Anatomy of the Airway: An Overview

Ronald C. Auvenshine, DDS, PhD[a,b,c,*]

KEYWORDS

• Airway • Larynx • Pharynx • Anatomy

The adult human supralaryngeal vocal tract must be viewed from a phylogenetic and a growth and development perspective. As man has assumed an upright position, variations have evolved that make the anatomy of humans different from the anatomy of close ancestors and other mammals. The face, eyes, maxilla, and mandible have migrated inferiorly and posteriorly, creating a short face or splanchnocranium. The splanchnocranium is composed of the mandible, palate, ethmoid, maxilla, and sphenoid bones, as well as a narrow supralaryngeal vocal tract and a more posterior oropharyngeal tongue, along with a descended larynx and shortened soft palate with the loss of an epiglottic–soft palate lockup. These anatomic features have allowed man the ability to speak and to develop language (**Box 1**).[1]

EMBRYOLOGIC DEVELOPMENT OF THE SUPRALARYNGEAL VOCAL TRACT

The head and neck are formed by pharyngeal (branchial) arches. These arches appear in the fourth and fifth weeks of development and contribute to the characteristic external appearance of the embryo. In humans, there are 5 pairs of arches. These arches correspond in numbers I, II, III, IV, and VI. The pharyngeal arches consist of bars of mesenchymal tissue separated by pharyngeal pouches or clefts. Each arch has its own outer covering of ectoderm, an inner covering of endoderm, and a core of mesenchyme derived from paraxial and lateral plate mesoderm cells and neural crest cells. Each arch contains its own artery, cranial nerve, muscle component, and cartilage bar or skeletal element (**Fig. 1**, **Table 1**). During the fourth and fifth weeks of development, outpocketings appear in the lateral wall of the pharyngeal gut. These outpocketings are referred to as pharyngeal pouches. The pouches penetrate the surrounding mesenchyme but do not establish open communication with the external clefts (**Fig. 2**).

Each of the pharyngeal pouches gives rise to an adult structure. The first pouch becomes the tympanic cavity and auditory (eustachian) tube. The second pouch gives rise to the palatine tonsils. The third pouch forms the thymus gland and inferior parathyroid glands, and the fourth pouch forms the superior parathyroid glands. The thymus and parathyroid glands migrate to their final position. The thyroid gland forms as a midline, ventral, endodermal invagination in the floor of the pharynx. Its point of invagination is marked in the adult by the foramen cecum on the upper surface of the tongue. This primordium of the thyroid gland elongates after its evagination, detaches from the pharyngeal endoderm, and finally migrates to its definitive location just inferior and ventral to the larynx.[2]

The tongue appears in embryos at approximately 4 weeks. It is formed by 2 lateral lingual swellings and 1 medial swelling (the tuberculum impar). These 3 swellings develop from the first pharyngeal arch. A second medial swelling, the copula, is formed by mesoderm of the second,

[a] Private practice, Temporomandibular Disorder and Orofacial Pain, 7505 South Main, Suite 210, Houston, TX 77030, USA
[b] Temporomandibular Disorder/Orofacial Pain Clinic, Veterans Affairs Hospital, 2002 Holcombe Boulevard, Houston, TX 77030-4298, USA
[c] Department of Restorative Dentistry and Biomaterials, University of Texas Health Science Center Dental Branch, 6516 John Freeman Street, Houston, TX 77030, USA
* Temporomandibular Disorder/Orofacial Pain Clinic, Veterans Affairs Hospital, 2002 Holcombe Boulevard, Houston, TX 77030-4298.
E-mail address: auvenshine244@pol.net

Sleep Med Clin 5 (2010) 45–57
doi:10.1016/j.jsmc.2009.09.001
1556-407X/10/$ – see front matter

sleep.theclinics.com

Box 1
Anatomic changes that facilitate speech

Short maxilla and mandible
Short ethmoid and palate
Anterior foramen magnum
Acute cranial base angulation
Oropharyngeal tongue
Descended larynx
Shortened soft palate
Loss of epiglottic–soft palate lockup
Narrow, distensible supralaryngeal vocal tract

Data from Davidson TM. The great leap forward: the anatomic basis for the acquisition of speech and obstructive sleep apnea. Sleep Med 2003;4:186.

third, and fourth arches. The third medial swelling that is formed by the posterior part of the fourth arch marks the development of the epiglottis. Immediately behind this swelling is the laryngeal orifice. The laryngeal orifice is completed posteriorly by the arytenoid swellings (**Fig. 3**).[2]

The lateral lingual swellings increase in size and begin to overgrow the tuberculum impar. As a result, the anterior two-thirds of the tongue, or body of the tongue, is composed of the merging 2 lateral lingual swellings and the disappearance of the tuberculum impar. The mucosa covering the tongue originates from the first pharyngeal arch; therefore, the sensory innervation is from the mandibular branch of the trigeminal nerve. The sulcus terminalis separates the posterior one-third of the tongue from the anterior two-thirds of the tongue. Because the posterior one-third of the tongue originates from the second and third arches and part of the fourth pharyngeal arch, the sensory innervation is supplied by the glossopharyngeal nerve and pharyngeal plexus.

The epiglottis and extreme posterior part of the tongue are innervated by the superior laryngeal nerve in keeping with their development from the fourth pharyngeal arch. The muscles of the tongue develop from myoblasts originating in occipital somites. Therefore, the tongue musculature is innervated by the hypoglossal nerve. The chorda tympani branch of the facial nerve provides special sensory innervation (taste) to the body of the tongue.[3]

The hard palate is made up of fusion of the primary palate, which is derived from the intermaxillary segment and the 2 shelflike outgrowths of the maxillary processes (palatine shelves). These palatal shelves appear in the sixth week of development and are positioned on each side below the developing tongue. Between the seventh and eighth week of development, the tongue moves inferiorly between the 2 shelves, allowing the lateral shelves to fuse, forming the secondary palate (**Fig. 4**). The most reliable explanation for the mechanism by which the tongue drops between the palatine shelves is that the mouth first opens in the human embryo at seven and a half weeks.[4,5] The movement provided by mouth opening is necessary for the development of the temporomandibular joint.[6] The process by which a joint space is created is called cavitation.[7]

GROWTH AND DEVELOPMENT

According to Enlow, "morphogenesis works constantly toward a state of composite, architectonic balance among all the separate growing

