AUTONOMOUS NEURAL REGULATION

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Summary

Autonomous regulation is involuntary and occurs without the subject's awareness through autonomic reflexes. It is also adapted according to activeness and emotions. The autonomic nervous system controls many functions of the cardiovascular, respiratory, gastrointestinal and urogenital and various other systems. The autonomic central network integrates large amounts of information about the external and internal environment, and controls different organs (the efferent system) to change their functions in order to maintain body homeostasis.

The autonomic efferent nervous system consists of sympathetic and parasympathetic divisions, which differ from each other in their structures, functions and neurotransmitter secretion. Many organs of the body are under control of both sympathetic and parasympathetic regulation. Clinical disorders of autonomic regulation are associated with many cardiovascular diseases including orthostatic intolerance, hypertension, coronary heart disease, cardiac dysrhythmias, and heart failure, as well as with metabolic disorders such as obesity, and diabetes.

1. Introduction

The autonomic nervous system controls in many ways circulation, respiration, and functions of the gastrointestinal and urogenital systems. It has important influences on energy balance and body temperature regulation. The purpose of this regulation is to enable a subject to meet with the challenges taking place during normal life and during exposure to physical and mental stress. Autonomous regulation is fast. Its influences being carried out within a few seconds. The autonomic nervous system acts through the control of heart, smooth muscles throughout the body and endocrine and exocrine organs.

Autonomous regulation is involuntary and occurs without the subject's awareness of these functions, through autonomic reflexes. The autonomic central network receives information from internal sensory organs (the afferent system), integrates large amounts of information about the external and internal environment, and controls different organs (the efferent system) to change their functions in order to maintain body homeostasis.

In addition to the reflex mechanisms described above, autonomic functions are influenced by higher brain activities which control general activity and alertness. In this respect, autonomous neural regulation is also adapted with great appropriateness according to activeness and emotions.

A schematic presentation of the autonomic nervous system is presented in Figure 1.

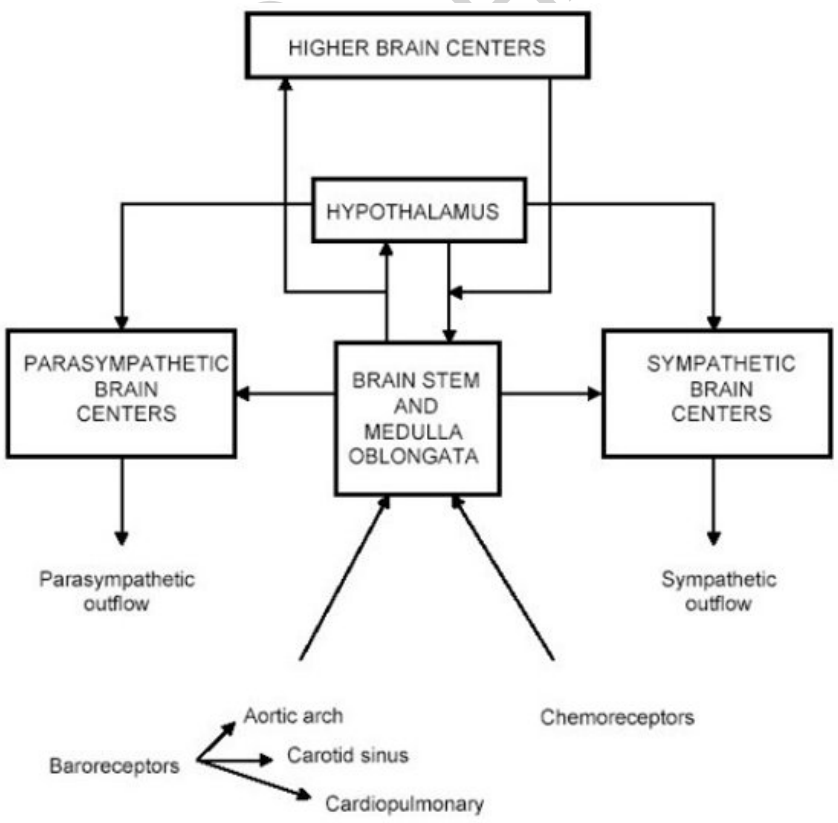

Figure 1. Schematic presentation of the autonomic nervous system.

