tends to fail in central facial palsy and it may be absent in peripheral cases also. Cords. In its continued absence, the effects of exposure during sleep are shown in the cornea and the conjunctiva.

Graefe and others reported downward rotation in some cases of facial palsy. This paradoxical Bell's phenomenon was described by Coppez in two of 200 patients.

In addition it is known that lid-closing is easier when the gaze is upwards, and harder when it is downwards.

Further relationship between palpebral and ocular movement is seen in Graefe's sign in goitre. This is probably due, as Dalrymple wrote in describing it, and the sign known by his own name—to increased tone in the levator.

Retraction Syndrome.

The following are the characteristics of this rare syndrome:

1. Partial or complete absence of horizontal movements of the affected eye.
2. Attempted adduction leads to ocular retraction and narrowing of the palpebral aperture.
3. Attempted abduction rarely leads to retraction but causes retraction of the lids.
4. Attempted adduction may cause rotation up and in or down and in.
5. Remote near point of convergence. As a rule fibrosis of the affected muscle is present. This may be due to a birth injury or imperfect development. Spaeth, (1944). Kirby (1946) and White (1946) described the results of treatment.


Summary.

1. A syndrome.
2. Palsy obscured.
3. Three stages.
4. Summary of movements.

I. Types of Palsy and their characteristics.
   Incidence and causes of ocular palsy.
   Analysis of 402 cases of muscular defects.
   Analysis of defects associated with "concomitant" strabismus.

II. Concomitance.
    Overaction and contracture of antagonist and synergist.
    Inhibitional palsy of contralateral antagonist.
III. Compensation.
   (1) Chin and face rotation.
   (2) Head tilting.

IV. Various causes of Overaction of the Inferior Oblique Muscles.
   Analysis of 228 cases.
   (1) Secondary to superior palsies.
   (2) Primary overaction.
   (3) Overaction with pseudo-trochlear palsy.
   (4) Elevation in adduction.
   (5) Overaction with alternating hyperphoria.

V. Differential diagnosis of oblique and vertical rectus palsies.
   Two schools. Bielschowsky and Duane.

PALSIES OF OCULAR MUSCLES.

The investigation of an ocular paralysis includes the study of a syndrome rather than of a single paresis. Torticollis, the rotation of the face to either side or vertically, and overaction and weakness of one or more ocular muscles may co-exist.

One of the following may make the recognition of the original palsy difficult or almost impossible, unless the patient has been followed from an earlier stage:
   1. The recovery of the palsy.
   2. The persistence of contractures and of inhibitional paresis.
   3. The development of concomitance.
   4. Suppression or a pre-existing anisometropia and amblyopia.
   5. The development of anomalous projection.
   6. The addition of a concomitant horizontal squint.
   7. The patient’s early age or lack of intelligence.

These factors may also interfere with the development of the usual compensatory face and head positions. Frequently the need for concomitance arises only if torticollis disappears or is inadequate to permit single binocular vision.

Diagnosis may be difficult if the paresis is survived by a secondary contracture of an antagonist or of a synergist. For example:

Paralysis of the right superior oblique may lead to an overaction of the right inferior oblique. Vertical deviation increases when looking to the left, because the oblique muscles have greatest influence on vertical positions of the right eye whilst adducted.

Paralysis of the left superior rectus may lead also to an overaction of the right inferior oblique. The vertical deviation increases on looking to the left because the recti have little to do with the left eye when looking to the right.
The variation in the vertical deviation in abduction and adduction will usually indicate the affected muscle. It is unwise to rely on the horizontal deviation and sometimes on the obliquity of the images.

One of the following stages may be found when investigating an ocular palsy:

1. An early stage with overaction of the ipsilateral antagonist and the contralateral synergist.
2. A later stage with a secondary contracture of the antagonist and synergist. The downward vergent eye may rotate in rather than down and in.
3. A postparetic stage when the palsied muscle may have recovered but the secondary contractures and possibly an inhibitory palsy of the contralateral antagonist persist.

When observing binocular movements in the presence of a horizontal strabismus of high degree, one must remember that a vertical deviation of one eye may be more apparent than real for the eyes are not in comparable positions. This may account for an apparent overaction of the inferior oblique in extreme adduction. Similarly in looking down and to either side a very convergent eye may rotate in rather than down and in. The downward rotation may be so much less than its fellow, looking down and out, that a paresis of the superior oblique may be diagnosed.

Before coming to a consideration of the muscular actions that concern us principally it is well to state that the obvious retracting influence that the four recti muscles exert on the eyeball is largely balanced by the influence of the oblique muscles in causing protrusion.

SUMMARY OF MUSCULAR ACTIONS.

Later the means of recognising each type of palsy will be discussed, but at present merely the characteristics of each type will be summarised.

The vertical rotators are also rollers, that is they are capable of producing in- or extorsion. Their ability to rotate the eyeball round a vertical axis needs only brief reference. The following are fundamental facts to keep in mind:

1. The superior rectus and the inferior oblique muscles rotate the globe upwards and the inferior rectus and the superior oblique rotate it downwards.
2. The superior muscles intort and the inferior muscles extort the globe.
3. In abduction the globe is rotated up principally by the rectus and in adduction by the oblique muscle. Wolff (1940) replaced the word "principally" by "only."
In abduction the oblique muscles are the main or even the only torters and in adduction the recti predominate.

In other words the vertical rotation and the power of torsion of any one muscle vary indirectly as the eye is in abduction or adduction. That means the torsion of the recti increases and their vertical rotation lessens in adduction. The torsion of the obliques increases and their vertical rotation lessens in abduction.

(5) The adduction-power of the vertical recti and the abduction of the obliques can be neutralised by a previously existing heterophoria.

To show action of Right Superior Rectus when eye is
(a) directed in front; elevation, adduction, rotation of upper pole inwards.
(b) directed outwards; elevation increased, other actions reduced and even reversed.
(c) directed inwards; elevation reduced and adduction and rotation increased.

The increase in the depressing action of the Superior Oblique in adduction is also shown. As a similar increase occurs in the elevation due to the Left Inferior Oblique when in adduction its influence in rotating the gaze up and to the right can be easily understood.

It will be seen later that many errors in diagnosis and statistics are due to a failure to appreciate the necessity of concentrating on (1) the main actions of each muscle, (2) the increase of these in one direction and their disappearance in the other, (3) the opposite influence of movements in these directions on torsion.

The characteristics of each palsy when recent are definite and permit accurate diagnosis. Later confusion may occur owing to a tendency for the deviation to become concomitant as a result of the recovery of the palsied muscle and the persistence of the contracture of its antagonist. In addition suppression of one image makes reliance on diplopia, as a guide, of little value. Not a little confusion may result from preference for fixation with the paretic eye. This may occur because its visual acuity is better, because it is the dominant eye or because the two images are further apart and so less troublesome then.
ILLUSTRATION 9.
To show action of the right inferior oblique when the eye is
(a) directed in front; elevation, abduction, rotation of upper pole
outwards.
(b) directed outwards; abduction less marked, other actions increased.
(c) directed inwards; elevation marked, other movements reduced.
The insertion is 9'5 mm. behind that of the external rectus, which is
6'9 mm. from the limbus.
(d) The insertions of the oblique muscles as seen from behind.
Distances from optic disc are shown.

1.—TYPES OF PALSIES AND THEIR
CHARACTERISTICS.

(a) Paralysis of Superior Rectus.
As a rule the head is held so that the confusion due to diplopia
is lessened. The chin is slightly raised and the face usually
turned towards the palsied side. The head may be tilted towards
the sound side, but head tilting towards one shoulder is not as characteristic as in palsies of the superior oblique. The palsied eye, if not fixing, is rotated down and slightly outwards. Its inability to rotate the eyeball up and outwards is easily seen.

**Paralysis of R.S.R.**
1. L. fixing and R. down and out
2. Looking up and R. influence of + L.I.O. + R.I.R. is shown

**Paralysis of R.I.R.**
1. L. fixing and R. up and out
2. Looking down and R. + L.S.O.

**Paralysis of R.I.O.**
(1) L. fixing and R. down and in
(2) Looking up and L. + L.S.R.

**Paralysis of R.S.O.**
(1) L. fixing and R. up and in
(2) Looking down and L. + L.I.R. and − R.I.O.

**Illustration 10.**
Paralyses of the vertical ocular muscles. The upper of each pair of drawings shows the characteristic deviation of the affected eye. The lower drawings show the failure of the affected eye to rotate in the direction of greatest diplopia and the excessive rotation of the fellow eye that may occur in this direction. After Spaeth.

