Anatomy of the pituitary, thyroid, parathyroid and adrenal glands

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Abstract
The anatomy of four major endocrine glands (thyroid, parathyroid, pituitary and adrenal) is the subject of this chapter. Other endocrine glands (such as the hypothalamus, pineal gland, thymus, endocrine pancreas and the gonads) exist, but are beyond the scope of this chapter. A detailed understanding of anatomy is essential for several reasons: to enable accurate diagnosis and plan appropriate management; to perform surgery in a safe and effective manner avoiding damage to adjacent normal structures and; to anticipate and recognize variations in normal anatomy. In addition to gross anatomy, clinically relevant embryological and histological details of these four glands are also discussed.

Keywords Adrenal; anatomy; endocrine; parathyroid; pituitary; thyroid

Thyroid gland

Embryology of the thyroid
The thyroid gland is derived from endodermal epithelium from the median surface of the pharyngeal floor. It arises between the primitive tongue bud and the copula (a ridge formed by fusion of the ventral ends of the first and second pharyngeal pouches) as a structure called the foramen caecum at around 24th day of gestation. This differentiates into precursory thyroid, a midline thickening of epithelium called the thyroid primordium, which subsequently hollows into a diverticulum. It remains attached to the tongue by the thyroglossal duct as it begins to descend down the neck to its final position just inferior to the thyroid cartilage. This takes a path anterior to the pharyngeal gut, hyoid bone and laryngeal cartilages. Between 7 and 10 weeks’ gestation the tubular diverticulum solidifies and the thyroglossal duct obliterates, leaving only a blind pit between the anterior two-thirds and posterior third of the tongue. The thyroid develops its anatomical shape during descent, with two lateral lobes connected across the trachea by an isthmus. Remnants of the track along the line of descent may persist and present in childhood and adult life as a thyroglossal cyst or fistula or a pyramidal lobe (Figure 1).

The parafollicular (C) cells from neural crest tissue develop separately in the ultimobranchial body (which develops from the 4th pharyngeal pouch). These cells migrate into the thyroid tissue following fusion of the ultimobranchial body with the thyroid gland. Glandular development is controlled by thyroid-stimulating hormone (TSH) and the thyroid becomes functional during the third month of gestation.

Gross anatomy
The thyroid gland lies anterior to the cricoid cartilage and trachea, and slightly inferior to the thyroid cartilages. It comprises two lateral lobes joined together by an isthmus. The lateral lobes can be traced from the lateral aspect of thyroid cartilage down to the level of the sixth tracheal ring. The isthmus overlies the second and third tracheal rings. The entire gland is enclosed within the pretracheal fascia, a layer of deep fascia that anchors the gland posteriorly with the trachea and the laryngopharynx; causing it to move during swallowing. The gland has a fibrous outer capsule, from which septae run into the gland to separate it into lobes and lobules. It is overlapped by strap muscles anteriorly. The carotid sheaths with their contents lie postero-lateral to the lobes. Two nerves related to the gland and at risk of damage during thyroidectomy are the recurrent laryngeal and external laryngeal nerves. These supply the larynx and are closely associated with the inferior and superior thyroid arteries respectively. Other related structures include the superior and inferior parathyroid glands, which lie in close proximity to the middle and lower poles of the thyroid lobes respectively.

The thyroid is a very vascular organ with extensive capsular and intra-thyroidal anastomoses between the named vessels.
from either side (Figure 2). The superior thyroid artery (branch of external carotid artery) enters the upper pole and the inferior thyroid artery (branch of the thyrocervical trunk) enters the posterior aspect of the middle/lower part of the gland. Additional branches may arise from pharyngeal and tracheal arteries, as well as the thyroidea ima artery. This latter vessel is variable in both its presence and origin and arises from either the aortic arch or the brachiocephalic artery. Arterial branches reach the gland beneath the pretracheal fascia and pierce the gland’s capsule to penetrate and supply the underlying tissue. Venous drainage is from the anterior surface of the gland into three veins: superior and middle thyroid veins draining the superior and middle aspect of the gland respectively, into the internal jugular vein, and; the inferior thyroid vein draining the inferior pole into the brachiocephalic vein. Lymphatic vessels run alongside arterial branches within the connective tissue separating the gland’s lobules. They drain into the pretracheal, paratracheal and prelaryngeal nodes and nodes belonging to the deep cervical chain.

