### GREYS HOSPITAL
#### NEURO-OPHTHALMOLOGY DEPARTMENT

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| Pupil diameter (mm) | Light | Dark 5° | 20° | Converg.
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<th>Nystagmus</th>
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<th>Fixation</th>
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<th>Vignence</th>
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Supranuclear Gaze Control
Supranuclear Gaze Control

- 6 ocular motor subsystems
- Enable the fovea to find and fixate a target
- Maintain binocular foveation during head or target movement or both
SIX NEURONAL SYSTEMS KEEP THE FOVEA ON TARGET

1. **Fixation** – holds eye still during intent gaze
2. **Saccadic** – points fovea to objects of interest
3. **Smooth pursuit** – keeps moving targets on the fovea
4. **Vergence** – aligns eyes to look at diff depths
5. **VOR** – hold images still on the retina during brief head movements, driven by vestibular system
6. **Optokinetic** – hold images still during sustained head rotn, driven by visual system
SIX NEURONAL SYSTEMS KEEP THE FOVEA ON TARGET

- Fixation
- Saccadic
- Smooth Pursuit
- Vergence
- Vestibulo-ocular (VOR)
- Optokinetic (OKN)
Fixation

- **Saccadic intrusions**
  - With intersaccadic interval
    - Square – wave jerks
    - Macrosaccadic oscillations
  - Without intersaccadic interval
    - Ocular flutter
    - Opsoclonus
    - Voluntary nystagmus
Saccadic Pathways
BSG - Brainstem Saccadic Generator
CS - Cerebellar Structures
PVC - Primary Visual Cortex
PPC - Posterior Parietal Cortex
SC - Superior Colliculus
SEF - Supplementary Eye Field

FEF - Frontal Eye Field
DLPC - Dorsolateral Prefrontal Cortex
CN - Caudate nucleus of the basal ganglia
SNr - Substantia nigra pars reticulata
PON - Precerebellar Pontine Nuclei
Saccadic dysfunction

- Disorders of speed
  - Slow_Saccades_Horizontal.mpg

- Disorders of initiation
  - Cogan_OM_Apraxia_F.mpg

- Disorders of accuracy
  - Saccade_Hypermetria_SCA8.mpg
  - Fastigial_Hypermetria.mpg
Disorders of Horizontal Gaze

- Cerebral cortical lesions
  - Frontal eye field lesions
  - Congenital ocular motor apraxia
  - Balint’s syndrome

- Pontine Lesions
  - Pontine conjugate gaze palsy- PPRF/6th nucleus
  - Internuclear ophthalmoplegia
  - One-and-a-half syndrome
Cerebral Cortical lesions

- Acute cerebral hemisphere infarct
- Conjugate eye deviation towards the lesion side
- Frontal and/or Parietal ocular motor areas involved
- Gaze deviation due to unopposed activity of normal contralateral hemisphere
- Vestibular reflexes (VOR, Calorics) remain intact
Ocular motor apraxia

- **Congenital**
  - Impairment of voluntary horizontal eye movements
  - VOR is normal
  - Head thrusts used to redirect gaze

- **Balint’s**
  - Bilateral posterior parietal lesions
  - Ocular motor apraxia, simultanagnosia and optic ataxia (impaired visual guided reaching)
**Pontine lesions**

- **Pontine conjugate gaze palsy**
  - All ipsiversive saccades are lost due to loss of burst neurons
  - 6th nerve nucleus lesion (H gaze palsy)
    - Horizontal gaze palsy
    - Saccades, pursuit, OKN and VOR affected
    - Conjugate palsy due to loss of abducens motoneurons and internuclear neurons
    - Esotropia may be present
  - PPRF lesion (H saccadic palsy)
    - VOR is preserved
Pontine lesions

- Internuclear ophthalmoplegia
  - Lesion of the Medial longitudinal fasciculus
  - Impaired adduction of eye ipsilateral to MLF lesion
  - Nystagmus of abducting eye
  - Complete INO vs incomplete INO

