Salient Anatomical Landmarks of Thyroid and Their Practical Significance in Thyroid Surgery: a Pictorial Review of Thyroid Surgical Anatomy (Revisited)

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Abstract Thyroid surgery is a prototype of operations requiring thorough knowledge of surgical anatomy. There are many vital and delicate anatomical structures such as recurrent laryngeal nerve, superior laryngeal nerve, parathyroid glands, and distinct fascial planes surrounding the thyroid gland. A protean range of pathologies such as goiter, nodules, thyroiditis, and malignancy distort or alter the location and course of these structures and planes. The distinct vascular supply and high vascularity of thyroid region challenges the surgeon's expertise. Several pathologies like malignancy, multinodularity, toxicity, and retrosternal extension further compounds this vascular aspect of surgery. Several structures of embryological importance such as pyramidal lobe, tubercle of Zuckerkandl, and ligament of Berry have decisive clinical implications in the surgical management of thyroid disorders. Surgeons attempting thyroidectomy need to have thorough knowledge of embryology and surgical anatomy of the thyroid gland. In this context, we highlight through a pictorial assay the embryological and anatomical aspects of the thyroid gland emphasizing on their clinical and surgical importance.

Keywords Thyroid gland · Pyramidal lobe · Tubercle of Zuckerkandl · Ligament of Berry · Recurrent laryngeal nerve

Introduction

The challenges and art of thyroid surgery are immortalized in the annals of surgery by this famous quotation of Halstead “The extirpation of the thyroid gland for goiter typifies, perhaps, better than any operation the supreme triumph of the surgeon's art” [1]. The technique of thyroid surgery and its surgical anatomy were established by great works of Kocher, Billroth, Lahey, Crile, etc. [1]. Even the monumental efforts in the field of thyroid surgery have yielded Nobel Prize in Medicine to Theodor Kocher in the year 1909. In spite of volumes of literature on embryology, anatomy, and pathology of the thyroid gland, comprehensive description of practical aspects of surgical anatomy is limited to fewer papers [2–4]. Surgeons contemplating thyroid surgery need to be aware of embryology, anatomy, and pathological alterations for optimal results and minimal morbidity. In this review, we attempted to collate and describe through a pictorial assay the surgical embryology and anatomy of the thyroid gland. In this paper, our main emphasis is on the practical relevance of salient surgical landmarks of thyroidal and perithyroidal structures.

Material and Methods

The work was carried out in the department of endocrine and metabolic surgery of a tertiary care teaching hospital in Southern India. Meticulous identification, photography, and documentation of the anatomical landmarks were done in all the thyroidectomy procedures. The search of related

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literature was done through PubMed/MEDLINE portal. Informed consent was taken from all the patients for the use of clinical material and photographs without revealing their identity. The subsequent format of this pictorial review is description of embryology, surgical anatomy of thyroid gland, and related structures synchronous with the relevant review of literature.

Discussion

The thyroid gland has dual origin embryologically from both endoderm and ectoderm. Endodermal component is from the floor of primitive pharynx originating at the junction of the first and second pharyngeal pouches. It corresponds to future foramen caecum at the junction of ventral two thirds and dorsal one third of the tongue. This endodermal outpouching descends caudad to form thyroglossal tract and thyroid parenchyma arises due to proliferation of thyrocytes from its distal end. Ectodermal component arises along with calcitonin-producing C cells from the neuroectodermal ultimobranchial body and forms the future posterolateral aspect of the thyroid parenchyma. The following sections deal with the salient embryo anatomical landmarks with surgical significance in this order.

1. Pyramidal lobe (PL)
 2. Tubercle of Zuckerkindl (TZ)
 3. Ligament of Berry (LB)
 4. External branch of superior laryngeal nerve (EBSLN)
 5. Inferior thyroid artery (ITA)
 6. Recurrent laryngeal nerve (RLN)
 7. Parathyroid glands (PT)
 8. Pretracheal fascia (PTF)
 9. Pretracheal plane (PTP)
 10. Linea alba of neck (LAN)
 11. Thyrocarotid space (TCS)
1. Pyramidal lobe: The distal end of thyroglossal tract persists as PL in up to 44–61 % of cases [5–7], located at the superior border of the isthmus (Fig. 1). It is mostly situated in the left paramedian position [8]. PL is usually a thick fibrous strand with minimal thyroid parenchyma in a normal thyroid gland. The clinical significance of PL lies in its non-resection during total thyroidectomy, which could lead to the following:
 - (a) Recurrence of hyperthyroidism due to compensatory hyperplasia in toxic goiters [9]
 - (b) Recurrence of goiter in nodular goiters [9]
 - (c) Recurrent malignancy in differentiated thyroid cancer due to multifocality [10]
 - (d) Recurrent thyroglossal fistula after incomplete Sistrunk's operation

