Thalamocortical Pathways

Virtual Neuroanatomy

October 2\textsuperscript{nd}, 2014
Outline

1. Overview
2. Afferents & Efferents
3. Neurophysiology
4. Neurochemical Systems
5. Physiological Correlates
6. Behavioral Correlates
7. Clinical Pathologies
Overview
Thalamocortical Pathways

• Relays sensory information to cortex
• Integrates information from different sensory modalities
• Projects throughout cortex
Thalamocortical Pathways

- Relays sensory information to cortex
- Integrates information from different sensory modalities
- Projects throughout cortex
  - Emotion

Thalamocortical Pathways

• Relays sensory information to cortex
• Integrates information from different sensory modalities
• Projects throughout cortex
  • Emotion
  • Motor
Thalamocortical Pathways

- Relays sensory information to cortex
- Integrates information from different sensory modalities
- Projects throughout cortex
  - Emotion
  - Motor
  - Somatosensory
Thalamocortical Pathways

• Relays sensory information to cortex
• Integrates information from different sensory modalities
• Projects throughout cortex
  • Emotion
  • Motor
  • Somatosensory
  • Auditory
Thalamocortical Pathways

- Relays sensory information to cortex
- Integrates information from different sensory modalities
- Projects throughout cortex
  - Emotion
  - Motor
  - Somatosensory
  - Auditory
  - Visual

Thalamocortical Pathways

- Relay sensory information to cortex
- Integrate information from different sensory modalities
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  - Emotion
  - Motor
  - Somatosensory
  - Auditory
  - Visual
  - Association
Thalamic Nuclei

Thalamic Nuclei

Categories of Thalamic Nuclei

• Relay Nuclei
  – Project sensory info to distinct sensorimotor cortical areas

• Association Nuclei
  – Cortico-thalamic-cortical connections, project to association regions of cortex

• Nonspecific Nuclei
  – Project to wide range of cortical regions without topographical organization
  – Also project to specific thalamic nuclei
Afferents & Efferents
Thalamic Inputs

- Relay Nuclei
- Limbic Structures
- Basal Ganglia
- Cerebellum
- Brain Stem Nuclei
- Association Nuclei
- Cortical Association Areas

Figure 12-4  Main connections of the thalamus. Afferent fibers are shown on the left, and efferent fibers are shown on the right.

Premotor Pathway

Basal Ganglia → VA → PMC
Motor Pathway

Cerebellum → Basal Ganglia → VL → M1
Somatosensory Pathway

Brainstem → VP → Postcentral Gyrus
Auditory Pathway

Inferior Colliculus → MGN → Auditory Cortex
Visual Pathway

Optic Tract → LGN → Visual Cortex
Limbic Pathway

Mammillothalamic Tract → AN → Cingulate Cortex
Prefrontal Association Pathway
Parietal-Occ-Temp Assoc. Pathway

Association Cortices
Superior Colliculus

Pulvinar/LP

Parietal-Occipital-Temporal Association Cortex
Path

Layer IV (ipsilateral)
Corona Radiata
Internal Capsule

Neurophysiology
Two Physiological States

• **Tonic Mode**
  - Slightly depolarized
  - Accurately transmits info
  - Focusing attention on stimulus, thought or task

• **Burst Mode**
  - “lookout function”
  - Very sensitive to input
  - Can’t accurately convey input info because of low frequency of bursts

Neurochemical Systems
Neurochemical Systems

• Most thalamic relay neurons are glutamatergic
• More sensory input → faster firing to cortex

Corticothalamic Regulation

- Thin type-1 fibers
  - Modulatory feedback onto sensory relays
- Course type-2 fibers
  - Feedforward mechanism in cortico-thalamo-cortical circuits

Physiological Correlates
Heart Rate & Respiration

- Negative correlation between VP firing and heart rate intervals in cat.
- Thalamic neurons carry information about the magnitude of respiratory activity.

