Anatomy and physiology of pituitary gland

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Abstract

The pituitary gland, known as the “master gland,” is involved in the homeostatic regulation of numerous body functions as well as in governing reproduction and childbirth. Found at the base of the skull, surrounded by cranial nerves and critical blood vessels, it is composed of the adenohypophysis and neurohypophysis. The adenohypophysis is controlled by the hypothalamus via releasing/inhibiting hormones released into the pituitary portal veins to secrete adrenocorticotropic hormone, thyroid-stimulating hormone, growth hormone, follicle-stimulating hormone, luteinizing hormone, and prolactin. These govern four major hormone systems: adrenal, thyroid, growth hormone, and reproduction/lactation. These systems are regulated by feedback loops from the effector hormones. The posterior pituitary gland is directly stimulated by the hypothalamus to produce vasopressin for fluid homeostasis and oxytocin for lactation and uterine contraction. Dysfunction or over activity of any of these hormones can affect multiple organ systems. It is important to understand the normal anatomy and physiology of the pituitary gland to help diagnose and treat patients with pituitary disorders

Keywords
Pituitary gland,hypothalamus,homeostasis,feedback loop,adrenal gland, thyroid gland, growth hormone,reproductive system,prolactin.

Introduction

Along with the nervous (central nervous system (CNS)) and circulatory systems, the endocrine system coordinates and integrates a huge variety of vital body functions. The blood circulation is a main carrier for the hormones' distribution to targettissues. The neurosecretory cells of the hypothalamus produceand release the neurohormones that through the anterior andposterior lobes of the pituitary gland (PITUITARY GLAND) stimulate the synthesis and secretion of different hormones into the bloodstream, which regulate and maintain the control of theadrenal and thyroid glands and gonads through the cascadeof complex neuroendocrine feedback and a number of neuronal peripheral mechanisms. The focus of this article is the organization of the PITUITARY GLAND, the major elements of the neuroendocrine pathways, and the role of the PITUITARY GLAND in the control and modulation of a variety of vital body functions.

The Brief History of the pituitary gland

The first historical description of the pituitary gland (hypothesis) was provided by Galen (AD 150) who proposed the potential role for the found anatomical structure as a draining passage for the phlegm from the brain to the nasopharynx. In 1742, Joseph Lieutaud discovered the pituitary-portal blood
system (hypothalamic-hypophyseal axis), and Saucerotte was the first to describe acromegaly in 1772. The gland was for thefirst time fully described in 1778

by Soemmering and called‘hypophysis cerebri.’ The anatomical formation of the PITUITARY GLAND was described by Rathke in 1838. The posterior part of the PITUITARY GLAND wasinvestigated by Oliver and Schafer in 1895 and by Dale in 1906, who discovered the vasopressor and oxytocic activitiesof the posterior pituitary, showing antidiuretic and galactokinetic properties. The first solid description of the clinical symptoms and pathology of the PITUITARY GLAND was provided by Minkowski in1887 and Vassale and Sacchi in 1892, who demonstrated thatsurgically removing the PITUITARY GLAND (hypophysectomy) causes irreversible change on the water and mineral metabolisms of the body,and it also has been stated that overdevelopment and hyperfunction of the PITUITARY GLAND cause acromegaly. The first experimentallinks between the reproductive organs and PITUITARY GLAND were demonstrated via hypophysectomy leading to dwarfism in growinganimals in 1909, by Aschner, and by Cushing in 1910.

Development and Basic Anatomy of the pituitary gland

Development

Complex development of the PITUITARY GLANDis occurring at the early stage of embryogenesis and linked to that of the forebrain. The PITUITARY GLAND

contains three lobes that have dual embryonic origins: anterior lobe

(adenohypophysis), intermediate lobe derived from Rathke's pouch (the primitive pharynx), and posterior lobe, whichdevelops from the infundibulum (a stalk derived from theregion of the ventral diencephalon). The anterior pituitarylobe (adenohypophysis) and posterior pituitary lobe (neurohypophysis) both develop from Rathke's pouch. During thedevelopment anterior pituitary loses contact with the oral cavity and the posterior pituitary stays connected with the base ofthe hypothalamus. Adenohypophys and neurohypophysisbasically are joined together in the sella turcica (turkish saddle)at the base of the middle cranial fossa. The forming of theanterior pituitary (adenohypophysis) primordium is controlledby a complex signal emanating from the ventral diencephalon/infundibulum and from Rathke's pouch, and after that,Rathke's pouch forms a sac that differentiates and forms theadenohypophysis, connecting to the hypothalamus via stalk. The molecular nature of extrinsic signals and especially transcriptionfactors/morphogenes that are involved in the patterning of many other organs, lineage specification, and cell type-specific geneexpression in pituitary organogenesis has been recently investigated. The ectodermal primordium of Rathke's pouch is foundto be induced by two major signals emanating from the diencephalon: BMP4 (bone morphogenetic proteins), inducing theformation of the pouch rudiment, and FGF8 (fibroblast growthfactor), activating the key regulatory gene and development ofthe rudiment into a Rathke's pouch. Highly regulated geneexpression of the controlling processes of cell proliferation and appearance of specific transcription factors allow the formation of gland cell types. A human PITUITARY GLAND embryogenesis andforming of the neuronal posterior pituitary and nonneuronalanterior pituitary tissues are usually complete at 12 weeks ofgestation.

