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Neck Dissection: Indications, Extension, Operative Technique

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A. L. Shifrin et al. (eds.), *Endocrine Surgery Comprehensive Board Exam Guide*,
https://doi.org/10.1007/978-3-030-84737-1_11

Case Presentation

An 18-year-old female, whose previous medical history was characterized by a Hashimoto thyroiditis and euthyroidism, underwent neck ultrasonography that showed a 15-mm suspicious nodule on the right thyroid lobe (TI-RADS 5) 8 months before consultation. Due to limitations related to the COVID-19 pandemic, she underwent ultrasound-guided fine needle aspiration cytology 5 months later. Cytological result demonstrated a papillary thyroid carcinoma of the right thyroid lobe (TIR5 – Bethesda VI).

Preoperative ultrasound performed at first surgical consultation showed an 18-mm right nodule with bilateral suspicious cervical lymph nodes. Fine needle aspiration cytology showed a metastasis of papillary thyroid carcinoma in a right lateral lymph node (level III, largest diameter 20 mm) and reactive changes in a 9-mm left lateral lymph node (level IIa).

Laboratory results showed normal calcitonin of 0.5 pg/mL in the context of functional euthyroidism, characterized by an fT3 level of 3.44 pg/mL, an fT4 level of 14.8 pg/mL, and a TSH of 2.31 µUI/mL. Furthermore, calcium was 9.2 mg/dL, parathormone level was 27.8 pg/mL, and vitamin D was 30.8 ng/mL.

She was scheduled for surgery. An intraoperative frozen section examination of left level IIa lateral neck nodes showed presence of metastases of papillary thyroid carcinoma, and she underwent total thyroidectomy plus central neck (level VI–VII) and bilateral lateral neck dissection (levels II–III–IV–Vb). The postoperative course was uneventful, in particular no hypocalcemia, no laryngeal nerve injury, no lymphatic leak, and no other complications occurred.

Final histology showed a multifocal papillary thyroid carcinoma (diffuse sclerosing variant) and confirmed central and bilateral lateral lymph node metastases (pT1bm, pN1b-TNM/AJCC 8th ed. 2017).

Two months after surgery she underwent ^{131}I treatment (150 mCi). Post-treatment whole body scan was negative for local residual disease and distant metastases. Stimulated serum thyroglobulin (TSH 45 µUI/mL) was 0.6 ng/mL, and neck ultrasound confirmed absence of structural residual and/or recurrent disease.

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? Questions

1. In case of diagnosis of papillary thyroid carcinoma with central and unilateral lateral neck nodal metastases, which of the following is indicated?
   I. Thyroid lobectomy is mandatory.
   II. Total thyroidectomy plus bilateral neck dissection is mandatory.
   III. Thyroid lobectomy plus ipsilateral central neck dissection is mandatory.
   IV. Total thyroidectomy is mandatory.
   V. Central neck dissection is mandatory.
   VI. Unilateral lateral neck dissection is mandatory.
   (a) I and VI
   (b) II
   (c) IV, V, and VI
   (d) III

2. If the ultrasound demonstrated a thyroid hypoechoic nodule of 18 mm in its maximum diameter with irregular margins and internal microcalcifications, which of the following is indicated?
   (a) Fine needle aspiration biopsy is always indicated.
   (b) Fine needle aspiration biopsy is never indicated.
   (c) Fine needle aspiration biopsy can be useful only when a compressive symptomatology is present.
   (d) Fine needle aspiration biopsy can provide useful information only in presence of extracapsular extension by the nodule.
3. In case of medullary thyroid carcinoma without evidence of lateral neck nodal metastases, which of the following is indicated?
   I. Level III and IV dissection is indicated.
   II. Total thyroidectomy is mandatory.
   III. Central neck dissection is mandatory.
   IV. Level II–V dissection is mandatory.
   V. Level II dissection on the side of the tumor is indicated.
   VI. Unilateral lateral neck dissection is mandatory.
      (a) I and II
      (b) II and III
      (c) I and V
      (d) IV and VI
4. Selective lateral neck dissection includes the following:
   I. Removal of lymph nodes from levels I to V and resection of the internal jugular vein
   II. Removal of lymph nodes from levels II to IV and the spinal accessory nerve
   III. Removal of nodal basins (levels I–V) with preservation of spinal accessory nerve
   IV. Removal of less than all five lateral neck nodal levels
   V. Preservation of spinal accessory nerve
   VI. Preservation of internal jugular vein
      (a) I and III
      (b) II
      (c) V and VI
      (d) IV, V, and VI
5. In the treatment of thyroid carcinoma "ipsilateral central neck dissection" includes:
   I. Contralateral node picking
   II. Removal of mid-jugular nodes on the side of the tumor
   III. Lateral neck dissection on the side of the tumor
   IV. Removal of prelaryngeal lymph nodes
   V. Removal of pretracheal lymph nodes
   VI. Removal of paratracheal lymph nodes on the side of the tumor
      (a) II and III
      (b) III and VI
      (c) IV, V, and VI
      (d) II

6. Regarding the treatment of papillary thyroid carcinoma, “cN0” means:
   I. Lymph node dissection is required.
   II. The absence of preoperative evidence at ultrasound examination of lymph node involvement.
   III. Final histology showed no lymph node metastases.
   IV. The absence of clinical preoperative evidence of lymph node involvement.
   V. There is clinical evidence of lateral neck lymph node involvement.
   VI. The absence of intraoperative evidence of macroscopic lymph node involvement.
      (a) II, IV, and VI
      (b) III and VI
      (c) I and III
      (d) V and VI
7. Are there unequivocal risk factors for occult lymph node metastases in the central neck compartment in patients affected by papillary thyroid carcinoma?
   I. No
   II. Yes, in particular age >45 years
   III. Yes, in particular female sex
   IV. Yes, in particular estimated thyroid volume >100 mL
   V. Yes, in particular male sex
   VI. Yes, in particular age ≤45 years
      (a) I
      (b) II and III
      (c) IV and V
      (d) V and VI
8. “Ipsilateral central neck dissection” is a valid treatment option in clinically unifocal cN0 papillary thyroid carcinoma but:
   (a) It reduces the overall survival.
   (b) It carries the risk of contralateral occult lymph node metastases being overlooked.
   (c) It increases the risk of hypoparathyroidism when compared with bilateral central neck dissection.
   (d) It decreases the accuracy of staging when compared with total thyroidectomy with bilateral central neck dissection.
9. Frozen section examination on the “ipsilateral central neck nodes” in the treatment of clinically unifocal cN0 papillary thyroid carcinoma:
   (a) Has an overall accuracy of 100%
   (b) Increases the disease-specific overall survival
   (c) Decreases the postoperative complications of total thyroidectomy
   (d) Allows an intraoperative decision-making approach regarding the extension of central neck dissection

11.1 Introduction

Lymph node involvement is common in patients with thyroid carcinoma. It may negatively affect recurrence rate and survival [1–4].

Lymph node neck dissections are technically demanding, and sometimes challenging operations associated with several possible complications, as several anatomic structures are at risk. The trachea, esophagus, laryngeal nerves, and parathyroid glands are extensively exposed during central neck dissection (CND). Moreover, when a lateral neck dissection (LND) is performed, the internal jugular vein (IJV), common carotid artery (CCA), vagus (VN), hypoglossal, spinal accessory (SAN) and phrenic nerves, sympathetic trunk, brachial plexus, and thoracic duct are at risk of injury.

Knowledge of surgical techniques, anatomic landmarks, nomenclatures, and classifications is essential to offer the most appropriate surgery, but also to obtain homogeneous data to evaluate and compare literature results [5, 6].

Inadequate lymph node surgery is the main cause of recurrent or persistent thyroid cancer [7] since recurrent disease in lymph nodes accounts for 60–75% of all neck recurrences [4, 8].

Lymph node metastases to the regional lymph nodes occur approximately in 30–80% of patients with papillary thyroid carcinoma (PTC) [9, 10]; nodal metastases from follicular thyroid carcinoma (FTC) are quite rare (1–8% of the patients) [11]. Metastases to regional lymph nodes in medullary thyroid carcinoma (MTC) have been reported in 34–81% of the patients [12–14].

Clinical evaluation and preoperative workup is of utmost importance to plan the correct initial surgical procedure, balancing complete oncological removal of tumor and nodal disease while minimizing the complication rate.

An accurate ultrasound evaluation, ideally performed by the surgeon him/herself [15], is essential in the evaluation of the thyroid tumor and of the nodal status. Loss of fatty hilum, calcifications, peripheral vascularity, hyperechogenicity, rounded rather than oval shape, cystic changes, and large size are all characteristics of lymph nodes suspicious for nodal metastases at ultrasound [4]. Pre-operative fine needle aspiration cytology confirms in many cases the suspicion of nodal involvement. Thyroglobulin measurement in the washing fluid of the fine needle aspirate can be helpful in the diagnosis of node positive (N1) differentiated thyroid carcinoma (DTC), especially in case of cystic lateral neck masses where aspiration cytology is often paucicellular [4]. Similarly, calcitonin measurement in the washing fluid of fine-needle aspirates is able to detect central and/or lateral neck metastasis of MTC [16, 17]. In selected cases, cross-sectional imaging studies (computed tomography, CT, or magnetic resonance imaging, MRI) with intravenous contrast could be helpful in the identification of tracheal/esophageal involvement and nodal involvement, especially in the upper mediastinum and in the retropharyngeal and parapharyngeal spaces [1, 4].

While macroscopic nodal disease and extranodal extension are well-recognized risk factors impacting prognosis in thyroid carcinomas, occult microscopic nodal disease seems to have no influence on survival and a limited impact on recurrence [2].

On the other hand, not all occult nodal disease is microscopic (<2 mm) nodal disease.

Therapeutic central with/without LND is mandatory in all patients with thyroid carcinoma and clinical evidence of central and/or lateral nodal involvement [1, 3, 4, 8, 18, 19].

The role of prophylactic CND in patients with clinically node negative (cN0) thyroid carcinoma remains a matter of debate [1, 2, 4, 8, 18–23]. It is strongly indicated in patients with MTC and encouraged in those with advanced primary DTC (T3, T4) [1, 3, 4, 8, 18, 19].

With regard to LND, current evidence supports no role for prophylactic LND in patients with DTC in the absence of any pre- or intraoperative evidence of lateral neck nodal metastases [1, 4, 8, 18, 19]. Some debate still exists with regard to the possible role of prophylactic LND in patients with MTC [1, 3, 8, 18].

Another important point is the surgical technique. Neck dissection has to be considered one of the most challenging (complicated) surgeries of the human body [24]. After the initial description by G. Crile in 1906 of a series of patients who successfully underwent radical neck dissection (RND) [25], (i.e., the removal of neck nodes *en bloc* with IJV, sternocleidomastoid muscle (SCM), and SAN), several modifications have been proposed over the last century to maximize functional outcomes. However, two main concepts have highly influenced the surgical approach to the neck nodal disease over the last seven decades. First of all, the understanding that the cervical lymph nodes are without exception contained in the spaces defined by the muscular fasciae and vascular aponeuroses. As a consequence, in the absence of direct muscular, vascular and/or nervous invasion, neck dissection can be safely achieved by removing the fascial covering *en bloc* with the fibrofatty tissue containing the lymph nodes, while preserving muscular, vascular, and nervous structures [26]. The crucial point is the fascial compartmentalization of the neck: the "wrapping cloth" (i.e., the whole aponeurotic system) can be removed in one piece together with the packing material (i.e., the cellular and fat tissue contained therein), while preserving important and non-affected structures [26]. The second aspect is that different head and neck tumors involve different levels of neck nodes. Therefore, neck dissection for a specific tumor may be limited to a group/groups of lymph node at higher risk of being affected, in the absence of overt involvement of other groups. Consequently, neck lymph nodes have been grouped in levels

(I–VI) by a Committee for Head and Neck Surgery and Oncology of the American Academy of Otolaryngology-Head and Neck Surgery (AAO-HNS), with the specific aim to standardize the nomenclature and the reporting system of neck dissections (see below).

Since both the discussed aspects represent the rationale for the current approach to neck dissection, the detailed knowledge of the anatomical basis and of the nomenclature are of utmost importance.

11.2 Applied Anatomy

The thyroid has an extensive lymphatic drainage, which may flow in a variety of directions [27]. The intraglandular lymphatic connections are extensive and enable lymphatic drainage from one lobe to the other through a complex of intrathyroidal and pericapsular nodes [27]. The major lymph vessels running efferently follow the branches of the thyroid arteries and veins in three main directions: superiorly, laterally, and inferiorly. The upper thyroid region is drained by the superior thyroid vessels into the upper jugular nodes. From the isthmus, the lymphatic vessels run to prelaryngeal, or Delphian, nodes, which are connected to the upper jugular nodes. Lateral lymph vessels follow the medial thyroid vein to the mid- and lower jugular nodes. The lower lymphatic drainage is directed to the pretracheal and paratracheal nodes and to the lower jugular chain.

The central compartment (defined as level VI and VII; see below) is typically the first site for lymph node metastases [5]. One exception can occur when the primary tumor is located in the upper pole and lymph node metastases may "skip" the central compartment, to be initially found in the lateral compartment only [28]. Unusual and rare sites for thyroid carcinoma nodal metastases include retropharyngeal, parapharyngeal, retrocarotid, sublingual, axillary, and intraparotid locations, as well as nodal involvement at level of thyrohyoid membrane and/or superficial to the strap muscles [29].

■ ■ Cervical fascial planes

In spite of some disagreements about the definitions and the limits of the cervical fascial planes in anatomic textbooks and published papers [26, 30, 31], classically four different fascial layers have been described in the neck: the superficial cervical fascia (SCF) and the deep cervical fascia (DCF). The last further recognizes three more different layers: the superficial (SLDCF), the middle (MLDCF), and the deep layer of the DCF (DLDCF).

The SCF, variably recognized [30], is just underneath the dermis and is composed of loose connective tissue, fat, the platysma muscle, and small unnamed nerves and blood vessels.

