Face and neck: airway and sensorial capacities

C. Kastoer1,2, R. Leach3 and O. Vanderveken1,2

1Department of Otorhinolaryngology, Head and Neck Surgery, Antwerp University Hospital, Wilrijkstraat 10, 2650 Edegem; 2Faculty of Medicine and Health Sciences, University of Antwerp, Antwerp; 3Department of Emergency Medicine, Hospital Sint Jan, Kruidtuinlaan 32, 1000 Brussels

Key-words. Face; neck; pharynx; larynx; anatomy; physiology; respiration; sensation

Abstract. Face and neck: airway and sensorial capacities. For the assessment and the management of face and neck trauma knowledge of the neuro-anatomy and physiology of the ear, nose, throat (ENT) and head and neck (HN) region and structures is essential, as this area is particularly vulnerable to injury. Indeed, the complex anatomy and physiology in this specific area supports important basic functions. In addition, this review elaborates on upper airway and sensorial capacities. Upper airway dimensions are influenced by bony and soft tissues. Age is of fundamental importance in the upper airway assessment, as significant differences in size and proportions apply in children and adults. The cranial nerves (CN) supply motor, sensory and special sensory fibres to the upper airway. Injury of the CN is a frequent complication of trauma.

Introduction

Understanding of normal anatomy and physiology provides the basis for recognizing abnormalities. A functional approach to anatomy can clarify normal and chronic or traumatic dysfunction. Although gross anatomy and physiology is unlikely to change in the future, advances in clinical treatment are predicated on the solid foundation of anatomical and physiological knowledge. In acute medicine a good understanding of anatomy and physiology is mandatory. The face and neck are particularly vulnerable to injury. The general principles rely on vascularisation and innervation. The cranial nerves supply the face and neck region with motor, sensory and special sensory fibres. Upper airway dimensions are influenced by the interaction between bony and soft tissues. From an otorhinolaryngological perspective primary focus lies on the upper airway and sensorial capacities.

Face and neck

1. Anatomy of the face

The eyes, ears, nose, mouth and cheeks together constitute the region commonly referred to as the face. Each of these elements’ idiosyncrasies together creates the unique combination that contributes to the anthropomorphic distinction between individuals. The face is commonly assimilated as one’s identity. The visible aspect of the ear has a cartilage under structure that is covered by skin. The external nose consists of the nasal pyramid (frontal process of the maxilla) with the paired nasal bones forming the dorsum and meeting the frontal bone superiorly at the glabella. Inferiorly are the upper lateral cartilages and lower lateral (alar) cartilages, which contribute to the nasal tip and nasal valves. The two maxillae (upper jaw bones), the two zygomas (cheek bones) and the mandible (jaw bone) provide the framework for the lower half of the face. The eyelids and cheeks form the dynamic walls that contribute to the function of the eyes and the oral cavity.

The face is highly equipped with a dense network of sensory nerve endings. The trigeminal nerve (CN V) supplies sensation to the scalp and face. This extensive coverage is possible since this cranial nerve divides into three regional branches. These divisions are named after the regions that the branches provide sensory coverage to namely; the ophthalmic, maxillary and mandibular branches. Each of these branches reach the subcutaneous tissue of via three foramina that are aligned.
verticaly. Each division supplies a distinct sensory zone, similar to a dermatome but without the overlapping of adjacent nerves; therefore, trigeminal injuries result in a distinct and clearly definable area of paresthesia. The different divisions of CN V supply sensory perception not only to the superficial epidermis of the face but also to deep mucosal surfaces of the nasal and oral cavities, and the vestibule. CN V furnishes sensory fibers to the entire facial region with one small exception which is the angle of the mandible. The skin covering this area, is innervated by the great auricular nerve, a branch of the cervical plexus.

The facial nerve (CN VII) divides into five branches in order to supply the facial muscles with motor command.2,3

The face lacks the deep fascia present elsewhere in the body, which is where many muscles, except those of the face, have their insertions. So facial muscles have often a skeletal origin and a cutaneous insertion. Some facial muscles play an important role as dilators and sphincters for the portals of the digestive, respiratory and visual systems, participating actively thus in these systems’ functioning. Facial muscles assist the muscles of mastication by keeping food between the teeth during chewing. Salivary glands provide saliva to initiate digestion thus facilitating chewing and swallowing. During periods of increased nasal breathing, such as during exercise, an increase in the activity of the nasalis muscle increases the nasal airway patency.4 The proper function of the peribuccal muscles contribute to pronunciation of words. This, however, is only one of the means by which facial muscles participate in communication. Since communication can also be non-verbal, contraction of facial muscles can create facial distortions that are familiarly associated with states of fear, anger, happiness etc.5