Basic Anatomy of the PITUITARY GLAND

The PITUITARY GLAND, which is a relatively small anatomical structure that is situated deep within the head, at the base of the skull, deep in the pit of the sphenoid bone, is surrounded by the optic chiasm, blood vessels, and other important brain structures. It consists of the larger part (80% of the PITUITARY GLAND size) called anterior pituitary lobe (adenohypophysis), intermediate lobe, and posterior pituitary lobe (or neurohypophysis), connected to the hypothalamus by the pituitary stalk. The adenohypophysis is composed of (a) pars distalis, containing epithelial cells surrounded by capillaries and fibers, with the cells being divided into acidophils (predominantly located in the lateral part of the lobe), basophils (concentrated in the central portion of the pars distalis), chromophils, and chromophobes, (b) pars intermedia, and (c) pars tuberalis. Acidophils consist of somatotrophs which produce growth hormone (GH), mammotrophs which produce prolactin (PRL), basophils consist of gonadotrophs which produce follicle-stimulating hormone (FSH), thyrotrophs which produce thyrotropin releasing hormone (TSH), and corticotrophs which produce adrenocorticotropic hormone (ACTH). Cromophils consist of cytoplasm with a large number of secretory granules in difference from chromophobes which consist of cytoplasm with no secretory granules. Pars inter media is located between the pars distalis and pars tuberalis and contains small basophilic cells. Pars tuberalis is a part of the adenohypophysis around the infundibulum, composed of basophilic cells that secrete gonadotrophs (luteinizing hormone (LH) and FSH). The adenohypophysis is responsible

for the majority of the signaling hormones released into the bloodstream through the well-developed hypothalamic-- hypophyseal portal capillary system that drains into hypothalamic-hypophyseal portal veins and The posterior pituitary lobe (or neurohypophysis, consisting of three distinct regions: pars nervosa (posterior lobe, which includes Herring bodies and pituicytes), infundibulum (pituitary stalk, which connects the hypothalamic and hypophyseal systems), and median eminence (ME) (which is included as part of the posterior pituitary). The pituitary stalk contains the fibers of the neurohypophysis connecting the posterior lobe tothe supraoptic nucleus (SON) and paraventricular nucleus(PVN) of the hypothalamus and the portal venous system,transmitting hypothalamic peptides that control anterior lobe secretion.

The pathology of the PITUITARY GLAND leads to the development of symptoms dependent on its change of secretion or symptomsdependent on the new anatomical intracranial relations thatarise (lesions, tumors, etc.). It has been found that lack ofbalanced PITUITARY GLAND hormonal secretion could lead to acromegalicgigantism (first time described by Pierre Marie in 1886), dwarfism, Frohlich's disease (dystrophia adiposa genitalis), acutepituitary insufficiency (causes fevers and toxemias), and polyglandular syndrome (autoimmune disease leading to inflammation, lymphocytic infiltration, and partial or completegland destruction). The typical anatomical pathology of the PITUITARY GLAND is a tumor (Cushing's disease) indicative of increased intracranial pressure causing headache, vomiting, vision impairment,nausea, and partial blindness, with main symptoms such asweak immune system, osteoporosis, extreme hair growth on face, fatigue, and cognitive dysfunctions

Neurovascular link between hypothalamus and pituitary gland

The pituitary stalk comprises mainly neural and vascular components, though an incomplete layer of epithelial cells, the pars tuberalis, whose function is uncertain, covers its ventral aspect .The bulk of the stalk is made up of neural tissue in which lie the various coiled capillary vessels on whichend the nerve fibres that are derived from cells in the hypophysiotrophic area. The neurohormones coming down these nerve fibres are transferred from the endings of the fibres into the blood passing through the coiled capillaries, and thus into the portal vessels. These portal vessels, as was first pointed out by Xuereb et al. (1954b), can be classified as long and short. The origin of the vessels which supply them makes a distinction most important. The afferent arterioles to the coiled capillaries from which the long portal vessels are derived spring from the arterial ring supplied by the superior hypophysial arteries (arising from the internal carotid arteries above the level of the diaphragma sellae), while those which supply the coiled capillaries that form the short portal vessels are derived from the inferior hypophysial arteries, which leave the internal carotid arteries within the cavernous sinus. The long portal vessels run down the pituitary stalk to supply the larger part of the pars distalis, while the short portal vessels supply a restricted part of the lobe adjacent to that part of the lower infundibular stem which is buried in the pars distalis. Xuereb et al. (1954a, b) describe this system of vessels, and Daniel and Prichard (1975) also describe the system in other species. A portal system of vessels is found in all vertebrates, and a valuable recent study is of that in the horse (Vitums, 1975).