If the affected eye fixes, the appearance suggests a palsy of the contralateral inferior rectus.

White (1933) wrote that the head will be tilted to the affected side if homonymous diplopia accompanies paresis of the superior rectus. Crossed diplopia will lead to the opposite result. With
Paralysis of left superior rectus. Head to right, face to L; chin up (1) and left ptosis (1) and (4). Defective upward rotation of left eye (2), (3), (5). Overaction of the right inferior oblique (2).

ILLUSTRATION 11.

Paralysis of left superior rectus and divergent strabismus (1). Overaction of right inferior oblique (2). Result of operation—myectomy of right inferior oblique, resection of left external rectus (3).

ILLUSTRATION 12.
no lateral deviation the head may be tilted to either side to overcome diplopia. Even if amblyopia prevents binocular single vision the head may be tilted and usually to the affected side.

(b) PARALYSIS OF THE SUPERIOR OBLIQUE.

This muscle is commonly paralysed. The frequency has been estimated variously by different observers. The variation is due largely to the influence of the contracture of the antagonist in the late stages. The confusion has been so real that the matter will be considered at length later.

Bielschowsky (May, 1935) described and discussed an increase in frequency of trochlear palsy. This is considered under "Differential Diagnosis of Superior Oblique and Rectus Palsies."

The position of the head is highly characteristic. The head is usually tilted towards the opposite side, the chin lowered and the face turned towards the opposite side. The object is to rotate the eyes so that the deviation is reduced to a minimum and the possibility of obtaining binocular single vision increased. The tilting of the head to one side may not be present if single "binocular" vision is already obtained by suppression or defective visual acuity of one eye is present, or if the angle of deviation is too great to permit single binocular vision. A habitually depressed position of the head in trochlear paralysis
is seldom met with. Bielschowsky, (January, 1935). Occasionally in slight trochlear pareses the head is turned towards the sound side so that the visual line of the paretic eye, being abducted, is not acted on by the oblique muscles. This removes the vertical deviation but not the meridional disinclination which may cause annoying diplopia during reading when the images cross each other at right angles.

![Diagram](https://example.com/diagram15.png)

**ILLUSTRATION 15.**
Paralysis of Right Superior Oblique (1). (Hess Chart, after Lyle and Jackson, modified) and overaction of Right Inferior Oblique (2) and Left Inferior Rectus (3).

The diplopia is very troublesome in trochlear palsy because of its increase with downward gaze. This worries the patient when walking, climbing and at near work. The lower image appears much nearer. Bielschowsky attributes the marked variation in degree of vertical separation and of the apparent distance of the images from the patient that often occurs to varying compensatory innervation. He (January, 1935) found that 80 per cent. of patients with trochlear palsy had a small convergence, which did not exceed 2-3°. In 20 per cent. a divergence or pure height-difference occurred.

A paralysis of the superior oblique can be diagnosed when by tilting the head towards the side of the lower eye the vertical divergence is lessened or abolished. Bilateral trochlear palsies were discussed by Freytag (1922). In such a condition the chin is usually lowered. The right or left eye rotates upwards with head tilting to the right or left shoulder.

Certain associations with trochlear paralysis are of great interest. If it be followed by paralysis of either the inferior rectus or the inferior oblique the lesion is probably nuclear as the cells supplying their innervation lie near the fourth nucleus.
Lifelong and inward strabismus of left eye. Torticollis typical for paresis of left superior oblique (1) & (4). Left inferior oblique overacts strongly (5) and right superior rectus appears defective (3). This is probably an inhibitional paresis. Forced tilting of head to left sends left eye upwards and produces discomfort (2).
Paralysis of left inferior rectus. Left eye fails when looking down to left (3). Secondary weakness of right inferior oblique when looking up to left (2). Head to left, face to left? Chin down (1).

Illustration 16.

Alternating upward and outward strabismus (1) and (2). Possibly due to weakness of both inferior recti. Each eye fails slightly downwards and outwards (3) and (4).

Illustration 17.
Paralysis of left inferior oblique. Left eye fails when looking up to right (2). Head to left, face to right and chin up (1).

ILLUSTRATION 19.
If both trochlear nerves are affected the lesion is probably near the decussation of the roots above the Sylvian aqueduct. If a trochlear paralysis is associated with paralysis of the extremities of the opposite side the nerve is affected at the cerebral base. If the trochlear and the trigeminal nerves on the same side are affected a lesion of the cavernous sinus is probable. Such a lesion or one in the superior orbital fissure may affect these two nerves and possibly the oculomotor nerve also.

(c) Paralysis of the Inferior Rectus.

This is very rare, much rarer than paralysis of the inferior oblique. Casten (1940) found only ten cases of isolated inferior rectus palsy in the literature. White and Brown (1939), however, reported 99 patients with unilateral inferior rectus underaction in a series of 475 patients with unilateral muscle defects associated with horizontal squint. It is most commonly due to trauma, for example, penetration of a sharp object below the globe. It may be combined with tearing of the lower lid and tear duct.

![Illustration 18](http://bjo.bmj.com/)

Paralysis of Right Inferior Rectus (1), (After Hess) and overaction of right superior rectus (2) and left superior oblique (3) and secondary paresis of left inferior oblique (4).

Immediate suture of the muscle and other tissue may be indicated. The face is usually turned towards the healthy side, the chin lowered and the head a little towards the paretic side. Bielschowsky (1930) found the head as a rule erect and not tilted towards the side.
(d) Paralysis of the Inferior Oblique.

This is not common though more frequent than paralysis of either the inferior or the internal rectus. Mauthner stated that the vertical deviation is larger in palsies of the inferior oblique muscle than in those of the other vertical rotators. The chin is raised, the face turned towards the opposite side and the head usually tilted towards the palsied eye.

Traumatic paralysis of this muscle from direct injury has been recorded by several observers. Maddox, (1907).

According to Steindorff (1913), up to 1913 only 14 undoubted cases of palsy of the inferior oblique had been reported. He quoted Mauthner (1890): “Only once during his career has the ophthalmologist the chance to cure paralysis of an inferior oblique.” For a latter report see Marlow (1923). In White and Brown’s series there were seventeen patients with underaction of the inferior oblique. Paralysis of both inferior oblique muscles with a convergent strabismus is illustrated by Chavasse (Fig. 116, and p. 249).

As the inferior oblique and inferior rectus have a common developmental origin and are supplied by the same branch of the ophthalmic division of the fifth cranial nerve, they are sometimes affected together. As the short root of the ciliary ganglion arises from the branch of the third nerve to the inferior oblique any paralysis of this muscle due to posterior orbital lesion may affect also the intrinsic muscles of the eye.

The non-fixing eye will be rotated upwards in abduction and downwards in adduction. If the affected eye fixes in abduction the other eye still tends to be the lower.

Some of the confusion existing in students’ minds is due to unwise emphasis on the actions of muscles in uniconular and not in binocular vision. Take, for example—a recent statement, Duke-Elder (1932)—that the L.S.R. and R.I.O. are primarily concerned in looking upwards and to the right. Surely the R.S.R. takes a much greater part as soon as the left eye is slightly adducted. It is wiser to state that the R.S.R. and L.I.O. are the right-hand elevators. See Duane in Fuchs’ Text-Book of Ophthalmology, 7th edition, p. 285, and his writings from 1897 onwards to 1932. Chavasse emphasised what he called the primary action of each muscle. For example, that of the superior rectus is elevation, of the inferior rectus depression, of the superior oblique intorsion, and of the inferior oblique extorsion. The word “primary” is used because the “main” action of any muscle depends on the position of the eye. “Thus when the right eye is abducted 23°, the superior and inferior recti are simply vertical motors.” But to remove the torsional effect as completely from the obliques of the other eye, it would have to be turned to the right 28° in addition, that is 51°.
Reference to Diagram 9 shows how much more strongly the R.S.R. acts as an up and outward rotator when the eye is slightly abducted and how its power of rotating the eye upwards is reduced in adduction.

Much more emphasis should be put on the main action of the muscle in binocular vision and the manner in which it can either greatly increase or even disappear with a lateral change of gaze than on the ability of the vertically acting muscles to abduct or adduct. In considering the results of a proposed operation it is wise to concentrate on the movements of the muscle in uniocular gaze, but for diagnosis of palsy it is essential to concentrate on the direction in which vertical action is most potent.