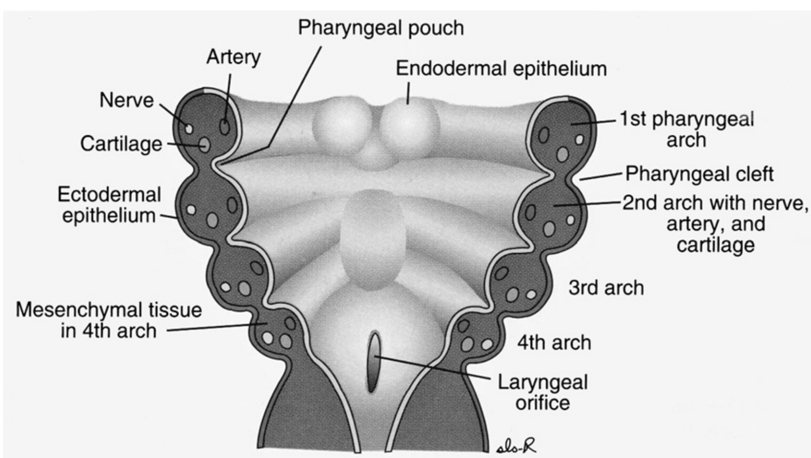

Fig. 1. Pharyngeal arches. (*From* Sadler TW. Langman's medical embryology. 8th edition. Baltimore (MD): Lippincott Williams & Wilkins; 2000. p. 351; with permission.)

Table 1
Derivatives of the pharyngeal arches and their innervation

Pharyngeal Arch	Nerve	Muscles	Skeleton
1 Mandibular	V. Trigeminal mandibular division	Mastication (temporal, masseter, medial, lateral pterygoids); mylohyoid; anterior; tensor palatine; tensor tympani	Quadrate cartilage; incus; Meckel cartilage; malleus; anterior ligament of melleus; sphenomandibular ligament; portion of mandible
2 Hyoid	VII. Facial	Facial expression (buccinator, auricularis, frontalis, platysma, orbicularis oris, orbicularis oculi); posterior belly of digastric; stylohyoid; stapedius	Stapes; styloid process; stylohyoid ligament; lesser horn and upper portion of body of hyoid bone
3	IX. Glossopharyngeal	Stylopharyngeus	Greater horn and lower portion of body of hyoid bone
4–6	X. Vagus Superior laryngeal branch (nerve to fourth arch) Recurrent laryngeal branch (nerve to sixth arch)	Cricothyroid; levator palatini; constrictors of pharynx Intrinsic muscles of larynx	Laryngeal cartilages (thyroid, cricoid, arytenoids, corniculate, cuneiform)

Data from Sadler TW. Langman's medical embryology. 8th edition. Baltimore (MD): Lippincott Williams & Wilkins; 2000. p. 348.

parts. This means that the various parts developmentally merge into a functional whole, with each part complimenting the others as they all grow and function together. During development, balance is continuously transient and can never actually be achieved because growth itself constantly creates ongoing, normal, regional imbalances."[8]

Enlow and Hans[8] state, "The facial and pharyngeal airway is a space determined by the multitude of separate parts comprising its enclosing walls. The configuration and dimensions of the airway are thus a product of the composite growth and development of the many hard and soft tissues along its pathway from the nares to the glottis. Although determined by surrounding parts, both parts in turn are dependent on the airway for maintenance of their own functional and anatomic positions. If there develops any regional childhood variations along the course of the airway that significantly alters its configuration or size, then growth proceeds along a different course, leading to variation in overall facial asymmetry that may exceed the bounds of normal pattern. The airway functions, in a real sense, as a keystone for the face."[9]

According to Enlow, the major but mutually interrelated form/functional components involved in the development are the brain and brain cranium, airway, and oral region. Each has its own separate timetable of development even though all are interrelated as a whole.

During later childhood and into adolescents, vertical nasal enlargement keeps pace with the growing body and lung size. Dental and other oral components approach adult sizes and configuration. The mandibular arch is lowered by the increasing vertical ramus length. Overall, the early wide face of the infant has become altered and in proportion by later vertical changes, leading more to the adult configuration of an elongated face (**Fig. 5**).

DIFFERENCES BETWEEN INFANT AND ADULT LARYNX

The infant larynx is more inferior. The cricoid cartilage is approximate to C3 and C4 but not C6. The epiglottis is longer, stiffer, and further away from the anterior pharyngeal wall. The narrowest portion is the cricoid cartilage, not the vocal cords. The tongue is relatively larger compared with that

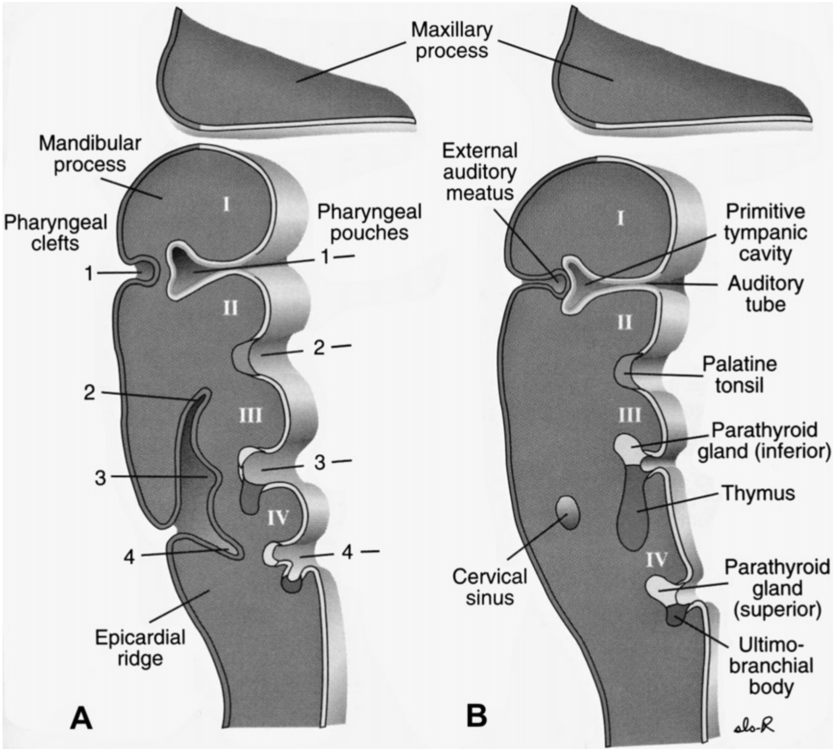

Fig. 2. Pharyngeal pouches (*A*, *B*). (*From* Sadler TW. Langman's medical embryology. 8th edition. Baltimore (MD): Lippincott Williams & Wilkins; 2000. p. 355; with permission.)

