Anatomical Complications in General Surgery

John E. Skandalakis, Stephen W. Gray, Joseph S. Rowe

Chapter 1: The Neck

The human neck is so designed that the swelling of a normal structure or the presence of an abnormal one is readily apparent. Neoplasms and infection can affect any of the 300 lymph nodes or the more than a dozen fascial spaces in the neck. Persistent embryonic structures may occupy spaces no longer assigned to them. The structures of the neck are packed so tightly that nearly every lesion expresses itself as a visible or palpable bulge. In most cases, even the most perfunctory physical examination will reveal the swelling.

Rule of 80

80 percent of nonthyroid neck masses are *neoplastic.*
80 percent of neoplastic neck masses are in *males.*
80 percent of neoplastic neck masses are *malignant.*
80 percent of malignant neck masses are *metastatic.*
80 percent of metastatic neck masses are *from primary sites above the clavicle.*

The probable diagnosis may be based on the average duration of the patient's symptoms:

Rule of 7

Swelling from inflammation has existed for *7 days.*
Swelling from a neoplasm has existed for *7 months.*
Swelling from a congenital defect has existed for *7 years.*

Embryogenesis of the Neck

The neck as seen in the adult human does not exist in the embryo. The history of the region is the history of the organs contained within it, chiefly the pharynx and its derivatives, the thyroid, parathyroid, and thymus glands. In addition, vessels passing through the neck from head to thorax are elongated and modified during the course of development.

Elongation of the pharynx at 5 weeks and later elongation of the esophagus, together with the descent of the diaphragm, separate the head of the developing embryo from the relatively large heart. By 7 weeks, a neck is visible. Further details of differentiation and migration will be discussed with specific organs.

Topographic Anatomy of the Neck

Triangles of the Neck

The topography of the neck lends itself to description by a series of natural triangular areas.

The anterior cervical triangle

The boundaries are:

Lateral: Sternocleidomastoid muscle.
Superior: Inferior border of the mandible.
Medial: Anterior midline of neck.

This large triangle may be subdivided into four more triangles: submandibular, carotid, muscular, and submental.

Submandibular Triangle

The submandibular triangle is demarcated by the inferior border of the mandible above and the anterior and posterior bellies of the digastric muscle below.

The largest structure in the triangle, and the most frequent object of the surgeon's attention, is the submandibular salivary gland. A number of vessels, nerves, and muscles also are found in the triangle.

For the surgeon, the contents of the triangle are best described in four layers, or surgical planes, starting from the skin. It must be noted that severe inflammation of the submandibular gland can destroy all traces of normal anatomy. Identifying and sparing the essential nerves becomes a great challenge. With this warning, we will describe the structures in the triangle at the four surgical planes.

The Roof of the Submandibular Triangle. The roof of the submandibular triangle is composed of skin, superficial fascia enclosing platysma muscle and fat, and the mandibular and cervical branches of the facial nerve (VII).

It is important to remember 1. that the skin should be incised 4 to 5 cm below the mandibular angle; 2. that the platysma and fat compose the superficial fascia, and 3. that the cervical branch of the facial nerve (VII) lies just below the angle, superficial to the facial artery.

The mandibular, or marginal mandibular, nerve is usually the second branch of the cervicofacial division of the facial nerve. It passes approximately 3 cm below the angle of the mandible to supply the muscles of the corner of the mouth and lower lip.

The curved course of this nerve and the similarly shaped courses of other nerves in this region have led to the term *neural hammocks.* The mandibular nerve forms the first of

such hammocks of the submandibular triangle. We have seen this hammock hanging so far below the mandible that a high transverse incision would have severed it.

The cervical branch of the facial nerve divides to form descending and anterior branches. The descending branch innervates the platysma and communicates with the anterior cutaneous nerve of the neck. The anterior branch, the ramus colli mandibularis, crosses the mandible superficial to the facial artery and vein and joins the mandibular branch to contribute to the innervation of the muscles of the lower lip. This anterior branch forms the second neural hammock of the triangle. It is frequently confused with the mandibular hammock.

Injury to the mandibular branch results in severe drooling at the corner of the mouth. Injury to the anterior cervical branch produces minimal drooling that will disappear in 4 to 6 months.

If the skin incision is placed at least 4 cm below the border of the mandible, even an exceptionally low cervical branch will not be accidentally cut.

The Contents of the Submandibular Triangle. The structures of the second surgical plane, from superficial to deep, are the anterior and posterior facial vein, part of the facial artery, the submental branch of the facial artery, the superficial layer of submaxillary fascia (deep cervical fascia), the lymph nodes, the deep layer of submaxillary fascia (deep cervical fascia), and the hypoglossal nerve (XII).

It is necessary to remember that the facial artery pierces the stylomandibular ligament. Therefore, it must be ligated before it is cut to prevent bleeding after retraction. It also is important to remember that the lymph nodes lie within the envelope of the submandibular fascia in close relationship with the gland. Differentiation between gland and lymph node may be difficult.

The anterior and posterior facial veins cross the triangle in front of the submandibular gland and unite close to the angle of the mandible to form the common facial vein, which empties into the internal jugular vein near the greater cornu of the hyoid bone. It is wise to identify, isolate, clamp, and ligate both these veins.

The facial artery, a branch of the external carotid artery, enters the submandibular triangle under the posterior belly of the digastric muscle and under the stylohyoid muscle. At its entrance into the triangle it is under the submandibular gland. After crossing the gland posteriorly, the artery passes over the mandible, lying always under the platysma. It can be ligated easily.

The Floor of the Submandibular Triangle. The structures of the third surgical plane, from superficial to deep, include the mylohyoid muscle with its nerve, the hyoglossus muscle, the middle constrictor muscle covering the lower part of the superior constrictor, and part of the styloglossus muscle.

The mylohyoid muscles are considered to form a true diaphragm of the floor of the mouth. They arise from the mylohyoid line of the inner surface of the mandible and insert on

the body of the hyoid bone into the median raphe. The nerve, a branch of the mandibular division of the trigeminal nerve (V), lies on the inferior surface of the muscle. The superior surface is in relationship with the lingual and hypoglossal nerves.

The Basement of the Submandibular Triangle. The structure of the fourth surgical plane, or basement of the triangle, include the deep portion of the submandibular gland, the submandibular (Wharton's) duct, the lingual nerve, the sublingual artery, the sublingual vein, the sublingual gland, the hypoglossal nerve (XII), and the submandibular ganglion.

The submandibular duct lies below the lingual nerve (except where the nerve passes under it) and above the hypoglossal nerve.

The Lymphatic Drainage of the Submandibular Triangle. The submandibular lymph nodes receive afferent channels from the submental nodes, the oral cavity, and the anterior parts of the face. Efferent channels drain primarily into the jugulodigastric, jugulocarotid, and juguloomohyoid nodes of the chain accompanying the internal jugular vein (deep cervical chain). A few channels pass by way of the subparotid nodes to the spinal accessory chain.

Submental Triangle

The boundaries of this triangle are:

Lateral: Anterior belly of digastric muscle.
Inferior: Hyoid bone.
Medial: Midline.
Floor: Mylohyoid muscle.
Roof: Skin and superficial fascia.
Contents: Lymph nodes.

The lymph nodes of the submental triangle receive lymph from the skin of the chin, the lower lip, the floor of the mouth, and the tip of the tongue. They send lymph to the submandibular and jugular chains of nodes.

Carotid Triangle

The boundaries are:

Posterior: Sternocleidomastoid muscle.
Anterior: Anterior belly of omohyoid muscle.
Superior: Posterior belly of digastric muscle.

Floor: Hyoglossus muscle, inferior constrictor of pharynx, thyrohyoid muscle, longus capitis muscle, and middle constrictor of pharynx.

Roof: Investing layer of deep cervical fascia.

Contents: Bifurcation of carotid artery; internal carotid artery (no branches in neck); external carotid artery branches, e.g., superior thyroid artery, superficial temporal artery, posterior auricular artery, internal maxillary artery, occipital artery, ascending pharyngeal artery, sternocleidomastoid artery, lingual artery (occasional), external maxillary artery (occasional); jugular vein tributaries, e.g., superior thyroid vein, occipital vein, common facial vein, the pharyngeal vein; and vagus nerve, spinal accessory nerve, hypoglossal nerve, ansa hypoglossi, and sympathetic nerves (partially).

