SURGICAL ROTATION OF THE EYEBALL*

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THE treatment of large tears and upper disinsertions of the retina poses serious and often insurmountable problems. Nor has any effective treatment yet been developed for retinal inversions caused by the total detachment of the upper retina, though most authors agree that detachments involving tears in the upper part of the retina are less frequently cured than inferior disinsertions and tears (Arruga, 1952).

The studies of Gonin (1904, 1934), Lindner (1931), Arruga (1936), Duke-Elder (1940), Schepens (1954), Teng and Chi (1957), and Wadsworth (1952, 1957) have demonstrated the influence exerted by the traction of the vitreous upon the pathogenesis of tears. If to the above we add the influence of gravity it is logical to infer that vitreo-retinal adhesions cause larger and more severe tears in the upper part of the retina.

This unfavourable state of affairs led us to seek a different approach to the problem, and we concluded that if the position of the tear or disinsertion could be changed the traction upon the retina might be modified.

To achieve this, we perform a surgical rotation of the eyeball so as to bring the affected area into the lower position, and also make a scleral resection or buckling in the usual way. After cicatrization of the tear, the eye is brought back to its original position.

This technique has been used in five patients who had undergone repeated unsuccessful operations. No final conclusions can be drawn from such a small series of cases, but we believe that a number of findings concerning the physiopathology of rotated eyes are worth reporting upon.

Technique

The conjunctiva is sectioned 7 or 8 mm. from the limbus throughout its length. The four rectus muscles are exposed and chromic catgut is placed in each of them. Their insertions are then divided and we separate any adhesions which may be present in areas already treated. These manoeuvres should be conducted with utmost care for there is always a risk of scleral rupture in areas treated with diathermy.

Thorough dissection is then performed as far back as practicable so that the vortex veins suffer the slightest possible traction when the eyeball is rotated.

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A further operation for retinal detachment is carried out at the place corresponding to the disinsertion or tear.

The eyeball is then rotated either clockwise or counter-clockwise, according to the case, the aim being to bring the affected area as low down as possible.

At a certain stage, the oblique muscles arrest the rotation of the eyeball; thus, if we wish to carry out an extorsion, the superior oblique prevents its continuation beyond a certain point; conversely, an intorsion is arrested by the inferior oblique.

In our cases we confined ourselves to the partial or total sectioning of the scleral insertion of the oblique muscle limiting the movement. An 8–10 mm. recession of the oblique which is hindering rotation is recommended.

The eyeball is then rotated and carefully watched through the ophthalmoscope. It is not possible to rotate the eye more than 90° because otherwise the central artery of the retina collapses and an intense ischaemia of the disc sets in.

The condition of the vortex veins should be watched to avoid excessive strain. The risk is lessened by dissecting the tissues surrounding these veins within the orbit as far back as possible.

After rotation, each muscle is sutured to the opposite stump (for instance, if an extorsion has been made, the lateral rectus is sutured to the stump of the superior rectus, the inferior rectus to the stump of the lateral rectus, etc.), and the conjunctiva is sutured as usual.

Post-operative Follow-up

The five patients followed a rather difficult post-operative course. Conjunctival and palpebral oedema is to be expected after an operation of this kind, but there was also some degree of circulatory embarrassment, caused by the torsion of the veins. The cornea showed slight oedema.

One patient developed severe symptoms, with marked swelling of the eyelids and conjunctiva, ocular protrusion, intra-ocular haemorrhage, and glaucoma. The thorough dissection of the vortex veins during surgery and their patency after ocular rotation were rather neglected in this case, and these complications may have been caused by the blockage of these vessels.

The external appearance of the eye gradually became normal in four patients, but in the case described, ocular atrophy supervened.

In two patients the ocular condition was unchanged. They could only just perceive light, and it was hard to elicit in what manner they projected the position of the light focus.

The other two patients (Cases 1 and 2) retained enough vision as to recognize changes in the position of objects, so that following movements of the eyes could be observed.

Case Reports

Case 1, a woman aged 47 years, presented with a large superior nasal disinsertion in the left eye. She had had a scleral buckling without success.

