Autonomic Nervous System (ANS)

Introduction

The autonomic nervous system helps to regulate the activities of cardiac muscle , smooth muscle , and glands ,. In this regulation , impulses are conducted from the CNS by an axon that synapses with a second autonomic neuron . It is the axon of this second neuron in the pathways that innervates the involuntary effectors .

Autonomic motor nerves innervate organs whose functions are not usually under voluntary control . The effectors that respond to autonomic regulation include cardiac muscle (the heart) , smooth (visceral) muscles , and glands . These are part of the organs of the viscera (organs within the body cavities) and of blood vessels . The involuntary effects of autonomic innervation contrast with the voluntary control of skeletal muscles by way of somatic motor neurons .

Autonomic Neurons

Neurons of the peripheral nervous system (PNS) which conduct impulses away from the central nervous system (CNS) are known as motor , or efferent , neurons . There are two major categories of motor neurons: somatic and autonomic . Somatic motor neurons have their cell bodies within the CNS and send axons to skeletal muscles , which are usually under voluntary control .

Unlike somatic motor neurons , which conduct impulses along a single axon from the spinal cord to the neuromuscular junction , autonomic motor control involves two neurons in the efferent pathway The first of these neurons has its cell body in the gray matter of the brain or spinal cord . The axon of this neuron dose not directly innervate the effector organ but instead synapses with a second neuron within an autonomic ganglion (a ganglion is a collection of cell bodies outside the CNS). The first neuron is thus called a preganglionic neuron .and the second one is a postganglionic neuron , has an axon that extends from the autonomic ganglion and synapses with the cells of an effector organ

Preganglionic autonomic fibers originate in the midbrain and hindbrain and the upper thoracic to the fourth sacral levels of the spinal cord . Autonomic ganglia are located in the head , neck , and abdomen ; chains of autonomic ganglia also parallel the right and left sides of the spinal cord . The origin of the preganglionic fibers and the location of the autonomic ganglia help to differentiate the sympathetic and parasympathetic divisions of the autonomic system.

Divisions of The Autonomic Nervous System

Pregangliotic neurons of the sympathetic division of the autonomic system originate in the thoracic and lumbar (thoracolumbar) levels of the spinal cord and send axons to sympathetic ganglia , which parallel the spinal cord . Preganglionic neurons of the parasympathetic division , in contrast , originate in the brain and in the sacral (craniosacral) level of the spinal cord , and send axons to ganglia located in or near the effector organs .

The sympathetic and parasympathetic divisions of the autonomic system share structural similarities both consist of preganglionic neurons that originate in the CNS and postganlionic neurons that originate outside of the CNS in ganglia . The specific origin of the preganglionic fibers and the location of the ganglia, however , are different in the two divisions of the autonomic system .

Addrenal Glands

The paired adrenal glands are located above each kidney . Each adrenal is composed of two parts ; an outer cortex and an inner medulla . These two parts are really two functionally different glands with different embryonic origins , different hormones , and different regulatory mechanisms . The adrenal cortex secrete steroid hormones , and different regulatory mechanisms . , the adrenal medulla secretes the hormone epinephrine (adrenaline) and , to a lesser degree norepinephrine , directly into bloodstream, when it is stimulated by the sympathetic system .

The adrenal medulla can be linked to a modified sympathetic ganglion ; its cells are derived from the same embryonic tissue that forms postganglionic sympathetic neurons . Like a sympathetic ganglion , the cells of the adrenal medulla are innervated by preganglionic sympathetic fibers, but there is no postganglionic fibers . The adrenal secretes epinephrine into the blood in response to this neural stimulation . The effects of epinephrine are complementary to those of the neurotransmitter norepinephrine , which is released from postganglionic sympathetic nerve endings .

Parasympatetic (Craniosacral) Division .

The parasympathetic system is also known as the caraniosacral division of the autonomic system . This is because its preganglionic fibers originate in the brain (specially , the midbrain and the medulla oblongata of the brain stem) and in the second through fourth sacral levels of the spinal column. These pregangiotic parasympathetic fibers synapse in ganglia that are located next to-or actually within-the organs innervated. These parasymphathetic ganglia, which are called terminal ganglia, supply the postganglionic fibers that synapse with the effector cells. It should be noted that, unlike sympathetic fibers, most parasympathetic fibers do not travel within spinal nerves. As a result, cutaneous effecters (blood vessels, sweat glands, and arrector pilli muscles) and blood vessels in skeletal muscles receive sympathetic but not parasympathetic innervation.