2. Anatomy of the neck
The neck contains many important structures and their study is assessed by dividing the neck into compartments, levels and fascial layers.7 The neck is supported by the first seven vertebrae in the spinal column (C1 through C7) and by the paraspinal muscles. The neck contains a superficial fascia, and a deep cervical fascia. The latter divides into a superficial, middle, and deep layer.8 This division is relevant when describing localisation of trauma, spread of infection and lymphatic spread of cancer. The first cranial bony structure one would encounter on the anterior midline of the neck is the free-floating hyoid bone. The head-tilt chin-lift or jaw thrust manoeuvres open the upper airway by anteriorly displacing the mandible thereby lifting up the hyoid bone.9 The cricothyroid membrane is a thin layer of connective tissue (fascia) which connects the thyroid cartilage with the cricoid cartilage. Since this membrane, between two cartilaginous structures is only covered by skin, one can clinically locate it as a soft depression in the midline of the neck. On either side of the lower larynx and the upper trachea lies the thyroid gland.5

Upper airway
The upper airway extends from the nose and mouth through the nasal cavity, nasopharynx, oral cavity, oropharynx, hypopharynx to the larynx and to the inlet of the trachea and oesophagus.5 Figure 1 depicts the gross upper airway anatomy. The complex anatomy and physiology of the upper airway contributes to basic functions in respiration, phonation, deglutition and to the special sense apparatus of the olfactory and gustatory systems. Some important aspects of this anatomy and physiology are reviewed here. When performing airway management procedures one should be aware of the high risk of bleeding due to the highly vascularized mucous membranes as well as the risk of important swelling or even occlusion due to infection or trauma.

Sensory perception above the epiglottis is provided by the trigeminal nerve (CN V) and the glossopharyngeal nerve (CN IX); the region below the epiglottis, receives its sensory fibers from the superior laryngeal and recurrent laryngeal branches of the vagus nerve (CN X).4,5
Upper airway and sensorial capacities

1. Nasal cavity and paranasal sinuses

There are two anatomical entrances to the airway: the nose and the mouth. The nose as well as being one of the two portals of the upper airway, it also serves as an immunological barrier, a source of warming and humidifying the inhaled air, and a threat/food detection system. The internal nasal and sinus anatomy is intricate and often varies amongst individuals. The percentage of nasal septal deformities changes with age. Septal deformities are present in approximately 90% of adult patients. The average nose is capable of sustaining 20 to 30 L of airflow per minute. If larger volumes are required, oral breathing must supplement nasal breathing.

The warming and humidification of inhaled air, olfactory function, and immune function all are aspects of nasal physiology. The nose and the paranasal sinuses participate in host defences, with mucociliary clearance being a key feature. The mucociliary transport is the mechanism by which the nasal cavity clears itself of secretions and trapped particulates. The nose is thus, an excellent filter. It is important to note that compared with adults, children have less efficient nasal filtering for large particles, especially in light exercise breathing conditions.

The lateral nasal wall is composed of the inferior, middle, and superior turbinates. The nasolacrimal duct terminates with the inferior meatus. There are four duct paired paranasal sinuses: the maxillary, frontal, ethmoid, and sphenoid. The posterior ethmoids drain via the superior meatus. The sphenoid ostia are situated near the level of the superior meatus on the anterior wall of the sphenoid sinus. The relation of the paranasal sinuses to some of the adjacent anatomic structures is of great clinical significance since this close proximity may facilitate the potential for the spread of infection following trauma or iatrogenic injury. The ethmoid forms the roof, medial and lateral walls of both nasal cavities as well as the medial walls of the orbits. The lateral lamella of the cribiform plate may vary in its height considerably and may also be extremely thin with the intracranial contents lying directly above it. The lamina papyracea separates the orbit from the ethmoids; an ethmoid infection can thus, easily reach the orbit.

The sphenoid sinus is bounded by the internal carotid artery, optic nerves, and cavernous sinus and sella; an overriding posterior ethmoid, the so called Onodi cell, may risk critical structures. Dehiscence of bone covering of the internal carotid within the sphenoid is relatively common. The frontal sinus is bounded by the orbit and the anterior fossa, and also may be a source of spread of rhinogenic infection.