The errors that have crept into some books are further causes of the confusion that prevails. See below the notes on certain statements by Chavasse under “Head Tilting.”

The following statements bear repetition:

(1) In studying vertical diplopia one must concentrate on the direction in which the vertical action of the muscles is greatest. In that direction the vertical separation of the images will be greatest. For example, when vertical separation is greatest up to the right the affected muscle will be either the right superior (up) rectus or the left inferior oblique—its opposite.

Exceptions are rare. See later under “The Divisions of Diplopia.”

(2) In considering, however, the effect on one eye of palsy, or of operation on one of its muscles, one must consider the three
actions it has or should have. For example, we no longer associate the superior rectus and the inferior oblique muscles with the up and out direction of gaze, for though the oblique muscles are slight abductors the rectus muscles are slight adductors. Recollection of the insertions and the axis of each muscle makes its action clear. Reference to the following diagram may aid memory. The right superior rectus and the left inferior oblique elevate the eyes concerned and rotate them horizontally and around the antero-posterior axes as shown by the arrows. For example, the right superior rectus adducts or rotates to the left and rolls the upper pole inwards, that is to the left, and the left inferior oblique abducts or rotates the eye to the left and rolls its upper pole outwards, that is to the left.

INCIDENCE AND CAUSES OF OCULAR PALSIES.

Amongst 20,000 patients A. Graefe (1898) found on an average 26 cases of superior oblique palsy and only 5 cases of inferior rectus palsy, 4 cases of superior rectus palsy and 1 case of inferior oblique palsy. This was before the days of motor cars and the widespread adoption of twilight sleep and instrumental delivery.

The following analysis of ocular palsies examined in the last few years reveals the small rôle played by frontal sinus operations. More important causes are (a) motor accidents, (b) birth injuries.

Two notes on these causes are of interest. (1) from 1919-21 in England motor cars increased from fifty thousand to two hundred and fifty thousand, and by 1941 the number became one
million eight hundred thousand. A similar increase in motor bicycles occurred. (2) Whereas early this century twilight sleep and obstetrical forceps were rarely used apart from the practices of specialists, anyway in this country. With the introduction of twilight sleep, however, the use of forceps became much more general. Asymmetrical moulding may make the neat application of forceps very difficult. This may cause injuries. Brow presentations particularly and any prolonged labour are fraught with danger.

It was possible to be sure of the causes in only a few instances in this series. They were: Injuries during birth, 10 cases; Injuries in motor accident, 7 cases; Frontal-sinus operation, 2 cases.

None of the other patients had had sinus operations. In the great majority no details of cause were forthcoming. The usual history was that "the turn" developed after whooping cough or measles. The widespread losses due to neurological disorders filled a very small place in this series as only patients in a private practice were included.

ANALYSIS OF 402 OCULAR MUSCULAR DEFECTS.

Total.—402 cases of horizontal and vertical deviations, concomitant and otherwise. Vertical deviations of not more than 1 dioptre and small horizontal errors are excluded.

ANALYSIS OF PALSIES OF INFERIOR MUSCLES.

1. Single palsies.

2. Probable initial lesion in combined palsies of an oblique and a contralateral rectus muscle.—11 cases.
   Right Inferior Rectus 1
   Left Inferior Rectus 5
   Right Inferior Oblique 2
   Left Inferior Oblique 3

   Total

In addition one patient with apparent weakness of both inferior recti, one with apparent weakness of both inferior oblique muscles and one in whom all four inferior muscles were paresed were found.

ANALYSIS OF PALSIES OF SUPERIOR MUSCLES.

1. Single palsies.
   Superior Oblique 34. Right 18. Left 16.
   Superior Rectus 68. Right 30. Left 38.
2. Probable initial lesion in combined palsies of one oblique and a contralateral rectus muscle.—18 cases.

Total

Superior Rectus 79. Right 32. Left 47.

In addition there were six patients with bilateral trochlear paresis and one who had paralysis of both superior recti and one with an additional inferior oblique palsy. All four superior muscles were paresed in two patients and in one of these an inferior rectus as well. Other defects in this series were:—

97 patients without any height defect.
101 patients with an overacting inferior oblique without obvious paresis.
7 patients with a variable defect of uncertain origin.
7 patients with oculomotor and other palsies.
16 patients about whom information was unreliable.
2 patients with "hyperphoria." Neither were really concomitant. They were Mrs. T. and G.D.P., described in an earlier section, "The Influence of Fusion."
8 patients with alternating hyperphoria as the only or the predominant sign. There were others in whom this defect was not marked.
1 patient with dissociated upward rotation of one eye only.

DEFECTS ASSOCIATED WITH "CONCOMITANT" CONVERGENT STRABISMUS.

The following analysis was made of 325 patients with, what appeared to them or their parents or even the doctor at first sight, to be an inward or outward squint or strabismus. Of these it was found that approximately one third had overaction of one or both inferior oblique muscles, and that approximately one third had no definite height difference. Of the remaining thirty per cent, fifteen per cent. showed signs of a paresis of the superior rectus and ten per cent. of paresis of one or both superior oblique muscles. In forty-two per cent. a right and in fifty-eight per cent. a left eyed muscle was affected. In this table + represents overaction and — paresis.

In my series the frequency of abducens paralysis was not as great as was anticipated. This is partly due to the exclusion of public hospital patients and so a considerable number of serious traumatic and neurological lesions. No effort was made as a routine to detect slight evidence of paresis of the external rectus in patients with "concomitant" horizontal strabismus. Such
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<td>4X</td>
<td>36  5</td>
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<td>Left convergent</td>
<td>8 16 22</td>
<td>1 6 11</td>
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<td>2</td>
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<td>Percentage ...</td>
<td>30.6 15.0</td>
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X. One of these patients had a dissociated upward rotation of the right eye only.
Y. One patient had paresis of an inferior rectus as well.
Z. The four inferior muscles were paralysed in one patient with a left convergent strabismus.
Pareses of horizontal ocular muscles are not included in this analysis.
evidence as is well known is very frequent. The external rectus is probably the muscle most commonly affected by trauma and intracranial disease, but congenital weakness of this muscle is much rarer than that of the superior rectus. For further statistics of the frequency of the various types of ocular palsies see later section, "Differential Diagnosis of Vertical Recti and Oblique Muscles."

II.—CONCOMITANCE.

There appears to be an inevitable tendency to restore by suppression and other means, singleness of binocular vision. Similarly by overactions and secondary pareses efforts are made to re-obtain muscular rectitude.

Let us concentrate on this tendency for the vertical deviations due to paretic elevators to become concomitant as a result of contractures and inhibitional palsies. They cannot become as concomitant as do the horizontal deviations in abducens palsy. As Davis (1944), emphasised the influence of the vertically acting muscles varies according to the position of the eyes. The influence of the vertical recti is greatest when eyes are abducted and of the oblique when in adduction. Concomitance can occur only in the spheres of action of the affected muscle. In both trochlear and abducens palsies concomitance is not pronounced when compensation by head tilting has gone or has not developed. In any long standing palsy of the superior muscles we may find the following:—

(1) Contraction of the ipsilateral antagonist, e.g. ... ... ... ... ... + R.I.O. + R.I.R.
(2) Overaction of the contralateral synergist, e.g. ... ... ... ... ... + L.I.R. + L.I.O.
(3) Secondary inhibitional paresis of contralateral antagonist, e.g. ... ... ... − L.S.R. − L.S.O.

OVERACTION AND CONTRACTURE OF ANTAGONIST AND SYNERGIS.

In an early case the vertical deviation is greatest in the field of the major vertical action of the muscle. In paresis of the R.S.O. this will be down and to the left. In addition to this right hyperphoria there will be a left hypophoria because the yoke muscle L.I.R. overacts. When looking up and to the left or to the left, the R.I.O. the antagonist of the paresed R.S.O. overacts. In looking to the right the right superior oblique is out of the field of its vertical action and there will be little or no vertical deviation. In this direction there is maximum obliquity of the images because the inferior oblique is unopposed.
The overacting ipsilateral inferior oblique, the antagonist of the superior oblique, may develop a secondary contracture which so dominates the scene that the vertical separation may be greater in the upper and not the lower contralateral field. In late paresis of the superior rectus too the vertical separation may vary little in the upper and lower ipsilateral fields because of the overacting contralateral synergist and the contraction of the ipsilateral antagonist. This is well shown in a report by Burian (1944) of a successful resection of the affected superior rectus.

If habitual torticollis is present the diagnosis is simplified. As long as binocular single vision is possible paresis of the superior oblique nearly always causes head tilting towards the sound side and paresis of the inferior oblique toward the affected side.

