A

Abbe Flap

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Synonyms

Cross-lip flap, Lip-switch flap

Definition

Two-staged cross-lip flap for lip reconstruction not involving the oral commissure. The pedicle containing the inferior of superior labial vessels is divided in the second stage, 2–3 weeks later.

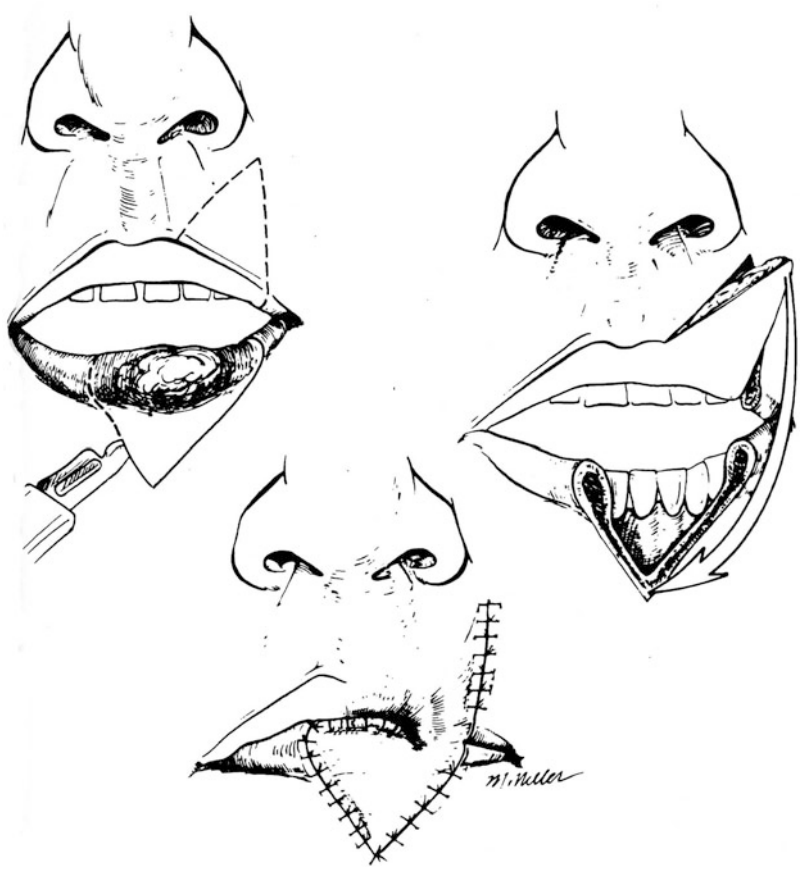
Basic Characteristics

Lip reconstruction using a cross-lip flap was first described more than 250 years ago by Johann Hierzel (Vrebos et al. 1994). Sabittini was the first to detail lip reconstruction using a two-staged cross-lip flap to repair more central lip defects in 1837 (Tommaso 2009). Abbe was the first to describe this type of flap in the English literature in 1898 and now has his name linked to this type of lip reconstruction. In 1872, ▶ Estlander described a single-stage cross-lip flap that involved the oral commissure that was similar to that originally described by Hierzel. The Sabattini and Abbe cross-lip flaps were used for defects that did not involve the oral commissure, and therefore required a second stage to divide the pedicle and release the attached upper and lower lip. Abbe detailed an operation to repair a deformity of the central upper lip in a young man with a bilateral ▶ cleft lip and palate. This two-staged cross-lip flap, or Abbe flap, continues to be used to repair secondary deformities after ▶ cleft lip repair, but more frequently is used for reconstruction of the lip after resection of malignancy.

Cross-lip flaps are pedicled flaps based on the labial artery that are used to transfer composite labial tissues from the opposite lip (Fig. 1). This allows for reconstruction of lip defects with the "like" tissue contained in the opposite lip. The cross-lip flap that was described by Sabattini and Abbe involved the transfer of a triangular-shaped full-thickness segment of lip tissue from the lower lip to a full-thickness defect of the upper lip. Staged cross-lip flaps may be used to reconstruct defects of the upper or lower lip. In fact, there is more often a need to transfer a flap from the upper lip to reconstruct a defect of the lower lip, where cancer occurs with greater frequency. Using the upper lip as a donor site is generally more challenging due to greater complexity of the upper lip anatomy. The effects on the complex upper lip anatomy should be taken into account while planning for lower lip reconstruction with a cross-lip flap.

Whichever lip contains the defect, the donor flap is pedicled on the labial artery of the opposite lip from the defect. The donor flap may be pedicled medially on the contralateral labial artery or laterally on the ipsilateral labial artery. With extreme lateral defects that do not involve the commissure, it is best to base the flap medially. Otherwise the pedicle should be based on the side that will allow for an easier transfer and inset of the flap. Schulte et al. (2001) described

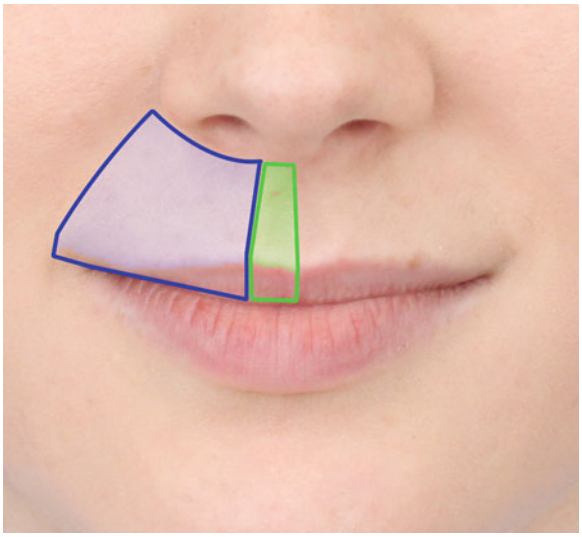
S.E. Kountakis (ed.), *Encyclopedia of Otolaryngology, Head and Neck Surgery*, DOI 10.1007/978-3-642-23499-6,



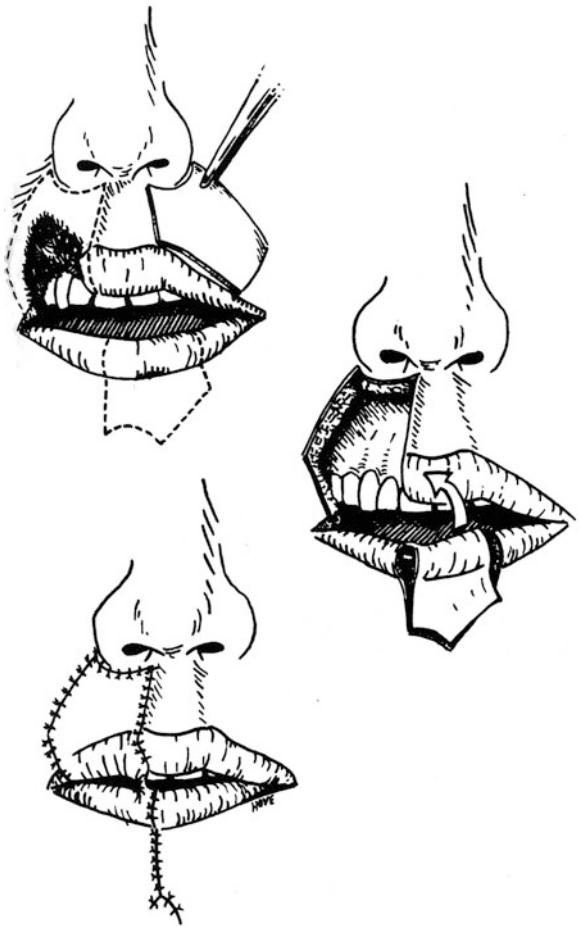
Abbe Flap, Fig. 1 Abbe cross-lip flap. A full-thickness wedge of tissue is rotated to repair a defect in the opposite lip. The donor site is closed primarily. A pedicle is left intact and attaches the two lips until the pedicle is divided 2–3 weeks later. (From DeFatta and Williams (2009). Fig. 61.5, p 845)

the location of the superior and inferior labial arteries as they course from lateral to medial. Laterally, near the oral commissure the vessel may be as far as 1.5–2.5 cm from the free margin of the lip. Within the central portion of the lip, the arteries generally lie within 1 cm from the free margin of the lip. The inferior labial artery was within the vermilion 100% of the time in the midline and 80% of the time at the commissure. The superior labial artery was within the vermilion 75% of the time at the midline and 6% of the time at the commissure. Therefore, medially based pedicles may allow for a greater degree of rotation as the pedicle is more likely to be located within the red portion of the lip, allowing the surgeon to decrease the cuff of tissue required around the pedicle. It is important to search for the artery prior to reaching the vermilion as the vessel may lie outside of the vermilion. Careful dissection may then be continued to reduce the bulk of the pedicle allowing for greater rotation and closure of the donor site on the side of the pedicle. One must be careful to leave enough tissue around the pedicle to allow for adequate drainage through the small veins that parallel the course of the artery.

The donor flap may be designed as a triangular or "V"-shaped flap as originally described by Abbe, or may be modified to be shaped as a W, rectangle, or other configurations depending on the shape of the defect. In general, the width of the donor flap is half the width of the recipient site. This allows for the two lips to remain proportionally similar in size after flap transfer. When estimating the size of the defect, one should take into account the pull of the orbicularis oris on the wound edges, which will widen the appearance of the defect. (McCarn and Park 2005) The height of the donor flap is generally the same height as the defect. In some cases, the donor site may be taken as roughly the same size as the defect to recreate an aesthetic subunit of the upper lip. Burget and Menick (Burget and Menick 1986) describe aesthetic restoration of the upper lip taking into consideration the principle of aesthetic subunits. They divide the upper



Abbe Flap, Fig. 2 Aesthetic subunits of the upper lip. Berget and Menick describe aesthetic subunits of the upper lip that include bilateral, lateral (*blue*), and medial (*green*) subunits



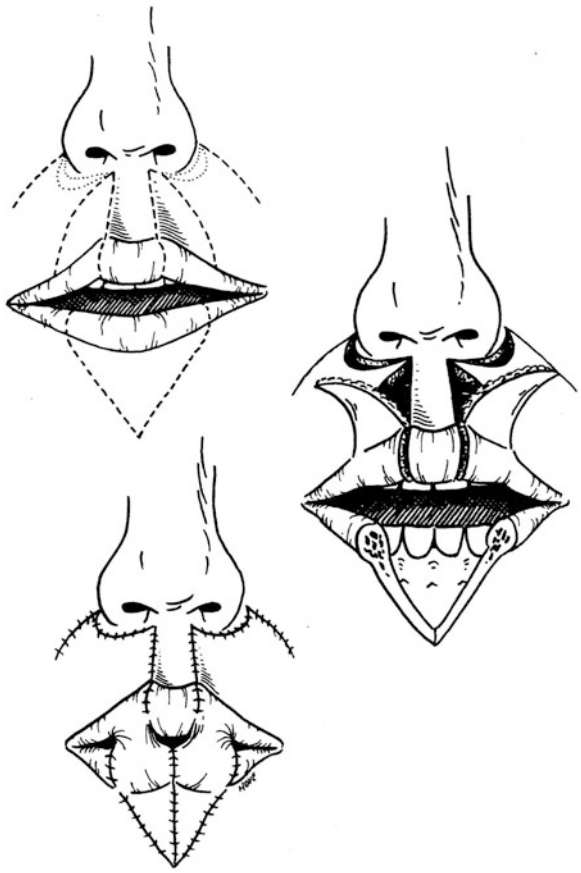
Abbe Flap, Fig. 3 Subunit reconstruction of the upper lip. Berget and Menick describe replacing an entire subunit when a defect involves greater than 50% of the subunit. The subunit is excised, a template of the subunit from the opposite side is transferred to the lower lip, and the flap is rotated to replace the defect. (From DeFatta and Williams (2009). Fig. 61.7, p 847)

lip into two halves, each containing a medial and lateral subunit (Fig. 2). When a defect involves more than 50% of a subunit they recommend excising the entire subunit, transferring a template of the defect to the lower lip, and rotating an Abbe flap containing this template into the upper lip defect (Fig. 3).

Defects that involve surrounding midfacial aesthetic subunits may also be reconstructed using an Abbe flap. Kriet et al. (1995) performed an anatomical and clinical study showing that the perfusion of the inferior labial artery extends to the anterior chin and into the submentum. Using this knowledge the authors performed an "extended" Abbe flap, creating a cross-lip flap that included skin from the anterior chin and submentum to reconstruct large defects involving the nose and cheek as well as the upper lip. Extended Abbe flaps may be used for large defects involving multiple midfacial aesthetic subunits such as the columella, perialar, and premaxillary regions. Extended Abbe flaps may also be indicated when adjacent cheek tissue used for reconstructions such as a Karapandzic flap are inadequate to achieve full closure of the defect, or premaxillary bone support is lacking which can result in collapse of soft tissues with conventional flaps.

Occasionally, bilateral cross-lip flaps may be used to close large central defects of the lower lip (DeFatta and Williams 2009). The donor flaps, taken from either side of the philtrum (Fig. 4) on the upper lip, are transferred to the lower lip defect. This allows for maintenance of the aesthetic subunits of the upper lip, but also distributes the loss between the upper lip lateral subunits instead of recruiting all of the tissue from one side, which would cause a noticeable upper lip asymmetry.

Cross-lip flaps involve the transfer of full-thickness lip tissue, which includes the transfer of muscle that has been separated from its innervation from the donor lip. This results in a temporary denervation of the muscle and loss of the orbicularis oris sphincter function over the reconstructed portion of the lip.



Abbe Flap, Fig. 4 Bilateral cross-lip flap. Central lower lip defects may be repaired with bilateral cross-lip flaps. The donor flaps are located lateral to the philtral columns thus preserving the central aesthetic unit of the upper lip. This also allows for symmetric shortening on the upper lip. (From DeFatta and Williams (2009). Fig. 61.6, p 846)

The function of the orbicularis sphincter generally returns to a near-normal with time. The first signs of motor reinnervation of the cross-lip flap begins to appear a few months after flap transfer and is demonstrated by irregular low-amplitude motor unit potentials (Renner 2007). By 1 year the amplitude increases to a near-normal level. The quality of movement may vary from near-normal function to some degree of persistent weakness. Rarely patients may experience oral incompetence due to this weakness.

Cross-lip flaps will also sustain a temporary loss of sensation as well. In a study of denervated cross-lip flaps (Smith 1960), sensation returned in a few months, starting with pain sensation at 2 months, tactile sensation at 3 months, cold at 6 months, and warmth at 9 months.

Surgical Techniques

The full thickness defect involving one third to two thirds of the upper or lower lip, not involving the oral commissure, is assessed and determined to be amenable to a two-staged cross-lip reconstruction. Some defects may result in significant destruction of the orbicularis oris muscle, but portions of the muscle and mucosa remain. In these cases, the sphincter function has already been compromised and it is generally best to excise the remaining tissue and create a full thickness defect. The lip can then be reconstructed with a full-thickness flap.

The defect is analyzed and flap size and shape is determined based on the defect. In cases where the upper lip is involved and greater than 50% of an aesthetic subunit is involved, the surgeon may want to consider enlarging the defect and reconstructing the entire subunit. For large defects involving adjacent facial subunits of the nose or cheek, an extended Abbe may be considered.

The defect template is created and then transferred to the opposing lip. In many cases, the defect will be a wedge, which will require a V-shaped flap. This flap is created to be half the width of the defect which allows for equalization of the lip proportions after flap transfer. The donor flap for rectangular-shaped defects may be created as a "W" to minimize the length of the burrow triangle required to close the donor defect. Whatever the shape, the template should be placed so that the flap is centered toward the edge of the excision on the contralateral lip on the pedicle side (Neligan 2009).

A full thickness incision is created through the cutaneous lip and the vermilion of the flap on the nonpedicled side. The labial artery is located and ligated. The location of the artery is noted. It is usually located in the submucosal plane immediately posterior to the orbicularis muscle. Next, a full thickness incision is created on the pedicle side through the cutaneous portion of the lip, starting at the point away from the vermilion. The full thickness incision is carried toward the vermilion and it is stopped approximately 5 mm from the vermilion. A partial thickness incision through the skin is created to the vermilion at this point and careful, blunt dissection is performed through the muscle to the vermilion. If the artery is encountered, dissection is stopped and the flap is rotated into place. If the artery is not encountered and the vermilion is reached, the flap is rotated into place.

The tissues surrounding the donor site may need to be undermined to close the defect. The donor site is closed up to the vermilion in layers, reapproximating the mucosa, the muscle, and subcutaneous/cutaneous tissue layers. The recipient site is closed in layers including the vermilion on the nonpedicle side. The pedicled side is closed up to the vermilion. At this point, the lips are connected to one another through the pedicle. The wound is dressed to minimize tension on the flap and the patient is placed on a soft or liquid diet to minimize biting and chewing and the possibility of placing excess stress on the flap.

Approximately 2–3 weeks later the pedicle is divided. A small portion of the closure on the cutaneous portion of the lip is excised as well to allow for an even closure once the pedicle is divided and inset. It is important to carry the incision through the vermilion in a perpendicular orientation to the lip margin. This allows for appropriate eversion and reapproximation of the vermilion margin.

Conclusion

The Abbe flap describes a two-staged cross-lip flap that is used for reconstruction of full-thickness defects of the upper or lower lip measuring one third to two thirds the width of the lip. This pedicled flap is used for defects that do not involve the oral commissure. Therefore, the flap crosses the lip at some point away from the commissure and tethers the upper and lower lips together for 2–3 weeks until the pedicle is detached. The flap will usually regain motor and sensory innervation allowing for competent oral sphincter function.

Cross-References

- ▶ Cleft Lip
- ▶ Cleft Lip and Palate
- ▶ Estlander Flap
- ▶ Lip Reconstruction

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ABI

▶ Auditory Brainstem Implant, Surgical Devices

Ablation of Frontal Sinus

▶ Paranasal Sinuses in Contemporary Surgery, External Approaches to

Ackerman's Tumor

▶ Verrucous Carcinoma of Temporal Bone

Acoustic Admittance

▶ Tympanometry

Acoustic Immittance

▶ Tympanometry

Acoustic Impedance

▶ Tympanometry

Acoustic Nerve

▶ Central Auditory System, Anatomy

Acoustic Rhinometry

▶ Nasal Function (Rhinometry, Rhinomanometry), Evaluation

Acquired Auditory Processing Disorders

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Synonyms

Auditory processing disorder (APD); Central Auditory processing disorder – [(C)APD]

Introduction

Although Auditory Processing Disorder (APD) has been described in the literature, there is a lack of consensus regarding the nature of the disorder. An early definition was the inability to attend to, discriminate, or understand speech under less than optimal conditions even though peripheral hearing and intelligence is within normal limits. This disability is more pronounced when listening to distorted speech, in noise, or in other poor acoustic environments. A recent definition of APD was described by the British Society of Audiology as listening difficulties in the absence of any hearing loss. According to a definition by the American Speech-Language Hearing Association persons affected with APD have difficulty with sound localization, auditory discrimination, auditory pattern recognition, perceiving temporal (timing) aspects of sound, and understanding speech that is competing in the two ears or acoustically degraded. A basic construct of APD is that it is specific to the auditory modality, and should be considered separately from a language, reading, or attention deficit disorder. The construct of auditory specificity is inferred in the 2005 statement on APD by a panel of the American Speech Language Hearing Association that describes APD as a deficit in the neural processing of auditory information that is not due to higher-order language, cognitive, or related factors (ASHA 2005). However, APD may lead to or be associated with difficulties in higher-order function, and it may coexist with other disorders (e.g., ADHD, Language Impairment, Learning Disability) but it is not the result of these other disorders as these difficulties may be due to a higher or more global disorder. There are many instances in which APD and other disorders of language, reading, attention, cognition, and memory are comorbid.

Auditory processing disorders are generally considered to be attributed to a dysfunction of the auditory pathways of the central nervous system. They are different from peripheral hearing loss of the middle or inner ear and from cognitive-based problems of intelligence and language. The central processing of auditory information is complex with multiple regions of the brain responsible for the analysis of acoustic signals. Due to shared processing with other sensory inputs, the behaviors of persons with APD are heterogeneous, and often overlap those of persons with other sensory deficits.

Persons with APD are heterogeneous in their symptoms and associated (comorbid) disorders. In general, they fall into two groups: (a) developmental and (b) acquired. ▶ Developmental disorders of auditory processing can occur through unknown causes such as low birth weight, intrauterine causes (e.g., fetal alcohol syndrome), viral infections, and many others. Acquired disorders of auditory

processing can occur through multiple causes ranging from head injury to disorders typically acquired at older ages. It should be recognized that there are some adults with acquired, and often progressive, APD of unknown etiology. These patients simply experience a decrease in auditory processing abilities that affect their performance in the workplace.

Basic Characteristics

Persons with APD generally have difficulty communicating through the auditory modality, they cannot hear and understand in the presence of background noise or other acoustically degraded speech (e.g., in highly reverberant conditions, when speech is muffled or presented with rapid rates, heavily accented speech, etc.). Those with developmental disorders of auditory processing often have a history of learning difficulties in the classroom. One medical student who was followed by Robert W. Keith had a severe auditory processing disorder, though he was extremely intelligent. He attended all lectures in medical school but learned little during that time. His primary learning was through careful reading of textbook materials and notes taken by classmates during lectures. Associated problems often include attention hyperactive deficit disorder (ADHD), and although they are often comorbid, it is important to recognize that APD is a separate and distinct entity from ADHD. One primary reason to appropriately identify APD is that people with this disorder are not prescribed stimulant medication as a treatment. One of the primary behavioral differences between ADHD and APD is that individuals with ADHD are hyperactive while those with APD are not. Also, individuals with ADHD do not have difficulty understanding speech in noise or competing speech while those with APD are typically handicapped in those listening environments.

Individuals who have an auditory processing disorder acquired through brain injury or other late insult (e.g., seizures, degenerative processes, or tumors) have similar disorders of auditory communication as those with developmental APD. Depending on the extent of the brain damage, those persons often have associated auditory-language problems involving memory and other cognitively based skills.

Etiology

Developmental Versus Acquired Disorders of Auditory Processing

According to a clinical guideline published by the American Academy of Audiology (2010), APD has been identified in patients with a number of different disease/injuries that compromise the central auditory nervous (CANS) system. They include neoplasms, degenerative processes such as multiple sclerosis, seizure disorders, cerebrovascular accidents, metabolic disorders, and age-related changes in CANS function. In addition, patients suffering from alcoholism, HIV, Parkinson's disease, and senile dementia are commonly affected with APD. Those patients with cortical lesions and those with traumatic brain injury have recently attracted the attention of the medical profession. Part of that interest came from the large number of wounded military returning from Iraq and Afghanistan. As awareness of APD in those patients grew, there was simultaneous interest in people with traumatic brain injury caused by motor vehicle accidents, sports, and other injuries.

According to the National Institute of Neurological Diseases and Stroke (NINDS), Traumatic Brain Injury (TBI) is a form of acquired brain injury that occurs when a sudden trauma causes damage to the brain (NINDS 2011). TBI can result when the head suddenly and violently hits an object, or when an object pierces the skull and enters brain tissue. Symptoms of a TBI can be mild, moderate, or severe, depending on the extent of the damage to the brain. Symptoms of mild TBI include headache, confusion, lightheadedness, dizziness, blurred vision or tired eyes, ringing in the ears, bad taste in the mouth, fatigue or lethargy, a change in sleep patterns, behavioral or mood changes, and trouble with memory, concentration, attention, or thinking. Those with a moderate or severe TBI may show the same symptoms as those with mild TBI, but may also have a headache that gets worse or does not go away, repeated vomiting or nausea, convulsions or seizures, an inability to awaken from sleep, dilation of one or both pupils of the eyes, slurred speech, weakness or numbness in the extremities, loss of coordination, and increased confusion, restlessness, or agitation. In addition to the APD caused by head injury there is the added concern of acquired hearing loss, either conductive or sensorineural.

In the military, service members stationed in Iraq and Afghanistan experienced injuries from different kinds of explosives, and debris such as bomb fragments and other environmental projectiles. Following a blast, the sudden increase and decrease in air pressure produces a concussion or contusion or penetrating injuries from fragments which can injure the brain directly. Air emboli can also form in blood vessels and travel to the brain, causing cerebral infarcts. The displacement of the brain, stretching of neurons and blood vessels, edema, and subsequent degeneration of neural tissue all affect cortical function. More service members have survived in recent wars because of advances in protective and medical care such as Kevlar body armor and improved helmets. According to one account, 22% of the wounded soldiers from these conflicts who passed through the military's Landstuhl Regional Medical Center in Germany had injuries to the head, face, or neck (Okie 2005). This percentage can serve as a rough estimate of the fraction that had TBI although the actual number may be higher since many soldiers with closed head injuries are not promptly diagnosed (Okie 2005).

To further understand the magnitude of the problem, in the nonmilitary segment of society, TBI is said to be the leading cause of death and severe disability in people less than 45 years of age. These injuries are predominantly caused by falls, motor vehicle accidents, and violence (CDC 2011). According to the Center for Disease Control, approximately 1.365 million persons with TBIs are treated and released from the US hospital emergency departments each year and an additional 275,000 are hospitalized for these injuries and 52,000 die (CDC 2011). Activities associated with the greatest number of TBI-related emergency department visits included bicycling, football, playground activities, basketball, riding all-terrain vehicles (ATVs) horseback riding, ice skating, and sledding. Unfortunately, TBI could have been avoided in many cases if appropriately fitted protective equipment had been worn.

Disabilities resulting from a TBI depend upon the severity of the injury, the location of the injury, and the age and general health of the individual. According to the NINDS some common disabilities include problems with cognition (thinking, memory, and reasoning), sensory processing (sight, hearing, touch, taste, and smell), communication (expression and understanding), and behavior or mental health (depression, anxiety, personality changes, aggression, acting out, and social inappropriateness) (NINDS 2011).

The CDC also states that traumatic brain injury is frequently referred to as the silent epidemic because the problems that result from it are often not visible (NCIPC 2003). While mild TBI accounts for a majority of patients seen, the consequences of mild TBI are often not mild. The outcomes of TBI including problems with cognition, sensory processing, communication, and behavior or mental health can be devastating to the affected person. One of the disorders associated with TBI that has received recent attention is the problem of APD. That is, a disorder in the person's ability to hear and understand speech under less than optimal acoustic conditions and the resulting poor listening skills.

Prevalence

Due to the lack of a gold standard for defining APD, different test approaches to evaluate an individual suspected of APD, and the recent interest in APD among persons with TBI and other diseases of the brain there are no statistics available to determine the prevalence of APD in this population. Nevertheless, it can be safely assumed that acquired APD will have an increased prevalence over developmental disorders of auditory processing in young people who have no history of birth or other brain injury.

Diagnosis of APD

The diagnosis of APD in individuals with traumatic and other brain disorders is accomplished through a battery of tests that are conducted as part of a comprehensive team approach. The team consists of a number of professionals including the audiologist, otolaryngologist, neurologist, physical medicine and rehabilitation specialist, psychologist, and speech-language pathologist. The auditory processing test battery includes both behavioral and electrophysiologic measures. The behavioral tests include those that describe functional disorders of auditory communication, and those that describe physiologic disorders including hemispheric function and cross-hemisphere transfer of auditory information. The electrophysiologic tests are sometimes used to diagnose the presence

of central auditory dysfunction but they are not used to describe functional behaviors. Tests of functional auditory communication generally include filtered words, auditory figure ground, and time-compressed sentence testing. Tests that describe auditory pathway processing include dichotic listening, pattern recognition, gap detection, and masking level difference tests.

A special concern when administering central auditory tests to people with traumatic brain injury is the increased possibility of acquired peripheral hearing loss, both conductive and sensorineural. Nearly all of the central auditory test results are negatively affected by the presence of hearing loss, thus complicating the interpretation of the findings. Guidelines to assessment of auditory processing published by a committee of the American Academy of Audiology (2010) indicate that it is possible to make a statement about CANS function in an individual with mild-to-moderate hearing loss when central auditory processing performance measures are normal or when certain patterns of performance emerge (e.g., poor central auditory performance in the normal hearing ear in individuals with unilateral hearing loss, or asymmetrical performance on a central test battery in individuals with symmetrical hearing loss). The lack of a clear discernible pattern of central auditory performance may represent the influences of peripheral hearing loss and a definitive diagnosis of APD should be withheld, even though the possibility of an APD may exist.

The Auditory Processing Test Battery

Behavioral tests for evaluating APD are abundant and each is designed to assess different components of auditory processing done in the brain. Table 1 highlights each of the tests and auditory process that it assesses.

Tests of Temporal Processing

Testing for temporal processing disorders is related to the construct that the inability to interpret rapidly changing acoustic cues in speech is a primary disability leading to disorders of speech perception. For example, the essential acoustic cue to stop consonants (e.g., /t/, /p/, /k/) is a rapidly changing spectrum provided by the second and third formant transition of the speech signal. These transitions are of relatively short duration (less than 40 ms). Vowels, on the other hand, have steady state formants of long duration (250 ms) and remain constant over the entire length of the stimulus. Therefore, it is necessary to be able to perceive acoustic rapidly changing acoustic signals of less than 40 ms (ms) in order to discriminate among speech sounds and to understand rapid rates of speech. An inability to hear those rapid transitions is described as an auditory processing disorder in the temporal domain.

One method of evaluating temporal resolution is through the use of gap detection tests that determine the smallest time interval between two closely approximated stimuli that can be detected. This interval, measured in milliseconds, is called the gap detection threshold. The gap detection threshold is obtained by having a listener attend to a series of stimuli presented in pairs where the silent interval (the interpulse interval) between each pair of tones increases and decreases in duration and as the silent interval changes, and the listener reports whether the stimulus pair is heard as one tone or two. The gap detection threshold is the stimulus interval at which the stimuli are heard as two rather than one. Examples of gap detection tests include the Random Gap Detection Test (RGDT) and the Gap in Noise test (GIN).

Pattern Recognition Tests

Temporal ordering or sequencing tasks are valuable screening tests because of the underlying processes they assess. The Frequency Pattern Test requires the patient to listen to a series of 3 tones, and report which pitch pattern they heard (i.e., low-high-low, low-low-high). Conceptually, the tones are initially processed in the nondominant right hemisphere then the interpretation of pitch perception is transferred through the corpus callosum to the language areas of the left hemisphere where a verbal response is sequenced. Low scores are associated with auditory dysfunction related to various auditory-based learning disabilities and to defined lesions of the auditory areas of the cerebrum (Pinheiro and Musiek 1985). Similarly, the Duration Pattern Test presents 3-tone signals of 200 and 500 ms and the patient is required to report the pattern that they heard (i.e., short-long-short, or long-long-short). Results of the pattern recognition tests are said to indicate interhemipheric integration of auditory information and help identify patients who experience difficulty using suprasegmental information (e.g., stress patterns, intonation, pauses) when listening to discourse in everyday language. However, that relationship is in need of more systematic investigation to

Acquired Auditory Processing Disorders, Table 1 Tests used to assess the different categories of auditory processing and what auditory processing function each test assesses

Test category	Selected tests	Auditory processes
Dichotic Listening Tests	Dichotic Digits	Binaural integration and binaural separation. Hemispheric dominance and maturation of the neural pathways of the auditory nervous system pathways
	Dichotic Consonant Vowels	
	Competing Words	
	Staggered Spondaic Words	
	Competing Sentences	
	Synthetic Sentence Identification – Contralateral Competing Message	
Monaural Low-Redundancy Tests	Low-Pass Filtered Speech Tests: e.g., Filtered Words (FW) Subtest	Auditory closure
	Speech-In-Noise Tests e.g., Auditory Figure Ground (AFG) Subtest, SSI–ICM Subtest	Auditory figure/ground
		Auditory closure
	Time-Compressed Speech Tests e.g., words, sentences	Auditory closure
Temporal Patterning/ Ordering and Temporal Processing	Random Gap Detection Test (RGDT)	Temporal resolution
	Duration Pattern Test (DPT)	Duration discrimination, temporal ordering
	Frequency Pattern Test (FPT)	Frequency discrimination, temporal ordering
Binaural Interaction	Masking Level Difference (MLD)	Binaural interaction

verify the relationship between test findings and functional associations.

Monaural Low Redundancy Speech Tests

Monaural low-redundancy (degraded) speech tests are those that are presented to one ear at a time using speech materials that are acoustically degraded in the frequency, time domain, or in background noise (► Auditory System Exam). In general, tests of monaural low-redundancy speech are used to describe functional disorders of auditory communication as shown by the ability to understand speech in the presence of background noise, to understand a distorted (e.g., muffled) speech signal, or to understand speech presented at rapid rates. While these tests are used to describe functional disorders of auditory communication they also identify the presence of cortical lesions in patients with temporal lobe lesions such as seizure disorders, space occupying lesions, and traumatic brain injury.

Physiologically, listening skills are dependent upon the afferent and efferent brainstem auditory neurons and reticular formation. Afferent neurons facilitate processing of relevant auditory input while efferent neurons inhibit unwanted information. This inhibition process occurs at all levels of the brainstem and proper functioning of these efferent fibers enhances the listening process. One of the results is that differential inhibitory responses create a favorable signal-to-noise ratio (SNR). That is, background noise is more apt to be reduced in intensity than the selected auditory message. Activation of the reticular formation also promotes adequate listening, resulting in an activating effect on the cortex and sharpening sensitivity. Another result is the habituation that occurs to a stimulus when it is given repeatedly. Therefore, integration of binaural cues, activation of the reticular formation, and functioning of the efferent fibers facilitate listening behavior. The presence of brain disorders therefore contribute substantially to listening problems.

A complete description of each of the monaural low-redundancy speech tests listed here is provided in the companion entry of ► developmental disorders of auditory processing.

Dichotic Listening Tests

Dichotic Listening Tests (DLT) provide powerful evidence to aid in the diagnosis of APD. They describe maturational delays in auditory system development in younger subjects, identify the presence of damage and disorders of the auditory pathways, and describe

hemispheric dominance for language. Specifically, DLTs evaluate the dominant hemisphere for language, delays in auditory maturation of language hemisphere, maturation and function of the corpus callosum, presence of hemispheric lesions, and possible problems of verbal working memory. There are many issues related to dichotic testing including the linguistic level of the signal ranging from digits to words to sentences, the intensity of the target and competing signals, and whether to use free recall or directed ear listening tasks.

Free recall testing is conducted by asking the subject to repeat everything heard in both ears but there is no instruction given regarding which ear or sequence of the response. When administering a dichotic test under free recall conditions, the response is simply scored as correct or an error and no attention is paid to which ear is reported first. When administering dichotic tests under directed ear listening conditions, the subject is required to listen with both ears, repeat the stimuli under conditions of the right ear first then the left ear, and the left ear first followed by the right. The expected finding under directed ear listening is that the ear advantage will narrow under directed ear left compared to the direct ear right listening condition. Free recall testing has fewer attention and cognitive demands on the subject than directed ear listening tests, and comparison of results of findings obtained using the two methods of instruction can sometimes provide evidence of the effect of cognitive and attention on the auditory processing test results. There are several dichotic tests that are available and span the linguistic hierarchy and all can be useful in the assessment of central auditory function as shown in Table 2.

Acquired Auditory Processing Disorders, Table 2 Examples of dichotic tests used in APD testing

Linguistic hierarchy	Test name
Consonant Vowel	Dichotic CV Test
Digits	Dichotic Digits Test
Words	SCAN-3: Competing Words Test
Spondees	Staggered Spondee Word (SSW) Test
Sentences	SCAN-3: Competing Sentence Test
Dichotic Sentence Identification	DSI

Dichotic Digits Testing

Dichotic digits test includes one, two, or three digits presented simultaneously to the right and left ears. Instructions can include either free recall or directed ear listening. The stimuli are numbers 1–10 except for 7. Scoring is completed simply by counting the number of digits correctly reported in the right and left ear, comparing the findings to available norms, and calculating the Ear Advantage.

Competing Words Testing

The Competing Words Test is conducted by presenting monosyllable words simultaneously to the two ears. The subject is required to repeat both words under instructions of free recall or directed listening conditions described elsewhere in this entry.

The Staggered Spondee Word Test (SSW)

The SSW test was designed by Jack Katz early in the 1960s. It was originally used to identify cortical lesions in adults before the time of CT Scans and MRI. It is currently used to identify APD in adults and children. The acoustic stimuli are presented in the following manner:

	RNC	Competing	LNC
Right ear	*Up*	Stairs	–
Left ear	–	Down	Town

RNC = right ear noncompeting with no competing signal from the left ear
LNC = left ear noncompeting with no competing signal from the right ear

The dichotic condition is presented in the RC (right competing) and LC (left competing) conditions. The interpretation can be similar to dichotic words and sentences tests through analysis of the number of errors and the size and direction of the ear advantage.

Competing Sentences Test

Competing Sentences Testing is conducted by presenting sentences with precise onset and offset times simultaneously to the right and left ears. The subject is instructed to repeat the sentence heard in one ear while ignoring the sentence in the opposite ear.

Interpretation of Test Results for Auditory Processing

Many years ago, Calearo and Antonelli (1973) summarized Carhart's five principles that describe

features of the normal flow and processing of incoming speech information within the auditory nervous system. Three of those principles can be used to describe processes that are relevant to this discussion. The first is the principle of *channel separation* where trains of speech are kept distinct from one another when the speech enters each ear separately. The two ears do not become confused and intertwined within the nervous system. The second principle is that of *contralateral pathways* reflecting the ear to the opposite hemisphere connection of the auditory nervous system. The third principle is that the *dominant hemisphere for language* resides in the auditory reception areas of the left temporal lobe with the right hemisphere being nondominant for language while possessing limited verbal capacity.

Contralateral Ear Effect and Effects of Lesions on Tests of APD

The early work on auditory processing disorders was conducted by several otolaryngologists from Milan, Italy. Their early test battery contained several of the auditory processing tests used today (Calearo and Antonelli 1973). Their studies were conducted prior to the development of modern imaging techniques with the purpose of identifying lesions of the central auditory pathways. One of the principles of interpretation described at that time that continues to be used is the "contralateral ear effect." This principle states that the ear opposite a hemispheric lesion will have decreased auditory capacity and therefore poorer performance than the ear opposite a normal temporal lobe. This is especially true for dichotic tests, but is also true for tests of monaural low-redundancy speech.

Results of Tests for Functional Auditory Processing Abilities

Expected findings on filtered words (FW), auditory figure ground (AFG), and time compressed sentence (TCS) tests include depressed overall performance, or marked overall abnormalities in ear advantage scores. The implication of these findings is that an affected individual will have greater difficulty listening to and processing auditory information than a normal individual. They will find it more difficult to follow group conversations, and will communicate most effectively in quite environments with few distractions and during one-on-one conversation. Problems associated with the auditory processing disorder will be compounded by other cognitive factors such as deficits in attention, concentration, and memory.

Results of Dichotic Listening Tests

Abnormal dichotic test results confirm the presence and extent of injury to the auditory pathways and the diminished auditory processing abilities of the affected person. Similar to the functional tests of auditory processing, abnormal dichotic performance indicates the need to identify and institute appropriate remediation programs.

Ear Advantage

During clinical testing, it is impossible to overstate the importance of understanding ear advantage information when interpreting monaural low-redundancy speech and dichotic tests. For those measures, the overall performance tells something about how well or poorly the subject is doing in general including whether there are delays or damage to the auditory nervous system. The ear advantage provides information about hemispheric function and the presence of lesions of the auditory pathways. These findings may help describe the extent of the damage to the auditory pathways and help predict the duration and perhaps outcome of management/rehabilitation. Every language-based test that is administered to the right and left ear separately (as opposed to those administered binaurally) should be interpreted for ear advantage.

The direct anatomic right ear to left hemisphere connection causes the normal strong right ear advantage in children during dichotic testing using speech. Speech presented to the left ear must travel to the right (nondominant) hemisphere, then through the corpus callosum to the language dominant left hemisphere. As the corpus callosum myelinates and matures, the ear difference diminishes until the child is 13 or 14 years old, when the responses are similar to those of an adult. Therefore, for dichotic listening tests, the typical normal child will show a right ear advantage for all dichotic tests until the auditory system is mature. It is important to understand that similar ear advantages are not present for monaurally presented tests of degraded speech and the presence of a substantial ear advantage for those tests would be an abnormal finding. In the normal/typical adult, there is no difference in performance on the right and left ears for either monaural tests using degraded speech or on any of

the dichotic measures. When a brain injury is present, however, there is a high possibility of decreased performance in the ear opposite the lesion; thus, it is called the "contralateral ear effect."