There is abundant external and internal carotid supply. Kiesselbach’s plexus (also known as Little’s area) of the anterior septum provides superficial anastomoses. External carotid branches supply the nose via the facial artery externally and the maxillary artery internally, including the sphenopalatine artery. Internal carotid branches are supplied via the ophthalmic artery to the anterior and posterior ethmoid arteries. Venous drainage occurs via facial veins as well as ophthalmic veins, which have valveless intracranial connections to the cavernous sinus and therefore relate to intracranial
Tongue musculature involves both intrinsic muscles and extrinsic muscles, including the genioglossus, hyoglossus, and styloglossus muscles, all of which are supplied with motor fibers by the hypoglossal nerve (CN XII). The lingual nerve provides sensation, and taste fibres of the chorda tympani, to the anterior two thirds of the tongue. CN VII provides motor supply to the orbicularis oris muscle, which encircles the lips. General sensation to the buccal mucosa is via CN V2.

The lingual artery is the primary blood supply to the tongue. The external facial artery supplies the lips via superior and inferior labial branches.

3. Pharynx

Food and respiratory gases move through the oral cavity and tonsillar pillars that form the walls of the oropharynx. The pharynx is divided into the nasopharynx, superior to the palate, the oropharynx and the hypopharynx separated by the epiglottis, located at the base of the tongue. The hypopharynx includes the piriform sinuses, posterior wall and postcricoid region. The cervical oesophagus extends inferiorly and the larynx is positioned anteromedially.

Waldeyer’s ring of lymphoid tissue includes the adenoids of the nasopharynx, the palatine tonsils of the oropharynx, and the lingual tonsil lining the base of tongue. These structures serve as an immunological barrier to pathogenic entry into the pharynx. The epiglottis protects the lower airway from foreign body aspiration. Airway obstruction in patients with a decreased level of consciousness is not caused from the tongue falling posteriorly, but rather initially by the soft palate and the epiglottis making contact with the posterior wall of the pharynx due to the loss of muscle tone.

The visceral layer of the cervical fascia envelope the pharyngeal constrictor muscles. The palatoglossus and palatopharyngeus muscles form the tonsillar pillars. The palatopharyngeus and stylopharyngeus muscles play a supportive role.

The tonsils are supplied by external carotid branches via the facial artery, lingual artery, lesser palatine artery, descending palatine artery, and ascending pharyngeal artery.

Sensory supply of the oropharynx and the supraglottic area is provided by CN IX, branches of this nerve include the lingual, pharyngeal, and
tonsillar nerves. Palatine tonsils have a sensory supply from CN IX as well as from the lesser palatine nerve, a branch of CN V2. The posterior pharynx, including the uvula, is innervated by branches from the sphenopalatine ganglion, derived from CN V2. Referred otalgia is common. Cranial nerves IX and X supply motor and sensory innervations to the hypopharynx.1,4

4. Larynx

Briefly, the basic functions of the larynx include airway protection, speech and respiration. The larynx is made up of a number of cartilaginous structures including the epiglottis, the cricoid, the thyroid cartilage (“Adam’s apple”) and the aryepiglottic folds that contain the arytenoid cartilages. The thyroid and cricoid cartilages are hyaline cartilage, which may ossify with age. These cartilaginous structures are maintained by muscles and ligaments.5

The larynx can be considered to function as a complex valve, which can regulate airflow. It is a dynamic organ that is involved with the respiratory/vocal system and the digestive tract because of its position in the pharynx. Its lumen continues superiorly with the pharynx and inferiorly with the trachea. Anterosuperiorly, the larynx articulates with the hyoid bone and inferiorly it joins the trachea. Posteroinferiorly the larynx is separated from the pharyngoesophageal lumen. Posteriorly, the larynx meets the muscular wall of the pharynx, with the cervical vertebrae posterior to this layer. Laterally and inferiorly is the piriform sinus, which funnels food and liquid into the oesophagus. The paired vocal folds extend from the vocal process of the arytenoids dorsally to the thyroid cartilage at the anterior commissure. The structure of the vocal folds includes the vocal ligament, lateral cricothyroid ligament, median cricothyroid ligament, the vocalis muscle (thyroarytenoid), and the mucosal covering. The membranous lining of the larynx is the quadrangular membrane superiorly, extending to the vestibular fold or false vocal fold; and the cricovocal membrane or conus elasticus, extending from the true vocal fold inferiorly. The aired aryepiglottic folds define the opening into the laryngeal lumen superiorly.4,5

