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SURGICAL ANATOMY OF THYROID AND PARATHYROID GLANDS AND BASIC PRINCIPLES OF OPERATIVE TECHNIQUE

Abstract: The thyroid gland is the largest endocrine organ with the highest frequency of disorders of all the endocrine organs. A successful treatment of both benign and malignant diseases of the thyroid is connected with adequate pre-operative evaluation, a precise operative technique and the knowledge of surgical anatomy. Complications that may occur due to the insufficient knowledge of the surgical anatomy of the thyroid and parathyroid glands permanently damage the health of the patient and cause his lifelong disability. Therefore it is necessary that the surgeon performing a thyroid and/or parathyroid glands operation should have sufficient knowledge of the surgical anatomy of these endocrine organs despite the wide availability of instruments which enable better visualization of the operative field, coagulation of blood vessels and intraoperative neuromonitoring.

The thyroid gland is the largest endocrine organ in an adult, weighing about 17g (1) in a healthy person and covering the anterolateral area of upper tracheal rings (from II to IV) and larynx. It is a bi-lobed organ, whose left and right lobes are connected by a bridge of isthmic glandular tissue. Each lobe is located in the area between the trachea and oesophagus medially, carotid sheath posteriorly, and sternocleidomastoid and sternohyoid muscles anteriorly and laterally.

If sternocleidomastoid and sternohyoid muscles must also be cut transversely during thyroidectomy (in order to approach the blood vessels of the upper pole), it should be done at the level of the cricoid cartilage, which ensures the preservation of

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their motor nerve (ansa nervi hypoglossi). From a clinical point of view, there are no functional consequences of the cuts of these muscles (1).

Thyroid capsules and connections

A normal thyroid is of soft consistency, dark red colour and surrounded by a thin fibrous capsule (tunica propria, anatomic capsule) which is very difficult to separate since it has grown into the glandular tissue. Via this anatomic capsule, the thyroid is surrounded by another fascial layer (deep layer of the cervical fascia), which is called the surgical capsule. The space between the inner and outer capsules of the thyroid (spatium praeviscerale) with the mealy connective tissue is exactly the surgical layer through which an extracapsular preparation of the lobe is performed (2). The thyroid is loosely attached to the surrounding structures and the changes in fixation may arouse suspicion of the existence of pathological changes particularly when anamnestic data indicate acute thyroiditis or carcinoma. Normally, the thyroid is fixed with the posterior and anterior suspensory ligaments. Anterior suspensory ligaments fixate the medial edge of the upper pole and the upper edge of the isthmus for the cricoid cartilage. They need to be cut in order to ‘open’ the cricothyroid space, which is an essential element of the operating technique to approach the blood vessels of the upper pole upon cutting the isthmus (separating the anterior and posterior parts of the isthmus from the trachea). The posterior suspensory ligament or the ligament of Berry is extremely important in surgical anatomy. The ligament of Berry represents a broader and much stronger connective tissue which connects the inner side of the anterior part of the thyroid lobe with the postelateral part of the cricoid cartilage and the first two tracheal rings. Beneath this ligament, there is a laryngeal nerve (n.recurrens) on its way to the larynx, which in 25% of all cases (3) also goes through the ligament, thus increasing the possibility of an operative lesion. Beneath the ligament, there is very often a bud-like part of the thyroid tissue, which makes operative extirpation very difficult. Considering the fact that the inferior laryngeal artery goes along the lower edge of this ligament and that the inferior laryngeal nerve often diverges there, it is clear why this area is one of the high- risk zones for the lesion of the inferior laryngeal nerve when performing total lobectomy.

Blood vessels and laryngeal nerves

The thyroid gland has a rich blood supply mostly from the superior and inferior thyroid artery. In a number of cases (10%), there is also the lowest thyroid artery (a.thyroidea ima), which diverges from the aorta arch or a.anonymae and moves up towards the thyroid in front of the trachea. This artery when it is of a larger caliber can replace the inferior thyroid artery when it is congenitally missing (1).