If we find head-tilting to the left increases the vertical diplopia greatly and that to the right produces little or no diplopia we know the left superior oblique is paresed. If, however, there is right hypophoria and little or no difference in vertical separation with the head in the two positions the right superior rectus is affected. Bielschowsky’s explanation of this has already been given.

Sometimes reliance on the Bite-tilting Test of Hofman and Bielschowsky or on the After-image Test will help. Though Bielschowsky (January, 1935 and August, 1938) found the first two of these tests of value in late cases, Davis (1944) did not. He relied solely on the presence and influence of head tilting when secondary changes were advanced.

The overaction of the antagonist is a characteristic of the clinical picture of any paretic ocular muscle. The frequency, however, with which this overaction outlasts the paresis is very striking. There may be little or no height difference in the primary position. The height difference, however, becomes marked on looking, either, or both, to right or left. Unlike an early trochlear palsy this condition shows an alteration in height difference on looking to either side only and not on looking up or down. Possibly no evidence of the paresis may persist and when one is ignorant of its actual occurrence it is tempting to suspect a congenital hyperfunction of the inferior oblique.

When overaction of the inferior oblique is present the head is usually slightly tilted away from the side of the deviation. As the head is straightened the affected eye, usually the left, rotates upwards. As the head is turned towards this side the left eye rotates up further.

We cannot, however, class all instances of apparently overacting inferior oblique muscles as post-paretic developments. The other causes will be discussed shortly.
It is wiser to refer to secondary underaction rather than to "secondary inhibitional paresis." The ipsilateral antagonist, e.g., R.I.O. becomes contracted because it is opposed by the paretic muscle, e.g., R.S.O. It requires then a weaker stimulus than normal for a given action. The yoke muscle of this antagonist, that is, L.S.R., which is also the contralateral antagonist of the paretic muscle, will also receive a weaker stimulus and so will appear paretic. This is in accordance with Hering's law that all voluntary ocular movements are caused by an equal innervation to the muscles of the two eyes. See F. H. Adler's article, "Physiologic Factors in Differential Diagnosis of Paralysis of Superior Rectus and Superior Oblique." Arch. of Ophthal., 36, 6, p. 661, December, 1946.
LEFT TROCHLEAR TORTICOLLIS TO RIGHT SHOULDER WITH INHIBITONAL PALSY OF RIGHT SUPERIOR RECTUS.

1. SHOWS FAILURE OF LEFT EYE TO LOOK DOWN TO THE RIGHT.
2. SHOWS FAILURE OF RIGHT EYE TO LOOK UP TO THE RIGHT.

ILLUSTRATION 21.
Illustration 23.
Fixation fields in paralysis of the left superior oblique. (S.L.) Projection Test of patient in previous photo.
(1) Red glass before right eye. Field shows - L S O, + L I O.
(2) Red glass before left eye. Field shows - R S R, + R I R.
(3) Marked influence of head tilting. Torticollis to right shoulder and chin down. The ordinary test with red and green glasses suggested simple - R S R. paralysis.

Illustration 24.
Fixation fields in paralysis of the right superior rectus. (Mr. R.)
(1) Red glass before right eye. Field shows - L S O, + L I O.
(2) Red glass before left eye. Field shows - R S R, + R I R.
(3) Slight influence of head tilting. This and the absence of any torticollis and the rotation of the face to the right makes the diagnosis of an initial paralysis of R S R more likely than that of L S O. The chin was not up or down.
Paralysis of left superior oblique shown in (3). Upward deviation in forward gaze in (2). Overacting left inferior oblique and weak right superior rectus in (1). Tilting of head to right, face to right and chin down is shown, also upshoot of left eye when head tilted to left. See chart of screen findings of S.L. Though torticollis is typical for LSO yet smaller fixation field in screen findings suggests—RSR as initial lesion. Increase of upward rotation of left with head to right proves weakness of LSO, S.

ILLUSTRATION 22.
Can the inhibitional palsy persist after the disappearance of the trochlear palsy and so produce a smaller field than that of the initially affected eye? Chavasse showed (Figures 104-105) typical trochlear torticollis even though marked palsy of the superior rectus was present. As the field of the right eye of S.L., see Figure 23, is smaller than that of the left, are we to assume a primary palsy of the right superior rectus? The primary nature of the weakness of the left superior oblique is suggested by the presence of right torticollis, and by the marked increase in vertical separation of the images when the head is towards the left.

In the following diagram the confusing production of a hyperphoria present on looking to one side and varying little in upward and downward gaze, due to late paresis of a superior rectus and of a superior oblique is shown. Similarly the opposite type

**Illustration 25.**

Fixation fields in early and late paralyses of the left superior rectus and the right superior oblique muscles. In the late stages each may produce a right hyperphoria on looking to the left, that is right visual axis will be higher and right image will be higher.
of hyperphoria due to paresis of the inferior muscles could occur but these are affected much more rarely.

A right hyperphoria increasing greatly on looking to the left but varying little on vertical rotation may be a late result of paresis of either the L.S.R. or the R.S.O.

In trochlear palsies the degree of inhibitional palsy appears to vary directly with the constancy of fixation with the paretic eye. As elevation above the horizontal line may not be possible a diagnosis of superior rectus palsy may be made. Torticollis tends to be replaced by comitance, suppression or alternation as time passes.

After the disappearance of trochlear torticollis a comitant horizontal convergence may persist with only slight vertical deviation that is equal in all directions of gaze. See Chavasse, Fig. 94.

There is another confusing type of late paresis and complications. In it there appears to be limitation of upward or downward movement of one eye which does not vary in abduction and adduction.

The difficulty of diagnosis was exemplified by a man of fifty years whose left trochlea had been injured at a frontal sinus operation twenty-five years earlier. The overaction of the left inferior oblique was still obvious though no deficiency of the superior oblique was demonstrable. The projection test, however, showed -L.S.O., -R.S.R., +L.I.O. Though the right field of fixation was the smaller an initial weakness of the L.S.O. was diagnosed because of the history and because the head was tilted to the right shoulder. The position of the chin was equivocal.

It is in such cases that the head-tilting test is very useful. See the Bite-board Test of Hofman and Bielschowsky under "The Investigation of Vertical Deviations."

(2) Combined Pareses of the Contralateral Inferior Muscles.

The second common type of combined strabismus is that in which a paresis of one inferior rectus is associated with weakness of the contralateral inferior oblique. In the present series there were eleven instances of this combination. In six an inferior rectus and in five an inferior oblique was considered the muscle originally affected. The differentiation depended on (1) the field of one eye being considerably smaller than that of the other, or (2) the characteristic rotation of head and chin. In one patient, who was amblyopic, the diagnosis was made on the strong over-action of the contralateral synergist.
Combined paresis of left inferior rectus and right inferior oblique muscles. Position of head suggests that the former was the initial lesion.

1. Head to left and chin down.
2. Right eye fails more up and in.
3. Then up and out.
4. Left eye fails down and out.
5. Excessive movement of right eye down and out.

Illustration 26.
ILLUSTRATION 27.

Paralysis of the right inferior rectus and left inferior oblique. Right microphthalmia makes interpretation difficult, but right eye fails when looking down and to right (3) and left eye when looking up and to right (4).
III.—COMPENSATION.

The compensatory adjustments to lessen the discomfort of diplopia vary with individuals.

They include (1) a motor group, and (2) a sensory group.

In the latter are suppression and amblyopia as well as the development of anomalous interretinal correspondence.

The motor group includes:

(a) Fixation with the paretic eye. If the secondary deviation is greater than the primary the paretic eye may become the fixing eye so that the separation of the images is increased. As will be seen later, this may lead to inhibitional paresis of the contralateral antagonist. White (1933) wrote that in congenital paralysis the affected eye is usually the fixing one. This might be so even though its visual acuity is inferior.

(b) Alternate fixation.

This is likely to occur if a secondary covergence develops.

(c) Rotation of face and head.

This is seen in a simple form when a lateral rotator is paralysed and the face is turned in the direction in which the muscle normally
rotates the eye. This brings the images closer and enlarges the field of single binocular vision. For example, in paralysis of the right external rectus the face turns to the right.

When a vertical rotator is paralysed the position is not so simple. But again the problem is to lessen the confusion due to diplopia. The most important compensation will be a reduction of the diplopia due to the primary action of the muscle. The secondary actions, and particularly abduction and adduction, call for less compensation.

