss, had ordered the evacuation of these wounded lying on stretchers. The majority walked to aid posts and were then transported as sitting cases. Two of these sitting cases arrived with a vitreous herniation through the wound. The bead of vitreous was 2.5 mm. in diameter in wounds about 3.5 mm. long, and it was covered with conjunctiva and surrounded by adhesions to Tenon's capsule and the episcleral tissues.

It is difficult to assess the protective value, if any, of the British steel helmet so far as the eyes are concerned. Some men were wearing their steel helmets when hit and others were not. No useful deduction could be made from these data in relation to the possible direction of the missile which struck the eye. Major P. B. Ascroft (O.C. Mobile Neurosurgical Unit) has prepared a composite photograph based on a radiograph of a soldier's skull when wearing in turn a British and an Italian steel helmet. On this radiograph he marked the sites of 150 penetrating wounds of the skull. Of these, 65 fell below the level of the British helmet but were covered by the Italian helmet. From this radiograph it seemed likely that the Italian helmet would protect the eyes from metal splinters flying from an angle of 90 degrees over on either side. There was a remarkable concentration of wounds about the frontal area.

Investigation of Cases

The soldier is asked about the position of his head when wounded and the direction from which the missile came. Information about this latter is often unreliable. When there is an associated head injury the soldier generally has no recollection of being hit. In a few cases such facts as the above are helpful in tracing the probable course of the missile. The position of lid injuries may assist in this respect but is sometimes deceptive.

The nature of the missile is important. Fragments of shells and bombs are generally magnetic, some in low degree. Italian hand grenades, booby-traps, and land mines are composed of non-magnetic alloys the fragments of which are about 1 mm. thick. Some booby-traps are made of bakelite, which is not radio-opaque and is non-magnetic. Such a fragment was extracted from an eye with forceps under direct view. In the case of land-mine, hand-grenade, and booby-trap explosions the wounds are generally multiple and, except for such serious injuries as traumatic amputation of one hand and multiple penetrating wounds of one or both eyes, are superficial. Fragments of metal may readily be taken from the skin and tested for radio-opaque and magnetic properties.

In all cases except one—that of a sepoy with both eyes penetrated by aerial-bomb fragments—the entry wound was

evident. The conjunctival wound showed localized hyperaemia, and in all cases of over one day from the time of wounding it was closed and the conjunctiva was adherent to the episcleral tissues and sclera around the site of the wound. In 50% the intra-ocular foreign body was seen with the ophthalmoscope, but in the remainder vitreous haemorrhage obscured its position. In the latter, x-ray location was done.

Location of Foreign Body by X Rays

Brigadier C. W. Graham has introduced a simple technique which, in the absence of elaborate x-ray apparatus, is of practical value. It is as follows: The eye is anaesthetized with cocaine, and when much inflamed 2 or 3 minims of novutox is injected into the episcleral tissues at the limbus at 12, 9, and 3 o'clock. A silver ring of a size to fit exactly the corneo-scleral junction is stitched in position by sutures of 000 silk passing through the conjunctiva at 12, 9, and 3 o'clock respectively. A drop of paroline 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 forwards and for the second to look downwards. For this purpose conspicuous marks such as red disks or lights 5 cm. in diameter are placed on the wall for sitting cases and on the ceiling for lying cases at the two points in which fixation of the eyes 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.

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 in. or more is used, parallax 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 limits of the ring are used in turn as the centre of a circle whose radius is 12 mm. (e.g., 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 carried out 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 round 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 relation 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. This point is settled by the movement of the foreign body, which is 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 relation to the ring in the second position it is probably outside the eye. When the foreign body is clearly outside the limit of the circles

described 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.

Operation

Anaesthesia.—(1) Surface. Cocaine 4%, 4 drops (the only suitable anaesthetic available). (2) Infiltration. 0.5 c.cm. of novotox 3% with 3 minims of 1 in 1,000 adrenaline may also be injected into the bellies of adjacent rectus muscles when traction is likely to be made on these. In cases of considerable ocular injection 1 c.cm. is also injected into the region of the ciliary ganglion. Anaesthesia has been adequate in all cases.

Incision.—With spring scissors a curved incision is made in the conjunctiva anterior to the area of sclera to be exposed, so as to fashion a flap with its convexity forwards. This is undermined down to the sclera so that it consists of conjunctiva, Tenon's capsule, and episcleral tissue. Two sutures of 000 silk are inserted 2 mm. behind the free edge of the flap, which is now reflected posteriorly and secured thus by clamping the sutures to the head-drapings. Care must be taken in separating adhesions around the site of a scleral wound. The overlying conjunctival wound is generally healed, and in most cases the conjunctiva can be dissected off intact. In two cases there was a prolapse of intra-ocular contents, making a knuckle about 2.5 mm. high by 2.5 mm. at its base. In such cases the covering of episcleral tissue and adhesions was left untouched until after diathermy had been applied and a scleral suture inserted. Then the prolapse and its coverings were cut off flush with the sclera.