Superior thyroid artery (a.thyroidea superior) and superior laryngeal nerve (n.laryngeus superior)

The superior thyroid artery is the first branch of the external carotid artery (a.carotis externa), from which it diverges directly above the thyroid cartilage at the level of the hyoid bone. After the divergence of its lateral branch of the superior laryngeal artery (a.laryngea superior), it goes forward and downward to the surface of the lower constrictor of the throat beneath the sternothyroid muscle and next to the thyreohyoid muscle and approaches the front posterior side of the upper pole of the thyroid lobe, where it diverges into three final branches: superior, external and inferior. The parathyroid artery for the superior parathyroid gland diverges from the anterior branch of the superior thyroid artery or its anastomosis with the upward branch of the inferior thyroid artery. Close to the superior thyroid artery, there is the trunk of the superior laryngeal nerve (n.laryngeus superior), and in the ultimate part, there is the external branch of this nerve (r.externus), which is the motor nerve of the cricothyroid muscle.

This muscle is the (indirect) tensioner of the vocal cord, which enables the production of high-pitched tones. The injury of this nerve, especially if it is on both sides, can be easily overlooked during postoperative laryngoscopy. In 6-18% of cases, the external branch of the superior laryngeal nerve goes along with or intersects the superior thyroid artery or its branches, during ligation of the superior thyroid artery it is at risk to be injured (4). However, a routine identification of this nerve during thyroidectomy is not recommended (5). Basically, in 20% of cases, this nerve is located around the upper pole of the thyroid in a surgically inaccessible area and it cannot be identified through the fibers of the lower pharynx constrictor so that this approach is not recommended due to the possibility of damaging the pharynx (5).

In order to avoid injuring the nerve during the ligation of the vascular pedicle of the upper pole, it is necessary to identify the branches of the superior thyroid artery, which enables the ligation of its trunk. This approach is particularly recommended in surgical treatments of an enlarged thyroid. The branches of the superior thyroid artery should be ligated as low as possible and as close to the thyroid capsule as possible. The ‘opening’ of the cricothyroid space by cutting the anterior suspensory ligament makes this procedure possible (4). The approach through this area reduces the risk of injuries of the superior laryngeal nerve and/or its external branch, especially if the dissection is performed from the medial to the lateral side, which is ensured by the traction of the upper pole of the thyroid lobe downward and outward. Thus, it is possible to observe the nerve going more or less cross-sectionally between the blood vessels of the upper pole and above the upper pole of the lobe, medially from the lower pharyngeal constrictor and cricothyroid muscle and below the sternothyroid muscle. According to Moosman and De Weese (6), these anatomic structures make the so-called sternothyroid-laryngeal triangle and the ability to identify these elements is one of the basic objectives in the education of endocrine surgeons. The electrocoagulation of small branches of the superior thyroid artery for the lower pharyngeal constrictor and the cricothyroid muscle can also lead to the injury of the nerve due to the fact that it goes beneath them, which means that their ligation is a much safer procedure. The lobectomy technique which begins by the preparation of the upper thyroid lobe was introduced by Halsted and improved by Coller, Boyden and Thomson (7,8,9).

Inferior thyroid artery (a.thyroideae inferior) and inferior laryngeal nerve (n.recurrens)