The SLDCF is described as a definite sheath of fibrous tissue encircling the neck and extending between the face and pectoral regions. It splits in two layers and envelops two muscles (the trapezius and the sternocleidomastoid) and two glands (the parotid and the submandibular) and forms two spaces (the supraclavicular and the suprasternal). It attaches cranially to the hyoid bone where it merges with the MLDCF and inferiorly to the acromion of the scapula, the clavicle, and the sternum. The fascia remains split in two layers until it attaches to the sternum. Thus, the superficial layer attaches to the anterior surface of the sternum and the posterior layer to the posterior surface of the sternum. It forms the roof of the anterior and posterior cervical triangles and the midline raphe of the strap muscles.

The MLDCF splits into an anterior portion (muscular component) that envelops the strap muscles (sternohyoid, sternothyroid, thyrohyoid, omohyoid) and a posterior layer (visceral component) that includes both the pretracheal and buccopharyngeal fascia and envelops thyroid gland, larynx/trachea, and pharynx/esophagus [24, 30].

The DLDCF has two main subdivisions: the first comprised the prevertebral fascia spanning the tips of the transverse processes anterior to the vertebral bodies and extending from skull base to coccyx. It continues laterally and posteriorly as the scalenus fascia covering the scalene muscles, splenius capitis, and levator scapulae to attach to the spinous processes of the vertebrae. The other subdivision consisted of a layer of alar fascia lying anterior to the prevertebral fascia but posterior to the pharynx/esophagus and visceral fascia. It is described to pass anterolaterally to fuse with the carotid sheath and prevertebral fascia and extends inferiorly from the base of the skull to about the C7 vertebral level where it fuses with the visceral fascia.

All the layers of the DCF contribute to the carotid sheath, which includes the CCA, the IJV, and the VN.

The fibrofatty tissue encompassing the lymph nodes in the neck can thus be found in two main spaces in the neck, the central and the lateral, which are separated by the carotid sheath.

The lateral space of the neck on both sides is limited externally by the SLDCF and MLDCF, posteriorly by DLDCF, and medially by the carotid sheath. The lateral space of the neck is divided vertically on each side by (1) the transverse aponeurosis, which originates from around the internal jugular vein and carotid artery and runs in a lateral direction toward the external jugular vein; and (2) the sagittal aponeurosis which, starting from the carotid sheath, runs posteriorly to the scalenus group of muscles [26]. The cervical and brachial plexus, embryologically independent of the branchial apparatus, lies outside the space limited by this aponeurotic system. The same is true for the phrenic nerve. The cervical sympathetic chain, which also lies outside this space, is in close connection with it [26]. The hypoglossal nerve and the SAN run across this space for a part of their course. The VN runs in the narrow fissure between the venous and arterial divisions of the sagittal aponeurosis, which envelops the internal jugular vein and carotid artery, respectively. The thoracic duct crosses the lateral space of the neck at its lower end [26].

The central space is further divided into several compartments: the visceral space, enveloped by the visceral layer of the MLDCF, and the paravisceral space, bilateral, which the carotid sheath separates from the lateral space [32]. The sagittal aponeurosis divides it from the retrovisceral (prevertebral) space, outlined by the MLDCF and the alar fascia.

Because of such anatomical basis, lymph node dissection, in both the central and the lateral compartments, can be achieved satisfactorily when vessels, muscles, and glands are carefully stripped of their aponeurotic coverings, and when all aponeurotic septa are removed in one block together with their contents. The essential structures running in them should have been previously identified and dissected free [26, 32]. Such an approach, as discussed later, emphasize that lymph node dissection is not the one-by-one removal of (enlarged) lymph nodes in a certain region or of a certain group of nodes (*cherry picking*), rather a systematic and comprehensive dissection of lymph nodes containing fibrofatty tissue embedded and covered by the relative fascial layer(s).

11.2.1 Standardized Terminology in Neck Dissection

Since the 1930s, the locations of cervical lymph node groups have been designated using a system developed at the Memorial Sloan-Kettering Cancer Center in which groups of lymph nodes at various anatomic levels are described. This system, initially used for labeling of neck dissection specimens, has achieved worldwide acceptance, as it not only designates the anatomical location of groups of lymph nodes, but also reflects, rather consistently, the progress of spread of tumors at various locations through the neck, and indicates which levels are at greatest risk of involvement for early metastasis from tumors at various primary sites.

In order to standardize the definition and the approaches to the cervical nodes, the American Head and Neck Society Committee for Neck Dissection Classification and the American Academy of Otolaryngology Head and Neck Surgery, Committee for Head and Neck Surgery and Oncology, in 1988 began the process that resulted in the publication of the classification of the neck dissection [33] that, with subsequent modifications [34, 35] still constitute the basis for the understanding and the reporting of the surgical approach to the cervical lymph nodes.

The two main objectives of the AHNS/AAOHNS Committees were the definition of the level system to delineate the location of nodal disease in the neck and the definition of a standard nomenclature for neck dissection [34].

11.2.2 Levels of Cervical Lymph Nodes

The cervical nodes have been divided into six levels (I–VI) that have been widely accepted. Anatomical boundaries that have been defined for neck lymph node levels represent practical intraoperative landmarks during neck dissection, but also well-defined and readily visible radiological landmarks, useful to preoperatively evaluate the extent of neck nodal disease and plan the surgical resection [34].

Of note, especially when dealing with thyroid carcinoma, upper mediastinal nodes, below the sternal notch to the level of the innominate artery, may be involved and need to be removed. This group of nodes, which represent an extension of the paratracheal nodes in both sides and are reachable and removable trough a neck (collar incision) approach, are usually indicated as level VII and included in the central compartment dissection (see below) [5, 35].

The neck lymph node levels are identified as follow:

Level I: it includes *submental (Ia)* and *submandibular nodes (Ib)*. Level Ia (submental triangle), which is unpaired, is a midline level bounded by the anterior belly of the digastric muscle and the hyoid bone, inferiorly. The level Ib, containing the submandibular gland and its nodes, is defined by the body of the mandible superiorly, the anterior belly of the ipsilateral digastric muscle anteriorly, the posterior belly of the ipsilateral digastric muscle inferiorly, and the stylohyoid muscle posteriorly. Radiologically, the sagittal plane passing through the posterior border of the submandibular gland is used to define the boundary between the Ib and IIa levels (posterior boundary). During neck dissection it is useful to consider the fascia overlying the posterior aspect of the submandibular gland [36]. Level I is not usually involved in thyroid carcinomas and does not need to be routinely dissected, in the absence of overt/gross involvement [6]. The key structures that can be found and should be preserved at this level include the lingual nerve, hypoglossal nerve, submandibular duct, and facial artery and vein are all found in level I. The only significant structure found lateral to the posterior belly of the digastric is the facial vein. The *marginalis mandibulae* branch of the facial nerve can be found in the fascia overlying the submandibular gland superficial to the facial vessels [24].

Level II: it includes the *upper jugular nodes*, which are located by the upper third of the IJV. It extends from the skull base to a horizontal line defined by the inferior border of the body of the hyoid bone. The anterior border of level II is the stylohyoid muscle but conventionally by a line passing along the posterior border of the submaxillary gland (see above), and the posterior border is the posterior (lateral) border of the SCM. The SAN, which travels obliquely across this area, is used as a landmark to subdivide this group into IIb, the portion above and behind the nerve, and IIa, the portion that lays antero-inferiorly to it [34].

The key structure found during dissection is the SAN, which runs deep to the posterior digastric muscle and the occipital artery, superficially to the internal jugular vein. It often gives off a small branch to the trapezius prior to entering the sternocleidomastoid muscle [24].

Level III: it includes the *mid jugular nodes*. This level is bounded superiorly by a horizontal plane passing along the inferior border of the body of the hyoid bone, inferiorly by a horizontal plane passing along the inferior border of the cricoid cartilage, posteriorly (laterally) by the posterior margin of the SCM, and anteriorly (medially) by the lateral border of the sternohyoid muscle [34]. Since this last is not an easily visible landmark from a radiological point of view, it has been proposed that the medial border of the CCA could serve as an alternate radiological landmark [35]. However, it should be noted that from an anatomical and surgical point of view, the lateral border of the sternohyoid muscle with its investing fascia (muscular component of the MLDCF), which participates to the carotid sheath (see above), better defines the boundary between the anterior (central) and the lateral (or posterolateral) compartments of the neck (◘ Fig. 11.1). Indeed, as described above, it is the carotid sheath that anatomically divides the anterior and the lateral compartments of the necks, and it is formed by the coalescence of all the layers of the DCF. Such consideration has important consequences during neck dissection, since following the investing fascia of the sternohyoid muscle would allow to avoid to expose the CCA during LND and to enter the central (anterior) compartment [35, 36]. All these considerations are true for both the III (mid-jugular) and the IV (lower-jugular) lymph node levels.

Conversely, not removing the lymph nodes along the lateral border of the sternohyoid muscle, during dissection of the central compartment could result in an inadequate dissection.

In addition, in the first version of the classification [33], the anterior belly of the omohyoid muscle was chosen as the surgical boundary between the III and the IV levels. In the revised classification it crosses the III levels, and the lymph nodes underneath the anterior belly of the omohyoid muscle should be included in the III levels [35].

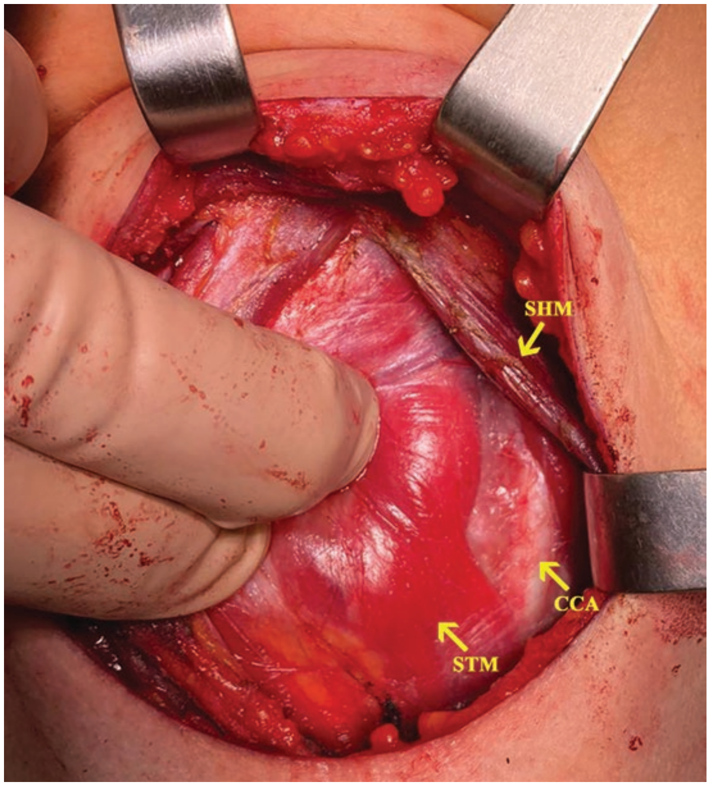


Fig. 11.1 Boundary between the anterior (central) and the lateral (or posterolateral) compartments of the neck: coalescence of the fascia covering lateral border of the sternothyroid muscle with the carotid sheet. SHM sternohyoid muscle, CCA common carotid artery, STM sternothyroid muscle

The key structures encountered during dissection at this level are the anterior belly and the intermediate tendon of the omohyoid muscle, the cervical rootlets, and the phrenic nerve which runs superficial to the anterior scalene muscle beneath the DLDCF.

Level IV: it includes the lower jugular nodes which are located between a plane passing along the inferior border of the cricoid cartilage superiorly and the clavicle inferiorly. The anterior (medial) and the posterior (lateral) boundaries of the level IV are represented, as for level III, by the sternohyoid muscle and the posterior border of the SCM, respectively (see above). The key structures which are encountered during dissection are the thoracic duct (more commonly seen in the left neck), the transverse cervical artery, phrenic nerve, and anterior scalene muscle, as well as the confluence of the IJV and the subclavian veins (Pirogoff's trunk). The lung apices may also be present at the inferior aspect of level IV.

Level V: it includes the posterior triangle of the neck. It is bounded anteriorly by the posterior border of the SCM, posteriorly by the anterior border of the trapezius muscle, superiorly by the convergence of the SCM, and the trapezius muscle and inferiorly by the clavicle [33]. This level is furtherly subdivided by a plane passing along the inferior border of the cricoid cartilage into level Va, superiorly, and level Vb, inferiorly [34]. The superior subgroup, level Va, primarily contains the spinal accessory nodes, and the SAN. Level Vb contains the transverse cervical and supraclavicular nodes. As a consequence, in order to reduce the risk of inadvertent SAN injury, dissection of level Va is usually not recommended in neck dissection for thyroid carcinoma (see below). Besides SAN, key structures encountered during dissection of this level are the posterior belly of the omohyoid muscle, the brachial plexus, and the confluence of external and anterior jugular veins.

Level VI–VII (central compartment): this group of nodes includes the lymph nodes of the anterior cervical compartment (level VI) and the superior mediastinal nodes that can be reached via cervical incision (previously reported as level VII), more commonly reported as central compartment.

The boundaries of the anterior compartment (level VI) are defined superiorly by the hyoid bone, inferiorly by the sternal notch, laterally by the medial aspect of the carotid sheath. Superior mediastinal nodes (Level VII lymph nodes) that are removable by a trans-cervical approach are those associated with the brachiocephalic vein and innominate artery. The boundaries of the level VII are the suprasternal notch superiorly, the medial aspect of the carotid sheath laterally, and the innominate artery on the right (at its point of tracheal crossing) and the corresponding axial plane on the left [5, 37]. Consequently, the central neck compartment is bounded superiorly by the hyoid bone, laterally by the medial aspect of the carotid sheath, inferiorly by point where the innominate artery crosses the trachea on the right and the corresponding axial plane on the left, anteriorly by the SLDCF, and posteriorly by the DLDCF [5, 37].

However, it should be noted that if the boundary between the anterior (central) and the lateral (posterolateral) compartments of the neck is represented by the lateral border of the sternothyroid muscle and its fascial insertion over the carotid sheath, as reported above (level III), the same boundary should be used as lateral limit of the central compartment, instead of the medial border of the carotid sheath [33].