Lymph is received by jugulodigastric, jugulocarotid, juguloomohyoid nodes, and nodes along the internal jugular vein from submandibular and submental nodes, deep parotid nodes, and posterior deep cervical nodes. Lymph passes to supraclavicular nodes.

Muscular Triangle

The boundaries are:

Superior lateral: Anterior belly of omohyoid muscle.
Inferior lateral: Sternocleidomastoid muscle.
Medial: Midline of the neck.
Floor: Sternohyoid and sternothyroid muscle.

Roof: Investing layer of deep fascia, strap muscles, sternohyoid, and cricothyroid muscles.

Contents: Thyroid and parathyroid glands, trachea, esophagus, and sympathetic nerve trunk.

Lymphatic drainage of the triangle will be discussed with the thyroid gland. Remember that occasionally the strap muscles must be cut to facilitate thyroid surgery. They should be cut across the upper third of their length to avoid sacrificing their nerve supply.

The Posterior Cervical Triangle

The posterior cervical triangle is sometimes considered to be two triangles, occipital and subclavian, divided by the posterior belly of the omohyoid muscle; we will treat it as one.

The boundaries of the posterior triangle are:

Anterior: Sternocleidomastoid muscle.
Posterior: Anterior border of trapezius muscle.
Inferior: Clavicle.

Floor: Splenius capitis muscle, levator scapulae muscle, and three scalene muscles.

This muscular floor is covered with investing and prevertebral fascia, between which lie the accessory nerve (XI) and a portion of the external jugular vein.

Deep to the fascia are the cervical nerves, the subclavian vessels and motor nerves to levator scapulae, the rhomboids, the serratus anterior, and the diaphragm.

Roof: Investing layer of the deep cervical fascia.

Contents: Subclavian artery, subclavian vein, cervical nerves, brachial plexus, phrenic nerve, accessory phrenic nerve, spinal accessory nerve, and lymph nodes.

Superficial occipital lymph nodes receive lymph from the occipital region of the scalp and the back of the neck. Efferent vessels pass to deep occipital lymph nodes (usually only one), which drain into deep cervical nodes along the spinal accessory nerve.

Fasciae of the Neck

1. Superficial fascia.
2. Deep fascia.
    a. Investing layer (anterior or superficial layer).
    b. Middle, or pretracheal, layer (in front and below hyoid bone).
    c. Prevertebral layer (posterior or deep layer).

Superficial Fascia

The superficial fascia lies beneath the skin and is composed of loose connective tissue, fat, the platysma muscle, and small unnamed nerves and blood vessels. The surgeon should remember that the cutaneous nerves of the neck and the anterior and external jugular vein are between the platysma and the deep cervical fascia. If these veins are to be cut, they must first be ligated. Because of their attachment to the platysma above and the fascia below, they do not retract; bleeding from them may be serious. For practical purposes, there is no space between this layer and the deep fascia.

Deep Fascia
Investing Layer

This fascia attaches above to the occipital and temporal bones and the mandible, posteriorly to the spines and supraspinous ligaments of the cervical vertebrae, and below to the clavicle, scapula, and manubrium of the sternum. It envelops two muscles, the trapezius and the sternocleidomastoid, and two glands, the parotid and the submaxillary. It forms two spaces, the supraclavicular and suprasternal, and forms the roof of the anterior and posterior cervical triangles.

Pretracheal, or Middle, Layer

The middle layer of the deep fascia splits into an anterior portion that envelops the strap muscles and a posterior layer that envelops the thyroid gland, forming the false capsule of the gland. This layer is fixed to the thyroid and cricoid cartilages above. The attachment to the cartilages may be thickened to form the suspensory ligament of the thyroid gland (ligament of Berry). Posteriorly the layer becomes ill-defined, permitting an enlarging thyroid

gland to extend posteriorly. Anteriorly the middle layer attaches above to the hyoid bone and below to the fibrous pericardium; laterally it contributes to the carotid sheath.

Prevertebral, or Posterior, Layer

This plane lies in front of the prevertebral muscles. It originates from the posterior surface of sternocleidomastoid and, together with the pretracheal fascia, forms the carotid sheath. The fascia divides to form a space in front of the vertebral bodies, the anterior layer being the alar fascia, the posterior layer retaining the designation of prevertebral fascia. Lateral to the carotid sheath, the prevertebral fascia covers the scalene muscles, phrenic nerve, and deep cervical muscles; posteriorly it attaches to the ligamentum nuchae.

The Carotid Sheath

Beneath the sternocleidomastoid muscle, the investing fascia, the pretracheal fascia, and the prevertebral fascia contribute to a fascial tube, the carotid sheath. Within this tube lie the common carotid artery, the internal jugular vein, the vagus nerve, and the deep cervical lymph nodes. The sheath extends from the base of the skull to the root of the neck.

Buccopharyngeal Fascia

This layer covers the lateral and posterior surfaces of the pharynx and binds the pharynx to the alar layer of the prevertebral fascia.

Axillary Fascia

This fascia takes its origin from the prevertebral facia.

Spaces of the Neck

Above the hyoid bone:

1. Intrafascial spaces: body of the mandible, submaxillary, masticator, and parotid spaces.

2. Peripharyngeal spaces: retropharyngeal, lateral pharyngeal, and submandibular spaces.

Below the hyoid bone:

1. Visceral compartment of Stiles.

2. Carotid sheath.

3. Space between prevertebral and alar fasciae, "danger space".

Visceral Compartment

The boundaries of the visceral compartment of the neck are:

Anterior: Pretracheal fascia.
Posterior: Prevertebral fascia.
Lateral: Carotid sheath.
Superior: Hyoid bone and thyroid cartilage.
Posteroinferior: Posterior mediastinum.
Anteroinferior: Bifurcation of the trachea, at the level of the 4th thoracic vertebra.

Contents: Part of esophagus, larynx, trachea, thyroid, and parathyroid glands.

The lower part of the visceral compartment is subdivided into an anterior pretracheal space and a posterior retrovisceral (retroesophageal) space, separated by lateral attachments of the esophagus to the prevertebral fascia. These two spaces are confluent above.

These spaces of the visceral compartment, together with the carotid sheath, are the chief pathways of infection. Pearse (1938) states that of neck infections that spread to the mediastinum, 71 percent spread through the retrovisceral space, 21 percent spread through the carotid sheath, and 8 percent spread through the pretracheal space.

Lymphatics of the Neck

It has been stated that there are about 800 lymph nodes in the human body (Bailey and Love, 1946). Three hundred of these are in the neck. In addition, the neck contains a number of subepithelial lymphoid structures, the tonsils.

Tonsils

The opening between the oral and nasal cavities and the pharynx is guarded by a group of lymphoid structures collectively called the ring of Waldeyer.

Superiorly, on the roof of the nasopharynx, is the pharyngeal tonsil (adenoids). Inferiorly, on the sides of the base of the tongue, are the lingual tonsils. Laterally, the entrance to the pharynx is guarded by the palatine tonsils. There may be a band of superficial lymph nodules, the lateral band, between the pharyngeal and palatine tonsils. These tonsillar organs differ from lymph nodes in that they originate, but do not receive, lymphatic vessels.

Lymph nodes

There is no widespread agreement on the nomenclature of lymph nodes and their division into groups.

Thoracic and Right Lymphatic Ducts

The thoracic duct originates from the cisterna chyli and terminates in the left subclavian vein. It is from 38 to 45 cm long. The duct begins at about the level of the 2d lumbar vertebra from the cisterna chyli or, if the cisterna is absent (about 50 percent), from right and left lumbar lymphatic trunks. It ascends to the right of the midline on the anterior surface of the bodies of the thoracic vertebrae. It crosses the midline between the 7th and 5th thoracic vertebrae to lie on the left side, to the left of the esophagus. It passes behind the great vessels to the level off the 7th cervical vertebra and descends slightly to enter the left subclavian vein. The duct may have multiple entrances to the vein, and one or more of the contributing lymphatic trunks may enter the subclavian or the jugular vein independently. It may be ligated with impunity.

