AUTONOMIC NERVOUS SYSTEM OF THE HEAD

Learning Objectives

By the end of the course students will be able to:

1. Describe the role that the two components of the autonomic nervous system, the parasympathetic and sympathetic, have on viscera in the Head and Neck regions
2. Describe pathways of autonomic fibers which pass through cervical sympathetic ganglia as well as parasympathetic fibers which are associated with cranial nerves CN III, CN VII, CN IX, and CN X
3. Be able to associate clinical signs of autonomic nerve dysfunction with particular lesions to cranial nerves or with skull fractures

Reference: Moore, Clinical Anatomy, Chapter 9

Particularly relevant Blue Boxes in Moore:

- Cervicothoracic Ganglion Block, p. 1017
- Lesion of cervical Sympathetic Trunk, p. 1017
- Horner Syndrome, p. 913
AUTONOMIC NERVOUS SYSTEM OF THE HEAD

INTRODUCTION (Netter 130)

The autonomic nervous system is concerned with those processes normally beyond voluntary control and beneath consciousness. It maintains the consistency of the body’s internal environment while buffering it against external or internal forces threatening to cause variation in this environment. In other words, the ANS acts as an interface between the external and internal environment and functions to maintain homeostasis.

Anatomically the ANS is not readily dissectible because its neurons are intermingled with neurons having other functions. The ANS is a motor system (general visceral efferent system) that is composed of a two neuron hook-up. The cell bodies of the first neuron in this hook-up are located within the central nervous system. The second neuron is localized in the PNS in structures known as autonomic ganglia. The axon that leaves the originating cell body in the CNS synapses on the second neuron within the autonomic ganglia. This axon is before the ganglion and hence called a pre-ganglionic fiber. The axon that emanates from the second neuron in the autonomic ganglia is found leaving the ganglion and hence referred to as a post-ganglionic fiber.

The two functional divisions of the ANS are sympathetic (thoracolumbar) and the parasympathetic (craniosacral). The sympathetic division has pre-ganglionic cell bodies located in the thoracic and lumbar regions of the spinal cord. Its preganglionic fibers are short and its postganglionic fibers long. The parasympathetic division has preganglionic cell bodies located in the brain and sacral region of the spinal cord. Its preganglionic fibers are long and its postganglionic fibers are short. In both divisions, the preganglionic fibers are usually myelinated whereas the postganglionic fibers are not.

Most of the effector organs of the autonomic nervous system are innervated by both the sympathetic and parasympathetic division. However, the parasympathetics are distributed mostly to the thoracic, abdominal and pelvic viscera and to smooth muscle and glands in the head. Moreover, blood vessels and sweat glands receive only sympathetic innervation.

The effects of the two divisions on the effector organs are antagonistic. Stimulation of the sympathetic division results in a diffuse outburst of activity (the fight and flight syndrome) and is concerned with processes involving the expenditure of energy. Stimulation of the parasympathetic division results in effects that are localized in character and concerned with conservative and restorative processes.
SYMPATHETIC NERVOUS SYSTEM (THORACO-LUMBAR)  (Netter 129)

This portion of the autonomic nervous system takes precedence during activity which could be thought of in terms of a “fight or flight” situation, in other words, emergency.

Activity of Sympathetic System in Head

- Dilation of pupil of eye (dilator pupillae muscle)
- Constriction of blood vessels of skin in face
- Causes sweating in glands of face
- Spontaneous (i.e., involuntary) constriction of smooth muscle in upper eyelid

Organization reganglionic cells are located in the intermediolateral cell column of the spinal cord between levels T1 and L2. (There are no preganglionic sympathetic cell bodies found at any other cord level). The preganglionic fiber exits along the spinal cord and gains access to the postganglionic cell body by traversing the following course:

- Ventral root
- Spinal nerve
- Ventral primary ramus
- White ramus

Postganglionic cells are located in sympathetic ganglia. There are two major categories of sympathetic ganglia.

- Paravertebral or sympathetic chain ganglia
- Pre-aortic

The sympathetic chain and its associated ganglia is a paired structure lying on the lateral border of the vertebral column. The first three ganglia found in cervical regions are named the **superior, middle and inferior cervical ganglia**, 
respectively. None of the other ganglia are named and generally are about 22 in number. Each ganglion between levels T1 and L2 is connected to a corresponding spinal nerve by two communicating branches called **gray and white rami**. The function of the white ramus is to allow preganglionic (generally myelinated, hence “white”) fibers access to the sympathetic chain. Since preganglionic fibers only originate in the spinal cord between T1 and L2, white rami can only be found at these levels. The function of the gray ramus is to allow postganglionic fibers (generally unmyelinated hence “gray”) an opportunity to exit sympathetic chain and gain access to a spinal nerve which distributes it with all of its branches. Gray rami are found at all cord levels.