- When convergence is preserved = Pontine (post. INO)
- When convergence is affected = Midbrain (ant. INO)

- Multiple Sclerosis, Ischaemia
Pontine lesions

- Internuclear ophthalmoplegia
  - WEBINO (wall-eyed bilateral INO) – exotropia with bilateral INO’s. MR subnuclei also affected
  - INO may be associated with
    - skew deviation. Hypertropia of the ipsilateral eye
    - Dissociated vertical-torsional nystagmus
    - Impaired VOR
Pontine lesions

- **One-and-a-half syndrome**
  - Unilateral pontine lesion that affects both the PPRF/Abducens nucleus and the MLF
  - Ipsiversive gaze palsy = One
  - INO of ipsilateral eye during contraversive gaze = Half
  - For first few days there may be an exotropia due to tonic abduction of the contralateral eye. (Paralytic Pontine Exotropia)
Pursuit Pathways
Retina
→ Afferent Visual Pathways
→ Striate Cortex
→ P-O-T Junction
→ FEF
→ DLPN
→ Cerebellum
→ Vestibular Nuclei
→ III, IV, VI Nuclei
Complete Left Homonymous Hemianopia

Parieto-occipito-temporal junction

Normal SEM (pursuit) to Both Sides, Despite Complete Left Homonymous Hemianopia
Complete Left Homonymous Hemianopia

Deep Right Parietal Lobe Lesion
Absent SEM (pursuit) to Side Ipsilateral to Parietal Lobe Lesion
Smooth pursuit dysfunction

- Impaired ipsilateral to parietal lobe lesion

Cerebral_Hemisphere_Pursuit.mpg

Right cerebral hemisphere lesion (arrows)
Vestibulo-ocular Pathways
WARM WATER CALORICS: The endolymph rises (arrow) toward the ampulla

COLD WATER CALORICS: The endolymph falls away from (arrow) the ampulla
Vestibular Dysfunction

- Impaired head impulse response
- Head shaking induced nystagmus

Head_Impulse_Unilateral.mpg

Head_Shaking_Unilateral.mpg
Cerebellar Influences on Eye Movements

- The cerebellum coordinates the OMS to drive the eyes smoothly and accurately

- The **flocculus and paraflocculus** stabilise gaze by matching the saccadic pulse and step

- The **nodulus** alters velocity storage of vestibular information...actually prolonging it

- The **dorsal vermis and fastigial nuclei** determine accuracy of saccadic amplitude.
Cerebellar Syndromes

- Vestibulo-cerebellar/ Floccular Syndrome
  - Gaze evoked nystagmus
  - Rebound nystagmus
  - Decreased pursuit
  - Impaired VOR cancellation
  - Downbeat nystagmus

- Nodulus Syndrome
  - Periodic alternating nystagmus
Cerebellar Syndromes

- Fastigial-Vermis syndrome
  - Decreased pursuit
  - Saccadic dysmetria
    - Hypermetric saccades
    - Hypometric saccades
    - Lateropulsion
      - Inferior cerebellar peduncle – Lat Med Syn
        - Ipsipulsion
        - Superior cerebellar peduncle
          - Contrapulsion
Vertical Eye Movements

- Premotor substrate for vert gaze lies in the Midbrain Reticular formation

- Some vertical saccades are programmed in the PPRF and an alternate MLF pathway

- riMLF contains EBN for both upgaze and downgaze

- EBN’s for upward saccades – project dorsally and laterally from riMLF – decussate in the posterior commissure – innervate both ipsilateral and contralateral 3rd and 4th nerve nuclei
Vertical Eye Movements contd..