Auditory-Language Disorders Related to TBI

One of the most common sequelae of traumatic brain injury is a deficit in short-term memory. Other deficits related to cognitive disorders caused by the TBI may include such things as decreased speed of cognitive/auditory processing, that is, persons with TBI may take longer to process the ongoing speech signal and have difficulty keeping up with normal conversational rates. Additional problems include a decrease in auditory attention, concentration, thinking, and reasoning. All of these factors contribute to the need for intervention to increase the person's communication skills.

Management of Persons with Acquired APD

Cortical Neuroplasticity

Cortical remapping or neuroplasticity is the ability of the human brain to recover function following trauma or other insult to the brain. The reality of plasticity is known to otolaryngologists who understand that persons with long-standing sensorineural hearing loss can be successfully fit with hearing aids after some months of use, but only if the patient is willing to continue wearing the instruments even when the first experience with them is disappointing. In the field of audiology, this process has been known as "acclimatization." There are critical periods, however, after which return of function through plasticity is limited. A case in point is the early (prior to the 1960s) frequent practice of fitting only one hearing aid on a young child with binaural sensorineural hearing loss. Years later, it was not possible to amplify the opposite ear as it was beyond the point of improvement. This fact is behind the neuroscientist's research into the study of critical periods. What is true of the ear is true of the brain with regard to auditory processing and other cognitive functions. That is, following injury to the primary and/or association areas of the brain, a given function can move to a different location. The notion of neuroplasticity is the basic construct behind treatment of TBI as related to rehabilitation approaches to recover functional communication skills.

Management and Remediation

There is basic agreement about therapy approaches to take following assessment of auditory processing and the identification of an APD. Two terms commonly used in discussing follow-up of an APD diagnosis are "management" and "remediation." Some authors believe that these two terms have distinct meanings and implications for APD. *Remediation* is an actual altering of the central auditory nervous system function while *management* involves modifying behavior, performance, or environment with compensatory or cognitive techniques. The following is a brief overview of strategies for remediation and management of APD.

Basic intervention strategies include medical intervention, perceptual training, compensatory training, management of the environment, and cognitive training. Medical therapy is the use of drugs or surgery in the treatment of conditions that exacerbate the symptoms of an auditory processing disorder. An example of medical therapy strategies is the prescription of a stimulant medication for the treatment of ADHD or use of medication to prevent seizures. Perceptual training includes such things as computer-based programs that train or modify auditory processing abilities. Compensatory techniques (Auditory Skills Development) are used to strengthen perceptual processes and teach specific academic skills. There are many different approaches to teaching auditory skills that assist the central auditory processing disordered person in academic, social, and emotional worlds. Auditory skills include temporal processing, speech sound discrimination (auditory discrimination), auditory figure ground, auditory analysis, phonemic synthesis (auditory synthesis), auditory memory and prosodic analysis.

Cognitive training involves teaching the patient to actively monitor and self-regulate their message comprehension skills and develop new problem-solving skills. Cognitive therapy may include language training (linguistic or metalinguistic), vocabulary development, and the teaching of organizational skills. Teaching of mnemonic strategies may assist the patient with auditory memory deficits. Strategies that use rehearsal, paragraphing, imagery, networking (building bridges to store new concepts), analysis of new ideas, and use key ideas to think systematically may improve memory ability.

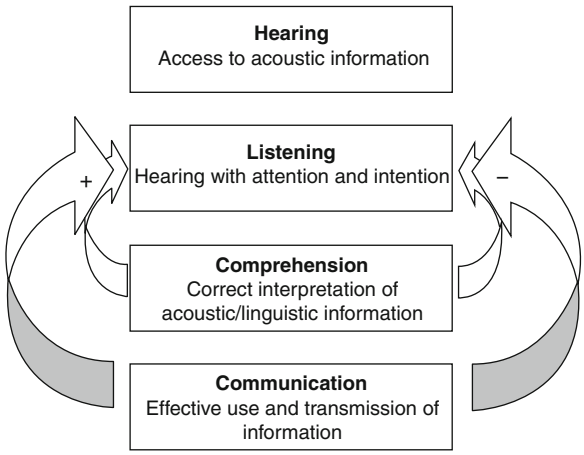
Cognitive therapy may also include the teaching of organizational skills. Some skills that may need to be taught to the patient include how to follow directions,

how to use written notes, self-monitoring strategies, learning to listen and anticipate, how to ask relevant questions, and how to answer questions.

Finally, management includes such things as enhancing the signal-to-noise ratio (SNR) and increasing visual communication. Enhancing the SNR can be accomplished through management of the environment and use of personal assistive listening devices (e.g., FM systems) to enhance the SNR ratio.

According to the AAA guidelines, clinical management includes a comprehensive, multidisciplinary interventional approach utilizing both bottom-up and top-down treatments (AAA 2010). Bottom-up (i.e., stimulus driven) intervention approaches reorganize the CANS using auditory and multimodal training skills remediation and environmental modifications. The environment can be modified to increase the clarity of the signal and/or improve the listening environment through the use of assistive listening systems and improved room acoustics. Top-down (i.e., strategy driven) intervention approaches build listening skills and strategies, promote efficient allocation of perceptual and higher-order resources (e.g., language, memory, attention), and provide compensatory methods to minimize functional listening deficits. These interventions include central resources training (i.e., language strategies, cognitive strategies, and metacognitive strategies), educational interventions (i.e., instructional modifications and learning strategies), and workplace, recreational, and home accommodations (e.g., written directives such as memos and e-mails, posting chores on white board).

One top-down intervention program is the LACE© (Listening and Communication Enhancement), a home-based, interactive adaptive computer program designed to engage the adult hearing-impaired listener in the hearing-aid-fitting process, provide listening strategies, build confidence, and address cognitive changes characteristic of the aging process (Sweetow and Sabes 2006). This innovative program that was designed to rehabilitate seniors with sensorineural hearing loss appears to have potential for remediation of persons with TBI. Many of the issues addressed in the LACE program are similar to those faced by persons with TBI and appear to have direct application with that population. For example, Fig. 1 shows the six levels of interactive memory skill exercises addressed by the program. The program works to improve auditory abilities in a number of specific areas including degraded and competing speech, speech in babble, time-compressed speech, competing speaker, auditory working memory, processing speed, interactive communication strategies, and cognition.



Acquired Auditory Processing Disorders, Fig. 1 Flowchart showing interactive remediation activities associated with the LACE© program (Sweetow and Sabes 2006)

As the person's memory skills improve the tasks become more difficult. This program, along with other computer-based programs, serve as excellent model of remediation strategies designed to assist persons with acquired APD from many causes.

Summary

In summary, APD related to acquired lesions of the brain from multiple causes is increasingly recognized as an important aspect of human hearing that should be considered when evaluating and treating affected persons. A multifactored assessment involving a transdisciplinary team will help to identify communication problems associated with auditory processing disorders. After identification of the APD, appropriate management and remediation strategies can be initiated to assist the patient in returning to their fullest potential and to aid in the communication of that patient with their family, friends, and the world at large.

Cross-References

▶ Auditory Processing Disorder (APD)
▶ Developmental Central Auditory Processing Disorders

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Acquired Hearing Loss

▶ Acquired Mixed Hearing Loss
▶ Congenital Mixed Hearing Loss

Acquired Mixed Hearing Loss

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Synonyms

Acquired hearing loss; Conductive and sensorineural hearing loss; Mixed hearing loss; Non-congenital mixed hearing loss

Definition

Acquired mixed hearing loss refers to combined conductive and sensorineural hearing losses which are not present at birth and/or develop after the first month of life (beyond the "neonatal" period).

Etiology

In addressing causes of mixed hearing loss, it is useful to divide discussion into conductive and sensorineural components – not only for diagnosis, but particularly as one considers potential treatment modalities.

Clearly, there can be many causes for mixed hearing loss (nearly any combination of conductive and/or sensorineural causes when combined can cause a mixed hearing loss). Table 1 lists many of these causes, categorized by type of hearing loss as well as anatomic location. Not emphasized here are congenital disorders causing mixed hearing loss (see ▶ Congenital Mixed Hearing Loss). Incidences of these pathologies vary greatly from childhood through adolescence and into adulthood. While many etiologies are mentioned in here in brief, the focus of this summary is largely on single etiologies responsible for both conductive and sensorineural hearing loss. Some of these may have a genetic predisposition, or be present at birth (considered by some as "congenital") but may not manifest until early or even late adulthood (i.e., otosclerosis, enlarged vestibular aqueduct (EVA), etc.). As a result, they are included in discussion here.

As insinuated above, the vast majority of hearing loss in children is conductive in nature from fluid in the middle ear space. The 2004 consensus clinical practice guideline published in the journal of Pediatrics indicates 90% of children will present to the physician's office with an otitis media with effusion (OME) at some time before school age. The overall rate of OME approaches 80% per ear (90% of all children) between ages 6 months and 4 years old; 30–40% of these children will have recurrent or persistent OME ("Otitis media with Effusion Clinical Practice Guideline" 2004). Among causes of sensorineural hearing loss (SNHL) in children, most are congenital (occurring secondary to infection, environmental causes or inherited defects). Using this data, one may infer that the most common cause of mixed hearing loss is likely middle ear effusion causing conductive hearing loss (CHL) in children with congenital sensorineural hearing.

Acquired Mixed Hearing Loss, Table 1 Causes of conductive and sensorineural hearing loss by most common location

Causes of CHL by location	Causes of SNHL by location
External auditory canal	Cochlea
Tympanic membrane perforation	Infection[a]
Foreign objects	Autoimmune[a]
Cerumen or otorrhea accumulation	Ototoxic medications/Radiation[a]
Narrowing of the ear canal (infection/inflammation, exostosis, osteoma or stenosis)	▶ Vestibular Dysfunction, Meniere's Disease
Neoplasm	Noise related hearing loss
▶ Primary Cholesteatoma	▶ Primary Cholesteatoma[a]
Middle ear	▶ Presbycusis[a]
Effusion	Latrogenic injury (middle ear or skull based surgery)[a]
▶ Tympanosclerosis, Treatment	Neoplasm[a]
▶ Otosclerosis[a]	Cochlear ▶ otosclerosis
Ossicular Fixation or malformation[a]	"Third-window" lesions[a]
Neoplasm[a]	Trauma[a]
Negative pressure	Internal Auditory Canal/VIII nerve
Latrogenic injury (middle ear surgery)[a]	Trauma[a]
Ossicular discontinuity	Vestibular schwannoma
▶ Primary Cholesteatoma[a]	Central
Inner ear	Presbycusis[a]
"Third-window" lesions[a]	▶ Developmental Central Auditory Processing Disorders
	Cerebrovascular accidents[a]
	Neoplasm[a]

[a]Several etiologies can impair hearing in multiple locations, by multiple mechanisms

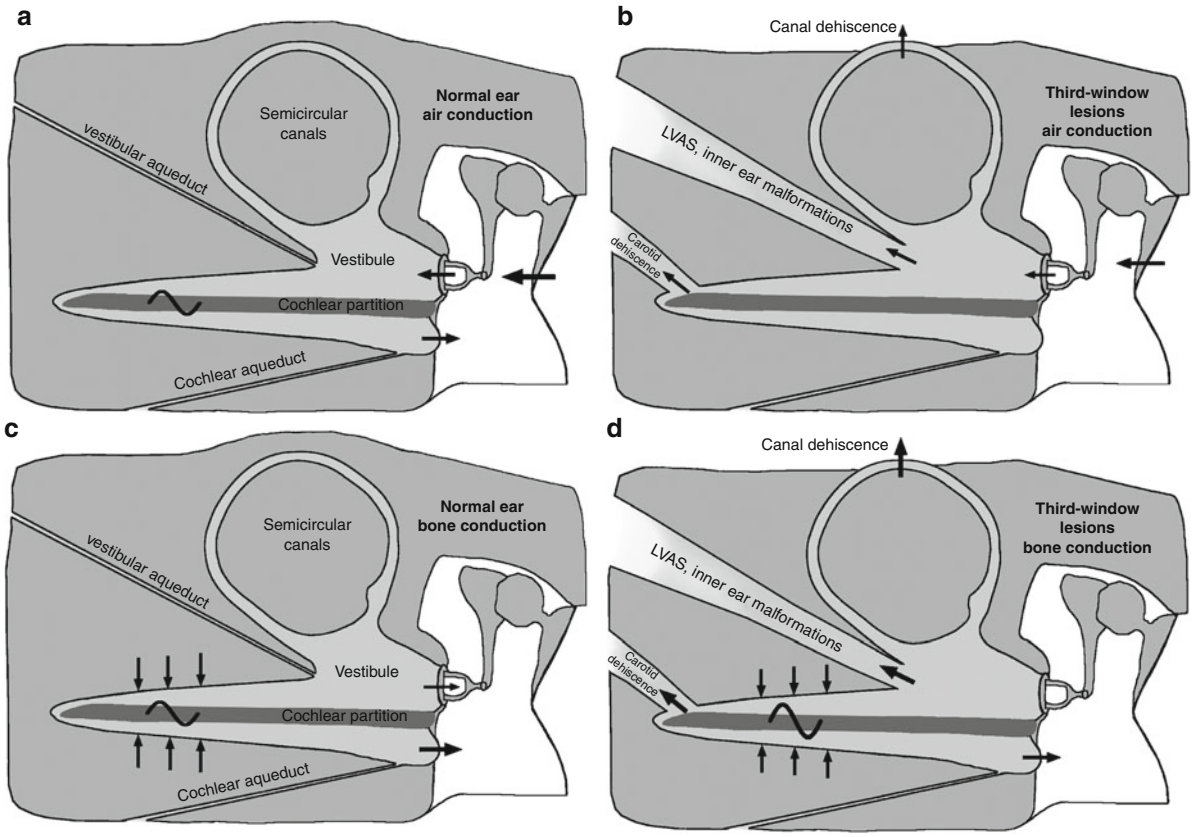
The focus of this chapter is refined to causes of mixed hearing loss in young children outside of common middle ear dysfunction. Among single etiologies for mixed hearing loss in early childhood, congenital causes must be high on the differential of the evaluating otolaryngologist. These losses are often not discovered until more formal audiometric data is obtained (ages 2–3). Many of these syndromic and non-syndromic causes are discussed in the entry: ▶ Congenital Mixed Hearing Loss.

Similar to the aforementioned combination of isolated conductive and sensorineural hearing losses in children, adolescent and adult onset mixed hearing loss may simply represent cerumen impaction (the most common cause for adult onset CHL) superimposed on ▶ presbycusis (the most common cause for SNHL in adults) (Isaacson 2010).

Setting aside obvious external or middle ear sources for the conductive component of the mixed hearing loss (the diagnosis and management which are discussed separately), one must consider less common singular disease processes which could be implicated. In order for a single lesion to affect both air and bone conduction, it must impair transmission of sound to or through the middle ear space and additionally cause deficits in sensorineural processing of the fluid wave or electrical impulse carried away from the cochlea.

In the case of trauma, this can be accomplished by isolated but simultaneous injuries to discrete areas of the hearing organ. As an example, otic capsule violating fractures or compression of the eighth cranial nerve (both causing SNHL) in addition to ossicular avulsion, discontinuity or hemotympanum (causing CHL) can together form a mixed hearing loss.

A few middle or external ear pathologies can cause a mixed loss via direct invasion of the otic capsule and the middle ear space (i.e. invasive cholesteatoma or other neoplasm). Diffuse, systemic diseases, particularly those with the tendency to cause granulomas or global hypofunction of both mechanical and neural elements (vascular or endocrine disorders), have the potential to create a mixed loss. Endocrine disorders specifically are known to cause eustachian tube obstruction (edema, mass effect) in concert with



Acquired Mixed Hearing Loss, Fig. 1 Schematic representations of mechanism of air-bone gap in third-window lesions. (**a**), Normal ear, air conduction. Air-conducted sound stimuli enter the vestibule through motion of the stapes. There is a pressure difference between the scala vestibuli and the scala tympani, resulting in the motion of the cochlear partition. The volume velocities of the oval and round windows are equal in magnitude but opposite in phase. (**b**), Third-window lesions, air conduction. It is hypothesized that a third window (in one of the canals, the vestibule or the scala vestibuli) allows a portion of the acoustic energy entering the vestibule through motion of the stapes to be shunted away from the cochlea. The shunting occurs primarily at low frequencies, resulting in a hearing loss by air conduction. (**c**), Normal ear, bone conduction. Compression of inner ear fluid by bone-conducted sound results in a hearing perception because of an inequality in the impedance between the scala vestibuli side and the scala tympani side of the cochlear partition. This inequality is primarily due to a difference in the impedance between the oval and windows. As a result, there is a pressure difference across the cochlear partition, resulting in motion of the basilar membrane that leads to perception of bone-conducted sound. (**b**), Third-window lesions, bone conduction. A third window increases the difference between the impedance on the scala vestibuli side and the scala tympani side of the cochlear partition by lowering the impedance on the vestibuli side, thereby improving the cochlear response to bone conduction. In patients with healthy cochleae as in SCD, supranormal bone conduction thresholds may be evident. In other patients with an accompanying true sensorineural hearing as in DFN-3, LVAS, etc., the improved bone conduction due to the third-window mechanism may not result in supranormal thresholds. LVAS indicates large vestibular aqueduct syndrome. (Figure and caption from: Merchant and Rosowski (2008). Conductive hearing loss caused by Third Window Lesion of the Inner Ear, Otology and Neurotology 29:282–289 © 2008. Used with permission)

cochlear degeneration (secondary to tectorial membrane or hair cell erosion, or nerve fiber degeneration) to induce a mixed hearing loss (Pellitteri et al. 2010).

Other mechanisms of impairment are based upon either bony defects or the process of bony remodeling. Most of these rely on the so-called "third-window effect". A proposed pathophysiology for this phenomenon has been well described by Merchant and Rosowski (see Fig. 1 – "Air-Bone Gap in Third-window" lesions). As the caption describes, these lesions in the bony capsule allow distension in response to a fluid wave on the scala vestibuli side of the cochlear partition. This allows for dissipation of the vibratory energy transmitted through the perilymph

and out through this defect. This dissipation of energy leads to less deflection of the cochlear partition and less hair cell stimulation (decreasing air thresholds). This same less rigid area in the bony capsule of the cochlea provides increased translation of bone-conducted sounds into the cochlea. Some authors indicate the increased pressure gradient between the scala vestibuli (now expandable) and scala tympani (relatively rigid volume) allows for increased bone conduction thresholds.

There are other etiologies for which a SNHL is commonly described, yet a CHL is sometimes observed (Meniere's syndrome, intralabyrinthine schwannomas, and others) (Merchant and Rosowski 2008). For these, there remains no clear explanation for the mechanism of the conductive component of hearing loss.

Clinical Presentation

With universal newborn hearing screening that is in place in most hospitals in the United States, infants are often identified with hearing loss shortly after birth (Katbamna et al. 2008). In children that are not identified with newborn screening, the symptoms of hearing loss can be variable and often subtle. Careful attention is required to developmental (speech and language) milestones. Lack of babbling, or failure to localize to sound as an infant or poor performance in school and/or lagging in speech development in older children may raise concerns about a child's hearing. Parents may comment on high volume while watching television or the need for repetition when speaking to their children. Because of the large proportion of infectious etiologies, symptoms of acute otitis media may accompany these and should be ruled out. Parents and primary care physicians bear the largest burden in identifying concern for hearing loss and appropriately referring patients for further otologic and audiometric evaluation (Katbamna et al. 2008). Further appropriate examination and workup for infants and young children relies on an understanding of the congenital etiologies for mixed conductive hearing loss.

In older children, adolescents, and adults, a complete history of present illness should include: onset and duration of hearing loss, progression, laterality, severity, and presence of associated symptoms such as otalgia, autophony and/or hyperacusis, vertigo, oscillopsia, tinnitus, aural fullness, or otorrhea. A history of head trauma can be helpful in directing workup. Review of systems should include other neurologic symptoms which could represent meningitic infection or stroke. Past medical and surgical history of otologic infections (recurrent acute otitis media, congenital infections) or surgery (tympanostomy tubes, cholesteatoma removal, middle ear exploration) as well as vascular disease, endocrine, or autoimmune disorders must be considered. Social history of tobacco use or IV drug use may shift the differential diagnoses (Katbamna and Flamme 2008). Probing for a family history of history loss or vertigo is important.

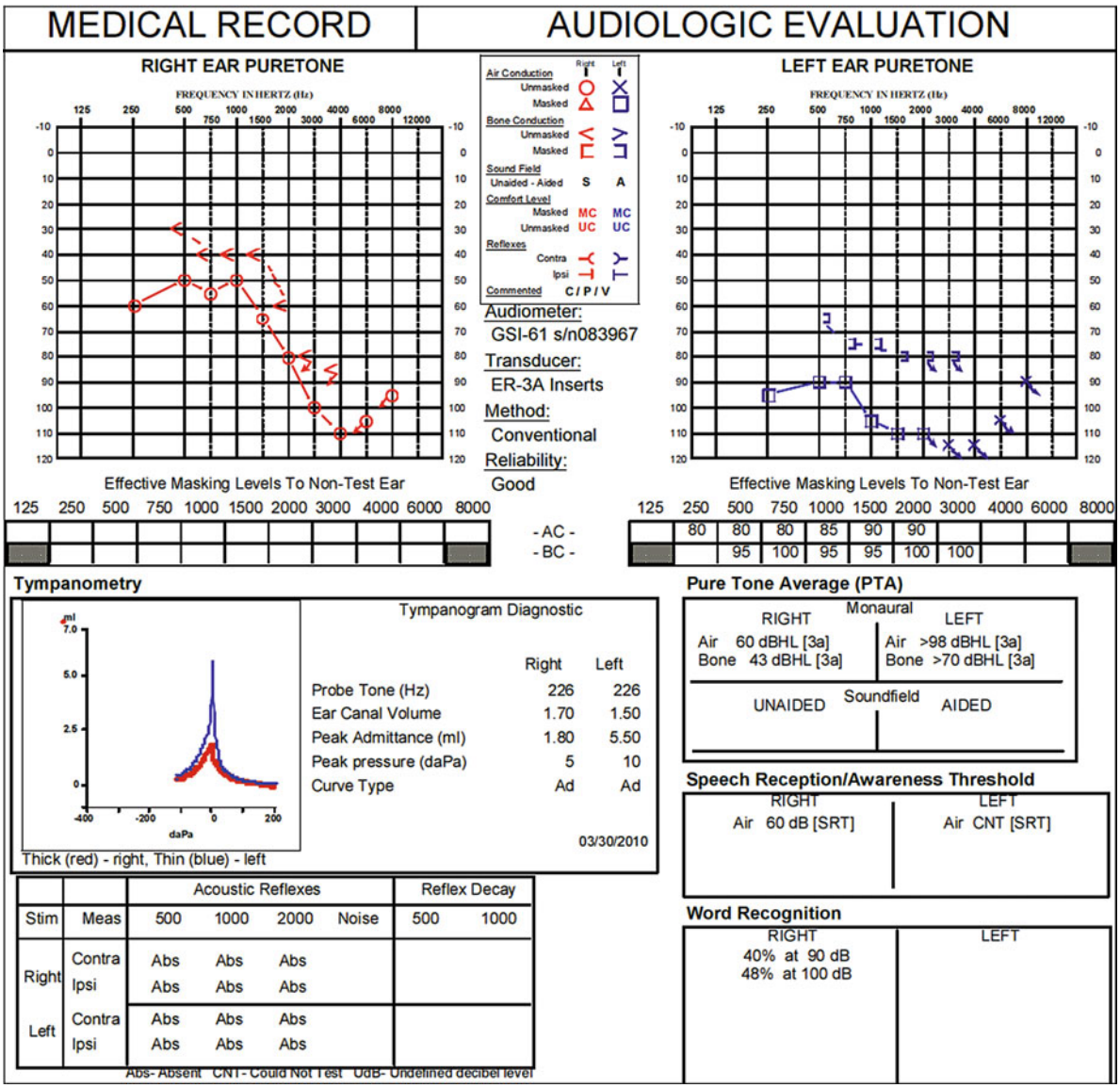
Physical exam should include an otoscopic exam (binocular microscopy if possible) for evaluation of external or middle ear anatomy (including Schwartze's sign) with pneumatic otoscopy testing for both tympanic membrane mobility and Hennebert's sign (vertigo in response to pressure changes). Tuning fork evaluation should be performed systematically. The Weber test assesses on the laterality of losses (localizing toward conductive lesions, away from sensorineural ones). The Rinne test assesses for bone versus air conduction (bone conduction greater than air on the side of conductive lesions). If the patient endorses autophony, placing a tuning fork on the medial or lateral malleolus to assess for supranormal bone conduction sensitivity may be revealing. A careful cranial nerve exam must include facial nerve assessment for impairment.

Diagnostics

Audiogram

The key to confirming a diagnosis includes full audiometric analysis including: air and bone conduction pure tone audiometry to quantify the proportion of CHL versus SNHL (see Fig. 2 – Mixed Hearing Loss Audiogram). Speech discrimination scoring is useful as it is often decreased relative to pure tone average losses for retrocochlear lesions. Tympanometry may confirm perforation or suggest a tympanic membrane mobility abnormality. Acoustic reflex testing can help confirm a diagnosis of otosclerosis (see below). In infants, otoacoustic emissions (OAE's) or auditory brainstem response (ABR) testing may be required (see ▶ Congenital Mixed Hearing Loss).

In patients with third-window lesions, bone conduction may actually be supranormal, which can be



Acquired Mixed Hearing Loss, Fig. 2 Mixed hearing loss audiogram. Moderate sloping to profound sensorineural hearing loss with progressive conductive component on *Right*. The left hearing profile shows severe to profound loss with variable conductive loss. Note the relatively normal tympanograms and absent acoustic reflexes

obscured by varying severities of sensorineural hearing loss but is, nonetheless, appropriate to request supranormal threshold testing if suspected (Merchant and Rosowski 2008) (see ► Hearing Exam).

Imaging

Determining a definitive diagnosis for patients with mixed hearing loss often requires multiple forms of imaging. CT has been reported to be the modality of choice for imaging the temporal bone and middle ear space. Contrast-enhanced MRI has been used to evaluate internal auditory canals and membranous labyrinth in SNHL (St. Martin and Hirsch 2008).

Children pose a particular diagnostic challenge secondary to the difficulty in obtaining key symptomatology as well as the possibility of delayed diagnosis of congenital lesions in addition to the above discussed incidence of middle ear dysfunction contributing to the

conductive component of hearing loss (Ahmad 2008). CT scans are expeditious (making them more tolerable to young patients) but require radiation exposure; a growing concerning in pediatric patients. Even non-contrast studies can reveal otosclerosis, osteogenesis imperfecta, or X-linked stapes gusher (see below) (Rodriquez et al. 2007). However, if the etiology for the SNHL cannot be adequately explained by CT findings, an MRI is warranted.

In adults, contrast-enhanced high resolution CT will provide additional detail in cases of trauma to the otic capsule or ossicular chain (Ahmad 2008). MRI is again indicated in either asymmetric sensorineural hearing loss (inter-aural difference of greater than 15 dB at 2 frequencies or 10 dB at 3 frequencies) or if the diagnosis is unclear from the CT images.

Additional Testing

Some authors describe exploratory tympanotomy or determining Umbo velocity although neither technique is widely employed (Merchant and Rosowski 2008).

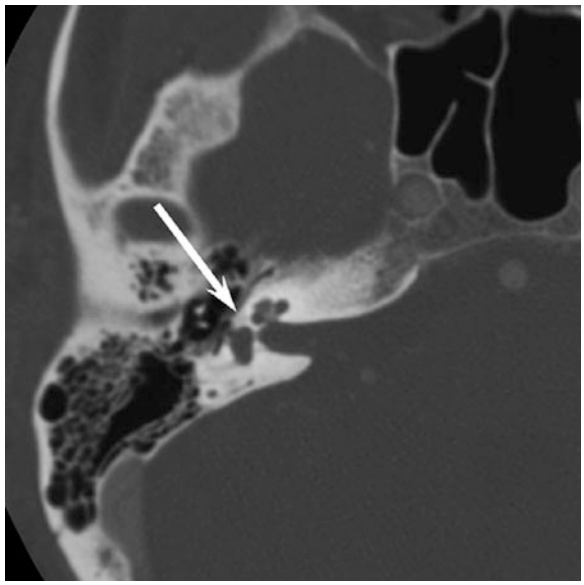
In patients who present with mixed hearing loss (particularly bilaterally) and vertigo, Vestibular Evoked Myogenic Potential (VEMP) testing may be of diagnostic benefit, and in cases requiring surgical intervention, it may provide information about severity, then guiding laterality for initial intervention.

When suspicious of infectious, endocrine, or inflammatory diseases, consider appropriately directed laboratory evaluations: CBC (acute infection with WBC elevation, peripheral eosinophilia in cases of Churg–Strauss syndrome), cANCA (Wegener's granulomatosis), TSH and free T4 (hypothyroidism), ESR and/or CRP (elevated in some neurologic and autoimmune disorders).

Differential Diagnosis

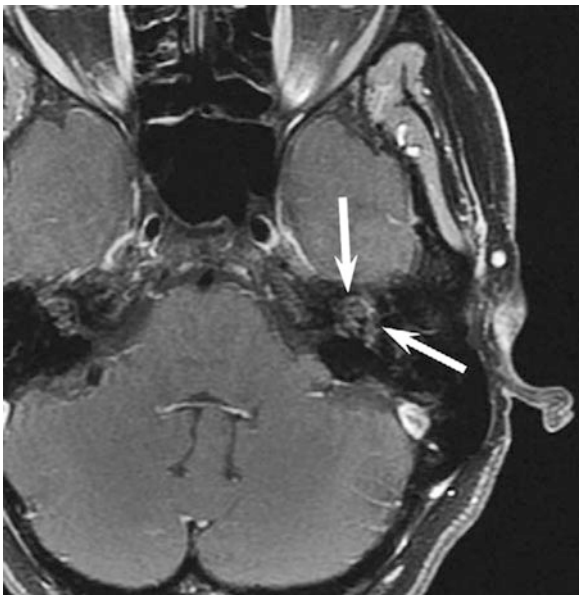
Cochlear Otosclerosis

The proposed mechanisms in this advanced form of ▶ Otosclerosis are believed to be secondary to bony remodeling that extends from the footplate onto the promontory. As that remodeling continues, it can progress to involve the cochlear endosteum (Cureoglu et al. 2010). This may cause a SNHL in addition to the classic CHL of otosclerosis. Some authors describe cavitating otosclerosis near the middle and apical turns of the cochlea which they propose cause



Acquired Mixed Hearing Loss, Fig. 3 Otosclerosis. The early CT findings of otosclerosis can be subtle, consisting of only an ill-defined focus of decreased density in the region of the fissula ante fenestram (*arrow*) in the otic capsule

a "third-window" effect (Makarem 2008). It is unclear if the disease is genetically predisposed (proposed autosomal dominant inheritance with incomplete penetrance) or caused by infectious etiologies (several reports of an associative link with rubeola virus) (Davis 2010). Onset is generally in the third to fourth decade of life (Isaacson 2010). Audiograms typically show a persistent air-bone gap with closure at 2,000 Hz. This Carhart's notch is thought to be from stapes fixation preventing the normal ossicular resonance. Many criteria have been described to diagnose cochlear otosclerosis: CHL and SNHL with good speech discrimination scores, tinnitus, vertigo (less common), absence of acoustic reflexes, binocular microscopic visualization of a reddish blush on the promontory in active lesions (Schwartze's sign), and a family history of otosclerosis (Cureoglu et al. 2010). Non-contrast-enhanced CT may show peri-cochlear hypodense "double ring" appearance secondary to demineralization of the otic capsule around the cochlea (see Fig. 3 – Otosclerosis on CT). More commonly described is a demineralized (dark) fissula ante fenestram (at the stapes footplate where the disease process is often most physiologically active) (St. Martin and Hirsch 2008). MRI may show nonspecific intermediate signal enhancement around the same



Acquired Mixed Hearing Loss, Fig. 4 Otosclerosis. The MR findings of otosclerosis are seen only when it has progressed to the cochlear form and consist of a halo (*arrows*) of enhancement and abnormal signal around the cochlea, as seen on this enhanced T1-weighted axial MR image. (The finding is bilateral. Images and captions from: Ahmad and Branstetter (2008). CT versus MRI: still a tough decision. Otolaryngology Clinics of North America, Elsevier Saunders. Copyright 2008. Reprinted with permission

areas (see Fig. 4 – Otosclerosis on MRI) (Cureoglu et al. 2010). The disease process is generally progressive with surgical therapy aimed at improving only CHL; although mild improvements in SNHL have been reported with surgical or medical intervention.

Enlarged Vestibular Aqueduct (EVA) or Large Vestibular Aqueduct Syndrome

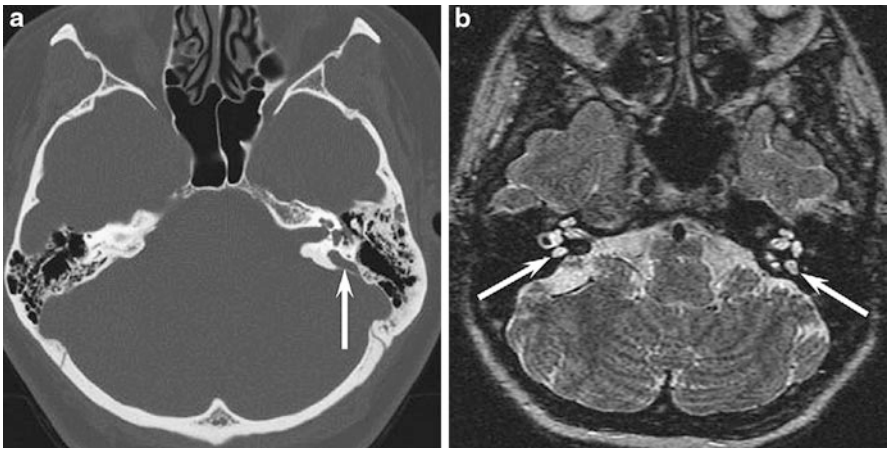
The vestibular aqueduct provides a communication between the intracranial cavity and the bony vestibule. Like otosclerosis, when present a patient can have a mixed hearing loss without visible evidence of middle ear disease on exam. While congenital etiologies are described (see ▶ Congenital Mixed Hearing Loss and Sect. "Perilymphatic Fistula" below), cases of acquired EVA often manifest as sudden onset hearing loss that often follows head trauma. Audiogram often shows low-frequency air-bone gap (similar to superior semicircular canal dehiscence-discussed below). Fine-cut temporal bone CT is diagnostic, with a pathologically enlarged vestibular aqueduct (greater than 1.5 mm in diameter) (St. Martin and Hirsch 2008) (see Fig. 5 – CT and MRI of EVA). The mainstay of treatment is counseling to avoid future head trauma.

Endolymphatic Hydrops (Meniere's Disease)

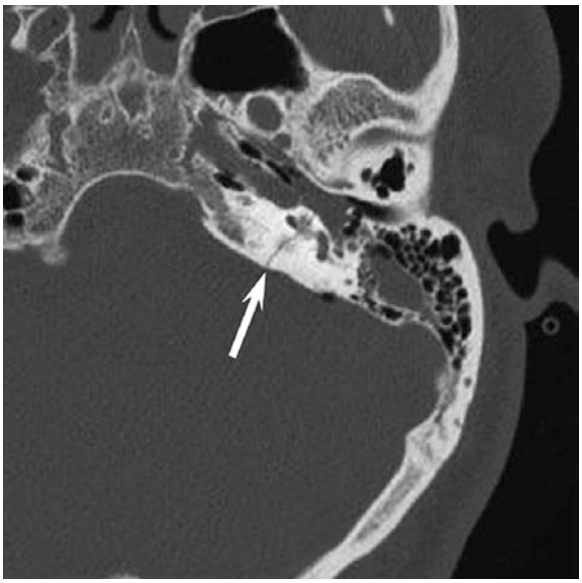
The well-known triad of low-frequency SNHL with tinnitus and vertigo are the typically described minimal criteria for diagnosis of Meniere's (Crane et al. 2010). Some suggest the cause of associated CHL lies in the "third-window" effect described above; others have proposed that the stapes' vibratory distortion causes the conductive component of the loss. Despite the unclear pathophysiology, recent studies show more than 25% of Meniere's patients will have a conductive loss (Yetişer and Kertmen 2007). Diagnosis relies on the characteristic duration of vertigo, confirmation of low-frequency SNHL in addition to a (likely low frequency) air-bone gap indicating a CHL. MRI may show some mild enhancement of the cochlea whereas CT imaging is likely to be normal. Treatment follows a ladder of escalating therapies from medical to hearing non-ablative, and then hearing ablative (see ▶ Vestibular Dysfunction, Meniere's Disease).

Temporal Bone Trauma or Otic Capsule Trauma

While ▶ temporal bone trauma can cause any type of hearing loss, classically longitudinal fractures (more recently described as otic capsule violating fractures) have been associated with sensorineural hearing loss. Because of the high incidence of conductive losses with any temporal bone trauma, these patients present with a mixed loss audiogram. CHL is most frequently caused by hemotympanum, perforation (EAC fractures avulsing the notch of rivinus), or ossicular discontinuity (most frequently incudostapedial joint) (St. Martin and Hirsch 2008). Hemotympanum may take weeks, even months to resolve; however, if follow-up audiograms show a persistent conductive hearing loss (greater than 30 dB), ossicular fracture or discontinuity must be considered. The sensorineural loss (nearly entirely associated with otic capsule violating fractures) may be from: disruption of blood supply to the cochlea or membranous labyrinth, injury to the cochlear nerve, bleeding into the cochlea, or obstruction of the endolymphatic sac causing SNHL in a similar mechanism to endolymphatic hydrops (see Sect. "Vestibular Dysfunction, Meniere's Disease" above), or perilymphatic fistula (see Sect. "Perilymphatic Fistula below). High-resolution CT can confirm otic capsule violation as well as ossicular



Acquired Mixed Hearing Loss, Fig. 5 Axial CT of the temporal bone (**a**) and T2-weighted MRI (**b**) showing large vestibular aqueducts. (**a**) Unilateral Left LVA (*arrow*). (**b**) Bilateral LVAs (*arrows*). (Image and caption from: St. Martin and Hirsch (2008) Imaging or hearing loss. Otolaryngology Clinics of North America, Elsevier Saunders. Copyright 2008. Reprinted with permission)



Acquired Mixed Hearing Loss, Fig. 6 Axial CT of the temporal bone showing a left temporal bone fracture that violates the otic capsule. The fracture line may be seen extending from the posterior fossa (*arrow*) into the basal turn of the cochlea. (Image and caption from: St. Martin and Hirsch (2008). Imaging or hearing loss. Reprinted with permission)

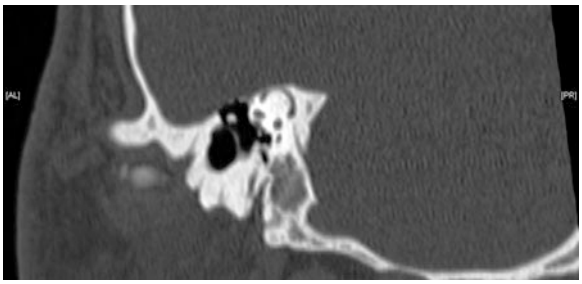
dislocation or fracture (see Fig. 6 – Temporal Bone Fracture), and although this remains an indication for surgical exploration (reconstruction of the ossicular chain with hydroxyapatite versus partial or total ossicular reconstruction prosthetics), discretion must be employed to determine if intervention beyond amplification is truly warranted. Caution is warranted even more in cases of bilateral hearing loss (Brodie 2010).