The gland’s nerve supply is autonomic and predominantly vasomotor, arising from the superior, middle and inferior cervical sympathetic ganglia and running into the gland with the arterial branches.

**Histology**

The gland is contained within a fibrous capsule. It consists of large spherical thyroid follicles that contain colloid, which contain thyroglobulin. The colloid is lined by a simple cuboidal epithelium. This takes up thyroglobulin from the colloid and release thyroid hormones in to the blood stream. Parafollicular cells are located between the follicles and synthesize and secrete calcitonin.

**Parathyroid glands**

**Embryology**

There are generally four parathyroid glands (two superior and two inferior) located in relation to upper and lower aspects of the posterior thyroid gland on both sides. The superior and inferior parathyroids develop from the pharyngeal pouches between the fifth and sixth gestational week: superior from the dorsal wing of the fourth pharyngeal pouch, inferior from the third pharyngeal pouch (Figure 3). The superior glands take a short descent to their final position relative to the inferior glands, which share a longer caudo-medial descent with the thymus gland. Pharyngeal connections are lost at the seventh week of gestation.

**Gross anatomy**

The normal gland is an ovoid or lentiform structure with a yellowish-brown colour. It is adherent to the posterior aspect of the thyroid capsule and may sometimes be within the capsule. There are four parathyroid glands; two pairs of superior and inferior glands on either side of the midline. The superior parathyroids usually lie midway along the posterior surface of the thyroid gland above the level at which the inferior thyroid artery crosses the recurrent laryngeal nerve. The inferior parathyroids are generally found at the inferior pole of the thyroid, below the inferior thyroid artery. In relation to the recurrent laryngeal nerve, the superior and inferior glands lie anterior and posterior to the nerve respectively (Figure 4). There may be significant variation in both the number and location of the parathyroid glands; the inferior glands being more variable in position compared to the superior glands. The inferior glands may travel caudally with the descent of the thymus gland during development as far as the mediastinum. The arterial
supply arises from the inferior thyroid artery or from the rich anastomotic network formed from vessels arising from both superior and inferior thyroid arteries. The venous drainage is usually into the thyroid plexuses. Lymph drainage is via paratracheal or deep cervical lymph nodes. They receive an autonomous nerve supply from thyroid branches of the cervical sympathetic ganglia.

**Histology**
The parathyroid gland comprises dense cords of ‘parathyroid hormone’ producing (chief) cells clustered around capillaries. Other cell types include oxyphil cells (whose function is unclear) and adipocytes. There is also a surrounding fibrous stroma that supports the blood supply.

**Pituitary gland**

**Embryology**
The anterior and posterior lobes of the pituitary gland have different embryological origins. The posterior gland (neurohypophysis) takes origin from the brain, developing as a downward extension from the floor of the diencephalon, this extension being known as the infundibulum. The infundibulum is composed of neuroglial and hypothalamic neural tissue and develops into the stalk and the pars nervosa (neurohypophysis) and maintains the continuity of the gland with the hypothalamus. On the other hand, the anterior gland (adenohypophysis) develops around the third week of gestation from cells derived from the anterior wall of Rathke’s pouch, an evagination of ectoderm from the primitive mouth (stomodeum). It grows dorsally towards the infundibulum, losing connection with the oral cavity by the second gestational month. An outgrowth of the anterior lobe forms the pars tuberalis, which extends up to envelop the infundibular stalk.

**Gross anatomy**
The pituitary gland lies within a fossa of the sphenoid bone called the pituitary fossa or sella turcica. It is composed of a cellular anterior lobe and a neural posterior lobe separated by colloid vesicles of the pars intermedia. The posterior lobe is connected to the tuber cinereum in the floor of the third ventricle by the infundibulum (or pituitary stalk), which passes through a fold of dura mater that covers the gland, the diaphragma sellae (Figure 5). Lateral to the gland lies the cavernous sinus and the optic tracts, and superiority the optic chiasma (anterior to the upper infundibulum). The thalamus lies dorsolaterally, and the mammillary bodies lie caudal to the gland. The diaphragm sellae attach to the anterior and posterior clinoid processes of the sphenoid, forming a seal of dura over the gland that doesn’t allow cerebrospinal fluid to enter. This keeps the pituitary outside the blood–brain barrier.
Blood supply to the anterior and posterior lobes is by superior and inferior hypophyseal arteries respectively, both originating from the internal carotid artery (Figure 5). In addition, a separate portal venous system fed by the branches of the superior hypophyseal artery carries hormonal signalling from the hypothalamus. Venous drainage is primarily through the anterior lobe, with venous tributaries draining first into the cavernous sinus and then into the internal jugular vein.