Mediastinal lymph nodes located inferior to the innominate artery and caudal to the brachiocephalic vein are rarely involved in patients with existing central compartment lymph node metastases, usually cannot be removed by a transcervical approach, and should be reported as a separate level (mediastinal lymph node below the innominate artery) [35, 37].

According to their anatomical locations, the lymph nodes of the central compartment are conventionally subdivided in prelaryngeal (Delphian), pretracheal, and left and right paratracheal lymph nodes [37]. Thyroid cancer often metastasizes to the lymph nodes in these four groups. It should be underlined once more that it is a conventional subdivision based on the anatomical position of the groups of lymph nodes, rather than a true anatomical subdivision. No fascial plane divides these groups of lymph nodes.

The retropharyngeal and retroesophageal lymph nodes deeper with respect to the sagittal fascia and not included in the visceral layer of the MLDCF (see above) are rarely involved and are outside the boundary of the central compartment, as delimited by the fascial planes.

The majority of the central region lymph nodes are inferior to the larynx. Upper pole tumors may occasionally metastasize to the paralaryngopharyngeal lymph nodes coursing along the superior thyroid vessels very close to the investing layers of the sternohyoid and omohyoid muscles, fascial layers that should consequently be removed in order to achieve adequate clearance. Sometimes the mediastinal lymph nodes inferior to the innominate artery can also be involved [5].

The *prelaryngeal (Delphian) lymph nodes* are localized in the fibrofatty tissue medial to the thyrohyoid muscle on both sides and bordered caudally by the upper edge of the thyroid isthmus and cranially by the hyoid bone [36]. The *pretracheal lymph nodes* are localized in the fibrofatty tissue on the anterior aspect of the trachea between the two edges of the trachea and bordered cranially by the lower edge of the isthmus and caudally by a line drawn from the intersection point between the innominate artery and the trachea. The *paratracheal lymph nodes* are embedded in the fibrofatty tissue contained in the trapezoidal compartment bordered cranially by the line passing through the lower edge of the cricoid cartilage, caudally by the line where the innominate artery crosses over the trachea on the right, the projection of this point on the axial plane on the left, laterally by the carotid sheath (or the lateral border of the sternothyroid muscle), medially by the ipsilateral lateral edge of the trachea, anteriorly by the muscular component of the MLDCF, and posteriorly by the sagittal aponeurosis. Due to the obliquus course of the right inferior laryngeal nerve (ILN) from behind the right subclavian artery to its laryngeal entry point, the right paratracheal region is further subdivided in two different areas by a plane passing through the right ILN: the posterolateral and the anterio-medial. That has important consequence during central neck dissection, since to obtain adequate clearance of the central compartment the lymph nodes both anteriorly and posteriorly to the ILN have to be removed. That requires a mobilization of the ILN in order to mobilize the fibrofatty tissue on the posterolateral area, transposing it antero-medially passing behind the ILN [37]. That is not true in the case of non-recurrent ILN [38]. On the left side the course of the ILN is more vertical from behind the aortic arch, along the tracheoesophageal groove. Thus, on the left side, the paratracheal lymphatic tissue is located anterolateral to the

ILN and esophagus. In this context, mobilization of ILN is not necessary when left paratracheal lymphatic dissection is performed [37].

11.3 Classification of Neck Dissections

Following the consensus statement of the working group of the American Thyroid Association (ATA) with participation from the American Association of Endocrine Surgeons (AAES), AAO-HNS, and American Head and Neck Society (AHNS) [5, 37], CND has been defined as the comprehensive removal of the pretracheal and prelaryngeal lymph nodes, along with at least one paratracheal nodal basin [5, 37]. The CND can be unilateral or bilateral if only one or both the paratracheal nodal basins are dissected and removed [5, 37].

The nomenclature of the LND follows the indications of the committee of the AHNS and the AO-HNS in 1991 [33] and subsequently updated in 2002 and 2008 [34, 35].

RND includes the removal of lymph nodes from levels I to V with *en bloc* resection of the IJV, SAN, and SCM [6, 34, 35]. This procedure, initially described by G. Crile [25] in 1906, rarely is indicated in patients with thyroid carcinoma.

Owing to the high morbidity and anatomical deformity due to RND, in 1963, O. Suarez [26, 39] and, subsequently, Bocca and Pignataro [26] and Gavilan et al. [40–42] described a modified RND (MRND) as functional neck dissection [26, 43] in which satisfactory oncological results could be obtained, while preserving key anatomical structures, i.e., SAN, IJV, and SCM, using a fascial dissection technique.

In 1989, Medina divided MRND into three types [44]. In type I, only SAN is preserved, in type II SAN and IJV, and in type III IJV, SAN, and SCM are all preserved. In addition, RND and MRND were divided into type A if all lymph nodes of levels I–V were all removed and type B if levels II–V were removed [44].

The study group of the AAO-HNS defined MRD as the comprehensive removal of all the levels included in the RND (levels I–V) with preservation of one or more of the non-lymphatic structures removed in the RND (SAN, IJV, SCM) [34, 35]. Preserved structures should be specifically named in the report (i.e., MRND with preservation of SAN) [35].

Alternate terms that have been used to refer to MRND in the published literature are total neck dissection, as proposed by the Japan Neck Dissection Study Group [45, 46], functional neck dissection [32, 42, 47, 48], and comprehensive neck dissection [35, 49, 50]. However, such terms are not widely accepted in the English literature, and their use has been discouraged or not recommended by the Neck Dissection Classification Committee of the AHNS [35].

The term selective neck dissection (SND) encompasses all the neck dissections in which there is the preservation of 1 or more of the lymph node levels routinely removed in RND. Dissection is thus directed by the patterns of lymphatic drainage of the primary tumor. In the 1991 classification of the AAO-HNS committee, four subtypes of SND were recognized (supraomohyoid, levels I, II, and III; lateral, levels II, III, and IV; posterolateral, levels II, III, IV, and V; anterior, level VI) [33], while in the revised consensus of the AAO-HNS committee such subtypes were abandoned, and it was suggested to report in parentheses next to SND the removed lymph node levels with roman numbers [i.e., SND (III–IV)], in order to avoid confusion and to encompass all the possible dissections [34]. SND (IIa, III, IV, and Vb) is the most commonly used in the management of lateral neck metastasis of thyroid carcinoma [(i.e., SND (IIa, III, IV, and Vb)].

The term extended radical neck dissection (ERND) refers to the removal of one or more additional lymph node groups or non-lymphatic structures, or both, routinely not removed in RND [34, 35]. Examples of additional lymph node groups include superior mediastinal, parapharyngeal, retropharyngeal, periparotid, postauricular, suboccipital, and buccinator. Examples of other non-lymphatic structures include CCA, hypoglossal nerve, VN, paraspinal muscles, and other neural, osseous, cutaneous, muscular, or vascular structures. All additional lymphatic and/or non-lymphatic structure(s) to be removed should be identified in parentheses [34].

Current accepted classification of neck dissections is reported in ◘ Table 11.1.

11

◘ **Table 11.1** Classification of neck dissections

Bilateral central neck dissection	Removal of the prelaryngeal, pretracheal, and both the right and left paratracheal nodal basins (levels VI and VII)
Unilateral/ ipsilateral central neck dissection	Removal of the prelaryngeal, pretracheal, and one paratracheal nodal basin (ipsilateral to primary tumor)
Radical neck dissection	Removal of levels I–V and resection of the internal jugular vein, the spinal accessory nerve, and the sternocleidomastoid muscle
Modified radical dissection	Removal of levels I–V, with preservation of one or more of the following non-lymphatic structures: spinal accessory nerve, internal jugular vein, or sternocleidomastoid muscle
Selective lateral neck dissection	Removal of less than all five lateral neck nodal levels, while preserving spinal accessory nerve, internal jugular vein, and sternocleidomastoid muscle. Removed lymph node levels have to be specified
Extended radical neck dissection	Removal of one or more additional lymph node groups or non-lymphatic structures, or both, routinely not removed in Radical Neck Dissection (parapharyngeal, retropharyngeal, periparotid, postauricular, suboccipital, and buccinators nodes/carotid artery, hypoglossal nerve, vagus nerves, paraspinal muscles, etc.). Additional removed lymph nodes and/or non-lymphatic structure have to be specified

In order to further reduce the possibility of confusion, misinterpretation, and redundancy of terms with respect to neck dissection, more recently an international group of experts has proposed a further revision of the classification of the neck dissections [51]. Three main aspects are needed to categorize the extent of the dissection: (1) the abbreviations "ND" should be used to represent the term neck dissection and applied as the first component of the description. A prefix should be included to denote the side of the neck upon which the dissection has been performed using the abbreviation L for left and R for right. If bilateral, both sides must be classified independently; (2) the second component of the description should be the neck levels and/or sublevels removed, designated with Roman numbers, in ascending order. For levels in which subdivision is applicable (such as I, II, V), the level is stated without a subdivision to indicate that the entire level (both a and b) was removed. If a sublevel is named, it means that the remaining sublevel was preserved; (3) the third component of the description should be the non-lymphatic structures removed, each identified using specified acronyms (symbols), all of which have been universally accepted.

For example, a left RND could be indicated as "L ND (I–V SCM, IJV, CN XI)" [51].

Subclassification into therapeutic and elective or prophylactic neck dissection refers to the indication for surgery but does not specify the extent of the dissection [1].

The term therapeutic neck dissection is used when cervical metastases are demonstrated pre- or intra-operatively. The term prophylactic, or elective, neck dissection is used when neck dissection is done for potential subclinical cervical metastases, not demonstrated at preoperative work up, intraoperative inspection, and/or intraoperative frozen section examination [1].

11.4 Central Neck Dissection: Indications and Extension

Current evidences endorse CND associated to total thyroidectomy in all the patients with clinical (pre- or intraoperative) evidence of central neck nodal involvement both for DTC (follicular cell-derived thyroid carcinomas – PTC and FTC) and MTC (C-cell carcinoma) [1, 3, 8, 18, 19, 52].

In order to reduce the complication rate (namely, ILN injury and parathyroid dysfunction) associated with bilateral CND, it has been proposed, in patients with DTC, in the presence of lymph node involvement clinically limited to only one paratracheal nodal basin, to limit the extension of CND (unilateral CND) [37]. However, if CND at the time of the initial thyroid surgery in clinically node positive PTC has the main role to comprehensively remove all the nodal metastatic disease, reducing the risk of persistent and/or recurrent disease, it is important to underline that the ipsilateral nodal involvement is one of the main risk factors for contralateral nodal disease [53, 54]. Contralateral occult nodal disease is indeed found in about 25% of the cases with nodal disease clinically limited to only one paratracheal region [55, 56]. Moreover, patients with clinical node involvement, >5 involved nodes and extranodal invasion are at higher risk of recurrence [57]. Therefore, patient with clinical central neck nodal involvement would probably benefit of a more aggressive approach (i.e., bilateral CND) if the potential benefits are not outweighed by the risk of complications. The extent of CND should then be adjusted on the surgeon's judgment balancing the safety of the procedure and the risk of recurrence and consequent eventual need of reoperation [37]. Indeed, even if it has been reported that in experienced hands reoperative CND can be as safe as primary surgery [58], it should be considered that reoperative surgical procedures are usually more challenging and at increased risk of complications, because of scar and altered anatomy [1]. Since in MTC lymph node metastases are present in the vast majority of patients at diagnosis and are not apparent by pre- or intraoperative assessment and no effective adjuvant treatment is available and indicated, prophylactic bilateral CND associated to total thyroidectomy is recommended in all the patients who undergo initial surgery for MTC [1, 3, 8, 18]. It has been recently proposed a more conservative approach, including unilateral thyroid resection instead of total thyroidectomy and bilateral CND for sporadic intrathyroidal MTC not showing desmoplasia at frozen section evaluation (FSE) [59], basing on the assumption that the absence of desmoplastic stromal reaction is correlated with the absence of lymph node involvement [60].

In patients with clinically node negative (cN0) DTC the role of prophylactic CND (pCND) remains controversial and matter of debate [1, 2, 8, 18–21, 23, 52].

pCND is associated with lower postoperative serum thyroglobulin; it allows to improve accuracy in staging and to reduce the risks of reoperation for recurrence [2].

In addition, the assessment of central compartment nodal status is particularly challenging with currently available diagnostic tools. Indeed, it has been demonstrated that neck ultrasonography, which can reliably diagnose lymph node metastases in the lateral neck compartments, has a poor sensitivity for the detection of the central neck nodal involvement [61]. The sensitivity of ultrasonography in detecting abnormal lymph nodes varies from 25% to 60% for the central neck and 70–95% for the lateral neck [62, 63]. One of the main factors influencing sensitivity is the expertise of the evaluating physician [1]. CT, MRI, and Positron Emission Tomography (PET) may give additional details, but they are indicated only in selected cases

[1, 37] and the sensitivity in detecting central nodal disease is relatively low (30–40%) [64]. Surgeon-performed ultrasonography, useful for mapping and planning the operative procedure, has been demonstrated to be more accurate in detecting lymph node involvement and associated with lower local recurrence rates compared to radiologist-performed ultrasonography, especially if performed just prior surgical incision with optimized patient's position under general anesthesia [15, 65, 66].

Conversely, one of the main arguments against pCND is the higher risk of complications, in the absence of unequivocal benefits [1, 2, 8, 18, 19, 52, 67]. In order to reduce postoperative morbidity, proponents of pCND would favor unilateral dissection that has complications rate similar to total thyroidectomy alone, while maintaining the accuracy in staging of bilateral pCND in clinical unifocal disease [67, 68].

In addition, the recurrence rate following total thyroidectomy alone is quite low (<5%) [57], and the prognostic impact of small volume lymph node involvement has been reduced by the current staging system (ATA Risk stratification, 8th Edition of AJCC TNM Staging) [1, 69].

Multifocal disease and extracapsular tumor invasion have been suggested as potential risk factors for occult nodal metastases [8, 20, 70, 71]. Possible risk factors included also age, sex, tumor size, and aggressive pathological variants [8, 20, 70, 71]. The available studies on this topic report discordant results, probably because of the heterogeneous patients' populations concerning operative and clinicopathologic features (prophylactic vs therapeutic central neck dissection, clinical unifocal vs clinical multifocal carcinomas, unilateral vs bilateral CND) source of uncontrolled bias [20]. None of the current molecular markers, including B-type RAF (BRAF) rearrangements, have been so far demonstrated to be strong independent prognostic indicators. Therefore they should not drive the decision to perform or not a pCND [37].

