Functional neuroanatomy the visceral nervous system (ANS)

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How do you evaluate the ANS in your neurological examination?
Visceral Nervous System

• Visceral efferent and afferent system
• Visceral afferent system
  – Receptors
    • GVA – pressure, stretch and chemical changes (pH, O$_2$, CO$_2$)
    • SVA – taste, olfaction
    • Not tactile/touch
      e.g. C-section in a cow
  – Single neuron with peripheral ganglion
  – Axons – cranial and spinal nerves
    • CNN ganglia
      – geniculate (VII),
      – distal ganglia CN IX (petrosal)
      – distal ganglion CN X (nodose)
    • Spinal ganglia
    • Use same pathways as the visceral efferent nerves
    • Spinoreticular and spinothalamic tracts
Visceral afferent system

- Input via cranial nerves
  - CN I – Olfaction SVA
  - Solitary nucleus (CN VII, IX, X)
    - Taste – CNN VII and IX (also known as gustatory nucleus)
    - Viscera (thoracic and abdominal), baroreceptors, chemoreceptors – CNN IX and X
      - CN X – 80% of fibres are visceral afferents
    - Output from solitary nucleus for reflex function via reticular formation
      - e.g. respiratory, CVS, swallowing, micturition
    - Conscious perception – solitariothalamic tract
- Input via spinal nerves
  - Reflexes – sympathetic or parasympathetic
    - e.g. tachy- or bradycardia
  - Conscious perception via spinoreticular tract to thalamus
Visceral efferent system (ANS)

- Autonomic nervous system ANS
  - Purely efferent system
  - To smooth and cardiac muscle, and glands
  - Two functional components
    - Differentiated morphologically, pharmacologically and physiologically
    - Parasympathetic NS
      - Housekeeping system ‘rest and digest’
    - Sympathetic NS
      - Prepares the body for flight or to fight
  - Dual innervation all body systems

http://staffsites.slcschools.org/
Anatomy of the ANS

- Central nervous system (CNS) components
  - Brain
    - Forebrain (diencephalon – UMN to ANS)
    - Brainstem –
      - UMN cardiac and respiratory and protective centres
      - LMN in CNN
        » Naming of CNN nuclei: parasympathetic nucleus of CN___
  - Spinal cord
    - Thoracic, lumbar, sacral

- Peripheral nervous system (PNS)
  - Cranial and spinal nerves
  - 2 neuron system with peripheral ganglia
    - (c/w visceral afferent – single neuron with peripheral ganglion)
Anatomical concepts of the ANS

• How many neurons?
  – One CNS neuron
    • Brain or spinal cord
  – Two neurons in the PNS
    • 1\textsuperscript{st} neuron cell body in CNS
    • 2\textsuperscript{nd} neuron cell body in ganglion
    • May pass through several ganglia without synapsing
      – e.g. sympathetic supply to head
        » T1-3 spinal cord, through cervicothoracic and middle cervical ganglion, synapses in cranial cervical ganglion
  – Terminology – pre and post synaptic neurons

• Where do ANS fibres leave CNS?
  – Parasympathetic NS = craniosacral NS
  – Sympathetic NS = thoracolumbar NS
Central controls for VNS

- **Hypothalamus**
- **Central regulator**
  - Receives input
    - From viscera
      - Via CN VII, IX and X
        » To nucleus solitarius in myelencephalon
        » spinothalamic tract with input from segmental spinal nerves
      - From telencephalon
        » Emotional input
  - Output
    - Neural – via brainstem and spinal cord
    - Humoral – via hypophysis

Clinical correlate: damage to hypothalamus can lead to autonomic imbalance such as excess or insufficient sympathetic function
Fergus 1.5yo MN Cocker Spaniel
Hx: 3wk blindness and dysuria
Reticular visceral control centres