Fig. 1 Intraoperative picture of total thyroidectomy showing PL (arrow)

2. Tubercle of Zuckerkindl: It is the condensed thyroid parenchyma located in the cricothyroid junction on the posterolateral aspect of the thyroid gland (Fig. 2). TZ can be graded into three grades as proposed by Gravante et al. [11] and is present in 63–75 % of cases [12, 13]. The practical importance of TZ lies in its surgical utility, in pointing the location of RLN, which enters the larynx behind it [12–14]. TZ is also the site for maximum density of C cells, making its resection mandatory in total thyroidectomy for medullary thyroid cancer [15].
3. Ligament of Berry: LB represents the condensation of PTF along with an entrapped flimsy layer of thyroid parenchyma on the posterolateral aspect of the thyroid gland (Fig. 3). It suspends and firmly attaches the thyroid gland to the cricoid cartilage and upper tracheal rings [16]. It is one of the primary causes of thyroid gland movement with deglutition. At surgery, an excessive medial rotation of thyroid gland leads to kinking of RLN due to its close proximity and entrapped

Fig. 2 Intraoperative view of TZ (arrow)

Fig. 3 LB (solid arrow), PT (horizontal hollow arrows), and RLN (vertical arrow)

location within the posterior fibers of LB [17]. This puts RLN at risk of injury in thyroidectomy. Close capsular dissection with RLN identification near LB stands as a litmus test for quality thyroid surgery. Another surgical significance is the presence of perforating laryngeal blood vessels parallel to LB, which leads to cumbersome bleeding if LB is not ligated close to the thyroid gland. The frantic effort to control this bleeding is one of the main reasons of RLN injury. LB also marks the most common site for airway invasion in high risk and poorly differentiated thyroid cancer [18].

4. External branch of superior laryngeal nerve: It is purely a motor branch of vagus nerve arising distal to the ganglion nodosum and supplies the cricothyroid muscle which primarily controls the quality and pitch of voice [19]. It is a largely neglected nerve among many thyroid surgeons. Depending on its level and relation with superior thyroid pole, various classifications were proposed by Cernea et al. [20] and Friedman et al. [21]. Careful and mandatory search for EBSLN prevents its inadvertent injury. Lateral traction of the superior thyroid pole and individual ligation of the superior thyroid vasculature close to the thyroid capsule ensure preservation of EBSLN in most cases [22]. EBSLN palsy leads to significant morbidity especially in teachers, announcers, and professional singers [21].
5. Inferior thyroid artery: ITA is the second major arterial supply of thyroid gland and the main vascular source of parathyroid glands [23]. It arises as one of the branches of thyrocervical trunk of the first part of subclavian artery [24]. It emerges into the neck from behind the common carotid artery and traverses horizontally to the posterolateral aspect of the thyroid gland on both sides [24]. The primary surgical implication is the close association of RLN with the terminal part of ITA. In most of the cases, RLN lies anterior

to ITA on the right side and lies posterior to ITA on the left side. In 10–20 % of cases, RLN lies between the branches of ITA [25]. Ligation of terminal branches of ITA, close to the thyroid capsule and away from RLN, is another yardstick for an expert thyroid surgery. Ligation of the trunk of ITA may jeopardize the vascular supply of parathyroid glands.

6. Recurrent laryngeal nerve: RLN or inferior laryngeal nerve is a branch of vagus nerve arising at the root of the neck and recouring back into the neck, after looping around the subclavian artery on the right side and the ligamentum arteriosum on the left side [26]. RLN supplies all the intrinsic laryngeal muscles except the cricothyroid. It also provides sensory supply to infraglottic mucosa. RLN palsy can lead to hoarseness of voice, dysphagia, ineffective cough, and respiratory difficulty. Prevention of RLN injury is another skill test for thyroid surgeon. Experienced surgeons develop their own way, though many standard techniques such as inferior, lateral, and superior approaches are described for RLN identification [27–29]. Capsular dissection of the thyroid and delineation of anatomical landmarks such as tracheoesophageal groove, ITA, TZ, LB, and inferior constrictor muscle are few basic surgical principles forming essential components of any approach for identification and preservation of RLN (Figs. 3 and 4) [2, 3, 30].
7. Parathyroid glands: Superior PT arises from the fourth branchial pouch and is located posterosuperior to RLN (Fig. 3) [31]. Inferior PT arises from the third branchial pouch along with the thymus and is located anteroinferior to RLN in most cases (Fig. 3) [31]. Preservation of vascularized and functional PT glands is another challenge in thyroid surgery. Inferior PT glands are especially prone to injury from central compartment neck dissection performed for differentiated thyroid cancer or thyroidectomy in difficult goiters. In such a