As discussed in the Abdomen section, pre-aortic ganglia are collections of postganglionic cell bodies found surrounding the major arterial branches of the abdominal aorta. Preganglionic fibers leave the spinal cord by the ventral root, ventral primary ramus and gain access to the sympathetic chain via a white ramus. These fibers then leave the sympathetic chain as the splanchnic nerves (greater, T5, T9; lesser, T10 - T11; least, T12). These nerves, carrying preganglionic fibers, pass through the diaphragm, enter the abdominal cavity and synapse on postganglionic cell bodies in the pre-aortic ganglia. The postganglionic fibers then are distributed to the abdominal and pelvic viscera by following the arterial system.

**The Sympathetic Chain and Cervical Ganglia**

At the uppermost region of the sympathetic chain are three cervical ganglia (see Netter image 129 below), which are continuous with the thoracic trunk, the superior, middle and inferior, the latter of which is known as the stellate ganglion if it combines with the first thoracic ganglion. From the cervical ganglia, there are grey communicating branches to the somatic cervical nerves (C1 – C8). Each cervical ganglion also has a vascular branch to distribute sympathetics to the neck and head on arteries. The vascular branches that have synapsed in the **superior cervical ganglion** and join the internal carotid artery are known as the **deep petrosal nerve** and reach the eye for pupil dilation and the upper eyelid for reflexively opening the eye (the upper eyelid, in addition to having striated muscle fibers that are supplied by the oculomotor nerve, CN III, also contain smooth muscle fibers). Sympathetics that join branches of the external carotid artery, for example, the facial artery, supply sweat glands in the face and also constrict these vessels during a sympathetic response. Postganglionic fibers from the middle and inferior (or stellate) ganglia, instead of travelling to the head, pass down into the thorax and supply the heart and lungs through the **cardiac plexus** of nerves.
Parasmpathetic Nervous System (Cranio-sacral)

This portion of the autonomic nervous system predominates during normal activity, thus maintaining homeostasis. Frequently spoken of as “vegetative” rather than “fight or flight”.

Activity of the parasympathetic system in Head:

- Constricts pupil of eye (constrictor pupillae muscle)
- Accomodation – rounding up of lens for near vision
- Stimulates saliva production in parotid, submandibular and sublingual glands
- Stimulates mucous production from glands in oral cavity and hard palate
- Stimulates tear production from lacrimal gland

Organization:

Preganglionic cells - located in the CNS in nuclei associated with cranial nerves III, VII, IX, X, and in the spinal cord at sacral levels 2,3,4.

Preganglionic fibers associated with the cranial nerves follow those nerves to ganglia supplying structures to be innervated. Preganglionics from the sacral component pass along with the pudendal nerve to pelvic and pudendal organs.

Postganglionic cells - those associate with the cranial portion are found in the named parasympathetic ganglia of the head and neck (ciliary, submandibular, pterygopalatine and otic ganglia) to be covered in ANS II. Ganglion associated with sacral and vagal outflow are found in the walls

---

Horner's Syndrome

Many diseases and syndromes can affect the autonomic nervous system. One example is Horner's Syndrome which often results from a compression lesion (e.g. tumour of the lung) in the superior mediastinum acting on the sympathetic chain, such that its ipsilateral (on same side) symptomatic manifestations are characterised by:

- Pupillary constriction (miosis)
- Drooping eyelid (ptosis)
- Absence of sweating (anhydrosis)
- Slight retraction of the eyeball (enophthalmos)
of the organs to be innervated and are called enteric ganglia (i.e. Auerbach’s and Meissner’s enteric ganglia).

The Parasympathetic Ganglia of Head and Neck

These are where preganglionic parasympathetic fibers via C.N.’s III, VII & IX synapse to supply many targets including:

- Parotid, submandibular and sublingual glands (secretomotor)
- Lacrimal glands
- Mucous membranes of nasopharynx, palate, upper lip and paranasal sinuses

**Ciliary Ganglion (Netter 131)**
Lies on the lateral side of C.N. II, posterior to the eyeball

**Otic Ganglion (Netter 133)**
Found behind trunk of V3, just outside foramen ovale, medial to mandibular n.

**Submandibular Ganglion (Netter 132)**
Found lateral to C.N. XII, suspended from lingual n.

**Pterygopalatine Ganglion (Netter 132)**
Suspended from maxillary n.

<table>
<thead>
<tr>
<th>Ganglion</th>
<th>Parasympathetic Fibers</th>
<th>Sympathetic Fibers</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ciliary</td>
<td>CN III</td>
<td>Int. carotid plexus</td>
<td>Pupillary/ciliary</td>
</tr>
</tbody>
</table>
Associated with the parasympathetic system are specific named nerves which carry pre-ganglionic parasympathetic nerve fibers to ganglia in the head. These nerves are the:

- Greater Petrosal Nerve
- Chorda Tympani
- Lesser Petrosal Nerve

**Greater Petrosal Nerve (CN VII)**

The pre-ganglionic parasympathetic fibers of the greater petrosal nerve have their cell bodies in the Superior Salivatory nucleus, associated with cranial nerve CN VII. These fibers join with the motor and taste fibers of CN VII and enter the internal acoustic meatus of the petrous part of the temporal bone. They then pass through the geniculate ganglion, and emerge in the middle cranial fossa and run in a groove under the dura and under the trigeminal ganglion to reach the foramen lacerum, on or near the internal carotid artery. Here the greater petrosal nerve is joined by post-ganglionic fibers to form the Vidian Nerve (or nerve of pterygoid canal). The Vidian nerve then enters its canal via an opening in the anterior wall of the upper end of the foramen lacerum.

