Chapter 83: Developmental Anatomy

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Most descriptions of the neck divide the anatomy for discussion purposes into triangles. To the novice student this seems a futile, pedantic exercise in geometry. However, the use of triangles is simply an organizational device that manages the volume of anatomic detail in the neck by parcelling it into reasonable study units. When an incision is made over the carotid triangle, surgeons can thereby predict the structures they will encounter in precise order. Similarly, the embryologic correlates of the triangles are important in understanding the development and differential diagnosis of certain masses in the various triangles of the neck.

This chapter begins with descriptions of the posterior triangle and the subdivisions of the anterior triangle. There is also a description of the root of the neck that relates the anatomy of the two major triangles to the radical neck procedure. The chapter concludes with a discussion of the embryology o the branchial arches and the pharyngeal pouches and their contribution to various masses in the neck.

The term *triangle* initially connotes a planar form, that is, a flat structure. In the neck, however, the triangles are three-dimensional spaces that should be visualized as shallow triangular boxes. These boxes not only have three sides, but also a roof (top) and floor (bottom). The next step is to define the contents of the box. As described shortly, most of the triangles are three-dimensional spaces bounded by bone and muscles, with distinct fascial layers forming the roof and floor of the space. In general terms the triangular space contains blood vessels, nerves, lymphatic vessels, and lymph nodes. With this somewhat contrived schema, one can greatly simplify the organizational problems of the neck anatomy.

Posterior Triangle

The posterior triangle is bordered by the sternocleidomastoid muscle, the anterior border of the trapezius muscle, and the middle third of the clavicle (Fig. 83-1). Specific layers of deep fascia form the floor (medial wall) and roof (lateral wall) of the triangle. An understanding of the fascial relationships in the neck is important, not only because of the boundary relationships, but also because fasciae form planes that provide routes of surgical access or pathways for hemorrhage and abscess formation. For this reason a brief discussion of the fascial planes is necessary before proceeding with the anatomy of the posterior triangle.

Fascia of neck

One of the earliest lessons in anatomy is that there are two types of fascia in the body: the superficial fascia and the deep fascia. In the region of the abdominal wall, superficial fascia consists of two layers: a fatty layer (Camper's) and a deeper, membranous layer (Scarpa's). The deep fascial layer of the abdominal wall is not subdivided but simply envelopes the abdominal muscles. In the neck the superficial fascia is very thin and is not divided into layers, whereas the deep fascia is divided into three layers (Grodinsky and Holyoke, 1938). The names of these layers vary with different authors, resulting in a somewhat chaotic terminology. Regardless of the terminology used, the divisions are arbitrary at best. A simple approach can provide a workable solution for either the anatomist or the surgeon.

Superficial layer of cervical fascia

As just noted, the superficial layer of cervical fascia is a single layer of fascia underlying the skin. It is usually thin, except in the obese individual, in which case it is thickened by adipose tissue. Its primary surgical significance is that it provides a fascial pad that protects underlying structures when a skin incision is made. In exceptionally lean individuals, however, the paucity of this layer may not protect underlying structures, such as the accessory nerve, so the surgeon should be wary when operating on such individuals.

Deep fascia

The deep fascia is divided into three layers, illustrated best when the neck is viewed in cross section (Fig. 83-2). These are the external, middle, and internal layers of deep fascia. The external layer of deep fascia underlies the platysma muscle and completely invests or encircles all of the superficial neck structures. For these reasons the external layer is also known as the superficial layer, or investing layer, of deep fascia. In the region of the sternocleidomastoid and trapezius muscles, it splits and envelopes the individual muscles.

A middle layer of fascia encloses the visceral structures of the neck (the trachea and esophagus); hence the synonym for the middle layer is the *visceral fascia.*

The third, or internal, layer of deep fascia surrounds the deep muscles of the neck and cervical vertebrae (Fig. 83-3). This layer is known by its descriptive term, the *prevertebral fascia* (although *paravertebral fascia* would have been a more appropriate term). The muscles enclosed by the prevertebral fascia include (1) the deep muscles of the neck (cervical part of erector spinae); (2) the levator scapulae; (3) the scalenus anterior, middle, and posterior muscles; and (4) the longus colli and longus capitis muscles, which lie on the anterior aspect of the cervical vertebrae. The latter pair of muscles serves as flexors of the vertebrae and, in the case of the longus capitis, assists in flexion of the skull. The scalenus group underlies the prevertebral fascia in the region of transverse processes of the cervical vertebrae. The anterior tubercles of the transverse processes provide origin for the scalenus anterior muscle, whereas the posterior tubercles provide the origin for the scalenus medius and posterior muscles. Continuing posteriorly, in order, are the levator scapulae and deep cervical muscles already noted.