Perilymphatic Fistula (PLF)

A perilymphatic fistula, or "gusher," is aptly named for the profuse flow of cerebrospinal fluid immediately on opening the vestibule (either iatrogenically or traumatically) (Crane et al. 2010). The resulting fluid leak (CSF) is thought to arise either from a widened cochlear aqueduct or a defect in the fundus of the IAC (habenula perforata) (St. Martin and Hirsch 2008). A rare occurrence, some even debate the existence of spontaneous lesions. It is most commonly associated with DFN-3 (X-linked deafness with stapes gusher) and congenitally fixed stapes footplate. The overall iatrogenic incidence noted by House et al. is quoted as 0.03% or less of middle ear surgeries, including syndromic and non-syndromic patients (House and Cunningham 2010). Following fistula creation, hearing loss is commonly fluctuating with mixed hearing loss on audiogram (largely sensorineural loss with low-frequency air-bone gap and preservation of the acoustic reflexes). It is important therefore to evaluate preoperative CT and MRI for widening of the IAC and vestibule, potentially with enlarged vestibular aqueduct as well in patients with suspected syndromic hearing loss or trauma-related losses. Radiographic evaluations may show increased signal density on T2-weighted images near the oval window on MRI or CT findings of air within the labyrinth (St. Martin and Hirsch 2008). Treatment for PLF is surgical exploration, plugging or sealing the dehiscent area with a tissue graft or fibrin-based glue, using a lumbar drain if necessary postoperatively (House and Cunningham 2010).

Superior Semicircular Canal Dehiscence (SSCD)

Loss of bone covering the superior semicircular canal causes diversion of perilymph from both the cochlear

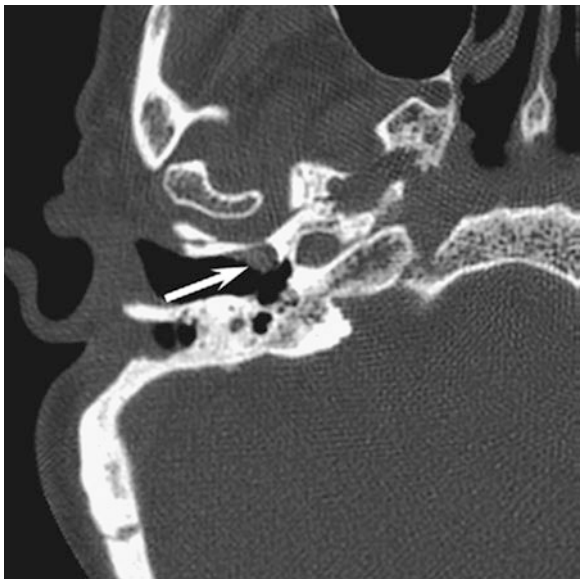


Acquired Mixed Hearing Loss, Fig. 7 Left superior semicircular canal dehiscence. Coronal CT in bone window, reformatted in the plane of the semicircular canal. The dehiscent area of bone covering the superior aspect of the semicircular canal caused vertigo after sneezing which, in this patient, caused a motor vehicle accident. This patient had undergone prior ossicular chain reconstruction (the lateral portion of the partial ossicular replacement prosthesis visible here)

and vestibular systems with increased intra-abdominal or intracranial pressures ▶ Superior Semicircular Canal dehiscence (SSCD). This causes vestibular manifestations (vertigo with straining) in addition to an air-bone gap, often with an apparent SNHL. As mentioned above, especially with a mild premorbid SNHL, the additional air-bone gap may appear to indicate significant conductive and sensorineural loss. Even without premorbid SNHL, some bone thresholds can be supranormal (particularly low frequency, with resolution of the air-bone gap at high frequencies) (Martin 2009). History is suggestive of pressure-related vertigo, autophony or hyperacusis, and correlating hearing loss. Exam findings may be (classically) positive for Tullio's and Hennebert's sign, often with the ability to detect bone conduction using a 256 Hz tuning fork placed on the medial malleolus (Merchant and Rosowski 2008). High-resolution CT (1 mm) images are reformatted both in the plane of the canal (Poschl plane) and perpendicular to the plane of the canal (Stenver plane) in order to reveal the bony defect (see Fig. 7 – Semicircular Canal Dehiscence) (St. Martin and Hirsch 2008). Treatment is surgical ablation of the canal with plugging (tissue graft and/or fibrin glue) or resurfacing.

Cholesteatoma

In its acquired form, chronic retraction of the tympanic membrane (or otologic surgery) causes nests of trapped keratin producing cells in the middle ear space ▶ Cholesteatoma. Although nonmalignant, the presence of even a small collection of squamous debris in the middle ear space can cause significant damage to the



Acquired Mixed Hearing Loss, Fig. 8 Cholesteatoma. Axial CT reveals an erosive mass (*arrow*) just lateral to the tympanic membrane along the anterior EAC, representing EAC cholesteatoma. (Image and caption from: St. Martin and Hirsch (2008). Imaging or hearing loss. Otolaryngology Clinics of North America, Elsevier Saunders. Copyright 2008. Reprinted with permission)

ossicular chain and surrounding structures (described pathophysiologies including proliferation of bacteria and associated osteolytic enzymes that erode bony structures). Typically, patients often present with otorrhea, tinnitus, otalgia, with occasional vertigo (indicating invasion of the lateral canal) and potentially facial nerve weakness. Otoscopic exam is often diagnostic. The typical losses caused by middle ear cholesteatoma are minimal and of a conductive nature. (However, bone conduction is often preserved by transmission of vibration through the mass.) Audiograms that confirm SNHL in addition to this CHL warrant CT imaging to determine the extent of the erosion. Often, scutal erosion with soft tissue density opacification of Prussak's space can be seen on high-resolution CT (see Fig. 8 – Cholesteatoma). Treatment is largely operative, but depends on extent of tumor and patient-specific considerations (some are followed with serial debridements in a clinic setting) (Isaacson 2010).

Smoking-Related Hearing Loss

Described particularly among adolescents, presumed etiologies for smoking-related mixed hearing loss surround a vascular insult or inflammatory process in the

cochlea and middle ear structures that increases susceptibility to SNHL from noise exposures (Katbamna and Flamme 2008). Additionally, a significant portion of these patients have CHL from middle ear dysfunction (caused by irritation of the respiratory cilia or mucosa in the nasopharynx). History alone is the source for diagnosis in concert with audiometric analysis, although one may see a retracted TM as evidence of negative pressure in the middle ear space. Imaging (both CT and MRI) tends to be normal. Smoking cessation may help prevent further loss and may allow improvement in eustachian tube dysfunction; however, it is unlikely to improve incurred SNHL (Kozak and Grundfast 2009).

Osteogenesis Imperfecta (OI)

Commonly known as "brittle bone disease," OI (▶ Distraction Osteogenesis) can encompass one of many connective tissue disorders. The genetic inheritance patterns vary from autosomal dominant to recessive, based on the type of collagen deficiency and locus (COL1A/COL1A2). Type I (autosomal dominant) arises from a substitution in amino acid structure rendering the collagen triple helix structure less durable (Marini 2011). The result is loose, inefficient joint motion, rapid bone turnover, and sclerosis (causing stapes fixation). In addition, weak bone allows for microfractures, which are suspected to cause a distributed "third-window" effect and lead to SNHL. Fifty percent of diagnosed patients will have resultant hearing loss, the majority (54%) of which are mixed (Cheung et al. 2005). It can appear audiometrically identical to otosclerosis but exam findings elsewhere (blue sclera, hypermobility, fractures, mitral valve prolapse, easy bruising) make OI easily distinguishable. Imaging of the middle and inner ear is similar to otoslcerosis, with diffuse skeletal findings in addition. Surgical complications in patients with OI are significant, as all surrounding skin, soft tissue, and bony structures are more susceptible to damage. As a result, treatment is often medical (bisphosphonates) (Cheung et al. 2005).

Paget Disease (Osteitis Deformans)

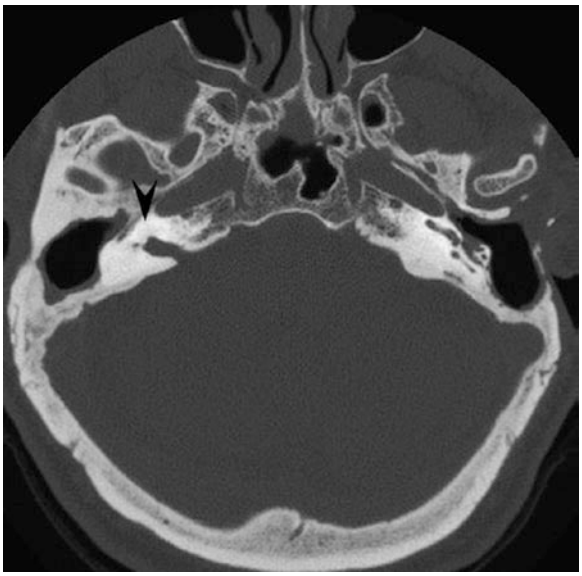
Likely secondary to mutations that upregulate TNF-beta RANK ligand pathway, IL-6 overproduction causes hyperstimulation of osteoclastic activity. The consequence is excessive remodeling of the axial skeleton, including ossicular chain and otic capsule (Cheung et al. 2005). Often not clinically present until the fourth decade of life or later, bony remodeling can cause histologically visible lytic lesions, sclerosis, or microfractures of the temporal bones. Eventually the otic capsule is entirely replaced and the membranous labyrinth is obliterated (although rarely in isolation from the axial skeleton). Audiograms show a mixed hearing loss, with the CHL at low frequencies and SNHL greatest at high frequencies (possibly from neural foramina encroachment) (Cheung et al. 2005). Skull radiography shows classic "cotton wool" appearance, with CT findings of stenotic EAC and IAC (St. Martin and Hirsch 2008). Treatment is medical and includes chemotherapeutics and calcitonin therapy (Cheung et al. 2005).

Autoimmune Disorders (Labyrinthitis Ossificans)

Underlying cause for labyrinthitis ossificans begins with meningitic infections. Both viral (CMV, rubeola, mumps) and bacterial (*Streptococcus pneumoniae*, *Hemophilus influenza*, and *Neisseria meningitidis*) causes have been suggested (Davis 2010). These infections travel through the cochlear aqueduct (which is often small and open in children) from the subarachnoid space and into the perilymphatic spaces (scala tympani). In bacterial infections, particularly *S. pneumoniae*, this response can lead to hemorrhage in to the intralabyrinthine spaces and quickly cause a fibrous response followed by ossification. Suppurative immune responses (to viral etiologies as an example) can similarly cause obliteration of the scala spaces (Cheung et al. 2005; Mark 2005). Early in the course of disease these changes create MRI enhancement, and the increased porosity of the blood/brain barrier then allows contrast enhancement which is visible on CT as well as T2-weighted MRI (see Fig. 9 – CT of labyrinthitis ossificans). Appropriate medical management of acute or chronic infections is paramount. However, once labyrinthitis ossificans is noted, hearing amplification versus cochlear implantation will be required, with careful attention to imaging to ensure patent scala for placement of the electrode (Davis 2010).

Granulomatous Diseases

▶ Granulomatous diseases of the temporal bone are overall uncommon. Specific underlying diagnoses may range from histiocytosis to ▶ Wegener's granulomatosis to Churg–Strauss syndrome. Exam will likely be significant for symptoms mimicking



Acquired Mixed Hearing Loss, Fig. 9 Axial CT of the temporal bone in a patient who has right-sided labyrinthitis ossificans. The view is at the level of the fundus of the right IAC, showing complete ossification of the right cochlea (*arrowhead*) and near-total ossification of the right labyrinth. (Image and caption from: St. Martin and Hirsch (2008). Imaging or hearing loss. Otolaryngology Clinics of North America, Elsevier Saunders. Copyright 2008. Reprinted with permission)

otitis externa (bloody otorrhea) or even mastoiditis (painful swelling of pre- and postauricular regions with facial nerve palsy or symptoms of peripheral vestibular lesions). Spontaneous perforation has been reported, and TM thickening may be observed on exam. Audiograms show mixed (but largely conductive) hearing losses. Symptoms are often responsive to topical (or systemic) steroid therapy as indicated for other manifestations of underlying disease processes (Bauer and Jenkins 2010).

Hypothyroidism

In children with congenital hypothyroidism (cretinism), the prevalence of mixed (and progressive) hearing loss is significant. In adults with hypothyroidism, the loss tends to be both less severe and less prevalent. The conductive component of a mixed loss may come from malformation of the ossicular chain or eustachian tube dysfunction (presumably from edema). Most infants with SNHL resolve with oral supplementation of thyroid hormone; however, prolonged hypothyroidism causes atrophy of the tectorial membrane and hair cells at the basal turn which, if not noted early in infancy, will cause substantial and permanent impairment (Pellitteri et al. 2010).

Prophylaxis

Immunization against bacterial etiologies associated with meningitis is important in preventing CNS infections causing labyrinthitis.

Population studies suggest a higher incidence of otosclerosis in geographic areas of low or no fluoride in drinking water (Cureoglu et al. 2010).

Avoidance of head trauma (i.e., contact sports) is recommended for children with diagnosis of EVA.

Hearing protection is the mainstay of prophylaxis against further SNHL.

Therapy

Hearing Amplification

Many with mixed hearing losses will meet indications for hearing amplification, which remains one of the first-line treatments and most effective mechanisms for improving quality of life in these patients. Options are largely behind the ear amplification and in canal amplification. The choice between these options relies on patient preference, anatomy, amplitude of loss, and other comorbid conditions (see ▶ Hearing Aid).

Medical Interventions

Relatively few effective medical therapies are available that have shown statistically significant benefits for causes of mixed hearing loss. Exceptions apply to metabolic or endocrine disorders, otosclerosis, and diffuse third-window lesions (e.g., Paget's disease, granulomatous disorders, and hypothyroidism).

Options for addressing the bony remodeling in otoslcerosis include both medical and surgical options. Sodium fluoride has been postulated to have inhibitory activity against proteolytic enzymes, thus reducing bony resorption. In one double-blinded randomized controlled study in Europe and several non-controlled studies, patients had a statistical decrease in recurrence and/or worsening of hearing loss with sodium fluoride therapy (60 mg/day initially then 20 mg for maintenance). Some physicians add calcium and vitamin D to this regimen (Cureoglu et al. 2010; Linthicum 2009). Higher frequency SNHL of less than 50 dB responded

best. Recent literature proposes bisphosphonates may also be effective by inhibiting osteoclastic activity (Cureoglu et al. 2010).

Surgical Interventions

With few notable exceptions, surgical therapy aims to improve conductive hearing loss, making the sensorineural losses more easily aidable or providing implantable modes of amplification.

When etiologies are discrete, the conductive loss can often be nearly resolved (e.g., ▶ tympanostomy tube placement, ▶ canalplasty, atresia reconstruction for EAC obstruction, ▶ Ossicular chain reconstruction for traumatic interruptions).

Surgical options for otosclerosis (mentioned in brief above and more comprehensively elsewhere) include middle ear exploration with ▶ complete stapedectomy, ▶ partial stapedectomy, or microfenestration. Except in extenuating circumstances, surgeons generally choose the worse hearing ear for initial procedures. Bone conduction thresholds have been shown to improve in 75% of patients, with 85% of those patients having retained their gains years later (Yazdi 2009). Even in patients with apparently severe SNHL, some authors still advocate for middle ear exploration and stapedectomy (due to the limits of bone conduction testing to 70 dB, the patient may appear to have no response and a profound mixed loss, when they may have some function and appear to improve after surgery). Conversely, for progression to profound disease with decreasing speech discrimination scores despite being appropriately aided, cochlear implantation may be an option (House and Cunningham 2010).

Certainly in etiologies with debilitating side effects such as superior semicircular canal dehiscence or refractory Meniere's disease, surgical intervention is dictated for control of symptoms. However, a frank discussion must be entertained between operating physicians and patients as not everyone will see a significant improvement in hearing and even among those that do, hearing amplification may still be required. For those with an otherwise asymptomatic mixed hearing loss, a reasonable approach is to pursue amplification until disease progression warrants further intervention. In superior semicircular canal dehiscence, surgical intervention commonly requires middle cranial fossa approach with either re-roofing or ablation of the dehiscent area. Hearing loss generally improves with correction of bony defect (either by ablation or re-roofing the defect) (Wilkinson 2008).

For temporal bone neoplasms and for cholesteatoma, surgical resection is often indicated; however, improvement of hearing thresholds is unlikely to be the primary objective or probable outcome of these procedures.

Implantable Hearing Devices

Hearing amplification (before or after surgical correction) that reaches profound thresholds, or provides poor return of speech discrimination warrants consideration of implantable devices (▶ Implantable Hearing Devices). The cause in most cases is inability of conventional hearing aids to provide enough gain for incoming signals. Generally, the maximum level of output needed to effectively aid speech and sound is approximately 50 dB above the pure tone average (Slatterly 2005). When this limit is reached without effective amplification, (usually occurring at severe to profound thresholds), implantable devices may be indicated.

Bone Anchored Hearing Aid (BAHA)

Candidates for osseointegrated cochlea stimulators (like the BAHA) are those with CHL or mixed hearing losses that are not effectively treated using standard surgical techniques (poor surgical candidates), or those ineffectively rehabilitated with traditional hearing aids due to severity of loss or inability to tolerate conventional hearing aids (Lustig and Della Santina 2010). With the advantage of relatively superficial surgical intervention, BAHA has been proven effective for severe mixed hearing loss which are too significant for even newer digital hearing aids, particularly when the conductive component is greater than 30 dB (Tjellstrom 2010; Flynn 2009) (see ▶ Bone-Anchored Hearing Aids (BAHAs)).

Cochlear Implantation

▶ Cochlear Implantation has FDA approval for bilateral severe to profound loss. By this guidance, patient must have greater than 70 dB on pure tone averages, have failed amplification with aided speech discrimination scores of less than 50%, and have no anatomic contraindications to placement. However, clinical trials and expert opinion both support less strict criteria, in addition to bilateral implantation. Many endorse implantation for low-frequency losses

(at 250–500 Hz) that would not, by strict criteria, meet FDA approval for implantation. Currently, several otologists use cutoffs of 70 dB loss at 1,000 Hz or above for better hearing ear with word discrimination scores of <70% (Wackym and Runge-Samuelson 2010). If imaging was not recently obtained during diagnostic evaluation, it is warranted prior to cochlear implantation to evaluate the cochlea, IAC, and middle ear to ensure anatomic suitability.

Results in case series and retrospective review articles show good recovery of speech discrimination results for patients with profound mixed losses (Bruschini 2010). Not surprisingly, the longer the duration of severe to profound hearing loss, the worse the outcome. Additionally, cochlear implantation in patients with cochlear otosclerosis and labyrinthitis ossificans has higher rates of facial nerve stimulation following implantation (Wackym and Runge-Samuelson 2010).

Several cases of BAHA users that have ultimately been transitioned to CI for progressive mixed losses show good results for this group of patients' mixed losses (Verhaegen et al. 2009).

Middle Ear Implantable Devices

More recently therapies have included implantation of the Vibrant Soundbridge or other ▶ middle ear implantable devices. These devices are similar to a cochlear implant in that they are approved to treat SNHL, but different in that they use mechanical amplification to increase movement of the ossicular chain. The Vibrant Soundbridge is one such device being used in Europe to treat conductive hearing loss. The device itself (called a floating mass transducer) is placed external to the cochlea and either attached to ossicular chain or, more recently, against the round window. Criteria for placement require word recognition scores greater than or equal to 50% with losses less than 65–85 dBs for 500–4,000 Hz frequencies, respectively (Slatterly 2005). Recent case series showed pure tone average gain at 32 dB, and 25 dB for speech recognition, with excellent subjective improvements in hearing and speech discrimination (particularly for round window insertion) (Dumon 2009; Baumgartner 2010).

Prognosis

The vast majority of SNHL is uncorrectable and progressive (rare exceptions noted above). Similarly, with most causes of mixed hearing loss, disease processes themselves are progressive. As such, patient counseling and treatment strategies are nearly all focused on protection of hearing, prevention of further loss, and capitalizing on retained hearing function, rather than curative therapies.

Acknowledgments Special thanks to authors Saumil Merchant, Barton F Branstetter IV, and Barry E Hirsch for generous use of their images and illustrations and to Elizabeth Cornish AuD for audiometric illustration.

Cross-References

- ▶ Acquired Mixed Hearing Loss
- ▶ Acute Otitis Media
- ▶ Audiometry
- ▶ Auditory System Exam
- ▶ Autoimmune Sensorineural Hearing Loss
- ▶ Bone-Anchored Hearing Aid in Pediatrics
- ▶ Bone-Anchored Hearing Aid in Single-Sided Deafness
- ▶ Bone-Anchored Hearing Aids in Conductive and Mixed Hearing Loss
- ▶ Boney Lesions of the Temporal Bone (Fibrous Dysplasia)
- ▶ Cartilage Tympanoplasty
- ▶ Cholesteatoma, Acquired
- ▶ Chronic Otitis Media
- ▶ Cochlear Implantation, Revision – Adult
- ▶ Cochlear Implants (CIs)
- ▶ Cochlear Nerve, Anatomy
- ▶ Conductive and Mixed Hearing Losses, Use of Vibrant Soundbridge
- ▶ Conductive and Sensorineural Hearing Loss
- ▶ Congenital Conductive Hearing Loss
- ▶ Congenital Cytomegalovirus and Sensorineural Hearing Loss
- ▶ Congenital Mixed Hearing Loss
- ▶ Distraction Osteogenesis
- ▶ Ear Canal Wall Replacement/Reconstruction
- ▶ ENG/VNG
- ▶ Esteem: Totally Implantable Hearing System
- ▶ Facial Nerve Imaging, CT and MRI
- ▶ Genetics of Adult Sensorineural Hearing Loss
- ▶ Genetics of Hearing Loss
- ▶ Granulomatous Disorders
- ▶ Hearing Aid
- ▶ Hearing Assessment in Infancy and Childhood

- Hearing Exam
- Hearing (Sensorineural Hearing Loss – Pediatric)
- Hearing Testing, Auditory Brainstem Response (ABR)
- Implantable Hearing Devices
- Langerhans Cell Histiocytosis of Temporal Bone
- Magnetic Resonance Imaging, Cholesteatoma
- Microtia and Atresia
- Microtia (Small Ear)
- Middle Ear Adenoma
- Middle Ear Hearing Loss
- Middle Ear Physiology
- OAEs
- Ossicular Chain Reconstruction
- Ossiculoplasty
- Ossifying Fibroma
- Otolaryngologic Manifestations of Proteus Syndrome
- Otologic Manifestations in Wegener Granulomatosis
- Otosclerosis
- Physiology of Cochlear Nerve
- Rotary Chair
- Sensorineural Hearing Loss
- Sensorineural Hearing Loss and Meningitis
- Sensorineural Hearing Loss (Iatrogenic)
- Stapedectomy and Stapedotomy
- Superior Canal Dehiscence
- Surgical Devices (Cochlear Implantation, Pediatric)
- Surgical Devices (Cochlear Implantation – Pediatric, Congenital Malformations)
- Temporal Bone Trauma
- Testing, Posturography
- Tympanoplasty, Underlay and Overlay Techniques
- Unilateral Vestibular Weakness
- Vestibular and Central Nervous System, Anatomy
- Vestibular Dysfunction, Meniere's Disease
- Vestibular Dysfunction Secondary to Trauma

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Acquired Nasal Abnormality

► Acquired Nasal Deformity and Reconstruction

Acquired Nasal Deformity and Reconstruction

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Synonyms

Acquired nasal abnormality; Nasal defect; Nasal irregularity; Nasal malformation; Nasal rebuilding; Nasal reformation

Definition

1. Acquired nasal deformity is defined as any abnormal variation of the normal appearance of the nose and/or its structures caused by a non-congenital etiology.
2. ► Nasal reconstruction is defined as any surgical procedure performed for the reassembling or reforming of the nose and/or its structures in order to attain normal appearance and function.

Introduction

Pediatric nasal deformities comprise a broad range of congenital and acquired pathologies. Congenital deformities are rare, whereas acquired deformities are more common. In contrast to congenital nasal deformities, surgical intervention is less frequently required in acquired nasal deformities in the pediatric population.

The decision to operate is based primarily on the extent of the functional impairment and the severity of the aesthetic deformity. Neonates are obligate nasal breathers, and hence the consequences of nasal deformity which causes nasal obstruction are more prominent in this age group. In older children as in adults, the nose has other important functions including moistening, warming, and filtration of the inhaled air, olfaction, resonance, immunity, adequate respiration, and subsequent gas exchange.

Nasal deformities in children can result in abnormalities of appearance, function, or both. Chronic nasal airway obstruction and mouth breathing can cause changes in facial growth and ► sleep-disordered breathing. Nasal appearance has a potential psychosocial and behavioral effect in all age groups. Table 1 summarizes the etiologies of acquired nasal deformities in the pediatric population.

In this entry, we will review the nasal surgical anatomy, the main causes of acquired nasal deformities, and the principles for reconstruction. Congenital nasal deformities will be discussed elsewhere.

Nasal Anatomy

Overlying Skin and Soft Tissues

The overlying skin of the nose may be divided into vertical thirds. The skin of the upper third is fairly thick

Acquired Nasal Deformity and Reconstruction, Table 1 Acquired nasal deformity: etiologies

Traumatic	Infectious	Inflammatory	Neoplastic	Pharmacologic	Iatrogenic
Falls	Infected septal hematoma or abscess	Pyogenic granuloma, cystic fibrosis	Hemangioma, lymphangioma	Vasoconstrictors (nasal sprays)	Surgery: septal deviation or perforation, saddle nose, synechia
Sports activities	Skin or intranasal infection (Strep., Staph.)	Sarcoidosis, Wegener's granulamatosis	Nasal polyps, squamous papilloma, angiofibroma	Cocaine, "crack"	Nasogastric tube, Nasal endotracheal tube
Road accidents	Tuberuclosis, rhinoscleroma	Relapsing polychondritis, vasculitis	Sarcoma, neuroblastoma	Glue and other chemical sniffing	Nasal stents, CPAP
Child abuse	Invasive fungal (Mucormycosis, Aspergillosis)	Rhinoliths	Carcinoma, Met. leukemia, lymphoma		Nasal piercing

but tapers into a thinner mid-dorsal region. The inferior third regains the thickness of the upper third owing to the more sebaceous nature of the skin in the nasal tip. The difference in the skin thickness must be appreciated during dorsal reduction.

The nasal muscles are encountered deep to the skin and comprise four principal groups: the elevators, the depressors, the compressor, and the dilators. The elevators include the procerus and levator labii superioris alaeque nasi. The depressors are made up of the alar nasalis and depressor septi nasi. The compressor of the nose is the transverse nasalis, whereas the dilators are the dilator naris anterior and posterior. The muscles are interconnected by an aponeurosis termed the nasal superficial musculoaponeurotic system (▶ Superficial Musculoaponeurotic System (SMAS)).

The internal nasal lining consists of squamous epithelium in the vestibule. This turns to pseudostratified ciliated columnar respiratory epithelium with abundant seromucinous glands inside the nose.

The external soft tissue of the nose can be divided into subunits. The purpose of subunits is to divide the nasal anatomy into segments useful for reconstruction. If more than 50% of the subunit is lost, one would strive to replace the whole unit with regional tissue or tissue from a donor site. The subunits includes the dorsal nasal segment, lateral nasal wall segments, the hemilobule segment, soft tissue triangle segments, the alar segments, and the columellar segment.

Blood Supply

The nose, like the rest of the face, has an abundant blood supply (Figs. 1–2). The arterial supply to the nose may be principally divided into: (1) branches from the internal carotid, namely, the branches of the anterior and posterior ethmoid arteries from the ophthalmic artery and (2) branches from the external carotid, namely, the sphenopalatine, greater palatine, superior labial, and angular arteries.

The external nose is supplied by the facial artery, which becomes the angular artery coursing over the superomedial aspect of the nose. The sellar and dorsal regions of the nose are supplied by branches of the internal maxillary artery (namely, the infraorbital) and ophthalmic arteries (which are from the internal carotid system).

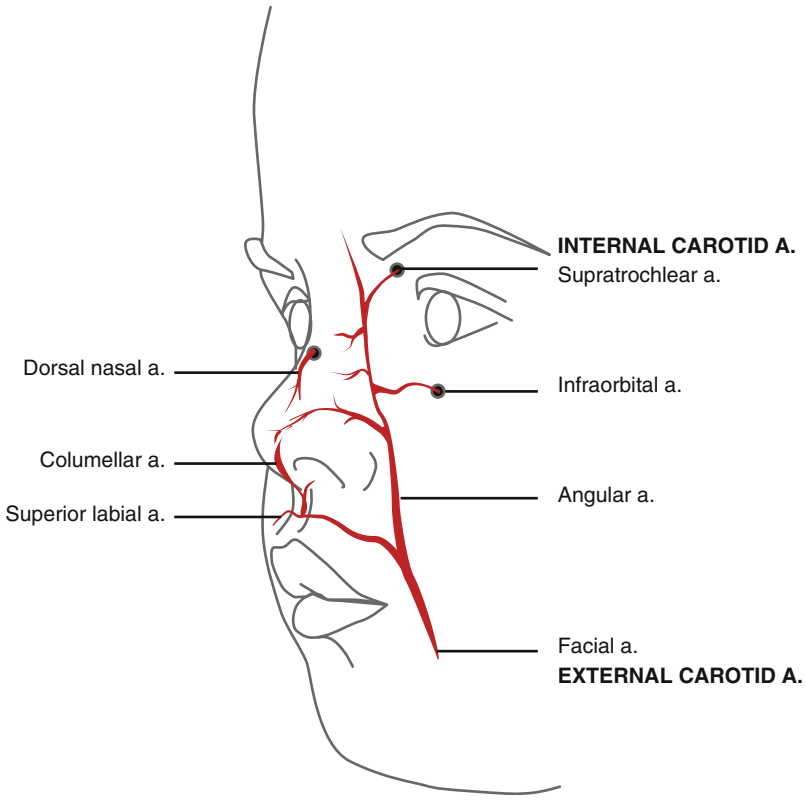
Internally, the lateral nasal wall is supplied by the sphenopalatine artery posteroinferiorly and by the anterior and posterior ethmoid arteries superiorly. The nasal septum also derives its blood supply from the sphenopalatine and the anterior and posterior ethmoid arteries with the added contribution of the superior labial artery (anteriorly) and the greater palatine artery (posteriorly). The Kiesselbach plexus, or the Little area, represents a region in the anteroinferior third of the nasal septum, where all three of the chief blood supplies to the internal nose converge.

Veins in the nose essentially follow the arterial pattern. They are significant for their direct communication with the cavernous sinus and for their lack of valves; these can cause intracranial spread of infection.

Lymphatics

Lymphatics arise from the superficial mucosa and drain posteriorly to the retropharyngeal nodes and anteriorly to the upper deep cervical nodes and/or submandibular glands.

Acquired Nasal Deformity and Reconstruction, Fig. 1 External vasculature



Nerves

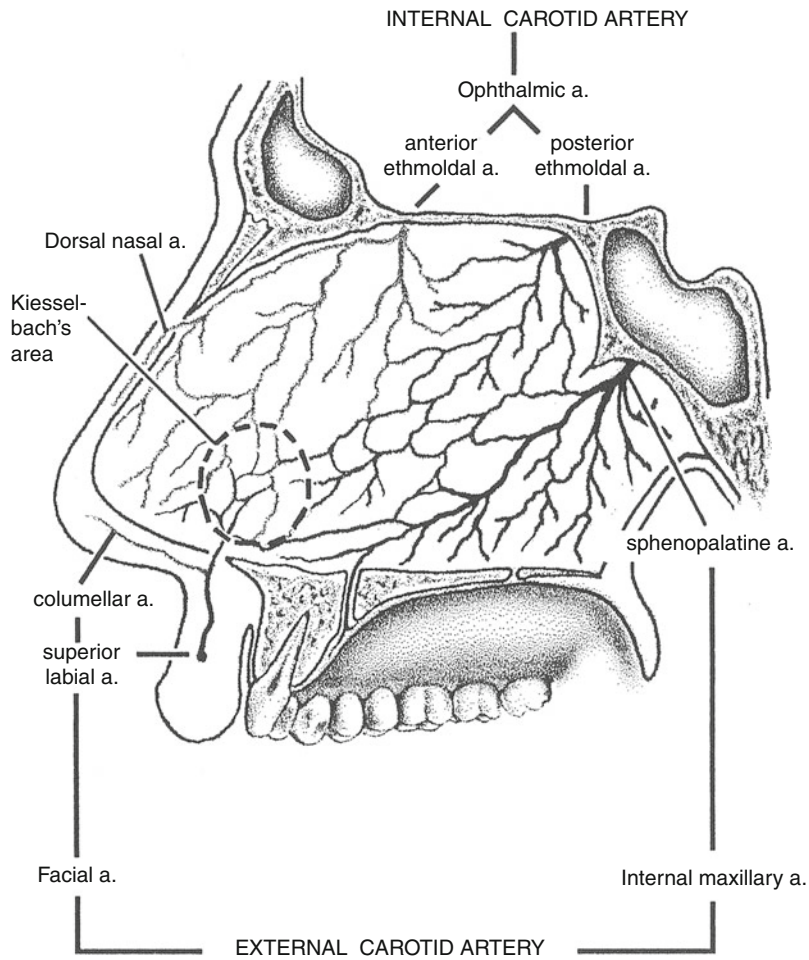
The sensation of the nose is derived from the first two branches of the trigeminal nerve (Figs. 3–4). The following outline effectively delineates the respective sensory distribution of the nose and face of the trigeminal nerve:

- Ophthalmic division
  - Lacrimal – Skin of lateral orbital area except lacrimal gland
  - Frontal – Skin of forehead and scalp
    - Supraorbital – Eyelid skin, forehead, and scalp
    - Supratrochlear – Medial eyelid and medial forehead
  - Nasociliary – Skin of the nose and mucous membrane of anterior nasal cavity
    - Anterior ethmoid – Anterior half of nasal cavity: (1) internal – ethmoid and frontal sinuses and (2) external – nasal skin from rhinion to tip
    - Posterior ethmoid – Superior half of nasal cavity, namely, the sphenoid and ethmoids
    - Infratrochlear – Medial eyelids, palpebral conjunctiva, nasion, and bony dorsum
- Maxillary division
  - Maxillary
  - Infraorbital – External nares
  - Zygomatic
  - Superior posterior dental
  - Superior anterior dental – Mediates sneeze reflex
  - Sphenopalatine – Divides into lateral and septal branches and conveys sensation from posterior and central regions of the nasal cavity

The parasympathetic supply is derived from the greater superficial petrosal (GSP) branch of cranial nerve VII. The GSP joins the deep petrosal nerve (sympathetic supply), which comes from the carotid plexus to form the vidian nerve in the vidian canal. The vidian nerve travels through the pterygopalatine ganglion (with only the parasympathetic nerves forming synapses here) to the lacrimal gland and glands of the nose and palate via the maxillary division of the trigeminal nerve.

Bony Anatomy

Superiorly, the paired nasal bones are attached to the frontal bone. Superolaterally, they are connected to the lacrimal bones, and inferolaterally, they are attached to



Acquired Nasal Deformity and Reconstruction, Fig. 2 Internal vasculature (septum)

the ascending processes of the maxilla. Posterosuperiorly, the bony nasal septum is composed of the perpendicular plate of the ethmoid. Posteroinferiorly lies the vomer, which in part forms the choanal opening into the nasopharynx. The premaxilla and the palatine bones comprise the floor of the nose.

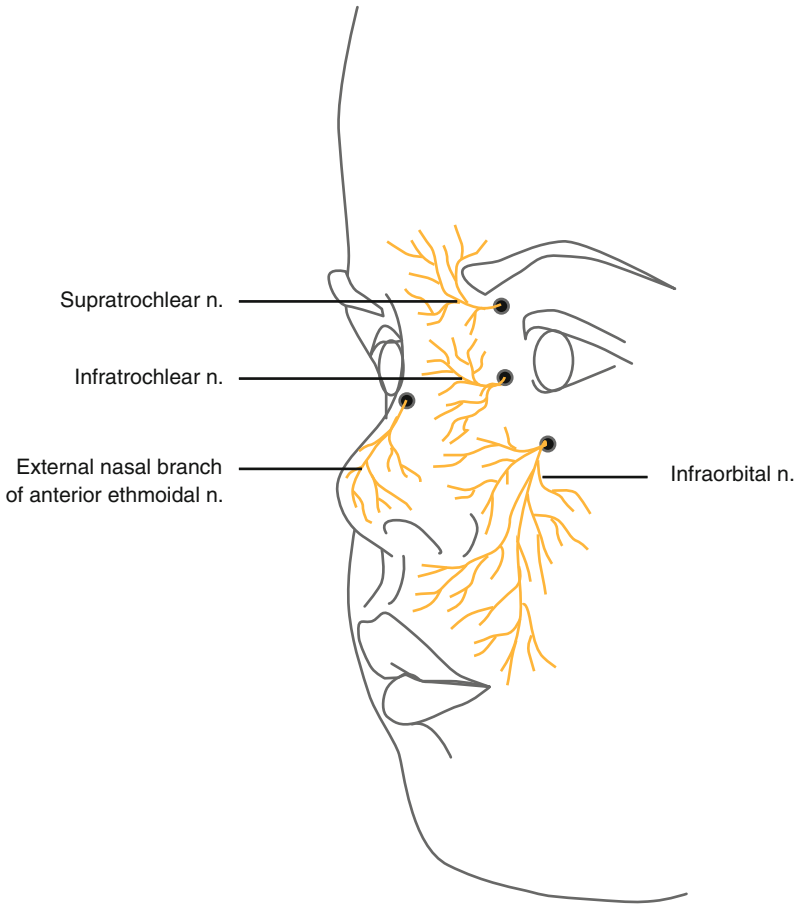
The lateral nasal walls contain three pairs each of small, thin, shell-like bones: the superior, middle, and inferior conchae, which form the bony framework of the turbinates. Lateral to these curved structures lies the medial wall of the maxillary sinus.

Inferior to the turbinates lies a space called a meatus, with names that correspond to the above turbinate, e.g., superior turbinate, superior meatus. The roof of the nose internally is formed by the cribriform plate of the ethmoid. Posteroinferior to this structure, sloping down at an angle, is the bony face of the sphenoid sinus.

Cartilaginous Pyramid

The cartilaginous septum extends from the nasal bones in the midline above to the bony septum in the midline posteriorly, then down along the bony floor (Fig. 5). It assumes a quadrangular shape. Its upper half is flanked by two triangular-to-trapezoidal cartilages: the upper lateral cartilages. These upper lateral cartilages are fused to the dorsal septum in the midline and attached to the bony margin of the pyriform aperture laterally by loose ligaments. The inferior ends of the upper lateral cartilages are free. The internal area or angle formed by the septum and upper lateral cartilage constitutes the internal valve. Adjacent sesamoid cartilages may be found lateral to the upper lateral cartilages in the fibroareolar connective tissue. These are found variably. Beneath the upper lateral cartilages lie the lower lateral cartilages. The paired lower lateral cartilages swing out from medial attachments to the caudal septum in the

Acquired Nasal Deformity and Reconstruction, Fig. 3 External nerve supply



midline, called the medial crura, to an intermediate crus area. They finally flare out superolaterally as the lateral crura. These cartilages are frequently mobile, in contradistinction to the upper lateral cartilages.

External Nasal Anatomy

Figure 6a depicts the external nasal anatomy. Subunits include the dorsum, the sidewalls, the hemilobules, the alae, the soft triangles, and the columella, shown in Fig. 6b.

The external valve is a variable area dependent on the size, shape, and strength of the lower lateral cartilage.

Internal Nasal Anatomy

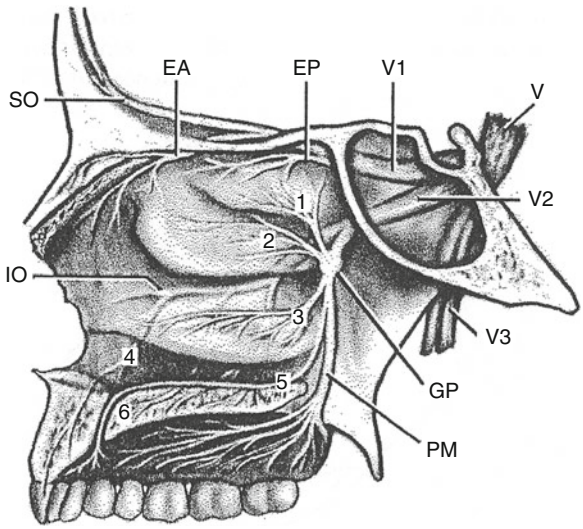
The septum is a midline bony and cartilaginous structure that divides the nose into two similar halves.