The inferior thyroid artery occurs by bifurcation of thyreocervical trunk (truncus thyreocervicalis) branch of the subclavian artery (a.subclavia), on the inner edge of the anterior scalene muscle. It goes up along the outer edge of the common carotid artery across the anterior scalene muscle to the Chassaignac carotid tubercle (tuberculum caroticum), then at the level of the cricoid cartilage, it changes the direction abruptly, becomes horizontal, turns inward and downward in front of the spinal artery (a.vertebralis), and beneath the common carotid artery. Its horizontal portion creates a curve in the shape of the lying letter S, it lies on the ante-spinal fascia and it intersects with the front side of the sympathicus, which in this particular point, can be easily hurt in case of an unprofessional “en masse” lygating the artery. Behind the lower pole or the border between the middle and lower third, approximately 1cm far from the thyroid lobe, the inferior thyroid artery is divided into three ultimate branches: inferior, posterior (upward) and internal (middle). The posterior (upward) branch of this artery goes along the posterior side of the lobe and anastomoses with the posterior branch of the superior thyroid artery. The artery for the inferior parathyroid gland diverges from the ultimate branches, and sometimes even from the trunk itself. The inferior laryngeal artery (a.laryngea inferior) is the largest extrathyroid branch of this artery which goes along the lower edge of the Berry ligament. A surgeon can identify the inferior thyroid artery only after medial mobilization of the thyroid lobe, and lateral mobilization of the jugular vein, which ensures the tension of the artery and its easier identification and is the basis of the lobectomy technique within which the lobe is prepared laterally or from the lower pole. The basis of this procedure procedure was first given by Kocher (10) and later improved by Lahey (11), whereas the second one was inaugurated by Edis at the Mayo clinic (12).

The inferior thyroid artery is in close relationship with the inferior laryngeal nerve (n.recurrens), motor nerve, which innervates all the internal muscles of the larynx. During surgery injury of this nerve, or in case of branching, injury of its motor branch, causes the paralysis of the vocal cord on its ipsilateral side. Anatomic variations of n.recurrensa are numerous, especially when the thyroid is enlarged, so that when the nerve is not identified there are no ‘safe’ areas where a surgeon can operate without any risk. It is extremely important that the surgeon should identify the point of intersection of n.recurrensa and the inferior thyroid artery, i.e. the point of neurovascular intersection (13), which ensures a low percentage of postoperative paralysis of n.recurrensa .

The left n.recurrens goes up towards the larynx through the tracheoesophageal groove or more laterally, along the front side of the oesophagus, usually behind the trunk of the inferior thyroid artery, sometimes between, and rarely in front of its ultimate branches. The right n.recurrens is much more inclined so that in the caudal part it is located one or more centimeters laterally away from the trachea. It rarely goes behind the trunk of the inferior thyroid artery but much more often through its branches. Numerous variations of this nerve have been described (14). From the practical point of view, it should be known that the n.recurrens goes behind the trunk of the inferior thyroid artery, in front of or between its branches and that it is safer to look for the nerve behind the artery. By identifying the trunk of the inferior thyroid artery and by careful ligation of its branches, the possibilities of damaging the nerve and devascularising the inferior parathyroid gland are much reduced. The branches of the inferior thyroid artery and, in particular, its lateral branch – the inferior laryngeal artery, may be misidentified as n.recurrens although, in its appearance, it is less regular, curved and elastic. Its sinusoidal vessels (vasa nervorum) can also be observed, and their curves are reduced when the nerve becomes ‘tense’ after the medial mobilization of the lobe. The nerve rarely branches below the inferior thyroid artery, and if branches exist, only one of them is a motor branch. A surgeon must bear this possibility in mind, consider each branch of n.recurrens the motor one and try to save all of them at all costs. After passing the inferior thyroid artery, the nerve goes upward and medially towards the posterolateral side of the middle third of the lobe and close to the lobe capsule. Sometimes, in this zone, n.recurrens can go through the thyroid tissue, which may be caused by a pathological process or, rarely, by a normal anatomic variation. At the level of the two upper tracheal rings, the nerve goes through the posterior portion of the Berry ligament and loosely connects the lobe with the oesophagus. Before entering the larynx, n. recurrens branches behind the cricothyroid muscle. The inferior laryngeal artery follows the nerve, and in the area of the Berry ligament, the artery is usually behind n.recurrens producing a small branch which intersects with it on the interior side before entering the thyroid lobe. Here, the nerve is most often subject to injuries and that is why homeostasis control by ligation of blood vessels should not be performed before identifying it first. Medial mobilization of the lobe, in spite of its importance for the identification of the inferior thyroid artery, may, on the other hand, harm n.recurrens. In this procedure, the trunk of the inferior thyroid artery becomes ‘ tense’ as well as its branches and the Berry ligament and, consequently, n.recurrens is ‘tensioned’ and dislocated forward towards the lateral side of the trachea. Posterior fibres of the Berry ligament put pressure on n.recurrens towards the lateral side of the tracheal rings, which makes it difficult to preparate. The mobilization of the lobe upward, after freeing the lower part, enables a more gentle procedure in identifying and preparating the nerve before it enters the larynx at the level of the cricoid cartilage (1).