The thoracic duct collects the lymph from the whole of the body below the diaphragm, as well as from the left side of the thorax. Lymph nodes may be present at the caudal end, but there are none along its upward course. Injury to the duct in supraclavicular lymph node dissections results in copious lymphorrhea. Ligation is the answer.

The right lymphatic duct is a variable structure about 1 cm long formed by the right jugular, transverse cervical, internal mammary, and mediastinal lymphatic trunks. If these trunks enter the veins separately, there is no right lymphatic duct. When present, the right lymphatic duct enters the superior surface of the right subclavian vein at its junction with the right internal jugular vein and drains most of the right side of the thorax. It is the remnant of an embryonically symmetrical right and left thoracic duct.

Thyroid Gland: Thyroidectomy

Embryogenesis of the Thyroid Gland

Normal Development

The thyroid gland appears by the end of the third week as an epithelial thickening of the floor of the pharynx at the level of the first pharyngeal pouch. It may be a diverticulum or a solid bud. Cranial growth of the tongue, together with elongation of the embryo, carries the origin of the thyroid gland far cranial to the gland itself. The site of this origin is the foramen cecum of the adult tongue. In some individuals it is not grossly visible.

The thyroid gland remains connected with the foramen cecum by a minute thyroglossal duct that passes through or anterior to the hyoid bone. By the fifth week of gestation, this duct usually becomes fragmented; persistence of any portion is not unusual. Distally the duct may be traced to the pyramidal lobe of the thyroid gland in about half of individuals.

The developing gland, at first an irregular plate, develops two lateral wings connected by the isthmus. Follicles appear during the second month of gestation and increase through the fourth month. Colloid formation and uptake of radioactive iodine begin at about the eleventh week.

An epithelial structure, the ultimobranchial body, is formed from the ventral portions of the fourth and fifth (?) branchial pouches. This structure becomes lost in the developing thyroid gland and its cells becomes dispersed as the C (calcitonin) cells among the thyroid follicles. The ultimobranchial body is the "lateral thyroid" primordium of older writers.

Present evidence suggests that the primary origin of the calcitonin-producing cells of the thyroid gland is the neural crest of the embryo. From the neural crest these cells migrate to the ultimobranchial body and later become part of the thyroid gland. Some authors believe that tumours of these cells account for 6 to 8 percent of thyroid malignancies (apudomas). C cells belong to a group of neural-crest derivatives known as APUD cells, the acronym coming from *a*mine *p*recursor *u*ptake and *d*ecarboxylation. A number of other endocrine-producing cells in the gut and tracheal walls, the pancreas, and the adrenal glands belong to the APUD system.

Abnormal Development

Lingual Thyroid

Occasionally, the thyroid gland is not in the normal cervical position, but lies beneath the epithelium of the tongue at the site of the foramen cecum. Such a lingual thyroid is not "undescended", but rather is abnormally ascended.

The lingual thyroid is usually small but normal and is the only thyroid tissue present. Radioactive iodine scintigraphy will aid in diagnosis and determine the presence of other thyroid tissue in the patient.

A thyroid gland may be found anywhere along the track from the foramen cecum to the normal site. Such "partially descended" glands are rare.

Excision of a lingual thyroid requires care, because the gland will be well-vascularized by the lingual arteries. Total excision is necessary. In one series, 2 out of 12 lingual thyroids were malignant. If no malignancy is reported from frozen sections, the excised tissue may be implanted into the anterior abdominal wall.

Persistent Remnants of the Thyroglossal Duct

The foramen cecum of the tongue and the pyramidal lobe of the thyroid gland are normal remnants of the thyroglossal duct. Between these structures is a very small epithelial tube, usually broken at several places. Occasionally these epithelial fragments hypertrophy, secrete fluid, and form cysts. Drainage or aspiration of these cysts is futile and often results in formation of a fistula, usually infected.

All fragments of the duct, the foramen cecum, and the midportion of the hyoid bone should be removed (Sistrunk procedure). Recurrence of the cyst is the result of failure to remove the entire duct. Failure to remove the central portion of the hyoid bone resulted in 17 percent recurrence in one series of operations.

No nerve, blood vessel, or organ need be injured in this procedure.

Anatomy of the Thyroid Gland

The thyroid gland consists typically of two lobes, a connecting isthmus and an ascending pyramidal lobe. One lobe, usually the right, may be smaller that the other (7 percent) or even be completely absent (1.7 percent). The isthmus is absent in about 10 percent of thyroid glands, and the pyramidal lobe is absent in about 50 percent. A minute epithelial tube or fibrous cord, the thyroglossal duct, almost always extends between the thyroid gland and the foramen cecum of the tongue.

The thyroid gland normally extends from the level of the 5th cervical vertebra to that of the 1st thoracic vertebra. It may lie higher (lingual thyroid) but rarely lower than normal.

The Capsule of Thyroid Gland

Like many other organs, the thyroid gland has a connective-tissue capsule continuous with the septa that makes up the stroma of the organ. This is the *true* capsule of the thyroid.

External to the true capsule is a more or less well developed layer of fascia derived from the pretracheal fascia. This is the *false* capsule, the *perithyroid sheath,* or *surgical capsule.* Anteriorly and laterally this fascia is well-developed; posteriorly it is thin and loose, permitting enlargement of the thyroid gland posteriorly. There is a thickening of the fascia that fixes the back of each lobe to the cricoid cartilage. These thickenings are the ligaments of Berry. The *false* capsule, or fascia, is not removed with the gland at thyroidectomy.

The superior parathyroid glands normally lie between the true capsule of the thyroid and the fascial false capsule. The inferior parathyroids may be between the true and false capsules, within the thyroid parenchyma, or lying on the outer surface of the fascia. The levator muscle of the thyroid is one or more muscular slips that occasionally connect the hyoid bone with the thyroid gland. These vestigial muscles are inconstant in occurrence, location, and innervation. They have been divided into anterior, lateral, and posterior levators.

Arterial Supply of the Thyroid and Parathyroid Glands

The thyroid gland receives more blood per gram of tissue (5.5 m/g per minute) than do most other organs. One consequence is that hemostasis is a major problem of thyroid surgery, especially in patients with toxic goiter. Two paired arteries, the superior and inferior thyroid arteries, and an inconstant midline vessel, the thyroid ima artery, supply the thyroid.

The superior thyroid artery arises from the external carotid artery just above, at, or just below the bifurcation of the common carotid artery. It passes downward and anteriorly to reach the superior pole of the thyroid gland. In part of its course, the artery parallels the superior laryngeal nerve. At the superior pole the artery divides into anterior and posterior branches. The anterior branch anastomoses with the contralateral artery; the posterior branch anastomoses with branches of the inferior thyroid artery. From the posterior branch, a small parathyroid artery passes to the superior parathyroid gland.

The inferior thyroid artery usually arises from the thyrocervical trunk, but in about 15 percent of individuals it arises from the subclavian artery. The inferior thyroid artery ascends

behind the carotid artery and the jugular vein, passing medially and posteriorly on the anterior surface of longus colli muscle. After piercing the prevertebral fascia, the artery divides into two or more branches as it crosses the ascending recurrent laryngeal nerve. The nerve may pass anterior or posterior to the artery, or between its branches. The lowest branch sends a twig to the inferior parathyroid gland and supplies the lower pole of the thyroid gland. The upper branch supplies the posterior surface of the gland, usually anastomosing with a descending branch of the superior thyroid artery. On the right, the inferior thyroid artery is absent in about 2 percent of individuals. On the left, it is absent in about 5 percent. The artery is occasionally double.

The thyroid ima artery is unpaired and inconstant. It arises from the brachiocephalic artery, the right common carotid artery, or the aortic arch. Its frequency has been reported from 1.5 to 12.2 percent. It may be as large as an inferior thyroid artery or be a mere twig. Its position anterior to the trachea makes it important to tracheostomy.