In definitive, to date there are no evidence to suggest unequivocal pre-operatively available clinical parameter as a reliable predictor of nodal disease in clinically node negative patients.

Basing on the previous considerations, most of the authors currently agree that pCND is generally not indicated in DTC [72]. Current guidelines [1, 4] and positional statements [37] suggest, instead, a selective approach to pCND in larger and locally more advanced tumor (T3 and T4) or in case of evidence of lateral neck nodal involvement (N1b). However, such kind of recommendation is mainly based on expert opinion, rather than on high level evidence [1].

Other selective approaches to pCND aim to intraoperatively evaluate central neck nodal status, assuming that an enlarged lymph node does not necessarily mean a metastasized node and that a normal-appearing node can harbor non-microscopic (>2 mm) metastasis [55, 56]. Indeed, intraoperative surgeon's judgment has a limited role in detecting occult central neck nodal disease [73].

Among these selective approaches, the sentinel lymph node biopsy technique has been proposed as an alternative to elective lymph node dissection in patients with clinically node negative (cN0) disease, theoretically allowing a histological staging of the lymphatic drainage without excising the whole lymphatic basin [74]. Vital blue dyes, radioisotopes, and the combination of both techniques are used in PTC patients [74, 75]. The results reported are variable and high-level evidence is lacking. Consequently, sentinel node biopsy for cN0 DTC has to be considered investigational [1].

FSE of central neck nodes is an important intraoperative adjunct to determine if CND is needed and has also been used to guide the need for bilateral CND, because of the high specificity and accuracy in detecting occult nodal involvement [1]. Delphian lymph node biopsy is able to predict other central neck nodal disease, but with a low sensitivity (35%) [76, 77].

It has been suggested that FSE on the ipsilateral central neck nodes can be used to intraoperatively assess the ipsilateral nodal status in clinically unifocal PTC and to subsequently modulate the extension of the prophylactic CND ensuring bilateral CND in case of positive FSE [55, 56]. The reported sensitivity, specificity, and overall accuracy of FSE are 80.7%, 100%, 90%, respectively, in detecting occult ipsilateral central neck metastases in clinically unifocal cN0 PTC [55, 56]. Most of the false negative results are observed in case of micrometastases, which are usually of negligible clinical significance [78]. Accuracy of N staging and short-term oncologic outcome seems comparable with those of patients with clinically unifocal cN0 PTC who underwent prophylactic bilateral CND [55].

FSE evaluation of prophylactically removed ipsilateral central neck nodes has been recently proposed also to guide the extent of thyroidectomy in patients eligible for thyroid lobectomy [79, 80]. In such protocol, ipsilateral pCND is performed at the time of lobectomy and sent for FSE. If central neck node metastases are found at FSE, completion thyroidectomy and contralateral paratracheal dissection is suggested, to reduce the risk of persistent/recurrent disease [79, 80].

In summary, bilateral CND is indicated at first time surgery in MTC, both with a therapeutic and prophylactic intent. A CND is indicated in clinically node positive DTC. Bilateral CND should be performed in case of bilateral paratracheal nodal basins macroscopic involvement. Unilateral CND could be considered adequate in the case of unilateral paratracheal involvement, even if it implies the risk of overlooking contralateral occult nodal disease. Given the lack of feasibility for a well-designed, adequately powered randomized clinical study on pCND [81] and the subsequent lack of high level evidences, the role of pCND in DTC remains controversial, although most of the guidelines and expert opinions are against, because of the increased risk of complications and the absence of clear-cut oncologic advantages [2]. Overall, basing on current evidences, whether prophylactic CND for PTC is performed or not during initial thyroidectomy should depend on tumor and patient characteristics and surgeon expertise [1].

11.4.1 Lateral Neck Dissection: Indications and Extension

In patients with DTC LND should be performed only with therapeutic intent for known disease and not for prophylactic purpose [1, 2, 6, 8, 18, 19, 52].

Indeed, it has been reported that prophylactic SND dissection (levels III and IV) yields occult nodal disease in 8–23% of patients that is a much lower rate with respect to central compartment involvement. In addition, accuracy of imaging studies (ultrasound) in detecting lateral neck node metastases is much higher than in the central compartment evaluation [82]. Furthermore, prophylactic LND results in high risk of surgical complications [83], and there is no evidence to indicate that prophylactic lateral neck dissection has clinical benefits in terms of survival or loco-regional control [83, 84].

In patients with MTC, guidelines recommend therapeutic uni- or bilateral LND in case of clinical evidence of lateral neck nodal metastases [1, 3, 8, 18, 85, 86].

Contrary to DTC, the role and indications of prophylactic LND in sporadic MTC without clinical evidence of lateral neck nodal metastases is debated [1, 3, 8, 18].

Several clinical and pathologic characteristics, including tumor size [87], serum calcitonin levels [18, 86], number of central neck nodes metastases [14], and the presence of stromal desmoplasia on tumor FSE [60, 88] have been investigated as potential risk factors for lateral neck metastases. No uniform conclusions have been derived, and the attitude toward the need/indication of prophylactic unilateral or bilateral LND in patients with MTC is still controversial.

In such context, the proposed approaches range from prophylactic bilateral LND (in the case of palpable tumors and/or central neck metastases and/or high serum calcitonin levels – >200 pg/mL) [12, 18, 86] to prophylactic ipsilateral LND (in the case of palpable tumors and/or moderately increased serum calcitonin levels – 20–200 pg/mL) [3].

Since persistent disease should be the unique source of increased calcitonin levels in patients with MTC, intraoperative calcitonin monitoring with or without provocative tests (high-dose calcium or pentagastrin stimulation tests) has been investigated in recent years, but the reported evidence are not unequivocal and not reliably applicable in the clinical practice [89, 90].

The optimal extension of LND in patients with thyroid carcinoma is still debated. Several approaches to lateral neck node dissection have been proposed raging from "cherry picking" to MRND [91–93]. Nodal metastases in level I are rare (<10%), and recurrence is also rare (<1%) if not dissected at initial SND [94–96]. It has been demonstrated that levels III and IV are the most common sites for lateral neck node metastases [92, 94, 95]. Thus, SND of levels III and IV could seem adequate in the treatment of regionally metastatic PTC, especially when there is no suspicion of lymph node metastases in the other levels or when multilevel aggressive neck metastases are not found [91, 95]. Conversely, it has been demonstrated that the rate of involvement of lymph nodes in levels II and V is quite similar to that of levels III and IV in patients undergoing LND [97]. Omitting the dissection of the levels II and V during therapeutic LND carries the potential risk to miss metastatic lymph nodes in two-thirds and one-fifth of the pN1b patients, respectively [97, 98].

To reduce the risk of injury to spinal accessory nerve and given the low likelihood of nodal involvement, level IIb should be dissected only in the presence of proven or suspected nodal metastases (similarly to level I) or if level IIa is positive, and similarly level Va is only dissected when it has clinically or ultrasound apparent nodal metastases [1, 2, 6, 98].

Consequently, SND, including levels IIa–III–IV–Vb, is considered the standard treatment for patients with DTC and MTC scheduled for LND [1–3, 8, 18, 19, 52, 72].

RND and ERND should be reserved to more aggressive and locally advanced cases in which a functional compartment oriented SND is not feasible or not allow adequate clearance. However, the sequelae and the risk of complications of such extended resection should be balanced with the possible benefits in each case, preferably by multidisciplinary discussion.

In summary, comprehensive compartment oriented SND is indicated in patients with lateral neck nodal metastasis of thyroid carcinoma. In the absence of lymph node involvement at levels I, IIb, and Va, SND should include levels IIa, III, IV, and Vb, balancing the risks of complication and of recurrent/persistent disease.

Prophylactic LND is not indicated in patients with DTC, but it can be considered in patients with MTC, basing on preoperative serum calcitonin levels and tumor size.

11.5 Operative Procedure

Neck dissections have been described as one of the most complicated surgeries of the human body [24]. Both if performed at the time of thyroidectomy or as a revisional surgery, CND and LND should comprehensively remove fibrofatty tissue in the target compartments, ensuring complete oncological removal of all nodal disease, while preserving anatomical integrity and function of non-lymphatic structures.

Adequate knowledge of applied anatomy and surgical experience, as well as surgical planning, are of utmost importance to accomplish a safe and radical operation.

Therefore, patients should be better operated in high volume centers by experienced surgeons [93].

11.5.1 Planning the Surgical Procedure

The operation should be adequately planned, by accurate preoperative evaluation, including patient history and lymph node mapping. If needed, second-line cross sectional imaging studies (CT, MRI, and PET scan) can be selectively used with this purpose [1]. However, in most of the cases, preoperative ultrasound lymph node mapping, integrated with fine-needle aspiration biopsy of suspiciously enlarged lymph nodes, is adequate for preoperative workup. As reported above, surgeon performed ultrasonography could improve the accuracy in detecting nodal disease. In the cases in which there is no cytologically/histologically proven nodal disease, FSE of suspiciously enlarged nodes can enable definitive intraoperative diagnosis, reducing the need for further operations for persistent/recurrent disease [15].

Besides lymph node mapping in all the patients with thyroid carcinoma, it is of utmost importance to preoperatively evaluate ILNs function, by means of direct laryngoscopy. Preoperative vocal fold paralysis may indicate gross invasion by the tumor and/or lymph node metastasis or surgical injury during previous operations. The affected nerve can be confidently resected in similar scenarios in order to achieve adequate oncological resection. On the contrary, if normal vocal folds motility is demonstrated at preoperative workup, any effort should be made to preserve anatomic integrity and function of the ILN, even in the presence of macroscopic invasion by the tumor itself or by metastatic nodes with extranodal growth pattern, at least in DTC. However, in such challenging settings, every effort should be made to remove all gross disease, while preserving ILN function. The benefits of preserving a functioning nerve should be always weighed against the risks of leaving structural disease, especially when facing aggressive histopathological variants of follicular cells derived tumors, less prone to respond to adjuvant treatment (i.e., radioiodine treatment), or MTC.

Beyond ILN function, in selected cases (bulky tumors, tumors showing an unexpected rapid growth, signs and symptom of local invasion – i.e., dysphonia, dysphagia, dyspnea, suspicious findings at preoperative ultrasonography), additional cross-sectional imaging studies (CT, MRI scan) should be performed to confirm/exclude invasion of adjacent organs/structures, including esophagus, trachea, larynx, vessels, or the presence of lymph node metastases in unusual site (i.e., retropharyngeal, retroesophageal basins). In suspicious cases, esophagogastroduodenoscopy and/or endotracheal endoscopy can be used to preoperatively confirm/exclude local invasion.

11.5.2 Intraoperative Surgical Adjuncts

In recent years, several innovative technologies, materials, and techniques have been proposed as intraoperative surgical adjuncts for thyroidectomy and neck dissections.

The use of magnification technique (surgical loupes or surgical microscope) has been investigated, but current evidences suggest no clear advantages in preventing laryngeal nerves injuries or hypoparathyroidism when compared with direct vision in thyroid surgery [99].

Energy-based vessel-sealing devices (ultrasonic devices, electrothermal bipolar devices, and hybrid systems) have been introduced as adjuncts to titanium clips, electrocautery, and knot-tying to improve surgical dissection and hemostasis showing safety and efficacy in several reports, while reducing operative time, but with no clear advantages in terms of reducing complications rate [100–104].

Moreover, topical hemostatic agents have been investigated in achieving hemostasis either passively, via contact activation of the intrinsic coagulation pathway, or actively, by including thrombin and/or fibrinogen to produce a fibrin seal, albeit discordant results are reported in preventing postoperative bleeding in thyroid surgery [105]. Moreover, the use of topical hemostatic agents (cyanoacrylate adhesives or fibrin glue) has been suggested to prevent, and in some experiences to control, chyle leak after neck dissections, although some reports have underlined how they are not effective and may render more challenging reoperation for chyle fistulas [106].

The use of intraoperative intermittent and continuous nerve monitoring has been extensively investigated to intraoperatively assess recurrent laryngeal nerves functional integrity [107, 108]. Its use does not replace an appropriate and meticulous surgical technique and knowledge of ILN anatomy and its variation. Several papers do support the use of intraoperative nerve monitoring in thyroid cancer surgery especially in patients with locally advanced disease and/or massive central neck nodal involvement, in reoperative cases, and in case of previous documented vocal cord paralysis [107, 109, 110]. Moreover, the use of intraoperative nerve monitoring has been proposed to intraoperatively assess integrity of external branch of superior laryngeal nerve (EBSLN) during thyroidectomy [111], and SAN and marginal mandibular nerve integrity during LND [112, 113]. Use of intraoperative nerve monitoring can also be helpful in knowing when to stage thyroidectomy, and/or neck dissection, if there is a loss of signal of the RLN.

Because it can be difficult to differentiate benign parathyroid tissue from pathology lymph nodes, intraoperative techniques aiming to better identify and preserve parathyroid tissue have been described, including methylene blue injection, near-infrared fluorescence imaging, and indocyanine green [114].

11.5.3 Surgical Technique

Regardless of the surgeon's preferred technique and the surgical adjuncts used, lymph node dissection for thyroid carcinoma should include a comprehensive, ideally *en bloc*, removal of all the target nodal basins: prelaryngeal, pretracheal, and paratracheal lymph nodes in CND and levels IIa–Vb in LND. Dissection of additional nodal groups (i.e., retropharyngeal, retroesophageal, level I, level IIb, and level Va) is selectively needed on the basis of the dissemination of nodal disease (see above).

To achieve an adequate and comprehensive clearance of the target basins, the surgeon should follow the planes of coalescence of different fascial layers, which are avascular and allow to remove the target nodes *en bloc* with their investing fascial layers. This is the well-known principle of the fascial dissection, theorized for LND by O. Suarez and worldwide diffused by Bocca and Pignataro [26] and Gavilan et al. [40, 42, 115]. Even though this concept was primarily developed for LND dissection, it is applicable also for CND, owing the fascial envelopments of the central (anterior) compartment, as described above.