After reflecting the conjunctival flap the sclera is swabbed and any bleeding-point arrested by touching it with a fine probe heated in a flame. Traction on the globe may be effected either by a scleral hook or by passing sutures of No. 1 white silk through the tendon of a rectus muscle or by seizing the tendon with fixation forceps (Fig. 1). If the scleral

FIG. 1.—A flap of conjunctiva, episcleral tissue, and Tenon's capsule is reflected in the lower temporal quadrant. Fixation forceps are applied to the tendon of the external rectus muscle. A No. 15 Bard-Parker knife incises the sclera where two applications of surface diathermy have been made.

wound is either over the posterior part of the pars plana of the ciliary body or between the ora serrata and the equator one or two applications of surface diathermy, 70 to 80 mA for 5 seconds, are made over the wound so as to extend just beyond its limits. This effects contraction and hardening of the sclera and incidentally reduces the size of the wound. Its purpose is to produce haemostasis in the sclera and underlying uveal tract and to ensure subsequent choroidal retinal adhesions where the foreign body tears these membranes on leaving the eye. Then a mattress suture is passed through the thickness of the outer half of the sclera, which it traverses 1.5 mm. from and parallel to the edges of the wound for a distance of 2 mm. (Fig. 2). For this purpose Merson (Edinburgh) made for me a small eyeless needle threaded with 000 silk. Generally one suture is sufficient, but two may be necessary in larger wounds. The loop and ends are placed clear of the scleral wound.

The wound is now enlarged to a size 1 mm. greater than the maximum diameter of the foreign body as measured on

the radiograph. This is done by cutting the sclera with a No. 15 Bard-Parker blade kept on the sclera and run gently to and fro for 2 to 4 mm. as required. All but the deepest layers of the sclera are divided in this manner. The head and eye are then turned so that the scleral wound lies uppermost, thus by gravity minimizing the risk of vitreous loss. Fine hooks are now inserted into the edges of the scleral wound and are drawn apart. The uvea shows through the remaining layers of the sclera, which are now cut with the point of a cataract knife (Fig. 2).

FIG. 2.—A mattress suture has been inserted through the superficial layers of the sclera. Fine hooks retract the edges of the scleral wound, whilst a cataract knife completes the incision through the deeper layers of the sclera to expose the uveal tract.

The procedure is similar in cases in which the scleral wound has healed or is not evident, the scleral incision being made at some site of election. The only difference is that the incision is made through about half the thickness of the sclera and then the mattress suture is inserted. With effective diathermy there is no bleeding.

The Mellinger giant electro-magnet is now swung into position, and the terminal introduced into the lips of the wound. A "click" is heard as the foreign body strikes the terminal, which is then removed. The mattress suture is now seized with Arruga's capsule forceps and drawn upon, thus closing the lips of the scleral wound. It is then tied. Any traction sutures in the rectus muscles are now cut and removed. The conjunctival flap is replaced and the conjunctival incision closed by a continuous key-pattern suture of 000 black silk. Ung. atropin. 1% is inserted on a glass rod swept beneath the upper lid at the outer canthus. A pad moistened with paroline is applied over the closed lids and secured by a bandage.

To date, vitreous loss has never occurred and the eyes have shown no post-operative exacerbation of inflammation.

Summary

The reasons for removing by the posterior route intra-ocular magnetic foreign bodies due to war missiles are discussed. The investigation of a case, a simple method of x-ray location of intra-ocular foreign bodies, and the operative technique of extraction are described.

Major W. H. Milligan, x-ray specialist (Scottish) General Hospital, has devoted much skill, care, and patience to the location of intra-ocular foreign bodies. I thank him for his admirable work and invaluable help and advice in this respect. I also thank Brigadier C. W. Graham, Consulting Ophthalmologist, M.E., and Colonel H. D. F. Brand, O.C. Scottish General Hospital, for permission to publish this paper.

There have been numerous reports in the American medical press during the past year on the formation of sulphonamide crystals in the renal tubules. In one of these (*J. Urol.*, 1942, 47, 258), H. R. Newman and I. H. Shleser point out that there is the less-recognized risk of the formation of putty-like renal calculi. They record a case where, two years after the administration of sulphapyridine and prontosil, renal calculi were found on x-ray examination to be in the pelvis of the right kidney, and were removed. They crumbled easily on slight pressure, and chemical analysis showed the presence of large quantities of sulphonamide intermixed with protein and some magnesium, ammonium phosphate, and a trace of calcium carbonate.