Venous Drainage

veins of the thyroid gland form a plexus of vessels lying in the substance and on the surface of the gland. The plexus is drained by three pairs of veins.

The superior thyroid vein accompanies the superior thyroid artery. Emerging from the superior pole of the thyroid, the vein passes superiorly and laterally across the omohyoid muscle and the common carotid artery to enter the internal jugular vein alone or with the common facial vein.

The middle thyroid vein arises on the lateral surface of the gland at about two-thirds of its antero-posterior extent. No artery accompanies it. It crosses the common carotid artery to open into the internal jugular vein. This vein may be absent and occasionally is double. The extra vein is inferior to the normal one; it has been called the "fourth" thyroid vein. The importance of these middle thyroid veins is in their vulnerability during thyroidectomy.

The inferior thyroid vein is the largest and most variable of the thyroid veins; the right and left sides are usually asymmetric. The right vein leaves the lower border of the thyroid gland, passes anterior to the brachiocephalic artery, and enters the right brachiocephalic vein. The left vein crosses the trachea to enter the left brachiocephalic vein. Rarely, the right vein crosses the trachea to enter the left brachiocephalic vein, sometimes forming a common trunk with the left vein. This common trunk is called the *thyroid ima* vein.

Lymphatic Drainage

Several broad patterns of lymphatic drainage of the thyroid gland have been proposed. Each of them is based on the same facts and each is correct.

Median Superior Drainage

Three to six vessels arise from the superior margin of the isthmus and from the median margin of the lateral lobes. These vessels pass upward in front of the larynx to end in the digastric lymph nodes. Some vessels may enter one or more prelaryngeal ("Delphian")

nodes just above the isthmus. Secondary drainage may be to upper jugular nodes on either side or to pretracheal nodes below the thyroid by a vessel passing from the Delphian nodes downward over the front of the thyroid.

It has been suggested that there is a connection between the superior thyroid lymphatic drainage and the orbit by way of the jugular chain of cervical lymph nodes. In neither the orbit nor the eye itself can lymphatic vessels be demonstrated. The immediate cause of exophthalmus associated with thyroid disease is the enlargement of extraocular muscles, especially the inferior rectus and the inferior oblique. Thyroid antigen or antigen-antibody complexes reaching the eye from the thyroid gland produce an autoimmune response in the extraocular muscles.

Median Inferior Drainage

Several lymph vessels drain the lower part of the isthmus and the lower medial portions of the lateral lobes. They follow the inferior thyroid veins to end in the pretracheal and brachiocephalic nodes.

Right and Left Lateral Drainage

Lymphatic trunks arise from the lateral border of each lobe. Superiorly they pass upward with the superior thyroid artery and vein. Inferiorly they follow the inferior thyroid artery. Between these two groups, some vessels pass laterally, anteriorly, or posteriorly to the carotid sheath to reach lymph nodes of the internal jugular chain. Occasionally, such vessels drain into the right subclavian vein, jugular vein, or thoracic duct without passing through a lymph node.

Posterior Drainage

Posterior lymphatic vessels arise from the inferior and medial surfaces of the lateral lobes to drain into nodes along the recurrent laryngeal nerve. Occasionally, a posterior ascending trunk from the upper part of the lobe reaches the retropharyngeal nodes.

Metastatic Spread

Feind (1972) found metastatic involvement of middle jugular lymph nodes in 85 of 111 specimens from patients with thyroid carcinoma. In 67 of these, lower jugular nodes were positive. Submandibular and mediastinal nodes were rarely affected.

The Thyroid Gland and Recurrent Laryngeal Nerves

In intimate relation to the thyroid gland are the two recurrent laryngeal nerves. The right nerve branches from the vagus as it crosses anterior to the right subclavian artery. The recurrent nerve loops around the artery from posterior to anterior and ascends in or near the tracheoesophageal groove, passing posterior to the right lobe of the thyroid gland to enter the larynx behind the cricothyroid articulation and the inferior corner of the thyroid cartilage.

The left recurrent nerve arises where the aorta crosses the vagus nerve. It loops under the aorta and ascends in the same manner as the right nerve. Both nerves cross the inferior thyroid arteries near the lower border of the middle third of the gland.

Several variations may occur in the course of the recurrent nerves. All serve to increase the liability of injury to the nerve during the thyroid surgery.

In about 1 percent of patients, the right recurrent nerve arises normally from the vagus but passes medially almost directly from its origin to the larynx without looping under the subclavian artery. In these cases, the right subclavian artery arises from the descending aorta and passes to the right behind the esophagus. This anomaly is asymptomatic, and the thyroid surgeon will rarely be aware of it prior to operation. Even less common is a non-recurrent left nerve in the presence of a right aortic arch and a retroesophageal left subclavian artery.

In the lower third of its course, the recurrent laryngeal nerve ascends behind the pretracheal fascia at a slight angle to the tracheoesophageal groove. In the middle third of its course, the nerve may lie in the groove, medial to the suspensory ligament of the thyroid gland (ligament of Berry), within the ligament, or within the substance of the thyroid gland.

We have examined the course of the recurrent laryngeal nerve in 102 cadavers (204 sides). In about half of our specimens, the nerve lay in the tracheoesophageal groove. In the other half, most lay anterior to the groove (paratracheal) and a few lay posterior (paraesophageal). In less than 4 percent the nerve lay within the gland. The nerve is safest and least visible when it lies in the tracheoesophageal groove. It is the most vulnerable when it transverses the thyroid parenchyma. Where it runs in the suspensory ligament of the thyroid, it must be identified and protected before the ligament is divided.

The recurrent laryngeal nerve crosses the inferior thyroid artery at the middle third of the gland. It may lie anterior, posterior, or between the branches of the artery. For practical reasons, there are three major types of crossing. In our series, the right nerve most frequently lay between arterial branches (48 percent); the left nerve was usually behind the artery (64 percent). No one pattern can be considered "normal"; the surgeon must be prepared for any configuration of artery and nerve.

The nonrecurrent nerve may pass directly to the larynx with no relation to the inferior thyroid artery, or such a nerve may loop around the artery.

Exposure of the Laryngeal Nerves

Exposure of the recurrent nerve during any procedure on the thyroid is a sound principle and should be done wherever possible. If the nerve cannot be found readily, the surgeon musty avoid the areas in which it may be hidden.

At one time the recurrent nerve was considered to be so delicate that "if a recurrent laryngeal nerve is seen during thyroidectomy, it is injured" (Prioleu, 1933). At the other extreme are those who would require demonstration of the nerve by direct stimulation during laryngoscopic observation the vocal cords (Riddell, 1970). We believe that visual identification, with avoidance of traction, compression, or stripping the connective tissue, is

all that is necessary. Complete anatomical dissection is not required, but simple exposure will not destroy it.

The recurrent laryngeal nerve forms the medial border of the triangle bounded superiorly by the inferior thyroid artery and laterally by the carotid artery. The nerve may be identified where it enters the larynx just posterior to the inferior cornu of the thyroid cartilage. If the nerve is not found, a nonrecurrent nerve should be suspected, especially on the right.

In the lower portion of its course, the nerve may be palpated as a tight strand over the tracheal surface. There is more connective tissue between the nerve and the trachea on the right than on the left.

The superior laryngeal nerve arises from the inferior ganglion of the vagus nerve just outside of the jugular foramen of the skull. The nerve passes Inferiorly, medial to the carotid artery. At the level of the superior cornu of the hyoid bone it divides into a large, sensory, internal laryngeal branch and a smaller, motor, external laryngeal branch, serving only to cricothyroid muscle. The bifurcation is usually within the bifurcation of the carotid artery.

The internal laryngeal branch is rarely identified by the surgeon - only where there is a greatly enlarged upper pole of the thyroid gland rising above the superior border of the thyroid cartilage.

The external laryngeal branch, together with the superior thyroid vein and artery, passes under the sternothyroid muscles. The nerve then passes beneath the blood vessels into the lower part of the thyropharyngeal muscle to continue Inferiorly and innervate the cricothyroid muscle.