When neck dissection is performed at the time of thyroidectomy, the central compartment should ideally be removed *en bloc* with the thyroid gland, in order to respect the principles of oncologic resection. When LND is planned and performed at the same time of thyroidectomy and/or CND, it is preferred to accomplish LND first, to reduce the risk that traction on an empty thyroid bed (central compartment) could cause inadvertent injury of ILN and/or parathyroid glands, which are no longer protected by adjacent structures. For this reason, in the present chapter, the operative technique of LND will be discussed first.

En bloc resection of lateral and central compartment is not suitable, since the central and the lateral compartment are separated by the carotid sheath. Only in the case of RND or ERND for locally advanced tumors invading structures included in the carotid sheath *en bloc* resection of the lateral and the central compartment could be feasible and advisable.

11.5.3.1 Patient's Preparation and Positioning

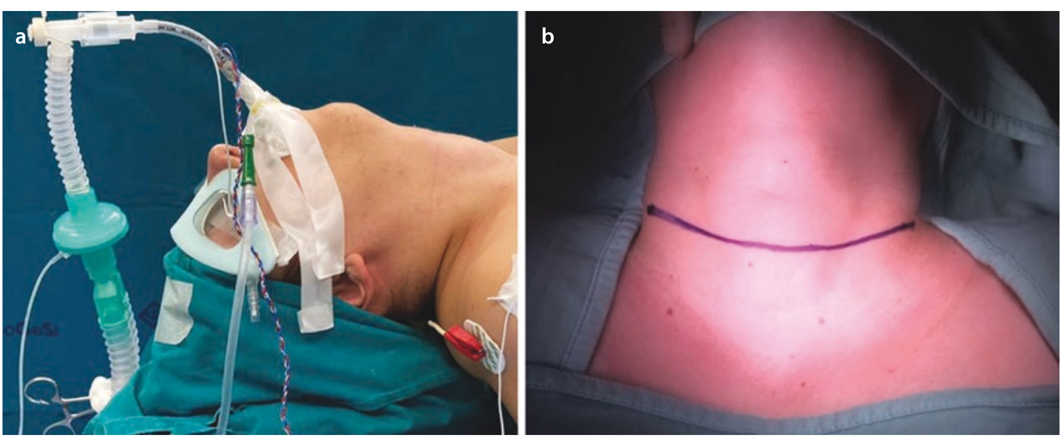
General anesthesia with oro-tracheal intubation is needed. Nerve-monitoring endotracheal tube is preferred. The patient is in supine position with the neck slightly hyperextended, by means of a shoulder roll (◘ Fig. 11.2). Following confirmation of the integrity of the nerve monitoring system, the patients is prepared and draped in the usual way. The trapezoidal operative field should include the chin, the inferior margin of the mandible and the earlobe cranially, the anterior margin of the trapezius muscle laterally, and the sternal notch and the clavicle caudally (◘ Fig. 11.2).

In the case of LND, the head of the patients should be rotated on the opposite side to maximize exposure. During such maneuver it is important to avoid any dislodgment of the orotracheal tube and of its electrodes for intraoperative nerve monitoring.

11.5.3.2 Skin Incision and Flap Elevation

In conventional procedure, a 4–5-cm collar incision about 2 fingers above the sternal notch, ideally in a natural neck crease, is usually adequate to provide access and good exposure for total thyroidectomy and CND. In the case of LND, incision should be prolonged on the side(s) of the dissection (◘ Figs. 11.2b and 11.3a). The horizontal skin incision should be prolonged until the posterior third/posterior margin of the ipsilateral SCM (◘ Fig. 11.3a). The extended collar incision can offer adequate exposure for neck dissections required in thyroid carcinoma. Other, less cosmetically favorable incisions (J shaped, U shaped, inverted T shaped), prolonged vertically to the mastoid area, are almost never required.

Monopolar cautery is used to elevate subplatysmal flap (◘ Fig. 11.3b), preserving the SLDCF, preserving the external and the anterior jugular veins and the greater auricular nerve.



◘ **Fig. 11.2** **a** Position: patient in supine position with the neck slightly hyperextended. **b** Incision: A collar incision about 2 fingers above the sternal notch

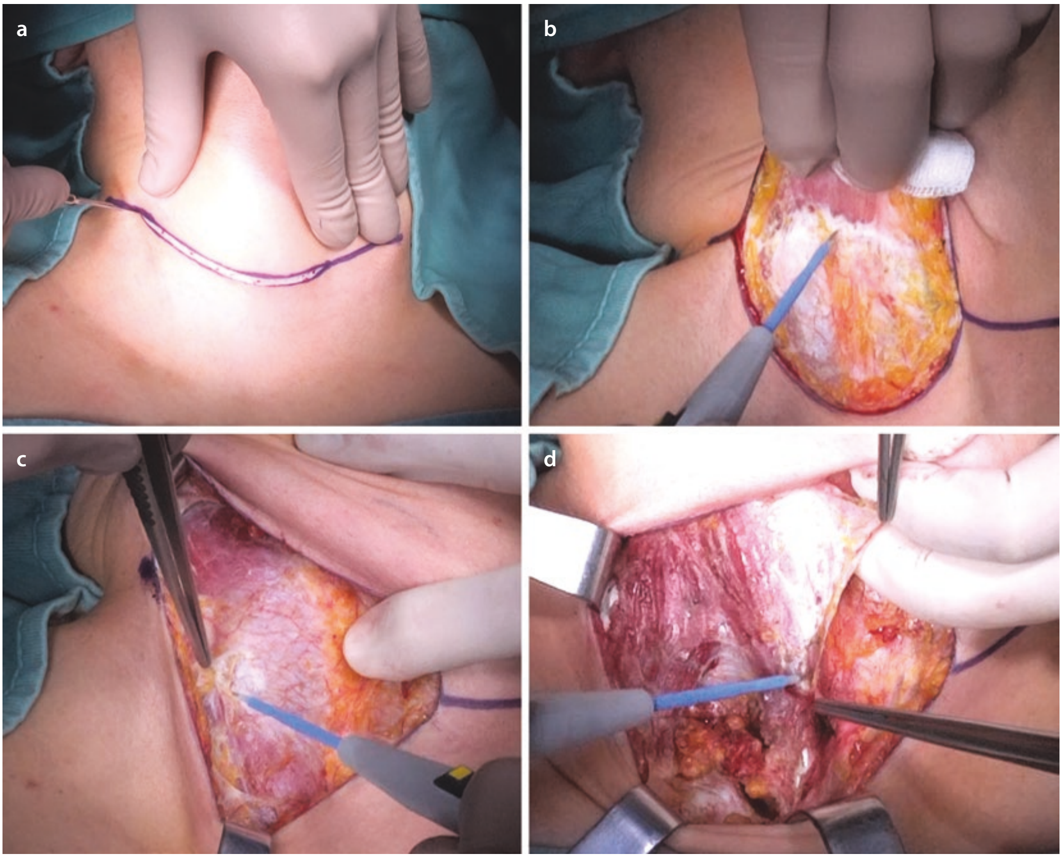


Fig. 11.3 **a** Skin incision should be prolonged on the side of the planned lateral neck dissection; **b** subplatysmal flap; **c** vertical incision of the superficial layer of the deep cervical fascia close to the posterior border of the sternocleidomastoid muscle; **d** the fibrofatty tissue contained between the two heads of the sternocleidomastoid muscle is dissected away, and the superficial layer of the deep cervical fascia detached from its infero-anterior attachments at the level of the sternum and the medial third of the clavicle

The flap should be extended cranially to expose the hyoid bone in the midline and the submaxillary gland laterally, if a LND is planned. Inferiorly the flap is elevated to the sternal notch in the midline and the clavicle laterally. The posterior border of the SCM should be exposed as well, if a LND is planned.

11.5.3.3 Selective Lateral Neck Dissection: Levels II–Vb

It should be underlined that the sequence of the steps usually reflects the operating surgeon's preference and experience (i.e., lateral to medial dissection, medial to lateral, clockwise, etc.). Usually, a medial to lateral approach is used by general and endocrine surgeons, while a lateral to medial approach is usually preferred by Head and Neck surgeons. Every approach has its own advantage(s). A combination of both a lateral to medial and medial to lateral approaches can be useful, depending on the step of the procedure and the individual patients and tumor to be treated.

What is of utmost importance is the comprehensive removal of all the fibrofatty tissue *en bloc* and embedded within the investing fascial planes.

1. ***Unwrapping the SCM***. The dissection usually starts with vertical incision of the SLDCF investing the SCM along all the length of the SCM itself. The incision is preferably close to the posterior border of the SCM (Fig. 11.3c). At this point the SCM should be completely enwrapped. Most surgeons usually prefer to first proceed with subfascial dissection toward the anterior margin of the muscle. However, it could be preferable to prepare the dissection of the subclavicular triangle first, proceeding with a posterolateral direction. The incised fascia is then elevated by means of forceps and retracted posterolaterally at the level of the distal third of the SCM. Dissection is achieved by means of monopolar electrocautery or bipolar scissors, in order to avoid any minimal bleeding.

   The fibrofatty tissue contained between the two heads of the SCM is dissected away, *en bloc*, and the SLDCF detached from its infero-anterior attachments at the level of the sternum and the medial third of the clavicle (Fig. 11.3d). Once reached the posterior border of the SCM, dissection of the fascia proceeds anteriorly along the posterior aspect of the distal third of the muscle, which is retracted antero-medially allowing progressive dissection of the fascial covering (Fig. 11.4a). The posterior belly of the omohyoid muscle is then identified and enwrapped of its fascial coating, from its intermediate tendon, until the crossing with the trapezius muscle (Fig. 11.4b, c). Unwrapping the omohyoid muscle, which will be continued anteriorly during the anterior dissection, it is essential to preserve the muscle and to obtain adequate exposure, especially during supraclavicular triangle dissection. In addition, it should be underlined that omohyoid muscle is embedded by the MLDCF that should be removed *en bloc* to ensure adequate clearance.

   Once achieved dissection of the posterior belly of the omohyoid muscle the SLDCF is detached inferiorly from the clavicle, posteriorly from the trapezius muscle. The clavicle and the trapezius muscle are exposed (Fig. 11.4c). Dissection is continued upward along the anterior margin of the trapezius muscle, until exposure of the externa jugular vein, that can be ligated but also preserved. If preservation of the external jugular vein is chosen, it should be freed from investing fibrofatty tissue (Fig. 11.4d). At this point, superficial dissection of the supraclavicular triangle is completed. A small gauze may be left at this level.

   From here dissection progresses anteriorly. The SLDCF is detached along the anterior aspect of the SMC. When dissection reaches the anterior border of the SCM, the mus-

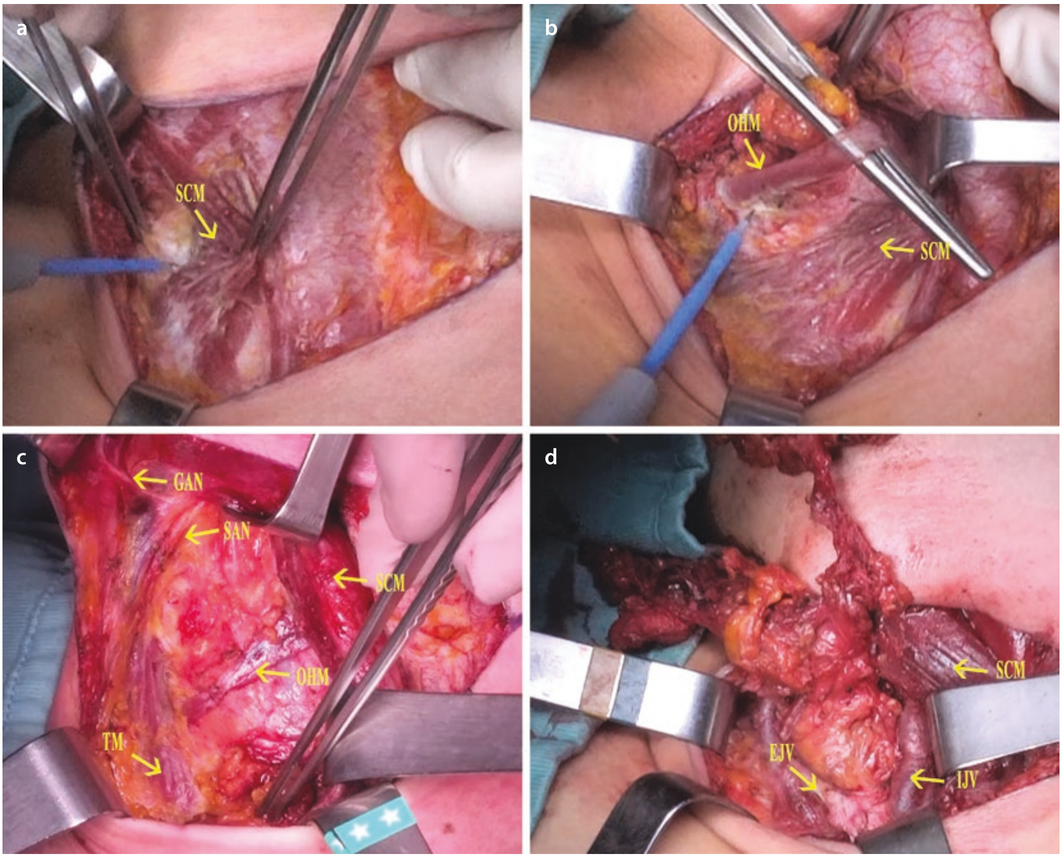


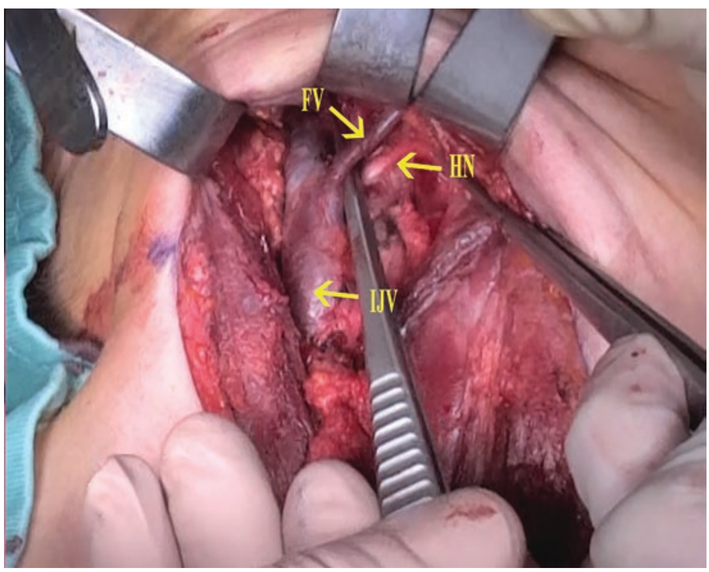
Fig. 11.4 **a** Dissection of the fascia along the posterior aspect of the distal third of the sternocleidomastoid muscle, which is retracted antero-medially allowing progressive dissection of the fascial covering; **b** the posterior belly of the omohyoid muscle is enwrapped of its fascial coating, from its intermediate tendon, until the crossing with the trapezius muscle; **c** superficial dissection of the supraclavicular triangle; **d** completing the supraclavicular triangle dissection. SCM sternocleidomastoid muscle, OHM omohyoid muscle, GAN great auricular nerve, SAN spinal accessory nerve, TM trapezius muscle, EJV external jugular vein, IJV internal jugular vein

cle is retracted posteriorly to continue dissection underneath, over its medial aspect, starting from the caudal portion upward, aiming to free the fascial covering from the posterior border of the SCM. Inferiorly, the dissection reaches the previously dissected supraclavicular triangle, as evidenced by the identification of the gauze left at that level.