Four of the twelve pairs of cranial nerves contain preganglionic parasymapthetic fibers. These are the oculomotor (III), facial (VII), glossopharyngeal (IX), and vagus (X) nerves. Parasympathetic fibers within the first three of these cranial nerves synapse in ganglia located in the head; fibers in the vagus nerve synapse in terminal ganglia located in many regions of the body.

Functions Of The Autonomic Nervous System

Function of sympathetic division can be memorized as mnemonic rule of 3Fs "Fear, Fight or Flight", largely through the release of norepinephrine from postganglionic fibers and the secretion of epinephrine from the adrenal medulla. The parasympathetic division often has antagonostic effects through the release of acetylcholine from its postganglionic fibers. A balance between the actions of both divisions of the autonomic system for homeostasis to be preserved.

The sympathetic and parasympathic divisions of the autonomic system affect the visceral organs in different ways. Mass activation of the sympathetic system prepares the body for intense physical activity in emergencies and stress (physically or mentally); the heart rate increases, blood glucose level rises, and blood is diverted to the skeletal muscles (away from the visceral organs and skin).

The effects of parasympathetic nerve stimulation are in many ways opposite to the effects of sympathetic stimulation. The parasympathetic system, however, is not normally activated as a whole. Stimulation of separate parasympathetic nerves can result in slowing of the heart, dilation of visceral blood vessels, and an increased activity of the digestive tract. The different responses of a visceral organ to sympathetic and parasympathetic nerve activity are due to the fact that the postganglionic fibers of these two divisions release different neurotransmitters.

Neurotransmitters of the Autonomic Nervous System

Acetylcholine (ACh) is the neurotransmitter of all preganglionic fibers (both sympathetic and parasympathetic). Acetylcholine is also the transmitter released by all parasympathetic postganglionic fibers at their synapses with effector cells. Transmission at these synapses is thus said to be cholinergic.

The neurotransmitter released by most postganglionic sympathetic nerve fibers is norepinephrine (noradrenaline). Transmission at these synapses is thus said to be adrenergic. There are a few exceptions to this rule: some sympathetic fibers that innervate blood vessels in skeletal muscles, as well as sympathetic fibers to sweat glands, release ACh (are cholinergic).

In view of the fact that the cells of the adrenal medulla are embryologically related to postganglionic sympathetic neurons, it is not surprising that the hormones they secrete (normally

about 85% epinephrine and 15% norepinephrine) are similar to the transmitter of postganglionic sympathetic neurons. Epinephrine differs from norepinephrine only in the presence of an additional methyl (CH_3) group. Epinephrine, norepinephrine, and dopamine (a transmitter within the CNC) are deprived from the amino acid tyrosine, and are collectively termed catecholamines.

Receptors of ANS

Parasympathetic nervous system has two types of receptors: nicotinic and muscarinic (for simplicity). Sympathetic nervous system also has two types of receptor: a and b, the b is subdivided into b1 and b2 receptors (for simplicity).

Nicotinic receptors are located in the ANS ganglia, whether sympathetic or parasympathetic, and on muscle cells. Muscarinic receptors are located on all target cells innervated by cholinergic fibers except for those organs innervated by nicotinic receptors.

b1-adrenergic receptors are located on heart conductive system and on lipocytes. b2-adrenergic receptors are located by all other organs innerved by adrenergic fibers. a-adrenergic-receptors, for simplicity, are located on blood vessels and eye (radial iris muscle).

Agonist and antagonist

If a chemical does the same function as that of stimulated-sympathetic nervous system it is given the name sympathetic agonist or sympathomimetic. If it does inhibition, it is called sympathetic antagonist or sympatholytic.

Likewise for parasympathetic nervous system. There are parasympathetic agonist (parasympatholytic) and parasympathetic antagonist (parasympatholytic).

