Airway Anatomy & Anesthesia

This handout contains a written transcription of the narration in the online presentation (video). Please review the online presentation for additional material including interactive multimedia content, audio, and practice quizzes.

Case Study

Christine is a 52-year-old female with a history of an unanticipated difficult airway. During the preoperative assessment, Christine says she nearly died during her previous anesthetic and was unable to proceed with the planned surgical procedure. Additionally, she shows you the letter written by her previous anesthesia provider that details the airway complications encountered, along with a recommendation for an awake intubation whenever the airway must be secured. After discussing the risks and benefits with the patient, you agree to perform an awake intubation supplemented with light sedation and airway nerve blocks.

What is the clinical anatomy required to perform this procedure? Which nerves must be anesthetized to ensure patient comfort? How will you perform these blocks? Let's begin with a review of clinically oriented airway anatomy, and then apply this information to anesthetizing the airway in preparation for awake intubation.

Introduction

An understanding of airway anatomy is fundamental to successful airway management, so we're going to discuss this topic with a focus on the clinically oriented anatomy that impacts patient care.

Nasal Cavity

During normal breathing, a reduction in intrathoracic pressure draws air through the nares and into the nasal cavity, where it is warmed, humidified, and filtered. The nasal septum divides the nasal cavity at the midline to form the left and right nasal passages. The nasal turbinates (3 on each side) project from the lateral wall of each nasal passage. It's important to understand that the nasal turbinates are highly vascular, rendering them susceptible to traumatic injury during airway instrumentation. To reduce the risk of bleeding, common practice suggests that any device inserted into the nasal cavity (such as a nasal airway or endotracheal tube), is directed between the inferior turbinate and the floor of the nasal cavity. The bevel should be oriented towards the turbinates. This ensures that the leading-edge travels along the septum, where it's less likely to traumatize the turbinates. Finally, the scroll-like shape of the nasal turbinates imparts a high degree of airway resistance, which explains why a patient in respiratory failure will convert to mouth breathing.

Oral Cavity

Because it's easier to access and less susceptible to traumatic injury, the mouth is most commonly selected for the insertion of an airway device. Mouth opening is dependent on the functional integrity of the temporomandibular joint. The tongue occupies a significant percentage of the volume of the mouth, which has implications for tracheal intubation. During anesthesia, posterior displacement of the tongue into the oropharynx is a common cause of upper airway obstruction as a function of relaxation of the genioglossus muscle. A jaw thrust (subluxation of the temporomandibular joint) and an oral airway can remedy this problem. Additionally, relaxation of the tensor palatine muscle can contribute to airway obstruction at the level of the soft palate.