Dissection over the medial surface of the SCM is then continued, allowing complete mobilization of the SCM. When dissection reaches the cranial third of the muscle, it should be paid special attention to the SAN that enters the muscle, approximately at the junction of its upper and middle thirds. In order to reduce the risk of SAN injury, it could be preferable to stop posterior dissection before reaching such dangerous area. Dissection can be more safely accomplished after dissection of the submandibular triangle and identification of the SAN in its proximal tract below the posterior belly of the digastric muscle.

In summary, the first step of the procedure consists of the complete unwrapping of the SCM and of the inferior belly of the omohyoid muscle and the dissection of the SLDCF from its clavicular and sternal attachments and from the anterior border of the trapezius muscle. Below the Erb's point dissection is accomplished posterior to the SCM, in the upper two thirds dissection is accomplished anterior to the SCM.

2. ***Preparing the submandibular triangle*** – At this point the SLDCF is incised along the inferior margin of the submaxillary gland. The gland is then retracted upward in order to expose the cranial boundary of the dissection represented by the posterior belly of the digastric muscle and the stylohyoid muscle. In the SND required for thyroid carcinoma section of the facial vein is unnecessary. However, it should be unwrapped of the investing fascial layer, since small lymph nodes may be missed along its posterior aspect, below the inferior margin of the submaxillary gland (◘ Fig. 11.5).
3. ***Dissecting the medial boundary*** – At this point the dissection of the SLDCF is continued along the lateral margin of the sternohyoid muscle by preserving the anterior jugular veins. The SLDCF is dissected away from the antero-lateral aspect of the sternohyoid muscle. That allows to expose the medial border of the LND, which is represented by the coalescence of the fascia covering lateral border of the sternothyroid muscle with the carotid sheath (◘ Fig. 11.6a). Proceeding in a posterolateral direction, the superior belly



◘ **Fig. 11.5** Submaxillary gland and posterior belly of the digastric muscle are retracted upward, the hypoglossal nerve is identified and preserved, and the facial vein is unwrapped of the investing fascial layer. FV facial vein, HN hypoglossal nerve, IJV internal jugular vein

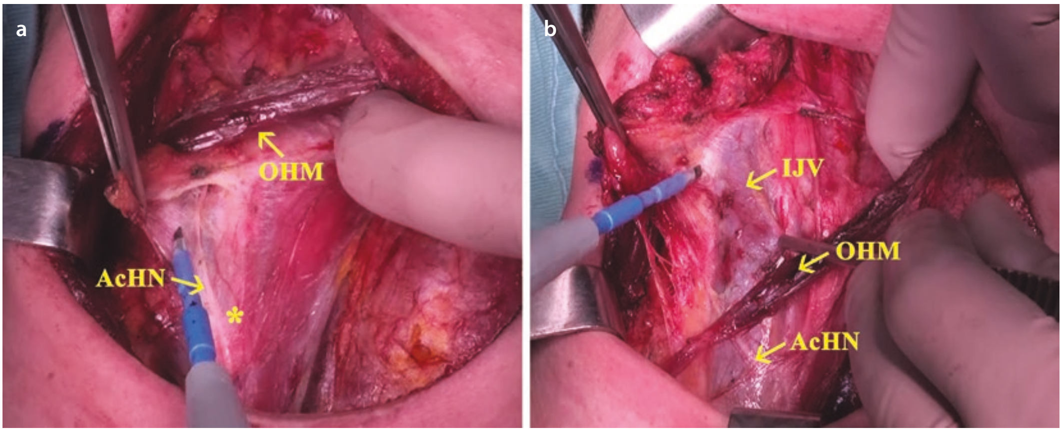


Fig. 11.6 **a** The superior belly of the omohyoid muscle is unwrapped of its investing fascia; the medial border of the lateral neck dissection is exposed; **b** the neuro-vascular bundle is unwrapped, caudal to cranial, until to reach the sagittal aponeurosis, posterior to the neurovascular bundle, and, consequently, the avascular plane of coalescence with the deep layer of the deep cervical fascia. OHM omohyoid muscle, AcHN *ansa cervicalis* hypoglossal nerve, * medial border of the lateral neck dissection represented by the coalescence of the fascia covering lateral border of the sternothyroid muscle with the carotid sheet, IJV internal jugular vein

of the omohyoid muscle is identified, and completely unwrapped of its investing fascia. That allows for a complete the mobilization of the muscle, very useful for further steps of the dissection, and for a complete exposure of the carotid sheath and neuro-vascular bundle of the neck. By retracting posterolaterally the medial border of the dissected SLDCF, the neuro-vascular bundle is unwrapped, caudal to cranial, until to reach the sagittal aponeurosis, posterior to the neurovascular bundle, and, consequently, the avascular plane of coalescence with the DLDCF (Fig. 11.6b). It should be paid attention to preserve the descending branch of the *ansa cervicalis* that should be followed upward till its origin from the hypoglossal nerve. Moreover, during the most posterior part of the dissection, its ascending branch should be preserved as well, since it represents an important landmark for the deepest plan of dissection. During this step of the dissection, it is usually unnecessary to ligate facial, lingual, and thyroid artery and veins, but they should be completely freed from the investing fascia.

In the caudal portion of the field, the IJV has to be freed till the confluence with subclavian vein (Pirogoff's trunk), eventually preserving also the external and anterior jugular veins. At this level, it should be paid attention to avoid injury of the thoracic duct on the left and the right lymphatic duct (if present) at their confluence on the Pirogoff's trunk.

Finally, it should be kept in mind that dissecting behind the neuro-vascular bundle may result in inadvertent injury of the sympathetic chain, and subsequent Horner's syndrome.

4. ***Dissecting level II*** – Proceeding upward, the fascia is incised along the posterior belly of the digastric muscle. Countertraction by the assistant over the upper most portion of CCA facilitates the identification of the hypoglossal nerve (◘ Fig. 11.5), following the descending branch of the *ansa cervicalis*. Dissection over the fascial plane is then continued laterally, to complete the dissection of the anterior and lateral aspect of the IJV. At this point, while supero-medially retracting the posterior belly of the digastric muscle and latero-inferiorly the SCM muscle, the SAN is exposed between the SCM and the IJV. The SAN has then to be completely dissected from its surrounding tissue, since it does not follow a fascial plane, but it crosses the intrafascial tissue and it is completely embedded by lymph nodes containing fibrofatty tissue. In the absence of gross involvement of such lymph nodes, it would be enough to dissect the tissue anterior to the nerve (IIa dissection) (◘ Fig. 11.7a). In the case where a level IIb dissection is needed, the SAN must be gently displaced to dissect the fibrofatty tissue cranial and posterior. Then the dissected IIb tissue has to be passed behind the nerve to be removed *en bloc* with the remaining specimen. Thus, in level IIb dissection the splenius capitis and the levator scapulae muscles represent the most posterior aspect of the dissection in the cranial part of the operative field (◘ Fig. 11.7b).
5. ***Level III and IV dissection*** – At this point while the SCM in retracted laterally and the vascular bundle medially, downward retraction of the specimen allows to complete the dissection of the posterior boundary along the plane of coalescence of the SLDCF and DLDCF, by preserving the roots of the cervical plexus (level III). The specimen is then

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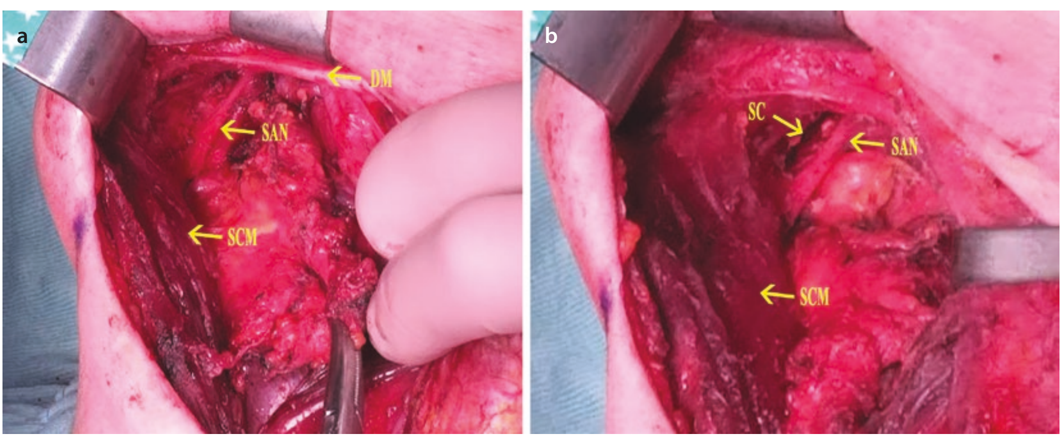
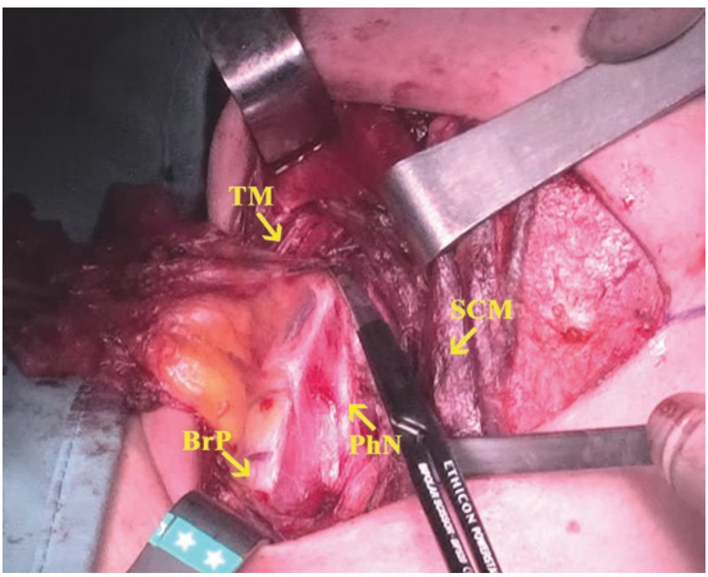


◘ **Fig. 11.7** **a** The spinal accessory nerve is exposed between the sternocleidomastoid muscle and the internal jugular vein; IIa dissection includes the fibrofatty tissue anterior to the nerve; **b** IIb dissection includes the fibrofatty tissue cranial and posterior to the spinal accessory nerve. Splenius capitis and the levator scapulae muscles represent most posterior aspect of the dissection in the cranial part of the operative field. DM digastric muscle, SAN spinal accessory nerve, SCM sternocleidomastoid muscle, SC splenius capitis passed behind the omohyoid muscle, and dissection continued downward (level IV). Following the fascial plane preserves the integrity of the phrenic nerve and thyrocervical trunk. However, infrascalenic nodes can be safely removed *en bloc*, after identifying the phrenic nerve. Small vascular branches arising from the thyrocervical trunk have to be ligated. Preserving the thyrocervical trunk, it is of utmost importance to reduce the risk of postoperative hypoparathyroidism. The utmost care of the thoracic duct as it emerges posterior to the inferior IJ is essential when one is dissecting in low level IV. The thoracic duct should be identified and ligated. No evidence of chylous fistula should be confirmed prior to closure.

In summary during this step, since both the lateral and the medial border have been already prepared, it is possible to safely dissect the posterior aspect along the DLDCF that should not be violated.