of the adult. Other differences include a more rostral larynx, angled vocal cords, differently shaped epiglottis, and funnel-shaped larynx, the narrowest part of which is the cricoid cartilage, not the vocal cords.[10]

KLINORYNCHY

Klinorynchy is described as the posterior migration of the facial skeleton under the brain case.[1] According to Barsh's[9] studies, the maxilla and other facial bones, along with the mandible, moved posteriorly and rotated downwardly. This posterior migration caused the pharynx to become compressed. To preserve the pharynx for respiration and deglutition, the mandible and maxilla, along with the ethmoid and palate, became shortened.[9] Evidence of this change is seen within the teeth also. The narrowing of the dental arches in the maxilla and the mandible has been proved by

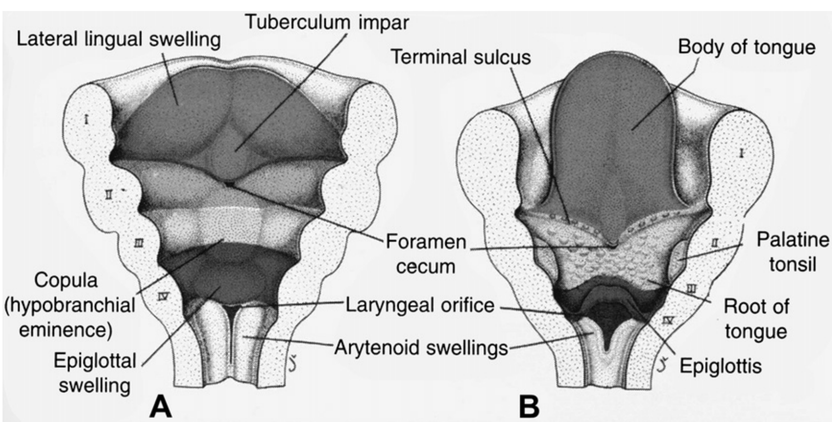

Fig. 3. Development of the tongue (*A*, *B*). (*From* Sadler TW. Langman's medical embryology. 8th edition. Baltimore (MD): Lippincott Williams & Wilkins; 2000. p. 363; with permission.)

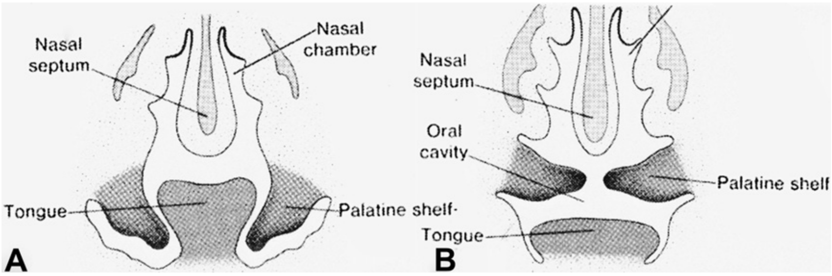

Fig. 4. (*A*) Frontal section through head at 6.5 weeks. Tongue is between palatine shelves. (*B*) Frontal section through head at 7.5 weeks. Tongue is below palatine shelves. (*From* Sadler TW. Langman's medical embryology. 8th edition. Baltimore (MD): Lippincott Williams & Wilkins; 2000. p. 371–72; with permission.)

the fact that man is the only primate with impacted third molars. The narrowing of the dental arches anterior-posteriorly with expansion laterally has resulted in the shortening of the oral cavity and has contributed to the narrowing of the pharynx. Crelin[11] notes that man is the only animal whose tongue resides partially in the pharynx. In all other animals, the tongue resides exclusively in the oral cavity. The human oral cavity is smaller than that of similar-sized primates, yet the tongue remains approximately the same volume. Therefore, according to Negus, the tongue is oversized and has pushed the larynx inferiorly. The tongue now protrudes into the oropharynx. Although in most animals the tongue is flat, the tongue of man is curvilinear and folds posteriorly and inferiorly (**Fig. 6**).[9,12]

Throughout the animal kingdom, there seems to be an overlap that exists between the soft palate and epiglottis. This is referred to as lockup. Man is the only animal that, in the adult form, has lost this epiglottic–soft palate lockup. This is because of laryngeal descent and shortening of the soft palate.[1]

The anatomy of human newborns and infants closely approximates the anatomy of the upper respiratory tract of primates. The close approximation and locking of the uvula and epiglottis allow for simultaneous suckling of milk and breathing (**Fig. 7**). However, the notion that infants can breath air and swallow liquid simultaneously has been challenged by several research studies.[10] Sensation of nasal airflow has been documented during nonfeeding and feeding swallows in term and preterm infants. However, the differences in relationship between anatomic structures and swallowing physiology suggest that the infant swallow must be viewed as distinct and not as a miniature adult swallow.

At approximately 18 months of development, the human infant experiences an anatomic change in the supralaryngeal vocal tract. The laryngeal complex migrates from its original subcranial

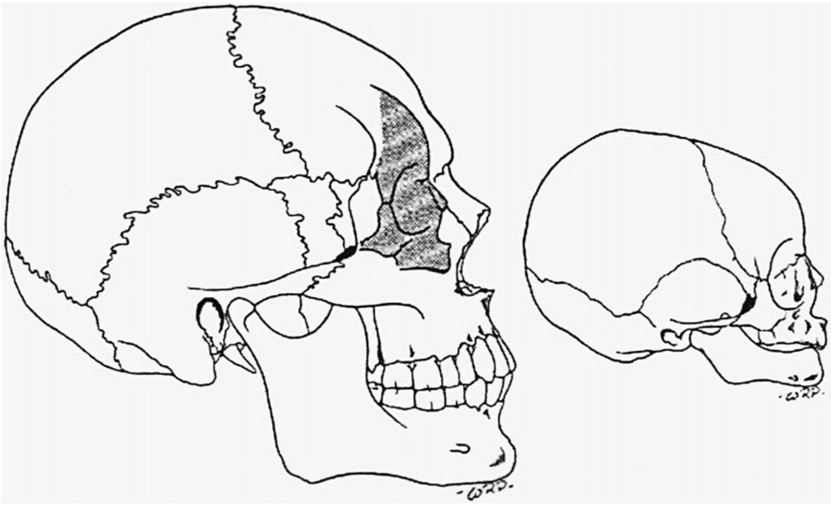

Fig. 5. Facial growth. (*From* Enlow DH, Hans MG. Essentials of facial growth. 2nd edition. Ann Arbor (MI): Needham Press; 2008. p. 30; with permission.)