- **Medulla oblongata (myelencephalon)**
  - **Respiratory centre**
    - Afferents – PaO$_2$ and PaCO$_2$ chemoreceptors, aortic and carotid bodies, input to solitary nucleus,
    - Efferent – medullary reticulospinal tract to respiratory muscles
  - **Cardiovascular centre**
    - Afferents – blood pressure baroreceptors, aortic and carotid sinus, to solitary nucleus
    - Efferents – medullary reticulospinal tract to intermediate horn and sympathetic outflow
  - **Vomiting centre**
    - Coordination visceral and somatic nervous systems
    - Afferents – stomach and small intestine (chemo and mechanoreceptors), forebrain, vestibular, solitary n. and chemoreceptor trigger zone (area postrema near obex; outside blood brain barrier)
    - Efferents to glossopharyngeal, hypoglossal and parasympathetic nucleus of X, reticulospinal tract (trunk muscles)
  - **Swallowing**
    - Afferents – to sensory nucleus of V
    - Efferents – nucleus ambiguus
  - **Coughing**

- **Pons**
  - **Micturition centre**
    - Reticulospinal efferents to sacral cord

Dog MRI, transverse caudal myelencephalon

Area postrema
Brainstem compression

- Loss of cardiopulmonary UMN function
- Altered respiratory pattern

- Raised ICP
  - Cerebral ischaemic response
  - Catecholamine surge to maintain cerebral perfusion pressure
  - Cushing reflex bradycardia
Bates: 4yo MN Sp Spaniel
Hx seizures,
Tetraparesis, stupor, proprioceptive deficits
Peripheral components of the ANS

- 2 x LMN + ganglion
- Location of ganglion PS vs Symp
- Neurotransmitter
Fig 12.1 Thomson and Hahn, ANS
Sympathetic innervation of viscera

- **Thoracolumbar** outflow from CNS
  - C8/T1 to L4/5
  - Thoracic cavity
    - Sympathetic chain of nerves and **paravertebral** ganglia
  - Abdominal and pelvic cavities
    - Fusion of fibres to form **prevertebral** ganglia
      - e.g. celiac, cranial and caudal mesenteric ganglia
  - Head
    - Supplied by spinal nerves from T1-3 (C8-T5)
    - Via vagosympathetic trunk
Sympathetic trunk and ganglia

Figure 8–55 Transection of the vertebral column to show the formation of a spinal nerve. 1, Spinal cord; 2, dorsal root; 3, spinal ganglion; 4, ventral root; 5, spinal nerve; 6, dorsal branch of spinal nerve; 7, ventral branch of spinal nerve; 8, body of vertebra; 9, sympathetic trunk; 10, epaxial muscles.

Figure 22.4 Uemura

The sympathetic trunk ganglia are paired, and the ganglia on one side are illustrated lying on the ventrolateral surface of the vertebral column.
Fig 3.8 deLahunta and Glass

Fig 8.76 Dyce
Autonomic innervation of the eye

Figs 10.8 and 9 Thomson and Hahn, Pupillary light reflex

Pupillary light reflex

- What CNN?
- Signs of dysfunction
  - Afferent lesion
    - Other signs?
  - Efferent lesion
    - Other signs?
Regarding pupillary constriction in birds, is it only parasympathetic innervation?

Pupillary dysfunction

- In acute brain disease
  - Miosis
    - Compression of mesencephalon
    - Mechanism?
      - Parasympathetic nucleus of CN III
        » facilitation or loss of forebrain inhibition?
      - Loss of sympathetic function?
  - Mydriasis
    - Loss of parasympathetic nucleus of CN III function

Cat found unconscious by road
Thoracolumbar lesion in alpaca, courtesy Dr. Caroline Hahn

Fig 7-13 deLahunta and Glass
Ruminants: smaller palpebral fissure, hyperthermia, loss of ipsilateral nasal planum sweating
Lesion classification for Horner’s syndrome

1st order – brain and spinal cord pathway
2nd order – presynaptic neuron
3rd order – post synaptic neuron
Dysfunction in pupil innervation

• Which has a more favourable prognosis?
• Why?
Distance penlight test: for subtle anisocoria and strabismus
Localising the lesion causing pupil dysfunction

- Other neurological signs
- Pharmacological testing
  
  Presynaptic neuron damage
  - Post synaptic neuron and NMJ intact
  Post synaptic neuron damage
  - Loss of post-synaptic neuron and NMJ
  - Smooth muscle is hypersensitive to neurotransmitter