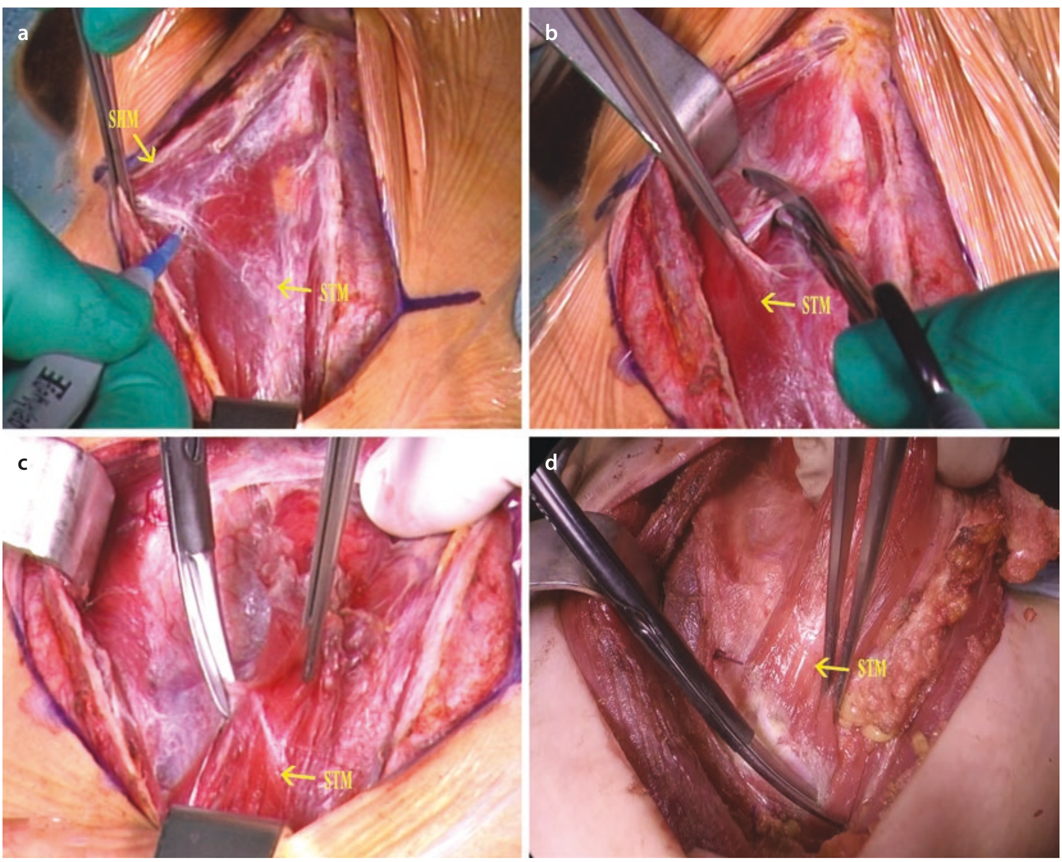
6. ***Completing level Vb dissection (supraclavicular)*** – At this point in time the SCM is retracted medially, and the specimen passed behind and transposed posterolaterally. The dissection follows along the superior aspect of the subclavian vein, exposing posteriorly the brachial plexus (◻ Figs. 11.4d and 11.8). Then, the dissection is completed along the anterior margin of the trapezius muscle and the specimen removed.



◻ **Fig. 11.8** Completing level Vb dissection/supraclavicular triangle. TM trapezius muscle, SCM sternocleidomastoid muscle, PhN phrenic nerve, BrP brachial plexus

11.5.3.4 Central Neck Dissection (Level VI–VII)

1. *Strap muscles dissection* (◘ Fig. 11.9) – The strap muscles are separated along the midline, as extensively as possible from the hyoid bone to the sternal notch. In order to obtain an adequate clearance, especially in large infiltrating tumors and/or bulky lymph node metastases, *en bloc* resection of the sternothyroid muscles can be preferable. In such cases, the posterior aspect of the sterno-hyoid muscle should be completely freed from the anterior aspect of the ipsilateral sternothyroid and thyrohyoid muscles, in order to be completely mobilized. After that, the sternohyoid muscle is sectioned at its proximal (thyroid cartilage) and distal (sternal) insertions. If needed or preferred, the SLDCF, in its anterior portion, covering the strap muscles, can be removed *en bloc* with the central compartment. It is sectioned cranially at the level of the hyoid bone and caudally at the level of the sternal notch. Then the sternohyoid muscles are unwrapped from lateral to medial. When the dissection reaches the



◘ **Fig. 11.9** Strap muscles dissection – The posterior aspect of the sterno-hyoid muscle should be completely freed from the anterior aspect of the ipsilateral sternothyroid and thyrohyoid muscles; after that, the sternohyoid muscle is sectioned at its proximal (thyroid cartilage) and distal (sternal) insertions. SHM sternohyoid muscle, STM sternothyroid muscle medial border of the sternohyoid muscles on each side, it changes direction and the posterior aspect of the sternohyoid muscles is dissected as described above, leaving the fascial envelopment connected along the median raphe with the sternothyroid muscles and the "content" of the central compartment.

2. *Dissection of the lateral boundary (Exposure of the CCA)* – The dissection, using both monopolar or bipolar cautery, follows the lateral margin of the sternothyroid muscle, along the carotid sheath (◘ Fig. 11.1). Complete exposure should be obtained from the thyroid cartilage to the innominate trunk on the right side and as low as possible on the left side, depending on patient' morphotype, but at least to the plane corresponding to the level where the innominate trunk crosses the trachea on the right side.
3. *Identification of the ILN and paratracheal dissection* – If total thyroidectomy is associated, after the section of the vessels of the upper pole (see ► Chap. 10), the thyroid lobe is retracted medially, to expose the tracheoesophageal groove. The ILN is usually identified where it crosses the inferior thyroid artery or its branches, possibly using intraoperative nerve monitoring to confirm correct identification. On the right side, the nerve should be dissected from the surrounding fibrofatty tissue in all along its cervical course from its origin behind the subclavian artery to its entrance into the larynx. After that the sagittal aponeurosis posterior to the carotid sheath should be incised and the posterolateral fibrofatty tissue dissected from lateral to medial along the lateral aspect of the ILN, preserving the small sympathetic-inferior laryngeal nerve connecting branches [116]. Then, the posterior aspect of the nerve is freed from the fibrofatty tissue. ILN is cautiously anterolaterally displaced, and the posterolateral portion of the paratracheal nodes are transposed behind it medially (◘ Fig. 11.10). At this point dissection continues in the antero-medial portion of the paratracheal nodes, exposing the antero-lateral aspect of the esophagus and the lateral aspect of the trachea. In most of the cases, the infero-lateral part of the dissected field may expose the apex of the ipsilateral lung. On the left side, the nerve is similarly identified where it crossed the inferior thyroid artery and followed in a caudal direction as deep as possible in the upper mediastinum. At this point the sagittal aponeurosis is incised behind the carotid sheath. By lateral to antero-medial retraction, the lymph node containing fibrofatty tissue is completely freed along the antero-lateral aspect of the ILN, exposing the esophagus and the lateral margin of the trachea. Any effort should be done to preserve the superior parathyroid glands (◘ Figs. 11.10d and 11.11) (see ► Chap. 10). For re-operative central node dissection,

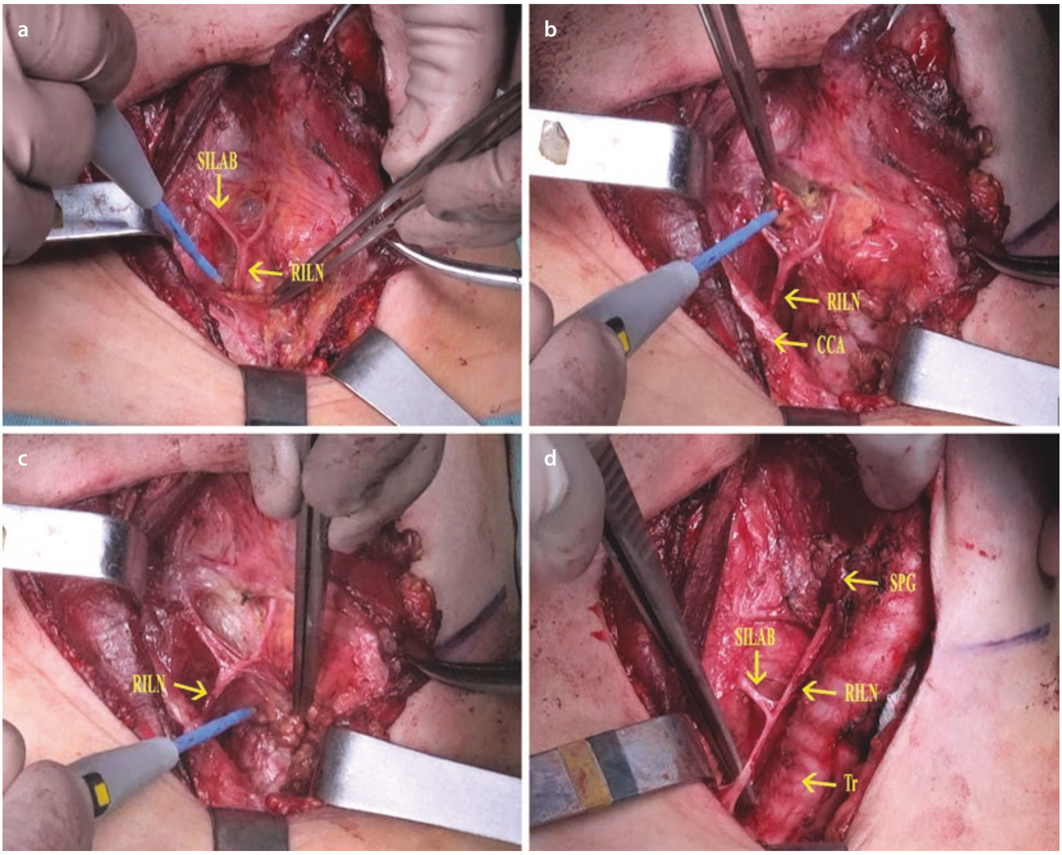


Fig. 11.10 Identification of the right inferior laryngeal nerve and paratracheal dissection – On the right side the nerve should be dissected from the surrounding fibrofatty tissue all along its cervical course from its origin behind the subclavian artery to its entrance into the larynx. The sagittal aponeurosis should be incised and the posterolateral fibrofatty tissue dissected from lateral to medial along the lateral aspect of the inferior laryngeal nerve, preserving the sympathetic-inferior laryngeal nerve anastomotic branches. Then, the posterolateral portion of the paratracheal nodes is transposed behind it medially. SILAB sympathetic inferior laryngeal anastomotic branch, RILN right inferior laryngeal nerve, CCA common carotid artery, SPG superior parathyroid gland, Tr trachea

it is essential to dissect posterior to the laryngeal nerve as it is in this region that recurrent/ persistent pathologic central lymph nodes are found.

4. *Pretracheal dissection* – Just below the sternothyroid muscle, it is possible to identify the thymus. It should be explored for identifying intrathymic parathyroid glands which are often encountered or used as a landmark for the identification of inferior parathyroid gland embedded in the thyrothymic tract. The thymus, and the eventually identified inferior parathyroid gland, in the absence of overt involvement by the tumor or nodal disease, should be preserved, since it lies in an anatomical plane anterior to the pretracheal nodes, in order to preserve inferior parathyroid glands viability (Fig. 11.11). After that the most inferior portion of the central compartment (upper mediastinal nodes) is dissected from the antero-superior aspect of the innominate

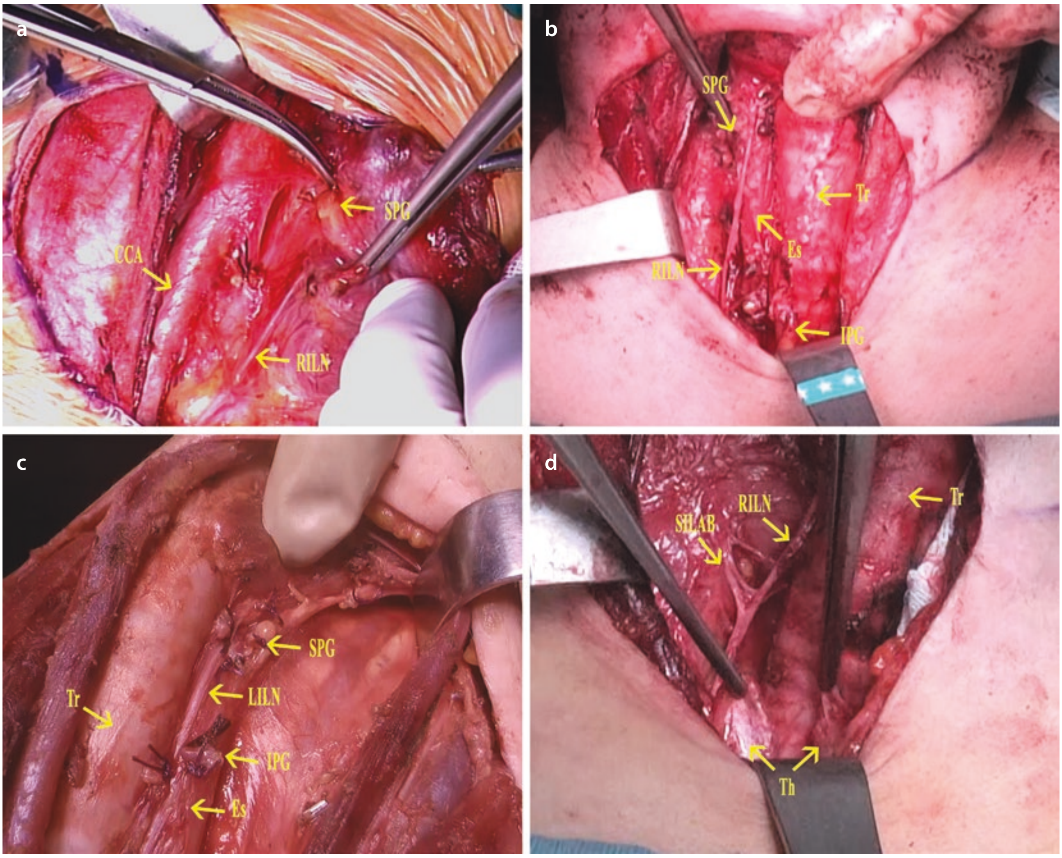


Fig. 11.11 Parathyroid preservation during central neck dissection – During central neck dissection any effort should be done to preserve the superior parathyroid glands. The thymus should be explored for identifying intrathymic parathyroid glands or using it as a landmark for the identification of inferior parathyroid gland embedded in the thyrothymic tract. SPG superior parathyroid gland, CCA common carotid artery, RILN right inferior laryngeal nerve, Tr trachea, Es esophagus, IPG inferior parathyroid gland, LILN left inferior laryngeal nerve, SILAB sympathetic inferior laryngeal anastomotic branch, Th thymus

trunk, exposing the right brachiocephalic vein. Dissection is continued upward dissecting the fibrofatty tissue embedded in the visceral portion of the MLDCF from tracheal fascia.

5. *Prelaryngeal (Delphian) nodes* – Dissection then continues, en bloc with the thyroid gland and/or the resected sternothyroid muscles, in the prelaryngeal compartment, paying attention to avoid injury of the cricothyroid muscle, cricothyroid membrane, and thyroid cartilage, along with the pyramidal lobe in the case of synchronous thyroidectomy. Dissection should be continued extensively upward in order to expose the hyoid bone.
6. *Unilateral* vs *bilateral dissection* – If unilateral dissection is accomplished, it should be stopped at the lateral margin of the trachea on the contralateral side. If bilateral CND dissection is required, dissection continues in the contralateral paratracheal basin.