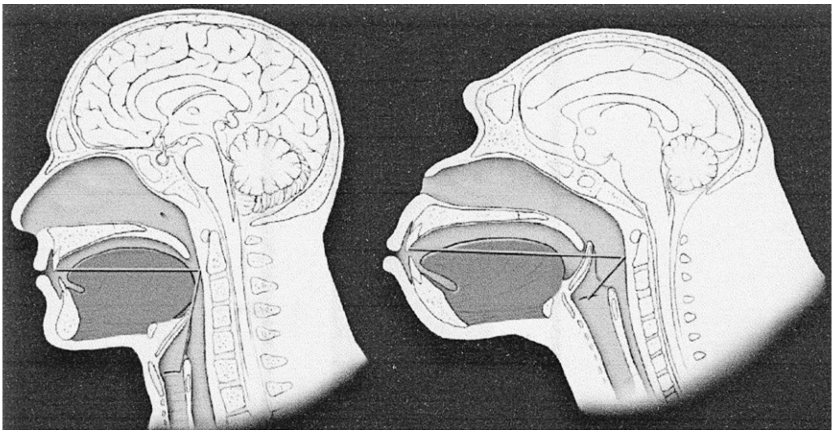

Fig. 6. Oropharyngeal tongue and oropharynx of human compared with oral tongue and palate lockup of chimpanzee. (*From* Davidson TM. The great leap forward; the anatomic basis for the acquisition of speech and obstructive sleep apnea. Sleep Med 2003;4:192; with permission.)

position to a more descended position. This leads to a gradual separation of the uvula from the epiglottis, and the interdigitation or lock is lost. In the mature human, however, the anterior wall of the respiratory tube is breached throughout the extended length of the newly developed oropharynx. The development of a wide, soft-walled oropharyngeal structure has an advantage in providing a resonating chamber in which the basis of human speech can be generated.

STRUCTURAL OVERVIEW OF THE PHARYNX

The pharynx is a fibromuscular, funnel-shaped tube, which is approximately 15 cm long. It serves as a common passageway for air and food. It extends from the base of the skull superiorly to the esophagus inferiorly.[13] The pharynx is divided into 3 parts: (1) the nasopharynx, posterior to the nasal cavity and superior to the soft palate, (2) the oropharynx, posterior to the oral cavity, between the palate and the hyoid bone, and (3) the laryngopharynx, posterior to the larynx, from the hyoid bone to the inferior border of the cricoid cartilage. The pharynx is widest opposite the hyoid bone and narrowest at its inferior end, where it is continuous with the esophagus posteriorly (**Fig. 8**).

Divisions of the Pharynx

Nasopharynx

The nasopharynx extends from the base of the skull to the soft palate. Except inferiorly, where it is bound by the soft palate, the nasopharynx has rigid walls and hence is continually patent under normal conditions. Superiorly, it is formed by the body of the sphenoid bone and the basilar part of the occipital bone. The body wall extends as far as the pharyngeal tubercle. Below this, the wall is formed by the pharyngobasilar fascia that overlies the anterior arch of the atlas. The cervical vertebrae form the posterior boundary of the nasopharynx. Inferiorly, the nasopharynx is continuous with the oropharynx. Pharyngeal openings of the eustachian tube are situated on the lateral walls of the nasopharynx, just posterior to the inferior turbinate. The posterior wall contains a condensation of lymphoid tissue, the pharyngeal tonsils. Just posterior to the auditory tube is an elevation, which separates the tube from the fairly deep fossa, the pharyngeal recess.

The soft palate can be considered as a partial floor for the anterior part of the nasopharynx. This flexible structure is attached to the posterior part of the hard palate and laterally to the walls of the pharynx. It extends into the cavity of the pharynx. A midline structure, the uvula, projects further posteriorly than the rest of the soft palate.[14]

Oropharynx

The oropharynx extends from the plane of the hard palate superiorly to the level of the valleculae (also the level of the hyoid bone). The oropharynx communicates with the nasopharynx above and the laryngopharynx below. It is continuous with the oral cavity through the oropharyngeal isthmus, that is, the boundary between the oral cavity and the oropharynx.

The most prominent structure seen in the oropharynx is the base of the tongue. The epiglottis is also obvious, but it is in the laryngeal portion of the pharynx. A fold tissue extends inferiorly from the sides of the soft palate to blend with the sides of the walls of the pharynx. This fold covers the palatopharyngeus muscle and

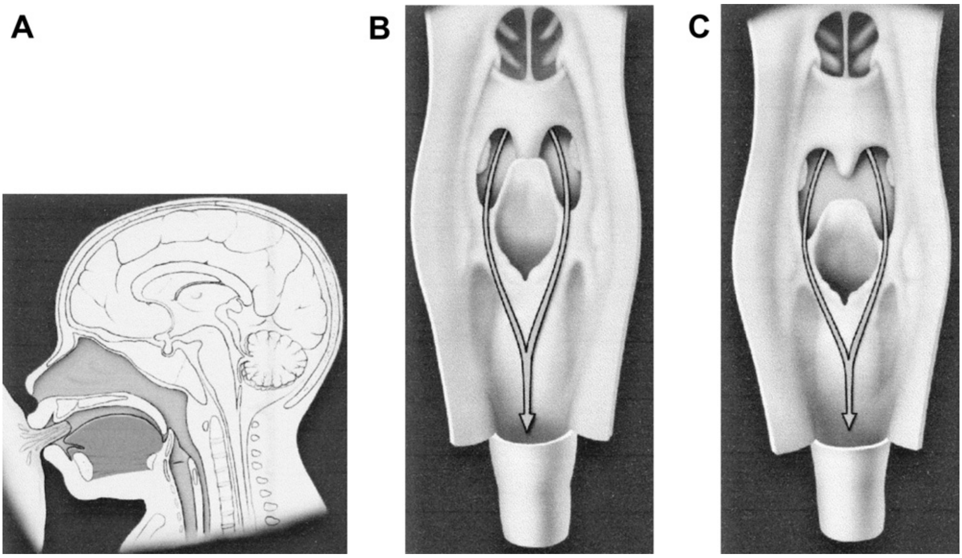

Fig. 7. (*A*) Infant epiglottic–soft palate lockup. (*B*) Epiglottic–soft palate lockup as viewed from the posterior pharynx. In human infants, the epiglottis overlaps the soft palate and food is diverted laterally around the epiglottis. Swallowing and respiration can occur simultaneously. (*C*) In human adults, the larynx is descended, the soft palate is shortened, and the epiglottic–soft palate lockup is lost. (*From* Davidson TM. The great leap forward: the anatomic basis for the acquisition of speech and obstructive sleep apnea. Sleep Med 2003;4: 189; with permission.)