The internal layer of deep fascia is described by some authors as enveloping the carotid and jugular vessels. Hence the carotid sheaths are included as part of the definition of the internal layer of deep fascia. An effective means of visualizing the spatial relationships of these layers of fascia is to examine a cross section of the neck. This view not only is informative in defining the three layers of deep fascia but also serves to relate them to the posterior triangle of the neck (Fig. 83-2). If one places a finger over the middle of the posterior triangle - that is, between the trapezius and sternocleidomastoid muscle - one sees that the roof (lateral wall) of the triangle is formed by the superficial layer of deep fascia. Palpation deeper into the triangle brings the tip of the finger into contact with the prevertebral fascia that forms the floor of the posterior triangle and invests the prevertebral muscles. If the superficial layer of the deep fascia is incised and a finger inserted into the space exploring anteriorly between the sternocleidomastoid and prevertebral muscles, one encounters the carotid sheath. This is a surgical approach to the retropharyngeal area or to the carotid vessels for vascular surgery.

Contents of posterior triangle

The major contents of the posterior triangle are the cutaneous branches of the cervical plexus, the accessory nerve (cranial nerve XI), two arterial branches of the thyrocervical trunk, and an abundant number of lymph nodes associated with the veins of the region.

Cutaneous branches of cervical plexus

The sensory branches of the cervical plexus contained within the posterior triangle are four cutaneous nerves, which supply the skin of the head and neck from the area of the posterior scalp to the supraclavicular region. These are (1) the lesser occipital nerve, (2) the great auricular nerve, (3) the anterior cutaneous nerve of the neck, and (4) the supraclavicular nerves (Fig. 83-4). The first three of these nerves contain cervical segments C2 and C3 and the supraclavicular nerves C3 and C4. The topographic relations of these nerves and their distribution to the skin are illustrated in Fig. 83-5. The important landmark for the cervical nerves is the accessory nerve at the point where it enters the posterior triangle from under the cover of the sternocleidomastoid muscle. If this point is viewed as the center of a clock's face, the cervical nerves mimic the hands pointing in different directions (inset, Fig. 83-4). For instance, on the right side the lesser occipital nerve is approximately at the 11 o'clock position, the greater auricular is at the 12 o'clock position, and the anterior cutaneous nerve of the neck can be found at the 3 o'clock position. The supraclavicular nerves consist of three or four bundles of filaments scattered between the 5 and 7 o'clock positions on the clock's face. Continuing this analogy, the accessory nerve can be seen to traverse the posterior triangle along the line of the 8 o'clock position until it enters the deep surface of the trapezius muscle. The accessory nerve serves in this manner as a focus for organizing the pathways of the cutaneous nerves as well as for emphasizing the eleventh nerve (cranial nerve XI) as a motor nerve in the posterior triangle.

Accessory nerve

The accessory nerve supplies both the sternocleidomastoid and trapezius muscles; however, in the posterior triangle the only fibers remaining in the nerve are those destined for the trapezius. The accessory nerve should be preserved whenever possible because paralysis of the trapezius muscle produces devastating effects on shoulder joint function. The range of shoulder abduction is diminished by at least 50% when scapular rotation is impaired because of a trapezius palsy.

The accessory nerve is the only motor nerve in the posterior triangle as just defined. However, if the prevertebral fascia is incised, it is possible to encounter the motor nerves of the deep cervical muscles, the phrenic nerve, or the brachial plexus. In regard to its innervation of the sternocleidomastoid and trapezius muscles, cranial nerve XI is in fact a spinal nerve. Cell bodies of motor neurons innervating these muscles lie near the ventral horn in the upper cervical spinal cord, in the region of segments C2 thorugh C4. The axonal fibers exit the anterior lateral portion of the cord as a series of fine filaments before becoming bundled as a nerve fiber within the subarachnoid space of the vertebral canal. The nerve ascends in the subarachnoid space, enters the posterior fossa through the foramen magnum, and joins with the cranial root of the accessory nerve before exiting the skull via the jugular foramen. As the nerve descends the neck adjacent to the carotid sheath, motor or sensory filaments may join the nerve directly from segments C2 through C4 (Haymaker and Woodhall, 1953). After crossing the deep surface of the sternocleidomastoid muscle, the nerve enters the posterior triangle, as already described.