Responses to Adrenergic Stimulation

If you understand the 3Fs (Fear, Fight, Flight) rule of the sympathetic system, you can easily figure out the effect of sympathetic stimulation on any organ innervated by this system.

Adrenergic stimulation-by epinephrine in the blood and by norepinephrine released from sympathetic nerve endings-has both excitatory and inhibitory effects. The deciding factor whether it is stimulatory or inhibitory function depends on the type of receptor located on the target organ. On stimulation of sympathetic nervous system there is dilation of pupils, decrease secretion (inhibition) of saliva leading to dryness of the mouth, increase in heart rate (causing stimulation), increase in cardiac output (stimulation), , increase in respiratory rate (stimulation) , bronchodilation (inhibition), and the smooth muscles of many blood vessels are stimulated to contract leading to increase in blood pressure , but those blood vessels supplying blood to nonvital organs are relaxed (inhibition) like skin and viscera, decrease motility and secretion of the digestive system (inhibition), contraction (stimulation) of the internal rectal sphincter, relaxation of the smooth muscles of the urinary bladder (inhibition), contraction (stimulation) of the internal urethral sphincter), lipolysis (stimulation of lipid breakdown) and hyperglycemia (stimulation of glycogen breakdown). Do not complicate the issue, just understand Fora's rule, then you are going to figure out more functions by yourself.

The stimulation of alpha adrenergic receptors consistently causes constriction of smooth muscles . We can thus state that the vasoconstrictor effect of sympathetic nerves always results from the activation of alpha-adrenergic receptors. The effects of beta-adrenergic activation are more complex; these receptors stimulate the relaxation of smooth muscles (in the digestive tract, bronchioles, and uterus, for example), but stimulate contraction of cardiac muscle and promote an increase in cardiac rate.

On the urinary system, B2 stimulation can cause relaxation of smooth muscles of urinary bladder and contraction of internal urethral sphincter, vasoconstriction of renal arteries, mainly the afferent, thus leading to decrease glomerular filtration rate (GFR). On the digestive tract it causes relaxation of smooth muscles leading to decrease motility and decrease of blood supply leading to decrease secretion. It also causes contraction of internal anal sphincter.

On the liver B2 stimulation cause glycogenoloysis. Also B2 stimulation inhibit insulin secretion. These two effects lead to increase blood glucose level.

b1 stimulation can cause increase in heart rate, stroke volume and cardiac output as well as lipolysis leading to increase free fatty acids in the blood.

Responses to Cholinergic Stimulation

Somatic motor neurons, all preganglionic autonomic neurons, and all postganglionic parasympathetic neurons are cholinergic-they release acetylcholine as a neurotransmitter. The cholinergic effects of somatic motor neurons and preganglionic autonomic neurons are always excitatory. The cholinergic effects of postganglionic parasympathetic fibers are usually excitatory, but there are notable exceptions-the parasympathetic fibers innervating the heart, for example, cause slowing of the heart rate. It is useful to remember that the effects of parasympathetic stimulation are, in general, opposite to the effects of sympathetic stimulation on those organs that have dual innervation.

The main function of parasympathetic nervous system is vegetation. It stimulates motility and secretion of digestive system (stimulatory), decrease heart rate (inhibitory), decrease cardiac output (inhibitory), bronchoconstriction (stimulation), constriction of pupil (stimulation of circular iris muscles), increase salivation (stimulation), contraction of urinary bladder smooth muscles (stimulation), relaxation of internal urethral sphincter (stimulation), contraction colon muscles for defecation (stimulation) and relaxation of internal anal sphincter (stimulation).

The muscarine effects of ACh are specifically inhibited by the drug atropine, derived form the deadly nightshade plant (Atropa belladonna). Indeed, extracts from this plant were used by women during the Middle Ages to dilate their pupils (atropine inhibits parasympathetic stimulation of the iris). This was done to enhance their beauty (belladonna=beautiful woman). Atropine is used clinically today to dilate pupils during eye examinations, to dry mucous membranes of the respiratory tract prior to general anesthesia, and to inhibit spasmodic contractions of the lower digestive tract.

Complementary Effects of Both Divisions.