takes the same name. Another pair of folds, palatoglossal, is located anterior to the palatopharyngeal folds and contains muscles of the same name. These 2 folds form an arch, which is clinically referred to as the palatine arch. Two important structures, the palatine tonsils, are located in the tonsilar fossa between the palatoglossus and palatopharyngeous muscle. Blood supply to the palatine tonsil is contributed by branches of the ascending pharyngeal branch of the external carotid artery from the lesser palatine branches of the maxillary artery and from the dorsal lingual artery and also by the ascending palatine and tonsilar branches of the facial artery.[14]

Laryngopharynx

The laryngopharynx is a region of the pharynx that lies behind the larynx and is continuous with the oropharynx above and the esophagus below. This part of the pharynx decreases rapidly in size from superior to inferior. The opening of the larynx is bounded anteriorly and superiorly by the upper portion of the epiglottis, laterally by the aryepiglottic folds and posteriorly by the elevation of the arytenoid cartilages. Below the opening of the larynx, the anterior wall of the laryngopharynx is formed by the posterior surfaces of the arytenoid cartilages and the posterior plate of the cricoid cartilage. The pyriform recess is situated on each side of the larynx. It is bounded laterally by the thyroid cartilage. The pyriform recess extends from the lateral pharyngoepiglottic fold to the upper portion of the esophagus. The superior laryngeal nerve lies deep to the mucosal fold in the lateral wall of the pyriform recess.

The pyriform recess is a fairly deep hollow between the arytenoid cartilages and aryepiglottic folds medially. The recess is situated on each side of the larynx.

The Pharyngeal Wall

The pharyngeal wall is composed of 4 layers: (1) a mucosa that is composed of ciliated columnar epithelium in the nasopharynx and stratified columnar epithelium in the oropharynx and laryngopharynx, (2) a fibrous layer, which forms the pharyngobasilar fascia and is attached superiorly to the skull, (3) a muscular layer composed of inner longitudinal and outer circular parts, and (4) a loose connective tissue layer that forms the buccopharyngeal fascia. The buccopharyngeal fascia is continuous with the epimysium (deep surface) of the pharyngeal muscles, and it contains the pharyngeal plexus of nerves and veins.

Pharyngeal Musculature

The muscles of the pharynx are

1. Superior constrictor
2. Middle constrictor

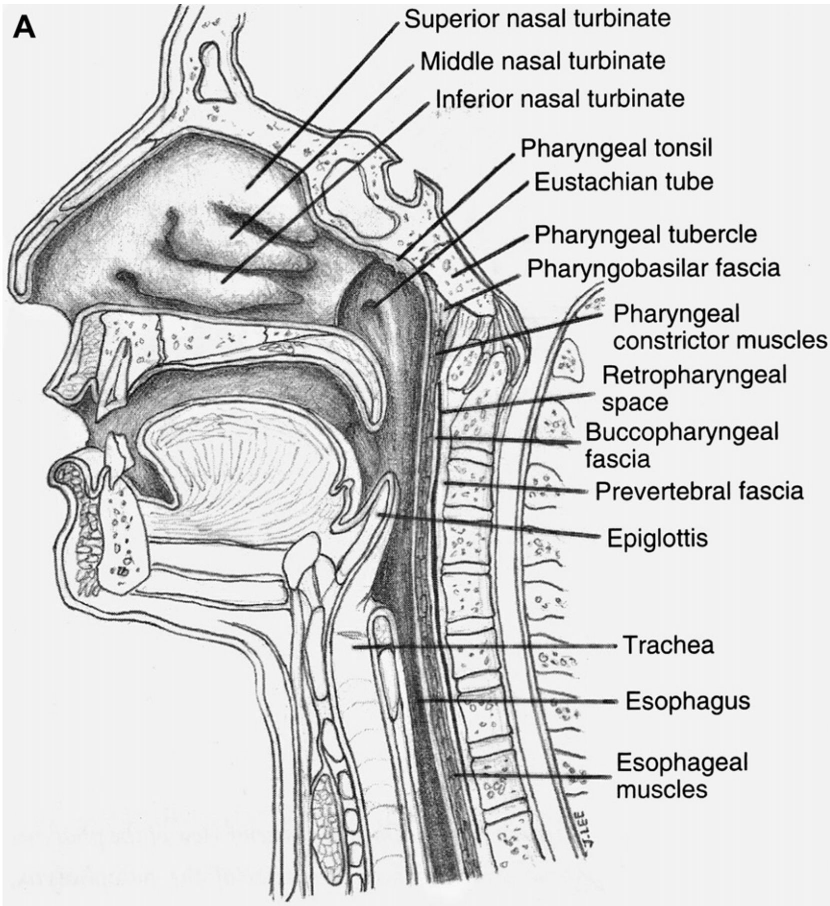

Fig. 8. (*A*) Sagittal view of pharynx. (*B*) Opened posterior view of pharynx otolaryngology. (*From* Van De Water TR, Staecker H. Otolaryngology. New York: Thieme; 2006. p. 554 (A), 553 (B); with permission.)

3. Inferior constrictor
4. Stylopharyngeus
5. Salpingopharyngeus
6. Palatopharyngeus.

The superior constrictor muscle arises from the posterior border of the lower part of the medial pterygoid plate, the pterygoid hamulus, the pterygomandibular raphe, the posterior part of the mylohyoid line of the mandible, and by fibers from the side of the tongue (**Fig. 9**). The fibers of the superior constrictor pass backward in a broad sheet and are inserted into the median raphe. The interval between the superior border of the muscle and the base of the skull is closed by fascia.

The middle constrictor muscle arises from the whole length of the superior border of the greater horn of the hyoid bone, from the lesser horn, and from the inferior end of the stylohyoid ligament. The fibers branch exteriorly to be inserted into the median raphe. As they spread downward from the greater horn of the hyoid bone, they form a fan-shaped sheath to their insertion.

The inferior constrictor, the thickest of the constrictor muscles, is composed of 2 parts: thyropharyngeus and cricopharyngeus. The thyropharyngeus part of the inferior constrictor arises from the oblique line of the thyroid cartilage, from the tendinous band across the cricothyroid muscle, from the lateral surface of the cricoid cartilage at the upper edge of the tendinous band, and from the inferior horn of the thyroid cartilage. The cricopharyngeus portion of the inferior constrictor rises from the side of the cricoid cartilage. The fibers run horizontally and posteriorly, encircling the junction between the pharynx and esophagus to insert on the opposite side of the cricoid cartilage. The cricopharyngeus fibers are continuous with the circular fibers of the esophagus and are believed to act as a sphincter, regulating material entering the esophagus.