The larynx acts as a sphincter, in concert with pharyngeal structures to prevent airway aspiration. A number of stimuli can trigger the involuntary reflex that causes the muscles to adduct the glottis and the false cords to provide an impenetrable barrier to foreign material. This is facilitated via an epiglottic tilt, contraction of the aryepiglottic folds, false vocal folds, true vocal folds and adductors. The intrinsic and extrinsic laryngeal muscles and their nerve supply found in the larynx are responsible for the pharyngeal reflex (“gag reflex”).1

Nerves derived from CN X supply the larynx. The superior laryngeal nerve has an external branch providing motor function to the cricothyroid muscle, and an internal branch providing sensation to the supraglottis and glottis. The recurrent laryngeal nerve provides motor supply to all other internal laryngeal muscles. On the left, the recurrent nerve passes around the aortic arch; on the right, it passes around the subclavian artery. Both recurrent nerves then ascend along the tracheoesophageal groove to enter the larynx at the inferior horn of the thyroid cartilage. Importantly, the recurrent laryngeal nerve may branch in the neck prior to entering the larynx. A nonrecurrent right laryngeal nerve may occur if an aberrant subclavian artery is present. CN IX and X innervate the base of the epiglottis. Arterial supply to the supraglottis arises from the external carotid via the superior laryngeal artery. The inferior laryngeal artery arising from the subclavian artery via the thyrocervical trunk supplies the subglottis. Venous drainage is via the internal jugular and to the brachiocephalic vein.4,5

5. Pediatric versus adult upper airway

The fundamental upper airway anatomy and physiology of children and adults are the same, although there are significant differences in size and proportions.

5.1. Anatomy

A pediatric patient’s head, when compared to the body, is disproportionately larger than an adult’s head. When a pediatric patient is in a supine position, a more protuberant occiput will tend to flex the neck and compress airway structures, resulting in turbulence and increased resistance to airflow.14

The pediatric airway is situated more anteriorly and is proportionally shorter than the adult upper airway. The child’s airway is smaller, so even a small degree of obstruction can significantly affect the pediatric patient’s oxygenation and ventilation.15
In the oropharynx, a child’s tongue is disproportionately larger than an adult’s when compared to the oral cavity. In addition, the tonsils and adenoids are also disproportionately large and the mucosa over them and the entire pharynx is more fragile. When traumatized, these structures tend to bleed. The pediatric hypopharynx has a much more acute angle between the pharynx and the epiglottis in. The epiglottis is “U” shaped and is less rigid as the cartilage has not yet fully matured. This immaturity also causes the epiglottis to slope more posteriorly, potentially obscuring the view of the glottis. Large arytenoids and pinker vocal cords are set on an angle in children, sloping upward from the front of the child toward the back. This is different from adult vocal cords that tend to be on the same plane from front to back.

The tracheal opening is relatively more anterior and significantly closer to the oropharynx. At birth, the tracheal opening lies at the level of C1. By ages 5 to 7, relative differences in structural growth rates have moved the glottic opening to the level of C3 to the level of C4, and by adulthood, the glottis rests at the level of C5. The cricothyroid membrane is proportionately smaller in children and is almost non-existent in infants. Up to age 10, it is difficult to identify the cricothyroid membrane by palpation. The narrowest point in the pediatric airway is the cricoid ring. Aspirated foreign bodies may also lodge at this point. In adults the narrowest point of the airway is at the level of the vocal cords.

5.2. Physiology
For their size, pediatric patients consume more oxygen than adults and may rapidly become hypoxic during respiratory failure. In times of respiratory distress, children are less able to draw upon the capacity to provide supplemental ventilation due to a disproportionately smaller functional residual capacity. Furthermore, in times of apnea, the pediatric patient will become hypoxic up to twice as quickly as an adult. Therefore, pediatric patients are more likely to progress to respiratory failure faster than an adult would in a similar clinical context and more likely to suffer early hypoxic injuries. In a pediatric patient hypoxia has to be considered as the cause of bradycardia. Pediatric patients have the potential for high vagal tone. Minimal airway stimulation can result in an excessively high vagal response including bradycardia and even cardiac arrest. Administration of appropriate vagolytic medications (e.g., atropine) before airway management may be necessary, but cannot prevent bradycardia in all cases.

Sensorial capacities
Except for the olfactory nerve, which has its origin in the nasal cavity, all the other cranial nerves originate from nuclei deep within the brainstem (or related structures), as pictured in figure 2. CN I governs the sense of smell. The optic nerve (CN II) carries impulses from the retina in the eye to the brain. The eye movements are controlled by the oculomotor (CN III), trochlear (CN IV) and abducens nerve (CN VI). CN V governs feeling in the face and participates in some muscular movements, such as chewing and swallowing. CN VII controls muscles involved in facial expression and conveying tastes. The vestibulocochlear nerve (CN VIII) carries balance and sound input from the inner ear to the brain. CN IX supplies nerves to the middle ear, tonsils and pharynx, among other tasks. CN X conveys motor and sensory fibres to various places in the head and chest. The accessory spinal nerve (CN XI) controls neck and shoulder muscles. CN XII controls tongue movements.