Arterial branches

The major arteries of the posterior triangle are the suprascapular and transverse cervical arteries, located in the supraclavicular fossa near the base of the triangle. They are derived from the thyrocervical trunk of the subclavian artery at the medial border of the scalenus anterior muscle and cross the muscle and the fossa transversely to course deep to the sternocleidomastoid muscle. Ascending and descending branches of the transverse cervical artery are usually described. The descending branch is of interest because it divides into a superficial branch that parallels the accessory nerve and a deep branch that parallels the nerve to the rhomboid muscle. The suprascapular artery, after crossing the fossa, is directed toward the suprascapular notch, where it supplies the posterior scapular muscle.

In addition to transverse cervical and suprascapular veins that parallel the course of the arteries, the posterior triangle contains the external jugular vein. It enters the triangle after crossing the superficial aspect of the sternocleidomastoid muscle in company with the great auricular nerve. The vein courses inferior to the base of the supraclavicular fossa, where it may anastomose with small vessels before entering the subclavian vein near the junction with the internal jugular vein.

Anterior Triangle of Neck

The anterior triangle of the neck is complementary to the posterior triangle and is bounded by the sternocleidomastoid muscle, the body of the mandible, and the midline of the neck. This space can be further subdivided into smaller triangular units, such as the submandibular triangle, described in Chapter 56, and the carotid and muscular triangles, which are included in this discussion (see Fig. 83-1).

Carotid triangle

The carotid triangle is bordered by the posterior belly of the digastric muscle, the superior belly of the omohyoid muscle, and the midportion of the sternocleidomastoid muscle. The roof (lateral wall) of the carotid triangle is bounded by the superficial layer of deep fascia, whereas the floor (medial wall) is formed by the prevertebral fascia of the vertebral column and the visceral fascia covering the pharynx and larynx. The contents of the carotid triangle are the carotid sheath structures. These include the common carotid with its internal and external branches, the last four cranial nerves (cranial nerves IX, X, XII, and XII), and the ansa cervicalis. In the carotid triangle only a small branch of cranial nerve IX is left to supply the carotid sinus, since its main portion let the sheath to enter the posterior third of the tongue. Cranial nerve XI, which is also in the upper portion of the carotid sheath, enters the sternocleidomastoid muscle at the apex of the carotid triangle, where the posterior belly of the digastric crosses the sternocleidomastoid muscle. The vagus nerve travels the entire length o the carotid sheath between the internal jugular vein and the carotid artery. Whereas the cranial nerves just mentioned lie in the posterior aspect of the carotid sheath, cranial nerve XII lies on the anterior aspect of the carotid sheath. At the level of the hyoid bone, cranial nerve XII courses anteroinferiorly to pass deep to the posterior belly of the digastric onto the surface of the hyoglossus muscle before entering the substance of the tongue.

The major focal point of the triangle is the bifurcation of the common carotid artery (Fig. 83-6). The internal carotid artery ascends the neck without branching. The external carotid artery provides several branches, many of which are important landmarks. The external carotid artery has anterior branches, posterior branches, and terminal branches.

Three anterior branches are common. In ascending order they are the superior thyroid, lingual, and facial arteries. In some individuals the lingual and facial arteries form a common lingual-facial trunk. Another important variation is the origin of the superior thyroid from the common carotid rather than the external carotid. The latter variation is important, since the external carotid is occasionally ligated (chronic epistaxis) at its origin from the common carotid. If the superior thyroid artery is used as a landmark in patients with this particular anatomic variation, it is possible to ligate the common carotid inadvertently instead of the external carotid.

The posterior branches of the external carotid are occipital and posterior auricular. The occipital is noteworthy for its small sternocleidomastoid branch, which supplies the sternocleidomastoid muscle. The origin of this small artery hooks cranial nerve XII as it courses anteroinferiorly and prevents it from ascending further in the neck. Thus the sternocleidomastoid artery can be used to trace the position of cranial nerve XII. Similarly, the sternocleidomastoid artery enters its muscle near the point of cranial nerve XI, thus also providing a means of locating the accessory nerve.