The effects of sympathetic and parasympathetic stimulation on salivary gland secretion are complementary. The secretion of watery saliva is stimulated through parasympathetic nerves, which also stimulate the secretion of other exocrine glands

in the digestive tract. Sympathetic nerves stimulate the constriction of blood vessels through the digestive tract. The resultant decrease in blood flow to the salivary glands causes the production of a thicker, more viscous saliva.

Cooperative Effects of Both Divisions.

The effects of sympathetic and parasympathetic stimulation on the urinary and reproductive systems are cooperative. Erection of the penis, for example, is due to vasodilation resulting from parasympathetic nerve stimulation; ejaculation is due to stimulation through sympathetic nerves. Although the contraction of the urinary bladder is myogenic (independent of nerve stimulation), it is promoted in part by the action of parasympathetic nerves. This micturition, or urination, urge and reflex is also enhanced by sympathetic nerve activity, which increases the tone of the bladder muscles. Emotional states that are accompanied by high sympathetic nerve activity (such as extreme fear) may thus result in reflex urination at bladder volumes that are normally too low to trigger this reflex.

Organs Without Dual Innervation

Although most organs are innervated by both sympathetic and parasympathetic nerves, some-including the adrenal medulla, arrector pili muscles, sweat glands, and most blood vessels-receive only sympathetic innervation. In these cases regulation is achieved by increases or decreases in the tone (firing rate) of the sympathetic fibers. Constriction of the blood vessels, for example, is produced by increased sympathetic activity, which stimulates alpha-adrenergic receptors, and vasodilation results from decreased sympathetic nerve stimulation.

Stress and ANS

On extreme stress like panic the SNS is completely paralyzed so that all functions of SNS are completely ceased. Thus the person may standstill and cannot do anything. (S)He may urinate or defecate on himself/herself.

Control of the Autonomic Nervous System by Higher Brain Centers

Visceral functions are regulated, to a large degree, by autonomic reflexes. In most autonomic reflexes, sensory input is transmitted to brain centers that integrate this information and appropriately respond by modifying the activity of efferent preganglionic autonomic neurons. The neural centers that directly control the activity of autonomic nerves are influenced by higher brain areas as well as by sensory input.

The medulla oblongata of the brain stem is the area that most directly controls the activity of the autonomic system. Almost all autonomic responses can be elicited by experimental stimulation of the medulla, which contains centers for the control of cardiovascular, pulmonary, urinary, reproductive, and digestive systems. Much of the sensory input to these centers travels in the afferent fibers of the vagus nerve, which is a mixed nerve containing both sensory and motor fibers.

Although the medulla oblongata directly regulates the activity of autonomic motor fibers, the medulla is itself responsive to regulation by higher brain areas. One of these is the hypothalamus, which is the brain region that contains centers for the control of body temperature, hunger, thirst, regulation of the pituitary gland, and-together with the limbic system and cerebral cortex-various emotional states.

Disturbances Clearly Related to Autonomic Involvement

1- Horner's syndrome:

Is a unilateral enophthalmos, ptosis, miosis, and flushing of the face often caused by an ipsilateral involvement of the sympathetic fibers in the cervical sympathetic chain or upper thoracic cord.

2- Hirschsprung's disease (megacolon):

Consists of a tremendous dilatation of the colon, with chronic constipation. It is associated with congenital lack of parasympathetic ganglia and the existence of abnormal fibrils in the apparently normal segment of large bowel wall

3- Spinal shock:

Is a type of vascular failure due to sudden release of sympathetic vasomotor tone resulting from transaction of or severe injury to the spinal cord or from an overdose of spinal anesthetic.

4- Raynaud's disease:

Is a disease of young women that affects toes, the fingers, the edges of the ear, and the tip of the nose and spreads to involve large areas. Beginning with local changes , when the parts are pale and cold, it may progress to local asphyxia

characterized by a blue-gray cyanosis and, finally, symmetric dry gangrene. It is a disorder of the peripheral vascular innervation..

5- Angioneurotic edema (Quinke's disease):

It consists of attacks of acute circumscribed nonpitting edema occurring on the arms or face and preceded by general malaise, chills, and slight fever. It may be precipitated by emotional stress but lasts only a few hours. In rare cases, death has resulted from involvement of the respiratory passages.

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