A new scleral buckling behind the previous one was followed by a 90° intorsion, so that the involved area was brought to the inferior nasal position. Within a few weeks the visual acuity was 20/200 with only a slight tilting of objects (approx. 20°). As this

did not bother her too much she refused to undergo a further operation. We attribute this adjustment of intorsion to the action of the inferior oblique that had been sectioned only partially to enable intorsion.

The fundus was difficult to observe because of the presence of opacities in the lens. In all the visible areas the retina was found properly attached. After 2 years this patient still preserves the same degree of visual acuity.

Case 2, a man aged 56 years, presented with a large superior temporal tear in the right eye. The visual acuity in the right eye was hand movements; the left eye was normal. A scleral buckling proved unsuccessful. A new buckling further back and a 90° extorsion of the eyeball were then performed and it was necessary to section the superior oblique. Moreover, since the area corresponding to the origin of the inferior oblique presented adhesions, this had to be cut as well, so that in this particular case both obliques were sectioned. Throughout the visual acuity was 20/300, and a small divergence was observed.

The fundus was not distinctly visible because of lens opacities but the retina was seen to be well attached.

At the end of 6 months his condition was unchanged and it was decided to bring the eye back to its original position, each rectus muscle being inserted into its corresponding stump.

The post-operative result was highly gratifying; the visual acuity is now 20/300 and the eye movements are performed correctly. Ptosis and hypertropia are present but these are being corrected.

Vision and Motility of the Rotated Eye:—Case 2 being the most easily demonstrable, we shall take it as an example and deal with it at length (Fig. 1).

FIG. 1.—Case 2. The patient after surgery, with eyes in the primary position.

Vision.—The visual acuity was 20/300. The patient saw the sign $\sqcap$ of the Project-o-chart corresponding to 20/300, as Ξ . A light placed in the periphery of his visual field was seen with a 90° difference, and all objects were seen to be rotated by 90°, in the opposite direction to the rotation, so that the vertical appeared to be horizontal, the top being at the nasal side and the bottom at the temporal side. When the patient was asked to set his ruler in the same position as one held vertically, he placed it almost horizontally (Fig. 2, opposite); when asked to set it in the same position as one held horizontally he placed it almost vertically (Fig. 3, opposite).

When he was asked to shake hands or to seize an object, he held out his hand with a 90° difference, but then realized that the object lay elsewhere. He was unable to walk using the operated eye because of the confusion caused by obstacles.

FIG. 2.—When asked to place his ruler like one held in a vertical position, the patient holds it almost horizontally.

FIG. 3.—When asked to place his ruler like one held horizontally, the patient holds it almost vertically.

Binocular Vision.—The patient preserved binocular vision and certain degree of fusion. When two fusion slides were placed in the synoptophore the patient saw dimly, but when the slide on the right was rotated by 90° , fusion was accomplished with the largest pictures.

Visual Field.—This was studied by perimetry with wide targets. The whole of the visual field was rotated by 90° , the largest part (corresponding to the temporal field) lying in the lower sector. The visual field, as far as its original shape was concerned, was rotated in the direction of the ocular rotation.

Ocular Movements

(1) **VOLUNTARY.**—These were performed normally either with both eyes together or with the operated eye only (Fig. 4).

FIG. 4.—Voluntary movements of the eye are carried out normally. With the left eye covered the patient is asked to look towards the right, and he does so normally.

(2) REFLEX.—Those brought on by labyrinthine stimulation were normal. Statokinetic movements were not recorded.

(3) OPTICALLY ELICITED.—These were performed correctly when the patient looked with both eyes, because he had command over his left eye. But when the left eye was covered, an abnormal response was elicited. Thus, when a luminous point was placed in the inferior portion of the field and the patient was instructed to look at it, he gazed towards the temporal side. Regardless of the sector of the periphery of his visual field within which an object was placed, he directed his eye with a difference of 90° in the opposite direction to the rotation.

Moreover, the patient projected both light and objects with a 90° difference in position, and turned his eye towards the point where he believed them to be placed. He kept up fixation on the false image and only realized that the object was not there when he tried to grasp it.

(4) FOLLOWING.—These were performed normally when the patient looked with both eyes, but if the left eye was covered various phenomena were observed. When an object was displaced downwards, the eye moved towards the temporal side (Fig. 5); when it was displaced from the temporal side in the nasal direction, the eye moved downwards (Fig. 6); when it was displaced from the nasal side in the temporal direction, the eye moved upwards. The patient followed the objects with his finger in the same way as with his eye.