- Downward saccades – EBN’s – project dorsomedially and caudally to innervate the 3rd and 4th nerve nuclei bilaterally

- Vertical saccades require bilateral supranuclear innervation

- The neural integrator for vertical and torsional movements is located in the interstitial nucleus of Cajal (INC)

- Burst-tonic and tonic neurons lie in INC
## Brainstem Saccade Generators

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<tr>
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<th>Horizontal Saccades</th>
<th>Vertical Saccades</th>
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<tbody>
<tr>
<td><strong>Burst Neurons</strong></td>
<td>PPRF</td>
<td>riMLF</td>
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<tr>
<td><strong>Integrator</strong></td>
<td>NPH</td>
<td>INC</td>
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<td>MVN</td>
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Brainstem Control of Vertical Gaze

UPWARD EYE MOVEMENTS

DOWNWARD EYE MOVEMENTS

Bilateral Saccadic Projections

Ipsilateral Saccadic Projections
Retinal slip is the sensory stimulus for vertical pursuit.

Info is encoded by the dorsolateral pontine nuclei and relayed to the flocculus and posterior vermis.

Then converges on the INC on the midbrain.

Then onto the relevant ocular motor nuclei.
Disorders of Vertical Gaze

- **Downgaze palsy** – a unilateral riMLF lesion impairs downgaze—rostral to 3rd Nucleus and dorsomedial to red nucleus (Midbrain stroke or tumour)

- **Upgaze palsy** – lesions are more dorsal, includes the posterior commissure

- **Vertical gaze palsies** are occasionally monocular
Disorders of Vertical Gaze

- riMLF control of upward saccades is bilateral, downward saccades is unilateral at the OMN level.

- Each riMLF projects to neurons innervating ipsilateral IR and contralateral SO therefore unilateral lesion impairs downward (but not upward) saccades.
Disorders of Vertical Gaze

- Parinauds
  - Upward gaze palsy.
  - Involvement of INC and its projections through the posterior commissure

- PSP
  - Impairment of voluntary and reflexive saccades
  - Downward saccades affected first. Upward and horizontal saccades affected as disease progresses
  - First saccade velocities affected but eventually all gaze movements are affected
  - VOR remains intact until very late in the disease
Disorders of Vertical gaze

- Oculogyric crisis
  - Tonic involuntary upward deviation of the eyes
  - Associated with neuroleptics, post encephalitic parkinsonism
Vergence Eye Movements
Vergence Eye Movements

- Binocular fusion is necessary to maintain ocular alignment on an approaching or retreating object
- EMG shows that divergence is an active movement
- Not as dynamic or under voluntary control as convergence
- The driving stimulus for vergence movements is retinal blur (unfocused) and fusional disparity (diplopia)
- Relayed via the occipital cortex
Vergence Eye Movements

- The precise location of the convergence and divergence centres is unknown
- 2 areas viz. the midbrain pretectum and nucleus reticularis tegmenti pontis (NRTP) are important
- Lesions of the pretectum cause vergence abnormalities
- The NRTP functions as a Vergence Integrator
- Lesions of the NRTP in monkeys cause sustained convergence or pendular convergence-divergence oscillations
Vergence Eye Movements

- The occipito-mesencephalic pathway runs more ventrally than does the light reflex pathway.

- Less susceptible to extrinsic compression.
Disorders of Vergence

- Spasm of the near reflex
  - Triad of convergence, accommodation, miosis
  - Simulates unilateral or bilateral abducens palsy
  - Usually psychogenic with variable esotropia
  - Rarely due to organic disease – head trauma, dorsal midbrain syn, intoxication, Wernicke’s syndrome
Disorders of Vergence

- Convergence paresis/paralysis
  - Diplopia at near or easy fatigability when reading
  - Usual causes: ageing, lack of effort
  - Rarely due to organic cause – dorsal midbrain syn, MS, encephalitis, diphtheria, botulism
Disorders of Vergence

- Divergence paresis/paralysis
  - Orthophoria at near
  - Comitant esotropia at distance
  - Full extraocular movements
  - Must exclude bilateral 6th nerve palsies
  - Causes – head trauma, PSP, brainstem CVA, cerebellar lesions incl ACM type 1
Tools for the Hunt

- **Saccadic** – target the prey
- **Pursuit** – follow the prey
- **Vergence** – depth perception
- **VOR** – fixate on the prey despite rapid head movement
- **OKN** – slow or sustained head rotation – refixate on target