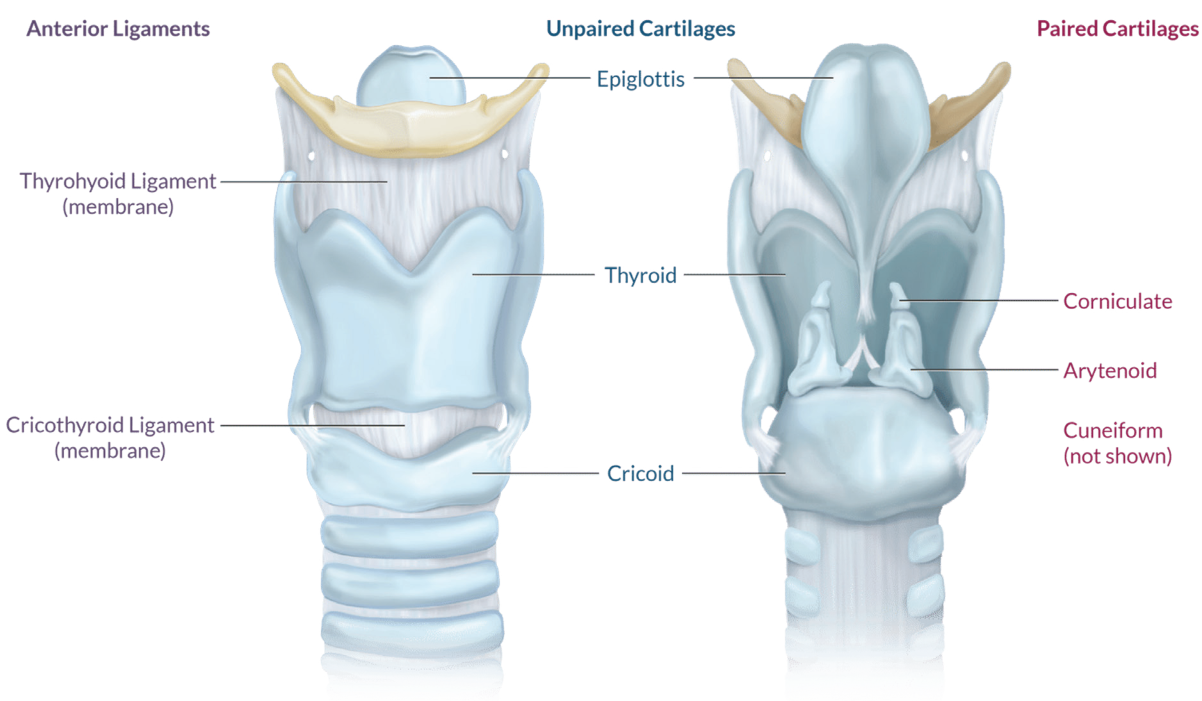
Pharynx

The pharynx connects the oral and nasal cavities with the larynx and esophagus, and it can be divided into three parts: the nasopharynx, oropharynx, and hypopharynx. Contraction of the pharyngeal dilator muscles helps to maintain upper airway patency, and relaxation of these muscles during anesthesia is a common cause of airway obstruction. A chin lift with a closed mouth can be used to mechanically restore airway patency in this situation. The adenoid tonsils reside on the superior and posterior walls of the nasopharynx, and their enlargement can complicate passage of an airway device through this region. Lingual tonsil hypertrophy can hinder direct vision laryngoscopy or impair seating of a supraglottic airway device. Trauma to the posterior pharyngeal wall (by an endotracheal or gastric tube) can cause retropharyngeal injury, which if undetected, can progress to retropharyngeal abscess.

Larynx

The larynx is a cartilaginous skeleton held together by ligaments. It lies anterior to C3 – C6 in the neck, and it participates in three primary functions: airway protection, respiration, and phonation.

There are three unpaired cartilages in the larynx - the thyroid, epiglottis, and cricoid. The thyroid cartilage serves as the major structural component of the larynx, and it's suspended from the hyoid bone via the thyrohyoid ligament. The epiglottis shields the lower airway from contamination during eating or vomiting. The cricoid cartilage forms the inferior border of the larynx, and it joins the thyroid cartilage via the cricothyroid membrane (or ligament). This structure should be identified during airway assessment, as it serves as the entry point should the need for a surgical airway arise. Of note, the cricoid cartilage is the only complete cartilaginous ring in the airway and swelling in this region reduces airway diameter. This is particularly relevant in children, where a small decrease in diameter yields a profound reduction in airflow.



There are three paired cartilages in the larynx — the arytenoids, corniculates, and cuneiforms. The corniculate and cuneiform cartilages typically appear as bumps on the aryepiglottic folds, and they're often incorrectly identified as the arytenoids during laryngoscopy. The arytenoids are important because they serve as the posterior attachment of the vocal cords. The base of each arytenoid articulates with the cricoid cartilage to form a ball and socket joint allowing the arytenoids to rotate, pivot, and glide, thus facilitating vocal cord movement. Conditions such as rheumatoid arthritis or systemic lupus erythematosus can impair arytenoid mobility, placing the patient at risk of airway obstruction.

Trachea

The trachea is a tube that consists of 16 – 20 semi-circular cartilaginous rings that open posteriorly. It begins at the inferior border of the cricoid cartilage and terminates at the carina (at about T4-T5). At the carina, the trachea bifurcates into the left and right mainstem bronchi. In the adult, the right mainstem bronchus takes off at a less acute angle, which explains why endobronchial intubation is more likely to occur on the right side. Additionally, the take-off to the right upper lobe is only 2.5 cm from the carina, which necessitates meticulous positioning of a right-sided double-lumen endotracheal tube.

Innervation Of The Airway

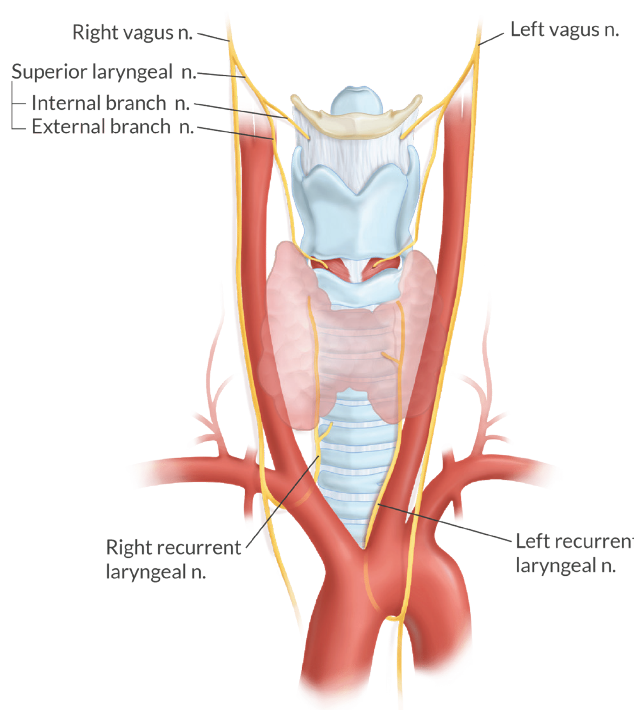
The neural pathways of the airway arise from three cranial nerves: the trigeminal, glossopharyngeal, and vagus.