The Vidian nerve opens into the pterygopalatine fossa. It then enters the pterygopalatine ganglion where the pre-ganglionic fibers of the greater petrosal nerve synapse. The sympathetic fibers, which have already synapsed in the superior cervical ganglion, pass through the ganglion unchanged. The post-ganglionic fibers...
then join branches of the maxillary nerve (CN V2) and ophthalmic nerve (CN V1) to reach:

- the lacrimal gland
- mucosal glands in the nasal cavity and hard and soft palate

After synapsing in the pterygopalatine ganglion, the post ganglionic fibers pass upwards along branches of V2 which suspend the ganglion in the fossa. These fibers then connect to the zygomatic branch of V2 to enter the orbit. The zygomatic nerve is purely sensory, and has two branches – the zygomatico-facial and zygomatico-temporal. Within the orbit, these autonomic fibers pass along a communicating branch to the lacrimal nerve of V1 and ultimately to the lacrimal gland. Thus, although the lacrimal nerve is a purely sensory nerve (to the skin of the upper eyelid), it conveys the parasympathetic and sympathetic fibers to its target, the lacrimal gland. It, like all the other branches of the trigeminal nerve, has no parasympathetic fibers originating in the brainstem – it only serves to convey the autonomic nerves to their targets.

Post-ganglionic fibers from the pterygopalatine ganglion also travel inferiorly to join the greater and lesser petrosal nerves, sensory branches of V2, to supply the mucosal glands of the hard and soft palate and the nasal cavity.

Chorda Tympani (CN VII)

This nerve has conveys two types of fibers (two lanes of traffic):
1. taste from the anterior 2/3 of the tongue
2. pre-ganglionic parasympathetic fibers to the submandibular and sublingual glands

The parasympathetic fibers have their cell bodies in the superior salivatory nucleus, associated with the facial nerve (CN VII).

The facial nerve, CN VII, has two bundles of parasympathetic fibers which will ultimately become the greater petrosal nerve and the chorda tympani. All of these fibers enter the skull by passing through the internal acoustic meatus. At the geniculate ganglion, the parasympathetic fibers that make up the chorda tympani pass through without synapsing. They then leave the motor fibers of CN VII and enter the middle ear cavity through its posterior wall. They pass between the incus and malleus and exit the skull through the petrotympanic fissure (the motor fibers of CN VII exit the skull through the stylomastoid foramen). The chorda tympani is now in the infratemporal fossa where it joins the lingual nerve (a branch of CN V3). It then leaves the lingual nerve so that the parasympathetic fibers can synapse in the submandibular ganglion (which is suspended from above by the lingual nerve) before supplying the submandibular and sublingual glands. The taste fibers of the chorda tympani reach the anterior 2/3 of the tongue by travelling with the lingual nerve.
Lesser Petrosal Nerve (CN IX)

This nerve is associated with cranial nerve CN IX and has its pre-ganglionic parasympathetic cell bodies in the inferior salivatory nucleus. As CN IX exits the jugular foramen, a branch, called the tympanic nerve (of Jacobson), enters the skull through a small foramen called the tympanic cannaliculus. It then enters the middle ear where it mixes with sympathetic fibers to form the lesser petrosal nerve. It then leaves the middle ear to enter the middle cranial fossa and runs under the dura towards the foramen ovale. Just as it exits this foramen, the parasympathetic fibers synapse in the otic ganglion. Sympathetic fibers which had joined the tympanic nerve, pass right through. Post ganglionic fibers join the auriculotemporal nerve, a branch of the mandibular division of the trigeminal nerve (CN V3), which then carries them to the parotid gland.
Autonomics of the Orbit.

Although there is no named parasympathetic nerve which supplies the orbit, we nevertheless discuss the autonomics of this region here. The preganglionic parasympathetic fibers associated with cranial nerve CN III, and which supply the orbit, are located in the Edinger Westphal nucleus. These fibers enter the orbit with CN III and then branch off to synapse in the ciliary ganglion. Post-ganglionic fibers then pass to the constrictor pupillae muscle (for pupil constriction) and to the ciliary muscle (for accommodation, or rounding-up of the lens) via short ciliary nerves. These nerves, like the long ciliary nerves, which do not pass through the ganglion, are sensory branches of the nasociliary nerve, a branch of the ophthalmic division (CN V1) of the trigeminal nerve. Under parasympathetic innervation, the eye will constrict and the lens will round-
up, for near vision. Sympathetic fibers, which have synapsed in the superior cervical ganglion, reach the orbit by hitch-hiking on the internal carotid artery and its branch, the ophthalmic artery. Once in the orbit, they reach the dilator pupillae muscle, via long and short ciliary nerves. Sympathetic fibers also supply the smooth muscle in the upper eyelid to open the eye reflexively. The striated muscle fibers in the levator palpebrae superioris, are under voluntary control through the oculomotor nerve (CN III).