**Histology**

Histological examination identifies the pars distalis of the adenohypophysis, the pars intermedia and the pars nervosa of the neurohypophysis. The pars distalis consists of dark chromophils and lighter chromoblasts. It secretes growth hormone (GH), thyroid-stimulating hormone (TSH), adrenocorticotropic hormone (ACTH), follicle-stimulating hormone (FSH), luteinizing hormone (LH) and prolactin. The pars intermedia secretes melanocyte-stimulating hormone (MSH). The pars nervosa consists of axons from secretory neurons from the hypothalamus that release oxytocin and antidiuretic hormone (ADH).

**Adrenal glands**

**Embryology**

The adrenal (or suprarenal) gland begins to develop by 25th day of gestation from cords of polyhedral cells in the coelomic epithelium, medial to the urogenital ridge. The gland comprises the inner medulla and the outer cortex, which have different embryological origins (similar to the pituitary). The adrenal medulla arises from sympathetic nerve tracts of neural crest tissue migrating into the adrenal gland at 45th day of gestation. Its surrounding mesenchyme is the skeleton for the foetal cortex, which is replaced by the adult cortex derived from mesothelium.

**Gross anatomy**

The adrenal glands are retroperitoneal structures weighing around 5 g each and sitting on the upper pole of the kidneys with the perinephric fat enclosed by Gerota’s fascia (Figure 6). The left gland is crescent shaped, whereas the right gland is more pyramidal. Their relational anatomy differs slightly on each side. The left gland lies posterior to the tail of the pancreas, the splenic artery and the stomach. It is separated from the gastric cardia by the omental bursa. The right gland sits posterior to the inferior vena cava, with the anterolateral surface against the liver. Both glands lie lateral to the inferior phrenic artery and are in contact with the diaphragm above and their corresponding kidney below.

Occasionally, nests of adrenal tissue can form outside of the adrenal gland. These accessory glands arise from migration of adrenocortical primordial cells along the gonadal tracts and can be present in relation to spermatic cords, testes or ovaries. They very

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**Figure 5**

The pituitary gland with its blood supply and anatomical relations

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rarely contain a medullary component. These may be clinically relevant, as they can still undergo the same disease processes that arise from adrenal glandular tissue.

The adrenal glands are richly vascular. Arterial blood supply is derived from the superior, middle and inferior adrenal vessels, which are branches of the phrenic artery, abdominal aorta and the renal artery respectively. Venous drainage is often through a single main adrenal vein running from the hilum and draining into the inferior vena cava on the right and into the renal vein on the left (Figure 6). Occasionally, there are multiple veins instead of a single large vein. Lymphatic drainage is into neighbouring periaortic and pericaval nodes.

**Histology**

The adrenal is surrounded by a fibrous capsule from which septae arise and penetrate the gland. The cortico-medullary boundary is apparent upon histological examination. The adrenal cortex has three anatomically and functionally distinct layers or zonae. Cells form concentric layers and from outer to inner are:

- **Zona glomerulosa** secreting mineralocorticoids (aldosterone). Cells form irregular cords that run in multiple directions
- **Zona fasciculata**, the thickest layer, producing glucocorticoids (cortisol). Cells are polyhedral forming straight cords running towards the medulla
- **Zona reticularis** — innermost layer, producing sex steroids (androgens). They consist of columnar cells running in irregular cords.

The medulla is neuronal in structure and function, originating from the neural crest from which sympathetic ganglia arise. It secretes the neurotransmitters noradrenaline and adrenaline in response to stimuli received from preganglionic sympathetic fibres from the greater splanchnic nerve. Chromaffin cells are the most abundant cells in the medulla; columnar, basophilic with a granular cytoplasm due to hormone-containing granules. They are arranged in clusters around medullary veins. In addition, polygonal sympathetic ganglion cells can be identified in clusters.

**FURTHER READING**