**VICARIOUS ROTATIONS OF THE HEAD.**

1. **FACE Rotation.**

<table>
<thead>
<tr>
<th>Paralysed Muscle</th>
<th>1. Chin Rotation</th>
<th>2. Face Rotation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bielschowsky</td>
<td>Chavasse</td>
</tr>
<tr>
<td>R.S.R.</td>
<td>↑</td>
<td>R</td>
</tr>
<tr>
<td>R.I.O.</td>
<td>↑</td>
<td>L</td>
</tr>
<tr>
<td>R.S.O.</td>
<td>↓</td>
<td>L</td>
</tr>
<tr>
<td>R.I.R.</td>
<td>↓</td>
<td>R</td>
</tr>
</tbody>
</table>

In my small series the vicarious positions of the head appeared as follows:

In undoubted pareses of the superior oblique the head was tilted to the opposite shoulder and the chin was down and the face nearly always was turned to the opposite side. In pareses of the superior rectus the tilting of the head and the rotation of the face varied in different cases, but except in one very old case the chin was raised.

The compensatory movements for vertical deviation and for torsion are most important, for these defects are most annoying. Elevation or depression of the chin is primarily to correct the former. Opinions are more definite concerning chin than face rotation. The lateral displacement is less disturbing and it may vary because of a pre-existing heterophoria in any patient, and so the lateral rotation of the face is not as definite. Note the diverse findings in the above analyses. One may summarise the adjustments as follows:

(1) The chin and face rotate in the direction of the maximum
vertical pull of the muscle. This lessens the burden placed on the weakened muscle.

R.S.R. rotates up especially in abduction so chin is up and face to R.

R.I.O. rotates up especially in adduction so chin is up and face to L. (R).

R.S.O. rotates down especially in adduction so chin is down and face to L.

R.I.R. rotates down especially in abduction so chin is down and face to R. (L).

Note.—The face positions given by most authorities are quoted here, and the views of Cords given in brackets. The face rotation in R.I.R. palsy is usually absent.

If the face rotation depended purely on interference with the lateral rotation one would expect in paralysis of

R.S.R., as adductor, to cause face to L.

R.I.O., as abductor, to cause face to R.

R.S.O., as abductor, to cause face to R.

R.I.R., as adductor, to cause face to L.

2. HEAD TILTING TOWARDS SHOULDER.

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Bielschowsky (1909–10)</th>
<th>Cords (1930)</th>
<th>Peter (1936)</th>
<th>Lyle and Jackson (1940)</th>
<th>Chavasse (1939)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R.S.R.</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>R</td>
<td>L</td>
</tr>
<tr>
<td>R.I.O.</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>R.S.O.</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>R.I.R.</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>L</td>
<td>R</td>
</tr>
</tbody>
</table>

1. Bielschowsky thought that head-tilting was of little importance in pareses of the recti muscles.

2. Peter wrote that the tilting "may be" as given.

3. Lyle and Jackson stated that the tilting was "usually" as given.

Bielschowsky’s view was that when the superior muscles, which are inward-rollers, are affected, the head tilts to the sound side as this produces extorsion. Paresis of an inferior muscle leads to tilting to the paralysed side.

If tilting of the head towards the side of the lower eye diminishes or removes the vertical deviation a paresis of the superior oblique exists. In 1938, Bielschowsky wrote "the results of the head-tilting test are different according to whether the vertical
divergence is due to the paresis" of the R.S.O. or the L.S.R. In 1935, "I have not yet been able to find out why the tilting is not of any use in palsies of the vertical recti, although these muscles help to bring rotation of the eyes around the visual axes necessitated by tilting the head towards the opposite side. But, according to my experience, one may assume that paresis of the superior or inferior oblique is in all probability the cause of the habitual tilting of the head, provided that only by this posture is binocular single vision to be obtained." Bielschowsky's certainty is based on the observation of "several hundred cases of the palsy under discussion which I saw before the atypical stage developed—positive results always indicating that the change in the vertical distance between the images is caused by the oblique muscles."

Chavasse (1939) appeared to agree with this view, see p. 331, but on p. 329 he suggested that in paresis of the R.I.O. the head is much tilted towards the sound side. This is apparently an error. Chavasse on p. 331 classed the inferior recti as in-rollers and surely on p. 329, fifth last line, "superior rectus" should be altered to inferior rectus.

Peter (1936) agreed with Bielschowsky's view. He wrote "Shoulder tipping in most instances, which the author has investigated, is in the direction of the physiologic action of the muscle from eyes front." He apparently meant their ability to produce torsion as the inferior muscles roll the eyeball outwards and the head tends to tilt to the affected side—the same direction. The head also leans with the false image. This makes it difficult to determine exactly which symptom the patient is attempting to overcome.

Peter (1936) added, p. 249, "Although the shoulder tipping is corrective of vertical diplopia and of the leaning of the false image, the turning of the face is of greater importance in the correction of vertical diplopia than is shoulder tipping."

Duane held that torticollis was the most important form of muscular compensation and that it could correct 25° or more of vertical diplopia.

Lyle and Jackson, Peter and others, however, consider that tilting may influence the position of the eyes in paralysis of the vertical recti muscles.

EXPLANATION OF HEAD-TILTING.

When the head is tilted to either side the superior muscles of the eye on that side, being intortors and the inferior muscles of the other eye being extorters receive labyrinthine stimulation. The vertical action of these muscles will be balanced if they are all healthy and so only torsion to the opposite side will occur. If,
however, the R.S.O. is paralysed the elevating power of the R.S.R. will be unopposed and the vertical deviation will increase when the head is tilted to the right shoulder. When the head is tilted to the opposite shoulder the affected R.S.O. will not be called upon and so no upshoot of this eye will occur.

Many writers considered torticollis to be an endeavour to lower the higher image. Bielschowsky (January, 1935) disproved this by his prism test. A 10° prism is placed base up or down before one eye, and the head tilted to each side alternately. The vertical images will retain the same height in relation to the basal line of the eyes. Even if the head is tilted so that they appear side by side with reference to the horizon they cannot be fused because they are still vertical to the base line of the eyes.

A further argument used by Bielschowsky was the failure of tilting to influence the distance between the two images in "concomitant" vertical divergence or paresis of a vertical rectus. This rather surprising fact is probably due to the much greater power of torsion due to the obliques than to the recti.

Duane, according to White (1932) finally concluded that when the head is tilted to obtain fusion, it is toward the higher images instead of always into the field of the paretic muscle. "Thus with a paralysis of a right superior rectus, the image of this eye is the higher. If, then, there is an homonymous diplopia associated with the vertical diplopia, the head will be tilted to the right. However, when there is a crossed diplopia present the head is tilted to the left. This I have observed many times." White published Duane's diagrams representing the effects of rotation.

Lyle and Jackson, p. 285, wrote that torticollis does occur in paresis of the superior recti and that towards the affected side. They claim two advantages for this: (1) Reduction of the hypotropia presumably by relaxation of the ipsilateral depressors and of the contralateral elevators. (2) Reduction of the obliquity of the false image. In paresis of the R.S.R. the extorsion of the overacting L.I.O. tends to be balanced by the intorsion of the eye on the side of the tilt. This is well illustrated in Fig. 80 of their book "Orthoptic Treatment of Squint."

Lyle and Jackson claimed that the head usually tilted towards the sound side in paralysis of a depressor and towards the affected side if an elevator was paralysed.

It is strange, however, that they omit reference to the influence of the overacting ipsilateral inferior oblique in trochlear palsy. Yet on p. 212 they wrote that torsion may be regarded as the primary action, meaning the chief action when the eyeball is in the primary position, but not the main action of the obliques.

Chavasse considered that intorsion is the primary action of the
superior and extorsion of the inferior oblique muscle. Yet Duane (1919) wrote "The intorting action of the superior oblique upon which so much stress has been laid, is quite subsidiary." The torsional power of the inferior oblique, he considered variable and as a rule slight or practically nil. Only once could he recollect marked torsional effect following tenotomy. He found that tenotomy in hyperphoria reduced the defect by from 5 to 25 centrads.

Characteristic head positions are not always seen. This may be due to the confusion that usually accompanies diplopia not arising because of suppression or defective vision in one eye. At other times the head may be turned opposite to the normal direction of the pull of the paralysed muscle so that the false image will be displaced far from the real image so that it can be easily suppressed. The usual vicarious positions of the head may not develop if the paretic eye is preferred for fixation.