Ansa cervicalis

The ansa cervicalis is part of the cervical plexus. Its essential role is to supply the inrahyoid muscles: the sternohyoid, sternothyroid, and omohyoid muscles (Fig. 83-7). C1 fibers, which descend the neck, enter the hypoglossal nerve and travel as far as the occipital artery. At this point the hypoglossal nerve curves anteroinferiorly, but C1 fibers descend the neck to form the branch of cranial nerve XII, termed the *superior root of the ansa.* Fibers from C2 and C3 form an inferior root, which descends the carotid sheath on the surface of the internal jugular vein before turning anteroinferiorly to join the superior root. The ansa, or "loop", is thus formed by the union of the two roots of the ansa. Three muscles are supplied directly by the ansa: the sternohyoid, sternothyroid, and omohyoid. At the origin of the superior root of the ansa, some C1 fibers do not follow the superior root but rather continue in the hypoglossal nerve transversely across the neck, before leaving cranial nerve XII to supply either the thyrohyoid muscle or the geniohyoid muscle (Fig. 83-7). In summary, all four of the infrahyoid, hyoid, or "strap" muscles are supplied by the ansa. In addition, one suprahyoid muscle, the geniohyoid muscle, is also supplied by the C1 fibers that have continued in route with the hypoglossal nerve. Except for proprioceptive fibers carried within the ansa, it is a motor nerve.

At this point in the discussion, two major groups of nerves of the cervical plexus have been discussed: the ansa cervicalis, principally motor; and the sensory, or cutaneous, branches of the posterior triangle. Two other groups of fibers comprise the cervical plexus. One is composed of motor filaments from cervical roots 3 and 4 supplying the levator scapulae muscle and located deep to the prevertebral fascia. The other is the phrenic nerve, derived from cervical segments C3, C4, and occasionally C5. This nerve not only is motor to the diaphragm but also supplies sensory fibers to the region of the central tendon of the diaphragm.

Root of Neck

The boundaries of the root of the neck are somewhat ill defined. The base of it is the plane of the thoracic inlet and can be traced from the manubrium laterally along the first ribs and then posterosuperiorly to the transverse process of C6 (Fig. 83-8). It contains the neck viscera and vessels. For the purposes of this chapter it is divided unilaterally by the midline into a pyramidal space - bounded laterally by the scalenus anterior muscle, inferiorly by the first rib, and medially by the tracheoesophageal tract and midline. The contents include the great vessels emerging from the mediastinum, principally subclavian and common carotid arteries, brachiocephalic vein, vagus, and sympathetic trunk. As the great vessels traverse the thoracic inlet from the mediastinum, their course is divided by the scalenus anterior muscle. The subclavian vein crosses anterior to the muscle, whereas the subclavian artery courses between the cleavage plane of the scalenus anterior and scalenus medius muscles. In this region the subclavian vessels usually divide into three parts: the first part proximal to the scalenus, the second part posterior to the scalenus anterior muscle, and the third between the lateral border of the scalenus and the lateral edge of the first rib.

The majority of the vascular branches arise from the first portion of the subclavian artery. The first branch of the subclavian artery is normally the vertebral artery, which ascends the root of the neck between the scalenus anterior and longus colli muscles to enter the foramen processus transversus of C6. The next is the thyrocervical trunk, which normally has four described branches. The first is a small ascending cervical, which supplies the prevertebral muscle region. The second branch of the thyrocervical trunk is the inferior thyroid artery coursing to the inferior pole of the thyroid gland. The third and fourth branches are the transverse cervical artery and the suprascapular artery, already described in relation to the posterior triangle of the neck.

Two branches arise from the inferior surface of the subclavian artery: the costocervical trunk and the internal thoracic artery, which descends over the suprapleural fascia into the mediastinum and anterior chest wall. There are multiple variations of these vessels; for details one should consult Daseler and Anson (1959). Other important relationships of this region are the major nerves. On the right side the vagus nerve lies in the posterior aspect of the carotid sheath and gives off its recurrent laryngeal branch at the level of the first rib. The recurrent branch circles the lateral aspect of the subclavian artery to cross medially and enter the tracheoesophageal groove.