Human pharyngeal constrictor muscles appear to be organized into functional fiber layers, as

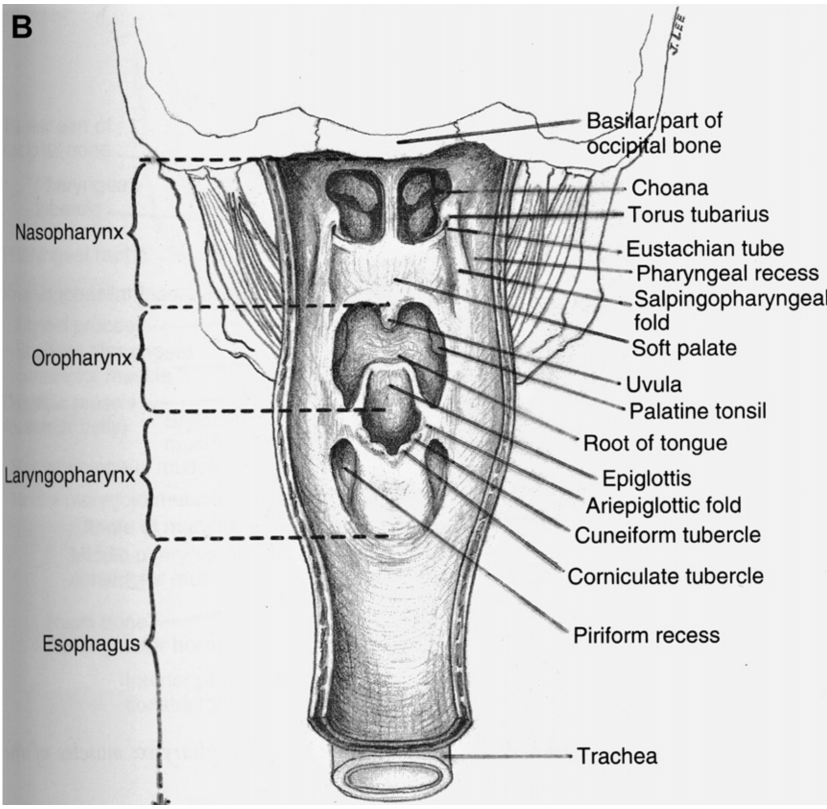

Fig. 8. (*continued*)

indicated by distinct motor innervation and specialized muscle fibers. The slow inner layer appears to be a specialized layer that is unique to normal humans. The presence of the highly specialized, slow-tonic, and alpha-cardiac myosin heavy chain isoforms, together with their absence in human newborns and nonhuman primates, suggest that the specialization of the slow inner layer fibers maybe related to speech and respiration. This specialization may reflect the sustained contraction needed in humans to maintain stiffness in pharyngeal walls during respiration and to shape the wall for speech articulation. In contrast, the fast outer layer fiber is adapted for rapid movement as seen during swallowing.[15]

ANATOMY OF THE LARYNX

The larynx connects the pharynx with the trachea. It functions as a valve that separates the trachea from the narrow digestive tract and maintains a patent airway. It also provides an instrument for vocalization. The larynx is made up of cartilages, ligaments, and membranes that connect the cartilages and muscles to cause movement of various parts. It is lined with a mucous membrane of columnar ciliated cells and contains many mucous glands.

There are 3 unpaired cartilages (thyroid, cricoid, and epiglottic) and 3 paired cartilages (arytenoid, corniculate, and cuneiform).

The thyroid cartilage has a peculiar shape, with 2 large plates anteriorly and laterally placed and fused in the midline anteriorly but open posteriorly. Projections extending superiorly and inferiorly from the posterior edges are called superior and inferior horns. The superior edge of the lamina presents a notch in the midline referred to as the thyroid notch. A structure called the oblique line is formed on the lateral surface of the thyroid cartilage. This line is important for the understanding of muscle attachments.

The cricoid cartilage is the only complete ring found in the respiratory system. It is larger posteriorly and anteriorly. The posterior portion is formed by 2 laminae, whereas the anterior portion presents an arch. Near the base of each lamina is found a facet for articulation with the inferior horn of the thyroid cartilage. On the superior surface of the lamina are facets for the articulation of the