Injury to the cranial nerves is a frequent complication with skull base fractures. Excessive movement of the brain within the cranium due to trauma for instance may tear or bruise CN fibres, especially those of the first cranial nerve. The cranial nerves are vulnerable because of their location within the confined cranial cavity, relatively fixed positions, and sometimes close relationships to bony or vascular formations. Paralysis of cranial nerves as a result of trauma can usually be detected as soon as the patient’s state of consciousness permits; however, in some people, the paralysis may not be clinically evident for several days.

1. Vision
Vision is beyond the scope of this chapter. Laceration or compression of the optic nerves and/or brain can result in visual field defects or vision loss.

2. Olfaction
The sensory fibres from CN I are situated in the roof of the nasal cavity and the area extending inferiorly
Gustatory perception or taste is the sensation created from the chemical reaction of a substance with taste receptor cells, located on taste buds. Taste buds are located in the oral cavity, mostly on the tongue. Each taste bud belongs to at least five different functional classes, which react to sweet, bitter, salt, sour and umami (the taste of glutamate) stimuli. Evidence exists of a sixth taste modality devoted to the perception of lipids. Taste receptor cells are rapidly and continuously renewed throughout life. The chorda tympani of CN VII innervates the anterior two thirds of the tongue and CN IX and X innervate taste buds of the posterior tongue. The chorda tympani runs through the middle ear and mastoid, it can be traumatized or sacrificed during middle ear surgery. Taste along with smell and CN V stimulation determines flavours.
Conclusions

The upper airway supports basic functions in respiration, phonation, deglutition and acts as a special sense apparatus, immunological barrier, a source of warming and humidifying air, and a threat/food detection system.

Take home messages
- When performing airway management procedures one should be aware of the risk of bleeding due to the highly vascularized mucous membranes as well as the risk of swelling and even occlusion caused by infection or trauma
- The trigeminal nerve (CN V) and the glossopharyngeal nerve (CN IX); provide sensory fibers for the area above the epiglottis and the superior laryngeal and recurrent laryngeal branches of the vagus nerve (CN X) for the area below it
- The narrowest point in the pediatric airway is the cricoid ring
- In adults the narrowest point of the airway is at the level of the vocal cords
- Pediatric patients are more likely to progress to respiratory failure faster than an adult would in a similar clinical context and more likely to suffer early hypoxic injuries
- Head trauma is one of the most common causes of olfactory loss
- Taste along with smell and trigeminal stimulation determines flavours
- Damage to the cochlear nerve will cause partial or complete deafness in the affected ear. The vestibular nerve innervates the vestibule and the semicircular canals of the inner ear and transmits information about balance.
- Balance involves the coordination of three sensory components: the visual, vestibular, and proprioceptive systems. Central nervous system integration of these sensory signals will generate an appropriate motor response in order to maintain balance.
- Proper assessment of balance and balance deficit disorders such as vertigo involves considering all three of these components. When damaged, the vestibular nerve may give rise to the sensation of dizziness and spinning. Damage to CN VIII may be responsible for a nystagmus, particularly when looking in a horizontal plane.

Acknowledgements

Figures courtesy of the first author of this manuscript.
Upper airway and sensorial capacities

Abbreviations

C1 through C7: cervical vertebrae
CN: cranial nerve
CN I: olfactory nerve
CN II: optic nerve
CN III: oculomotor nerve
CN IV: trochlear nerve
CN V: trigeminal nerve
CN VI: abducens nerve
CN VII: facial nerve
CN VIII: vestibulocochlear nerve
CN IX: glossopharyngeal nerve
CN X: vagus nerve
CN XI: accessory nerve
CN XII: hypoglossal nerve
ENT: ear, nose and throat
HN: head and neck

References


E-mail: olivier.vanderveken@uza.be

Prof. Dr. Olivier M. Vanderveken, M.D., Ph.D.
Department of Otorhinolaryngology, Head and Neck Surgery, Antwerp University Hospital, Wilrijkstraat 10, 2650 Edegem, Belgium
Tel.: +32 (0)3 821 33 84
Fax: +32 (0)3 821 42 71
E-mail: olivier.vanderveken@uza.be