Lyle and Jackson, p. 242, gave two reasons why the head is not tilted to the normal side to overcome the extorsion that occurs in superior rectus palsy (1) The height difference between the images may be more important than the extorsion and tilting to the affected or hypotropic side lowers the image of the eye on this side. (2) The extorsion of the other eye due to overacting of its inferior oblique may demand relief and this comes from tilting of the head to the paralysed side.

Exceptions are easy to understand and are commoner when a depressor is paralysed. Theoretically in the case of a depressor the position of greatest compensation should be chin down and the head and face turned to opposite sides. Now, though the latter combination exists in sterno-mastoid torticollis, when combined with chin depression it becomes intolerable. In practice a compromise occurs and there is a tendency to turn the face in the same direction as that of the head tilt. This permits a comfortable amount of chin depression.

The following considerations explain further the inability to lay down definite rules.

Most authorities agree that the head tilting in paresis of the obliques is characteristic and may be an aid in diagnosis. They disagree, however, on the side to which the head tilts in paresis of the vertical recti.

Torticollis is associated more frequently with trochlear than with superior rectus palsy. In the latter diplopia is lessened more effectively by a slight raising of the chin and a rotation of the face towards the paretic side. This enables the eye with the paretic muscle to turn downwards or inwards if the object for fixation is straight ahead.
SUMMARY.

1. The chin rotates up if an elevator is weak and down in paralysis of a depressor.
2. The head tilts in the direction of the torsion of the muscle, for example, the superior rectus and superior oblique muscles roll the eyeball inwards and the head in these pareses tilts to the opposite side.
3. The rotation of the face is to the sound side when an adductor is weak and to the affected side when an abductor is paralysed. Exceptions are very frequent if not the rule.

SUMMARY OF CHARACTERISTICS OF PARESES OF VERTICAL MUSCLES. Illustration 34.

1. The primary deviation of the paretic eye is in the opposite direction of the vertical and horizontal actions of the affected muscle.
2. The maximum vertical diplopia is in the direction of the maximum vertical pull of the muscle.
3. The maximum movement limitation.
4. The secondary deviation of the normal eye.
5. The chin and face rotation.
6. Head tilting is usually in the direction of the torsion of the muscle.
   - The many variations in face rotation have been discussed.
   - Apart from the chin rotations in general and the face and head rotations in the paralyses of the oblique muscles there is so far little agreement amongst the various authorities.
7. The obliquity of the false image is in the direction of the torsion of the muscle.
   - R.S.R. intorts especially in adduction. The image is tilted inwards especially in adduction.
   - R.I.R. extorts especially in adduction. The image is tilted outwards especially in adduction.
   - R.S.O. intorts especially in abduction. The image is tilted inwards especially in abduction.
   - R.I.O. extorts especially in abduction. The image is tilted outwards especially in abduction.

IV. — OVERACTION OF THE INFERIOR OBLIQUE MUSCLE.

(1) Overaction Secondary to Superior Muscle Palsies.
   Most marked examples of this condition are associated with paresis of either the contralateral superior rectus or the ipsilateral superior oblique.
Cords stated that the left inferior oblique was much more frequently affected than the right whether the overaction existed in the presence or absence of concomitant strabismus. It is tempting to look for a correlation with the prevalence of the birth presentation that permits greatest risk of trauma. Further investigation is required in this direction.

In my series the following were the relative frequencies with which overaction was associated with other defects:

**OVERACTION OF INFERIOR OBLIQUE WITHOUT OBVIOUS PARESIS OF VERTICAL MUSCLE**

<table>
<thead>
<tr>
<th>OTHER DEFECT</th>
<th>R. &amp; L.</th>
<th>R. I.O.</th>
<th>L. I.O.</th>
<th>TOTAL</th>
<th>PERCENTAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altern. C.C.S.</td>
<td>9</td>
<td>0</td>
<td>4</td>
<td>13</td>
<td>or 40 per cent. of 33</td>
</tr>
<tr>
<td>R.C.C.S. ...</td>
<td>13</td>
<td>12</td>
<td>11</td>
<td>36</td>
<td>or 33·3 per cent. of 108</td>
</tr>
<tr>
<td>L.C.C.S. ...</td>
<td>9</td>
<td>15</td>
<td>23</td>
<td>47</td>
<td>or 34 per cent. of 139</td>
</tr>
<tr>
<td>Divergence</td>
<td>1 L</td>
<td>1 R</td>
<td>2 R, 1 L</td>
<td>7</td>
<td>or 18 per cent. of 38</td>
</tr>
<tr>
<td></td>
<td>1 R</td>
<td>—</td>
<td>1 Alt.</td>
<td></td>
<td>Divergent Squint</td>
</tr>
<tr>
<td>Total ...</td>
<td>33</td>
<td>28</td>
<td>42</td>
<td>103</td>
<td>or 32 per cent. of 318</td>
</tr>
</tbody>
</table>

**OVERACTION OF INFERIOR OBLIQUE WITH PARESIS OF VERTICAL MUSCLE**

<table>
<thead>
<tr>
<th>Paralysis of</th>
<th>R. &amp; L. S.O.</th>
<th>...</th>
<th>6</th>
<th>0</th>
<th>0</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>R. &amp; L. S.R.</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R. &amp; L. S.O. &amp; S.R.</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R. S.R. ...</td>
<td>1</td>
<td>0</td>
<td>27</td>
<td>28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L. S.R. ...</td>
<td>0</td>
<td>45</td>
<td>0</td>
<td>45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R. S.O. ...</td>
<td>1</td>
<td>21</td>
<td>0</td>
<td>22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L. S.O. ...</td>
<td>0</td>
<td>0</td>
<td>17</td>
<td>17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total ...</td>
<td>10</td>
<td>66</td>
<td>44</td>
<td>120</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alternating Hyperphoria</td>
<td>3</td>
<td>—</td>
<td>2</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grand Total</td>
<td>46</td>
<td>94</td>
<td>88</td>
<td>228</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
THE FREQUENCY OF SUPERIOR RECTUS AND OBLIQUE PALSIES.

Though the relative frequency of these palsies varies in different statistics yet all agree that the combined figure for these palsies is great. One or both superior recti or oblique muscles may be injured at birth and accidental trauma or a radical frontal sinus operation may displace the trochlea or weaken the muscle itself. Other factors, however, must be considered if we are to explain the great frequency with which the inferior oblique shows overaction.

OTHER TYPES OF OVERACTION OF THE INFERIOR OBLIQUE MUSCLE.

2. Primary overaction or "Ueberfunktion."

Causes (a) Asymmetrical structure of the muscles. (b) Asymmetrical insertion of the muscles. (c) Deficiency of fascial check ligaments. (d) Oblique insertion of the internal rectus. (e) Nuclear hypoplasia and other explanations.

3. Overaction with binocular and pseudo-trochlear palsy.

4. Elevation in adduction of concomitant strabismus.

5. Overaction with alternating hyperphoria.

(2) PRIMARY OR CONGENITAL "OVERFUNCTION."

A congenital variety is found and it may be associated with a convergent or a divergent strabismus. The condition may be unilateral or bilateral. Usually the inferior oblique is the affected muscle. Bielschowsky (May, 1935) described these cases that were apparently congenital as "Ueberfunktion" of the inferior oblique. In such cases the field of fixation is enlarged considerably upward and inward, the direction in which the inferior oblique acts best as an elevator. In addition the obliquity of the vertical meridian of the affected eye that is present in every acquired case, primary or secondary to trochlear palsy, does not occur. As a rule the characteristic torticollis is present, the head being tilted towards the opposite side. Bielschowsky (1935). The deviation may increase greatly if we reverse the tilt. The influence of head tilting on the vertical diplopia, however, and the obliquity of the false image may be absent in these congenital cases. In addition the position of the eyes when looking straight ahead may be normal and this is never so in post-paretic cases.

The characteristics of a primary overacting inferior oblique muscle are:

1. In the primary position, as a rule, vertical divergence is absent. This is never so in secondary contracture.
2. The affected eye shows a varying upward rotation especially in full and in elevated adduction.
3. The field of fixation is enlarged in the direction in which the inferior oblique acts best as an elevator.
4. The field of fixation is not restricted downwards and inwards—the direction in which a weakness of the superior oblique is most marked.
5. The upward rotation is not present in convergence.
6. There is often no declination of the vertical meridian of the eye and consequently no obliquity of the image.
7. Even slight characteristic trochlear torticollis and the increase in vertical deviation on reversing the tilt may be absent in these cases. Bielschowsky (1935).