In very few cases (0.63%), the right inferior laryngeal nerve does not have a recurrent flow (15). On the left side, this anomaly is very rare and occurs in 0.04% of cases. As a rule, the origins of the non-recurrent laryngeal nerve is cervical. Depending on the level of occurrence, the nerve goes more or less downward along n.vagus and, to a smaller or larger extent, across the jugulocarotid groove, where it curves downward. It always goes beneath the common carotid artery. With a third of its length, it is closely connected with the trunk and the branches of the inferior thyroid artery and enters the larynx at the usual level. The non-recurrent laryngeal nerve occurs due to the vascular anomaly during the embryonic development of the arch of the aorta, where the right subclavian artery directly diverges from the arch of the aorta. The occurrence on the left side is connected with the right arch of the aorta and the visceral situs inversus. There is also a very rare variant of the non-recurrent inferior laryngeal nerve together with the ipsilateral recurrent nerve without a simultaneous anomaly in the development of blood vessels. If, during the total lobectomy, the nerve has not been found in the usual place, before its intersection with the inferior thyroid artery, it should be remembered that it might be non-recurrent and it should be looked for cross-sectionally, laterally towards the carotid space and medially towards the lobe of the thyroidea since the nerve, then, connects these two structures. In the case of a serious retrosternal goiter, particularly in the last mediastinum, or in the case of the extrathyroid spread of the thyroidea carcinoma, the nerve is difficult to identify and since it is not possible to perform surgery below the inferior thyroid artery, it should be looked for proximally at the point where it enters the larynx at the level of the cricoid cartilage and then preparated downward. This procedure demands the previous mobilization of the gland by ligating the vascular stem of the upper pole or medial mobilization of the lobe upon cutting the isthmus.

Veins of the thyroid gland

The variations in the vein drainage of the thyroid are much more common than in its arterial vascularisation. Intraglandular veins are of relatively small dimensions, they are directed towards the surface where, just below the anatomic capsule, they form a rich splice which makes the thyroid look very unique. In a pathologically changed thyroid, capsular veins may be of extremely large dimensions. So, bleeding from capsular blood vessels may be substantial and because of that, in the subtotal resection of the lobe, the blood vessel forceps should be placed on the capsular veins, which makes this procedure almost completely bloodless. The drainage of the network of the capsular veins is done through three vein trunks. The superior thyroid veins, directly or indirectly (via truncus thyreolinguofacialis), flow into the internal jugular vein just in front of and laterally from the superior thyroid artery. The lateral and middle veins vary considerably in terms of their number. They go from the anterolateral edge of the lobe, they are relatively short and may be of a large diameter, and they flow directly into the jugular vein. Their identification is important because they can be mistaken for capsular veins, and their splitting most commonly occurs at the very confluence of the internal jugular vein and in cases of lobe mobilization without a previous ligation of these veins. That is why they should be identified and tied after a careful lateral retraction of the common carotid artery and before medial mobilization of the lobe. The inferior thyroid veins go from the upper pole and isthmus via several trunks, and very often form a splice. They flow into the internal jugular vein, and sometimes they unite into a common trunk (v.thyroidea impar) into the innonimate vein. Before tying the most lateral inferior thyroid veins, it is necessary to identify the recurrent nerve since it can be mistaken for a vein.

Lymphatic drainage of the thyroid

Lymphatic drainage of the thyroid is highly developed and practically goes to all directions (16,17). The thyroid follicles are surrounded by intraglandular lymphatic capillaries. There is a number of intraglandular lymphatic connections, which enables lymphatic drainage from one to the other lobe via a complex of intrathyroid and pericapsular nodes, and this explains the intraglandular dissemination of the thyroid carcinoma (18).