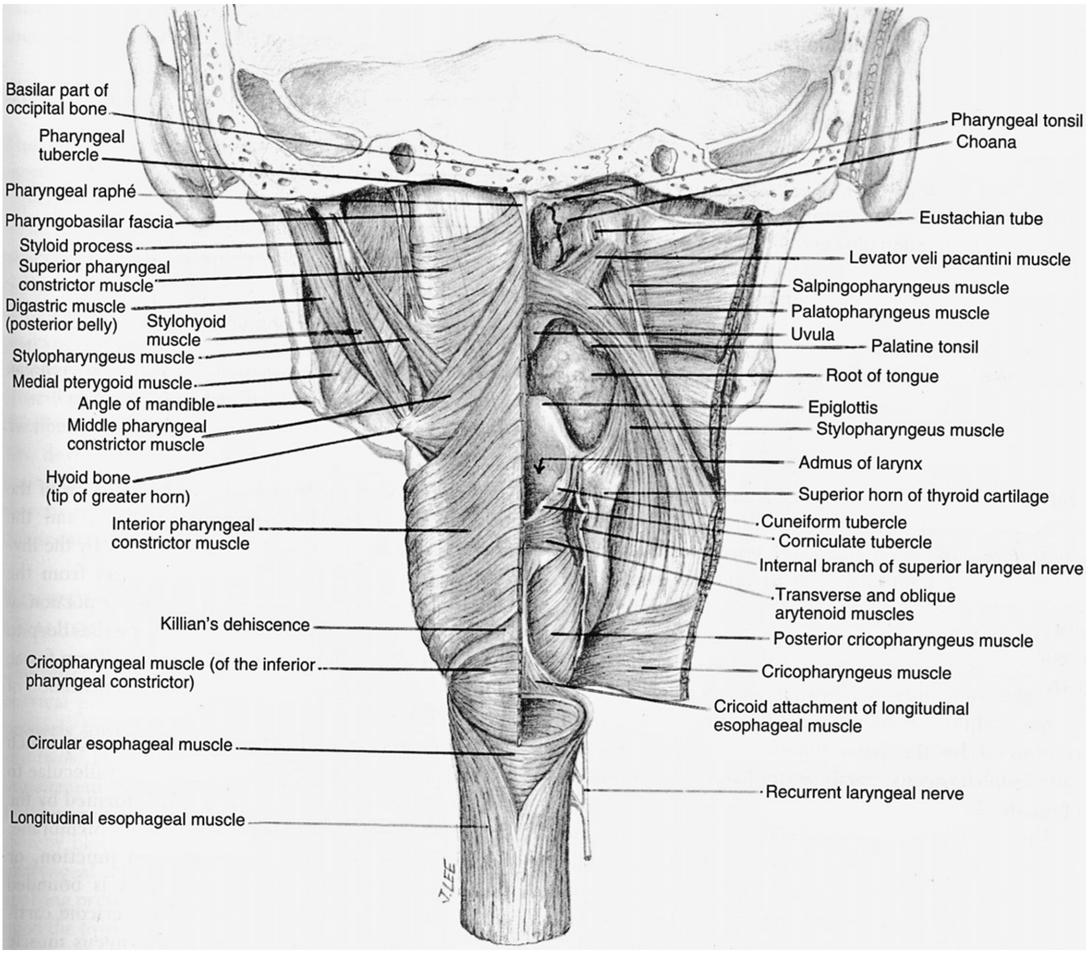

Fig. 9. Section through pharynx viewed from posterior otolaryngology. (*From* Van De Water TR, Staecker H. Otolaryngology. New York: Thieme; 2006. p. 555; with permission.)

arytenoid cartilages. The posterior surface of the lamina shows 2 hollow areas on either side of the midline for the posterior cricoarytenoideus muscles.

The epiglottic cartilage is a leaf-shaped structure. The base of the epiglottic cartilage is attached to the inside of the thyroid cartilage at the midline by the thyroepiglottic ligament.

The 3 paired cartilages—arytenoid, corniculate, and cuneiform—are small cartilages. The laryngeal folds consist of (1) paired aryepiglottic folds extended from the epiglottis posteriorly to the superior surface of the arytenoids, (2) paired vestibular folds (false vocal cords) extended from the thyroid cartilage posterior to the superior surface of the arytenoids, and (3) paired vocal folds (true vocal cords) extended from the posterior surface of the thyroid plate to the anterior part of the arytenoids. The interarytenoid fold bridges the arytenoid cartilages. The thyrohyoid fold extends from the hyoid bone to the thyroid cartilage. The sensory innervation is the recurrent laryngeal nerve to the supraglottic larynx and the internal branch of the superior laryngeal nerve to the infraglottic larynx.

The larynx is the guardian of the airway. Functioning in this role, the larynx can initiate a wide range of reflexes with significant physiologic effects. Laryngeal chemoreflexes that are initiated when chemical substances contact the laryngeal mucosa include apnea, swallowing, hypertension, and changes in peripheral resistance. All of these reflexes can have fatal consequences. The larynx also contains various mechanoreceptors in its muscles and joints, which respond to and influence laryngeal function. These mechanoreceptors can be further divided into 2 groups. The first group consists of touch receptors, which may act to identify foreign bodies in the airway and modulate phonation. The second group consists of mechanoreceptors responsive to airflow, transmural pressure change, and pharyngeal receptors. These probably have a role in reflex control of breathing. Last but not least, there are proprioceptors that act as muscle spindle receptors.[16]

The motor innervation is the external branch of the superior laryngeal nerve to the cricothyroid muscle and the recurrent laryngeal nerve to all other laryngeal muscles. The blood supply to the larynx is provided by branches of the superior and inferior thyroid arteries.

There are 2 joints within the larynx, the cricothyroid joint and the cricoarytenoid joint, that provide the necessary articulation for laryngeal movement. The ligaments and membranes connecting the cartilages of the larynx to one another and to the hyoid bone are important because they fill the gaps between the cartilages, thereby completing the walls of the hollow organ.

The ligaments and membranes are: (1) thyrohyoid membrane, (2) hyoepiglottic ligament, (3) cricothyroid ligament, (4) vocal ligament, (5) conus elasticus, (6) vestibular ligament, and (7) cricotracheal ligament.

The thyrohyoid membrane is attached superiorly to the body and horns of the hyoid bone and inferiorly to the superior horn and superior edges of the thyroid cartilage. Thyrohyoid membrane is pierced by the internal branch of the superior laryngeal branch of the vagus nerve and by the superior laryngeal blood vessels.

The hyoepiglottic ligament extends from the hyoid bone to the anterior surface of the epiglottis. This is an important ligament participating in the movement of the epiglottis during swallowing.

The vocal ligament is attached anteriorly to the inside of the thyroid cartilage near the midline and posteriorly to the vocal process of the arytenoid cartilage. The vocal ligament is covered with mucous membrane. The conus elasticus extends superiorly from the superior border of the cricoid cartilage to attach to the vocal ligament. The weak vestibular ligament is situated posterior to the vocal ligament and extends from the thyroid cartilage anteriorly to the lateral surface of the arytenoid cartilage posteriorly. These are called the false vocal cords or vestibular cords.

MUSCLES OF THE LARYNX

The muscles of the larynx can be divided into 2 broad groups: extrinsic muscles and intrinsic muscles. The extrinsic muscles of the larynx can be subdivided into 2 groups: suprahyoid and infrahyoid muscles. The suprahyoid group of muscles is composed of (1) the anterior belly of the digastric muscle, which draws the hyoid forward; (2) the posterior belly of the digastric muscle, which stabilizes and draws the hyoid back; (3) the genioglossus muscle, which elevates and advances the hyoid bone and lowers the mandible; (4) the stylohyoid muscle, which raises the hyoid and larynx and also serves to fix the hyoid bone during swallowing; and (5) the mylohyoid muscle, which raises the floor of the mouth and hyoid and lowers the mandible. The unique feature of the suprahyoid musculature is that these muscles have the capability of reversing origin and insertion, depending on demand.

The other group of extrinsic muscles of the larynx is referred to as the infrahyoid muscles. This group is composed of the (1) omohyoid muscle, which lowers the hyoid and opposes upward movement of the larynx; (2) the sternohyoid muscle, which lowers the hyoid and opposes upward movement of the larynx; (3) the sternothyroid muscle, which lowers the hyoid and opposes upward movement of the larynx; and (4) the thyrohyoid muscle, which lowers the hyoid and raises the larynx if the hyoid is fixed.