If the object was displaced vertically upwards the eye moved horizontally toward the centre (Fig. 7), and when the object reached the highest position on the vertical meridian the eye moved to the limit of adduction.

Optokinetic Nystagmus.—Ocular movements were likewise performed with a 90° difference with respect to the movement of the drum lines.

All the modifications observed in the sensory and ocular behaviour of the rotated eye remained unchanged throughout the 6 months during which the eye was in the above position, but the sensory motor alteration did not affect the patient to any large extent, as he suppressed it and focused with his sound eye.

When the eye was returned to its normal position 6 months later, the retinal sensory state and the ocular movements also returned to normal (Fig. 8).

FIG. 8.—After the eye has been rotated back to the normal position the patient is able to set his ruler parallel to one held by the author.

FIG. 5.—Following movements with the rotated eye alone are made at right angles. When the pencil is moved downwards the eye moves outwards.

FIG. 6.—When an object of fixation is moved horizontally from the temporal to the nasal side, the patient moves both his finger and his eye vertically downwards.

FIG. 7.—When the pencil is moved vertically upwards, the patient moves both his finger and his eye horizontally inwards.

Discussion

We have not found in the literature any papers describing observations similar to ours. Stratton (1896, 1897, 1899) performed interesting experiments with lenses which reversed the visual field (Duke-Elder, 1938).

Stone (1951) found that the only vertebrate eye possessing regenerative capacity in the retina and optic nerve, was that of the salamander. He states: "Neutral retina which degenerates in transplanted vertebrate eyes is replaced only in salamanders by regeneration from surviving retinal pigment epithelium."

In analysing the visual mechanism in transplanted eyes, he observed that vision is normal if the transplanted eyes are normally oriented, but if the eye is exercised, rotated 180°, and re-implanted, all the functional quadrants of the regenerated retina and the visuomotor reactions are reversed.

Abnormal swimming, reversed vision and reversed visuomotor responses, were retained as long as the eyes were rotated 180°, but all normal reactions "can be immediately restored by cutting the conjunctiva and ocular muscles and rotating the eye back to normal orientation without disturbing the blood supply to the retina or injuring the optic nerve while twisting it."

These interesting experiments with animals present certain points of similarity with the clinical observations in man which we believe ourselves to have been the first to carry out.

We are aware that the presence of lowered vision and of a number of scotomata, may diminish the value of the interpretation we have formulated. The severance of the oblique muscles in the patient chosen as an example (Case 2) casts doubt on the interpretation of the eye movements. Another point to be noted is that the eyeball was rotated not about an axis traversing the macula, but around that of the optic nerve.

Sensory Behaviour.—By rotating the right eye 90° in a counter-clockwise direction we changed the position of the retinal meridians so that the vertical meridian became horizontal, its upper part to the temporal side and its lower part to the nasal side (Figs 2 and 3).

Oculomotor Behaviour.—The ocular movements provoked by retinal stimulation (optically-elicited and following movements) were abnormal and could be differentiated from voluntary and vestibular movements which were made normally.

Modification of Following Movements.—When a normal person looks at an object moving downward (e.g. from A to B as in Fig. 9, opposite), the vertical meridian of the retina is stimulated from A' to B', that is upwards, in a maculofugal direction.

The fixation reflex then takes place, so that the gazer directs the macula toward the object's new position, B, and to do this, he must contract the inferior rectus and relax the superior rectus.

A new displacement in the same direction elicits a similar response until the extreme downward position of regard is reached.

If we now move the object vertically upwards, the retinal image moves downwards, and in order to fix the object with the macula the superior rectus must be contracted and the inferior rectus must be relaxed.

In other words, the displacement of an object along a vertical course elicits the stimulation of the vertical meridian of the retina and a displacement of the eye on the same meridian in the same direction as that of the object.

The diagram (Fig. 9) shows the normal relationships of the right eye between vertical and horizontal meridians with the muscles contracting by maculofugal stimulation.

FIG. 9.—Diagram showing the normal optomotor relationships between a meridian and the rectus muscles of the right eye.