Trigeminal Nerve

The trigeminal nerve (CN 5) provides sensory innervation to the face, and it gives rise to 3 divisions: the ophthalmic nerve (V1), maxillary nerve (V2), and mandibular nerve (V3). The anterior ethmoidal nerve (a branch of V1) innervates the nares and the anterior ⅓ of the nasal septum. The sphenopalatine nerve (a branch of V2) innervates the turbinates and the posterior ⅔ of the nasal septum. Finally, the lingual nerve (a branch of V3) provides sensory innervation to the anterior ⅔ of the tongue.

Glossopharyngeal Nerve

The glossopharyngeal nerve (CN 9) provides sensory innervation to the posterior ⅓ of the tongue, oropharynx, vallecula, and the anterior side of the epiglottis. Importantly, the glossopharyngeal nerve serves as the afferent limb of the gag reflex, while the vagus nerve completes the efferent limb.



Vagus Nerve

The vagus nerve (CN 10) gives rise to the superior laryngeal nerve and the recurrent laryngeal nerve. The superior laryngeal nerve further divides into an internal and external branch. The internal branch of the SLN provides sensory innervation from the posterior side of the epiglottis to the level of the vocal folds. It does not have a motor function. Conversely, the external branch of the SLN does not have a sensory function, but it provides motor innervation to the cricothyroid muscle (it tenses the vocal cords). Acute injury to the trunk of the superior laryngeal nerve or its external branch causes hoarseness, but this tends not to cause respiratory distress.

The recurrent laryngeal nerve gives sensory innervation to the larynx below the level of the vocal folds as well as the trachea. Additionally, it provides motor innervation to all intrinsic laryngeal muscles (except for the cricothyroid). The recurrent laryngeal nerve branches off the vagus inside the thorax. The right RLN loops under the subclavian artery, while the left RLN loops under the aortic arch. After looping under these vascular structures, both nerves ascend the tracheoesophageal groove to join the larynx. Due to its location in the thorax, the left RLN is more susceptible to injury.

Who is at risk for recurrent laryngeal nerve injury? Risk factors for RLN injury (on either side) include external pressure from an endotracheal tube or LMA, thyroid or parathyroid surgery, neck stretching, or neoplasm. Risk factors specific to left RLN injury include PDA ligation, left atrial enlargement (secondary to mitral stenosis), aortic arch aneurysm, or thoracic tumor.

How does RLN injury present? Acute unilateral injury results in paralysis of the ipsilateral vocal cord abductors, where the affected cord assumes the adducted paramedian position. This causes hoarseness, but not respiratory distress. By contrast, acute bilateral RLN injury results in bilateral paralysis of the vocal cord abductors. This favors a dangerous situation where the tensing action of the cricothyroid muscles acts unopposed, closing the vocal cords. This patient is at risk for stridor and respiratory distress and requires emergent airway control either through reintubation or tracheostomy. It's important to note that bilateral RLN injury presents similarly to laryngospasm, so this must be considered in your differential diagnosis.

Airway Anesthesia: Overview

Now that we've reviewed airway anatomy and its innervation, it makes sense to discuss how to anesthetize the airway for awake intubation. Don't worry; we'll cover management of the difficult airway in a latter objective, but for now we want to connect the dots for what we've covered thus far. On a macro level, we can administer topical or infiltration anesthesia, so we must consider the relative merits (and downsides) of each. Keep in mind, however, that both approaches are acceptable for awake intubation, so the specific technique should be based on provider experience and patient characteristics. Additionally, an infiltration technique can be used to supplement a failed topical approach.

Keeping in mind that there is a multitude of methods to provide topical anesthetic to the airway, we'll consider several of the most common techniques here.

Topical Anesthesia: Nasal Cavity, Oral Cavity & Pharynx

Cotton soaked pledgets can be used to anesthetize the nasal cavity. A common approach utilizes 4% lidocaine with the addition of a vasoconstrictor (such as 1:200,000 epinephrine or 1% phenylephrine). Alternatively, a 4% cocaine solution may be used. Cocaine is well suited for this application, due to its unique vasoconstrictive properties. The maximum dose is 1.5 mg/kg. It should be avoided in patients with pseudocholinesterase deficiency and must be used with caution (if at all) in patients susceptible to its positive sympathetic nervous system effects, such as hypertension, coronary artery disease, preeclampsia, hyperthyroidism, or if the patient is taking a MAO inhibitor.