In most patients, the blood vessels lie within the visceral compartment of the neck beneath the pretracheal fascia, while the external laryngeal nerve lies between the fascia and the inferior pharyngeal constrictor muscle. There is thus a plane of dissection between the vessels and the nerve. In about 25 percent of individuals, the nerve lies beneath the fascia together with the vessels.

Anatomical Complications of Thyroidectomy

Vascular Injury

Thyroid arteries must be ligated carefully; the superior thyroid artery tends to retract and fill the field with blood.

The superior thyroid artery should not be clamped above the upper pole of the thyroid because the external laryngeal nerve may be injured. If the artery is clamped at the pole, a branch may escape, with resulting hemorrhage. The entire superior pole, together with the artery, should be clamped and ligated.

Separation of the inferior thyroid artery from the recurrent laryngeal nerve requires care. Where the nerve passes between branches of the artery, the individual branches must

be ligated and divided separately. Retraction of the artery may result in a hasty attempt at hemostasis that will injure the recurrent nerve.

The middle thyroid vein is short and easily torn. If it is divided accidentally, it will retract, making hemostasis difficult. With too much traction on the thyroid gland, the vein becomes flattened and bloodless, being unrecognized until it is severed. The tear is often at the junction of the vein with the jugular vein. This requires immediate repair.

The thoracic duct is rarely injured in thyroidectomy, although injury during radical neck dissection is not unknown. The duct may be ligated with impunity.

Organ Injury

The pleura is rarely injured, but we have records of two patients in whom pneumothorax occurred. In one, a huge toxic goiter extended far laterally; in the other, the thyroid was retrosternal.

Both anteriorly and posteriorly, the two pleurae approach the midline and hence each other. Intrathoracic goiter may descend into the anterior or posterior mediastinum, bringing the thyroid gland close to the pleura.

Trachea and esophagus may be injured in the presence of thyroiditis, calcified adenoma, or malignancy. The true capsule of the thyroid, the pretracheal fascia, the trachea, and the esophagus may be fixed to one another so that vigorous attempts at separation may perforate the trachea. A tracheal perforation may require immediate tracheostomy.

The parathyroid glands are close to the posterior thyroid capsule. With total conservative thyroidectomy, hypocalcemia will occur in 20 to 25 percents of patients. In most of these, the drop in calcium will be small and transitory, perhaps owing to trauma to the glands. It will persist in from 1 to 4 percent. In radical thyroidectomy, the incidence is higher. Preservation of only one parathyroid gland will avoid the symptom of hypoparathyroidism.

Nerves

Most recurrent laryngeal nerve injuries occur "just below that point where the nerve passes under the lower fibers of the inferior constrictor muscle to become intralaryngeal". The usual cause is a hemostatic stitch. Another source of injury is mass ligation of the vessels of the lower pole of the thyroid. Such ligation may include a recurrent nerve more anterior than usual. The nerve should be identified before ligating the inferior thyroid vein. The specific causes of recurrent laryngeal nerve injury have been evaluated by Chang-Chien (1980).

The results of injury to the recurrent laryngeal and the external branch of the superior laryngeal nerves have been outlined by Esmeraldo and coworkers (1977):

1. Unilateral recurrent nerve injury. The affected vocal cord is paramedian owing to adduction by the cricothyroid muscle. Voice is preserved (not unchanged).

2. Unilateral recurrent and superior laryngeal nerve injury. The affected cord is in an intermediate position, resulting in hoarseness and inability to cough. The affected cord will move toward the midline with time. Voice improves, but is followed by narrowing of the airway. Tracheostomy becomes necessary.

Postoperative hoarseness is not always the result of operative injury to laryngeal nerves. From 1 to 2 percent of patients have a paralysed vocal cord prior to thyroid operations. We strongly advise the general surgeon to perform a mirror laryngoscopy prior to thyroidectomy.

We believe that the patient should be told that in spite of all precautions, there is a possibility that there may be some vocal disability following thyroidectomy.

A sympathetic ganglion may be confused with a lymph node and removed when the surgeon operates for metastatic papillary carcinoma of the thyroid. In one of our patients, inferior cervical and first thoracic ganglia were fused to form a nodelike structure that was removed. The surgeon must identify any apparent lymph node related to the vertebral artery and fixed in front of the transverse process of the 7th cervical vertebra.

Injury to the cervical sympathetic nerve results in Horner's syndroma: 1. constriction of the pupil, 2. ptosis of the upper eyelid, 3. apparent enophthalmus, and 4. dilatation of retinal vessels.

Parathyroid Glands: Parathyroidectomy

Embryogenesis of the Parathyroid Glands

Normal Development

The embryonic pharynx in the fifth and sixth weeks of gestation is marked externally by four branchial clefts of ectoderm. Internally there are five branchial pouches of endoderm. These clefts and pouches, together with the branchial arches between, compose the branchial apparatus. Although transitory, the apparatus leaves some normal derivatives: the thyroid and parathyroid glands, the thymus, the ultimobranchial body, the eustachian tube, the middle ear, and external auditory canal. There is also the possibility that some normally transient structures will persist into adulthood.

The parathyroid glands develop as epithelial thickenings of the dorsal endoderm of the third and fourth branchial pouches. As a result of their subsequent migration, the derivatives of the third pouch become the inferior parathyroids, while those of the fourth pouch become the superior parathyroids. Both primordia descend from their level of origin, but parathyroid III is closely associated with the thymus gland derived from the ventral portion of the third pouch. This association usually ends in the eight week, leaving the parathyroid gland near the level of the lower border of the thyroid gland. Occasionally parathyroid III becomes encapsulated with the thymus and may be carried into the mediastinum. This is of no significance to the patient, but it may be frustrating to the surgeon.

Anatomy of the Parathyroid Glands

The parathyroid glands are usually found on the posterior surface of the thyroid gland, each with its own capsule of connective tissue. They are occasionally included in the thyroid capsule, or one of them may even follow a blood vessel deep into a sulcus of the thyroid.

The frequency of such occult glands is not known. Farr and associates (1972) found 10 examples among 100 patients with parathyroid tumors. Few intrathyroid parathyroid glands are discovered in the absence of disease.

Extreme locations are very rare, although glands have been found as high as the bifurcation of the carotid artery and as low as the mediastinum. In practice, the surgeon should start at the point at which the inferior thyroid artery enters the thyroid gland. The superior parathyroid glands will *probably* lie about 1 inch above it, and the inferior parathyroid glands will *probably* lie 1 inch below it. If the inferior gland is not found, it is more likely to be lower than higher.

More or fewer than four parathyroid glands are not uncommon. Where fewer than four glands are found, the possibility of ectopic glands is hard to rule out. Two parathyroid glands may appear fused to one another. Such a pair can be differentiated from a bilobed gland by the presence of a cleavage plane between them.

Blood Supply

The superior parathyroid gland receives blood from a small parathyroid artery that arises from the communicating artery between the superior and inferior thyroid arteries. In the absence of a communicating artery, the parathyroid branch may arise from either the superior or inferior thyroid artery.

The inferior gland is served by an inferior branch of the inferior thyroid artery. The superior gland is thus served by both thyroid arteries, the inferior by only one. An enlarged inferior thyroid artery on one side should suggest the presence of a parathyroid adenoma on that side.

With the ligation of major thyroid arteries for total thyroidectomy, an adequate supply of blood to the parathyroid glands is provided by anastomoses of thyroid vessels with the bronchial, inferior laryngeal, or tracheoesophageal arteries. The last two arteries arise from the thyroid arteries proximal to the ligation.

Strategy for Finding Parathyroid Glands

General surgeons must take specific steps to find the glands, since they cannot explore the entire neck.

Step 1. Explore the superior surface of the thyroid gland. Ligate the middle thyroid vein, retract the lobe medially and anteriorly, and expose the recurrent laryngeal nerve.

Step 2. Dissect the superior mediastinum as far as possible, with special attention to the thymus or its remnant behind the manubrium.

Step 3. Explore the region above the upper pole of the thyroid gland as far as the hyoid bone.

Step 4. Explore the retroesophageal and retropharyngeal space.

