INTRODUCTION

Definitions

• **The visual axis** passes from the fovea, through the nodal point of the eye, to the point of fixation. In normal binocular single vision (BSV) the visual axes of the two eyes intersect at the point of fixation, the images being aligned by the fusion reflex and combined by binocular responsive cells in the visual cortex to give BSV.

• **Orthophoria** implies perfect ocular alignment in the absence of any stimulus for fusion; this is uncommon.

• **Heterophoria** (‘phoria’) implies a tendency of the eyes to deviate when fusion is blocked (latent squint).

○ Slight phoria is present in most normal individuals and is overcome by the fusion reflex. The phoria can be either a small inward imbalance (esophoria) or an outward imbalance (exophoria).

○ When fusion is insufficient to control the imbalance, the phoria is described as decompensating and is often associated with symptoms of binocular discomfort (asthenopia) or double vision (diplopia).

• **Heterotropia** (‘tropia’) implies a manifest deviation in which the visual axes do not intersect at the point of fixation.

○ The images from the two eyes are misaligned so that either double vision is present or, more commonly in children, the image from the deviating eye is suppressed at cortical level.

○ A childhood squint may occur because of failure of the normal development of binocular fusion mechanisms or as a result of oculomotor imbalance secondary to a difference in refraction between the two eyes (anisometropia).

○ Failure of fusion, for example secondary to poor vision in one eye, may cause heterotropia in adulthood, or a squint may develop because of weakness or mechanical restriction of the extraocular muscles, or damage to their nerve supply.

○ Horizontal deviation of the eyes (latent or manifest) is the most common form of strabismus.

○ Upward displacement of one eye relative to the other is termed a *hypertropia* and a latent upward imbalance a *hyperphoria*.

○ Downward displacement is termed a *hypotropia* and a latent imbalance a *hypophoria*.

• **The anatomical axis** is a line passing from the posterior pole through the centre of the cornea. Because the fovea is usually slightly temporal to the anatomical centre of the posterior pole of the eye, the visual axis does not usually correspond to the anatomical axis of the eye.

• **Angle kappa** is the angle, usually about 5°, subtended by the visual and anatomical axes .

○ The angle is positive (normal) when the fovea is temporal to the centre of the posterior pole resulting in a nasal displacement of the corneal reflex and negative when the converse applies.

○ A large angle kappa may give the appearance of a squint when none is present (pseudosquint) and is seen most commonly as a pseudoexotropia following displacement of the macula in retinopathy of prematurity, where the angle may significantly exceed +5°.

Anatomy of the extraocular muscles

• The primary action of a muscle is its major effect when the eye is in the primary position.

• Subsidiary actions are the additional effects, which depend on the position of the eye.

• The Listing plane is an imaginary coronal plane passing through the centre of rotation of the globe. The globe rotates on the axes of Fick, which intersect in the Listing plane

○ The globe rotates left and right on the vertical Z axis.

○ The globe moves up and down on the horizontal X axis.

○ Torsional movements (wheel rotations) occur on the Y (sagittal) axis which traverses the globe from front to back (similar to the anatomical axis of the eye).

○ Intorsion occurs when the superior limbus rotates nasally and extorsion on temporal rotation.

• **Medial rectus** originates at the annulus of Zinn at the orbital apex .Its sole action in the primary position is adduction.

• **Lateral rectus** originates at the annulus of Zinn . Its sole action in the primary position is abduction.

• **Superior rectus** originates from the annulus of Zinn

○ The primary action is elevation. secondary actions are adduction and intorsion.

○ When the globe is abducted 23°, In this position it has no subsidiary actions and can act only as an **elevator** . This is therefore the optimal position of the globe for testing the function of the superior rectus muscle.

○ If the globe were adducted 67.In this position the superior rectus could only act to intort the eye.

• **Inferior rectus** originates also from the annulus of Zinn

○ The primary action is depression; secondary actions are adduction and extorsion.

○ When the globe is abducted 23°, the inferior rectus acts purely as a depressor. As for superior rectus, this is the optimal position of the globe for testing the function of the inferior rectus muscle.

○ If the globe were adducted 67°, the inferior rectus could act to extort theeye.

• **Superior oblique** originates superomedial to the optic foramen and insert in the posterior upper temporal quadrant of the globe .

○ The primary action is intorsion ,secondary actions are depression and abduction.

○ When the globe is adducted 51°,In this position it can act only as a depressor . This is, therefore, the best position of the globe for testing the action of the superior oblique muscle. Thus, although the superior oblique has an abducting action in primary position, the main effect of superior oblique weakness is seen as failure of depression in adduction.

○ When the eye is abducted 39°,In this position the superior oblique can cause only intorsion.