Regarding the lateral nasal wall and paranasal sinuses, the superior, middle, and inferior concha form corresponding superior, middle, and inferior meatus on the lateral nasal wall. The superior meatus is the drainage area for the posterior ethmoid cells and the sphenoid sinus. The middle meatus provides drainage of anterior ethmoid and the maxillary and frontal sinuses. The inferior meatus provides drainage of the nasolacrimal duct.

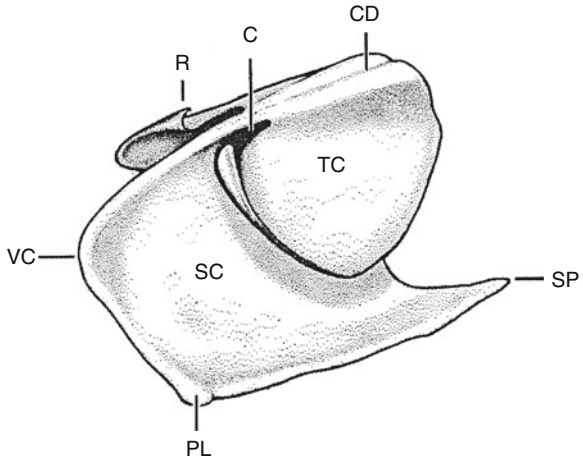
The internal ▶ nasal valve involves the area bounded by upper lateral cartilage, septum, nasal floor, and anterior head of the inferior turbinate. Generally, an angle wider than 15° is needed in this area. The width of the nasal valve can be increased with spreader grafts and flaring sutures.

Nasal Analysis

The nose can be conveniently divided into several subunits: the dorsum, the sidewalls (paired), the hemilobules (paired), the soft triangles (paired), alae (paired), and the columella. Viewing the external nasal anatomy by its subunits is important because defects that span an entire subunit are usually repaired with



Acquired Nasal Deformity and Reconstruction, Fig. 4 Internal nerve supply. V = Trigeminal n. 1 = Post. sup. lat. nasal n., V1 = Ophthalmic n. 2 = Post. inf. lat. nasal n., V2 = Maxillary n. 3 = Post. Inf. Lat.nasal n., V3 = Mandibular n. 4 = Ant. Alveolar n., GP = Pterygopalatinal ggl. 5 = Nasopalatinal n., EP = Posterior Ethmoidal n. 6 = Incisive n., EA = Anterior Ethmoidal n., SO = Supraorbital n., IO = Infraorbital n



Acquired Nasal Deformity and Reconstruction, Fig. 5 Cartilaginous vault. *SC* septal cartilage, *C* cleft, *CD* cartilaginous dorsum, *TC* triangular cartilage, *PL* lateral process, *SP* sphenoidal process, *VC* ventro-caudal corner, *R* returning

reconstruction of that subunit. Burget suggests replacement of the entire subunit if more than 50% of the subunit is lost during resection (Burget and Menick 1985). Aesthetically, the nose – from the nasion (nasofrontal junction) to the columella-labial junction – ideally occupies one third of the face in the vertical dimension. From ala to ala, it should ideally occupy one fifth of the horizontal dimension of the face.

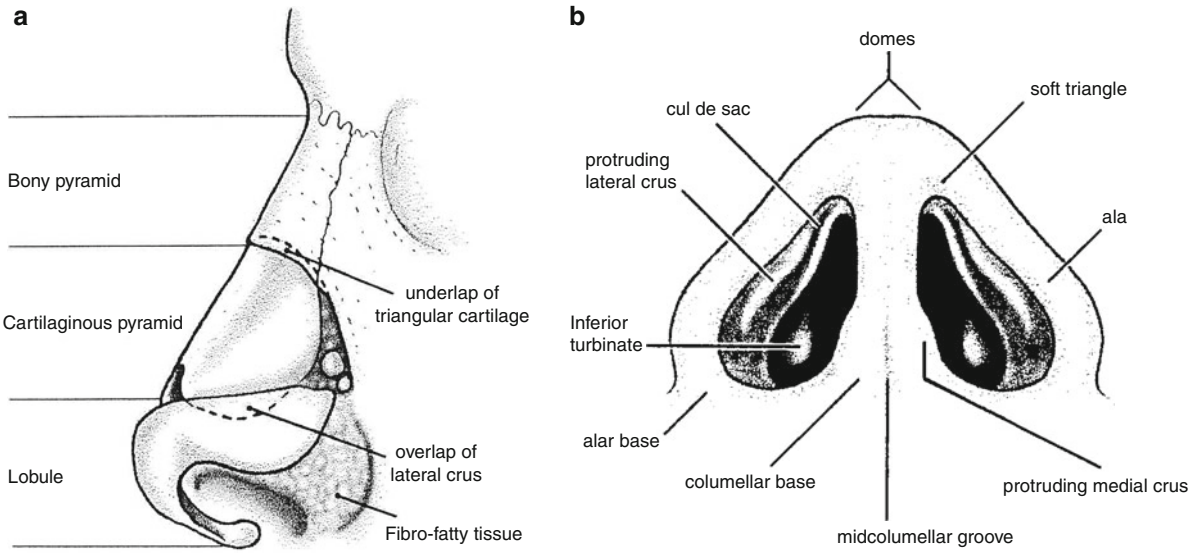
The nasofrontal angle between the frontal bone and nasion is usually 120° and slightly more acute in males than in females. The nasofacial angle, or the slope of the nose compared with the plane of the face, is approximately 30–40°. The nasolabial angle between the columella and philtrum is about 90–95° in males and 100–105° in females.

On profile view, normal columella show, i.e., the height of the nasal aperture visible is 2–4 mm. The dorsum should be straight. From below, the alar base forms an isosceles triangle, with the apex at the infratip lobule just beneath the tip. Appropriate projection of the nasal tip, or the distance of the tip from the face, is judged by using the Goode rule. Tip projection should be 55–60% of the distance between the nasion and tip-defining point. A columellar double break may be present, marking the transition between the intermediate crus of the lower lateral cartilage and the medial crus.

Traumatic Nasal Deformity

Nasal fractures are the most common facial bone injury in children (Anderson 1996). Childhood ▶ nasal trauma typically results from falls, contact sports, weight lifting, and automobile crashes (usually involving bicyclists or pedestrians). Child abuse also must be considered.

The nose of a child is markedly different from that of an adult. The main difference is that the projecting tissue in a child's nose is soft, compliant cartilage that readily bends during a blow to the face. The force is dissipated across the maxillary soft tissues and lateral buttresses. The result is a broad area of edema with loss of anatomic specificity. The soft projecting cartilages rarely sustain permanent injury, whereas the septum, which is more rigid and surrounded by bone in a tight perichondrial covering, is more likely to be fractured. Several types of septal injuries are known to occur. The septal perichondrium can be torn away from the cartilage, leaving a potential space into which bleeding can occur; the result is septal hematoma. The septum can be torn from its inferior and posterior bony attachment. The result is immediate nasal obstruction and long-term hypertrophic growth disturbances. Injury to the caudal septum can cause immediate nasal obstruction and long-term twisting deformities.



Acquired Nasal Deformity and Reconstruction, Fig. 6 (**a**) External nose (**b**) Lobule

The nasal bones have little projection in infants and very young children and are not frequently broken. Children older than 6 years are more susceptible to bony fractures. When the fractures do occur, they often are of the greenstick variety. Midline injuries can result in open-book fractures, with a central depression and lateral flaring of the nasal bones. Occult nasal orbitoethmoidal fracture always should be suspected with fractures of the nose.

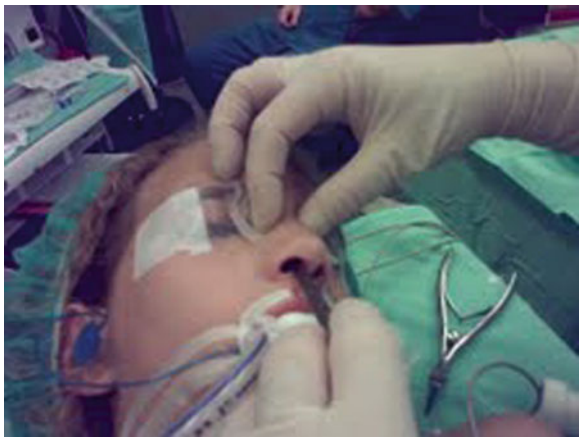
Management and Reconstruction: The management of nasal trauma in infants and children depends upon their age, the degree of nasal obstruction, and associated injuries. Septal deviations that cause nasal airway obstruction in newborn infants should be repaired by a pediatric otolaryngologist because newborns are preferential nose breathers. Similarly, children with septal hematomas or abscesses warrant prompt pediatric otolaryngology consultation.

Patients who have no symptoms, minimal swelling, and no septal deviation or hematoma do not need specific follow-up. Patients with nasal fracture but no septal hematoma may be referred to the otorhinolaryngologist within 3–5 days. This brief delay in evaluation permits resolution of the edema, facilitating visualization of the nasal structures. In addition, if parents are instructed to bring a recent photograph of the child to the appointment, the otorhinolaryngologist can compare the nasal contours before and after the trauma.

Deviation and fracture: Deviation of the nasal septum that was noted on the initial evaluation can be reduced by the otorhinolaryngologist at the follow-up visit. The short delay in definitive treatment has little adverse effect on outcome. However, delay beyond 7 days may render reduction of nasal fractures more difficult or cause permanent displacement because the active growth centers in the child's nasal bones promote rapid healing. The fractured elements become difficult to mobilize after 7–10 days (Bluestone et al. 1996).

Most nasal fractures in children can be managed with closed reduction. Fractures with splayed nasal bones and no impactions can be reduced with bilateral digital compression on the dorsum (Fig. 7). Nasal deviation to one side often can be reduced by digital compression on the side of the deviation. The endpoint of reduction in children is difficult to appreciate because the cartilaginous elements do not move into place as readily as the ossified elements do in adults; nor do the elements "snap" into place. Use of intranasal instrumentation may be necessary if digital compression alone is not successful. Open reduction may need to be performed if significant dislocations are present, the injury is more than 2 weeks old, or closed and intranasal instrumentation fail (Koltai and Rabkin 1996).

Hematoma and abscess: Management of septal hematoma and abscess should be carried out urgently by an otorhinolaryngologist. These lesions should be



Acquired Nasal Deformity and Reconstruction, Fig. 7 Closed reduction of nasal fracture

aspirated by needle to confirm the diagnosis of hematoma or abscess. Aspirated material should be sent for Gram stain and aerobic and anaerobic cultures.

Management of septal hematomas involves drainage followed by plication of the mucoperichondrial flaps to the cartilaginous septum with a through-and-through chromic suture. Septal abscesses are treated with incision, drainage, and nasal packing.

Children who undergo drainage of either septal hematoma or abscess should be treated with systemic antibiotics. Antibiotics should be chosen to cover anaerobes, *Staphylococcus aureus*, *Streptococcus pneumoniae*, group A beta-hemolytic streptococcus, and *Haemophilus influenzae*. Treatment with clindamycin is recommended until the results of cultures and susceptibility studies are available (Ginsburg and Leach 1995).

Children who have had nasal trauma complicated by septal hematoma should be examined periodically for evidence of cosmetic deformities for 12–18 months after the injury (Ginsburg 1998).

Nasal Septal Deviation

The incidence of septal deviation in newborns is approximately 1% (Jaffe 1981; Podoshin et al. 1991). It is not known whether septal deviation in newborns is due to intrauterine pressure or delivery trauma (Stoksted and Schønsted-Madsen 1979). Septal deviation from documented injury and from abnormalities of septal development in older children are much more common.

Management and Reconstruction of septal deviations of all age groups in the pediatric population is controversial. Although some have advocated that neonatal septal dislocations should be repositioned early, most surgeons have found septal deviations to self correct and remain asymptomatic over time (Sorri et al. 1990).

In older children with septal deviation, surgery is performed only in severe symptomatic cases not otherwise amenable to other treatments. Although concern has been expressed about the possible effect of surgery on subsequent nasal growth, there is little evidence to show that conservative nasal surgery will affect it adversely.

Nasal Septal Perforation

Nasal septal perforations are relatively uncommon in the pediatric population in comparison to the adult population. The most common causes are iatrogenic, traumatic, and drug induced. In the presence of a perforation, the normal intranasal laminar airflow becomes altered, which results in crusting, whistling, recurrent epistaxis, perichondritis, nasal tip collapse, saddle nose deformity, and a subjective sensation of nasal obstruction.

The symptomatology of septal perforations varies greatly, ranging from asymptomatic cases to devastated patients who become obsessed with this defect. Asymptomatic cases do not require reconstruction.

SMR (Sub Mucosal Resection of nasal septum) is a very common surgical procedure in adults but it is sometimes performed in children too. One of the complications of SMR is septal perforation.

Management and Reconstruction: The initial treatment of a patient with septal perforation consists of nasal hygiene, avoidance of digital cleaning, and nasal irrigation with saline. Antibiotic treatment or petroleum-based ointments can be used in cases of local infection or for lubrication, respectively. If the patient is still symptomatic, there are several surgical options to correct septal perforations.

1. Nasal septal button – A prosthetic device that is inserted into the perforation site. It can remain in place for years, depending on the proper care of the prosthesis and adequate nasal hygiene. Complications include pain, crust formation, epistaxis, and possible enlargement of the perforation.
2. Endonasal approach – This approach is suitable for the correction of small defects, measuring less than

5 mm. It begins with a hemitransfixion incision and elevation of mucoperichondrial flaps. An interposition graft is inserted, and then the septal mucosal flaps are approximated with basting sutures, and silastic splints are used for 2–3 weeks.

3. External Rhinoplasty Approach – This approach provides wide exposure and increased mobilization of the mucoperiosteal flaps with a 90% success rate (Kridel 1999). Complete description of the surgical technique is beyond the scope of the entry. In brief, the stages include:
   - Inverted V-midcollumellar and marginal incisions
   - Dissection in the subperichondrial plane
   - Closure of the defect
   - Graft placement
   - Repositioning
   - Incision closure
4. Inferior Turbinate Pedicled Flap – This technique is performed using an endonasal approach. It is suitable for perforations of the caudal septum measuring up to 2 cm. This procedure mandates a second stage to divide the pedicle.
5. Facial Artery Musculomucosal (FAMM) Flap – The FAMM flap is used to close relatively big perforations measuring 2–4 cm (Pribaz et al. 1992). The donor site is the buccal mucosa adjacent to the facial artery, which receives retrograde blood flow through the facial artery. The flap is tunneled through a subperiosteal dissection into the pyriform aperture, where it is sewn into position.
6. Radial Forearm Free Flap – This fasciocutaneous flap is based on the radial artery, and is used for the closure of very large defects.

Iatrogenic Nasal Deformity

Acquired nasal deformities have been reported after nasotracheal intubation, nasogastric tube placement, or from the use of nasal continuous positive airway pressure (CPAP) in neonates. Acquired nasal deformities result from poor immobilization and placement of the cannulas and can result in a spectrum of problems including skin ulceration, alar necrosis with secondary stenosis, and septal deformity. The nose can heal over time after the inciting factor has been removed; however, permanent deformity is well recognized. Strict attention should be given to preventing these deformities, although some children appear biologically more vulnerable for unexplained reasons. Nasal and ▶ sinus surgery is a main cause for acquired nasal deformity and should always be considered during the procedure and in evaluating a patient who had a previous nasal surgery.

Reconstruction of Nasal Defects Following Resections

When it comes to analyzing the need for nasal reconstruction, there are four major differences between a child and an adult: development, anatomy, injury causes, and the psychosocial factor (Giugliano et al. 2004). During the first years of life, the entire face changes from a small, flat, and undefined structure in newborns to a more prominent and globe-shaped tip at the age of 5, and surgical nasal development is complete at the age of 16. These changes raise specific questions regarding pediatric nasal reconstruction: will the reconstructed region grow in proportion to face development? When is the most appropriate time for reconstruction? Must a definitive reconstruction be planned in adulthood? Up to date, these questions remain debated.

The psychological aspect is highly important in nasal reconstruction in the pediatric population. At the age of 5 years a child develops self-image and self-esteem, so definitive reconstruction should ideally be completed by this age (Burget and Menick 1994).

The mode of reconstruction depends on the amount and type of the tissue resected: skin only defects, nasal lining (mucosal) defects, cartilage-including defects, and alar (full thickness) defects.

The modes for reconstruction of nasal defects are as follows:

Primary closure: Small nasal defects, especially in the upper 2/3, can be closed primarily (Moolenburgh et al. 2010).

Skin grafts: These grafts can be used when only a small amount of skin was resected.

▶ Local/Regional flaps: Local/Regional flaps for nasal reconstruction include: Forehead flap (the most commonly used local flap), Miter flap, Bilobe flap, Glabella flap, V-Y advancement flap, and Nasolabial flap. The forehead skin flap is considered by many surgeons to be the best donor site for resurfacing the nose, and is the best choice when at least one of the three subunits need to be reconstructed and when a full-thickness injury with cartilage or internal lining exposure is present. It is a reliable, aesthetic, and versatile way to reconstruct the nose, and has been described in the pediatric population.

Cartilage grafts: Are used in combination with other flaps in cases of complex nasal defects.

- Free flaps: The free radial forearm fasciocutaneous free flap is preferred because of its robust vascularity, large vessels, and thin subcutaneous adipose layer (Walton et al. 2005).

Others: Implant retained nasal prosthesis or a nasal prosthesis without implant. These options are used when total nasal amputation has occurred and reconstruction is not feasible.

Cross-References

- Classification of Flaps
- Deviated Nasal Septum
- Endoscopic Sinus Surgery (ESS)
- Facial Fractures in Children
- Free Tissue Transfer in Head and Neck
- Invasive Fungal Sinusitis
- Juvenile Nasopharyngeal Angiofibroma
- Local Flaps
- Nasal and Sinus Trauma
- Nasal Obstruction in Newborn
- Nasal Polyps
- Nasal Reconstruction
- Nasal Valve
- Nasal Valve Area
- Otologic Manifestations in Wegener Granulomatosis
- Otologic Manifestations of Tuberculosis, Diagnosis and Treatment
- Sarcoidosis
- Septal Perforation
- Sinus Surgery, Complications
- Sleep-Disordered Breathing
- Superficial Musculoaponeurotic System (SMAS)

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Acute and Chronic Rhinosinusitis

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Synonyms

Rhinitis; Rhinosinusitis; Sinusitis

Definition

"Rhinitis" is defined as an inflammatory condition that affects the nasal mucosa without the involvement of paranasal sinuses. The symptoms of rhinitis include nasal obstruction, clear rhinorrhea, and postnasal drip. Rhinitis can be caused by a variety of allergic and nonallergic conditions including viruses, bacteria, or other irritants.

"Sinusitis," on the other hand, is a bacterial infection arising from one or more paranasal sinuses. Adult sinusitis is consistent with the symptoms of a viral upper respiratory tract infection (URI) that have not improved after 10 days or that worsen after 5–7 days (Lanza and Kennedy 1997). The classic signs and symptoms of sinusitis are nasal congestion, facial pain or pressure, and mucopurulent nasal drainage. Frequently, sinusitis is preceded by a viral URI. Other symptoms may include toothache, hyposmia or anosmia. The duration of "acute" sinusitis is less than 1 month, "subacute" sinusitis 1–3 months, and "chronic" sinusitis more than 3 months. "Chronic recurrent rhinosinusitis" (CRRS) consists of multiple episodes with complete resolution of symptoms between episodes.

"Rhinosinusitis" has become the preferred term for several reasons: (1) rhinitis frequently precedes sinusitis leading to blockage of the paranasal outflow tracts, (2) sinusitis without preceding rhinitis is extremely rare, and (3) the mucosa in the nasal cavity and paranasal sinuses is contiguous. Hence, a separation of rhinitis and sinusitis would be somewhat arbitrary.

Epidemiology

Since the industrial revolution, the number of people diagnosed with rhinosinusitis has been on the rise in the USA. Currently, there are approximately 20 million cases of acute rhinosinusitis annually in the USA accounting for the fifth most common diagnosis leading to the prescription of antibiotics. Nine percent of antibiotics prescribed to the pediatric population are due to rhinosinusitis. In addition, 5–10% of pediatric patients with an URI will be complicated by acute sinusitis. The impact of rhinosinusitis to healthcare cost is estimated to be US$ 3.5 billion annually in the USA. Due to the lack of specific symptoms or the presence of nonspecific symptoms in the pediatric age population, the diagnosis of rhinosinusitis is difficult and frequently missed. Seventy percent of children suffering from chronic rhinosinusitis (CRS) also suffer from allergic rhinitis (Aitken and Taylor 1998).

History

Signs and symptoms that are highly suggestive of acute rhinosinusitis (ARS) are common cold complaints that persist beyond 10 days (URIs usually resolve within 5–7 days). In addition, a temperature above 39°C with concurrent purulent nasal discharge lasting longer than 3–4 days is another warning sign. Lastly, worsening symptoms (rather than just lack of improvement) after 5–7 days of an upper respiratory tract infection is another indicator for rhinosinusitis.

Clinical Features

Patients suffering from acute rhinosinusitis typically have complaints of nasal congestion, purulent nasal discharge, and facial or sinus pressure with a temperature above 39°C. Unfortunately, signs and symptoms in the pediatric population are frequently nonspecific and diagnoses are often missed. Historically, the presence of two major and one minor factor, or one major and two minor factors were strongly suggestive of ARS (see Table 1) as established by the Rhinosinusitis Task Force in 1996. However, this technique for diagnosing rhinosinusitis has decreased in popularity in recent years.

Laboratory tests to aid in the diagnosis of rhinosinusitis are rarely helpful.

Acute and Chronic Rhinosinusitis, Table 1 Major and minor factors in the diagnosis of rhinosinusitis

Major	Facial pain/pressure
	Facial congestion/fullness
	Nasal obstruction/blockage
	Nasal discharge/purulence
	Purulence in nose
	Fever
	Hyposmia/anosmia
Minor	Headache
	Halitosis
	Fever (if CRS)
	Dental pain
	Fatigue
	Cough
	Otalgia/aural pressure

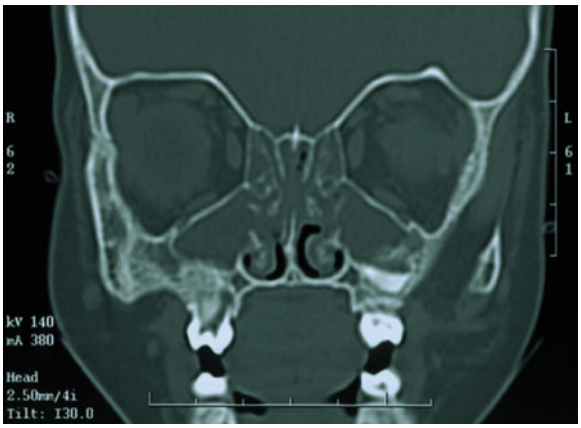
Lanza and Kennedy (1997)
The presence of two major and one minor or one major and two minor factors is highly suggestive of rhinosinusitis as a diagnosis

Tests

History and physical examination are the most important modality to diagnose acute rhinosinusitis. However, physical examination adds little to the diagnosis of ARS in children due to the lack of specific findings; and hence, history is the key factor in the pediatric patient population to establish a diagnosis of ARS. Facial swelling, sinus tenderness, proptosis, and diplopia, if present, are highly suggestive of acute rhinosinusitis. Symptoms of upper respiratory infections that either worsen after 5–7 days and/or persist beyond 10 days are highly suggestive of ARS. The medical practitioner needs to have a very high index of suspicion as signs and symptoms in children are often nonspecific. A fiberoptic endoscopic evaluation, as is frequently performed in the adult patient population, is not easily done in the pediatric population.

Imaging studies, such as plain sinus radiographs have very little, if any, value due to their low specificity. In children younger than age 6 years, history predicted abnormal X-rays in 88% and one can safely omit X-rays in this age group. Controversy exists in the age group above 6 years of age with regards to sinus plain radiographs (Wald et al. 2001). CT scanning is currently the imaging modality of choice but reserved for suspected extracranial complications, persistent/recurrent disease despite antibiotics, and for surgical planning. If, however, a CT scan is performed, mucosal thickening, air-fluid levels, or sinus opacification are suggestive of ARS. Coronal cuts on CT scan of paranasal sinuses provide optimal visualization of the ostiomeatal complex (OMC) (Fig. 1). The Lund-MacKay scoring system (see Table 2) in the pediatric population is different from adults: for adults, a normal score is 0, whereas, in children a normal score is up to 3. The abnormal cutoff in the pediatric population is 5. MRI is not the imaging modality of choice for suspected rhinosinusitis for several reasons: (1) poor visualization of bone, (2) overly high sensitivity with increased false positive rate, and (3) children would need sedation for the longer period of the test. If, however, intracranial complications are suspected or if differentiation between retained mucus versus a soft tissue mass is required, MRI is the imaging modality of choice.

If cultures are needed after failure of empiric first line medical therapy (see below), sinus taps have been considered the gold standard. Owing to the invasiveness and pain associated with direct sinus aspiration, transnasal or sublabial sinus taps in children are unfavorable. Indications for sinus aspirates, however, include: severe toxic illness, acute illness unresponsive to antibiotics within 72 hours, immunocompromised patients, suspected suppurative complications, and workup for fever of unknown origin (FUO). Recently, endoscopically guided middle meatal swabs have gained popularity due to the ease of obtaining samples and studies showing relatively good microbiologic correlation between middle meatal swabs and direct sinus aspirates.



Acute and Chronic Rhinosinusitis, Fig. 1 Coronal CT scan of paranasal sinuses without contrast of a 2-year-old patient with bilateral complete maxillary and ethmoid sinus opacification. Both lamina papyracea appear intact, no evidence of fovea ethmoidalis or cribriform plate defects, nasal septum appears non-deviated but with presence of a small right caudal spur

Acute and Chronic Rhinosinusitis, Table 2 Lund-MacKay CT staging system

Sinus	Right	Left
Maxillary	2	2
Anterior ethmoid	2	2
Posterior ethmoid	2	2
Sphenoid	2	2
Frontal	2	2
Ostiomeatal Complex (OMC)	2	2

Lund et al. (1995)
Each individual sinus is scored: 0 = clear, 1 = partial opacification, 2 = complete opacification. Scoring for OMC is 0 = clear, 2 = occluded. Highest possible score = 24. In children, normal = 0–3, abnormal = 5

Differential Diagnosis

The differential diagnosis of rhinosinusitis is broad as symptoms in the pediatric population are frequently nonspecific. Possible diagnoses include viral rhinitis (common cold), temporomandibular joint (TMJ) pain, headache or migraines, dental or trigeminal pain, and neoplasms. If symptoms of facial pressure, mucopurulent nasal discharge, nasal congestion, hyposmia, and dental discomfort are present with a poor response to nasal decongestants, a diagnosis of rhinosinusitis is more likely.

Etiology and Pathogenesis

Humans have four pairs of paranasal sinuses: maxillary, ethmoid, sphenoid, and frontal sinuses. The maxillary and ethmoid sinuses are present at birth, whereas the sphenoid and frontal sinuses start to form at ages 3 and 5 years, respectively. The sphenoid sinus grows rapidly to reach the sella turcica by age 7 years and adult size by age 18 years. The frontal sinus grows more slowly and reaches adult size by adolescence.

The maxillary sinuses are located between the orbits and oral cavity and drain into the middle meatus. The ethmoid sinuses consist of 4–17 air cells and create a honeycomb structure that is located between the orbits. They are divided into anterior and posterior air cells by the basal or ground lamella of the middle turbinate. Drainage of the anterior ethmoid sinus cells occurs into the middle meatus; the posterior ethmoid cells drain into the superior meatus. The agger nasi is the most anterior ethmoid air cell; the concha bullosa is an aerated middle turbinate; a Haller cell is an infraorbital ethmoid air cell located medially; and the Onodi cell is the most posterior ethmoid air cell and considered as a sphenoethmoidal cell. The sphenoid sinuses are a paired structure with an intersinus septum and located posteroinferior to the posterior ethmoid sinuses. The face of the sphenoid sinus is located approximately 7 cm from the nasal columella. The frontal sinuses are a paired structure with an intersinus septum and located between the anterior ethmoid sinuses and the forehead.

The ostiomeatal complex (OMC) describes a functional unit that consists of the maxillary sinus' natural os, the anterior ethmoid sinus, the hiatus semilunaris, and the middle meatus.

The mucosal lining of the sinonasal cavities is respiratory epithelium and therefore pseudostratified ciliated columnar epithelium with goblet cells that produce mucus. Mucus has a lubricant and immunologic role trapping particles and microbes. With its lysozymes and lactoferrin, mucus plays an important antibacterial role.

The anatomy of paranasal sinuses does not promote passive, gravitational drainage, and consequently, mucociliary function is crucial to provide for adequate sinus drainage. Viruses may have direct cytotoxic effects interrupting mucociliary clearance. With any of four factors (paranasal sinus obstruction, reduction in number of cilia, impaired ciliary function, or

overproduction/change in viscosity of secretions), mucus will become trapped triggering a vicious cycle: decreased oxygenation worsens ciliary function, leading to further stasis of secretions and lack of bacterial export, resulting in bacterial overgrowth secondary to stasis. Anaerobic conditions further provide an optimal milieu for bacterial overgrowth.

Mucociliary function can be interrupted, altered, or absent due to several factors that can broadly be divided into systemic, local, or mechanical factors (see Table 3).

Acute rhinosinusitis (ARS) may result from edema of the nasal mucosa resulting in blockage of the natural drainage pathway, which leads to stasis and subsequent bacterial infection. The most common organisms accounting for ARS are *Streptococcus pneumonia* (30–66%), *Haemophilus influenzae* (20%), and *Moraxella catarrhalis* (20%). Penicillin resistance via several different mechanism is an increasing problem: porin channel formation (*Pseudomonas*), beta-lactamase production (*H. influenzae*, *M. catarrhalis*), and penicillin binding protein (PBP) alteration (*S. pneumonia*) (Brook 2005). Approximately 33% of *S. pneumoniae* are penicillin-resistant, 33% of *H. influenzae* produce beta-lactamase, and nearly all strains of *M. catarrhalis* produce beta-lactamase (Lalwani 2004).

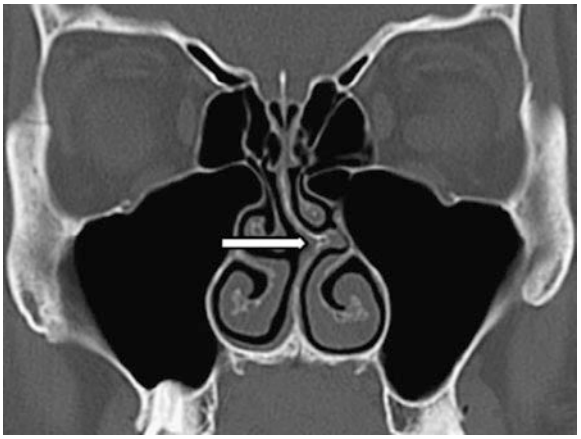
Chronic rhinosinusitis (CRS) results from chronic inflammation and edema of sinonasal mucosa. It is frequently caused by bacteria that differ from the ones that lead to ARS. Laboratory analysis with cultures of maxillary sinus contents from endoscopic sinus surgery (ESS) showed coagulase-negative *Staphylococci*, *Staphylococcus aureus*, and *Streptococcus viridans* in addition to *Corynebacterium* and anaerobes (Lalwani 2004).

Prevention of ARS is difficult as the disease is associated with viral infections that trigger the inflammatory cascade. Patients with recurrent ARS or CRS should be carefully evaluated for predisposing medical comorbidities such as allergies, anatomic abnormalities, or immune dysfunctions. Anatomic abnormalities, however, are uncommon in the pediatric population.

Adenoid hypertrophy may play a role in development of pediatric rhinosinusitis. Adenoids may cause predisposition to sinus infections by several mechanisms, including mechanical obstruction, stasis of secretions, or by serving as a reservoir for bacteria that may live in biofilms. Several studies have been performed and found that adenoid size did not correlate with the grade of sinusitis even though the bacterial isolation rate increased with adenoid size. It is believed that adenoids in CRS play a role as a reservoir rather than as an obstructive obstacle for sinus drainage (Shin et al. 2008). A meta-analysis of five cohort studies and four case series suggests that 70% of patients subjectively have improvement in rhinosinusitis symptoms after adenoidectomy. The authors suggest that adenoidectomy should be considered as the first line surgical treatment before FESS is considered if medical therapy fails (Brietzke and

Acute and Chronic Rhinosinusitis, Table 3 Factors predisposing to rhinosinusitis

Systemic	Viral URI
	Allergy/asthma
	Immotile cilia (e.g., Kartagener syndrome)
	Cystic fibrosis
	Immune disorder
	GERD
Local	Trauma
	Rhinitis
Mechanical	Choanal atresia
	Deviated septum (Fig. 2)
	Polyps/foreign body
	Hypertrophy of turbinate or adenoids



Acute and Chronic Rhinosinusitis, Fig. 2 Coronal CT scan of paranasal sinuses without contrast. The *arrow* shows a left septal deviation, which can lead to obstruction of the ipsilateral ostiomeatal complex (OMC). Note the absence of mucoperiosteal thickening in this patient. Also seen are the right inferior, right middle, left inferior, left middle, and left superior turbinates. The fovea ethmoidalis and cribriform plates are non-dehiscent

Brigger 2008). Asthmatics are less likely to benefit from adenoidectomy, and older children obtain longer lasting relief than children <6 years of age from adenoidectomy for rhinosinusitis (Ramadan and Tiu 2007).

Treatment

The goals of therapy in acute rhinosinusitis is to return the paranasal sinuses back to a healthy state, decrease the duration of symptoms, sterilize secretions, and prevent complications (orbital and intracranial) or chronic sinus disease. Treatment failure is defined as a lack of clinical response within 72 hours (Anon et al. 2004). As ARS is a self-limited disease with spontaneous cure rates of 70%, the decision when and if to start antimicrobial therapy frequently provides a challenge to the practitioner. Spontaneous cure rates differ among different microorganisms and have been reported to be 15% for *S. pneumonia*, 50% for *H. influenzae*, and 50–70% for *M. catarrhalis*. Risk factors for bacterial resistance are age less than 2 years, day care attendance, antibiotic treatment within prior 3 months, and cultures showing resistant organisms.

Medical therapy with antibiotics is the main treatment for acute rhinosinusitis. Initial therapy should consist of amoxicillin (45 mg/kg divided into twice daily or 90 mg/kg divided into twice daily if risk factors present). If no improvement of symptoms is noted within 2–3 days, one should reconsider the diagnosis or change the antibiotic regimen. Cephalosporins are reserved for refractory cases and are considered second line treatment. First-generation cephalosporins have poor activity against *H. influenzae*, whereas third-generation cephalosporins need to be administered at least for the first dose parenterally (intravenous or intramuscular) followed by an oral regimen. Macrolides (Clarithromycin 15 mg/kg divided into twice daily or Azithromycin 10 mg/kg on day 1 followed by 5 mg/kg for 4 more days) are first line therapy in penicillin-allergic children, but resistance is on the rise. If patients do not respond to initial drug therapy, beta-lactamase resistant antibiotics such as amoxicillin/clavulanate (80–90 mg/kg divided into twice daily dosing) should be prescribed (Brook 2007; Anon et al. 2004). If anaerobic organisms are suspected, Clindamycin or Metronidazole is the antibiotics of choice. Chronic rhinosinusitis is associated with different pathogens (see "Etiology and Pathogenesis" section); and therefore, it requires a different treatment regimen. Gram-negative, anaerobic and *Staphylococcus* coverage is required in addition to Gram-positive coverage. Typically, beta-lactamase stable antibiotics (amoxicillin/clavulanate) are administered in conjunction with nasal steroids as adjuvant therapy. Antihistamines should be considered if an underlying allergic condition is suspected. Anti-reflux treatment has been shown to be beneficial for those where gastroesophageal reflux disease (GERD) is present.

The duration of antimicrobial treatment is subject to controversy even though most authors agree that treatment for acute rhinosinusitis is anywhere between 10–14 days. Some authors suggest that treatment should last 7 days beyond symptom resolution. In cases of chronic rhinosinusitis, antimicrobials are typically given for 4–6 weeks.

Topical treatments for rhinosinusitis include nasal saline, topical steroids, and topical antibiotics. Nasal saline provides important humidification to decrease dryness and nasal crusting thereby improving mucociliary clearance. Saline rinses provide patients not only with symptomatic relief by washing out mucoid discharge, but they also decrease the load of the offending agents (bacteria, viruses, or allergens). Nasal steroids should be given to patients, particularly in cases of chronic rhinosinusitis, to decrease mucosal edema and to help open the ostiomeatal complexes promoting drainage of the paranasal sinuses. Studies have shown that symptom improvement is significant with nasal steroids when compared to placebo with antibiotics. The only FDA-approved nasal steroid in children is mometasone (Nasonex®, 200 mcg twice daily) (Lindbaek 2005). Patient education plays an important role when prescribing nasal steroids for patient compliance as topical steroids take several days to weeks before taking effect. Short-acting topical decongestants (such as oxymetazoline) may provide symptomatic relief but should not be used beyond 3 days due to the risk of epistaxis and rebound mucosal edema (rhinitis medicamentosa). However, no evidence for topical decongestants exists of additive effect when compared to amoxicillin (McCormick et al. 1996).

Topical antibiotics (such as gentamicin irrigations, 80 mg/l) are rarely used but may be considered in

refractory cases and/or in immunocompromised patients. There is no data that supports the use of antihistamines in nonallergic children suffering from ARS. Mucolytics have also not been shown in clinical trials to be beneficial (McCormick et al. 1996).

Systemic steroids should be considered in patients with chronic rhinosinusitis, particularly in the presence of longstanding nasal polyps. However, patient and parent education with regards to side effects of systemic steroid therapy is important. Guaifenesin, a systemic decongestant and mucolytic, may provide symptomatic relief and is often added to the antimicrobial treatment.

Surgical treatment for acute or chronic rhinosinusitis is reserved for cases where medical therapy has failed, and it is rarely indicated in the pediatric population. Nonetheless, maximal medical therapy has traditionally been defined as 4–6 weeks of treatment with appropriate antibiotics, nasal steroids, and sometimes, systemic steroid therapy. If medical therapy fails, surgical therapy will be considered starting with adenoidectomy with or without functional endoscopic sinus surgery (FESS). Those patients with clear anatomic abnormalities or polyposis usually respond best to FESS. Several key principles need to be considered when performing FESS: (1) large antrostomies in nonanatomic drainage patterns may fail to drain sinuses due to the directionality of mucociliary clearance ("sinus recirculation" phenomenon), and (2) mucosal stripping leads to delayed healing, contracted paranasal sinuses, and loss of ciliary function. Therefore, mucosal stripping should be avoided by using through-cutting instruments that preserve sinonasal mucosa. Before performing endoscopic sinus surgery, CT imaging or endoscopic evaluation needs to show clear evidence of sinonasal disease with or without polyposis. Symptomatic improvement with FESS in the adult population is to be expected in more than 90% of cases, whereas numbers in children are not available. Surgical complications include orbital fat herniation with subsequent hemorrhage and orbital hematoma, blindness, cerebrospinal fluid (CSF) leak, herniation of cranial contents and injury to intracranial contents, meningitis, or intracranial hemorrhage. Controversy exists with regard to midfacial growth retardation in children undergoing FESS. The current belief among most otolaryngologists is that there is no negative effect on midfacial growth but level 1 evidence is lacking (Van Peteghem and Clement 2006).

Medical therapy with antibiotics, steroids, saline irrigations, and decongestants together with surgical treatment as a last resort should not distract the physician to investigate whether underlying medical conditions such as diabetes mellitus, immunodeficiency syndromes, allergic disease, or immotile cilia syndrome exist.