Step 5. Perform subtotal thyroidectomy.

Step 6. Further explore the mediastinum at a second operation. This should be done only after the pathology report on thymus and thyroid tissue has been received and no parathyroid tissue is reported.

We believe mediastinal exploration should be the procedure of last resort.

Complications of Parathyroidectomy

The complications of parathyroidectomy are the same as those associated with thyroidectomy and radical neck surgery.

Failure to find an adenomatous gland in the presence of hyperparathyroidism is evidence of inadequate procedure.

Trachea: Tracheostomy

Embryogenesis of the Trachea

Normal Development

At the end of the third week of gestation, the laryngotracheal groove appears on the ventral surface of the upper end of the embryonic foregut. The distal end of the groove grows caudad, while the proximal end and the foregut grow cephalad. The trachea (anterior) and the esophagus (posterior) become separated caudally, and in the fourth week, the lung buds appear at the tip of the tracheal primordium. At first the tracheal bifurcation is high in the cervical region; at birth it will be at the level of the 4th or 5th thoracic vertebra.

Cartilage appears in the trachea and primary bronchi in the tenth week, and glands a week later.

Abnormal Development

The trachea is rarely subject to anomalies. Tracheoesophageal fistula is the only defect frequently encountered. Its repair does not fall into the field of the general surgeon.

Anatomy of the Trachea

The trachea, together with the esophagus and the thyroid gland, lies in the visceral compartment of the neck. The anterior wall of the compartment is composed of sternothyroid and sternohyoid muscles covered anteriorly by the investing layer of the deep cervical fascia and posteriorly by the pretracheal fascia. The trachea begins at the level of the 6th cervical vertebra and its bifurcation is at the level of the 6th thoracic vertebra in the erect position or the 4th to 5th thoracic vertebrae when supine.

Arterial Supply

The chief source of arterial blood to the trachea is the inferior thyroid arteries. At the bifurcation, these descending branches anastomose with ascending branches of the bronchial arteries.

Venous Drainage

Small tracheal veins join the laryngeal vein or empty directly into the left inferior thyroid vein.

Lymphatic Drainage

The pretracheal and paratracheal lymph nodes receive the lymphatic vessels from the trachea.

Nerve Supply

The trachealis muscle and the tracheal mucosa receive fibers from the vagus, recurrent laryngeal nerves, and the sympathetic trunks. Small autonomic ganglia are numerous in the tracheal wall.

Anatomic Landmarks

The usual site of a tracheostomy is between the second and fourth tracheal rings. The structures encountered are as follows.

Skin and Superficial Fascia

The platysma lies in the superficial fascia and is absent in the midline. The anterior jugular veins may lie close to the midline, and more important, they may be united by a jugular venous arch at the level of the seventh to eight tracheal rings.

Investing Layer of Deep Cervical Fascia

The sternohyoid muscle lies between the investing layer and the pretracheal fascia on either side of the midline.

Visceral Compartment under the Pretracheal Fascia

The inferior thyroid veins arise as a venous plexus on the anterior surface of the isthmus of the thyroid gland. Left and right descending veins enter the respective brachiocephalic veins. The two veins may form a common trunk entering the superior cava or the left brachiocephalic vein.

The isthmus of the thyroid gland commonly lies at the level of the second and third tracheal rings. It is often more cranial, less often more caudal. In about 10 percent of individuals, the two lobes of the thyroid are not connected by an isthmus. The isthmus may be retracted upward or downward to reach the trachea, or if necessary, it may be ligated and incised. The possibility of a thyroid ima artery should not be forgotten. A suspensory ligament of the thyroid and a levator thyroid muscle may also be present in or close to the midline.

Complications of Tracheostomy

Bleeding may occur from the following vessels:

1. The anterior jugular veins may be encountered as the investing fascia is incised.

2. The venous thyroid plexus over the thyroid gland drains into the thyroid veins. The inferior thyroid vein is often asymmetric, hence more liable to injury.

3. The branches of the superior and inferior thyroid arteries may anastomose across the midline.

4. A thyroid ima artery is very occasionally present and must be ligated if found.

5. The brachiocephalic artery and vein may be injured if sharp dissection is carried too far downward. The artery may be eroded by a tracheostomy tube, resulting in a tracheoarterial fistula.

6. The subclavian artery and vein may be compromised by a tracheostomy tube that is incorrectly curved or is placed too low.

7. The common carotid artery may be injured in the newborn. Moreover, it has been mistaken for the trachea.

Organ Injury

Esophagus

Injury to the esophagus usually occurs not from an error of perception of the anatomy, but from errors in the use of the tracheostomy tube. It is possible, however, to create an iatrogenic tracheoesophageal fistula by careless manipulation.

Pneumothorax and Pneumomediastinum

See "Radical Neck Dissection".

Recurrent Laryngeal Nerves

Injury to these nerves can occur during tracheostomy as well as during thyroidectomy.

Vocal Cords

Too high a tracheostomy can result in direct injury to the vocal cords. Placement of the tube through the thyrohyoid membrane may also produce vocal cord injury. The stoma should be formed below the first ring.

Posttracheotomy Swallowing Dysfunction

The adverse effect o a cuffed tracheostomy tube on the swallowing mechanism has been studied. Evaluation of the maxillary, glossopharyngeal, recurrent, and external laryngeal nerves revealed that nerve injury was not a factor. The dysfunction was probably produced by inhibition of elevation and anterior rotation of the larynx and failure of the hypopharyngeal sphincter to open completely.

Inadequate Procedures

A proper appreciation of the angle of the trachea to the surface of the neck is important in selecting a tube with the proper curvature. The distal end of a tube with too much curvature will erode the anterior tracheal wall. Roe recommends a curvature of 60 degrees.

Parotid Gland: Parotidectomy

Embryogenesis of the Parotid Gland

Early in the sixth week of development, the parotid duct appears as a solid outgrowth of the oral epithelium. It grows posteriorly, toward the ear, investing the facial nerve (VII) with its branches. The solid cords subsequently become canalized, and the cells at the tips of the branches differentiate into secretory acini. Accessory glandular tissue separated from the main gland is not rare.

Relations of the Parotid Gland

The parotid gland lies beneath the skin in front of and below the ear. It is contained within the investing layer of the deep fascia of the neck, called locally the *parotid fascia.* It is separated from the submandibular gland by a fascial thickening, the stylomandibular ligament.

The parotid gland occupies the parotid space, the boundaries of which are:

Anterior: Masseter muscle, ramus of mandible, and internal pterygoid muscle.
Posterior: Mastoid process, and sternocleidomastoid muscle.
Superior: External auditory meatus, and temporomandibular joint.
Inferior: Sternocleidomastoid muscle, and the posterior belly of digastric muscle.
Lateral: Investing layer of deep cervical fascia, skin, and platysma muscle.
Medial: Investing layer of deep cervical fascia, styloid process, internal jugular vein, internal carotid artery, and pharyngeal wall.

From the anterolateral edge of the gland, the parotid duct (Stensen's) passes lateral to the masseter muscle and turns medial at the anterior margin of the muscle to pierce the buccinator muscle and enters the oral cavity at the level of the upper second molar tooth. Accessory parotid tissue may extend along the duct. A short accessory duct may enter the main duct.

Structures Traversing the Parotid Gland

Facial Nerve

There has long been a controversy about the lobulation of the parotid gland. Two important studies, both appearing in 1956, illustrate the problem. Davis and coworkers (1956) conclude that there is a superficial lobe and a deep lobe of the gland; the branches of the facial nerve run between them. In contrast, Winsten and Ward (1956) visualize the gland as essentially unilobular; the branches of the facial nerve are "intimately enmeshed within the gland tissue", with no cleavage plane between nerve and gland. Beahrs (1977) agrees with the unilobular concept, as does Hollinshead (1968). The view that one may accept does not change the actual surgical procedure.

The main trunk of the facial nerve enters the posterior surface of the parotid gland about 1 cm from its emergence from the skull through the stylomastoid foramen about midway between the angle of the mandible and the cartilaginous ear canal. At birth the child has no mastoid process and the stylomastoid foramen is subcutaneous.

