Vision Science III, Introduction to Eye Movements

Reading: Borish's Chapter 10 pgs 315
Eye Movement Basics for the Clinician Chapter 1
Web site http://cim.ucdavis.edu/eyes/eyes.sim.htm
http.//www. Richmondeye.com/apd.asp#examples

Extraocular Muscles: function to initiate and maintain foveal fixation. Causing clear, single vision. We take the ballet of eye movement for granted. A few people are born with oculomotor dysfunction or else acquire it from disease or trauma.

Rectus Muscles:

- Medial rectus:
  Originates from the upper and lower parts of the Annulus of Zinn and from the optic nerve sheath

  Inserts 5.5mm from the limbus…the tendon is 3.7mm long
  CN III (Oculomotor) innervates
  Contraction results in nasal horizontal motion (adduction)

- Lateral Rectus:
  Originates at the ring and spina recti lateralis
  Inserts 6.9 mm from the limbus, tendon is 8.8 mm long.
  CN VI (Abducens) innervates
  Contraction results in temperal rotation (abduction)

- Inferior Rectus:
  Originates at the tendinous ring, tendon is 5.5mm long
  Insertion is 6.5mm from the limbus in an arc with the nasal side closer to the limbus
  CN III (Oculomotor) innervates the IR
  Makes an Angle of 23 degrees with the sagittal (anterior-posterior) axis

- Superior Rectus:
  Originates at the tendinous ring and the optic nerve sheath
  SR sheath is connected to the levator muscles sheath to coordinate eye movement with lid position.
  Insertion is 7.7 mm from the limbus and curved slightly, tendon s 5.8 mm long
  CNIII (Oculomotor) innervates the SR fig 10-8 spiral of Tilleaux.

- Fig 10-6 angle of insertion

Oblique Muscles:

- Superior Oblique:
  Originates above the Circle of Zinn on the lesser wing of the sphenoid bone, medial to the optic canal and near the frontoethmoid suture.

  Passes through the Trochlea, which acts like a pulley
  Longest and thinnest of all EOMs, tendon is 2,5 cm long.
  Inserts behind the superior rectus and posterior to the equator.
  Innervated by CN IV (Trochlear) nerve
  51 degrees between line of sight and axis of muscle
  Insertion spread out like a fan
  See fig. 10-7

- Inferior Oblique:
  Originates on the maxillary bone, posterior to the inferior medial orbital rim and lateral to the nasolacrimal gland.
  Runs back within the rectus muscle cone and above the inferior rectus.
  Inserts behind insertion of the inferior rectus and posterior to the equator close to the macula.
  Innervated by CNIII.
  Axis of muscle is also between 51 and 53 degrees like the SO
  Insertion spread out like a fan

Review of Innervation

CN III: emerges ventrally from the midbrain, near the midline and the two nerves pass between the ipsilateral superior cerebella and posterior cerebral arteries. Each 3rd nerve goes forward along the ipsilateral posterior communicating artery, pierces the wall of the cavernous sinus. It lies close to the 4th, 6th and 5th nerves. The 3rd nerve divides into superior and inferior branches. The branches go into the circle of Zinn. The preganglionic parasympathetic fibers exit the inferior branch of the 3rd nerve and synapse with the ciliary ganglion. Postganglionic fibers innervate the iris sphincter and the ciliary muscle. The inferior branch continues on t o innervate the medial rectus, inferior rectus, inferior oblique. The superior branch innervates the superior rectus and the levator. The fibers in CNIII are supplied by the oculomotor complex located near the central gray mater of the midbrain at the level of the superior colliculi. Most fibers are uncrossed, but some are crossed.

CN IV: Pair of nuclei lie in the midbrain, uncrossed fibers are supplied to the 4th nerve. The two slender nerves merge behind the midbrain in a downward direction and decussate behind the brainstem. Then they travel ventral, the 4th

nerve runs inferior and lateral to the 3rd nerve, but in the cavernous sinus goes above the 3rd nerve and does not pass through the Circle of Zinn, but innervates the SO. The 4th nerve have the longest intracranial course and are the only completely crossed nerves. They are the only nerves to emerge dorsally and are the thinnest. They are somewhat fragile due to their structure and course.