Chen et al. (1992). Resp Phys. 90, 91-113
Behavioral Correlates
Motor Movements

- Somatotopic arrangement of motor movements induced by microstimulation of motor thalamus in primate

Vitek et al. (1996). Journal of Neurophysiology, 72, 2486-95.
Pain Perception

• VPL cells show large response to noxious heat stimulation

Pain Perception

- VPL cells show large response to noxious heat stimulation
- Implicated in attention/arousal to pain stimuli in humans

Auditory Perception

- MGN essential for auditory avoidance conditioning

Visual Attention

• Attention to visual stimuli associated with increased BOLD activation in LGN and visual cortex in human

O’Connor et al. (2002). Nature Neuroscience, 5, 1203-1209.
Clinical Pathologies
Fatal Insomnia

- Accumulation of prion proteins in mediodorsal and anterior thalamic nuclei
  - Disrupted sleep
  - Autonomic hyperactivity
  - Cognitive deficits
  - Motor abnormalities
    - Sudden motor contractions
    - Ataxia (lack of motor coordination)
    - Dysphagia (Difficulty swallowing)

Schizophrenia

- Reduced volume and neuronal density of MD
- Greater mean diffusivity
  - Correlated with working memory performance
- Reduced FA of thalamocortical tracks in chronic patients
- Implicates degeneration of thalamic nuclei in pathophysiology of schizophrenia

Catani et al. (2012). Atlas of Human Brain Connections
Thalamic Pain Syndrome

- VPL/VPM lesions causing damage to spinothalamic fibers
- Thalamic pain: Intense pain triggered by somatosensory stimuli
- Hemianesthesia: Loss of somatic sensation in contralateral head or body
- Sensory ataxia: loss of coordination (due to loss of proprioception)

Bible (2012). Nat Rev Neurology, 8, 412.
## Symptoms of Thalamic Injury

<table>
<thead>
<tr>
<th>Pathway</th>
<th>Principal nuclei</th>
<th>Function</th>
<th>Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Limbic</strong></td>
<td></td>
<td><strong>Anterior thalamic group</strong>&lt;br&gt;Anterodorsal (AD)&lt;br&gt;Anteroventral (AV)&lt;br&gt;Anteromedial (AM)</td>
<td>Amnesia, language difficulties (reduced spontaneous speech, anoma)</td>
</tr>
<tr>
<td><strong>Prefrontal</strong></td>
<td></td>
<td><strong>Medio-dorsal nucleus (MD)</strong> and <strong>Midline (Mid) group</strong>&lt;br&gt;Drive, motivation, emotion, executive functions, working memory, attention, autonomic and sleep-wake cycle regulation.</td>
<td>Apathy, abulia, disinhibition, working memory deficits, sleep dysregulation</td>
</tr>
<tr>
<td><strong>Association</strong></td>
<td></td>
<td><strong>Ventral group</strong>&lt;br&gt;Anterior (VA)</td>
<td>Dystonia, language impairment (reduced fluency, perseveration, stuttering), behavioural problems</td>
</tr>
<tr>
<td><strong>Premotor</strong></td>
<td></td>
<td><strong>Lateral</strong>&lt;br&gt;– anterior (VLa)&lt;br&gt;– medial (VLM)&lt;br&gt;– posterior (VLP)</td>
<td>Ataxia, mild motor weakness, language, memory difficulties</td>
</tr>
<tr>
<td><strong>Motor</strong></td>
<td></td>
<td><strong>Posterior</strong>&lt;br&gt;– lateral (VPi)&lt;br&gt;– medial (VPm)&lt;br&gt;– inferior (VPi)</td>
<td></td>
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<tr>
<td><strong>Somatosensory</strong></td>
<td></td>
<td><strong>Lateral group</strong>&lt;br&gt;Dorsal (LD)&lt;br&gt;Posterior (LP)&lt;br&gt;Pulvinar (Pol)</td>
<td>Dejerine-Roussy disease (thalamic pain syndrome); contralateral hemianesthesia (typically for all sensory modalities) of body and limbs (VPI) or head and neck (VPm)</td>
</tr>
<tr>
<td><strong>Par-Occ-Temp</strong></td>
<td></td>
<td><strong>Metathalamus</strong>&lt;br&gt;Lateral geniculate nucleus (LGN)</td>
<td>Impaired visual discrimination, hemispatial neglect, language deficits, psychosis</td>
</tr>
<tr>
<td><strong>Association</strong></td>
<td></td>
<td><strong>Visual</strong>&lt;br&gt;Visual-sensory-motor integration and visual salience (discriminating relevant from irrelevant visual stimuli)</td>
<td>Contralateral homonymous hemianopcia (loss of vision in the same visual field on both eyes)</td>
</tr>
<tr>
<td><strong>Auditory</strong></td>
<td></td>
<td><strong>Medial geniculate nucleus (MGN)</strong></td>
<td>Central deafness</td>
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