Fig. 4 PTP (horizontal solid arrow), RLN (hollow arrow), and esophagus (vertical solid arrow)

scenario, prophylactic autotransplantation of the inferior PT is an option proposed by few [32, 33]. Mandatory preservation and differentiation of PT from the perithyroidal lymph nodes, thymus, fat lobules, and ectopic thyroid tissue is facilitated by minimal handling of PT and ligation of individual blood vessels close to the thyroid gland [34, 35].

8. Pretracheal fascia: It is one of the four well-defined layers of the deep cervical fascia investing the neck viscera including the thyroid gland, larynx, and trachea. PTF forms the pseudocapsule of the thyroid gland outside its true capsule [36]. Its surgical significance lies in dissecting between the PTF and the true capsule of the thyroid gland for thyroidectomy. Though it is flimsy, it forms the first barrier against extrathyroidal extension of thyroid malignancy. Sometimes, it is very thick in the presence of underlying Hashimoto's thyroiditis in the goiter. This leads to difficulty in identification of RLN and PT due to thick PTF, especially in the posterolateral aspect of the thyroid gland. Meticulous dissection close to the thyroid capsule and use of bipolar diathermy prevent injury to the perithyroidal structures [3].
9. Pretracheal plane: This is a surgical plane located in between the posterior surface of thyroid gland and tracheal perichondrium (Fig. 4). Multiple perforating blood vessels traverse this space between the thyroid gland and trachea. In most cases, this plane is easily dissectible and facilitates final dislodgement of goiter from the neck. In three surgical situations, PTP becomes crucial. First, dense adhesions can occur in Hashimoto's thyroiditis and cystic thyroid nodules, which necessitates sharp dissection in this plane. Second, this is one of the sites of tracheal invasion in differentiated thyroid cancer, which requires window resection of the trachea or shave excision of tumor using sharp dissection. PTP is also important in mobilization of the trachea for tensionless anastomosis after circumferential resection of the trachea in invasive thyroid cancer [37]. Third, PTP dissection with diathermy predisposes to tracheal injury. Thus, meticulous sharp and/or blunt dissection without high-energy source (such as diathermy) is advisable in thyroidectomy.
10. Linea alba of neck: This is the midline interface between bilateral strap muscles formed by thickened deep cervical fascia, anterior to the thyroid gland [38]. It is invested by the deep cervical fascia and often margined by the anterior jugular veins on either side. LAN is the most frequent entrance for approaching goiter both in conventional open thyroidectomy and endoscopic thyroidectomy [39–41]. Larger goiters, strap muscle hypertrophy, excess fat, and asymmetrical anterior jugular veins preclude the identification of

Fig. 5 TCS (solid arrow) showing common carotid artery (hollow arrow), prevertebral fascia in the floor, and trachea medially

LAN due to distortion or deviation, especially in beginners. It is convenient to start dissection at the lower part of the neck as LAN becomes wider distally [39]. Exact identification of LAN is important as paramedial entry can injure the goiter or anterior jugular veins causing troublesome bleeding.

11. Thyrocarotid space: This is a lateral space in the visceral compartment of the neck's deep investing layer of deep cervical fascia and sternocleidomastoid muscle (SCM) between common carotid artery laterally, thyroid gland medially, and prevertebral fascia posteriorly (Fig. 5). TCS is exposed after the incision of deep cervical fascia between SCM and lateral border of strap muscles [42, 43]. TCS is an avascular space except for ITA. The surgical importance of TCS lies in its provision of an alternative route to the traditional midline approach for goiter. This lateral approach is especially beneficial in reoperative cases, malignant and large goiters. TCS also facilitates early identification of RLN, PT, and ITA and early ligation of middle thyroid vein [42]. Approach through TCS keeps the great vessels of the neck under vision and away from the area of dissection during thyroidectomy. TCS is also one of the sites of ectopic parathyroid adenomas [44].

Conclusions

1. Knowledge of surgical anatomy and embryology of thyroid gland is the cornerstone of successful thyroid surgery.
2. Routine identification of all the anatomical landmarks will shorten the learning curve and reduce the complication rate in thyroid surgery.
3. Surgeons with adequate training and experience in thyroid surgery should only contemplate it.

Conflict of Interest There are no potential conflicts of interest regarding any content between the authors.

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