2. Sympathetic and parasympathetic divisions of the autonomic nervous system

The autonomic efferent nervous system consists of sympathetic and parasympathetic divisions, which differ from each other in their structures, functions and neurotransmitter secretion. Many organs of the body are under control of both sympathetic and parasympathetic regulation, which often act as physiologic antagonists. Their complementary actions are also required in many functions enabling fine tuning of organ functions.

Sympathetic activity predominates in situations where a subject increases activeness. As a result of sympathetic predominance, heart rate and heart muscle contractility increase, blood pressure increases, blood vessels in working musculature dilate, pulmonary airways dilate, blood glucose concentration increases, the rate of digestion decreases and sphincters of the gastrointestinal and urogenital systems become constricted. Parasympathetic activity predominates in situations where a subject decreases activeness and completes energy storages. This results in decreases in heart rate, heart muscle contractility and in blood pressure. In addition, pulmonary airways constrict, secretion of insulin and enzymes related to digestion increase and sphincters of gastrointestinal and urogenital systems become relaxed.

The efferent autonomic pathways of sympathetic and parasympathetic systems include myelinated preganglionic neurons originating in the central nervous system and unmyelinated postganglionic neurons terminating at effector organs.

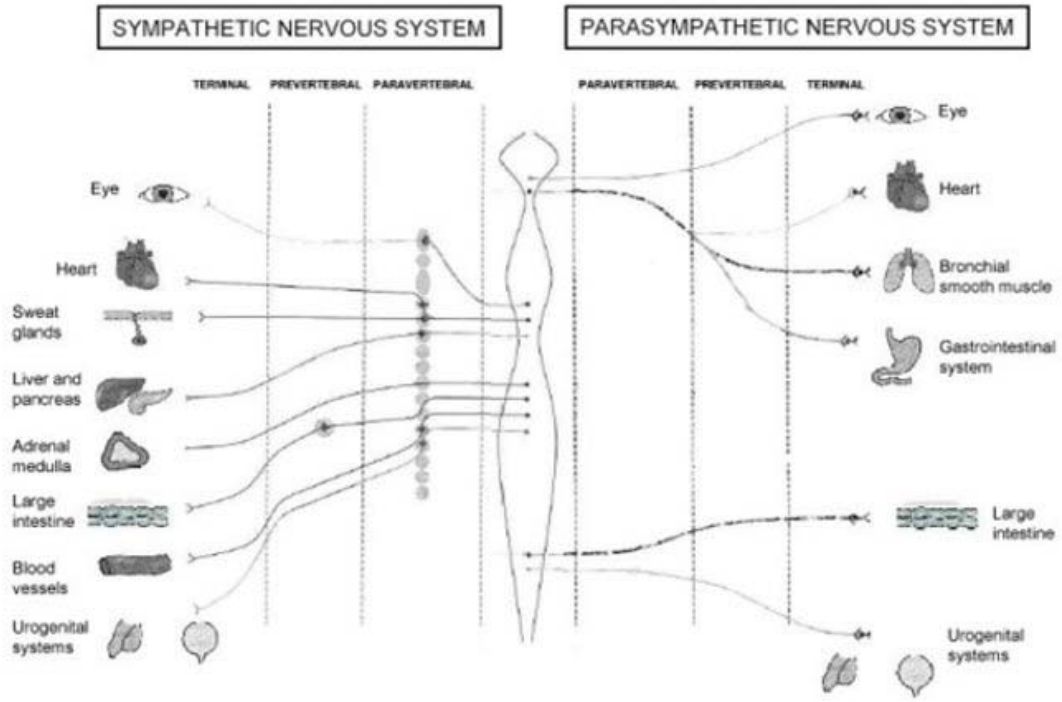

Figure 2. Sympathetic and parasympathetic nervous systems and enervation of the most important target organs.

The thoracolumbar outflow of the autonomic nervous system has been considered to be a part of the sympathetic nervous system (see Figure 2). Sympathetic preganglionic neurons arise in the thoracic and upper lumbar spinal cord and join ventral roots of T1 to L2.

The sympathetic preganglionic neurons synapse in paravertebral ganglia of the sympathetic chain or may pass through the ganglia as splanchnic nerves to synapse in prevertebral ganglia near viscera. The postganglionic fibers from paravertebral ganglia are connected to ventral nerve roots which are distributed through the spinal nerves to the periphery. The craniosacral outflow is considered as a part of the parasympathetic nervous system (see Figure 2).