• **Inferior oblique** originates behined orbital rim lateral to the lacrimal sac. It insert in the posterior lower temporal quadrant of the globe close to the macula.

○ The primary action is extorsion; secondary actions are elevation and abduction.

○ When the globe is adducted 51°, the inferior oblique acts as an elevator only.

○ When the eye is abducted 39°, its main action is extorsion.

Innervation

• Lateral rectus. Sixth cranial nerve (abducent nerve – abducting

muscle).

• Superior oblique. Fourth cranial nerve (trochlear nerve)

• Other muscles are supplied by the third (oculomotor) nerve.

Ocular movements

Ductions

Ductions are monocular movements around the axes of Fick. They consist of adduction, abduction, elevation, depression, intorsion and extorsion. They are tested by occluding the fellow eye and asking the patient to follow a target in each direction of gaze.

Versions

Versions are binocular, simultaneous, conjugate movements (conjugate – in the same direction, so that the angle between the eyes remains constant).

• Dextroversion and laevoversion (gaze right and gaze left), elevation (upgaze) and depression (downgaze). These four movements bring the globe into the secondary positions of gaze by rotation around either the vertical (Z) or the horizontal (X) axes of Fick.

• Dextroelevation and dextrodepression (gaze up and right; gaze down and right) and laevoelevation and laevodepression (gaze up and left; gaze down and left). These four oblique movements bring the eyes into the tertiary positions of gaze

• Torsional movements to maintain upright images occur on tilting of the head; these are known as the righting reflexes. On head tilt to the right the superior limbi of the two eyes rotate to the left, causing intorsion of the right globe and extorsion of the left (laevocycloversion).

Vergences

Vergences are binocular, simultaneous, disjugate movements (disjugate – in opposite directions, so that the angle between the eyes changes, also termed disjunctive).

Convergence is simultaneous adduction (inward turning) and divergence is outwards movement from a convergent position.

Convergence may be voluntary or reflex. Reflex convergence has four components:

• Tonic convergence, which implies inherent innervational tone to the medial recti.

• Proximal convergence is induced by psychological awareness of a near object.

• Fusional convergence is an optomotor reflex that maintains BSV by ensuring that similar images are projected onto corresponding retinal areas of each eye. It is initiated by bitemporal retinal image disparity.

• Accommodative convergence is induced by the act of accommodation near reflex.

○ Each dioptre of accommodation is accompanied by a constant increment in accommodative convergence, giving the 'accommodative convergence to accommodation' (AC/A) ratio.

○ This is the amount of convergence in prism dioptres (Δ) per dioptre (D) change in accommodation.

○ The normal value is 3–5 Δ. This means that 1 D of accommodation is associated with 3–5 Δ of accommodative convergence. Abnormalities of the AC/A ratio play an important role in the aetiology of strabismus.

○ Changes in accommodation, convergence and pupil size, which occur in concert with a change in the distance of viewing, are known as the 'near triad'.

Positions of gaze

• **Six cardinal positions** of gaze are identified in which one muscle in each eye is principally responsible for moving the eye into that position as follows:

○ Dextroversion (right lateral rectus and left medial rectus).

○ Laevoversion (left lateral rectus and right medial rectus).

○ Dextroelevation (right superior rectus and left inferior oblique).

○ Laevoelevation (left superior rectus and right inferior oblique).

○ Dextrodepression (right inferior rectus and left superior oblique).

○ Laevodepression (left inferior rectus and right superior oblique).

• **Nine diagnostic positions** of gaze are those in which deviations are measured. They consist of the six cardinal positions, the primary position, elevation and depression .

Laws of ocular motility

• **Agonist–antagonist** pairs are muscles of the same eye that move the eye in opposite directions. The agonist is the primary muscle moving the eye in a given direction. The antagonist acts in the opposite direction to the agonist. For example, the right lateral rectus is the antagonist to the right medial rectus.

• **Synergists** are muscles of the same eye that move the eye in the same direction. For example, the right superior rectus and right inferior oblique act synergistically in elevation.

• **Yoke muscles (contralateral synergists)** are pairs of muscles, one in each eye, that produce conjugate ocular movements. For example, the yoke muscle of the left superior oblique is the right inferior rectus.

• **The Sherrington law** of reciprocal innervation states that increased innervation to an extraocular muscle (e.g. right medial rectus) is accompanied by a reciprocal decrease in innervation to its antagonist (e.g. right lateral rectus). This means that when the medial rectus contracts the lateral rectus automatically relaxes and vice versa. The Sherrington law applies to both versions and vergences.

• **The Hering law** of equal innervation states that during any conjugate eye movement, equal and simultaneous innervation flows to the yoke muscles .