For example, when an object is moved vertically from A to B, it stimulates the vertical meridian of the retina from A' to B', and the maculofugal stimulation of this meridian elicits the contraction of the inferior rectus.

If, however, the eye is rotated 90° counter-clockwise, the relationship between the meridians and the muscles will be changed.

Fig. 10 shows that the horizontal meridian normally associated with the horizontal recti now occupies a vertical position while the vertical meridian normally associated with the vertical recti occupies a horizontal position. With the eye in this position, an object moving vertically stimulates the normal horizontal meridian of the retina.

FIG. 10.—Diagram showing the changes in relationships between the retinal meridians and the rectus muscles resulting from a 90° counter-clockwise rotation of the right eye. An object moving downwards stimulates the horizontal nasal meridian and sets up the contraction of the lateral rectus in the rotated eye.

Following movements in our patient demonstrated that the stimulation of the true horizontal meridian continued to cause the contraction of the horizontal recti while the stimulation of the vertical meridian elicited the contraction of the vertical recti.

Thus, when an object is displaced downwards from A to B (Fig. 10), the image moves from A' to B' along the meridian which is normally nasal horizontal, and which, on being stimulated in a maculofugal direction, normally causes the contraction of the lateral rectus; in point of fact when the object moved downwards the eye moved outwards.

When the object moved vertically or horizontally, the same phenomenon was observed, the eye moving in the direction controlled by the muscle associated with the stimulated meridian.

From the above it may be concluded that although the eye had undergone a 90° rotation, the retinal meridians preserved their normal relationship to the same muscles as before rotation, and it may safely be maintained that, at least in the adult, there exists an indestructible interdependence between retina and the oculomotor muscles.

The rotation of the eyeball brought out further facts which are more difficult to interpret:

(1) *Macular Fixation does not persist in Following Movements.*—If the downward movement of an object causes the eye to move outwards, fixation with the macula does not persist.

It might be argued that our patient had a very much lowered visual acuity and that a central scotoma was present; but even in cases with large central scotomata the eye follows moving objects in a normal way.

In our patient, fixation persisted with peripheral areas of the retina; he looked in the direction in which he believed the object to lie, and pointed in that direction with his finger when asked where it was situated. Normally, an object moving downwards is followed by the macula and the eye also moves downward. But, in our patient, the downward movement of the object stimulated the former horizontal meridian and the external rectus contracted carrying the eye outwards.

It is not quite consistent with current knowledge that the patient did not resume fixation. In effect, when the object moved downwards, the eye was carried outwards and then stayed in that position, the patient no longer fixing with the macula. Normally, when a peripheral zone of the retina is stimulated, the eye fixes with the macula, and when the nasal horizontal meridian is stimulated the lateral rectus contracts to accomplish this manoeuvre. In our patient, when the object moved downwards, he maintained fixation on that point without focusing with the macula.

Thus when the eye was rotated 90°, the normal fixation movement did not carry the image to the macula because the wrong muscle contracted.

It is significant that the patient continued to fix with the point of the retina which had elicited the muscular contraction, and the eyeball stopped at the point to which it was carried by the muscular contraction.

If the macular fixation reflex were so preponderant as is usually thought, the eye should always move so as to fix with the macula, but this was not the case, and it appears that the most important factor in ocular movement is the normally

established relationship between the retina and the extra-ocular muscles. This leads to the assumption of the presence of an acquired reflex mechanism relating each point on the retina to a particular oculomotor response. In other words, each retinal point has its own oculomotor value, possibly acquired during development, which persists even when the eyeball is rotated.

(2) *The Direction of Ocular Movement is determined by the Maculofugal or Maculopetal Character of the Stimulus.*—The rotation of the eyeball gives rise to a number of observations on this well known axiom.

Carrying on with the previous example (Fig. 10), when the object has stopped at B the eye is fixed in a certain position. If, starting from this position, the object continues to move downwards, the eye moves a little further outwards.

Thus the image is displaced in a maculofugal direction along the formerly horizontal nasal meridian, so producing the contraction of the lateral rectus.

But if the object moves upwards from B, the eye is carried inwards.

It may be assumed that the maculopetal movement of the image along the nasal meridian causes the contraction of the internal rectus and carries the eye inwards when the object moves up.