Main lymphatic vessels have an efferent flow and follow the small branches of thyroid arteries and veins in three major directions: upward, lateral and downward. The upper area of the thyroid is drained along the superior thyroid vessels into the upper jugular nodes. Lymphatic vessels from the isthmus are directed towards prelaryngeal and delphian nodes which are connected with the upper jugular nodes. Lateral lymphatic vessels follow the medial thyroid vein to the middle and lower jugular nodes. The lymphatic drainage from the lower parts goes towards pretracheal and paratracheal nodes and the chain of lower jugular nodes. The links with the anterior mediastinal and retropharyngeal nodes are frequent, whereas the drainage into submandibular and suprahyod nodes is rare. Contralateral drainage is possible via pericapsular, pretracheal prelaryngeal nodes (19).

From the practical point of view, a surgeon needs to consider the existence of two zones of lymphatic drainage. The primary zone of lymphatic drainage consists of the paraglandular space or the middle or visceral region of the neck (VI and VII group of lymphatic nodes). The second or secondary zone of lymphatic drainage consists of the lateral region of the neck (II,III,IV and V group of lymphatic nodes). The link between these two zones is the carotid space.

In the visceral region, there are two groups of lymphatic nodes: prelaryngeal and pretracheal lymphatic nodes and the paratracheoesophageal group of lymphatic nodes. Prelaryngeal lymphatic vessels lie in front of and above the isthmus and unite above and laterally with the lymphatic vessels of the upper pole of the thyroid and follow the blood vessels of the vascular stem of the upper pole, finally draining themselves into the lateral nodes of the neck. Pretracheal lymphatic vessels are located below the isthmus and unite caudally with the lymphatic vessels of the anterior upper mediastanum. The anterior edge of the visceral portion is the posterior surface of prethyroid muscles, but sometimes metastases in the nodes can be found in the front and in the middle line immediately above the isthmus (delphian lymphatic nodes). Paratracheoesophageal lymphatic vessels lie along the lateral and posterior sides of the thyroid as well as along the recurrent laryngeal nerves. They are laterally connected with the lymphatic vessels of the supraclavicular triangle, and posteriorly with the ones around and behind the trachea, larynx, pharynx and oesophagus. The lymphatic drainage of the isthmus is directed downwards into mediastinal nodes and upwards into paralaryngeal nodes. The normal flow of the lymphatic drainage is from the central and lower parts of the lobe towards tracheoesophageal nodes. The lymphatic drainage of the upper poles of the lobe is the only one which is performed directly into the lateral lymphatic nodes. This is explained by the fact that in two thirds of papillary thyroid carcinoma diagnosed on the basis of the metastases in laterocervical lymphatic nodes, the primary tumor is located in the upper pole of the thyroid (20), whereas in all other thyroid carcinoma, the central and the middle regions of the neck are the primary zone of the lymphatic drainage.

The secondary zone of the lymphatic drainage consists of the lateral regions of the neck (a chain of deep lymphatic nodes which go along the internal jugular vein and the posterior triangle of the neck). The obstruction of the lymphatic flow in the central region of the neck may lead to the enlargement of the lymphatic nodes only in the lateral region of the neck due to the retrograde flow of the lymph (19). Initially, the metastases in the lymphatic nodes are usually observed in the central region of the neck (medially from the space a. carotis comm.) in the pretracheal and paratracheal nodes, and then they spread to the lateral region into the deep upper and lateral cervical nodes (19). Most often, patients with larger primary thyroid tumors have a larger number of metastases in the lymphatic nodes (18), although some patients may have an occult thyroid carcinoma and deposits in the lymphatic nodes.

Most surgeons are in favour of the profilactic dissection of the visceral and central region of the neck during the primary operation of papillary and medular carcinoma since this is the primary zone of lymphatic drainage. Reoperation in this region, due to the appearance of metastases in the lymphatic nodes, is connected with an increased risk of damaging the recurrent nerve and parathyroid glands.