Treatment of the horizontal strabismus when present is all that is necessary in many cases to make the overfunction of the inferior oblique negligible. As a rule a two stage operation is desirable, particularly if both inferior oblique muscles are overactive and operation on them is considered necessary. The development of fusion appears to obscure or remove the previously obvious overaction. See treatment in Part III.

The asymmetry of the oblique muscles that may account for primary overfunction can be considered under several headings:

(a) Structural Differences.

Chavasse described a normal lack of balance between the oblique muscles. "The short, completely fleshy, and comparatively primitive inferior oblique maintains its original phylogenetic feature of strength, undiminished by concession in the interests of equal accuracy of action over a large range of movement. But in the course of a racial development, which has been associated with an increase in the range, and accuracy over that range, of ocular movement, the superior oblique has surrendered some of that strength which, before the extension of its origin to the orbital apex, it used to share with its antagonist." He suggested that when inward movement of an adducted eye begins to be retarded by the check ligament and more widespread attachments of Tenon's capsule the inherent imbalance of the opposing obliques may issue in elevation of the adducted eye.

Any tendency to dissociation facilitates this elevation.

(b) Insertional Differences.

If one eye is adducted 39° a considerable vertical action of the recti persists, while that of the oblique muscles of this eye increases. The vertical action of the oblique muscles of the other eye disappears. Has the inferior oblique a vertical mechanical advantage
over the superior oblique in adduction? This could account for many examples of elevation in adduction which have been described as normal. Chavasse.

While the inferior oblique is inserted at or near the equatorial level the superior oblique is inserted medially and much above this level. This means that a considerable change in the direction of action of the latter muscle and scarcely any in that of the former occurs as the direction of gaze rises. In elevation the abducting action of the superior oblique is increased at the expense of its torsion and depression.

(c) DEFICIENCY OF FACIAL CHECK LIGAMENTS.

This is a likely explanation as it could prevent the normal restricting influence on the contracting inferior oblique. A moderate innervation is enough to bring eyes to normal limits which check ligaments do not allow to be exceeded. Therefore even a paretic muscle may appear to act fully unless binocular fixation is studied. Lancaster (1939).

If the vertical deviation is absent in the primary position and varies not with vertical but with horizontal movements "the anomaly is very probably of congenital origin, due perhaps, to an anomalous weakness or a deficiency of the check ligament, which under normal conditions restricts the function of the inferior oblique." Bielschowsky (1938). He found such a condition, even without weakness of the superior oblique, after operations on the frontal sinus.

(d) OBLIQUE INSERTION OF THE INTERNAL RECTUS.

This has been described as a cause of upward rotation during adduction. Cords (1922) found in some of his patients a very oblique insertion of the internal rectus. These he treated by re-attachment of the tendon. In some of these, however, he thought a recession of the inferior rectus of the other eye was indicated. Bielschowsky (August, 1938) found occasionally a slight asymmetry of insertion which he held was not responsible for the upward rotation. Chavasse considered that this theory was unsupported by proper evidence.

It has been found by Foster and Pemberton (1946) that raising of the insertion of the external rectus caused elevation of the eyeball and that lowering caused depression. The results of varying the insertion of the internal rectus produced similar results. Unfortunately they did not report the effects in diagonal directions of gaze.
(e) OTHER EXPLANATIONS.

The insertions of the oblique muscles are more variable in position than those of the recti. Whitnall found considerable variation in the origin of the inferior oblique. It may lie immediately adjacent to the incisura lacrimalis or be seven millimetres lateral to it. It is possible that the overaction of this muscle may be influenced by such a variation or by the rare accessory muscle that has been described, or by a remnant of the primitive retractor of the globe. Whitnall (1921).

Verhoeff (1941) suggested that "overaction of the inferior oblique" never really is such, but is a condition due either to paresis of the superior oblique muscle or to hypoplasia of the nucleus of the trochlear nerve.

The importance attached to labyrinthine stimulation by Ohm (1921) has less justification than the theory of developmental defects of the centres and association paths postulated by de Lapersonne.

3. BINOCULAR AND PSEUDO-TROCHELEAR PALSY.

There exists occasionally with an overacting inferior oblique muscle an imperfect rotation of the eye downwards in adduction in binocular gaze. The action of the superior oblique may be full in uniconal gaze, that is when the affected eye fixes. In binocular
gaze, however, the affected eye rotates inwards rather than downwards. It is as if the nose, preventing vision in this field, has made such a movement purposeless. Possibly the inter-nuclear association fibres that link the superior oblique muscle with the opposite inferior rectus and the other muscles associated in this movement have failed to develop. This condition is bilateral. See Illustrations 29 and 30.

In the analysis of my series these patients have been grouped under 'paralysis of both superior oblique muscles.' There were six of such patients and the defect of the superior oblique muscles in unilateral gaze varied and sometimes was very slight. Considering the extent of the muscular upset the cosmetic effect in most of these children was very slight. Only one required an operation. In addition to these patients, several children showed lesser degrees of the same lack of concomitance.

4. Elevation in Adduction of Concomitant Strabismus.

This deviation is common and, according to Bielschowsky especially affects the left eye. It must not be confused with a true post-paretic overacting inferior oblique. It occurs in from 8-10 per cent. of all convergent squints. Albrecht von Graefe and Laquer detected it many years ago. Many cases have a congenital origin. Chavasse claimed that hyperphoria in adduction was a normal state. Such elevation may occur also in divergent strabismus, as well as with congenital abducens palsy.

5. Overaction with Alternating Hyperphoria.

Sometimes these conditions are found together. The diagnosis of the overaction depends on the increased elevation in adduction. In two of my patients the overaction appeared to lessen and the alternation tended to increase as time passed.

ABDUCTION IN ELEVATION.

It is of interest to discuss this related condition at this point. The tendency for a dissociated eye to diverge in elevation is very common. Diagram No. 32 supplies one explanation of this condition.

Apart from the normal advantage of the superior oblique as an abductor in elevation there may be variations in the insertions of the various muscles that may facilitate this outward swing.

The internal and the external recti are inserted approximately parallel with and 5.5 and 6.9 millimetres respectively from the limbus. If, for example, the insertion of the external rectus was closer to the limbus in its upper part than was normal it would tend
Illustration 31.

Bilateral palsy of superior oblique and overaction of inferior oblique muscles.
Apparent paresis of both superior oblique, (1) and (2), and overaction of both inferior oblique muscles, (3) and (4). In unioocular gaze each superior oblique acts almost fully when looking down and inwards, (5) and (6). Left convergent strabismus in frontal gaze, (7).

ILLUSTRATION 30.
Divergence in elevation. (3) and (4) show divergence after occlusion of either eye. In forward gaze eyes were straight except when fatigued. (1) and (2) show divergence of either eye in elevation. (5) shows attempted convergence in elevation. A defect of each inferior oblique muscle was suspected.

ILLUSTRATION 32.
to increase abduction in elevation. In addition a faulty insertion of an oblique muscle is a conceivable factor.

I have recently operated on a young woman in whom a divergence increased so much in elevation that either eye would swing out on occlusion or in an attempted gaze to the opposite side. That is, there was a failure to rotate inwards either eye in elevation. There was only slight weakness of adduction during convergence when elevated and when tested monocularly. It was considered possible that oblique insertions of the horizontal recti might explain this divergence in elevation. At operation each internal rectus showed an oblique attachment to the sclera the upper end being at least two millimetres further from the limbus than the lower end. This, however, would permit the opposite defect, for it would favour adduction in elevation. The insertions of the external recti were not examined. A diagnosis of paresis of both inferior oblique muscles was made. Illustration 31.

This condition was similar to the divergence in elevation found sometimes after operation. D. O. was a child aged five years with an accommodative concomitant strabismus that varied from 15° to 60°. Each inferior oblique overacted strongly. After recession and resection the eyes converged normally in depression when reading, but diverged in the forward resting position and diverged widely in elevation.
OVERACTION OF THE SUPERIOR OBLIQUE.

This is a not uncommon sequel of paralysis of the contralateral inferior rectus. It is characterised by a "downshoot" of the eye in adduction. Its treatment by recession of the trochlea is described by Hughes (1944).

PRIMARY SPASM OF OCULAR MUSCLES.

The types of overaction already discussed must not be confused with the spasms that occasionally occur in chorea, athetosis, epilepsy, migraine, etc. The symptoms of a spasm of any one muscle resemble closely those due to paralysis of its synergist. In the former the excursion of the faster moving eye is greater than that of its fellow which is normal. False projection is present when the faster moving eye is fixing in spasm and not the slower eye as in paralysis. The slower eye usually fixes in spasm and the deviation tends to vary more than in paresis.