The prognosis of acute rhinosinusitis is excellent, as 70% of patients recover without any medical or surgical intervention. Oral antimicrobial therapy decreases the healing time. Chronic rhinosinusitis, however, has a more variable course. If no underlying medical comorbidity or immunocompromise exist, surgical therapy is successful in 90% or more of the patients. Close monitoring and sound preventative strategies are essential in the patient with CRS.

Several complications of acute and chronic rhinosinusitis may occur and usually result from delayed diagnosis and subsequent lack of treatment in a timely manner.

Orbital infection can ensue as the lamina papyracea, a paper-thin portion of the ethmoid bone that separates the ethmoid air cells from the orbit, may be dehiscent. Orbital infection is the most common complication of ARS owing to the weakness of this barrier. In addition, the ophthalmic venous system has no valves and is in direct continuity with ethmoid veins providing a direct path for spread of infection into the orbit. James Ryan Chandler described orbital complications of sinusitis in 1970 (see Table 4) (Chandler et al. 1970).

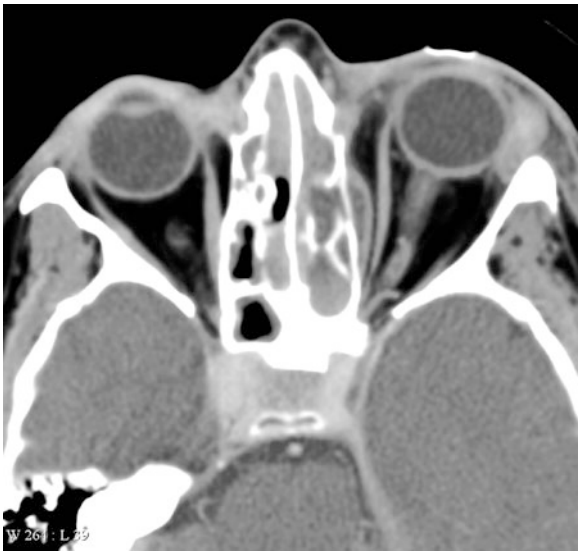
Intracranial complications (meningitis, epidural abscess, cavernous sinus thrombosis, or Pott puffy tumor) are usually secondary to frontal sinus disease. Owing to the absence of frontal sinuses in early childhood, intracranial complications in the pediatric population are rare.

Meningitis may occur as a result of infectious extension from either the ethmoid or sphenoid sinuses. Patients usually have a diminished sensorium are obtunded and less playful. The classical signs on physical examination are the Kernig sign or Brudzinski's sign. If meningitis is suspected, a lumbar puncture with culture and sensitivities ought to be performed and the child started on empiric antibiotics. In addition, a high-resolution CT brain and paranasal sinuses with contrast need to be obtained.

Acute and Chronic Rhinosinusitis, Table 4 Chandler classification: orbital complications of sinusitis

I. Preseptal cellulitis	Upper eyelid swelling
	No limitation of EOM
	No visual changes
II. Orbital cellulitis	Upper eyelid swelling
	Proptosis, chemosis
	No or mild limitation of EOM
	No or mild visual changes
III. Subperiosteal abscess (Fig. 3)	Downward displacement of globe
	Impaired EOM
	Possible visual impairment
IV. Orbital abscess	Severe proptosis
	Limited EOM
	Impaired visual acuity, may lead to blindness
V. Cavernous sinus thrombosis	Orbital pain, unilateral headache
	Picket-fence fevers
	Ophthalmoplegia
	Meningeal signs
	Progresses to contralateral side in 24–48 hours

Chandler et al. (1970)



Acute and Chronic Rhinosinusitis, Fig. 3 Axial CT scan of paranasal sinuses and orbit demonstrating a left subperiosteal abscess of orbit. Please note that the location of the abscess is medial of the medial rectus muscle and would therefore be amenable to endoscopic drainage

Epidural abscess is a rare but feared complication of rhinosinusitis. Typically, an epidural abscess, if present, is a result of frontal sinus disease and characterized by a collection of pus between the bone of the skull and the dura mater. The disease may spread further, either via direct extension or hematogenous seeding, and lead to a subdural empyema and possibly a brain abscess. Treatment consists of surgical drainage of both, the abscess and the offending sinus, in addition to broad-spectrum parenteral antibiotics. Mortality is high especially once subdural involvement is present.

Cavernous sinus thrombosis is secondary to retrograde spread of infection through the valveless ophthalmic venous system. Septic emboli get seeded in the cavernous sinus triggering an inflammatory cascade, which leads to thrombosis of the sinus. Ocular symptoms that ensue are frequently bilateral, consist of chemosis, sluggish or absent pupillary response, ophthalmoplegia, and may ultimately lead to blindness. Surgical drainage of the offending sinuses, in addition to intravenous antibiotics, must be performed immediately. Controversy exists with regards to steroid or anticoagulation therapy to prevent further thrombus formation.

Pott puffy tumor is osteomyelitis of the frontal bone as a result of direct extension from frontal sinusitis after the infection involved the marrow space. Bone destruction allows for spread of pus into the soft tissues in the forehead causing edema, erythema, induration, and fluctuance. Surgical drainage and debridement in conjunction with parenteral antibiotics are imperative.

Summary

Children with acute rhinosinusitis may present with symptoms of upper respiratory tract infections, which are somewhat nonspecific. Diagnosis of ARS in children is mainly by history and clinical criteria with little role of ancillary tests. Medical therapy with antibiotics and topical steroids is the mainstay of treatment. If medical therapy fails, conservative surgery should be pursued in a step-wise fashion starting with adenoidectomy, as adenoids seem to act as a reservoir for bacteria in biofilms. However, there appears to be no correlation between adenoid size and severity of

sinusitis. Asthmatics and very young children do worse with adenoidectomy. Even though recent evidence suggests that there is no negative effect of endoscopic sinus surgery on midfacial growth, FESS is reserved as a last resort.

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Acute Otitis Externa (AOE)

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Synonyms

Swimmer's ear

Definition

Acute otitis externa (AOE) is an acute bacterial infection of the subdermis of the external auditory canal.

Etiology

The infection occurs more commonly in summer months, often in association with water sports, and is commonly referred to as "swimmer's ear." Predisposing factors, in addition to warmth and moisture, are micro-trauma from scratching or instrumenting the ear, preexisting seborrheic dermatitis of the ear canal, and alkalization of the external canal (Coffin 1963; Fabricant and Perlestein 1949). The most commonly recovered pre-therapy isolates are *Pseudomonas* species (most commonly *aeruginosa*), and *Staphylococcus aureus*. Less frequently, other gram negatives, especially *Proteus* sp. and *Klebsiella*, are encountered (Hawke et al. 1984; Roland and Stroman 2002).

Clinical Presentation

The principal symptom is pain, which is sometimes very severe. Pain is exacerbated by movement of the auricle or tragus which helps distinguish the pain of AOE from the pain of acute otitis media. Pain develops steadily over hours to a day or two. Hearing loss is

common only in moderate to severe cases when swelling compromises the patency of the external auditory canal (Marple and Roland 1997).

The infection is often accompanied by a scanty, milky drainage but it is usually neither copious nor thick. Both swelling of the ear canal and erythema are often present but severe swelling tends to limit erythema and sometimes, if swelling is very severe, the canal skin is blanched (Hawke et al. 1984).

Diagnosis

Diagnosis rests mainly on physical findings and no additional diagnostic testing or laboratory evaluation is needed.

Differential Diagnosis

Herpes Zoster Oticus
Carcinoma of the external auditory canal or temporal bone
Eczematous dermatitis
Otitis media with perforation
Folliculitis
Malignant otitis externa

Prophylaxis

In patients prone to recurrent acute otitis media, dry ear precautions can be helpful in preventing infection. If the patient will or cannot avoid water, drying the ear canal with a blow-dryer on a low setting or using alcohol-containing otic drops can prevent recurrent infections. Foreign bodies such as cotton swabs should be avoided.

Therapy

Treatment should include cleansing of the external auditory canal (aural toilet) and use of an antimicrobial topical ear drop (Rosenfeld et al. 2006a). Both antiseptic and antibiotic drops are used with equal efficacy. Since alkalization of the normally slightly acidic EAC is important in the pathophysiology of the AOE, acidic solutions are useful (and may be sufficient) in resolving the infection (Coffin 1963; Rosenfeld et al. 2006b). Among the antibacterial agents, the fluoroquinolones may be slightly more effective than the aminoglycosides and are not ototoxic (Roland et al. 2004).

Preparations without potential ototoxicity should be used unless it is certain that the tympanic membrane is intact.

Antibiotic drops are commercially available as 2–3% solutions which have antibiotic concentrations of 2,000–3,000 mcg/mL: concentrations which greatly exceed the MICs of any known relevant pathogen (Rosenfeld et al. 2006b; Roland et al. 2004). Consequently, antibiotic sensitivity profiles performed in commercial laboratories are not relevant and topical antibiotic solutions will be effective even against organisms labeled "resistant" provided only that the antibiotic solution comes into contact with infected tissues.

Successful treatment depends on contact of the topically administered ear drop with the infected skin of the ear canal. If the ear canal is swollen, then a wick should be utilized to help keep the canal open and to draw the medication into the canal and keep it in contact with the canal skin.

Assuming that the infection is bacterial, as is most commonly the case, failures of topical therapy are failures of delivery. Systemic antibiotics are rarely indicated for the treatment of AOE but an exception to this rule is appropriate for persons with diabetes or other immunocompromising conditions.

AOE is often painful and appropriate management of pain is an important aspect of comprehensive treatment. When the condition is severe, oral narcotic analgesics are sometimes necessary for adequate pain control.

Prognosis

The prognosis is excellent for patients with routine acute otitis externa. In immunocompromised patients, otitis externa can progress to malignant otitis externa. This is a potentially life-threatening infection requiring intravenous antibiotics and possible surgery.

Cross-References

► Osteomyelitis of Temporal Bone
► Squamous Cell Carcinoma of the Ear

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Acute Otitis Media

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Synonyms

Purulent otitis media; Suppurative otitis media

Definition

Acute otitis media (AOM) is an infection of the middle ear space, defined by the presence of middle ear fluid, with rapid onset of signs and symptoms of acute inflammation, such as otalgia and fever. AOM is the illness which most commonly brings children to their physician (Bluestone and Klein 2007).

Etiology

The middle ear space is a closed space located behind the tympanic membrane. Its only communication with the outside world is through the Eustachian tube, which connects the middle ear space to the nasopharynx. The normal middle ear space is filled with air, and the system is lined by respiratory mucosa. The anatomy of the Eustachian tube in infants and young children differs from that of adults, contributing to the increased incidence of AOM in this population. In an infant, the Eustachian tube (ET) is shorter and lies at a more horizontal angle as compared to an adult. It reaches its adult length by the time a child is 7 years of age. The Eustachian tube equilibrates middle ear pressure and allows for drainage of middle ear. The ET is collapsed at rest, but intermittently opens through active movements of the jaw, such as yawning, or by actions such as swallowing, via contraction of the tensor veli palatini muscle. This allows for equilibration of pressure in the middle ear space with atmospheric pressure. Dysfunction of the ET can lead to AOM (Bluestone 2003).

The pathogenesis of AOM generally follows this sequence: An inciting factor, such as a viral upper respiratory infection or allergy, causes inflammation and edema of the respiratory mucosa of the nose, pharynx, and Eustachian tube. The Eustachian tube becomes obstructed, inhibiting drainage and pressure equilibration of the middle ear. Secretions accumulate in the middle ear, and the bacteria and viruses which colonize the respiratory tract enter and become trapped in the normally sterile middle ear. Microbial growth then occurs within the middle ear, causing a suppurative effusion, which leads to the signs and symptoms of an acute otitis media.

Risk factors for recurrent acute otitis media include male gender, genetic susceptibility, daycare attendance, pacifier use, lack of breastfeeding, and environmental pollution, including second hand tobacco smoke exposure. Peak incidence occurs between 6 and 18 months of age (Bluestone and Klein 2007).

Clinical Presentation

Symptoms may range from mild to severe. Otalgia is the most common symptom of AOM, but in young

children, the presentation may be vague and nonspecific, manifesting as irritability, poor sleep, poor appetite, and ear tugging. Other common symptoms include fever, nausea, vomiting, and diarrhea. If the tympanic membrane ruptures (or if there is a patent tympanostomy tube), purulent discharge may be seen. Since AOM is frequently triggered by upper respiratory infections, children with AOM will commonly exhibit signs such as congestion or rhinorrhea. Because of the fluid in the middle ear, AOM may be accompanied by a decrease in hearing acuity and, in some cases, balance problems or dizziness.

Diagnosis

History and Physical Exam

Acute otitis media is a clinical diagnosis, and requires the presence of a middle ear effusion (MEE) and signs of infection and inflammation, with rapid onset. Physical exam with pneumatic otoscopy is the standard of care in making the diagnosis. Accurate diagnosis is critical, as it ensures appropriate therapy for those patients with AOM, while avoiding antibiotics in patients with otitis media with effusion, in whom antibiotics are unnecessary.

In acute otitis media, the tympanic membrane (TM) appears full or bulging, opaque, and with poor mobility. Erythema may or may not be present. Purulent otorrhea may be seen if the TM has ruptured. Pneumatic otoscopy is the primary tool used to evaluate the TM and the status of the middle ear.

In addition to a thorough exam of the ears, a complete head and neck examination is important, as it may identify conditions that predispose a child to acute otitis media. Facial features should be assessed as craniofacial abnormalities, such as Down Syndrome or Treacher-Collins Syndrome, are associated with an increased incidence of otitis media. The oral cavity should be inspected for either a bifid uvula or evidence of a submucous cleft palate. The patient's voice may also provide additional insight – hypernasality indicates velopharyngeal insufficiency, and hyponasality may indicate either obstructing adenoids or nasal obstruction. Both can cause dysfunction of the Eustachian tube mechanism.

Tympanometry and Audiometry

Tympanometry can be a helpful adjunct in assessing middle ear status and TM function, particularly when otoscopic evaluation is either inconclusive or difficult to perform. A small probe which emits a tone is placed in the ear canal with an airtight seal. The tympanometer measures the acoustic energy of the reflected tone, and graphically represents the relationship of air pressure in the ear canal to the impedance of the tympanic membrane. A "flat" tympanogram with a small volume indicates a MEE, whereas a "flat" tympanogram with a large volume is indicative of a perforation or patent tympanostomy tube. It is important to note that tympanometry cannot make the diagnosis of AOM, but can only reveal the presence or absence of middle ear fluid. It cannot distinguish whether the fluid is infected or sterile. AOM, however, can be effectively ruled out with a normal tympanogram.

Fluid in the middle ear space can cause a mild to moderate conductive hearing loss, so abnormal audiometry can be seen in patients with AOM. However, again, this would only be indicative of the presence or absence of fluid, but would not give information regarding acuity or inflammation. Audiometry therefore does not contribute significantly to the diagnosis of AOM, nor does it help to distinguish AOM from OME.

Differential Diagnosis

As discussed above, it is important to distinguish acute otitis media from otitis media with effusion, in which no acute inflammation is present. Bullous myringitis must also be considered in the differential diagnosis. This entity represents an acute inflammation of the tympanic membrane itself. The TM is red and inflamed, with large bullae or blisters. This condition also causes intense otalgia and can cause otorrhea with rupture of the bullae; it is often, but not necessarily, associated with a severe acute otitis media. Other conditions, such as otitis externa, teething pain, tempormandibular joint problems, and pharyngitis, may present as otalgia. However, these should be easily distinguishable from AOM by history and physical examination.

Prophylaxis

Antibiotic prophylaxis, consisting of prolonged use of low-dose antimicrobials, has fallen out of favor, secondary to concerns regarding the development of resistant organisms, but can be effective and may be appropriate in select situations.

Environmental and lifestyle factors may be managed to decrease risk of acute otitis media. Promotion of breastfeeding in the first 6 months of life, as well as avoidance of passive tobacco smoke, bottle propping, and pacifier use may all decrease AOM risk. Daycare attendance is an often unavoidable risk factor for AOM. For children with significant atopy, allergy management may decrease the incidence of AOM.

The three most common pathogens responsible for AOM are *Streptococcus pneumoniae, Haemophilus influenzae*, and *Moraxella catarrhalis*. The pneumococcal conjugate and polysaccharide vaccines have shown efficacy in several large studies in decreasing the incidence of AOM (Black et al. 2000; Klein 2004). There is a vaccination for *H. influenzae*, type B; however, this subtype accounts for only a small percentage of acute otitis media (Klein 2004). It should be noted, however, that although studies have shown a decrease in episodes caused by the specific serotypes covered by the pneumococcal conjugate vaccine (57% in one study), the overall decrease in incidence of AOM episodes was only 6% and, in fact, a 33% increase in AOM caused by all other serotypes of *S. pneumoniae* was found (Eskola et al. 2001; Klein 2004). So it would appear that the vaccine may be changing the incidences of bacterial pathogens which cause AOM, but not the overall incidence. Respiratory viruses play an important role in the development of AOM; several studies have shown the efficacy of the influenza virus in decreasing influenza-associated AOM (Heikkinen 2004).

Tympanostomy tubes have been shown to be effective in multiple clinical trials in decreasing episodes of recurrent acute otitis media (Casselbrant 2004). The tubes allow for equalization of pressure and drainage of the middle ear in the setting of poorly functioning Eustachian tubes.

Therapy

In an effort to reduce antibiotic use and stem increasing bacterial resistance, observation without use of antibiotics is listed as an option for selected children with AOM in the guidelines published by the American Academy of Pediatrics and American Academy of Family Physicians in 2004 (AAP Subcommittee on AOM 2004). Children for whom this is an option are to be selected on the basis of diagnostic certainty, age, illness severity, and access to medical care.

Severe disease is defined as moderate to severe otalgia, fever with temperatures higher than 39°C (102°F) orally or 39.5°C rectally, or a toxic-appearing child. Children younger than 6 months of age should be treated with antibiotics regardless of severity or diagnostic certainty. Children between 6 and 23 months, if the illness is nonsevere, may be observed if the diagnosis is uncertain, but if AOM is certain or severe, should be treated with antibiotics. Children 24 months or older may be watched if the diagnosis is uncertain or disease is nonsevere, but should be treated if AOM is severe.

Medical Management

According to the guidelines document published in 2004, high-dose amoxicillin is still the first line antibiotic treatment for nonsevere AOM, which provides coverage for *S. pneumoniae*, including resistant strains. For severe AOM the recommendation is amoxicillin and clavulanic acid, in order to broaden coverage to include *H. influenzae* and *M. catarrhalis*. Cephalosporins are considered first line treatment only for patients with penicillin allergies. Macrolides should be used in patients with allergies to both penicillins and cephalosporins. A 10-day treatment course is recommended, although symptoms should be reassessed after 2–3 days. Treatment failure is considered when there is persistence of symptoms after 48–72 h of antibiotic therapy; in this situation, antibiotic coverage should be broadened. If there is continued failure of response to antibiotics, a tympanocentesis should be considered to obtain middle ear fluid for culture, to help direct further antibiotic therapy.

The impact of decongestants and antihistamines on AOM therapy has been investigated, and there is no proven benefit.

Surgical Management

Tympanocentesis is the insertion of a needle into the middle ear space to aspirate fluid and allow for drainage. Tympanocentesis can be both diagnostic and therapeutic: Cultures can be obtained to tailor antibiotic

therapy, and the drainage of fluid can provide immediate relief of pressure and pain. However, it does not shorten the overall duration of effusion, nor does it lower the recurrence rate for AOM.

When medical treatments for recurrent AOM have failed, insertion of tympanostomy tubes may be considered. Recurrent AOM is usually defined as three or more episodes of AOM in 6 months or four or more episodes in 12 months. Several randomized controlled trials have found tympanostomy tube placement to be an effective treatment in preventing recurrent AOM (Rosenfeld and Bluestone 2003).

Adenoidectomy may be helpful in children who continue to have recurrent AOM after extrusion of tympanostomy tubes. Studies have shown the procedure to reduce OM incidence by 33% and to decrease the need for another set of tubes by 50% (Rosenfeld and Bluestone 2003). However, adenoidectomy is not recommended as an initial surgical procedure for children with recurrent AOM who have not previously had tubes, unless indicated for other reasons, such as nasal obstruction or chronic rhinosinusitis.

Prognosis

Studies evaluating the natural history of acute otitis media have shown that 61% of patients experience improvement of symptoms within 24 h without antibiotic therapy, and that 80% experience improvement by 48–72 h. No significant difference in suppurative complications of acute otitis media was noted in patients who received antibiotics as compared to those who did not (Rosenfeld and Kay 2003).

Acute otitis media is the most common reason for antibiotic administration in children (AAP Subcommittee on AOM 2004). Fortunately, the incidence decreases after the first year of life, and AOM is much less common in children over the age of 6 years (Bluestone and Klein 2007).

Cross-References

- ▶ Chronic Otitis Media
- ▶ Eustachian Tube, Anatomy and Physiology
- ▶ Middle Ear Physiology
- ▶ Otitis Media with Effusion
- ▶ Otitis Media, Complications

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Acute Rhinosinusitis

▶ Rhinosinusitis, Pathophysiology and Medical Management

Acute Sinusitis

▶ Rhinosinusitis, Pathophysiology and Medical Management

Adenocarcinoma of Middle Ear

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Definition

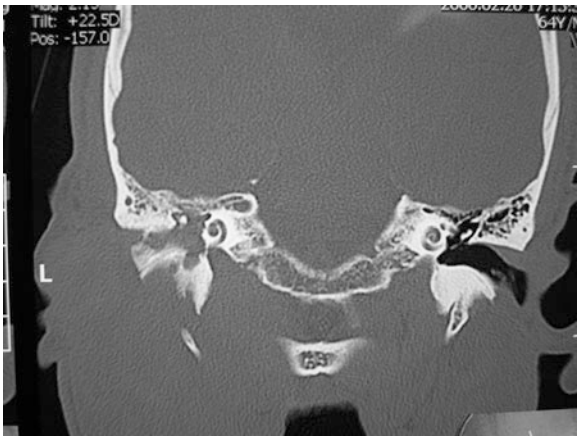
These are rare tumors arising from the middle ear mucosa. They may be primary glandular lesions or metastatic from distant sites.

Etiology

These are very rare tumors that may or may not develop on top of previous chronic otitis media (Schmoldt et al. 1990; Morita et al. 1994). Metastatic adenocarcinomas have also been described from the stomach, colon, lung, prostate, breast, vagina, and other sites (Marques et al. 2002; Hosokawa et al. 2007; Chang et al. 2009; Owers et al. 2010).

Clinical Presentation

Patients may variably present with a friable bleeding mass in the external auditory meatus, erosion of the mastoid bone, and various neurotological signs and symptoms depending on the extent of invasion of the lesion. In some cases a vascular mass behind an intact tympanic membrane may mimic a paraganglioma. Diagnosis is usually delayed as the symptoms are usually confused with common infectious otological conditions. A history of persistent otorrhea (with or without otorrhagia) and associated otalgia should raise the index of suspicion. Persistence of pain in spite of antibiotic treatment can be a warning sign. The appearance of other symptoms, such as peripheral facial palsy, hearing loss, or cervicofacial adenopathies, would suggest a higher grade of malignancy which is more difficult to treat. They usually fill the middle ear, encase the ossicles, and erode into the EAC. Involvement of the antrum, mastoid, petrous bone, and parotid gland has been described. They may also extend intracranially (Paulus et al. 1999; Marioni et al. 2001; Goebel et al. 1987).



Adenocarcinoma of Middle Ear, Fig. 1 Coronal CT of a case showing soft tissue filling the middle ear and eroding the ossicles, EAM, and facial canal

Diagnosis

Radiologically there is widespread erosion of bone with a variably enhancing soft tissue mass (Figs. 1, 2).

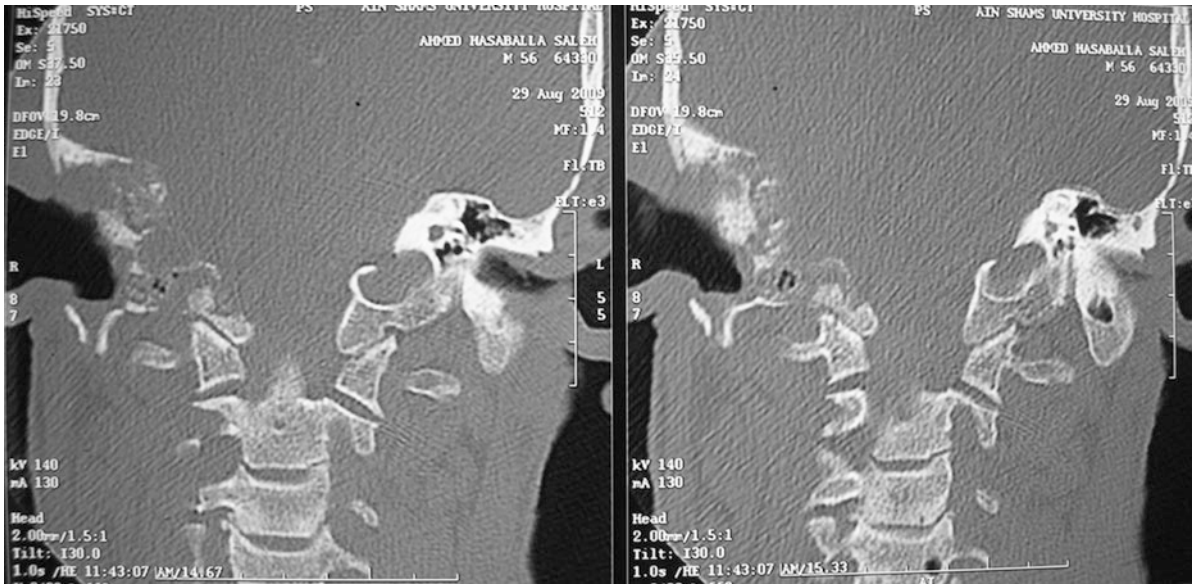
Biopsy is mandatory to differentiate between various similar lesions as this bears on the prognosis of the patient.

Pathology

The lesions are formed of glands or tubules composed of uniform single layer of cuboidal or columnar cells with variable eosinophilic cytoplasm and round/oval hyperchromatic nuclei and eccentric nucleoli. Variable patterns may be seen: sheets, solid, trabecular, cystic, cribriform or glandular but not papillary. Some lesions may appear plasmacytoid, with significant pleomorphism, mitotic figures and extensive infiltration of surrounding tissue. A mucoepidermoid primary middle ear tumor was also described. Immunocytochemically they stain positive for CK7 and chromogranin (Saliba and Evrard 2009).

Differential Diagnosis

Benign adenomas, carcinoids, and aggressive endolymphatic papillary tumors. Other destructive lesions of the middle ear. Exclusion of metastatic adenocarcinoma is imperative.



Adenocarcinoma of Middle Ear, Fig. 2 Coronal CT scan of a patient with recurrent adenocarcinoma showing bone rarefaction and destruction with intracranial spread

Therapy

Aggressive surgical excision followed by radiotherapy for residual or recurrent tumors. The clinical stage has an obvious prognostic value and that the most serious therapeutic problem is the impossibility of complete resection of the tumor due to its localization. Operable patients have a better prognosis than those who are not (Morita et al. 1994; Paulus et al. 1999; Shailendra et al. 2008; Glasscock et al. 1987).

Cross-References

- ▶ Langerhans Cell Histiocytosis of Temporal Bone
- ▶ Middle Ear Adenoma
- ▶ Radiologic Evaluation of Central Skull Base
- ▶ Skull Base Neoplasms
- ▶ Temporal Bone Resection

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Adenoidectomy

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Synonyms

Pharyngeal tonsillectomy

Definition

The adenoids are considered a collection of lymphoid tissue positioned on the posterior nasopharyngeal surface. They are anatomically linked to Waldeyer's ring which includes the palatine and lingual tonsils. Adenoidectomy refers to the surgical excision of this tissue, which is done to treat a variety of disease processes. Although adenoidectomy suggests complete excision of adenoid tissue, most surgical techniques shave off the superficial adenoid tissue.

Purpose

Adenoid hypertrophy or chronic adenitis may cause significant problems related to craniofacial morphology in the growing child, excessive snoring, obstructive sleep apnea (OSA), and poor oral intake. Removal of adenoid tissue is performed to improve the quality of life and reduce the negative sequelae associated with these problems. It is generally a well-tolerated procedure with a fairly low risk profile and the majority of patients have significant improvement in symptoms following the operation. Because adenoid hypertrophy is often associated with tonsillar hypertrophy, the tonsils and adenoids are often removed together, in a procedure referred to as a T&A (tonsillectomy and adenoidectomy).

Principle

Inflammatory and infectious processes involving the adenoids and the tonsils are very prominent in the pediatric population, and often result in two of the most common operations in young children: tonsillectomy and adenoidectomy. The adenoids are a triangular-shaped tuft of tissue in the posterior nasopharynx and were first described in 1868 by the Danish physician Meyer (Curtin 1987). He reported a case of a young woman who complained of nasal obstruction and decreased hearing. He discovered that her nasopharynx was obstructed with soft tissue which he called "adenoid vegetations." He constructed a ring knife which he passed through the nose to excise the adenoids. Seventeen years later in 1885, Gottstein described the first use of an adenoid curette. In the early 1900s, tonsillectomy and adenoidectomy were commonly performed to treat problems such as anorexia, mental retardation, and enuresis, or simply to promote good health (McClay 2008).

The adenoid tissue forms the central part of Waldeyer's ring, which also includes the palatine and lingual tonsils to form a ring of lymphoid tissue around the upper end of the pharynx. The adenoid develops during the third to seventh month of gestation as a midline structure resulting from the fusion of two lateral primordia. The adenoid tissue continues to grow until approximately the fifth year of life, in response to various antigenic challenges, and then typically regresses by puberty. The blood supply is from the ascending pharyngeal artery, the ascending palatine artery, the pharyngeal branch of the maxillary artery, the artery of the pterygoid canal, and the tonsillar branch of the facial artery. Venous outflow occurs via the pharyngeal plexus which ultimately drains into the internal jugular and facial veins. Nerve supply is via the pharyngeal plexus which is supplied by both the glossopharyngeal and vagus nerves. Lymphatic drainage of the adenoids goes to the retropharyngeal and pharyngomaxillary space lymph nodes (Bailey et al. 2005).

The anatomic location of the adenoids as well as the relationship to surrounding structures has major implications in terms of the pathophysiology of disease processes related to adenoid hypertrophy. Obstruction of the Eustachian tubes, which are located laterally, plays a significant role in middle ear disease. Adenoid enlargement and inflammation are also significant in

chronic sinusitis as well as allergic rhinitis. Given their location in the nasopharynx, adenoid hypertrophy also results in nasal obstruction, mouth breathing, nasal voice, and obstructive sleep apnea. Chronic mouth breathing due to nasal obstruction during the age when the facial bones are developing can produce a high arched palate and narrowing of the midface. This results in elongation of the face with predominance of the upper teeth, the so-called adenoid facies (Bailey et al. 2005).

The adenoids are a predominantly B-cell organ, and are involved in inducing secretory immunity and regulating secretory immunoglobulin production. Immunoglobulins produced by the adenoids include IgA, IgM, IgG, and IgD. Despite their clear role as secondary lymphatic organs, the overall effect of adenoidectomy on the immune system appears to be minimal. There have been some reports of decreased nasopharyngeal IgA production against polio vaccine following adenoidectomy and increased rates of Hodgkin's disease following tonsillectomy and adenoidectomy, but these claims have been unsubstantiated by more in-depth studies. Many different organisms can cause adenoid inflammation, from viruses and yeasts to anaerobes and aerobes. Most infections are polymicrobial because the oropharynx is colonized with many bacteria, which can also make it difficult to distinguish between organisms which are colonizers versus invaders. However, hypertrophied and chronically infected adenoids have been shown to have more beta-lactamase producers than non-diseased adenoids (Bailey et al. 2005).

Historically, the adenoids were removed using sharp instrumentation, such as curettes. Although this technique remains in use, several other techniques have gained favor in recent years, including thermal, microdebrider, and bipolar radiofrequency (Coblator™) reduction. The Coblator™ utilizes a system of radiofrequency bipolar electrical current which passes through a field of normal saline and results in the production of a plasma field of sodium ions which are able to break down intracellular bonds and vaporize tissue. The Coblator™ can be used for adenoidectomy and works well for fairly small adenoid pads, but is not as effective in larger adenoid pads. The microsurgical debrider consists of a rotating blade, which has a suction incorporated into it and, therefore, effectively shaves tissue. It is a very efficient and effective method of removing adenoid tissue, and is particularly useful for removing adenoid tissue that extends through the choanae into the nasal cavity (Flint et al. 2010).

Adenoidectomy is most commonly performed in conjunction with tonsillectomy but can be performed alone. After induction of general anesthesia, the patient is placed in Rose's position, and a mouth gag is placed to expose the oropharynx. The soft and hard palate are then visualized and palpated for any evidence of submucous cleft palate. Typically, a red rubber catheter is passed through one or both nares, brought back out through the oral cavity, and used to suspend the soft palate to allow better visualization of the nasopharynx. A nasopharyngeal mirror is then used to assess the adenoid pad and guide placement of the curette, which is placed high in the nasopharynx, along the margin of the vomer. It is then drawn downward with mild pressure to remove the adenoid tissue, with care being taken not to penetrate into the prevertebral fascia and not to disturb the Eustachian tube orifice (Thiessing et al. 2010). Smaller curettes or a nasopharyngeal punch can then be used to remove residual adenoid tissue in the choanae. If a microdebrider is used, the exposure is the same, and the mirror is used to guide the microdebrider and shave down the adenoid tissue. Once all desired tissue has been removed, the nasopharynx is packed, and then possibly suction electrocautery is used to achieve hemostasis. (Flint et al. 2010) Some prefer to perform adenoidectomy with thermal reduction alone using suction monopolar cautery.

Indications

The most common indication for tonsillectomy and adenoidectomy in the pediatric population is obstructive sleep apnea, which has a reported incidence of 1–3% (Flint et al. 2010). Airway obstruction typically results from the tonsils and adenoids filling the area of the oropharynx and nasopharynx, thus obstructing airflow. This can lead to intermittent complete airway obstruction, particularly during sleep, owing to the effects of gravity and relaxation of the surrounding oropharyngeal and nasopharyngeal soft tissue. Obstructive adenoid hyperplasia is diagnosed by clinical history and physical examination. A triad of obligate mouth breathing, snoring, and hyponasal speech are seen. Rhinorrhea and post-nasal drip may

also be seen, but these symptoms are less specific and must be differentiated from allergic rhinitis. Polysomnography should be performed to determine the degree of obstruction.

Obstructive sleep apnea, if untreated, results in severe and potentially life-threatening consequences including pulmonary hypertension and cor pulmonale (Sargi and Younis 2007). Apneic events and associated oxygen desaturations are typically short and associated with a brief period of arousal, during which the patient repositions himself and opens the airway. However, in severe cases, the apnea can be prolonged, resulting in significant oxygen desaturation, which puts significant stress on the cardiovascular system.

Adenoid hypertrophy can also be associated with failure to thrive, dysphagia, speech abnormalities, and craniofacial growth abnormalities. The presence of any of these, even in the absence of sleep apnea, is an indication for adenoidectomy. Failure to thrive in these patients is thought to be secondary to disruptions in growth hormone secretion during REM sleep in patients with OSA (Lieberman et al. 2006). The most common speech abnormality seen in these patients is hyponasal speech, which typically improves significantly following adenoidectomy. Craniofacial abnormalities associated with adenoid hypertrophy include the "adenoid facies" described above, as well as occlusion abnormalities.

Children with middle ear disease also benefit from adenoidectomy. The close proximity of the adenoid tissue to the orifice of the Eustachian tubes is significant in the pathogenesis of middle ear disease. Eustachian tube dysfunction can result in chronic otitis media with effusion as well as recurrent acute otitis media. Removal of the adenoid tissue has been shown to be effective in resolving both of these disease processes, regardless of the size of the adenoids. The mechanism of the adenoids role in middle ear pathology is unclear, but it has been postulated that either the bacteria harbored in the adenoids cause irritation of the Eustachian tube lining resulting in Eustachian tube dysfunction, or the harbored bacteria cause a chronic infection of the middle ear space.

Finally, patients with a history of chronic recurrent sinusitis may also benefit from adenoidectomy. A recent study showed that biofilms are prominent in the adenoids of children who have chronic sinusitis (Coticchia et al. 2007). Adenoids removed for OSA were compared to adenoids removed for chronic sinusitis, and showed that 95% of the surface of the adenoids of sinusitis patients was covered in biofilms, compared to only 2% of the surface in OSA adenoids.

Contraindications

There are no absolute contraindications to adenoidectomy, but there are several relative contraindications. The most commonly recognized contraindication to adenoidectomy is the presence of palatal abnormalities. These patients are at increased risk of developing velopharyngeal insufficiency, one of the most dreaded complications of adenoidectomy where there is nasal escape of speech or food. It is important to include a complete palatal examination as part of the preoperative work-up, to determine the presence of a submucosal cleft palate or bifid uvula. Patients with a history of cleft palate or evidence of an occult cleft palate should not undergo adenoidectomy unless absolutely necessary, and a conservative adenoidectomy should be performed, taking care to preserve the lower portion of the adenoid pad (Ruben and Weg 1975).

Children with a history of nasal regurgitation or hypernasal speech are also at increased risk of postoperative VPI. These patients should be carefully evaluated, and adenoidectomy only performed if absolutely necessary. Another group in which adenoidectomy should be performed cautiously are patients with neuromuscular disorders. These patients frequently have Eustachian tube dysfunction, and adenoidectomy is performed in the hope of improving their middle ear disease. However, the Eustachian tube dysfunction is often directly related to their hypotonicity rather than the adenoids, so this should be investigated preoperatively (Ruben and Weg 1975).

Advantages

Adenoidectomy significantly improves symptoms in a majority of patients. In conjunction with tonsillectomy, adenoidectomy significantly improves symptoms of OSA, and reduces the risk of cardiac and pulmonary sequelae associated with severe OSA. In patients who already have ventricular dysfunction, T&A results in rapid improvement of ventricular function. Many patients with OSA also have failure to

thrive, and reports have shown catch-up growth following T&A in these patients (Lieberman et al. 2006). Given its simplicity, low risk profile, and effectiveness, adenoidectomy is considered a first-line treatment for a variety of disease processes related to adenoid hypertrophy/infection.

Disadvantages

Most patients tolerate adenoidectomy fairly well, although there are potential serious postoperative complications. These complications are primarily related to pain, bleeding, airway obstruction, postoperative pulmonary edema, velopharyngeal insufficiency, and nasopharyngeal stenosis. Advances of modern surgical technique and anesthesiology have significantly reduced the number of complications related to adenotonsillectomy.

The most serious complication of adenotonsillectomy is postoperative hemorrhage, with rates reported from 0.5% to 10% (Flint et al. 2010). Bleeding can occur intraoperatively, immediately postoperatively or in the delayed postoperative period. Intraoperative hemorrhage may be related to an underlying coagulopathy or major arterial damage. Steps to control intraoperative bleeding include suction cautery, and if needed, the placement of packing in the tonsillar fossa and oversewing the tonsillar pillars to provide pressure in the fossa. Suture ligatures should be used with caution, as they may damage the underlying arterial vessels, thereby worsening the bleeding, or predisposing to postoperative bleeding. In severe cases, ligation of larger arteries or embolization may be necessary, but this is extremely uncommon. Postoperative bleeding in the immediate postoperative period following adenoidectomy can be initially controlled with topical decongestant nasal sprays. If the bleeding is severe, these patients should be taken back to the operating room for examination of the nasopharyngeal pad. Patients and parents should be made aware of the risk of delayed postoperative bleeding, and instructed to return to the emergency room immediately if there is any evidence of bright red bleeding from the nose or mouth, as this can be fatal if not managed appropriately. Patients with delayed bleeding should be taken to the operating room for examination of the tonsillar fossa and adenoid bed.