In normal conditions, if the peripheral retina is stimulated in the nasal sector, the fixation reflex elicits a contraction of the lateral rectus to direct the macula to the object. In our patient the fixation reflex did not take place, and the external rectus did not contract. A contraction of the internal rectus was seen when the stimulation of the nasal retina was displaced in a maculopetal direction.

Similar findings were observed in all meridians, and it was therefore possible to study the influence of the movement of images along the retinal meridians without the occurrence of the fixation reflex.

This suggests that the successive stimulation of two retinal points assumes a different oculomotor significance according to the order in which stimulation occurs, and the ocular movement will differ according to the maculofugal or maculopetal direction of the stimulation. This permits us to modify the diagram of retino-muscular relationship shown in Fig. 10 and to show it as in Fig. 11; the successive stimulation of two retinal points are seen to cause the eye to move without the intervention of the macular fixation reflex.

FIG. 11.—Optomotor relationships in an eye rotated 90°, in which the macular fixation reflex does not take place.

Theoretically, if the eyeball had been rotated 180° , the eye would move upwards when the object moved downwards, as Stone's salamanders moved away from the stimulating light instead of towards it.

(3) *Optomotor Relationship of Extramacular Vertical and Horizontal Meridians.*—Not only the vertical and horizontal meridians traversing the macula but also the meridians parallel to them assume the oculomotor significance described above.

Thus, an object was displaced a little below the fixation point (Fig. 12), the eye moved outwards with an equivalent angular movement and remained in that position. When the object moved further down, the eye moved a little further outwards. When it is arrested at the first point, the fixing point of the retina will not lie on the macular meridian, but on another meridian parallel to it. When the object is moved a little further down (C), the eye moves further out and a retinal point on another meridian is now found to be fixing the object.

FIG. 12.—When the object moves downwards, the rotated eye moves outwards, and the object stimulates retinal points lying on meridians other than that traversing the macula.

This suggests that all the horizontal meridians are associated with the horizontal recti and all the vertical meridians with the vertical recti.

Obviously, a similar relationship must exist as regards the oblique muscles, but because these had been sectioned in our patient, no definite conclusions can be drawn.

As a working hypothesis we may assume that each retinal area presents meridians associated with each pair of muscles governing the direction of movement. The course of the movement is conditioned by the maculofugal or maculopetal character of the successive stimuli of two points on these meridians. Thus the same macula must present multiple meridians each with its corresponding oculomotor significance.

This hypothesis calls for experimental confirmation, which is now being carried on in our department.

Summary

For the purpose of treating retinal detachments with large tears or disinsertions in the upper quadrants the surgical rotation of the eyeball was carried out in five cases in order to bring the tears towards the lower part

orbit. The rectus muscles were sectioned, the globe rotated 90°, and the muscle ends sutured to the stumps lying opposite. Conventional scleral buckling (or scleral resection) was done first as in the usual treatment of retinal detachment.

It was not possible to accomplish a rotation of more than 90° owing to retinal ischaemia. After a few months, when the detached retina was successfully reapposed the eyeball was again rotated to its original position. This operation was successful in only two of the five cases.

While the eye remained rotated the visual acuity and ocular movements were studied. Objects of regard were seen with an inclination of 90° in opposite direction to that of the rotation. The motility of the rotated eye showed that there was a definite dissociation between the voluntary and labyrinthine movements and those of retinal origin (optically elicited). The former were performed normally, but those of retinal origin were made with a 90° inclination. This demonstrated the existence of a close association between the retinal meridians and the ocular muscles habitually related thereto, which does not disappear despite eye rotation.

The muscular response is conditioned by the maculofugal or maculopetal quality of the stimulus.

In rotated eyes the macular fixation reflex is absent when the peripheral retina is stimulated; a muscle contracts other than that necessary for macular fixation and the eye moves to a new position, where another extramacular point is stimulated.

Some of these observations on retinomuscular relationships bear out the observations of Stone (1951), and others call for experimental confirmation which is now being sought.

The small number of cases studied prevents us from drawing firm conclusions regarding the value of this method of treatment, and the successful results obtained by present-day methods of diathermy with the eye in the normal position, limit the scope of the procedure described.

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