The intrinsic muscles of the larynx connect the various cartilages and membranes between the cartilages and allow for movement of the cartilaginous skeleton. The intrinsic muscles of the larynx are: (1) cricothyroid, (2) posterior cricoarytenoid, (3) lateral cricoarytenoid, (4) transverse arytenoid, (5) oblique arytenoid, (6) thyroarytenoid, (7) thyroepiglottic, and (8) aryepiglottic. All of these names reveal the muscle attachments. The cricothyroid muscle pulls the thyroid cartilage anteriorly and inferiorly in a rocking motion, thereby increasing the tension on the vocal cords. The posterior cricoarytenoid muscle contracts to widen the space between the 2 vocal cords (the rima glottidis). The lateral cricoarytenoid rotates or pulls the vocal process medially, thereby decreasing the width between the 2 vocal cords. The transverse arytenoid muscle pulls the arytenoid cartilages closer together by a gliding motion and is used in closing the rima glottidis. The oblique arytenoid muscle is used to bring the arytenoid cartilages closer together and to tighten the aryepiglottic fold. This muscle is used in the process of swallowing. The thyroarytenoid muscle can be used in contracting a portion of the vocal cord in production of high tones. When these muscles contract, they bring the arytenoid cartilage closer to the thyroid cartilage, thereby decreasing the tension on the vocal cords. A portion of this muscle, which is located on the lateral side of the vocal ligament, is called the vocalis muscle. It is thought that this muscle can be used in contracting a portion of the vocal cord in production of very high tones. The thyroepiglottic muscle aids the aryepiglottic muscle in tightening the aryepiglottic fold and in bringing the epiglottic cartilage into closer contact with the arytenoid cartilages during the process of closing the opening into the larynx during swallowing.[14]

DISCUSSION

The oral apparatus is the "gateway to the gut."[13] The oropharyngeal system is in unbroken continuity with the pharynx and funnels food directly into the esophagus. The structure of the food channel is complicated by the peculiar crossing of the airway at the larynx. The oral apparatus not only prepares food but also initiates swallowing. It is designed to function in close coordination with the pharynx. The oropharyngeal system is meticulously integrated with the production of speech. One of the major reasons the upper respiratory tract of man developed as it did is partly to facilitate speech. As man assumed an upright posture compared with quadripeds, the eyes, face, and mouth rotated downward and forward so that the interpupillary line of the eyes would be maintained parallel with the horizon. For the eyes and face to assume this anatomic position, the maxilla and mandible and also the ethmoid and palatine bones had to migrate posteriorly. This led to a shortening of the face and the dental arches anterior-posteriorly. The resulting movement of the maxilla and mandible posteriorly forced the tongue to shift from its position residing solely in the oral cavity to a position where the distal portion of the tongue protruded into the pharynx. As the larynx descended and the soft palate shortened, the epiglottic–soft palate lockup, which is seen in other primates, was lost. The soft palate and uvula became more flaccid to facilitate speech.

With the descent of the larynx and the development of the oropharynx and the support of speech, certain disadvantages of morphology developed. There are 3 distinct roles of the pharynx, which require different muscular activities. The roles are respiration, deglutition, and phonation. For deglutition, the pharynx assumes the role of a flexible tube, the muscles of which force food from the oral cavity into the esophagus. For phonation, the pharynx is a muscular tube that can change length and shape to alter sounds passing through it. For air passage, the pharynx must remain as a rigid tube without collapse, especially during sleep. No muscle or group of muscles assumes this function as a primary role, leaving the pharynx subject to collapse and obstruction during certain conditions of respiration.

One reason the upper respiratory tract of man developed or evolved as it did is partly to facilitate speech. The pharynx was narrowed to form a narrow, descendible tube for better sound modulation by rotation of the foramen magnum inferiorly, migration of the palate posteriorly, and shifting of the tongue into the oral pharynx. Orobuccal speech was generated as the larynx descended and the soft palate shortened, causing loss of the epiglottic–soft palate lockup. Cranial-based angulations further improved vocal quality.

The obstructing anatomy is clearly a soft tissue phenomenon, as it is absent during the day and present at night. The soft tissue is suspended and supported by the underlying skeleton. Soft tissue obstruction sites during sleep include the nose, upper and lower pharynx, and occasionally the larynx. Perhaps there are other contributing soft tissue changes, such as floppy epiglottis or lax pharyngeal musculature. The descended larynx, the oral pharyngeal tongue, and the acute cranial-based angulations are primary contributors to sleep disorder breathing.[9]

REFERENCES

1. Davidson TM. The great leap forward: the anatomic basis for the acquisition of speech and obstructive sleep apnea. Sleep Med 2003;4:185–94.
2. Sadler TW. Langman's medical embryology. 8th edition. Baltimore (MD): Lippincott Williams & Wilkins; 2000. p. 345–81.
3. Schoenwolf GC. Larson's embryology. 4th edition. Philadelphia: Elsevier; 2009. p. 543–582.
4. Humphrey T. The development of mouth opening and related reflexes involving the oral area of human features. Ala J Med Sci 1968;5(2):126–57.
5. Humphrey T. The relation between human fetal mouth opening reflexes and closure of the palate. Ala J Med Sci 1969;125(3):317–44.
6. Auvenshine RC. The relationship between structure and function in the development of the squamomandibular joint in rats. Dissertation for PhD, Department of Anatomy, LSU Medical School of Graduate Studies. 1976. New Orleans, LA.
7. Pitsillides AA. Early effects of embryonic movements. J Anat 2006;208(4):417–31.
8. Enlow DH, Hans MG. Essentials of facial growth. 2nd edition. Ann Arbor (MI): Needham Press; 2008. p. 1–19.
9. Barsh LI. The origin of pharyngeal obstruction during sleep. Sleep Breath 1999;3:17–21.
10. Newman LA. Anatomy and physiology of infant swallow, swallowing, and swallowing disorders. March 2001:3–4.

11. Crelin ES. The human vocal tract: anatomy, function, development and evolution. New York: Vantage; 1987. p. 97, 220, 223, 224.
12. Negus VE. The comparative anatomy of physiology of the larynx. New York: Grune and Stratton; 1949. p. 21, 187.
13. DuBrul EL. Sicher and DuBrul's oral anatomy. 8th edition. St Louis (MI): Ishiyaku EuroAmerica, Inc; 1988.
14. Crafts RC. Textbook of human anatomy. New York: Ronald Press Company; 1966. p. 553–69.
15. Mu L, Sanders I. Neuromuscular specializations within human pharyngeal constrictor muscles. Ann Otol Rhinol Laryngol 2007;116(8):604–17.
16. Van De Water TR, Staecker H. Otolaryngology. New York: Thieme; 2006. p. 552–65.