7. *Wound closure* – After checking the hemostasis and lymphatic leak, the sternohyoid muscles are re-approximated along the midline. The wound is closed with subcuticular running suture. Suction drains may be left inside.

11.5.4 Alternate Operative Approaches (Minimally Invasive, Remote Access, and Radio-Guided Procedures)

Even though the conventional approach to CND and LND via cervical incision remains the standard approach, in recent years numerous minimally invasive and remote access procedures approaches have been described [47, 117–122].

Among cervical minimally invasive approaches, video-assisted CND has been proposed and validated in selected preoperative cN0 low-risk papillary thyroid carcinoma in case of intraoperative evidence of enlarged/suspicious central neck nodes during video-assisted thyroidectomy [118] and in *RET* mutation carriers [123]. Nonetheless, overt lymph node involvement remains a contraindication for video-assisted approach, and conversion to conventional approach is mandatory when an accurate node clearance cannot be obtained using the video-assisted approach [124].

Supported by the results of video-assisted approach for selected cases of DTC and encouraged by the results of video-assisted CND, a preliminary experience showing only the feasibility of the technique, a video-assisted approach to LND has been described for selected low-risk PTC with lateral neck nodal metastases <2 cm, without evidence of great vessels involvement [47], but it remained a feasibility study with no further diffusion.

Among remote approaches for ND, endoscopic and robot-assisted techniques have been evaluated including transaxillary, retroauricular, modified facelift, and trans-oral approaches [119–122]. Preliminary results demonstrated the feasibility and safety of such alternate approaches, but high level evidences and data on long-term outcomes are lacking and they haven't so far gained wide diffusion worldwide and, in most cases, remained limited to the authors' experience [1]. To date alternate approaches for ND are to be considered investigational [1].

Radio-guided surgery has been investigated for possible utilization in patients with iodine avid recurrent disease to achieve targeted resection in patients previously undergone comprehensive ND, aiming to ensure the completeness of the resection of iodine avid tissue [125]. In limited experiences radionuclide occult lesion localization, by injecting 0.5 mCi Tc-99m macroaggregate albumin into the lesion under ultrasound guidance (USG), has been used as an adjunct for targeted removal of recurrent or persistent nodal disease [126].

11.5.5 Knowing and Avoiding Complications of ND

CDN and LND increase both intra- and postoperative complication rates when compared with thyroidectomy alone [78, 127, 128].

Knowledge, prevention, and management of complications that could occur during neck dissections are essential for a proper care of thyroid cancer patients.

Complications related to ND include nerve complications, hematoma and vascular complications, hypoparathyroidism, chyle fistula, pneumothorax, and wound complications.

Nerve complications include great auricular nerve, cervical sensory nerves, facial nerve, lingual nerve, hypoglossal nerve, SAN, sympathetic nerves, phrenic nerve, brachial plexus, VN, external branch of superior laryngeal nerve, and ILN injuries.

The great auricular nerve emerges from beneath the posterior border of the SCM in the upper half of level V of the neck; it travels across the lateral surface of the SCM toward the auricle. Sacrifice of this nerve during ND leads to a sensory deficit of the auricle that usually diminishes with time. Ear lobule numbness, however, tends to persist [129].

Injuries to the cervical and marginal mandibular branches of the facial nerve may occur during ND. The cervical branch of the facial nerve innervates the platysma muscle, and its sacrifice does not usually produce clinically significant deficits. The marginal mandibular nerve is encountered when approaching level I of the neck and its injury results in asymmetry of the lower lip at rest with inability to depress the lip during facial expression. During the dissection, elevating the submandibular fascia inferiorly on the gland adequately protects the nerve [130].

In the case of level I lymph node dissection and/or concomitant submandibular gland excision, injury of the lingual nerve may occur. Clinically, injury results in loss of taste and sensation from the ipsilateral anterior two-thirds of the tongue.

Hypoglossal nerve injury is a rare complication of LND [131]. The nerve is susceptible to injury during dissection of levels I and II. The deficits from hypoglossal injury include ipsilateral tongue weakness, deviation of the tongue toward the affected side with tongue protrusion, and difficulty with speech and swallowing.

Shoulder dysfunction has been reported in up to 30–40% of patients undergoing LND, even when the SAN is anatomically preserved [132, 133]. SAN injury results in shoulder drooping, aberrant scapular rotation, inability to fully abduct the shoulder, and a dull ache secondary to atrophy of the trapezius muscle and adhesive capsulitis of the glenohumeral joint [132, 133].

In several cases, atrophy and stiffness of the SCM may occur after vigorous and protracted retraction, and they might be mistaken for SAN injury [132, 134].

Physical therapy and postoperative shoulder rehabilitation have positive effects on quality of life in selected patients. Low-dose botulin toxin injection in the territory of the nerve was proved effective in managing the condition in some patients [135].

The cervical sympathetic chain consists of two to four ganglia with a connecting neural trunk that runs parallel and posteromedial to the carotid sheath. Loss of sympathetic innervation results in Claude-Bernard-Horner syndrome (ptosis, miosis, and anhidrosis). The manifestations of partial losses vary depending on the location of the injury in relation to the ganglia. In order to reduce the risk of this complication, attention should be paid in dissecting behind the neuro-vascular bundle.

Phrenic nerve paralysis is considered a rare complication of LND. Injury to the phrenic nerve leads to ipsilateral hemidiaphragm elevation, with or without mediastinal shift on chest radiograph, and symptoms such as cough, chest pain, or abdominal discomfort mediated by the somatic afferents. The paresis is generally transient and without sequelae. Preserving the fascial layer over the nerve and anterior scalene muscle during level IV dissection is the primary method for prevention of injury.

Brachial plexus injury is rarely reported after neck dissection. The roots lie between the anterior and middle scalene muscles, the trunks in the posterior triangle, the divisions behind the clavicle, and the cords in the axilla. The plexus is involved with the motor and sensory function of the shoulder down to the fingertips. Injuries to this plexus can lead to significant deficits in quality of life [136, 137]. Dissecting above the DLDCF allows to avoid any injury.

Injury to the main trunk of the VN may occur during dissection of level III and IV lymph nodes and eventual ligation of the IJV in the inferior neck or at the skull base. High VN injuries result in significant dysphonia from vocal fold paralysis, dysphagia, and sensory loss.

For complications related to injury to ILN, EBSLN please refer to ► Chap. 10.

Hematoma occurs in approximately 1% of neck dissections. A hematoma within the central neck after thyroidectomy and/or neck dissection can sufficiently impede the venous and lymphatic outflow of the larynx, causing life-threatening airway problems [109, 138]. In case of compressive hematoma, bedside evacuation of the hematoma may be necessary. At the time of surgical re-exploration, attention to the structures at risk remains of paramount importance, as always. Gentle irrigation and clot evacuation, as well as blind clamping of vessels, are mandatory to avoid further complications. Saline solution is useful in cleaning the operative field and identifying any source of bleeding.

The use of hemostatic agents (i.e., oxidized cellulose, fibrin sealant, etc.) may be useful in selected cases to facilitate hemostasis by mechanical pressure and promoting coagulum formation, thus resulting in reducing capillary ooze, wound collection, and drainage [105].

In rare cases, intraoperative injuries to the common carotid could occur and generally require primary vascular repair, and vascular surgery consultation is highly recommended. Acute postoperative carotid artery rupture has been described: this rare but life-threating condition is generally subsequent to wound necrosis and infection, salivary fistula, prior radiation therapy, and tumor involvement of the arterial wall.

Finally, other vascular complications following neck dissections include postoperative thrombosis and hemorrhage of intraoperatively preserved IJV. Many IJV postoperative thromboses result in a recanalization of the vessel with reestablishment of the patency after adequate anticoagulant therapy [139]. IJV ligation should be avoided if possible since in case of bilateral neck dissection it is demonstrated that the preservation of at least one IJV is beneficial to avoid facial or laryngeal edema, intracranial pressure elevations, and stroke [140].

Hypoparathyroidism and hypocalcemia are the most common complications following thyroidectomy and neck dissection [141] (see ► Chap. 10).

The best way to avoid parathyroid damage is to clearly know the embryology and the surgical anatomy of the glands and their blood supply and make every effort to preserve them avoiding removal or devascularization of parathyroid tissue or to perform an auto-transplant of de-vascularized or inadvertently removed normal parathyroid glands [109].

The incidence of parathyroid gland injury is related to the extent of the operation and to surgeon's experience.

Some technical aspects have a crucial role in parathyroid glands preservation.

First of all, a bloodless surgical field is essential, since any bleeding could determine an alteration of the colors that is essential for parathyroid identification.

Given the high variety of inferior parathyroid location, missing identification of one or two inferior parathyroids does not mean inadvertent removal: the gland(s) can be located cephalad or caudal (i.e., intrathymic) to the site of dissection. Conversely, not identifying a superior parathyroid gland can signify inadvertent removal, since it is usually located on the posterior aspect of the thyroid lobe, close to the point where the ILN enters the larynx.

During lateral neck dissection, it is of the utmost importance to preserve the thyrocervical trunk to preserve parathyroid vascularization from branches of inferior thyroid artery.

Moreover, intraoperative techniques aiming to better identify and preserve parathyroid tissue have been described, including methylene blue injection, near-infrared fluorescence imaging, and indocyanine green [114], but to date no technique or technology is able to replace a meticulous surgical approach based on detailed knowledge of embryology and anatomy of the parathyroid glands and their blood supply.

Several postoperative protocols have been proposed and validated for the management of symptomatic and asymptomatic hypocalcemia and/or clinical or relative hypoparathyroidism. Routine or selective oral calcium and calcitriol supplementation results effective in the majority of the cases [142–145]. Intravenous calcium administration should be considered in case of severe symptomatic hypocalcemia or in case of symptoms progression (paresthesias, numbness, tingling, cramps, etc.) despite oral calcium and calcitriol therapy (see ► Chap. 10).

Chyle leak may complicate neck dissection in 1–8% of the cases [146, 147]. Chyle leak occurs in the majority of the cases after left neck dissections, but it is important to remember that up to 25% of chyle leaks occurs on the right side [146, 147]. The thoracic duct consists of a plexus of tributaries and terminal ducts, each of which can create a chyle fistula if transected or incompletely ligated.

Intraoperative suspicion of chyle leak during any lower neck dissection should be investigated. In case of intraoperatively identified chyle leak, gentle exploration and meticulous ligation of the duct and identifiable branches with nonabsorbable sutures are recommended. Postoperative leaks are usually discovered with resumption of feeding. Most are easily diagnosed clinically by observing a change in the character of the drain output from serosanguinous to milky. Conservative management with use of a long-acting analog of the hormone somatostatin (subcutaneous octreotide) and low-fat diet, closed drainage to promote adherence of skin flaps, and/or pressure dressings may be sufficient to promote spontaneous closure of most fistulas [148]. Cases of persistent leak after conservative management and/or high-output leaks (>500 mL/24 hours) require operative intervention and ligation of the duct and identifiable branches. Most recently the role of lymphangiography and percutaneous embolization of the thoracic duct has been shown to be feasible and effective in chyle leaks [149]. Video-assisted thoracoscopic ligation of the thoracic duct has been recommended by some as the preferred treatment of chyle leaks [150].

In rare cases a leak originating in the neck or retrograde pressure formation from cervical thoracic duct ligation leads to extravasation or mediastinal propagation of the chyle leak (chylothorax) [151]. In such cases, thoracentesis or thoracostomy tube drainage is indicated, and, rarely, operative intervention via thoracoscopic or open thoracotomy approaches is necessary to identify the leak and ligate the thoracic duct in the chest.

Pleural injury during dissections at the base of the neck can lead to pneumothorax. Thoracostomy tube placement is required. Chest radiographs after neck dissection could be considered in selected cases (changes in ventilator status, decreased breath sounds on chest auscultation, extensive dissection at the base of the neck for gross nodal involvement) to exclude pneumothorax [152].

Extensive dissection at the pharyngoesophageal junction for infiltrative thyroid tumors or parotid leaks may cause salivary fistula after neck surgery. Conservative management with antibiotics and closed drainage is usually successful. In selected cases salivary gland botulinum toxin injection improves the closure of the fistula [153].

Wound complications following neck surgery include dehiscence and flap necrosis, seroma, wound infection, and lymphedema.

Wound dehiscence and flap necrosis is quite rare in case of correct surgical technique and adequate subplatysmal flap, but its incidence is increased in case of excision of previous skin scars or excision of skin *en bloc* with underlying involved fascial/muscular/vascular/lymphatic structures increasing tension on the skin closure. Other reported risk factors include previous neck irradiation and poor microvasculature secondary to tobacco use, malnutrition, and diabetes mellitus [154].

Seroma is the collection of serous fluid in the space between cervical skin flaps, and underlying structures could be subsequent to division of lymphatic and adipose tissue during neck dissections. Early drain removal, incorrect drain placement, or drain failure could cause seromas. Self-reabsorption is observed in the majority of small seromas; needle aspiration or drain replacement is indicated in selected cases avoiding flap necrosis or infection.

Wound infection is quite rare in case of neck dissection for thyroid carcinomas and could be subsequent to seroma and/or hematoma formation. Collections must be completely drained, wounds should be cultured, and adequate antibiotics therapy should be used according to the potential or confirmed pathogens.

Lymphedema can be subsequent to stagnation of lymphatic fluid and may develop externally in the superficial layers and/or internally within the mucosa, submucosa, and muscles of the upper aerodigestive tract. Neck stiffness, limitations in motion, pain, dysphagia, hearing impairment, and, rarely, airway compromise may be observed. Referrals to certified lymphedema therapists should be recommended in selected cases with decreased quality of life [155].

Postoperative wound infection or inadequate skin closure techniques may lead to the development of a *keloid* (hypertrophic scar). Neck lift and midline platysmoplasty can be considered in selected cases [156].

Answers to the Questions

1. (c); 2. (a); 3. (b); 4. (d); 5. (c); 6. (a); 7. (a); 8. (b); 9. (d)

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