Postoperative airway obstruction may occur secondary to edema of the tongue, nasopharynx, and palate. Intravenous corticosteroids may be given intraoperatively to reduce this complication. In patients with a history of obstructive sleep apnea and long-term upper airway obstruction, pulmonary edema may arise after adenotonsillectomy. Therefore, patients with a prolonged history of severe OSA or patients who have evidence of cor pulmonale should be observed closely after surgery with pulse oximetry. Patients with postoperative hypercapnia sometimes require mechanical ventilation until their hypercapnia resolves.

Velopharyngeal insufficiency, or hypernasality, is a relatively uncommon complication related to adenoidectomy, with an estimated incidence of around 0.1% (Flint et al. 2010). A family history of VPI or personal history of hypernasal speech or nasal regurgitation as an infant may predispose patients to postoperative VPI. The incidence of VPI is increased in patients with palatal anomalies, and therefore adenoidectomy should be performed conservatively in this cohort of patients. Patients with VPI should be evaluated by a speech pathologist. Most cases are transient and resolve over time; however, in some situations surgical intervention, such as a pharyngeal flap, sphincter pharyngoplasty, or posterior pharyngeal wall augmentation, may be necessary.

Nasopharyngeal stenosis is the result of excessive cauterization or laser application with subsequent mucosal destruction of the nasopharynx, lateral nasopharyngeal wall, and posterior tonsillar pillars. This can result in scarring of the soft palate to the posterior pharyngeal wall and can result in significant obstruction of the nasal airway. This requires surgical repair, typically using a combination of skin flaps, mucosal flaps, stents, and skin grafts, and often requires multiple surgical procedures to repair (Mankekar 2010). Cotton describes a laterally based pharyngeal flap in which an incision is made laterally through the scar tissue into the pharyngeal wall (Cotton 1985). The mucosa is then elevated to allow for scar tissue removal, and the entire posterior pharyngeal wall is elevated as a laterally based pharyngeal flap which is elevated as a mucomuscular flap at the plane of the prevertebral fascia. The inferior limit of the flap is dissected posteriorly as far as possible, and the flap is mobilized and sewn into position. Bivalved flaps as well as transnasal endoscopic approaches have also been described.

Cross-References

- ▶ Acute Otitis Media
- ▶ Chronic Otitis Media with Effusion
- ▶ Cleft Lip and Palate
- ▶ Obstructive Sleep Apnea
- ▶ Tonsillectomy
- ▶ Waldeyer's Ring

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Adenoiditis

- ▶ Adenotonsillar Disease

Adenoma with Neuroendocrine Differentiation

- ▶ Middle Ear Adenoma

Adenomatous Tumor of Middle Ear

- ▶ Middle Ear Adenoma

Adenotonsillar Disease

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Synonyms

Adenoiditis; Adenotonsillitis; Nasopharyngitis; Pharyngitis; Pharyngotonsillitis; Tonsillitis

Definition

Pharyngotonsillitis (tonsillitis, ▶ pharyngitis) is a general term used to describe diffuse inflammation of the structures of the oropharynx, including the tonsils. The disorder presents with symptoms of sore throat; however, objective signs of inflammation must be present in order to make the diagnosis. Pharyngotonsillitis may be classified based on duration of symptoms as acute, subacute, or chronic, with most patients presenting acutely. Alternatively, inflammatory disease of the nasopharynx may be considered *nasopharyngitis* (adenoiditis), in which common symptoms include rhinorrhea, nasal congestion, sneezing, and cough. Inflammation limited to the adenoid pad (adenoiditis) is difficult to diagnose in the primary care setting due to the inaccessibility of this tissue to direct visualization.

Introduction

The tonsils and adenoid are lymphoid organs that participate in the mucosal immune system of the pharynx. They are positioned strategically at the entrance of both the respiratory and gastrointestinal tracts, where they serve to initiate immune responses against antigens entering the body through the mouth or nose. As such, myriad infectious and inflammatory disorders are manifest in the tonsils and adenoid. This entry serves to

review some of those disorders that are of the greatest importance to the otolaryngologist.

Functions of the Tonsils and Adenoid

The palatine tonsils and adenoid are tissues of "Waldeyer's ring," a group of lymphoepithelial tissues that also includes the tubal tonsils in the nasopharynx and the lingual tonsil. Collectively, these tissues participate in the mucosal immune system of the pharynx. Positioned strategically at the entrance of both the gastrointestinal and the respiratory tracts, the tonsils and adenoid serve as secondary lymphoid organs, initiating immune responses against antigens entering the body through the mouth or nose. The size of the tonsils appears to correlate with their level of immunological activity, peaking between the ages of 3 and 10 years, and demonstrating age-dependent involution. There is also some evidence that their size increases with the bacterial load.

The tonsils are covered by a non-keratinizing stratified squamous epithelium featuring some 10–30 deep crypts that effectively increase the surface area exposed to incoming antigens. The crypts occasionally harbor degenerated cells and debris that give rise to so-called tonsilloliths, in which the presence of biofilms has also been implicated. Although the tonsils lack afferent lymphatics, the epithelium contains a system of specialized channels lined by "M" cells that take up antigens into vesicles and transport them to the intra- and subepithelial spaces where they are presented to lymphoid cells (Brandtzaeg 1987). The transport function of M cells also serves as a portal for mucosal infections and immunizations, and M cells also can initiate immunologic responses within the epithelium, introducing foreign antigens to lymphocytes and antigen-presenting cells (APCs).

After passing through the crypt epithelium, inhaled or ingested antigens reach the extrafollicular region or the lymphoid follicles. In the extrafollicular region, APCs process the antigens and present them to helper T lymphocytes that stimulate proliferation of follicular B lymphocytes. The B lymphocytes ultimately develop into one of two types of cell: antibody-expressing B memory cells capable of migration to the nasopharynx and other sites, or plasma cells that produce antibodies and release them into the crypt lumen. Tonsillar plasma cells can produce all five immunoglobulin (Ig) classes helping to combat and prevent infection. In addition, the contact of memory B cells in the lymphoid follicles with antigen is an essential part of the generation of a secondary immune response (Brandtzaeg 1987).

Among the Ig isotypes, IgA may be considered the most important product of the adenotonsillar immune system. In its dimeric form, IgA can attach to the transmembrane secretory component (SC) to form secretory IgA (SIgA), a critical component of the mucosal immune system of the upper airway. This component is necessary for binding of IgA monomers to each other and to the SC, and is an important product of B-cell activity in the tonsil follicles. While the tonsils produce immunocytes bearing the J (joining) chain carbohydrate, SC is produced only in the adenoid and extratonsillar epithelium, and therefore, only the adenoid possesses a local secretory immune system.

Common Viral Infection of the Tonsils and Adenoid

Nasopharyngitis typically occurs during the cold weather months among young children during their early exposures to respiratory viruses. Adenoviruses, influenza viruses, parainfluenza viruses, and enteroviruses are the most common etiologic agents. Rhinovirus and respiratory syncytial virus occur almost exclusively in preschool children and are rarely associated with overt signs of pharyngeal inflammation. Adenoviruses are more common among older children and adolescents. Nasopharyngitis of viral etiology may also cause a concomitant pharyngotonsillitis. The infection is most commonly acute and self-limited, with symptoms resolving within 10 days. Nonviral agents are less frequently associated with nasopharyngitis, but may include *C. diphtheriae, N. meningitidis*, *H. influenzae*, and *Coxiella burnetii*.

The viruses responsible for pharyngotonsillitis are more diverse than those in nasopharyngitis. Adenoviruses, influenza viruses, parainfluenza viruses, enteroviruses, Epstein-Barr virus, and *Mycoplasma* account for most of these infections. As in nasopharyngitis, most viral pharyngotonsillitis requires no specific therapy.

Infectious Mononucleosis

Pharyngitis is one of the hallmarks of infectious mononucleosis, a disorder associated with primary infection by the Epstein-Barr virus (EBV). Exposure to EBV is nearly universal, with serologic reactivity to EBV antigens demonstrable in an estimated 80–95% of adults. However, while primary infection by EBV occurs during the second and third decade in developed nations and regions of high socioeconomic status, young children may still be exposed, especially in developing countries and regions of low socioeconomic status. When the virus is acquired at a younger age, symptoms are generally less severe.

The incidence of infectious mononucleosis in the United States is approximately 1:50–100,000 per year, but increases to about 1: 1,000 among adolescents and young adults. Infected individuals transmit EBV by way of saliva exchanged during kissing or other close contact.

EBV is a member of the herpesvirus family that preferentially infects and transforms human B lymphocytes. The virus enters the cell by attaching to a receptor designed for proteins of the complement chain, and its genetic material is transported by vesicles to the nucleus, where it dwells as a plasmid and maintains a "latent" state of replication. An incubation period of 2–7 weeks follows initial exposure, during which EBV induces a proliferation of infected B cells. This process is subsequently countered by a potent cellular immune response, characterized by the appearance of atypical lymphocytes (most likely T lymphocytes responding to the B-cell infection) in the blood. The number of infected circulating B cells is reduced during this 4–6 week period.

Infectious mononucleosis is characterized by a prodrome of malaise and fatigue, followed by the acute onset of fever and sore throat. Physical examination typically reveals enlarged, erythematous palatine tonsils, in most cases with yellow-white exudate on the surface and within the crypts. Cervical adenopathy is present in nearly all patients, and involvement of the posterior cervical nodes often helps distinguish EBV infection from that by streptococcus or other organisms. Between the second and fourth weeks of illness, approximately 50% of patients develop splenomegaly, and 30–50% develop hepatomegaly. Rash, palatal petechiae, and abdominal pain may also be present in some cases. The fever and pharyngitis generally subside within about 2 weeks, while adenopathy, organomegaly, and malaise may last as long as 6 weeks.

Adenotonsillar Disease, Table 1 Expected results of serologic testing for Epstein-Barr (EB) virus

	Never been EBV infected	EBV infected now	EBV infected in past
Anti-viral capsid antigen (VCA)	Negative	Positive	Positive
Anti-EB nuclear antigen (EBNA)	Negative	Negative	Positive

Diagnosis of infectious mononucleosis can usually be made on the basis of clinical presentation, absolute lymphocytosis, the presence of atypical lymphocytes in the peripheral smear, and detection of Paul-Bunnell heterophil antibodies. The latter is the basis of the Mono-Spot, Mono-Diff, and Mono-Test assays, which test for agglutination of horse erythrocytes. Children under 5 years of age may not develop a detectable heterophil antibody titer; in these patients, it is possible to determine titers of IgG antibodies to the viral capsid antigen, as well as antibodies to the "early antigen" complex. Antibodies to EBV nuclear antigen appear late in the course of the disease (Table 1).

In most cases, rest, fluids, and analgesics are adequate to manage the symptoms of infectious mononucleosis. In more symptomatic patients, particularly those with respiratory compromise due to severe tonsillar enlargement and those with hematologic or neurologic complications, a course of systemic steroids may hasten resolution of the acute symptoms. Placement of a nasopharyngeal trumpet or endotracheal intubation may be necessary on rare occasions when complete airway obstruction is imminent. Antibiotics may be useful in cases of concomitant group A beta-hemolytic pharyngotonsillitis; however, ampicillin use is known to induce a rash in this setting.

The use of antiviral agents in infectious mononucleosis has yielded disappointing results. In clinical trials, acyclovir reduced viral shedding in the pharynx but demonstrated little efficacy in the treatment of symptoms. Other agents have exhibited greater in vitro effect than acyclovir but are yet to be tested clinically.

Exposure to EBV has been implicated in the development of post-transplantation lymphoproliferative

disorder (PTLD). Children who have received bone marrow and solid organ transplants may develop abnormal proliferation of lymphoid cells in the setting of immunosuppression; approximately 80% of affected individuals have a history of EBV infection (Shapiro et al. 2003). EBV-seronegative transplant recipients may develop acute EBV infection from environmental exposure or from the EBV-seropositive donor once they become immunosuppressed (Shapiro et al. 2003). The clinical presentation is variable and can mimic graft-versus-host disease, graft rejection, or more conventional infections. Signs and symptoms may resemble an IM-like illness or an extra-nodal tumor, commonly involving the gut, brain, or the transplanted organ. Mononucleosis-like presentations typically occur in children within the first year after transplant, and are often associated with primary EBV infection after transfer of donor virus from the grafted organ. Extra-nodal tumors are more common among EBV-seropositive recipients several years after the transplant. Studies have shown that young age at the time of transplant and EBV seronegativity conferred increased risk of adenotonsillar hyperplasia, which may be a precursor to PTLD (Shapiro et al. 2003). A higher incidence of PTLD has also been demonstrated with use of more potent immunosuppressive agents.

Initial management involves reduction of immunosuppression with care to preserve the transplanted organ. Patients who do not tolerate or respond to reduction of immunosuppression require more aggressive therapy and often have a poorer prognosis. Additional treatments include antivirals, such as acyclovir and gancyclovir, antibody therapy, interferon, chemotherapy, and radiation therapy with varying results. Prognosis is poor with mortality rates as high as 50–90%. Novel forms of immunotherapy have been tested in PTLD, including both antibody and cell-mediated approaches.

Group A β-Hemolytic and Other Streptococci

The group A β-hemolytic streptococcus (GABHS) is the most common bacterium associated with pharyngotonsillitis in children. In the 70 years since the advent of antibiotics, most pharyngeal infections by GABHS have been benign, self-limited, and uncomplicated processes. In fact, most patients improve symptomatically without any medical intervention whatsoever. However, a small number of affected children continue to develop renal and cardiac complications following GABHS infection, and some authors have implicated GABHS in the development of common childhood neuropsychiatric disorders. In addition, there is evidence that early antibiotic therapy may be useful in treating the symptoms of GABHS. As a result, appropriate diagnosis and treatment of these infections is imperative.

The incidence of GABHS pharyngitis has not been estimated on the basis of population-based data. Nevertheless, "strep throat" is well recognized as a common disease among children and adolescents. The incidence peaks during the winter and spring seasons, and is more common in cooler, temperate climates. Close interpersonal contact in schools, military quarters, dormitories, and families with several children appears to be a risk factor for the disease.

Transmission of GABHS is believed to occur through droplet spread. Individuals are most infectious early in the course of the disease, and the risk of contagion depends upon the inoculum size and the virulence of the infecting strain. The incubation period is usually between 1 and 4 days. After starting antimicrobial therapy, most physicians will allow affected children to return to school within 36–48 h. The role of individuals colonized with GABHS in the spread of the disease is uncertain, although data suggest that carriers rarely spread the disease to close contacts.

The streptococci are gram-positive, catalase-negative cocci, characterized by their growth in long chains or pairs in culture. These organisms are traditionally classified into 18 groups with letter designations (Lancefield groups) on the basis of the antigenic carbohydrate component of their cell walls. While the group A beta-hemolytic streptococcus is isolated from most patients with streptococcal pharyngitis, group C, G, and B streptococci may also occasionally cause this disorder. Further subclassification of streptococci is made based on their ability to lyse sheep red blood cells in culture; the beta-hemolytic strains cause hemolysis associated with a clear zone surrounding their colonies, while alpha-hemolytic strains cause partial hemolysis and gamma-hemolytic strains cause no hemolysis. The alpha-hemolytic strains are normal flora of the oral cavity and pharynx and should not be confused with the more pathogenic beta-hemolytic strains.

The primary determinant of streptococcal pathogenicity is an antigenically distinct protein known as the M protein. This molecule is found within the fimbriae, which are finger-like projections from the cell wall of the organism that facilitate adherence to pharyngeal and tonsillar epithelium. Over 120 M serotypes are known. The M protein allows a streptococcus to resist phagocytosis in the absence of type-specific antibody. In the immunocompetent host, the synthesis of type-specific anti-M and other antibodies confers long-term serotype-specific immunity to the particular strain in question. In laboratory-produced penicillin-resistant strains of GABHS, the M protein is absent, thereby rendering these strains more vulnerable to phagocytosis. This finding may help to explain why there have been no naturally occurring penicillin-resistant GABHS isolated in over 70 years of penicillin use.

GABHS are capable of elaborating at least 20 extracellular substances that affect host tissue; the interested reader may find a complete discussion of these substances elsewhere. Among the most important are streptolysin O, an oxygen-labile hemolysin, and streptolysin S, an oxygen-stable hemolysin, which lyse erythrocytes and damage other cells such as myocardial cells. Streptolysin O is antigenic, while streptolysin S is not. GABHS also produce three erythrogenic or pyrogenic toxins (A, B, and C) whose activity is similar to that of bacterial endotoxin. Other agents of significance include exotoxin A, which may be associated with toxic shock syndrome, and bacteriocins, which destroy other gram-positive organisms. Spread of infection may be facilitated by a variety of enzymes elaborated by GABHS, which attack fibrin and hyaluronic acid.

Signs and symptoms of GABHS pharyngotonsillitis are acute in onset, usually characterized by high fever, odynophagia, headache, and abdominal pain. However, the presentation may vary from mild sore throat and malaise (30–50% of cases) to high fever, nausea and vomiting, and dehydration (10%). The pharyngeal and tonsillar mucosa are typically erythematous and occasionally edematous, with exudate present in 50–90% of cases. Cervical adenopathy is also common, seen in 30–60% of cases. Most patients improve spontaneously in 3–5 days, unless otitis media, sinusitis, or peritonsillar abscess occur secondarily.

The risk of rheumatic fever following GABHS infection of the pharynx is approximately 0.3% in endemic situations, and 3% under epidemic circumstances. A single episode of rheumatic fever places an individual at high risk for recurrence following additional episodes of GABHS pharyngitis. Acute glomerulonephritis occurs as a sequela in 10–15% of those infected with nephritogenic strains (Kaplan and Gerber 1998). In patients who develop these sequelae, there is usually a latent period of 1–3 weeks.

PANDAS (pediatric autoimmune neuropsychiatric disorder associated with group A streptococcal infection) has been described as a selective immunopathy similar to Sydenham's chorea in which the response to streptococcal infection leads to dysfunction in the basal ganglia, resulting in tic, obsessive-compulsive, and affective disorders (Swedo et al. 1998). Classically, the behaviors are abrupt in onset and must have some temporal relationship to infection by GABHS. Clinical improvement has been reported among some patients treated with antibiotics, particularly as prophylaxis against recurrence. However, a cause-and-effect association of PANDAS with GABHS infection has yet to be established. Many experts believe that, as has been observed with other stressors, infection of any kind may provoke the neuropsychiatric phenomena.

Early diagnosis of streptococcal pharyngitis has been a priority in management of the disease, primarily due to the risk of renal and cardiac sequelae. A number of authors have studied the predictive value of various combinations of signs and symptoms in an effort to distinguish streptococcal from nonstreptococcal pharyngitis; however, none of these has been particularly reliable. Taken together, these studies demonstrate a false negative rate of about 50% and a false positive rate of 75%. Adenopathy, fever, and pharyngeal exudate have the highest predictive value for a positive culture and rise in anti-streptolysin O (ASO) titer, and absence of these findings in the presence of cough, rhinorrhea, hoarseness, or conjunctivitis most reliably predicts a negative culture, or positive culture without rise in ASO.

Most clinicians advocate throat culture as the gold standard to determine appropriate treatment for GABHS. However, the tonsils, tonsillar crypts, or posterior pharyngeal wall must be swabbed for greatest accuracy. Tests for rapid detection of the group-specific carbohydrate simplify the decision to treat at the time of the office visit, and often eliminate the need for additional post-visit communication. However, while these tests have demonstrated a specificity of greater than 95%, their sensitivity is generally in the

70–90% range. As a result, many clinicians advocate throat culture for children with suspected streptococcal disease and negative rapid strep tests. Rapid antigen detection is usually more expensive than throat culture, and this technique must still be interpreted with care given the high incidence of post-treatment carriers. Studies also suggest possible clinician bias in interpretation of this test.

Carriage of GABHS may be defined as a positive culture for the organism in the absence of a rise in ASO convalescent titer, or in the absence of symptoms. The prevalence of GABHS carriers has been estimated at anywhere from 5% to 50% depending on the time of year and location, however this figure is sometimes overestimated due to the use of antibiotics that occasionally interfere with the rise in ASO titer. Carriers are at low risk to transmit GABHS or to develop symptoms or sequelae of the disease. The importance of this condition is in the distinction of true acute streptococcal pharyngitis from nonstreptococcal sore throat in a carrier. When this distinction is important, a baseline convalescent ASO titer should be drawn. A subsequent positive test may be defined as a twofold dilution increase in titer between acute and convalescent serum, or any single value above 333 Todd units in children. However, a low titer does not rule out acute infection, and a high titer may represent infection in the distant past. As a result, the American Academy of Pediatrics and the Infectious Disease Society of America currently recommend that testing for GABHS should not be performed in children with conjunctivitis, cough, hoarseness, coryza, diarrhea, oral ulcerations, or other clinical manifestations highly suggestive of viral infection. Furthermore, it is critical that patients referred for potential tonsillectomy for "recurrent strep" be ruled out as carriers before they are considered candidates for surgery.

Although most upper respiratory infections by GABHS resolve without treatment, studies suggest that antimicrobial therapy prevents suppurative and nonsuppurative sequelae including rheumatic fever, and may also hasten clinical improvement. Treatment is therefore indicated for most patients with positive rapid tests for the group A antigen. When the test is negative or not available, one may treat for a few days while formal throat cultures are incubating.

GABHS is sensitive to a number of antibiotics, including penicillins, cephalosporins, macrolides, and clindamycin. Expert panels have designated penicillin the drug of choice in managing GABHS owing to its track record of safety, efficacy, and narrow spectrum. To date, no strains of GABHS acquired in vivo have demonstrated penicillin resistance or increased minimum inhibitory concentrations in vitro. Beginning in the 1980s, several studies reported a decrease in bacteriologic control rates, attributed primarily to inoculum effects and to increased tolerance to penicillin. Whether cephalosporins may achieve greater eradication of GABHS than penicillin remains controversial.

Depot benzathine penicillin G is still advocated by the American Heart Association for primary treatment of GABHS pharyngitis; however, a 10-day course of penicillin orally is the most widely prescribed regimen. Twice daily dosing by the enteral route yields results similar to those obtained with four times a day dosing. Courses of shorter duration are associated with bacteriologic relapse and are less efficacious in the prevention of rheumatic fever. Amoxicillin appears to have efficacy equal to that of penicillin. In poorly compliant or penicillin allergic patients, azithromycin dosed once daily for 5 days may be a reasonable alternative. Erythromycin is now used less commonly than in the past due to its gastrointestinal side effects.

Most patients with positive cultures following treatment are GABHS carriers; *these individuals need not be retreated if their symptoms have resolved*. For patients in whom complete bacteriologic clearance is desirable, such as those with a family member with a history of rheumatic fever, a course of clindamycin or a second course of penicillin combined with rifampin may yield increased success. In patients with recurrent symptoms, serotyping may aid in distinguishing bacterial persistence from recurrence. There are no data available regarding the use of antibiotic prophylaxis in these patients, and in such cases tonsillectomy may sometimes be advantageous.

During antimicrobial therapy, patients must be monitored carefully for fluid intake, pain control, and impending suppurative complications such as peritonsillar abscess. Small children may become dehydrated rapidly, and may require hospitalization for administration of fluids intravenously.

"Chronic" Tonsillitis

Chronic tonsillitis is poorly defined in the literature but may be the appropriate terminology for sore throat of

at least 3 months' duration accompanied by physical findings of tonsillar inflammation. Affected individuals may report symptoms of chronic sore throat, halitosis, or debris or concretions in the tonsil crypts known as "tonsilloliths" in which the presence of biofilms has been implicated. Affected patients may also have persisting cervical adenopathy. Throat culture in such cases is usually negative. Although there exist no clinical trials to help guide medical management of such patients, tonsillectomy is a reasonable consideration for those patients who do not respond to improved oropharyngeal hygiene and aggressive antibiotic therapy.

Peritonsillar Infection

Peritonsillar infection may present as either cellulitis or abscess (PTA). Most cases are thought to represent a suppurative complication of tonsil infection. Peritonsillar infection occurs more commonly in adolescents and young adults than in young children. Affected patients present with symptoms of sore throat, odynophagia, fever, voice change, and otalgia. Common physical findings include fever, drooling, trismus, muffled "hot potato" voice, and pharyngeal asymmetry with inferior and medial displacement of the tonsil. Radiographic evaluation is usually not necessary, but may be useful in young or uncooperative children or in equivocal cases. Although some authors have found intraoral ultrasound to be useful in adults, computerized tomography with contrast remains the imaging modality of choice in children.

While patients with peritonsillar cellulitis may be treated with antibiotics alone, most abscesses require removal of the pus as definitive therapy. Evacuation of PTA can be managed by needle aspiration, incision and drainage, or immediate ("quinsy") tonsillectomy with nearly equivalent efficacy. In very young or poorly cooperative patients, or in those in whom an abscess has been inadequately drained, tonsillectomy is curative and essentially eliminates any chance of recurrence.

Abscess cultures usually reveal a polymicrobial infection, often containing gram-positive organisms and anaerobes. Appropriate antimicrobial therapy in the emergency room or office setting would include initial parenteral administration of penicillin with or without metronidazole, clindamycin, or ampicillin-sulbactam. Options for oral therapy include amoxicillin-clavulanate, penicillin, and clindamycin, although children may resist taking the latter due to its taste. Intravenous hydration should also be considered for those individuals who have not been able to take liquids orally.

The efficacy of ▶ tonsillectomy in the prevention of recurrent PTA has not been compared to that of watchful waiting in a prospective, controlled trial. However, large case series demonstrate an increased rate of recurrent PTA among those who also had recurrent tonsillitis. Recurrence of PTA is heralded by a history of 2–3 episodes of acute tonsillitis in the year prior to the initial event; such a history has been elicited in 15–30% of patients with PTA (Herzon and Nicklaus 1998). Based on the available evidence, it has been suggested that routine elective tonsillectomy or quinsy tonsillectomy is not indicated for patients who present with their first PTA. However, if a patient is a candidate for elective tonsillectomy for other reasons (i.e., 2–3 tonsillitis events in the previous 12 months), then it seems rational to perform a quinsy tonsillectomy for treatment, or to proceed with planned elective tonsillectomy after successful abscess drainage (Herzon and Nicklaus 1998).

Recurrent Tonsillitis and Tonsillectomy

When tonsils have been recurrently or chronically infected, the controlled process of antigen transport and presentation is altered due to shedding of the transporting M cells from the tonsil epithelium (Brandtzaeg 1987). As a result, tonsillar lymphocytes can theoretically become overwhelmed with persistent antigenic stimulation, rendering them unable to respond to antigens or to function adequately in local protection or reinforcement of the upper respiratory secretory immune system. Furthermore, the direct influx of antigens disproportionately expands the population of mature B-cell clones and, as a result, fewer early memory B cells go on to become J-chain positive IgA immunocytes (Brandtzaeg 1987). There would therefore appear to be a therapeutic advantage to removing recurrently or chronically diseased tonsils. The surgeon should bear in mind, however, that ▶ tonsillectomy and ▶ adenoidectomy procedures remove a source of immunocompetent cells, and some studies demonstrate minor alterations of Ig concentrations in

the adjacent tissues following tonsillectomy (Kaygusuz et al. 2003).

Cultures from the deeper tissues of recurrently infected tonsils frequently reveal unusual pathogens including *S. aureus*, *H. influenzae*, *Actinomycetes, Chlamydia*, *Mycoplasma*, and anaerobes; however, it remains unclear whether such cultures truly represent the offending organisms. Several studies suggest that bacteria in biofilms may be more important in recurrent tonsillitis than their planktonic counterparts.

Recurrent sore throat of a noninfectious nature is a hallmark of PFAPA, or Marshall's syndrome. This disorder is characterized by periodic fever, aphthous stomatitis, pharyngitis, and adenitis, occurring primarily in children less than 5 years of age. The illness usually lasts more than 5 days and recurs at regular intervals of 3–6 weeks. Systemic steroids and cimetidine have demonstrated efficacy in controlling the events. Two small randomized controlled trials demonstrated that tonsillectomy was effective for treating PFAPA syndrome, but children in the control groups also showed improvement. Tonsillectomy may be considered based on the frequency of illness, severity of infection, and the child's response to medical management.

Appropriate medical and surgical management of children with recurrent infectious pharyngotonsillitis depends on accurate documentation of the cause and severity of the individual episodes as well as the frequency of the events. The clinician should record for each event a subjective assessment of the patient's severity of illness; physical findings including body temperature, pharyngeal and/or tonsillar erythema, tonsil size, tonsillar exudate, cervical adenopathy (presence, size, and tenderness); and the results of microbiologic testing for GABHS. A summary of the documentation should be made available to the consultant to aid in the medical decision-making regarding potential surgical intervention. In children with recurrent sore throat whose tests for GABHS are repeatedly positive, it may be desirable to rule out streptococcal carriage concurrent with viral infection as carriers are unlikely to transmit GABHS or to develop suppurative complications or nonsuppurative sequelae of the disease such as acute rheumatic fever. Supportive documentation in children who meet criteria for tonsillectomy may include absence from school, spread of infection within the family, and a family history of rheumatic heart disease or glomerulonephritis.

In all randomized controlled trials of ▶ tonsillectomy for infection, sore throat with each event was a necessary entrance criterion, and in most of these trials sore throat was the primary outcome studied. As a result, no claim can be made that tonsillectomy is indicated for children whose constellation of symptoms does not include sore throat, even when GABHS can be cultured from the throat. These studies also suggest that patients whose events are less severe or well documented do not gain sufficient benefit from tonsillectomy to justify the risk and morbidity of the procedure; in such patients, tonsillectomy should be considered only after a period of observation during which documentation of additional events may be made.

Children with frequent recurrences of throat infection over a period of several months demonstrate high rates of spontaneous resolution. As a result, an observation period of at least 12 months is generally recommended prior to consideration of tonsillectomy. In rare cases, early surgery may reasonably be considered for severely affected patients, such as those with histories of hospitalization for recurrent severe infections, rheumatic heart disease in the family, or numerous repeat infections in a single household ("ping-pong spread"), or those with complications of infection such as peritonsillar abscess or Lemierre's syndrome (thrombophlebitis of the internal jugular vein).

Observation of patients is also a reasonable management strategy in children who have had frequent recurrences of pharyngotonsillitis for more than 1 year. In several studies, non-tonsillectomized children demonstrated spontaneous improvement during the follow-up period, often with patients no longer meeting the original criteria for study entry (Paradise et al. 1984; Burton and Glasziou 2009). Additional information regarding the natural history of recurrent pharyngotonsillitis is found in case series describing outcomes for patients on "wait lists" tonsillectomy; many children who were reevaluated after months on such lists later no longer met criteria for surgery.

Tonsillectomy has been suggested for centuries as a means of controlling recurrent infection of the throat. However, clinical trials investigating the efficacy of tonsillectomy have had a high risk of bias because of poorly defined entrance criteria, nonrandom selection of operated subjects, exclusion of severely affected patients, or reliance on caregivers for postoperative data collection. In the most frequently cited and

meticulous trial, Paradise and colleagues (1984) included patients only if their episodes of throat infection met strict criteria as outlined in Table 2. The key findings of the study were as follows:

1. A mean rate reduction of 1.9 episodes of sore throat per year among tonsillectomized children during the first year of follow-up compared with controls. However, the sore throat associated with performance of the surgery (which would otherwise count as one episode) was excluded from the data. In the control group, patients also improved compared with their pre-enrollment frequency of infection, experiencing a mean of only 3.1 annual events. Differences between groups were reduced in the second year and not significant by the third year of follow-up.
2. For episodes of *moderate or severe* throat infection, the control group experienced 1.2 episodes compared to 0.1 in the surgical group. The rate reductions diminished over the subsequent 2 years of follow-up and were not significant in the third year.
3. Mean days with sore throat in the first 12 months were not statistically different between the two groups, but included a predictable period of sore throat postoperatively.

Adenotonsillar Disease, Table 2 The "Paradise criteria" for tonsillectomy in recurrent tonsillitis (Paradise et al. 1984)

Criterion	Definition
Frequency of sore throat events	7 or more episodes in the preceding year, or
	5 or more episodes in each of the preceding 2 years, or
	3 or more episodes in each of the preceding 3 years
Clinical features (one required in addition to sore throat)	Temperature >38.3°C, or
	Cervical lymphadenopathy (tender lymph nodes or >2 cm), or
	Tonsillar exudate, or
	Positive culture for GABHS
Treatment	Antibiotics are administered at appropriate dose for proven or suspected episodes of GABHS
Documentation	Each episode and its qualifying characteristics are synchronously documented in the medical record, or
	In cases of insufficient documentation, two subsequent episodes of throat infection are observed by the clinician with frequency and clinical features consistent with the initial history

In a subsequent study by the same authors, the entrance criteria were relaxed, with less rigorous criteria for the number of episodes, clinical features required, and documentation (i.e., 4–6 episodes in the last year or 3–4 episodes per year in the last 2 years). In the two arms of the study (tonsillectomy or adenotonsillectomy vs. control, and adenotonsillectomy vs. control), patients undergoing surgery experienced rate reductions of 0.8 and 1.7 episodes/year respectively in the first year. For episodes of moderate or severe sore throat, control subjects in the two arms of the study combined experienced 0.3 episodes/year overall compared with 0.1/year in subjects undergoing surgery. Mean days with sore throat in the first 12 months were not statistically different in either arm of the study. The investigators concluded that the modest benefit conferred by tonsillectomy in children moderately affected with recurrent throat infection did not justify the inherent risks, morbidity, and cost of the surgery.

A randomized controlled trial comparing tonsillectomy with watchful waiting in children aged 2–8 years examined fever >38.0°C for at least 1 day as the primary outcome measure. During a mean follow-up of 22 months, children in the tonsillectomy group had 0.2 fewer episodes of fever per person year, and from 6 to 24 months there was no difference between the groups. The surgical group also demonstrated, per person year, mild reductions in throat infections (0.2), sore throats (0.6), days with sore throat (5.9), and upper respiratory tract infections (0.5). Pooled data from these studies have also been analyzed in systematic reviews. In one such study, patients undergoing tonsillectomy experienced 1.4 fewer episodes of sore throat in the first year compared to the control group; however, the "cost" of this reduction was 1.0 episode of sore throat in the immediate postoperative period (Burton and Glasziou 2009).

Despite the modest advantages conferred by tonsillectomy for sore throat, studies of quality of life universally suggest a significant improvement in patients undergoing the procedure. Only two of these studies enrolled children exclusively and both reported improved scores in nearly all subscales. However, both also had numerous methodological flaws including enrollment of patients with "chronic tonsillitis" without definition based on signs and symptoms,

absence of a control group, low response rates with potential selection bias, poor follow-up, and caregiver collection of data.

In summary, tonsillectomy may be considered an option for children severely affected by recurrent throat infection. Families of patients who meet the appropriate criteria for tonsillectomy as described above must weigh the modest anticipated benefits of tonsillectomy for this indication against the natural history of resolution and the risk of surgical morbidity and complications.

Recurrent and Chronic Adenoiditis

The disorders characterized in children as adenoiditis, rhinosinusitis, and nasopharyngitis are not easily distinguished from one another on the basis of symptoms. Most individuals in whom the diagnosis is made present with nasal stuffiness, mucopurulent rhinorrhea, chronic cough, halitosis, and "snorting" or "gagging" on mucus throughout the day. However, there are no established criteria for making this diagnosis, or for differentiating it from viral upper respiratory illness or acute sinusitis.

In chronic or recurrent nasopharyngitis, the persistence of disease may be due to colonization by pathogenic bacteria. *H. influenzae, S. pneumoniae, S. pyogenes*, and *S. aureus* are commonly found in adenoid cultures and tissue samples among children so affected. Rates of drug-resistant bacteria may be higher among patients with chronic or recurrent infection. Furthermore, molecular typing of paired bacterial isolates from the adenoid and lateral nasal wall in children undergoing adenoidectomy demonstrates a high degree of correlation, and sinonasal symptom scores appear to correlate with quantitative bacteriology of the adenoid "core" and not with adenoid size. Several studies have demonstrated bacterial biofilm formation in the adenoid; however, it is not clear if this is more common in persistent and recurrent nasopharyngitis than in obstructive adenoid hyperplasia. In some patients, sinonasal infection is more likely due to stasis of secretions secondary to obstructive adenoid tissue rather than bacterial factors, although the two may certainly be related. Gastroesophageal reflux has not been established as a cause of chronic adenoid inflammation.

Data suggest that ▶ adenoidectomy may be useful in the management of children with persistent and recurrent sinonasal complaints, although a systematic review indicates the evidence is currently inadequate to firmly establish efficacy (van den Aardweg et al. 2010a). Most clinicians favor adenoidectomy prior to consideration of endoscopic sinus surgery, especially for those children with recurrent acute symptoms rather than those with more chronic sinonasal disease.

Otitis Media and Adenoiditis

The proximity of the adenoid pad to the Eustachian tube has prompted a number of clinicians to study the potential benefits of adenoidectomy and adenotonsillectomy in the management of otitis media. The effect of the adenoid on the Eustachian tube is likely one of regional inflammation or infection rather than one of direct compression.

Since 1980, there has been substantial evidence that ▶ adenoidectomy (van den Aardweg et al. 2010b; Paradise et al. 1999), and perhaps adenotonsillectomy, (Paradise et al. 1999) has a role in the management of both recurrent acute and chronic otitis media. However, some studies report results to the contrary, at least for recurrent acute otitis media. Benefit may be greatest for those children in whom the adenoid pad abuts the Eustachian tube; however, such children can be identified only by preoperative nasopharyngoscopy.

Based on the available data, it is reasonable that ▶ adenoidectomy be considered along with the first set of tubes if the child has significant symptoms of nasal obstruction or recurrent rhinorrhea, or when a second set of tubes is necessary, particularly for chronic middle ear effusion. Children with tympanostomy tubes who develop otorrhea refractory to management with topical and/or systemic antibiotics may also reasonably be considered candidates for adenoidectomy. In children with a history of cleft palate, the procedure should be performed only when the otitis is relentless; in such cases, an inferior strip of adenoid should be preserved to avoid velopharyngeal insufficiency. Tonsillectomy with adenoidectomy carries additional morbidity and has less support in the literature. Tonsillectomy is a reasonable additional procedure when indications such as airway obstruction or recurrent pharyngitis are also present.

Other Inflammatory Tonsil and Adenoid Disorders

Halitosis

Halitosis may result from food debris and bacteria retained within the crypts of the tonsils and adenoid. However, although bad breath is often cited as an indication for adenotonsillectomy, a wide variety of other causes including periodontal disease, debris of the tongue or lingual tonsils, sinonasal infection or foreign body, and gastroesophageal reflux should also be entertained. There are no clinical trials to support adenotonsillectomy for this indication.

Gonorrhea

Infection by *Neisseria gonorrhea* is a rare source of pharyngotonsillitis resulting from orogenital contact. Among young children, gonococcal infection occurs almost exclusively due to sexual abuse. In contrast, the demographic most commonly affected are adolescent girls aged 15–19, who are more likely engaging in consensual orogenital sex. The highest rates of pharyngeal involvement are reported among men having sex with men.

Gonococcal infection of the throat most commonly presents as an exudative pharyngitis accompanied by fever and adenopathy, not unlike that associated with a number of other organisms. The infection is symptomatic less than 70% of the time. The physician must therefore remain cognizant of other possible manifestations of gonococcal infection, such as urethritis in males and vulvovaginitis in females, as well as signs and symptoms of other sexually transmitted diseases. In cases of child abuse, infection of the throat, anorectal region, and/or vagina may occur concurrently. Cultures should be obtained and grown on Thayer-Martin medium to confirm the diagnosis in suspicious cases and to direct antibiotic therapy. In some cases of disseminated gonococcal infection, the pharynx may be the only culture-positive site.

Pharyngeal infection usually resolves spontaneously within 10–12 weeks but should be treated when diagnosed. In most cases, gonococcal pharyngitis may be adequately treated with a single parenteral administration of ceftriaxone or cefotaxime, although some physicians prefer to continue the injections daily for 7–10 days. Treatment should also be offered to the offending individual, and the infections must be reported to the appropriate local and national authorities.

Diphtheria

Diphtheria pharyngitis, caused by the gram-positive bacillus *Corynebacterium diphtheria*, remains a rare but serious cause of airway obstruction in children. With the development of diphtheria toxoid and aggressive immunization programs, diphtheria infection has become all but extinct in developed countries; no cases have been reported in the United States since 2003. Nevertheless, there are scattered cases in the United States in unimmunized or underimmunized individuals in the lower socioeconomic groups and a large proportion of adults in the western world lack protective serum levels of antitoxic immunity.