On the left side, the recurrent nerve arises from the vagus at the aortic arch and hooks posteriorly around the ligamentum arteriosum. It enters the tracheoesophageal groove, ascending the mediastinum and neck until it enters the larynx at the level of the cricoid cartilage.

In the most posterior part of the root of the neck, against the longus colli muscle, the sympathetic trunk ascends from the mediastinum following the prevertebral space to the level of C2, where the superior cervical sympathetic ganglion is located. The inferior cervical ganglion lies close to the level of C7, and sometimes a middle sympathetic ganglion is described at approximately the level of C4.

This region is of particular importance during radical neck surgery, since the deep dissection is usually begun by detaching the sternocleidomastoid muscle from its attachments to the manubrium and clavicle. This exposes the carotid sheath and its contents and opens up the posterior and anterior triangles. As the dissection proceeds, the internal jugular vein is mobilized, exposing the carotid and its branches, which have been left in place. Since the en bloc mass of the internal jugular vein and sternocleidomastoid muscle is mobilized superiorly, it is important to leave the prevertebral fascia intact. In this manner it provides a protective veil over the brachial plexus, phrenic nerve, sympathetic trunk, and motor nerves to the deep cervical muscles. When the prevertebral fascia is exposed, two muscles - the scalenus anterior and the longus capitis - serve as important landmarks for the spinal nerves. As the nerves emerge from the intervertebral foramina, they lie in a groove on the transverse process of the cervical vertebrae. If the vertebrae and prevertebral muscles are envisioned as being enclosed in a cylinder of prevertebral fascia, the logical conclusion is that the spinal nerves must penetrate this fascia to reach superficial structures in the neck (Fig. 83-3). With these guidelines it is possible to identify cervical nerves C1 through C4 at the lateral border of the longus capitis, and the roots of C5 through T1 can be identified at the lateral edge of the scalenus anterior (Fig. 83-8).

At this point in the radical neck dissection, the cutaneous nerves of the posterior triangle are encountered at their origin from the spinal nerves, and the surgeon has returned to the anatomic relationships of the posterior triangle, which began this chapter.

Lymphatic Drainage of Head and Neck

Earlier in this chapter the fascia of the neck was described as having outer, middle, and inner layers. This same rule might be applied to the lymphatic drainage of the head and neck. This plan is similar to one described by Last (1978). The superficial layer might be thought of as an outer circle o superficial or regional lymph nodes, the middle layer as a visceral layer of nodes draining the viscera of the neck such as the larynx and pharynx, and the deep circle of nodes composed of the paired carotid sheaths containing the internal jugular vein and deep cervical lymph nodes. The deep cervical lymph nodes are tributaries for both the superficial and visceral circles of lymph nodes.

Superficial lymph nodes

The superficial nodes may be thought of as a circle of nodes beginning on the face and extending posteriorly to the occipital area of the scalp. The efferent lymphatics of these nodes drain inferiorly along the major veins of the face and scalp. On the anterior face, buccal nodes in the cheek and facial nodes along the path of the facial vein drain inferiorly across the mandible, into the submandibular triangle, and to submandibular nodes. Inferior to the mandible the superficial circle is composed of submandibular and anterior cervical lymph nodes. Sublingual nodes adjacent to the tongue receive afferent lymphatics from the anterior part of the face, particularly the lower lip and tip of tongue, and then drain superficially on the neck to deep cervical nodes approximately at the level of the omohyoid. The lymphatics from these nodes then enter the plexus of lymphatics in the carotid sheath, follow the internal jugular vein, and connect with other deep cervical nodes.

In the more posterior portion of the face (in the region of the parotid), afferent lymphatics begin in the scalp along the path of the superficial temporal vessels and drain inferiorly to parotid nodes in the superficial aspect of the parotid gland. Efferent lymphatics from parotid nodes course inferiorly along the common facial vein and thence to deep cervical nodes. Posterior to the ear, retroauricular nodes and occipital nodes follow their major channels to the deep cervical nodes of the internal jugular vein.

The general rule is that the more anterior regions of the face have a more rapid lymphatic drainage to the lower portion of the neck because there is a sparser chain of nodes to traverse before entering the deep cervical nodes. In contrast, the deeper and more posterior portions of the face usually have a more complicated chain of lymphatic nodes and channels and thus require more time before reaching the jugular lymph chain.