The nasal cavity can be anesthetized by instilling 5 mL of 4% viscous lidocaine into each nare. This approach will also provide some coverage to the pharynx as the solution drips down the back of the throat. Alternatively, viscous lidocaine can be administered as swish and swallow for anesthesia of the mouth and pharynx. A key side effect is that viscous lidocaine may cause nausea and vomiting in some patients.

A local anesthetic spray, such as 20% benzocaine, can be used to anesthetize the oropharynx and the back of the throat. Being cognizant of the dose is essential to reduce the risk of local anesthetic toxicity. For instance, a half-second spray delivers approximately 30 mg, which is about one-third of the maximum dose of 100 mg. Methemoglobinemia is another concern when using benzocaine or a benzocaine-containing product such as Cetacaine. Methylene blue (1 – 2 mg/kg IV over 5 minutes) is the antidote for this complication.

Finally, nebulization and atomization can be used to deliver aerosolized droplets of local anesthetic to the upper airway. A drawback of atomization is the lack of ability to accurately deliver a predetermined dose of local anesthetic.

Topical Anesthesia: Vocal Cords

Several techniques can be used to provide topical anesthesia to the vocal cords. First, a nasopharyngeal airway or endotracheal tube can be placed so that the tip resides just above the vocal cords. Local anesthetic is injected through the lumen which lands on the vocal cords. Second, the "spray as you go" approach involves using the injection port of the fiberoptic scope to directly deposit local anesthetic on to the vocal cords. Alternatively, some practitioners may elect to inject local anesthetic through a multi-orifice epidural catheter that has been inserted into the suction port of the fiberoptic scope.

Airway Nerve Blocks

Let's review the essential airway blocks.

Glossopharyngeal Nerve Block

Glossopharyngeal nerve blockade provides sensory anesthesia to the posterior ⅓ of the tongue, oropharynx, vallecula, and the anterior side of the epiglottis. To perform the block, displace the tongue caudad and medially and insert a 23- or 25-gauge spinal needle at the base of the palatoglossal arch to a depth of 0.25 – 0.5 cm. Aspiration of air means that the needle is too deep, and aspiration of blood means that the needle should be withdrawn and redirected medially (this could indicate carotid puncture). After establishing correct needle placement, inject 1 – 2 mL of local anesthetic, and then repeat the procedure on the contralateral side of the mouth. Know that there's about a 5% incidence of carotid injection. Since all of the injected volume travels to the brain, even a small dose of local anesthetic (far below the recommended maximum dose) can produce a seizure.

Superior Laryngeal Nerve Block

The superior laryngeal nerve innervates the posterior side of the epiglottis down to the level of the vocal folds. To perform this block, the greater cornu of the hyoid bone is identified below the angle of the mandible, and then the hyoid is stabilized by displacing it to the contralateral side with an understanding that this may produce patient discomfort. After anesthetizing the skin, the needle is "walked off" the greater cornu of the hyoid to encounter the thyrohyoid membrane. At this point, 1 mL of local anesthetic is injected outside of the thyrohyoid membrane and then 2 mL of local anesthetic is injected 2 – 3 mm beyond the thyrohyoid membrane. Aspiration of air means that the needle is too deep (it's in the pharynx), and aspiration of blood suggests needle placement in the superior laryngeal artery or vein or the carotid artery. The procedure is repeated on the contralateral side of the larynx. Bradycardia and hypotension are risks of SLN blockade, and some sources advocate an intravenous anticholinergic prior to performing the block.

Recurrent Laryngeal Nerve Block

The recurrent laryngeal nerve innervates below the level of the vocal folds as well as the trachea. To perform the block, identify the cricothyroid membrane. After anesthetizing the skin, attach a 22- or 24-gauge intravenous catheter to a syringe filled with 3 – 5 mL of 2% lidocaine. The needle is inserted at the midline and advanced in a caudal direction as it punctures the cricothyroid membrane. Aspiration of air confirms correct needle placement in the trachea. Just before injection, the patient should take a deep breath. During that inspiration, all the local anesthetic is injected. The patient will cough, spraying the local anesthetic up through the vocal cords.

Key Points For Your Practice

Here are some key points for your practice:

- Innervation of the airway is derived from 3 cranial nerves: trigeminal (CN 5), glossopharyngeal (CN 9), and vagus (CN 10).
- Rheumatoid arthritis or systemic lupus erythematosus can impair arytenoid mobility, placing the patient at risk for airway obstruction.
- Thyroid surgery is a common cause of injury to the superior and recurrent laryngeal nerves. Diagnosis requires inspection of the vocal cords during inspiration and phonation.
- Bilateral injury to the recurrent laryngeal nerves can present with stridor and respiratory distress. Emergent airway management is indicated.
- If a topical approach to airway anesthesia fails, an airway nerve block may be used to supplement airway anesthesia.