Parathyroid glands

Knowing embryology helps a surgeon to understand where parathyroid glands can be located whereas their macroscopic appearance enables him to identify them and differ from other structures

The upper pair of parathyroid glands (PIV) is of embryological origin of the fourth pharyngeal pouch, it is located more cranially and in close contact with the thyroid. The lower pair of parathyroid glands (PIII) is developed from the third pharyngeal pouch just like the thymus, and that is why PIII are located more caudally and very often near or inside the thymus itself.

The common embryological origin of PIII and thymus causes the position of PIII to be from the corner of the mandibule to the pericardium.

Parathyroid glands are of various shapes (oval, tongue-shaped, leaf-shaped, discus-shaped) and of compact structure in 94-98% cases (21). The colour depends on the amount of fat tissue and vascularisation: lightbrown or the colour of coffee is present when the amount of fat tissue is larger and they are dark, yellowish-brown or reddish-brown when they are more cellular and with a better blood flow. In terms of palpation, they are soft and of elastic consistency. During the development of the nodes, they can be flattened in the thyroid, but they regain their normal shape by separating themselves from the surface of the nodes. The average size is around 5x3x1 mm according to Gilmour (22) and Wang (23), whereas according to the same authors, the weight ranges from 10 to 78 mg, with the average weight being 40 mg. parathyroid glands are incapsular, with sharp edges and with a smooth and glossy surface. They are usually completely or partially immersed in the fat tissue and together with it they form a 'greasy ball' because of their special affinity towards the fat tissue, from which they can be easily separated. Regardless of the variations in size, colour and shape, parathyroid glands are always incapsular, which gives them a special, mainly yellow appearance. The fat tissue is of softer consistency, paler and without a definite shape. The lymphatic nodes are harder, more rounded, less homogenous, white or dark grey with black spots, they are difficult to separate from the surrounding fat tissue and there are usually more of them. The thyroid tissue is harder, from dark red to light bluish-grey in colour when under pressure, whereas the thymus tissue is paler, yellowish-grey or pinkish-grey, granulated and adherent to the fat tissue.

Arterial vascularisation of the parathyroid is of terminal type, and in two-thirds of all cases there is only one artery. The length of the artery is between 1 and 40 mm, so that the preservation of this artery during lobectomy mainly depends on the distance between the point of divergence of the artery and the thyroid capsule.

PIII vascularisation mainly depends on the inferior thyroid artery, from whose ultimate branches, and sometimes even from the trunk itself, the parathyroid artery diverges. The parathyroid artery for PIV appears by diverging from the posterior (upward) branch of the inferior thyroid artery, the posterior branch of the superior thyroid artery or its anastamoses with the upward branch of the inferior thyroid artery. The inferior thyroid artery can ensure arterial vascularisation of both superior and inferior parathyroid glands. A surgeon must always bear this in mind and avoid the ligation of its main trunk. Individual ligation of the branches of the superior thyroid artery as low towards the capsule as possible ensures the preservation of the posterior branch of the superior thyroid artery.

Vein drainage is performed in three ways: via the capsular splice of the thyroid, via the small branches entering the thyroid or using the combination of these two methods. The hemostasis of the parathyroid veins should be avoided due to the risk of glandular infection. The change of colour of the thyroid and its progressive darkening is a certain sign of ischemia. The incision of the capsule and the surface of the parenchyma may stop a venous stasis and enable the recovery of the gland and its normal colour.

There are numerous variants in the localization of the parathyroid glands. From the practical point of view, it is necessary for a surgeon to know that PIII is localized in a usual way, caudally from the intersection with the inferior thyroid artery and the recurrent laryngeal nerve. If it is not in this place, it is probably in the thymus. The localization of PIV is more constant, they are located deeper than PIII at the level of the cricoid cartilage. When they are not typically localized, they have most probably gone downward across the oesophagus into the posterior mediastinum.

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