Parasympathetic preganglionic fibers arise in the visceral brainstem nuclei and second to fourth sacral segments of the spinal cord. These fibers are distributed by the third, seventh, ninth and tenth cranial nerves to head and neck, thorax and abdominal viscera. The distal ganglia of the descending colon and pelvic organs receive preganglionic fibers from the sacral segments. Parasympathetic preganglionic neurons synapse in terminal or peripheral ganglia located on or within the walls of effector organs and from these parasympathetic ganglia, the postganglionic neurons enter their target sites.

3. Autonomic neurotransmitters

On the basis of the chemical mediator released, the autonomic nervous system can be divided into cholinergic and noradrenergic divisions. Cholinergic neurons include all preganglionic neurons, the anatomically parasympathetic postganglionic neurons, the anatomically postganglionic sympathetic neurons terminating in sweat glands and anatomically sympathetic vasodilatory neurons which end in blood vessels in skeletal muscles, whereas all other sympathetic neurons are noradrenergic. Furthermore, the adrenal medulla is essentially a sympathetic ganglion in which postganglionic neurons secrete norepinephrine, epinephrine and dopamine into the bloodstream.

A large number of other neuromodulators or cotransmitters (e.g. Substance P, Somatostatin, Vasoactive intestinal polypeptide, Thyrotropin-releasing hormone, Cholecystokinin, Bombesin, Calcitonin Gene-related Peptides, Neuropeptide Y, Galanin, Oxytocin and Enkephalins) or their receptors are present in the structures of the autonomic nervous system and modulate autonomic function.

Autonomic neurotransmitters can excite specific receptors in effector organs and in other neural structures. Acetylcholine activates two types of receptors, muscarinic and nicotinic receptors. Norepinephrine excites mainly adrenergic alpha receptors and to a less extend also adrenergic beta receptors.

Epinephrine excites equally both types of receptors. Both parasympathetic cholinergic stimulation and sympathetic adrenergic stimulation may cause excitatory effects in some organs but inhibitory effects in other organs. In general, the effects of acetylcholine and catecholamines are opposite. The influences of cholinergic and adrenergic stimulation in specific organs are presented below.

4. Autonomic nervous functions

The most important brain center controlling autonomic nervous system is the hypothalamus (see Figure 1). It serves as a co-ordinating center, which receives information about the subject's internal environment from different brain structures, such as cerebral cortex, limbic system, thalamus, cerebellum and formatio reticularis. The hypothalamus controls the autonomic nervous system to ensure an appropriate and correct response in the different situations to which a subject becomes exposed. Structural connections between hypothalamus and higher brain centers enable autonomic reactions in response to emotions e.g. responses to aggression, fear, pleasure and during sexual stimulation. The hypothalamus acts through its connections to sympathetic and parasympathetic nervous systems and also through its control of endocrine organs.

Although the hypothalamus plays an important role in controlling autonomous regulation, many autonomic functions, such as control of respiration and circulation, can operate without hypothalamic influences. In particular, control of circulation takes place mainly in vasomotor center located in structures of the brain stem and medulla oblongata (see Figure 1). It consists of sensory, vasoconstrictor and vasodilator areas. It is capable of integrating sensory information coming from different receptors measuring the internal environment and modulating sympathetic and parasympathetic efferent outflow to heart and blood vessels. The most important sensory organs in this respect are arterial baroreceptors measuring arterial blood pressure, cardiopulmonary baroreceptors measuring volume of venous return, chemoreceptors measuring oxygen and carbon dioxide levels in blood and pulmonary stretch receptors measuring pulmonary volumes and respiration (see Figure 1).

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Biographical Sketch

Tomi Laitinen received the M.D. degree in 1991 and the Ph.D. degree in 2000 from the University of Kuopio, Finland. His Ph.D. research was concerned with physiological correlates of the cardiovascular variability. Since 2004 he has been a University docent (Adjunct professor) in the Department of Clinical Physiology and Nuclear Medicine in the University of Kuopio. He is currently a clinical lecturer in the University of Kuopio and consultant in the Department of Clinical Physiology and Nuclear medicine in Kuopio University Hospital. His current research is focused on physiology and pathophysiology of cardiovascular regulation and vascular function.