V. — DIFFERENTIAL DIAGNOSIS OF VERTICAL RECTUS AND OBLIQUE MUSCLES.

There has been much confusion in the differentiation of paresis of the superior rectus and oblique muscles. In the early stages this may be due to reliance on the subsidiary actions of the muscles, e.g., (1) the superior oblique is an abductor and so paresis should cause convergence and a homonymous diplopia. A pre-existing exophoria may, however, neutralise this and a crossed diplopia result or even a crossed in one field and an uncrossed diplopia in the other. Failure to realise this may cause a faulty diagnosis of inferior rectus paresis. In only about 25 per cent. of typical troclear palsies is there any lateral deviation. (2) The superior oblique rolls the eyeball inwards and therefore tilting of the image to the opposite side should occur. But sometimes, even early, owing to strong dominance of the paretic eye its image may be the vertical one or both may appear oblique. The cyclophoria goes in time and therefore has no diagnostic value. Bielschowsky (January, 1935). The necessity for using a horizontal and not a vertical source of light becomes apparent when we realise that vertical images will diverge or converge upwards according to whether there is crossed or uncrossed diplopia. This tendency to concentrate on the unioocular defects of paresis instead of the upset in binocular vision has produced many errors.

Two well established schools of thought exist in America regarding the separation of these lesions. Those who follow Duane's principles (1916) consider that paralysis of the superior rectus is the more common lesion. Those who adhere to Bielschowsky's
reasoning consider it rare and paralysis of the superior oblique common. He wrote "By far the most frequent and important type of paralysis of a single vertical motor anomaly is trochlear nerve palsy." The underlying cause of this difference was a failure to agree on the primary action of these muscles and the occurrence of torticollis with their paresis.

The following authors considered that trochlear palsy was less common than a lesion of the superior rectus: Duane (1916) appeared to consider that paresis of the superior rectus was the commonest cause of ocular torticollis.

In Duane's analysis of 105 cases of congenital ocular palsy he found the superior rectus affected in 54, the inferior rectus in 26, the external rectus in 12, the superior oblique in 7, the inferior oblique in 5 and the internal rectus in 1.

White (November, 1944) stated that "Bielschowsky never convinced Duane, and Duane never convinced Bielschowsky." He supported Duane with whom he had worked in 1914. Amongst 475 patients with horizontal strabismus and a vertical defect White and Brown (1939) found 347 patients with under-action of one superior rectus muscle and only 12 with a weak superior oblique. Smith (1945) wrote in support of their findings. In 1944 he, Smith, stated "I encounter palsy of the trochlear nerve less frequently than any other type."

White (1932) stated that the majority of cases of hyperphoria were due to paresis of the muscles in the following order of frequency: a superior or an inferior rectus muscle, the superior oblique and inferior oblique muscles being much less frequently affected. In 1933 he wrote that paralysis of the superior rectus accounted for 24 per cent. of muscle anomalies and was second only to convergence insufficiency.

Amongst those who found trochlear palsy more commonly than that of the superior rectus were the following:—

Gifford (1941) in a careful analysis covering eight years found 15 patients of trochlear paralysis and 13 in which the superior rectus was paralysed. In two was the inferior oblique and in only one was the inferior rectus alone affected. He relied on Bielschowsky's method of diagnosis. All the trochlear cases were congenital and only one of the superior rectus pareses was so. Trochlear paresis "occurs at least half as often as abducens paresis, which is the most frequent of all." Bielschowsky.

Tomizo (1936) analysed a series of 150 ocular palsies. He found the following percentages:—

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Per cent.</th>
<th>Muscle</th>
<th>Per cent.</th>
</tr>
</thead>
<tbody>
<tr>
<td>External rectus palsy</td>
<td>43.3</td>
<td>Inferior rectus palsy</td>
<td>3.3</td>
</tr>
<tr>
<td>Oculomotor</td>
<td>29.3</td>
<td>Internal</td>
<td>1.3</td>
</tr>
<tr>
<td>Superior oblique</td>
<td>10.7</td>
<td>Inferior oblique</td>
<td>0.7</td>
</tr>
<tr>
<td>Superior rectus</td>
<td>3.3</td>
<td>Others</td>
<td>8.1</td>
</tr>
</tbody>
</table>
In my own series of one hundred and twenty-one individual ocular palsy, as far as I could decide the superior rectus was affected in 56 per cent., the superior oblique in 28 per cent., the inferior rectus in 83 per cent., and the inferior oblique in 7·5 per cent. I cannot deny that errors may have crept into my diagnosis particularly amongst patients not seen during the last three years.

Davis (1944) reported that the superior oblique was involved in 54·5 per cent. and the superior rectus in 45·5 per cent.

Chavasse (1939) wrote “It is probable that cases without a history of significant congenital ptosis, which some have diagnosed as paresis of a superior rectus, are really cases of recovered trochlear paralysis in the other eye with persistent contracture of its antagonising elevator, the inferior oblique.” See also “Inhibitional Palsy of the Contralateral Antagonist.”

The key to the situation, according to Bielschowsky, is the presence of and the effect of head tilting. He wrote of paresis of the superior rectus: “The head tilting test does not give such unequivocal clues for the diagnosis as it does in paresis of the oblique muscles” quoted by Davis (1944). Bielschowsky had written “I have not yet been able to find out why the tilting is not of any use in palsies of the vertical recti, although these muscles help to bring about rotation of the eyes around the visual axes necessitated by tilting the head toward the opposite side. But according to my experience one may assume that paresis of the superior or inferior oblique is in all probability the cause of the habitual tilting of the head, provided that only in this posture is binocular single vision to be obtained.” Also “In cases of concomitant vertical divergence or of paresis of the superior or inferior rectus muscle the tilting of the head does not influence the distance between the two images.” Duane, however, considered that children with congenital paresis of a vertical rectus or an oblique muscle sought relief either by shutting one eye or by head-tilting or by developing a horizontal deviation.

Lyle and Jackson (1940) stated that in paralysis of the superior recti the head is usually tilted to the affected side and to the opposite side if an inferior rectus is paralysed. They wrote that a primary paresis of the superior rectus was the commonest cause of head tilt.

The position of the chin should aid the diagnosis for it tends to be elevated when the superior rectus is paralysed and depressed when the superior oblique is affected.

Bielschowsky from his unique series of cases drew this interesting conclusion:—The Killian and similar operative measures have greatly increased the frequency of paresis of the superior oblique. Up to 1908 Bielschowsky found the superior oblique the affected muscle in 10 per cent. of ocular palsy and
the external rectus in 25 per cent. Between 1908 and 1934 he (May, 1935) found that the incidence of superior oblique palsy doubled and that of the external rectus remained unchanged. In the nine years ending 1934 he had 80 cases of trochlear paralysis and of these 15 resulted from a frontal sinus operation. Of ocular palsies that spontaneously recovered the trochlear form had the highest percentage, 57 per cent., the external rectus 50 per cent. and the others only 28 per cent. The average for all was 38 per cent.

In such operations when the periosteum is cut through the trochlea may recede into the orbit. It should be refixed to its original attachment by exact periosteal sutures, otherwise the function of the superior oblique is weakened.

When we remember the nerve supply and the anatomy of the two muscles it is reasonable to expect paresis of the superior oblique to be more common than that of the superior rectus. Admittedly the latter muscle is exposed to injury during birth, but one would expect to find ptosis as well in the great majority of cases. Apart from this cause it is difficult to understand an isolated palsy occurring without an obvious orbital lesion. In each third nerve the majority of the nerve fibres for the homolateral accompany some for the contralateral superior rectus. The superior branch of this nerve supplies in addition the levator palpebrae superioris. However, the vulnerability of the trochlear nerve and of the superior oblique tendon to operative and other trauma is obvious. This nerve has a long intracranial course; its root, unlike those of the other ocular nerves, decussates in the roof of the aqueduct. As a delicate thread it is very exposed to pressure and inflammation as it winds around the cerebral peduncle.

PART III.—THE INVESTIGATION OF VERTICAL DEVIATIONS.

(a) Unocular macular projection. Red and green glass test. 
(b) Binocular macular projection.
   1. The Hess Test.
   2. The Projection Test.  
   3. The Polaroid Test.


The fundamental problem is to recognise the type of defect presented by any patient. We must ask: Is the error concomitant