When the pituitary stalk is cut surgically, to try to produce regression of various forms of carcinoma

Hormones of the Adenohypophysis

The different cells of the adenohypophysis synthesize and release into the bloodstream vital endocrine hormones such as ACTH (secreted by corticotrophs), TSH (secreted by thyrotrophs), FSH (secreted by gonadotrophs), LH (secreted by gonadotrophs) in females also known in males as interstitial cell-stimulating hormone, growth hormone (GH, secreted by somatotrophs), GHRH (secreted by somatotrophs), PRL (secreted by lactotrophs), and melanocyte-stimulating hormone (a-MSH, secreted by melanotrophs). All those hormones can be classified into three major groups: glycoproteins (TSH, LH, and FSH composed of a common a-subunit and a hormone-specific b-subunit), growth hormones (GH and GHRH), and proopiomelanocortins (a-MSH, regulating the production and distribution of melanin by melanocytes)

Hormones of the Neurohypophysis

The large (magnocellular) neurons located in the SON and PVN of the hypothalamus synthesize and transport along the axons to terminals situated within the posterior lobe of the PITUITARY GLAND (neurohypophysis) two vital hormones: oxytocin and VP (or antidiuretic hormone (ADH)), which are secreted by calcium-dependent exocytosis. The posterior pituitary hormones are transported in association with specific proteins, the neurophysins, via the ‘unmyelinated’ nerve fibers that extend through the infundibulum along with small cellscalled pituicytes to end in nerve terminals that lie withinthe posteriorlobe; prior to secretion, they are stored in secretory granules in the Herring bodies. The oxytocin stimulates contraction of the uterus during labor, prevents posttraumatic hemorrhage, and is involved in lactation and milk ejection from the nipples, sexual arousal, suppressing appetite, etc. Oxytocin is also called the ‘love and bonding hormone’ that plays an important role in social recognition (especially in trust, empathy, rejection, and suspicions in the group), increasing positive attitudes, the formation and realization of maternal instinct, orgasm, depression and anxiety, wound healing, and soothing inflammation. Oxytocin receptors are expressed by neurons not only in the neurohypophysis but also in the septum, nucleus accumbens, brain stem, amygdala, and other parts of the

brainand body. The chemical structure of VP (ADH) is very\ similar to oxytocin, and this is why oxytocin has milddiuretic properties, and high levels of ADH can cause uterine contractions. The main functions of the ADH are waterretention and maintaining normal body fluid volume viaspecific renal (V2) and vascular (V1) receptors, regulation ofbody temperature, initiation of aggressive behavior, and male pair-bonding behavior. ADH produces vasodilationin the renal, pulmonary, cerebral, and mesenteric vascularbeds by stimulating endothelial nitric oxide (NO) releaseand increases the systemic blood pressure. ADH is alsoinvolved in the modulation of the corticosteroid releasefrom the adrenal gland in response to stress during pregnancy and lactation and also may cause an analgetic (nociceptive) effect during sex and stress. ADH demonstrates

anti-inflammatory properties via inhibition of the inflammatory cytokine interleukin-1 released in response totrauma or infection. ADH deficiency, as a result of the hypothalamic-neurohy pophyseal lesions or in sensitivity ofthe kidney to ADH in nephrogenic diabetes insipidus, leadsto dehydration, diarrhea, hyperosmolality, and eventualdeath. ADH overproduction promotes excessive water retention and hyponatremia, which may cause convulsions andcoma. ADH could be effective in reversing hypotensionproduced by septic shock and could be a useful therapy for hypovolemic cardiac arrest.

Conclusion

Recent advances using a wide range of methodologies provide more detailed knowledge and generate new valuable insights about the cellular, molecular, and genetic mechanisms involved in the anatomy, organization, development, and

function of the human PITUITARY GLAND. The recognition of the fascinating role of the PITUITARY GLAND and its sophisticated hormonal system, which is a retrograde regulator of hypothalamic and peripheral endocrine functions, raises important questions regarding the extraordinary complexity and vital role of the PITUITARY GLAND in neuroendocrine regulation of a huge variety of human physiological functions on molecular, organic, and systemic levels that remain virtually not fully explored.

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