Deep cervical lymph nodes

The deep cervical lymph nodes are a series of nodes that parallel the course of the internal jugular vein from the base of the skull to its terminus at the brachiocephalic junction. Most of the nodes are closely associated with the vein within the carotid sheath and lie deep to the sternocleidomastoid muscle. Two particular areas are notable. One is the region where the posterior belly of the digastric crosses the internal jugular; it is usually the site of one or more palpable lymph nodes, which are termed the *jugulodigastric nodes.* Similarly, another large node or series of small nodes exists at the junction of the superior belly of the omohyoid and sternocleidomastoid muscles, which are termed the *jugulo-omohyoid nodes.* Efferent lymphatics from the deep nodes enter the internal jugular trunks, which ultimately enter the venous system at the jugulosubclavian angle.

Lymphatic Drainage of Pharynx and Larynx

The upper portion of the pharynx, the nasopharynx, drains directly to the upper cervical lymph nodes along the jugular chain. The oropharynx and particularly the tonsil drain through the parapharyngeal spaces to the region of the midportion of the jugular and particularly the jugulodigastric nodes. Some books describe the jugulodigastric nodes as the "tonsillar node". The region of the hypopharynx and larynx drains principally along the vascular pedicles of the hypopharynx and larynx. The upper portion of the larynx from the false cord drains along the superior laryngeal vessels to deep cervical nodes on the internal jugular vein near the bifurcation of the common carotid artery. The lower half of the larynx (from the true cords inferiorly) drains along the interior laryngeal vessels to nodes about the pretracheal region and eventually to deep nodes near the base of the internal jugular vein.

Embryology of Head and Neck

The development of many structures in the head and neck is intimately related to either the branchial arches or the pharyngeal pouches (Fig. 83-9). These are transient embryonic structures that undergo substantial remodelling so that their original embryonic form is essentially unrecognized in the adult. The derivatives of these structures, nevertheless, are important to adult morphology; hence, aberrations in branchial arch development may produce significant malformations of adult anatomy.

Embryology of Branchial Arches

At 5 weeks of age the area of the future face and neck of the embryo consists of five or six pairs of fingerlike masses of tissue named the *branchial arches.* Prominent in lateral profile (Fig. 83-9), these masses are aligned transversely to the plane of the neck and are separated by clefts termed the *branchial clefts.* The surface of the arches and clefts is lined by ectoderm, with mesodermally defined tissues contained within the branchial arches. The tissues underlying the region of the clefts are thin because of the close approximation of out-pouchings from the foregut region, called *pharyngeal pouches* (Fig. 83-9). The derivatives of the arches and pouches are different because of the embryonic germ layers contained within the branchial arch (the mesoderm), whereas the pharyngeal pouches are composed of endoderm. Because of the difference in the embryonic germ layers, one can generalize by stating that in the adult the derivatives of the branchial arch will be structures composed of muscle, bone, or similar mesodermal derivatives, whereas the derivatives of the endodermal pharyngeal pouch will be glandular or associated with the digestive tract.

Derivatives of Branchial Arches

In the early phase of branchial arch development the mesodermal mass of the arch forms a bar of cartilage, which remodels into bone, cartilage, or other connective tissue elements in the adult. Similarly, the adult musculature of the face and neck also develops from the mesoderm of the arches. The development of these is considered separately.

Skeletal derivatives of branchial arches

First branchial arch. The proximal part of the first arch cartilage (Meckel's) is remodeled and contributes to the formation of the ramus of the mandible (Fig. 83-10). The distal part of the cartilage withers, and the body of the mandible is formed from intramembranous bone. Other structures formed by the proximal part of the cartilage are the sphenomandibular ligament, anterior malleolar ligament, malleus (except the manubrium, which is from the second arch), and the incus (except for its long process, which is from the second arch).

Second branchial arch. The cartilage element in the second branchial arch forms bony structures proximally and distally, but its central portion withers, leaving a fibrous band - the stylohyoid ligament - in the adult. Proximally it forms the styloid process, manubrium of the malleus, long process of the incus, and stapes, except for the foot plate, which is mostly derived from the otic capsule (Anson and Donaldson, 1973; Shambaugh, 1967). Distally (anteroinferiorly) the second arch cartilage forms a portion of the body of the hyoid and the lesser cornu of the hyoid bone. In the adult one can trace the path of the embryonic second arch cartilage from the styloid process, to the stylohyoid ligament, ending at the lesser cornu of the hyoid bone (Fig. 83-10).