<table>
<thead>
<tr>
<th>Drug</th>
<th>Indirect acting (IA)</th>
<th>Direct acting (DA)</th>
<th>Presynaptic nerve damage</th>
<th>Post synaptic nerve damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phenylephrine (1 or 10%)</td>
<td></td>
<td>DA sympathomimetic</td>
<td></td>
<td>Mydriasis or change in eyelash angle due to denervation hypersensitivity</td>
</tr>
<tr>
<td>Adrenaline (0.001%)</td>
<td></td>
<td></td>
<td>Minimal effect</td>
<td></td>
</tr>
<tr>
<td>Hydroxyamphetamine (1%)</td>
<td></td>
<td>IA sympathomimetic</td>
<td>Mydriasis</td>
<td>No effect</td>
</tr>
<tr>
<td></td>
<td></td>
<td>triggers release of Ad at NMJ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pilocarpine 2%</td>
<td></td>
<td>DA parasympathomimetic</td>
<td>Minimal effect</td>
<td>Miosis due to denervation hypersensitivity</td>
</tr>
<tr>
<td>Phystostigmine 0.5%</td>
<td></td>
<td>IA parasympathomimetic</td>
<td>Miosis</td>
<td>No effect</td>
</tr>
<tr>
<td></td>
<td></td>
<td>inhibits AChesterase at NMJ</td>
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</table>
This alert cat, with normal gait, has no pupillary light reflex (PLR), and decreased vestibulo-ocular reflex (VOR), OD (right eye). Lesion localisation is ...
Innervation of the Urinary Bladder

- **Micturition**
  - Primarily reflex function
  - Uses CPG
    - Maintains bladder contraction and sphincter relaxation

- **Spinal cord**
  - Spinoreticular and spinothalamic tracts
  - Reticulospinal tract

- **Brainstem centres (pons)**
  - UMN control
    - (spinoreticular activation)
    - (cerebrocortical activation)

- **Cerebrum**
  - Conscious awareness
  - Initiates learned toileting behaviour

- **Cerebellum**
  - Coordinates contraction-relaxation
Innervation of pelvic viscera

Fig 12.7 Thomson and Hahn

<table>
<thead>
<tr>
<th></th>
<th>Storage</th>
<th>Voiding</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Parasympathetic</strong></td>
<td>- detrusor relaxation</td>
<td>+ detrusor contraction</td>
</tr>
</tbody>
</table>
| **Sympathetic**      | + β receptors bladder wall inhibition of detrusor  
                        + α bladder neck smooth muscle contracts | - β receptors in the bladder wall  
                                              - α bladder neck muscle |
| **Somatic**          | + striated sphincter contracts       | - striated sphincter relaxes         |
Incontinence (UMN or LMN)

Figs 12.8 and 5.6, Thomson and Hahn

R – reflexes
A – atrophy
T – tone

Brain lesions
- Cerebral – loss of learned toileting behavior
- Cerebellar - ?
## Pharmacological Rx urinary incontinence

<table>
<thead>
<tr>
<th>target</th>
<th>innervation</th>
<th>drug</th>
</tr>
</thead>
<tbody>
<tr>
<td>Striated sphincter relaxation</td>
<td>Somatic inhibition</td>
<td>Diazepam, dantrolene</td>
</tr>
<tr>
<td>Smooth muscle sphincter stimulation</td>
<td>Sympathetic alpha adrenergic stimulation</td>
<td>Phenylpropanolamine, Oestrogen</td>
</tr>
<tr>
<td>Smooth muscle sphincter relaxation</td>
<td>Sympathetic alpha adrenergic inhibition</td>
<td>Phenoxybenzamine, Prazosin HCl</td>
</tr>
<tr>
<td>Detrusor muscle stimulation</td>
<td>Parasympathetic</td>
<td>Bethanechol</td>
</tr>
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Defaecation

- Primarily reflex
  - Local enteric plexus
  - Cranially directed paths for conscious perception
    - *which funiculus?*
  - Sphincters
    - Striated muscle
    - Smooth muscle
‘Puppy’
14 yo MN Gold Ret
Chronic incontinence – faecal and urinary
  Urinary bladder is ...
  Anal sphincter is ...
  Perineal reflex is ...
  Sciatic reflexes ...
  What else?
George, 7yo MN Siamese
3d Hx paraparesis
Acute urinary incontinence
- Urinary bladder is …
- Anal sphincter is …
- Perineal reflex is …