About 1 cm from its entrance into the gland, the facial nerve divides to form five branches: temporal, zygomatic, buccal, mandibular, and cervical. In most individuals, an initial bifurcation forms an upper temporofacial and a lower cervicofacial division, but six major patterns of branching based on a series of simple to complex have been distinguished (Davis et al., 1956).

In general, the nerve and its branches lie in a plane dividing the deep and superficial portions of the gland, but there is no true fascial plane between these portions.

Other Structures Traversing the Parotid Gland

Arteries

The external carotid artery enters the inferior surface of the gland and divides into the maxillary and superficial temporal arteries. The latter gives rise to the transverse facial artery. Each of these branches emerges separately from the superior or anterior surface of the parotid gland.

Veins

The superficial temporal vein enters the superior surface of the parotid gland and receives the middle temporal vein to become the posterior facial vein. Still within the gland, the posterior facial vein divides; the posterior branch joins the posterior auricular vein to form the external jugular vein, while the anterior branch emerges from the gland to enter the common facial vein. Remember, the nerve is superficial, the artery is deep, and the vein lies between them.

Lymphatics

The preauricular lymph nodes in the superficial fascia drain the temporal area of the scalp, upper face, and anterior pinna. Parotid nodes within the gland drain the gland itself, as well as the nasopharynx, nose, palate, middle ear, and external auditory meatus. These nodes, in turn, send lymph to the subparotid nodes and eventually to the nodes of the internal jugular and spinal accessory chains.

Great Auricular Nerve

The great auricular nerve arises from the second and third nerves of the cervical plexus. It reaches the posterior border of the sternocleidomastoid muscle and, on the surface of the parotid gland, follows the course of the external jugular vein. It is sacrificed at parotidectomy. Numbness in the preauricular region, the lower auricle, and the lobe of the ear results from injury to this nerve, but it disappears after 4 to 6 months.

Auriculotemporal Nerve

The auriculotemporal nerve, a branch of the mandibular nerve (V_3), traverses the upper part of the parotid gland and emerges with the superficial temporal blood vessels from the superior surface of the gland. Within the gland, the auriculotemporal nerve communicates with the facial nerve.

The order of the structures from the tragus anteriorly is usually auriculotemporal nerve, superficial temporal artery and vein, and temporal branch of the facial nerve. The auriculotemporal nerve carries sensory fibers from the trigeminal nerve and motor (secretory) fibers from the glossopharyngeal nerve. These motor fibers arise from cell bodies in the otic ganglion.

The Parotid Bed

Complete removal of the parotid gland reveals the following structures; the acronym *VANS* may be helpful in remembering them:

one Vein: Internal jugular
two Arteries: External and internal carotid
four Nerves: Glossopharyngeal (IX), vagus (X), spinal accessory (XI), hypoglossal (XII)
one Styloid process and three muscles: Styloglossus, stylopharyngeus, stylohyoid.

Identification of the Facial Nerve

The main trunk of the facial nerve is within a triangle bounded by the mastoid process, the external auditory meatus, and the angle of the mandible. Beahrs (1977) suggests the following: the lower tip of the mastoid process is palpated and a fingertip is placed on the lateral surface pointing forward. The trunk of the facial nerve will be found deep and anterior to the center o the fingertip.

The styloid process is an unreliable landmark because of variations in its shape and size. Other landmarks for locating the facial nerve have been suggested, e.g., the external auditory canal, and the tympanomastoid suture.

Complications of Parotidectomy

Vascular Injury

The major vessels crossing the parotid bed must be divided and ligated. Bleeding from small vessels may result in hematoma.

Nerve injury

The facial nerve and its branches are obviously in danger during parotidectomy. They can be preserved only by careful observation and awareness of the previously described anatomy. The facial trunk is large enough for anastomosis of the cut ends should this be

necessary. The smaller branches are more usually injured and are much less easily sutured. No repair will completely restore function.

Injury to the auriculotemporal nerve produces Grey's syndrome, in which the skin anterior to the ear sweats during eating ("gustatory sweating").

Submandibular Gland: Excision

Embryogenesis of the Submandibular Gland

The submandibular gland develops from the oral ectoderm toward the end of the sixth weeks, slightly later than the parotid gland. It forms as a solid primordium, becoming canalized later.

Anatomy of the Submandibular Gland

The superficial portion of the submandibular gland is about 4 cm long, lying in the submandibular triangle superficial to the mylohyoid muscle. A tongue of glandular tissue passes deep to the muscle, enveloping its posterior border to form the much smaller, deep portion of the gland.

Important relationships of the superficial portion are (1) the inferior surface is related to the facial vein and the cervical branch of the facial nerve; (2) the lateral surface is related to the facial artery; and (3) the medial surface is related to the submandibular ganglion and the glossopharyngeal, lingual, and hypoglossal nerves. The deep portion of the gland is related to the lingual nerve above and the hypoglossal nerve below.

The submandibular (Wharton's) duct emerges from the middle of the deep portion of the gland, crosses the sublingual space, and opens into the mouth on the side of the frenulum of the tongue. Proximally it lies between mylohyoid and hypoglossus muscles; distally it lies between the genioglossus muscle and the sublingual gland.

The lingual nerve, a branch of the mandibular division of the trigeminal nerve (V_3), has a special relationship to the duct. The nerve lies first above and then lateral, below, medial, and above the duct. The danger of injuring the nerve when sectioning the duct is obvious. The hypoglossal nerve inferior to the duct must also be protected.

Identification and Protection of the Mandibular Branch of the Facial Nerve

In about 50 percent of subjects, the mandibular branch of the facial nerve lies beneath the lower margin of the mandible. In the remainder it lies below the mandible, posterior to the crossing of the facial artery. To avoid injury to this nerve, Martin (1957) suggested that the facial (external maxillary) artery or vein be exposed, sectioned, and ligated well below the edge of the mandible. The distal stump of the vessels is then dissected upward with upward traction so that the nerve is carried upward by the loop of the vessel. The artery and vein may be sutured to the underside of the skin flap. This completely protects the mandibular nerve from subsequent injury. Notice that the nerve is multiple in about 80 percent of individuals.

Complications of Excision of the Submandibular Gland

Vascular Injury

The vessels most frequently injured are the facial (external maxillary) artery and vein. The procedure just outlined will ensure ligation of these vessels before they can be sectioned inadvertently.

Nerve Injury

Facial Nerve, Mandibular Branch

Injury to the mandibular branch of the facial nerve results in a flattening of the lower lip on the affected side. If a nerve stimulator is used to identify the nerve, the anterosuperior portion of the platysma may contract. Depression of the corner of the mouth may also be observed.

Excision of Branchial Cleft and Pouch Remnants

Embryogenesis

Between the fourth and sixth weeks of gestation, the embryonic foregut changes from a flattened tube into a complicated series of structures, some of which represent the primordia of the respiratory apparatus of our aquatic vertebral ancestors. In mammals these structures become rearranged and adapted to new functions, or they disappear, leaving only occasional vestiges.

In other sections of this chapter we have discussed the structures adapted to new functions: the thyroid and parathyroid glands and the ultimobranchial bodies. Here we are concerned with structures that normally disappear during embryonic life. These are the ectodermal clefts and the endodermal pouches of the pharynx.

Of these gill-like organs, only the dorsal portion of the first cleft and first pouch persist - as the external auditory meatus from the former and the middle ear and eustachian tube from the latter.

Anatomy of Branchial Remnants

Fistulas

Fistulas are patent ductlike structures that have both external and internal orifices.

Cervicoaural fistulas extend from the skin at the angle of the jaw and may open into the external auditory canal. These fistulas lie anterior to the facial nerve. They are remnants of the ventral portion of the first branchial cleft.

Lateral cervical fistulas are almost always from the ventral portion off the second branchial cleft and pouch. They originate on the lower third of the neck on the anterior border

of the sternocleidomastoid muscle. The orifice may be pigmented. The path is upward through the platysma muscle and deep fascia. Above the hyoid bone the track turns medially to pass beneath the stylohyoid and the posterior belly of the digastric muscle, in front of the hypoglossal nerve, and between the external and internal carotid arteries. It enters the pharynx on the anterior surface of the upper half of the posterior pillar of the fauces. It may open into the supratonsillar fossa or even the tonsil itself.