CN VI: The abducens nuclei lie in the back of the pons well below the IV and III nerve complex. Uncrossed fibers are supplied to the root of nerve. The nerve travels ventrally. The thin nerve travels a long course and enters the orbit through the superior orbital fissure, then through the Circle of Zinn to the lateral rectus.

Directions of gaze and ocular orientation:

Ductions: movements involving just one eye

Adduction: rotation medially around the vertical Z Axis, eye moves towards nose
Abduction: rotation laterally around the vertical Z axis, the eye moves temporally away from the nose.
Supraduction: rotation upwards around the horizontal X axis, the eye elevates
Infraduction: rotation downwards along the horizontal X axis, the eye depresses.

Torsions:
Rotations around the line of sight Y axis
The line of sight is the line that extends from the fovea to the entrance pupil to the object of regard.

Described relative to the 12o'clock position on the superior limbus

Real torsion vs. False torsion. False torsion is an apparent cyclorotation of the eye associated with a change in direction of regards from the primary point to some tertiary pt.

Restriction in movement may be related to enlargement and swelling of EOMs from Graves disease which can lead to restriction in movement. The IR is usually first affected.

Binocular Movements:

Vergences and Versions

Both eyes work together. Vergences are disjunctive movements where the eyes move in opposite directions leading to:

Direction of Movement:

Convergence: both eyes Adducting or moving inwards
Divergence: both eyes abducting or moving outwards

Types of Vergence Movements: these allow the tracking of an object moving in depth

1. Disparity : stimulated by target disparity

2. Accommodative: stimulated by target blur

3. Proximal: stimulated by apparent nearness or perceived distance of target

4. Tonic: baseline neural innervation stimulated by midbrain, does not contribute to following a moving target in depth.

Versions: both eyes look in the same direction… These are conjugate movements

Direction of Movement:

Dextroversion: right gaze, both eyes move to the right
Levoversion: left gaze, both eyes move to the left
Supraversion: superior gaze, both eyes move up
Infraversion: inferior gaze, both eyes move down

Types of Version Movements:

1. Fixational: response to a stationary target, functions to stabilize target onto the fovea
2. Saccadic: response to step of target displacement, functions to acquire an eccentric target onto the fovea.
3. Pursuit: response to target velocity, tries to match eye velocity with target velocity to stabilize retinal image.
4. Optokinetic: response to target or field velocity, trying to maintain a stable image during sustained head movement.
5. Vestibular: response to head acceleration, tries to maintain a stable image with the target on the fovea during transient head movement.

Definitions;

Object of regard: The point at which an observer directs his gaze, also called the fixation point

Visual axis: a line from the object of regard to the first nodal pint of the eye and then from the second nodal point of the eye to the fovea. The two nodal points are usually considered to be coincident.

Pupillary axis: a line perpendicular to the cornea and passing through the center of the entrance pupil.

Fixation axis: the line connecting the object of regards to the best approximation of the center of rotation of the eye.

Entrance pupil: the image of the real pupil of the eye formed by the refraction at the cornea

Line of sight: the line connecting the object of regard and the center of t he entrance pupil.

Optic axis: the best approximation of a line passing through the anterior and posterior poles of the eye.

Angle alpha: the angle formed at the first nodal point by the intersection of the optic axis and the visual axis

Angle gamma; the angle between the fixation axis and the optic axis

Angle kappa: the angle formed at the nodal point by the intersection of the visual axis and the pupillary axis

Angle lambda: the angle subtended at the center of the entrance pupil by the intersection of the pupillary axis and the line of sight.

Globe: A sphere rotating about a point fixed within its self. The center of rotation is the zero-velocity sport approximately at the mid point. It has 3 degrees of freedom, rotation about vertical, horizontal and anteroposterior axes.