Corynebacterium diphtheriae is a club-shaped, gram-positive bacillus acquired via the respiratory passages or, rarely, the mucous membranes. Infection by the organism is followed by symptoms of nasal congestion, pharyngitis, anorexia, and low-grade fever. Cervical lymphadenitis and edema of the soft tissues of the neck are also common.

Following an incubation period of 2–4 days, diphtheria exotoxin is released by the organism, initiating local tissue necrosis and exudate. As the affected area expands, the exudate turns fibrinous, and develops into an adherent gray membrane also containing inflammatory cells, epithelial cells, and red blood cells. Enlargement of the membrane and progressive edema cause airway compromise and stridor, and dislodgment of the membrane may cause frank obstruction. Systemic effects of the toxin include myocarditis, peripheral neuritis, and acute tubular necrosis of the kidneys.

Definitive diagnosis is made on the basis of a culture of the membrane and/or demonstration of toxin production by immunoprecipitation, polymerase chain reaction (PCR), or immunochromatography; however, management should not be delayed for culture results. Pharyngeal membranes due to diphtheria are tenacious and difficult to remove; patients with airway compromise may urgently require a more secure airway. Once the airway is established and a presumptive diagnosis is made, the patient is tested for sensitivity to horse serum and antitoxin is obtained through the National Immunization Program of the Centers for Disease Control. Antibiotic therapy with penicillin or erythromycin is subsequently started, and nonimmune personal contacts are treated as well. Prognosis depends on the immunization status of the host, the promptness of medical therapy, and the virulence of the infecting organism. Prevention of diphtheria is achieved through immunization during infancy.

Kawasaki Disease (Mucocutaneous Lymph Node Syndrome)

Kawasaki disease (KD) is a multisystem vasculitis characterized by fever, rash, pharyngitis, conjunctival inflammation, edema of the extremities, and cervical adenopathy. Initially reported in the Japanese literature in 1967 as a benign disorder of childhood, KD has been linked over the last three decades to serious cardiac complications, arthritis, and a number of other manifestations.

KD is a disease of young children, with 80% of cases occurring in children less than 5 years of age. Fatalities are most common during infancy. The disease is slightly more common in males and among individuals of Asian extraction. Between 3,000 and 5,000 cases occur annually in the United States.

The etiology of KD remains unknown. Epidemiologic and clinical data occurrence of KD supports infectious etiology is likely; however, the mode of transmission is not known.

KD occurs in three distinct clinical phases. The acute phase lasts 1–2 weeks, and is characterized by prolonged high spiking fever, rash, erythema of the bulbar conjunctiva, swelling and erythema of the extremities, and adenopathy. Oral and oropharyngeal manifestations are also common, including swollen, fissured, and bleeding lips; "strawberry tongue" (resulting from diffuse erythema and prominent papillae); and erythema of the oropharyngeal mucosa. Each of these findings is observed in over 90% of patients, except for adenopathy >1.5 cm which is seen in 50–75%. In the subacute phase, days 10–25, most of these signs and symptoms resolve; however, conjunctival changes usually persist and the child remains irritable. The toes and fingers begin to desquamate and joint pain is present in about 30% of patients. Cardiac dysfunction, including coronary arteritis, vascular dilatation and aneurysm formation, myocarditis, arrhythmia, and coronary insufficiency, typically become evident during this period, affecting about 20% of patients. The third or convalescent stage begins when clinical signs of KD have completely resolved and ends when the sedimentation rate returns to normal. KD may also be associated with sterile pyuria, aseptic meningitis, hepatic dysfunction, distension of the gallbladder, diarrhea, uveitis, otitis media, and pneumonitis.

Diagnosis of KD is based on the clinical presentation. Patients must have a history of persistent fever, as well as four of the five other acute signs listed above. Laboratory evaluation is nonspecific; however, elevation of the sedimentation rate in the acute phase aids in excluding other etiologies, and thrombocytosis and anemia are common in the subacute phase.

Therapy for KD in the acute phase is directed at prevention of cardiac complications. High-dose aspirin is usually administered with a watchful eye for signs of Reye's syndrome to decrease myocardial inflammation and prevent thrombosis. Addition of intravenous immune globulin (IVIG) to the protocol results in a more rapid anti-inflammatory effect than that seen with aspirin alone. IVIG also appears to lessen the risk of long-term coronary artery abnormalities. Other manifestations of KD are treated symptomatically. Once the convalescent phase is reached, patients are generally monitored at regular intervals for evidence of cardiac complications.

No specific therapy for the oral and oropharyngeal manifestations is necessary, although use of anesthetic and antacid mouthwashes may alleviate odynophagia. Lubrication of the lips may reduce fissuring and bleeding. Systemic antibiotic are indicated only if the diagnosis remains in doubt.

Cross-References

- ▶ Adenoidectomy
- ▶ Adenotonsillectomy (Surgery, Pediatric)
- ▶ Lymphomas Presenting in Head and Neck
- ▶ Pharyngitis
- ▶ Tonsillectomy

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Adenotonsillectomy

► Tonsillectomy

Adenotonsillectomy (Surgery, Pediatric)

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Synonyms

Intracapsular tonsillectomy; Pharyngotonsillitis; Tonsillotomy; Waldeyer's ring

Definition

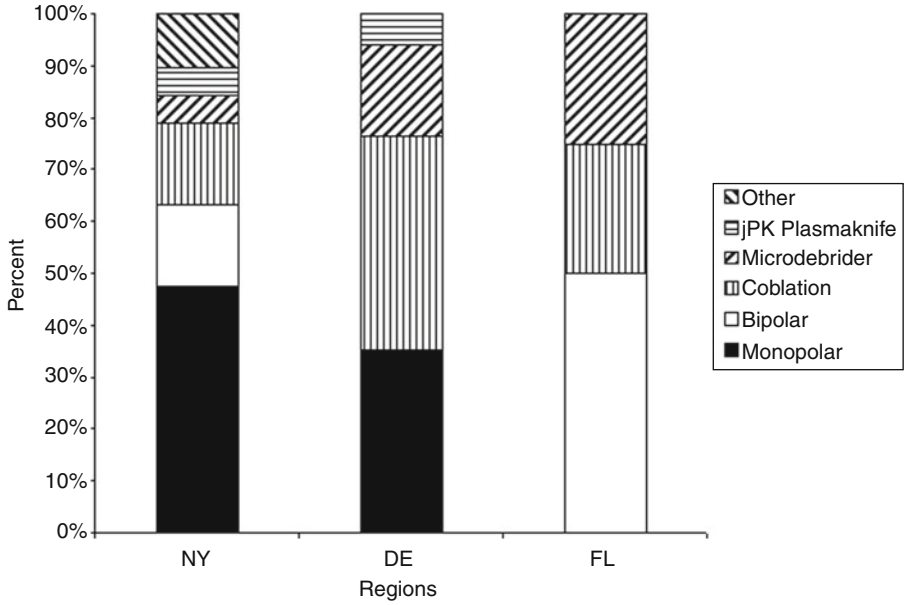
The complete or partial removal of pharyngeal tonsillar lymphoid and adenoid tissue.

Basic Characteristics

Overview

Adenotonsillectomy continues to be one of the most commonly performed surgical procedures in the Western world. Surgery for adenotonsillar disease is safe and effective as demonstrated in terms of health care costs and quality-of-life measures. The indications for ► tonsillectomy have shifted over the past 40 years. In the early 1970s, close to 90% of ► tonsillectomy procedures were performed in response to infections. Today, most procedures are performed to treat sleep-disordered breathing (SDB), which is defined as a continuum from primary snoring to obstructive sleep apnea (OSA). This trend reflects not only improved control with antibiotics of the complications of group A streptococcal pharyngitis, but also increased rates of childhood obesity, a concomitant and perhaps related increase in the diagnosis of SDB, and a greater awareness of the impact of SDB on children's educational progress and cognitive development. A revitalization of "older" techniques (such as ► tonsillectomy), the development of new technologies (such as powered microdebridement and Coblation®), and the drive to measure, report, and improve surgical outcomes have resulted in a wider range of operative approaches to adenotonsillectomy than that which was available in the past (Shah 2008). A broad variation in the types of techniques is practiced amongst surgeons. A more recent survey found regional variations among surgeons' use of ► tonsillectomy devices (Fig. 1) (Shah and Terk 2009). A survey of pediatric ORLs found differences in the instruments and technique by indication for surgery with fewer surgeons using intracapsular microdebrider techniques for infection (Walner et al. 2007). At the authors' institution, nearly all tonsillectomies are performed using intracapsular techniques whether by microdebrider or by Coblation®.

The American Academy of Otolaryngology – Head Neck Surgery (AAO-HNS) does not advocate one technique over another (AAO-HNS 2007). A breadth of surgical experience across the various options



Adenotonsillectomy (Surgery, Pediatric), Fig. 1 Device use prevalence by geography (Reprinted from Operative Tech Otolaryngol, 20, Shah UK, Terk A, New techniques for tonsillectomy and adenoidectomy, pp. 160–166, Copyright (2009), with permission from Elsevier)

enables the surgeon to fit the best procedure to the individual patient and circumstance. With the exception of ▶ tonsillectomy for tumors, in which case cold or monopolar complete ▶ tonsillectomy is recommended in order to optimize histopathological analysis and assessment of the tonsillar capsule, the authors of this entry generally defer to the surgeon's judgment in recommending a specific procedure for their patient, and they trust that appropriate referral will be made to another provider if a surgeon is not confident in their ability to perform the required procedure.

Purpose

This entry offers a brief review of the pertinent anatomy, explains several of the more common technologies used today for adenotonsillectomy, and details the authors' techniques.

Surgical Anatomy

The exophytic lymphoid tissue encircling the posterior oropharynx is collectively known as Waldeyer's ring, and it is classically separated into three distinct structures: the palatine tonsils, the adenoid ("the nasopharyngeal tonsil"), and the lingual tonsil. Lymphoid tissue around the Eustachian tube tori (Gerlach's tonsils) may be considered a fourth, distinct entity. The palatine tonsils are bounded anteriorly and posteriorly by the palatoglossus (anterior pillar) and palatopharyngeus (posterior pillar), respectively. A fibrous capsule envelops the tonsil laterally and separates the lymphoid tissue from the superior constrictor muscle. The loose areolar tissue that fills this potential space may become fibrotic and friable in chronic or recurrent tonsillitis making dissection difficult. The tonsils are bound by the soft palate superiorly and by the musculature of the tongue and lingual tonsil tissue inferiorly. The arterial blood supply usually derives superiorly from branches of the internal maxillary artery. The inferior vascular pedicle is frequently the most prominent and derives from branches of the facial artery and external carotid. Venous outflow occurs via the pericapsular venous plexus, which drains to the lingual, pharyngeal, and internal jugular veins. In adults, the carotid space is approximately 2.5 cm posterolateral to the tonsillar fossa.

The adenoid pad rests on the posterior nasopharyngeal wall superior to the soft palate. Superiorly, the adenoid pad begins just posterior to the nasal septum and choanae – very large adenoid tissue can grow into

the nasal vault here and is referred to colloquially as "choanal adenoid." Laterally, adenoid tissue may extend to the torus tubarius immediately medial to the fossa of Rosenmuller. The adenoid usually ends inferiorly above Passavant's ridge, a submucosal prominence of the superior pharyngeal constrictor. Rarely, adenoid tissue is so large, or the nasopharynx is so steeply angled and shallow, that the adenoid may be seen inferior to the soft palate transorally. The ascending pharyngeal and descending palatine arteries, both ultimately branches of the external carotid, supply blood to the adenoid tissue. Venous drainage occurs via the pharyngeal plexus or, less commonly, the pterygoid plexus.

Pre- and Perioperative Considerations

Preoperative blood work (i.e., complete blood count and coagulation studies) is recommended for those patients with a family or personal medical history suggestive of a bleeding diathesis or when genetic information about the biological family is unavailable. Hematologic evaluation and recommendations are helpful for perioperative management when coagulopathy or platelet dysfunction is suspected or present (e.g., use desmopressin [1-desamino-8-D-arginine vasopressin (DDAVP)] for patients with von Willebrand disease).

When dealing with pediatric patients, it is important to know the preoperative weight; it will help guide medication dosages, discharge recommendations, and considerations for blood loss. Total blood volume can be estimated at 75 ml per 1 kg of body weight. This value is slightly higher in newborns, who have an estimated blood volume of 80–90 ml/kg. Maximum allowable blood loss can be approximated with the following equation: (estimated blood volume) × ([hematocrit − 25]/[hematocrit]). Blood loss over 100 ml sometimes occurs and may pose a concern especially in younger children with low total blood volumes.

Administration of a single dose of 0.5–1 mg/kg of dexamethasone up to a maximum one-time dose of 10 mg at the start of the procedure has been consistently shown to decrease postoperative pain and nausea with negligible morbidity or cost. While perioperative antibiotic prophylaxis has been advocated to hasten the return to activity and diet, there is not sufficient evidence to support routine use of antibiotics, due to concerns over bacterial resistance, risk of allergic reactions, and other side effects (Baugh et al. 2011).

Adenotonsillectomy is practiced primarily as an elective ambulatory procedure. There are, however, exceptions to this norm that must be recognized in order to ensure safe perioperative planning. A systematic review by Brigger et al. of the literature on outpatient ▶ tonsillectomy applied subgroup analysis to pooled data and demonstrated an increased risk of complications and unplanned admissions in children younger than 3 years (Brigger and Brietzke 2006). Obese children constitute another high-risk subgroup, as they have been shown to develop respiratory complications at a higher rate than controlled counterparts when undergoing ▶ tonsillectomy for SDB. Planning for postoperative admission with interdisciplinary-care coordination is recommended for certain high-risk subgroups: children younger than 3; children with a BMI over 95%, or with severe OSA; children with cardiac, pulmonary, hematologic, and/or metabolic disorders; and children with conditions requiring special fluid restriction or metabolic control (such as diabetics). Discharge should occur after concurrence between the patient's family, surgeon, anesthesiologist, and recovery-room staff.

Available Technology

Powered Microdebrider

The microdebrider is an oscillating tool that consists of a variably sized, serrated blade within a hollow cylinder. Suction within the cylinder pulls tissue into a partial opening at the tip and permits gentle tissue resection. At lower speeds, it allows for hemostasis as very small vessels are compressed and blood is suctioned. Saline within the unit prevents clogging. The typical speed setting for adenotonsillectomy varies from 800 to 1,800 revolutions per minute (RPM). The device can be used for both soft (lymphoid) as well as hard (bony [e.g., clival], cartilaginous, or septal) tissue; thus, precise application is critical.

Coblation®

Coblation® is the application of a bipolar radiofrequency current that generates a localized plasma field, which is used to dissect tissue. A low power electrocautery current that provides vessel coagulation is produced simultaneously. Larger vessels may be addressed separately with the cautery-only setting. A constant flow of saline irrigation is passed through the tip of the wand. The senior author of this

entry advocates regular, intraoperative tip cleaning by abrasion against a thick, cloth towel while hitting the "ablate" foot pedal; suction of mildly soapy saline will prevent wand clogging. More specific instructions are found in other work (Shah 2008). This technique provides a clean, hemostatic plane-of-dissection with minimal thermal damage. Because the ablation setting easily dissects through tissue, it is important to ensure only the coagulation setting is applied to cauterize vessels. This technology can be used for either traditional or intracapsular techniques.

The theoretical benefit of Coblation is that this plasma field occurs at relatively low temperatures (between 60°C and 70°C) and thus results in less thermal injury than monopolar cautery (Shah and Terk 2009). Improved recovery as measured by less pain medication use, earlier return to diet, and equivalent complications to other technologies have been shown in the literature (Stoker et al. 2004; Shah and Dunham 2007).

PlasmaCision®

In PlasmaCision®, the jPK™ device generates a localized plasma energy field. PlasmaCision® differs from Coblation in that local tissue electrolytes replace the need for exogenous saline. The jPK™ device is used similar to a Coblation® wand or monopolar electrocautery wand to perform a traditional ▶ tonsillectomy (Shah and Terk 2009). Both traditional and intracapsular techniques can be performed with PlasmaCision®.

Radiofrequency Ablation

Radiofrequency ablation has been reportedly used to perform ▶ partial tonsillectomy or tissue reduction primarily for sleep-disordered breathing in children. Advocates report that it produces decreased postoperative pain with minimal morbidity (Hultcrantz and Ericsson 2004).

Harmonic Scalpel

As in the Coblation® technique, the harmonic scalpel is thought to deliver lower amounts of thermal damage as tissue resection is performed using high-speed vibratory tissue dissection, thus causing less postoperative pain and morbidity. Increased reports of intraoperative hemorrhage are balanced against reported lower rates of postoperative hemorrhage and improved healing attributed to decreased thermal spread (Kamal et al. 2006).

Technique

Adenotonsillectomy

Adenotonsillectomy in the United States is typically performed with the patient under general anesthesia. The patient is placed in the "Rose position" – supine with the neck extended and a shoulder-roll in place. Head and spine extension and rotation should be undertaken with caution in patients with cervical spine concerns (as those with trisomy 21). Ventilation may be performed using an endotracheal tube or laryngeal mask airway. Dentition should be inspected for looseness or chipping, and any concerns should be documented before and after the procedure.

Exposure is achieved using a McIvor or Crowe-Davis-style mouth gag, and suspension is usually achieved by hooking the device to a Mayo stand across and above the patient's chest. An "open-sided" mouth gag (Fig. 2) optimizes exposure by permitting better angulation and visualization, which are particularly useful during adenoidectomy. Gags that open both to the left and to the right side are available.

Bupivicaine (0.25%) with 1:200,000 epinephrine is injected through the anterior tonsillar pillar into the peritonsillar space. This allows for added hemostasis, improved pain control, and "hydrodissection." Hydrodissection facilitates surgery whether extracapsular or intracapsular. With experience, one can inject into the appropriate tissue plane particularly if surgical loupes are worn. The fluid-filled peritonsillar space is particularly useful with Coblation®. Injection also facilitates surgery by medializing the tonsillar tissue, which is very helpful for endophytic tonsils.

Further exposure is achieved after infiltration with bilateral, transnasal, non-latex catheters to retract the soft-palate cephalad. This provides tissue tension for ▶ tonsillectomy, enhanced visualization, and it reduces the risk of palatal injury during adenoidectomy.

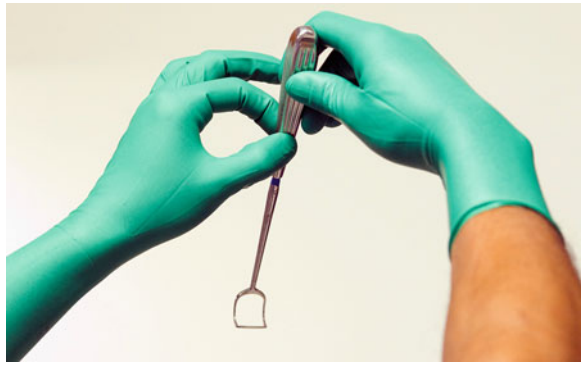
Adenoidectomy

Adenoidectomy may be performed using an adenoid curette, microdebrider, or with Coblation® or electrocautery techniques. Following curette or microdebridement, electrocautery is frequently used to achieve superior hemostasis. Prior to proceeding with adenoidectomy, the soft palate should be inspected and palpated for a submucus cleft palate, which is suggested by a bifid uvula with sometimes visible

Adenotonsillectomy (Surgery, Pediatric), Fig. 2 Open-sided mouth gag (Davis mouth gag; Medtronic-ENT, Jacksonville, FL, USA)

and generally palpable midline separation of the soft-palate musculature and by palpation of a notch in the hard palate. Maintaining a central or inferior ridge of adenoid tissue reduces the likelihood of postoperative ► velopharyngeal insufficiency (► Velopharyngeal Dysfunction, Diagnosis and Management) particularly in patients with a suspected submucus cleft palate.

Prolonged soft-palate retraction may lead to edema that can compromise postoperative breathing and swallowing. Intermittent relaxation of the catheters is recommended when procedure time is in excess of 30 min. A laryngeal mirror or rod-lens telescope may be used to visualize the adenoid pad. The surgeon must always be cognizant of the conductive capacity of the metal mirror-shaft and should keep a gloved finger between the shaft and any oral mucosa while using electrocautery or Coblation® (Shah and Terk 2009). The Eustachian tube tori laterally, the posterior aspects of the inferior nasal turbinates, and the nasal septum should be protected. An approximately 2–3-mm-high ridge of adenoid tissue left inferiorly can help prevent



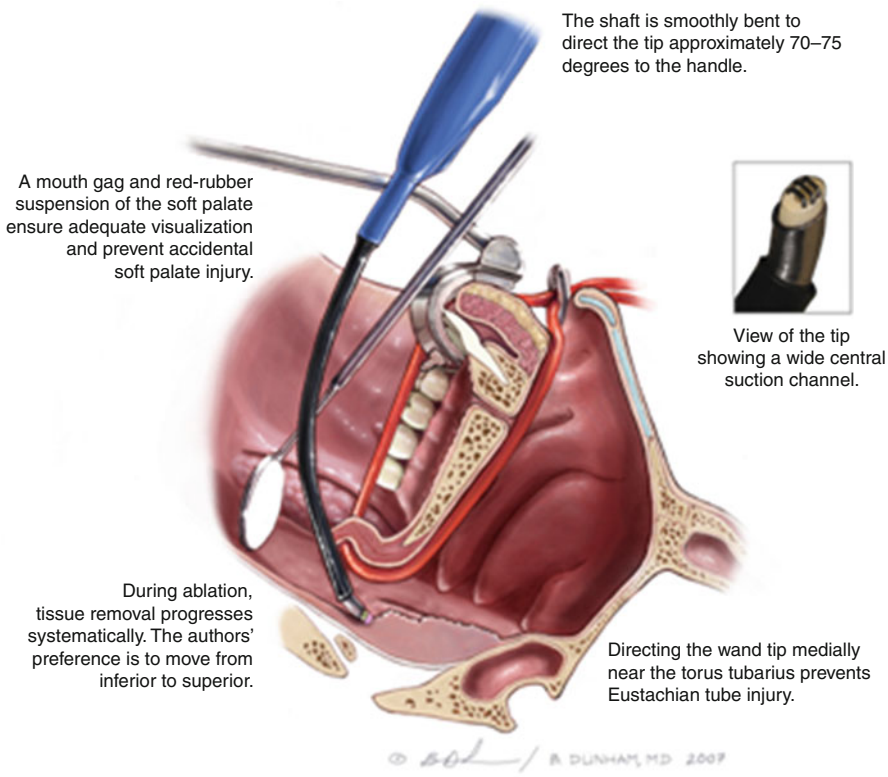
Adenotonsillectomy (Surgery, Pediatric), Fig. 3 Adenoid curette hand position

► VPI. Approximately 1–2 mm of adenoid tissue may be left at the "floor" of the surgical field (really the roof of the nasopharynx) against the posterior pharyngeal wall to prevent excessively deep dissection into the retropharyngeal or prevertebral spaces. Posterolaterally (the "high deep corners" of the nasopharynx), the depth of resection should also be limited to prevent profuse bleeding.

Curette: The adenoid curette is placed in the nasopharynx to the level of the choana and, in a forward sweeping motion, the curette resects adenoid tissue when the blade is sharp by gentle, bimanual, forward to-and-fro motion. For the right-handed surgeon, the left thumb is placed in the divot on the shaft of the curette to gently push posteriorly. The right thumb and palm provide anterior pressure with direction and oscillation from above (Fig. 3). The curette should achieve a gentle "upward climb" assisted by the left thumb upon approaching the inferior adenoid pad to permit an inferior hedgerow of adenoid tissue as recommended above. Multiple passes with progressively narrower curettes may be necessary to ensure adequate tissue reduction. Remaining adenoid tissue may be removed with a St. Clair-Thompson forceps, a sponge-covered gloved finger, or electrocautery.

Microdebrider: Microdebridement of the adenoid pad proceeds in a cephalad-to-caudal direction. A gently angled (30°–40°) "adenoid blade" is used, with or without coagulation, at variably oscillating resection between 800 and 1,800 RPM.

Coblation®: In most cases, when the Evac® Xtra wand is used, tissue reduction for adenoidectomy is achieved at settings of 9 for "ablate" and 5 for "coag." The authors prefer this specific iteration of the



Adenotonsillectomy (Surgery, Pediatric), Fig. 4 Coblation® adenoidectomy (Used with permission from: Shah UK, Dunham B (2007) Coblation for tonsillectomy: an evidence-based review. ORL J Otorhinolaryngol Relat Spec 69:349–357)

Coblation® devices due to its large central suction channel, which prevents clogging and facilitates hemostasis.

Ablation should proceed in a saline pool with the tip of the instrument hovering slightly above the tissue. Moving slowly during adenoid tissue ablation with frequent suctioning of the "lightly soaped" saline solution avoids clogging of the wand. Cleaning the grill of the wand against a moistened towel by pressing "ablate" and gently brushing the grill against the towel ensures pristine electrodes for effective energy delivery. Gentle and slow application of the Coblation® wand on the "ablate" setting is usually effective to reduce adenoid tissue hemostatically without the need for electrocautery. Suction electrocautery tends to be needed rarely, but more frequently for hemostasis for the infected adolescent adenoid (Fig. 4).

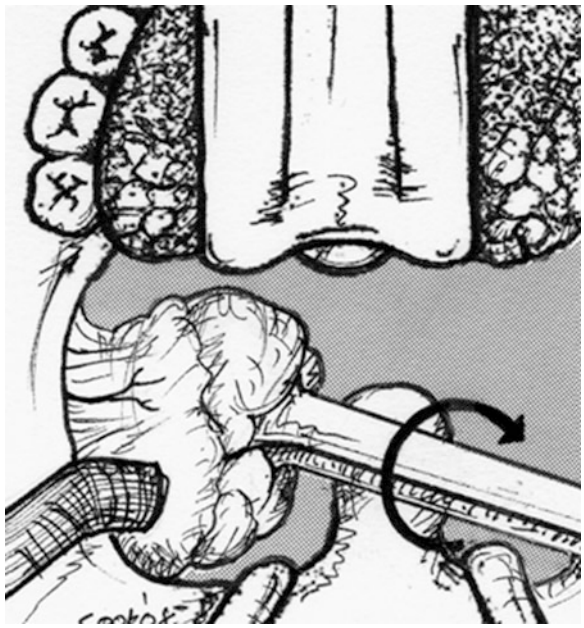
Suction electrocautery: A suction "Bovie," set initially on a "fulgurate" and then switched to a "blend" current distribution between 15 and 35 W power, is manually contoured to an angle between 20° and 40° (this angle mirrors that of the adenoid blade used with microdebridement). Wand clogging is reduced by frequent suctioning of saline; saline suctioning in addition to frequent visual confirmation of insulation integrity along the device shaft helps to

reduce shaft heat and the attendant risk of skin or mucosal injury. It is important to make sure that the foot pedal is released when entering or exiting the pharynx for microdebrider, cautery, and Coblation®.

Hemostasis: Suction "Bovie," Coblation®, and tonsil sponges are usually effective for hemostasis. For microdebriders with a cautery capability, some surgeons are able to achieve effective hemostasis without the need for additional electrocautery. Brisk nasopharyngeal bleeding is controlled by a tonsil sponge applied to one side of the nasopharynx while a transnasal suction catheter is placed in the "open" side to evacuate blood and smoke. Prevent fire during cauterization by instilling saline intermittently to reduce heat and evacuate clot and by maintaining suction Bovie-tip distance away from the flammable plastic catheter tip.

Traditional Tonsillectomy

Traditional ▶ tonsillectomy may be performed with any number of instruments (e.g., cold steel, monopolar or bipolar cautery, plasma knife, or Coblation® devices). Although subtle differences exist between the use of each device whether intra- or extracapsular, the underlying principles are optimizing exposure and tissue tension and then finding and staying in the proper plane-of-dissection. The tonsil is grasped with an Allis tenaculum and retracted medially. Repeated medial and lateral displacement of the tonsil allows for appreciation of the depth of the tonsil tissue with respect to the anterior and posterior pillars. As highlighted in the Adenoidectomy section, any metal instrument used for retraction or visualization purposes should be buffered from the oral mucosa by a gloved finger to prevent thermal burns while performing electrocautery, Coblation®, or PlasmaCision®. A curvilinear mucosal incision is made at either the lateral margin on the tonsil or at the superolateral aspect of the anterior pillar. The incision can be made with a sickle knife in the case of cold-steel ▶ tonsillectomy, monopolar cautery, or the ablate function on the Coblation® wand. Following inferomedial displacement of the tonsil with the Allis clamp, dissection begins. The fibrous tonsillar capsule is recognized when loose areolar tissue is encountered. In patients suffering only from sleep apnea, the potential space between the tonsillar capsule and constrictor musculature is an easily separable plane. However, if the patient has had recurrent tonsillar infections, this plane may become hypervascular and scarified; in this case, recognizing the plane is more challenging.



Adenotonsillectomy (Surgery, Pediatric), Fig. 5 Medial rotation for tonsillectomy (Figure used with permission from, and illustration by, Steven P. Cook, MD)

Once the fibrous capsule is identified, dissection along this plane typically continues in a superior-to-inferior manner. Loss of the plane-of-dissection by violating the tonsil tissue or the constrictor musculature should be immediately recognized, either by a change in the tissue's smell ("burnt flesh" if the tonsil is entered) or by a visualized loss of the sheen of the tonsillar capsule, and corrected (Of note: the authors routinely wear surgical magnifying loupes for ▶ tonsillectomy, which aid in subtle visual distinction of intra- versus extracapsular planes.). A number of instruments may be used to perform this dissection including a Hurd dissector, a Fisher knife, or a Freer elevator. The Fisher knife has a serrated, hockey-stick-shaped end. It is manipulated by placing the serrated edge into the plane-of-dissection and slowly pushing the instrument forward to elevate the tonsil from the underlying musculature while simultaneously providing continuous medial traction with the tenaculum. Monopolar electrocautery and Coblation® techniques proceed in a similar manner: the surgeon uses medial traction and rotation (Fig. 5) while slowly cauterizing or coblating through the potential space. With the use

of either device, areas of hypervascularity may be "precoagulated" to provide improved hemostasis prior to dissection.

Once the superior pole is freed from the tonsillar fossa, it is often necessary to reposition the Allis clamp to provide constant surgical tension; however, multiple passes at grabbing tonsillar tissue often leads to fragmentation and bleeding thus compromising further dissection. Dissection is continued in a systematic manner inferiorly toward the inferior pole, which is the site of significant blood supply. Frequently, the tonsil tissue lacks an obvious inferior extent, and instead blends into the lingual tonsil tissues. As the inferior pole is approached, a decision must be made to dissect through some of the lymphoid tissue. To prevent excessive bleeding, avoid extensive dissection inferiorly. Rather, Coblation® on "ablate" or electrocautery to truncate the inferior pole is recommended. The surgeon should use a gentle, medial sweep following the curvature of the superior tonsillar tissue.

Intracapsular Tonsillectomy

Intracapsular ▶ tonsillectomy (ICT), also referred to as ▶ partial tonsillectomy or tonsillotomy, involves the exteriorization of tonsillar crypts by removing most of the lymphoid tissue of the tonsil and leaving a thin rim of tissue against the tonsillar capsule. Preserving a thin rim of tissue facilitates healing, reduces dehydration and returns to the OR for hemorrhage, and expedites recovery (Schmidt et al. 2007).

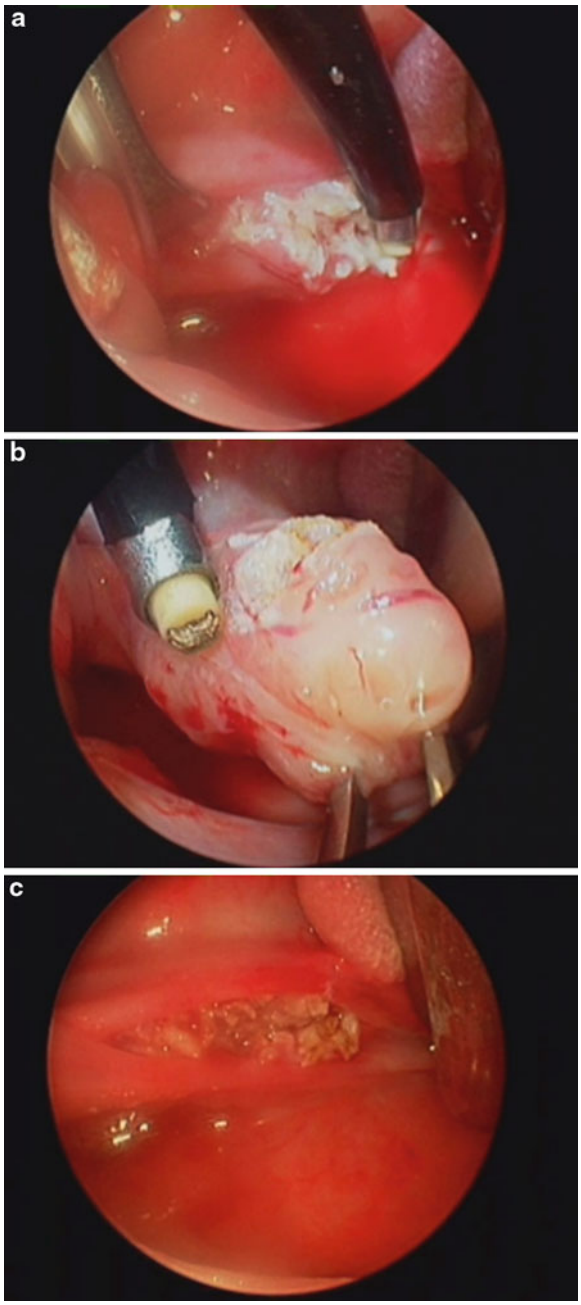
Multiple techniques for ICT have been described: carbon dioxide laser, bipolar scissors, Coblation®, electrocautery, and powered microdebridement. The most common approaches to ICT today are microdebridement and Coblation®.

Microdebrider ICT: Straight and angled blades may be used for ICT at a variable rate of oscillation between 800 and 1,800 RPM. Instead of grasping the tonsil with a tenaculum, the tonsillar tissue is presented using the blunt end of a Hurd retractor applied laterally against, and "toeing" into, the anterior tonsillar pillar while lifting the Hurd up toward the surgeon; this everts the tonsil. Gradual, lateral tissue resection proceeds from the center of the tonsil to the upper pole and permits for optimal tissue removal superiorly. The surgical limit of dissection is identified by noting the stringy appearance of pericapsular fibers, which are best appreciated when using magnifying surgical loupes.

ICT with Coblation®: Two techniques are effective for partial Coblation® ▶ tonsillectomy: the "lop-off" technique for large, exophytic tonsils, and the "reduction" technique for endophytic tonsils.

The "lop-off" technique: With large exophytic tonsils, the Coblation® approach is similar to that taken during total ▶ tonsillectomy. The body of the tonsil is grasped with a tenaculum that is then used to medialize the tonsil. Once the lateral extent of the tonsil is appreciated via palpation with the instrument, a curvilinear mucosal incision is made in the superolateral anterior pillar. This incision should be slightly medial to the desired location of a mucosal incision for total ▶ tonsillectomy so that the tonsillar capsule is left down within the fossa. By employing a slow, deliberate brushing technique with the "ablate" mode, the surgeon will expose a shiny, white plane of white capsule, again, best seen using surgical loupes. This tissue is the tonsillar capsule and should be preserved within the fossa as the lymphoid tissue is excised. Firm medial tonsillar retraction is helpful here: the surgeon should "feel the burn" (in athletic muscular terms) in their thenar eminence as they learn this technique. This assures firm retraction, which protects the capsule and the pillars. Spot hemostasis can be achieved during dissection by switching to the "coag" mode to cauterize any individual vessels encountered. Once the tonsil has been removed, hemostasis can be completed with the "coag" setting (Fig. 6).

The "reduction" technique: Small, endophytic tonsils can be approached with a slightly different technique. With a tenaculum, the tissue is grasped and retracted medially. The lateral extent of more endophytic tonsils can often be difficult to appreciate. In this circumstance, the "ablate" setting can be used to shave the tonsil down along the sagittal plane of the pillars. Care must be taken to keep the tip of the wand directed medially at all times. Inevitably, stumps of lymphoid tissue, likened to small growths of shrubbery, are left behind within the tonsillar fossa. This remaining tissue can be reduced by switching to the "coag" setting and directing the wand laterally. This same technique can be applied in the setting of chronic or recurrent tonsillitis. In these circumstances, the cryptic and friable tonsillar tissue can be difficult to grasp or retract with the tenaculum and may be ablated in a piecemeal manner. Once the tonsil has been resected to the sagittal plane of the pillars, the remaining tissue can be reduced with the "coag" setting.



Adenotonsillectomy (Surgery, Pediatric), Fig. 6 Coblation® ICT using the "lop-off" technique. (**a**) The lop-off technique. (**b**) Tissue reduction. (**c**) Post-op after partial tonsillectomy

Hemostasis

Regardless of technique, hemostasis must be achieved following removal of lymphoid tissue. A tonsil sponge can be used to apply pressure to the tonsillar fossa followed by electrocautery using monopolar (Bovie) or bipolar (Coblation®) techniques or 3–0 chromic sutures with atraumatic needles. Severe bleeding refractory to cautery or sutures may require tissue sealants (fibrin) or hemostatic agents (thrombin). Pillar placation may also be applied in such difficult cases with the additional benefit of opening the pharyngeal airway further as adjunctive management for obstructive indications. The authors recommend relaxation of the transnasal catheters and removal from suspension with closure of the mouth gag for a defined time period (30 s by the clock) to permit vessels that may have been "pulled" closed during retraction to declare themselves and permit hemostasis upon re-exposure. In addition, relaxation permits edema of the soft palate, lips, and tongue and allows the uvula to regress.

Completion of Surgery

The oral cavity is irrigated with warm saline solution after tissue resection and initial hemostasis. The stomach and oral cavity are subsequently suctioned clear. Hemostasis is confirmed. Most importantly, electrocautery and surgical set-up should not be removed from the operating suite until the patient is extubated and taken to the post-anesthesia recovery area.

Tonsil tissue should be sent for pathology only if significant differences in size between the tonsils are noted, or if there is a concern over abnormal tonsillar surface appearance (such as friability or a fish-flesh appearance). A suction sock can be used to capture specimen when neoplasia is suspected or microbiology is required for microdebrided tissue. Complete ▶ tonsillectomy is recommended when neoplasia is suspected, as is curette adenoidectomy, to facilitate histopathological evaluation.

Special Population Considerations

Trisomy 21 (Down Syndrome)

Children with Down syndrome have a high incidence of obstructive sleep apnea and, as a result, frequently undergo adenotonsillectomy. In addition to unfavorable anatomy that makes airway management difficult, a specific concern to the otolaryngologist is the increased incidence of atlantoaxial instability in this population. Atlantoaxial subluxation is the displacement of the first cervical vertebrae over the second cervical vertebrae and is known eponymously as Grisel's syndrome when this occurs due to adenotonsillectomy. Untreated atlantoaxial subluxation can lead to severe neurologic consequences.

The craniofacial features of Down syndrome (i.e., midface hypoplasia, micronagthia, narrow nasopharynx, macroglossia, and short neck) exacerbate obstructive symptoms in this population. It is recommended that polysomnography should be performed in all trisomy 21 patients undergoing adenotonsillectomy in order to ensure adequate perioperative preparation and plans for post-procedure intensive care. Associated cardiac defects predispose this population to cor pulmonale and contribute to the recommendation for elective admission postoperatively. The multifactorial nature of UAO in trisomy 21 children may require more than just adenotonsillectomy.

Velocardiofacial Syndrome

Velocardiofacial (VCF) syndrome, the phenotypic manifestation of the 22q11 chromosomal deletion, is among the more common identifiable malformation syndromes associated with clefts of the secondary palate. The palatal defects in these patients are most commonly occult submucosal clefts. Thus, a normal oropharyngeal exam in the office does not preclude the possibility that a VCF patient has an underlying palatal defect that could predispose her to post-adenoidectomy ▶ VPI.