Third branchial arch. The remaining portions of the hyoid bone - that is, the body and greater cornu - are formed by cartilage elements derived from the third branchial arch.

Fourth through sixth branchial arches. The cartilaginous elements of the fourth, fifth, and sixt arches contribute to the formation of the thyroid, cricoid, arytenoid, corniculate, and cuneiform laryngeal cartilages.

Muscle derivatives of branchial arches

First branchial arch. The muscles formed by mesodermal elements in the first arch include the muscles of mastication: the temporalis, masseter, and medial and lateral pterygoid muscles. In addition, the tensor tympani, tensor veli palatini, anterior belly of the digastric, and mylohyoid muscles are also derived from first arch mesoderm.

Second branchial arch. Muscles formed from mesoderm of the second arch include all of the muscles of facial expression from the region of the scalp inferiorly to the platysma muscle in the neck. In addition to those muscles, grouped as the muscles of facial expression, the posterior belly of the digastric, the stylohyoid, and the stapedius muscles are also derived from second arch mesoderm.

Third branchial arch. Only one muscle is formed from mesoderm in the third arch. This is the stylopharyngeus muscle, a small muscle that aids in elevating the pharynx during swallowing.

Fourth through sixth branchial arches. The muscles of the fourth, fifth, and sixth arches include the muscles that form the pharynx and larynx. Pharyngeal muscles include the superior, middle, and inferior constrictor muscles. In addition, the mesodermal elements from these branchial arches also form the striated muscle composing the upper half of the esophagus. The inferior part of the esophagus is usually composed of smooth muscle derived from the splanchnic mesoderm of the primitive foregut.

The muscles of the larynx are also formed from mesodermal elements in the fourth, fifth, and sixth arches. These include the extrinsic muscle of the larynx, the cricothyroid, as well as all of the intrinsic muscles associated with movement of the arytenoid cartilage and true and false vocal folds.

Innervation of branchial arches

Because of the proximity of the developing branchial arches to the brain stem, each branchial arch receives motor or sensory innervation from an adjacent cranial nerve. A comparable parallel to this pattern occurs in the trunk, where a muscle is derived from the myotome region of a somite and receives its innervation from the adjacent segmental spinal nerve. In both cases, regardless of where the primordial muscle cell migrates, it retains its primary embryonic innervation. After each arch receives its cranial nerve innervation, then the adult pattern is established regardless of its future migration onto the back of head or base of the neck.

Innervation of first branchial arch. The nerve of the first arch is the trigeminal nerve, which supplies motor innervation to all the muscles derived from the first arch. In addition, sensory innervation is provided not only over the region of the mandible via the third division of the trigeminal, but also over the maxillary process of the first arch and the frontal nasal process via the second and first divisions of the trigeminal nerve.

Innervation of second branchial arch. The nerve of the second branchial arch is the facial nerve, which supplies motor innervation to all of the muscles derived from this mesoderm. Other than a small sensory branch of cranial nerve VII, which may supply part of the external auditory meatus, there is no sensory distribution of cranial nerve VII to ectoderm.

Innervation of third branchial arch. Cranial nerve IX supplies the single muscle derived from the third arch - the stylopharyngeus muscle; however, as will be seen in the next section, it also supplies sensory innervation to parts of the pharynx associated with this region.

Innervation of third through sixth branchial arches. The vagus nerve and the cranial part of the accessory nerve supply the muscles derived from arches three through six. Originating in the nucleus ambiguus of the medulla, the axonal processes of these nerves descend in the vagus nerve after exiting the skull via the jugular foramen. Specifically the pharyngeal constrictors are supplied by the pharyngeal branch of the vagus and the transitional portion of the pharynx and esophagus via its recurrent laryngeal branch. In addition, the superior laryngeal and recurrent laryngeal nerves supply the muscles and mucosa of the larynx.