Sinuses

External sinuses are blindly ending spaces that extend inward from openings in the skin. *Internal sinuses* are blindly ending spaces that extend outward from openings in the pharynx.

Internal sinuses are usually asymptomatic and hence undetected. External sinuses usually arise at the anterior border of the sternocleidomastoid muscle and end in a cystic dilatation. Many such sinuses result from an infected cyst or previous incomplete excision of a cyst.

Cysts

Cysts are spherical or elongated spaces lying in the track of a branchial pouch or cleft that have no communication with the pharynx or skin.

Superficial cysts lie at the edge of the sternocleidomastoid muscle. Deeper cysts lie on the jugular vein or in the bifurcation of the carotid artery. These are of branchial cleft origin and are lined with stratified squamous epithelium. Cysts on the pharyngeal wall deep to the carotid arteries are usually of branchial cleft origin and are lined with ciliated epithelium unless inflammatory or pressure changes have occurred.

Complications of Excision of Branchial Remnants

Vascular Injury

The following veins must be avoided; if they cannot be avoided they must be ligated: external jugular vein, anterior jugular vein, common facial vein, lingual vein, and internal jugular vein.

The external and internal carotid arteries just above the bifurcation of the common carotid artery are especially exposed to injury, because a second cleft cyst or the path of a second-cleft fistula will lie in the crotch of the bifurcation.

Nerve Injury

A first-cleft sinus or cyst passes over the facial nerve below and anterior to the ear. The cyst may displace the nerve either upward or downward. While removing the cyst, the surgeon must take care to protect the nerve.

Several nerves will be found above the pathway of a second-cleft or pouch branchial fistula:

1. The mandibular and cervical branches of the facial nerve (protection of these nerves is discussed under "Submandibular Gland Excision").

2. The spinal accessory nerve, which may be injured when trying to free a cyst or fistulous tract from the sternocleidomastoid muscle.

3. The ansa hypoglossus, which may be cut with impunity.

4. The hypoglossal nerve (above the bifurcation of the common carotid artery the fistula crosses the nerve).

5. The superior laryngeal nerves.

6. The vagus nerve, which lies parallel to the carotid artery (the fistula crosses the nerve near the level of the carotid bifurcation).

Organ Injury

The pharyngeal opening of a fistula or an internal sinus must be closed without producing a large iatrogenic defect. Remember, you are at or near the tonsillar fossa. Uncontrolled bleeding can be a problem.

Inadequate Procedure

Drainage or aspiration of branchial cysts is useless and will sooner or later result in infection. Removal of all epithelial tissue is the only cure.

Radical Neck Dissection

Definition

A *radical neck dissection* must be planned as a curative procedure. It involves complete excision of the primary lesion, together with all nonessential structures and their lymph nodes, collecting lymph trunks, fascia, and fat. The bed of a radical neck dissection is bounded above by the inferior border of the mandible, below by the clavicle, posteriorly by the anterior border of the trapezius muscle, and anteriorly by the midline.

In addition to lymphatic tissue, which must be removed as completely as possible, nonlymphatic tissue falls into three categories: (1) structures that can be sacrificed with impunity, (2) structures whose sacrifice is controversial, especially for cosmetic reasons, and (3) structures that must be preserved unless directly invaded by cancer.

Anatomical Elements

Superficial Cervical Fascia

The anterior cutaneous nerves and the supraclavicular nerves must be sacrificed. The result is anesthesia of the posterior scalp, neck, and shoulder.

There is disagreement as to the need to sacrifice the platysma muscle. Some would sacrifice the muscle routinely, while others believe that preservation of the muscle minimizes scarring and "that once superficial LYMPHATICS are involved, the carcinoma is so widely disseminated that nothing is gained by further surgical procedures" (Beahrs, 1977).

Deep Cervical Fascia

The deep cervical fascia must be removed as completely as possible, since lymph nodes and lymphatic vessels are largely distributed in the connective tissue between the layers off the fascia. The carotid sheath and the internal jugular vein also should be sacrificed.

Anterior Triangle

1. Submental triangle. Remove the entire contents.

2. Submandibular triangle. Remove the submaxillary gland and lymph nodes.

3. Carotid triangle. Remove the internal jugular vein. High ligation of the vein is facilitated by removal of the lower pole of the parotid gland. The great auricular nerve and all superficial branches of the cervical nerves should be cut. All lymph nodes along the internal jugular vein must be removed.

Posterior Triangle

Remove all tissue above the spinal accessory nerve without injury to the nerve. With blunt dissection, free the nerve from the underlying tissue. Ligate the external jugular vein close to the subclavian vein, and transect the sternocleidomastoid and omohyoid muscles.

The area beneath the spinal accessory nerve is the "danger zone" of Beahrs and contains a number of structures that must be identified: the nerves to rhomboid and serratus muscles, , the brachial plexus, the subclavian artery and vein with the anterior scalene nerve between, and the phrenic nerve. All these should be preserved if possible. The object of dissection in this area is to remove completely the transverse cervical (inferior horizontal) and spinal accessory chains of lymph nodes.

Deep to the sternocleidomastoid muscle and posterolateral to the internal jugular vein, the thoracic duct on the left and the right lymphatic duct on the right lie in a mass of areolar connective tissue. Some lymphatic trunks may open independently into the subclavian or jugular veins. They should be preserved if possible.

Between the jugular vein and the carotid artery lies the ansa cervicalis, which innervates the strap muscles of the neck. This nerve is on or in the carotid sheath medial to the internal jugular vein. It may be cut with impunity.

Complications

Vascular Injury

The vessels injured in a radical neck dissection are, in order of frequency, the internal jugular vein, the thoracic duct, the subclavian vein, and the carotid artery.

Internal and External Jugular Veins

The internal jugular vein should be ligated as close to the subclavian veins as possible. Venous return will then be through the vertebral, pharyngeal, pterygoid, esophageal, deep cervical, and occipital plexus. The most important of these is the vertebral plexus.

Unilateral ligation of external and internal jugular veins produces transient cyanosis and edema of the head. Bilateral ligation or excision must be undertaken with caution. Martin (1957) considers simultaneous bilateral ligation "standard procedure in selected cases", but Zarem (1973) calculates, rom the work of several authors, that there is a 20 percent mortality if ligation of both sides is done simultaneously. He would allow at least 1 month between ligations to permit the vertebral veins to compensate for increased venous flow.

Too much traction on the internal jugular vein may result in a tear at its lower end, which will retract under the clavicle, requiring removal of the midportion of the bone to reach and ligate it.

There is a danger of air embolism through the subclavian, internal jugular, or external jugular veins. Immediate suturing of the veins is mandatory. The actual mortality from air embolism is not known. Pneumothorax and pneumomediastinum also have been reported.

Carotid Artery

A number of individuals will tolerate unilateral obstruction of the carotid artery, but this tolerance cannot always be determined prior to operation. Complete unilateral obstruction of the internal carotid artery carries a 50 percent mortality.

Pressure from manipulation of the carotid sinus at the bifurcation of the carotid artery may result in serious hypotension. If such pressure cannot be avoided, infiltration of the area with Xylocaine is suggested.

Thoracic Duct

The thoracic duct may be safely ligated if it is injured. The number of lymphatic trunks and their inconstant anatomy make it difficult to avoid lymph leakage.

Nerve Injury

Spinal Accessory Nerve (Xi)

Section of the spinal accessory nerve denervates the trapezius muscle, limiting abduction off the arm. Subsequent wasting of the muscle results in a "dropped shoulder". If removal of the nerve is considered unnecessary, it must be protected from injury.

Ramus Mandibularis of the Facial Nerve

The ramus mandibularis of the facial nerve need not be injured if it is identified and protected.

Brachial Plexus

The upper cord of the brachial plexus is most frequently injured when the connective tissue of the retroclavicular space is removed.