Object vertical: a frame of reference used to specify the position of the eye within the orbit, a hanging plumb line representing true gravity vertical.

Torsion: True cyclorotation of the eye about an anteroposterio axis such as the line of site.

False Torsion: The apparent cyclorotation of the eye associated with a change in direction of regard from the primary position to some tertiary position. The angular difference between the objective vertical and the vertical corneal meridian when the eye is in a tertiary position.

Listing's Plane: A plane passing through the head and the center of rotation of the eyes that is perpendicular to the line of sight when the eyes are in primary position.

Listing's law; The movement of the eyes from primary position to any other position is equivalent to a single rotation about an axis in Listing's plane. Each movement of the eye from a primary to tertiary position is always associated with a unique false torsion of the corneal vertical meridian with respect to objective vertical. There is no real torsion.

Listing's 2D coordinate system:

The eye has a 2 D coordinate system of movement based on Fick's Axes instead of the 3D anatomy.
Fick's Axis system: The eye rotates first around a vertical and then around a horizontal axis. The plane formed by these two axes is Listing's Plane. This is the Plane that passes through the head and center of rotation of the eyes and is perpendicular to the line of sight when the eyes are in primary position.

With Listing's Law:

1. Anything that is actually straight in the real world, no matter how it is oriented will continue to give a straight image as the eye travels along it, even though the eye is really shaped like a bowl and the image should be distorted.
2. This allows eye movements to be described in terms of 2D instead of 3 D.

Violations of Listing's Law;

It is applied when the patient is upright and head is stationary, and observer is monocularly viewing an object at optical infinity.

Violated; with convergence, extreme voluntary effort, sleep, extreme positions of gaze, postural changes, head tilt with cycloversison, Vestibulo-Ocular Reflex.

False torsion and Listing's Law:

Listing's Law says that all eye movements from the primary position have no net torsion. This is important or the world would be skew and tilted with each eye movement. There is real torsion that can happen with specific ocular muscle function. These laws are functional not anatomical.

Donder's Law: The angle of tilt for any given tertiary position of the eye is the same regardless of how the eye got to that position.

Descartes-Sherrington law of reciprocal innervation: When an agonist contracts during movement of an eye, there is a simultaneous and equal relaxation of its antagonist fellow muscle. The right lateral rectus contracts, the right medial rectus relaxes. This law is for monocular eye movement.

Hering's laws of equal innervation: Corresponding or yoke muscles of each eye are equally innervated. Hering's law is specified with respect to static eye position changes. This applies to conjugate movement.

Primary position of gaze: The position of the eye with the head erect, the eyes located at the intersection of the sagittal plane of the head and the horizontal passing through the center of rotation of both eyes and the eye is focused for infinity.

Secondary position of gaze: rotations around either the vertical or the horizontal axis only. Purely horizontal or vertical movements are made from the primary position. No tilt

Tertiary positions of gaze: rotations around both the vertical and horizontal axes.
An oblique deviation of the line of sight… the line connecting the object of regards and the center of the entrance pupil.

Duane's Isolated Agonist Model:

This model is to explain the movement around the different axes which occur as each muscle contracts. During eye movements all of the muscles are in play either relaxing or contracting. The movement in this model is from primary position. Agonist muscles are the mover, antagonist are the opposer. Yoked muscles work to move the eyes in the same direction:

See chart p 7 of Cuiffreda

Due to the insertion angle of the muscle there are different effects when muscles contract and the eye is in the field of action of that insertion.

As the eye increases in abduction, the depressing ability of the vertical rectus muscle increase, as it moves towards adduction the elevating and depressing abilities of the obliques increase.

Fields of actions where each EOM is maximized;

LR…. Temporal/lateral gaze
MR……nasal /medial gaze
SR….superior temporal gaze
IR… inferior temporal gaze
SO…. inferior nasal gaze
IO…..superior nasal gaze