Embryology of pharyngeal pouches

The pharyngeal pouches are lateral out-pouchings of the foregut or region of the primitive pharynx (Fig. 83-9). At the extreme lateral wall of each pharyngeal pouch the endodermal lining contacts the ectodermal epithelium of a branchial cleft (Fig. 83-11). Thus the branchial clefts are named in relation to the pharyngeal pouch with which they are apposed. The endodermal epithelium lining either the branchial arch or the pharyngeal pouch contributes to the formation of specific elements of the pharynx in the adult (Langman, 1981).

First pharyngeal pouch

The first pharyngeal pouch becomes elongated and incorporated into the temporal bone and forms the epithelial lining of the middle ear (Fig. 83-12). The most lateral portion of the pouch along with the first closing plate of the first branchial cleft forms the tympanic membrane (Fig. 83-12). From this relationship it is clear that the external auditory canal is nothing more than a remodeling of the first branchial cleft (Fig. 83-13).

Second branchial pouch

The endodermal layer of the second pharyngeal pouch forms the epithelial lining of the palatine tonsil, whereas underlying mesenchymal elements contribute to the formation of the tonsillar tissue itself (see Fig. 83-12 and 83-13).

Third pharyngeal pouch

The region of the third pharyngeal pouch is subdivided into superior and inferior portions. The superior portion forms cells that eventually differentiate into the inferior parathyroid (see Fig. 83-12). The inferior portion of the third pouch forms thymic tissue, which eventually migrates in the neck and mediastinum to form the thymus (see Fig. 83-14).

Fourth through sixth pharyngeal pouches

The endoderm of the fourth pouch forms the superior parathyroid. The adjacent area is variably named as the fifth or sixth pouch or the ultimobranchial body (Fig. 83-13). Subsequently, the ultimobranchial body is infiltrated by cells migrating from the neural crest region. These cells are eventually incorporated into the thyroid gland and become the parafollicular cells (C cells) responsible for the secretion of calcitonin (Pearse and Carvalheira, 1967; Pearse and Polak, 1971).

Branchial clefts and branchial cysts, sinuses, and fistulae

The first branchial cleft becomes part of the external auditory canal, but the remaining branchial clefts are remodeled and normally do not form derivatives identifiable in the adult. However, the complicated morphodynamics of the branchial arch region seem to predispose this area to various abnormalities, varying from minor cysts to major orofacial malformations.

Abnormalities of first branchial cleft

Aberrant development of the first branchial cleft may lead to the formation of a cervical cyst or sinus in the region of the ear. Work (1972) and Aronsohn et al (1976) emphasized the difference in the embryogenesis of preauricular cysts versus cysts of the first branchial cleft. Preauricular cysts occur anterior to the external auditory canal in the region of the tragus. In essence, they are inclusion cysts related to the fusion of the ectodermal hillocks on the first and second branchial arches during formation of the auricle (Minkowitz and Minkowitz, 1964).

In contrast, true branchial cleft abnormalities are duplications of the membranous part of the external auditory canal, and they present clinically as cysts, sinuses, and so forth. Work (1972) has classified these into two types: type I, of ectodermal origin, involving only the membranous part of the canal; and type II, involving both ectoderm and mesoderm, since there is also duplication of cartilage. As cystic masses or sinus tracts they may involve the parotid nerve and cranial nerve VII (this particularly true of type II) or lie inferior to the ear on the superficial neck.

Abnormalities of second through fourth branchial clefts

During closure of the cervical sinus lying between the second branchial arch and the epipericardial ridge, ectoderm may become trapped, resulting in an inclusion cyst at a later time (see Figs. 83-12 and 83-13). These are the more familiar branchial cysts or sinuses, which lie on the lateral neck anterior to the sternocleidomastoid muscle. As such, they may overlie the carotid or muscular triangles of the neck. The fistulous forms of these abnormalities are surgically challenging, because they may extend from the superficial area of the neck near the clavicle superiorly to the bed of the palatine tonsil. The course of the tract through the deep part of the neck usually lies between the internal and external arteries. The pathway of this tract is easily explained on an embryologic basis. The medial wall of the cervical sinus is the region of closing plates 2 to 4 (see Fig. 83-12). A fistulous pathway breaking through into the pharynx will penetrate one of these closing plates and thus enter either into the tonsillar bed (the second) or the thyrohyoid membrane (third), or between the cricoid and thyroid cartilages (fourth).