Patients with VCF may have medial displacement of the internal carotid arteries into the nasopharynx. Therefore, when adenoidectomy is considered, imaging (CT and/or MRI) and flexible nasopharyngolaryngoscopy to assess for pulsations of the lateral nasopharyngeal walls and degree of airway impingement by the adenoid and tonsillar tissue are recommended.

If the decision is made to proceed with adenoidectomy, the soft palate should be palpated at the time of surgery. Should an occult submucus cleft be detected at that time, a ridge of adenoid tissue should be left behind centrally or inferiorly as described previously. An underlying syndromic genotype should be considered even in the face of an otherwise normal-appearing phenotype, when ▶ VPI persists more than 3 months after adenoidectomy.

Complications

Perioperative

Fire: The use of electrocautery during the procedure places the patient at risk for mucosal burns and airway fire. These risks are best mitigated by avoiding arcing, buffering the interface of mucosal surfaces and metallic instruments with a gloved finger, and reducing inspired oxygen concentration to 25–30%. Saline or water to douse flames should be kept close at hand – usually on the Mayo stand serving as the instrument tray and suspension apparatus. If airway fire is suspected, immediately and simultaneously turn off the oxygen, remove the burning object (usually the endotracheal tube), douse the fire with saline or water, protect the airway via mask ventilation, reintubation, or bronchoscopy, and alert all persons in and around the operating room of the airway fire. A damage assessment and airway control must then proceed, and, if all is well, then surgery may be completed.

Hemorrhage: Primary hemorrhage, defined as bleeding within the first 24 h, is typically blamed on inadequate intraoperative hemostasis. Secondary or delayed hemorrhage occurs after the first 24 h. Secondary hemorrhage usually occurs between postoperative days 5 and 10 when the eschar sloughs and vessels within the healing tonsillar fossae are exposed. Adenoid bleeding is rare and may occur as long as 2–3 weeks after surgery. Surgical control of bleeding is usually required when blood loss is severe. Observation in the hospital setting is recommended for children in whom bleeding concerns are significant and no active bleeding or clot are seen upon evaluation.

Postoperative pulmonary edema: Respiratory distress or desaturation at the conclusion of the case or in the immediate postoperative period, particularly when accompanied by frothy, sometimes pink tracheal secretions, may indicate postobstructive pulmonary edema (POPE). Relief by adenotonsillectomy of long-standing obstruction causes vasodilatation of the pulmonary vascular bed, which in turn increases hydrostatic pressure and leads to transudation of fluid into alveoli. Postobstructive pulmonary edema can be confirmed with chest x-ray, and initial management includes positive-pressure ventilation with supplemental oxygen and, in some cases, chemical diuresis. Rarely, POPE requires intubation and mechanical ventilation with ICU management.

Long-term ▶ VPI: Transient ▶ VPI can occur rarely after adenotonsillectomy. Postoperative ▶ VPI is best avoided by leaving a small pad of adenoid tissue inferiorly measuring approximately 2 mm in height. If symptoms of ▶ VPI, such as hypernasal speech and regurgitation of food or drink, persist beyond 8 weeks, then a speech and swallowing evaluation should be initiated. Prolonged ▶ VPI is rare and should prompt investigation into possible predisposing conditions as discussed in the previous section on VCF Syndrome.

If unresponsive to speech therapy, ► VPI may require surgical treatment.

Pharyngeal stenosis: Nasopharyngeal and oropharyngeal stenosis are even more rare than ► VPI, but can be seen weeks to months after adenotonsillectomy. Symptoms include nasal obstruction, mouth breathing, and recurrence of obstructive sleep apnea. The pathogenesis is scarring, which results from the apposition of raw or thermally injured mucosal surfaces – between the cephalad soft palate and nasopharyngeal roof most commonly. Prevention of palatal injury is best achieved by strong palatal retraction with full visualization of all surfaces (particularly with the microdebrider, suction "Bovie," and with Coblation®), as well as by avoidance of excessive cautery in the nasopharynx. For this reason, some surgeons never cauterize in the nasopharynx and instead achieve hemostasis by pressure alone. Diagnosis of stenosis is made with nasopharyngoscopy and the treatment is surgical.

Conclusion

Surgeons today have the ability to apply a wider variety of techniques and technologies to treat adenotonsillar diseases than ever before. Analyses of the results and economic costs across prospectively studied, large patient populations over varying ages, indications, and for time periods in the 3–5 years range will permit for more prudent application and teaching.

In the meantime, it behooves surgeons to be aware of the opportunities and limitations presented by these various options and to undertake responsible use of these technologies through appropriate training and mentoring.

Cross-References

► Tonsillectomy
► Velopharyngeal Dysfunction, Diagnosis and Management

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Adenotonsillitis

► Adenotonsillar Disease

Adhesive Otitis

► Retraction Pockets, Treatment Algorithm

Admittance

► Tympanometry

Adult Bilateral Cochlear Implantation

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Definitions

Sequential bilateral cochlear implantation: The placement of a cochlear implant in each ear where the individual surgeries are separated by a given time period.

Simultaneous bilateral cochlear implantation: The placement of a cochlear implant in each ear where the devices are placed bilaterally during the same operation.

Introduction

Since the introduction of cochlear implants (CI) over 25 years ago, tens of thousands of patients worldwide with bilateral, severe to profound sensorineural hearing loss (SNHL) have undergone cochlear implantation for hearing rehabilitation. According to the U.S. Food and Drug Administration (FDA), as of December 2010, approximately 219,000 people across the world have received CIs. In the United States alone, roughly 42,600 adults have undergone cochlear implantation.

In the infancy of CI technology, candidacy for surgery was strict, and only adults with profound, bilateral sensorineural deafness were considered. Furthermore, monaural implantation was the rule. Unilateral CI users were able to achieve benefits such as improved sound and speech perception, normal or near-normal auditory and verbal language abilities, and tinnitus suppression, to name a few. Over the next decades, with the continued improvement of speech-coding strategies and modernization of hardware and software design, speech perception achieved by profoundly deaf patients with a CI approached that of normal hearing listeners. As a result of these successes and the refinement of CI surgery, audiologic candidacy criteria broadened to include patients with measurable amounts of residual hearing and word recognition, various etiologies for hearing loss, prolonged periods of profound deafness, and elderly patients with associated comorbidities.

Despite these tremendous successes with monaural CI, many of these patients continued to suffer disabilities associated with unilateral deafness such as the inability to localize sound and difficulties with speech comprehension in noisy listening environments when compared to peers with binaural stimulation. As the literature expanded supporting the benefits of binaural hearing, selected patients with residual hearing in the non-implanted ear were fit with traditional amplification devices, and using bimodal stimulation were able to recover some of the advantages seen in normal binaural listeners. For many CI patients, however, the non-implanted ear derived no significant benefit from amplification due to profound deafness and bimodal stimulation was not possible. For this growing subset of patients, bilateral cochlear implant (BCI) surgery was an important new era in hearing rehabilitation.

Since the first report of BCI in 1988, BCI users have demonstrated significantly improved speech understanding in quiet and in noise, improved sound localization, subjective reports of reduced social isolation, reduced subjective perceptions of hearing disability, and a trend toward reduced emotional distress compared to their unilaterally implanted peers (Peters et al. 2010). Based on these positive results and similar data in the literature, BCI is now considered "accepted medical practice" and has been endorsed by medical and professional societies from around the world (Balkany et al. 2008).

Advantages of Bilateral Implantation

Sound localization in the horizontal plane. Sound does not have a physical dimension in space, and therefore, localization of sound and improved speech recognition requires binaural processing by the human auditory system utilizing cues such as interaural time differences (ITD) and interaural latency differences (ILD). This type of binaural benefit is seen in normal hearing listeners and individuals using bilateral hearing aids (HA) and more recently has also been reported in BCI recipients. ITD is the difference in arrival time of a sound between the ear closest to the source and the ear furthest away from the source and is useful only at

low frequencies (<800 Hz). Conversely, ILD is the difference in loudness level (amplitude) between the two ears based on the location of a sound source closer to one ear, and is useful only in the higher frequencies (>1,000–2,000 Hz). Both ILD and ITD can be used to provide binaural information in the midrange frequencies, and this is referred to as the duplex theory of sound localization. While most single-sided CI users localize sound at or near a chance level, recent data suggests that BCI users have improved discrimination of ILD and ITD and are therefore more proficient at sound localization in the horizontal plane (van Hoesel and Tyler 2003).

Head shadow effect. The head shadow effect produces the most robust binaural advantage in the hearing-in-noise condition ranging from 4 to 7 dB, and can attenuate high frequency sounds by as much as 20 dB while offering 2–6 dB attenuation in the lower frequencies (Laszig et al. 2006). When a listener is presented with sound, the sound arriving at the ear further from the source is attenuated relative to sound arriving at the ear nearer the source, with the head producing an "acoustic shadow." Utilizing both ears can provide separation of the acoustic signal from the noise source creating an improved signal to noise ratio (SNR) in the protected ear. This phenomenon allows the listener to selectively attend to the ear with better SNR and improve speech intelligibility in noise. While the head shadow effect is not a direct function of central auditory processing (CAP), it is the physical consequence of sound diffraction around an object and benefits for hearing-in-noise are immediately perceived following BCI (Gantz et al. 2002; van Hoesel and Tyler 2003; Murphy and O'Donoghue 2007).

Binaural squelch. In contrast to the head shadow effect, which relies purely on the physical separation of signal and noise to localize a sound, binaural squelch is a CAP effect by which both ears combine to create a signal at the auditory cortex different than could be achieved from either single ear alone. When competing noise is spatially separated from the target signal on the horizontal plane, each ear receives different inputs (often referred to as the "cocktail party effect"). Adding an ear with a poorer SNR allows the auditory system the opportunity to compare timing, amplitude, and spectral differences between the two signals to provide better speech understanding in noise. The benefit obtained when comparing the better unilateral condition to the bilateral condition is reported as squelch (also known as binaural unmasking) (Basura et al. 2009). The binaural advantage from squelch is limited, with estimations of improvement on the order of 3 dB. However, squelch does not appear to be an immediate effect following BCI. Instead, the effects require months or years of binaural listening before the advantages are realized, perhaps indicating a necessary central neural reorganization for bilateral input following years of deafness in adults receiving BCI.

Binaural summation. Similar to squelch, binaural summation is also a result of complex CAP which occurs in the binaural listening condition but results in a more modest benefit (1.5–3 dB) than squelch or the head shadow effect. When both ears are presented with a similar signal, the perceived sound is louder than that presented to either single ear alone. The doubling of perceptual loudness, called binaural summation (or binaural redundancy), is also accompanied by increased sensitivity to differences in intensity and frequency, leading to improvements in speech intelligibility in both quiet and, more importantly, in noisy conditions. Binaural summation has been shown to offer BCI recipients improved speech understanding in noise when compared to single CI users (Litovsky et al. 2006).

Speech perception in quiet. Following the initial introduction of CI technology, for many years post-implantation, objective performance testing for subjects with either unilateral or bilateral CI relied on speech testing in quiet. A number of studies in the literature clearly proved that patients performed better on these measures using bilateral electrical stimulation (i.e., BCI) when compared to unilateral CI. Many of these trials also showed that performance continued to increase over time with the bilateral condition outperforming either unilateral ear alone (Laszig et al. 2006; Litovsky et al. 2006; Tyler et al. 2007; Buss et al. 2008). These results appear to be durable and replicated over the lifetime of the CI.

Speech perception in noise. As speech processor technology improved, asymptotic performance results in speech in quiet testing conditions were noted in unilateral CI and BCI users alike. In addition, patients' demands increased, prompting postoperative performance outcomes to be judged by the user's ability to hear in noisy environments rather than in quiet. Adding a second CI enables a listener to take advantage of an ear with a better SNR, resulting in improved speech

perception in noise as a result of the head shadow effect (Gantz et al. 2002; van Hoesel and Tyler 2003). This finding is especially important in the hearing rehabilitation of patients frequently exposed to environments with a substantial background noise floor that cannot be easily altered to aid the monaural listener. Adding an ear with a poorer SNR also allows binaural squelch to provide better speech understanding in noise, although the advantages of squelch are much less than those from head shadow or binaural summation effects (Litovsky et al. 2006). Buss et al. (2008) demonstrated that binaural squelch benefits in BCI patients continued to increase over time from 6 months to 12 months following simultaneous bilateral CI surgery. While results uniformly show improvements for speech perception in noise for BCI users, individual results tend to vary, suggesting the possible influence of specific patient variables such as hearing loss characteristics and duration, age, residual hearing levels, and speech-coding strategies.

Practical Advantages of Bilateral CI

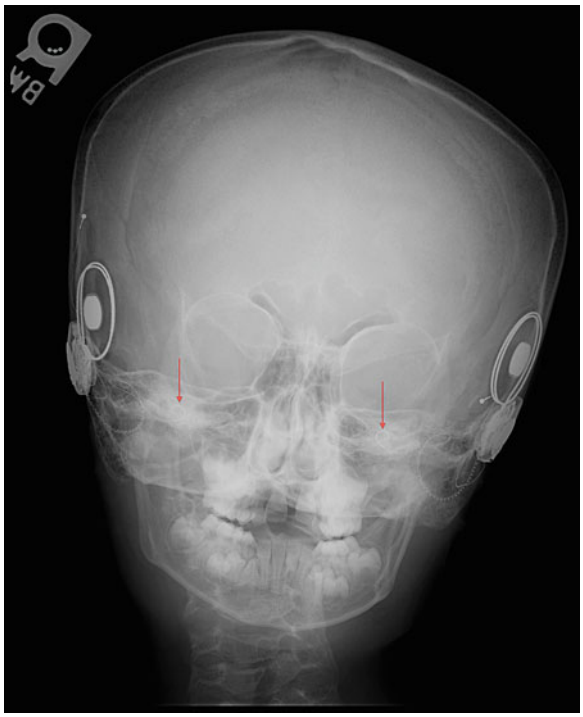
There are several other advantages of BCI that are not related to binaural hearing effects. First of all, BCI guarantees that the better hearing ear is implanted. While speech perception testing scores, length of deafness, etiology of deafness, and macroscopic anatomy may be identical between the two ears, it is possible that microscopic factors such as neuronal integrity or hair cell survival between the two ears differ explaining, at least in part, why one ear may demonstrate improved performance with electrical stimulation compared to the contralateral ear. This makes predicting the better ear prior to implantation difficult and a process potentially fraught with errors. Furthermore, if each ear provides separate encoding of different speech cues and auditory information, then the synergistic effect of BCI may support better fine structure analysis of speech and result in better performance than a single CI can provide.

While the reliability of the newest generation CI devices has continued to improve, occasionally, there is a device malfunction either related to hard failure (hardware malfunction demonstrated on either in-vivo or ex-vivo integrity testing) or soft failure (declining performance, aversive symptoms, or intermittent function associated with normal device integrity testing and device imaging) of the internal receiver-stimulator. Additionally, external speech processor batteries can lose charge and external hardware can become nonfunctional rendering the CI temporarily inactive. Individuals with BCI are much less likely to be "off line" while the affected device is nonfunctional, and in the cases where the internal device must be replaced, having one functional device allows greater flexibility while considering the appropriate timing of cochlear implantation revision surgery.

The CI literature unequivocally demonstrates the binaural listening benefits discussed above in BCI patients. However, very few of these studies investigate whether these improvements in hearing lead to a significant improvement in quality of life (QOL) in BCI patients, or if the improvements are substantial enough to justify BCI from a cost-effectiveness standpoint. Recently, there has been an emphasis on QOL outcome measures, and it is clear that there is a measurable QOL advantage and increased subjective benefits seen in patients with BCI when compared to unilateral CI patients. While incremental QOL benefits may be greater in unilateral CI patients when compared with BCI patients, subjective benefits in BCI patients include improvements in depression and loneliness, emotional well-being, cognition, ease of communication, and pain (Peters et al. 2010). Furthermore, some patients showed equal gains in QOL after the second implant when compared with the first implant, and even approached normal QOL ratings following BCI (Bichey and Miyamoto 2008). Further analysis of these QOL improvements together with cost-utility measures showed not only that BCI can make a significant improvement in QOL thereby justifying the cost of the second-sided CI procedure, but also that the incremental improvement in QOL after a second CI is large enough to significantly improve the cost-utility of the second CI compared with the actual cost of the implant itself (Bichey and Miyamoto 2008).

Sequential Versus Simultaneous Surgery

Bilateral cochlear implants can either be placed simultaneously (simultaneous bilateral CI) or sequentially (sequential bilateral CI) (Fig. 1). The question of optimal timing for BCI continues to be debated in the literature, and in a recent survey sent to 35 leading CI centers around the world, Peters et al. (2010) reported that 76% of all adult BCI surgeries are performed



Adult Bilateral Cochlear Implantation, Fig. 1 This is an anterior-posterior skull X-ray of a patient with bilateral cochlear implants. The *red arrows* are showing the electrode arrays curled within the lumen of the cochlea bilaterally

sequentially, and only in children less than 3 years old did simultaneous BCI predominate (58%).

There are no studies directly comparing postoperative objective outcomes between patients undergoing simultaneous versus sequential BCI, but several studies have indirectly addressed the issue. While the literature clearly supports early implantation in prelingually deafened children in order to take advantage of cortical plasticity, for post-lingually deafened adults, the issue of prolonged auditory deprivation has lesser influence upon outcomes and the results following cochlear implantation are somewhat more variable. In some studies, sequential implantation with long delays between ears has resulted in poor second ear performance and has limited the degree of bilateral benefit that can be obtained by these users. Conversely, other studies have shown that the time between the first and second CI does not affect performance in the second implanted ear regardless of the time between implants (as many as 15 years in some subjects) (Zeitler et al. 2008). However, one clear benefit to simultaneous BCI or sequential BCI with a short inter-implant interval is that it ensures the devices will be matched and that bilateral stimulation of the auditory system will occur (Basura et al. 2009).

One argument for simultaneous BCI involves postsurgical auditory rehabilitation programs. Currently, no consensus exists in the literature concerning the optimal rehabilitation techniques to use for the second ear in BCI patients. In patients undergoing sequential BCI, many centers encourage complete auditory deprivation of the dominant, first-implanted ear for an extended period of time following second-sided surgery. This presents significant practical challenges for those dependent on optimized hearing in day-to-day activities (i.e., professional duties, child care, etc.). Such an approach can lead to low compliance rates with the rehabilitation protocol and possible compromise of the objective results in the second side.

Bilateral CI is of special consideration in patients with post-meningitic deafness, and the timing of BCI after meningitis remains controversial. Proponents for simultaneous BCI at the time of the initial surgical intervention believe this approach guarantees capture of the better hearing ear while at the same time preserves binaural hearing. Furthermore, the opportunity for BCI following meningitis may be lost with ongoing cochlear ossification in the non-implanted ear following unilateral CI. Proponents of simultaneous BCI also argue that spontaneous or late recovery of hearing is anecdotal, and that early electrical stimulation of the spiral ganglion neurons may increase neural survival and prevent neuronal degeneration. On the other hand, there have been reports of late, spontaneous recovery of hearing loss following meningitic deafness and imaging of the bony and soft tissue anatomy of the labyrinth has become incredibly precise. Therefore, with less than severe hearing loss and normal cochlear anatomy on computed tomography (CT) and/or magnetic resonance imaging (MRI), some propose a more conservative "watch-and-wait" approach with frequent imaging of the temporal bones (using both CT and MRI), regularly scheduled comprehensive audiological testing, and use of traditional amplification. In this case, unilateral CI in the poorer hearing ear or the ear with more severe ossification can be done early and contralateral bimodal stimulation used. Sequential BCI can then be performed with changes in hearing or worsening cochlear anatomic compromise.

There are also some medical and surgical considerations in deciding between sequential versus simultaneous BCI. Simultaneous BCI surgeries result in longer operative times, increased anesthetic risks, and increased blood loss when compared with unilateral CI surgery. However, surgical tolerability to BCI has been found to be equivalent in both sequential and simultaneous BCI surgery (Basura et al. 2009). For young, healthy patients, these factors may not have significant effect on surgical outcomes, but with the rising age of CI recipients, each patient must be considered individually if bilateral CI surgery is being considered. Additionally, using the traditional transmastoid, facial recess approach to the middle ear, the facial nerve is placed at risk during exposure of the basal turn of the cochlea. Despite the use of continuous intraoperative monitoring of the facial nerve, simultaneous BCI poses a small but theoretical risk of bilateral iatrogenic facial nerve paresis/paralysis that would be devastating to a patient. Therefore, many CI surgeons have adopted an "adaptive approach" in cases of simultaneous BCI, in which the decision to perform a second CI may be aborted intraoperatively with signs of anesthetic compromise, significant blood loss, or other complications such as facial nerve injury or cerebrospinal fluid leak/perilymphatic gusher.

Disadvantages of Bilateral Implantation

Despite the literature objectively and subjectively supporting BCI in adults, there are some disadvantages one must consider before deciding to proceed with second-sided CI surgery. As discussed above, there are some medical and surgical disadvantages to operating on both ears either sequentially or simultaneously. Second, placement of the intracochlear electrode array may damage remaining neural structures and/or distort the normal anatomy precluding use of the ear in the future. Therefore, many patients are interested in adopting a "wait-and-see approach" for the contralateral ear with rationales including "saving" the second ear for hair cell regeneration, anticipation of the development of microbiological rehabilitation such as stem cell transplantation, and/or a desire to take advantage of future advances in CI technology. While these options remain experimental and investigative at this point, it is unclear whether implementation of these therapies will require a naïve cochlea or some amount of residual hearing, both of which are compromised with CI.

Bilateral CI users likely benefit from coding strategies that are developed with the intention of providing detailed interaural cues. However, currently, BCI patients use two separate signal processors, one controlling each ear, which function independently from each other in terms of automatic gain control circuitry. Furthermore, these strategies may not replicate timing and intensity cues faithfully enough to permit optimal binaural hearing due to the unsynchronized processor outputs. Therefore, BCI patients may be unable to preserve differences in interaural levels accurately and will fail to detect coherent fine structure information at the two ears. Tyler et al. (2007) showed that patients with BCI with different electrodes, insertion depths, processing algorithms, channel numbers, and/or pulse widths were able to obtain binaural benefits despite these differences between devices. It is unclear if these results are comparable to those obtained in patients with two identical devices implanted bilaterally. While there have been only a small number of studies in the literature to date, there is some hope that these disadvantages of BCI may be improved with the development of a single speech processor that is capable of controlling bilateral electrode arrays.

There are continuing debates regarding the impact of CI on vestibular function and more specifically the possibility of bilateral vestibular deafferentation with BCI. Anecdotally, a small group of patients suffer temporary, short-term vertigo following cochlear implantation perhaps due to a serous labyrinthitis similar to that seen in the postoperative period following stapedectomy. Postoperative vertigo seems to be more common in the adult and elderly population, perhaps due to preexisting vestibular hypofunction in this cohort. However, estimation for the risk of bilateral vestibular compromise following BCI is probably less than 10% in adults, and more likely in the range of less than 1% (Basura et al. 2009). In patients with a history of vestibular compromise in the contralateral ear such as endolymphatic hydrops, vestibular nerve surgery, or labyrinthitis/vestibular neuritis, there may be a role for preoperative vestibular testing in order to identify possible subclinical vestibular hypofunction in the second, unaffected ear prior to BCI. However, lack of consistent correlation between vestibular testing and postoperative symptoms of vertigo has made vestibular testing optional in the preoperative BCI algorithm.

Future Directions

Bilateral cochlear implantation was introduced several decades ago, but in a majority of the early patients undergoing BCI, the indications were technical complications or failure of their first implant rather than the rehabilitation of their second ear. It was not until the late 1980s or early 1990s that interest in BCI for the primary purpose of restoring binaural hearing to profoundly deafened adults became popular.

In the last two decades, clinical research evaluating objective speech outcomes, industry dollars dedicated to product research and development, basic science investigations into hearing preservation and restoration, and technology advancements have driven worldwide acceptance of BCI. The twenty-first century has ushered in an exponential rise in the number of adult BCI patients who desire not only restoration of sound awareness and moderate perceptual improvements, but results that rival those experienced by their normal hearing peers.

A major concern with current processing strategies is that they may limit the potential for binaural CI outcomes, as these strategies may not accurately replicate normal binaural hearing. Current research has been focusing not only on matching electrode pairs postoperatively, but also exploiting these differences in order to improve signal detection. There is also ongoing research using other mechanisms such as frequency table matching, patient-driven frequency table selection, and high-definition imaging algorithms that may be used to create more subjective and objective perceptual symmetry and synergism between bilateral implant devices.

One question regarding BCI in adults that has demanded recent attention is the decision of whether to implant pre-lingually deafened adults unilaterally or even bilaterally. While many of these patients have retained residual speech perception abilities, and may develop rudimentary or in some cases moderate speech intelligibility, late secondary plasticity in pre-lingually deafened adults appears unable to achieve what is lost from chronic auditory deprivation during the critical period of speech and language development. Anecdotally, there are cases in which these patients obtain modest but important benefits in hearing from BCI. Future research should strive to identify those pre-lingually deafened adults who may benefit the most from BCI and perhaps predict those patients who may benefit from central nervous system reorganization and plasticity despite years of deprivation. Additionally, changes in processor strategies may assist these patients obtain results more similar to those patients with post-lingual deafness.

With the emphasis in modern healthcare on evidence-based medicine and cost-effective medicine in hopes of improving access, improving quality, and improving outcomes, there has been a movement toward the creation of clinical guidelines for the allocation of various treatments and medical devices. This trend has also been evident in determining CI candidacy, and specifically BCI, as various professional societies and study groups have proposed algorithms for BCI candidacy. While these guidelines could feasibly assist the practitioner in many cases to determine ideal BCI candidates, it is not practical for clinical guidelines to be comprehensive enough to cover all possible clinical scenarios for the placement of either simultaneous or sequential BCI. The decision to proceed with BCI in each individual patient must be considered independently as these decisions are often straightforward, but at other times can be complex and require the CI surgeon to utilize sound judgment, experience, and even intuition. As more experience with BCI in the adult population is acquired, as research results materialize, and as long-term outcomes become available, the hope is to better predict those patients who will benefit significantly from BCI.

Cross-References

- ▶ Audiometry
- ▶ Canal Wall Up Mastoidectomy
- ▶ Cochlear Implantation, Revision – Adult
- ▶ ENG/VNG
- ▶ Facial Nerve Imaging, CT and MRI
- ▶ Facial Paralysis
- ▶ Otosclerosis
- ▶ Physiology of Cochlea
- ▶ Sensorineural Hearing Loss
- ▶ Traumatic/Iatrogenic Facial Nerve Paralysis, Medical and Surgical Management

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Adult Glottic Stenosis

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Synonyms

Glottic web; Laryngeal stenosis; Laryngeal web; Posterior glottic stenosis

Definition

Chronic narrowing of the airway at the glottic level of the larynx; that is, at the level of the true vocal folds.

Classification

Stenosis at the level of the glottis can be divided into three categories: (1) anterior, (2) posterior, and (3) complete.

Anterior stenosis can be seen in two forms. The first is a simple anterior glottic web, which can be congenital or acquired (Fig. 1a). A web is a bridge of scar tissue between the true vocal folds that is covered with epithelium. It usually involves the anterior commissure. The second is a more complex form in which the true vocal folds, false vocal folds, and the ventricles are adherent to one another. This is usually the result of severe external laryngeal trauma and thyroid cartilage fracture.

Posterior glottic stenosis (PGS) refers to narrowing of the airway at the posterior aspect of the glottic space. PGS has been further subclassified by Bogdasarian and Olson (1980):

- Type 1: Interarytenoid synechia or scar with a sinus tract posteriorly (Fig. 1c)
- Type 2: Interarytenoid scar without a sinus tract posteriorly, in which there is no fixation of either cricoarytenoid (CA) joint
- Type 3: Interarytenoid scar with fixation of one CA joint
- Type 4: Interarytenoid scar with fixation of both CA joints

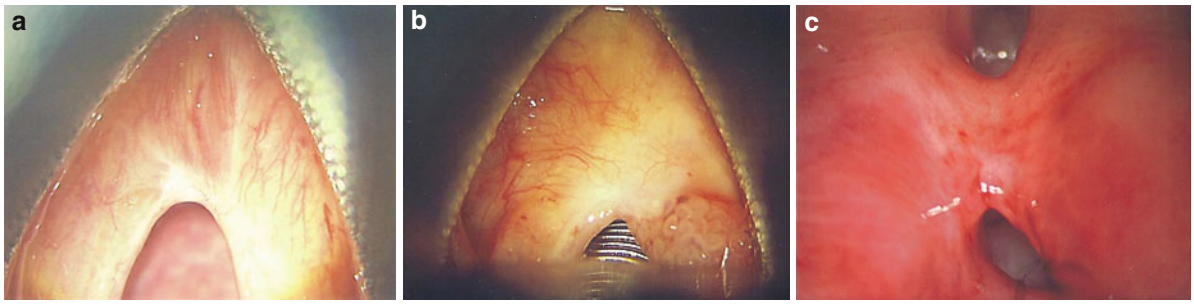
Complete glottic stenosis typically results from inadequately managed external trauma. However, infection or trauma from prolonged intubation or endolaryngeal surgery may also cause complete stenosis.

Etiology

Endotracheal Intubation

Prolonged or traumatic endotracheal intubation is the most common cause of PGS. Intubation trauma can also result in anterior glottic webs and complete glottic stenosis (Rosen and Simpson 2008a); however, this is far less common.

The true incidence of PGS secondary to endotracheal intubation is unknown. In a prospective study of 200 patients, Whited noted an overall incidence of approximately 6% (Whited 1984). However, patients intubated greater than 10 days had a threefold increased risk of developing stenosis.



Adult Glottic Stenosis, Fig. 1 (**a**) A small anterior glottic web. (**b**) A large anterior glottic web secondary to surgical trauma. Note the laryngeal papilloma visible on the right true vocal fold. (**c**) Interarytenoid scar band with a posterior sinus tract (Type 1 posterior glottic stenosis)

Endotracheal intubation results in pressure on the posterior glottis, causing mucosal ischemia, which eventually leads to ulceration, granulation tissue formation, and secondary infection (Benjamin 1993). The areas most affected are the medial aspects of the arytenoids, the CA joints and the interarytenoid space (Benjamin 1993; Weymuller 1988). Injury may also be the result of a traumatic intubation causing a mucosal tear. The healing process involves deposition of fibrous tissue, resulting in stenosis and CA joint fixation. Thus, patients typically develop symptoms in a delayed fashion, weeks to months after the intubation. Risk factors for the development of stenosis include the duration of intubation, size of the endotracheal tube, traumatic or repeated intubations, the presence of gastroesophageal reflux disease (GERD), acute or chronic conditions that lead to poor tissue perfusion or hypoxia (e.g., diabetes mellitus), and bacterial superinfection (Benjamin 1993; Gardner 2000).

Endolaryngeal Trauma

Surgery of the larynx, either via endoscopic or open approach, can result in trauma that leads to the formation of stenosis. Any procedure that creates a wound not covered with epithelium that crosses the anterior or posterior commissure is at risk of forming a web or stenosis. This is a common cause of anterior glottic webs.

Caustic ingestions and foreign bodies can also lead to inflammatory reactions that can result in glottic stenosis.

External Trauma

Trauma can result in fractures of the thyroid and/or cricoid cartilages, mucosal lacerations, and hematoma formation. The healing process, as discussed above for endotracheal intubation, can result in fibrous tissue deposition and stenosis.

Anterior or posterior glottic stenosis can occur if the relevant portions of the glottic mucosa or cartilaginous support are involved in the injury. Complete glottic stenosis is usually the result of severe external trauma to the laryngeal framework (Shapshay and Valdez 2003).

Radiation Therapy

External beam radiation therapy for aerodigestive tract malignancies induces an inflammatory response in the tissues within the radiation volume. This can range from mild reactions to severe inflammation resulting in chondronecrosis. As the tissues recover, there is a variable amount of fibrosis, which can lead to glottic stenosis (Benninger et al. 1998). These cases are particularly challenging to manage – surgical repair is complicated by poor wound healing.

Neoplasms

Neoplasms are a rare cause of glottic stenosis. Chondromas and chondrosarcomas of the larynx typically arise from the posterior cricoid lamina and may result in PGS. Respiratory papillomatosis, a benign neoplasm caused by the human papillomavirus, can also result in glottic stenosis. Common laryngeal malignancies such as squamous cell carcinoma can cause narrowing of the glottic airway due to impaired vocal fold mobility as well as mass effect from the tumor itself.

Inflammatory Conditions

Wegener's granulomatosis (WG) is a vasculitis resulting in necrotizing granulomatous inflammation

of the upper respiratory tract, lungs, and kidneys. The head and neck manifestations can present in the nasal cavity, middle ear, oral cavity, and larynx. The typical laryngeal manifestation is subglottic stenosis, with both acute or subacute stenosis from active inflammation and chronic stenosis from scar tissue formation. PGS, however, can also be seen. Although systemic disease is commonly seen, a form of WG that involves isolated airway manifestations has been described (Gardner 2000).

Relapsing polychondritis is an autoimmune inflammatory disorder that typically affects that cartilage of the ears, nose, and laryngotracheobronchial tree. The classic laryngeal manifestation is subglottic stenosis; however, PGS has also described.

Amyloidosis involves extracellular protein deposition in the larynx and can result in glottic stenosis. Other rare causes of stenosis include other inflammatory autoimmune diseases and sarcoidosis. The latter, however, typically affects the supraglottic structures. Anterior glottic webs can be caused by WG, sarcoidosis, and amyloidosis (Rosen and Simpson 2008a).

Infections

Infectious causes of chronic glottic stenosis are rare in the developed world. Tuberculosis classically causes granulomatous inflammation of the periarytenoid and interarytenoid region, posterior true vocal folds, and laryngeal surface of the epiglottis. Mucosal ulceration can lead to extensive perichondritis and chondritis. The resulting healing process can lead to extensive scarring and stenosis. Other rare infections such as Klebsiella rhinoscleromatosis, syphilis, leprosy, and diphtheria can also result in glottic stenosis.

Gastroesophageal Reflux Disease

GERD has been implicated in the pathogenesis of PGS as either the sole cause or as a contributing cause that prevents normal healing in the presence of injury caused by other mechanisms such as intubation or surgery (Hirshoren and Eliashar 2009).

Clinical Presentation

Patients with anterior glottic stenosis may have very minimal symptoms. Small anterior glottic webs (Fig. 1a) can cause mild dysphonia with an increase in vocal pitch and vocal effort. Webs can also be much larger (Fig. 1b), encompassing the entire length of the membranous vocal folds. These larger webs or more extensive stenoses can impair true vocal fold movement and thus can present with varying degrees of phonatory and respiratory symptoms.

PGS causes more significant airway-related symptoms due to limitation of true vocal fold abduction. Patients typically have dyspnea and stridor. This will vary from mild stridor and dyspnea only with exertion to respiratory distress and stridor at rest. Patients are often treated for asthma or other pulmonary conditions prior to presenting to an otolaryngologist for evaluation. The severity of the symptoms depends upon the degree of stenosis as well as the time frame over which the stenosis develops – patients may be relatively comfortable with a significantly narrowed airway that has developed over months to years. Voice complaints are less prominent in PGS; however, patients may have a rough and breathy quality to their voice, with complaints of vocal fatigue and decreased vocal projection. Swallowing problems, though less common, can occur if the stenosis prevents adequate adduction of the true vocal folds to protect the airway during swallowing.

Diagnostics

Physical Examination Including Flexible Laryngoscopy

A detailed and thorough physical examination is essential for the diagnosis and evaluation of patients with glottic stenosis. Stridor, signs of respiratory distress, and dysphonia should all be noted. The neck should be examined for signs of trauma, surgical scars, or masses.

Flexible fiber-optic laryngoscopic examination of the airway is the most crucial aspect of the patient's evaluation. A thorough examination is facilitated by the application of topical laryngotracheal anesthesia, which allows for a detailed examination of the glottic, subglottic, and tracheal airway. Anesthesia can be administered via injection of topical lidocaine through the cricothyroid membrane or in a transtracheal fashion. This will induce a forceful cough that will effectively deliver the anesthetic to the laryngeal introitus. Alternatively, if a sideport is available on the flexible laryngoscope, the anesthetic can be dripped directly onto the true vocal folds.

Examination of the larynx should identify areas of stenosis and the amount of true vocal fold mobility with regard to abduction and adduction. Areas of

significant scar tissue deposition that are contributing to the stenosis should be carefully examined. Furthermore, the scope can be passed distal to the vocal folds to assess for any coexistent pathology of the subglottis or trachea which may be contributing to the patient's symptoms. Other sites of stenosis are common in patients with PGS, with reports ranging from 9.3% to 27.8% (Shapshay and Valdez 2003).

It can sometimes be difficult to distinguish between PGS and bilateral vocal fold paralysis. If this is the case, laryngeal electromyography (LEMG) and intraoperative examination may help elucidate the diagnosis (see below).

Imaging Evaluation

A high-resolution CT scan of the neck with 1 mm (or thinner) cuts through the larynx is helpful in further characterizing the location and extent of the stenosis. It is particularly helpful in evaluating for coexistent subglottic or tracheal stenosis. Both the degree and the length of such stenoses can be measured from the scan. The CT is also helpful in cases of external laryngeal trauma for determining the location and nature of cartilaginous framework disruption as well as in the diagnosis of neoplasms.

Laryngeal Electromyography

LEMG may be useful in distinguishing between PGS and bilateral vocal fold paralysis by testing for integrity of the recurrent laryngeal nerve function.

Evaluation of Swallowing

Many of the surgical treatments for PGS may worsen swallowing and aspiration. Any patients with swallowing difficulties or symptoms of aspiration at presentation should undergo a formal evaluation of their swallowing prior to any surgical intervention that may worsen swallowing function. A modified barium swallow (MBS) or flexible endoscopic evaluation of swallowing (FEES) are appropriate tools for conducting such an evaluation.

Pulmonary Function Tests

Although pulmonary function tests are not required to make the diagnosis of glottic stenosis, they can be helpful in monitoring success of treatment. Examination of flow volume loops and peak inspiratory flows provides objective measurement of airflow to complement patients' subjective report of their symptoms.

Operative Evaluation

Rigid endoscopic examination under general anesthesia permits the surgeon to gather further essential information regarding the degree and nature of the stenosis. A rigid laryngoscope can be used to expose the glottis and can be suspended to allow for bimanual examination. The anterior and posterior glottis can then be carefully examined under magnified vision with either rigid telescopes or an operating microscope. Such telescopes or rigid bronchoscopes can also be used to evaluate the suglottis and trachea. The CA joints can be palpated to determine if they are mobile or fixed. Finally, areas of scar tissue can be palpated to determine consistency and suitability for surgical correction (Gardner et al. 1995). Biopsies for histopathology and/or microbiology can be done at this time if a neoplasm, infection, or inflammatory etiology is suspected.

Operative evaluation and intervention in patients with glottic stenosis requires careful airway management and excellent communication between the surgeon, anesthetist, and operating room team. If a preoperative tracheotomy is not present, the surgeon and anesthetist must decide upon the safest method for providing ventilation prior to beginning the procedure. Intubation may be possible, but even if this is the case, the endotracheal tube often obscures the laryngeal structures such that diagnostic evaluation is difficult of impossible. Jet ventilation can be delivered supraglottically when a rigid laryngoscope has exposed the larynx, via a rigid ventilating bronchocope, or through a Hunsaker Mon-Jet subglottic ventilation tube (Orloff 2002). If there is concern that the patient may obstruct when administered paralytic medications and that bag-mask ventilation or exposure of the airway may be difficult or impossible, exposure of the larynx can be obtained while the patient is spontaneously breathing prior to administration of paralytic medications. If the above methods are felt to be unsafe, a tracheotomy under local anesthesia should be performed (Gardner 2000).

Differential Diagnosis

Bilateral vocal fold paralysis
Bilateral arytenoid dislocation
Cricoarytenoid joint ankylosis
Paradoxical vocal fold motion disorder/laryngospasm

Prophylaxis

As the vast majority of cases of adult glottic stenosis are acquired, prevention is possible. The incidence of intubation-related stenosis can be dramatically reduced by decreasing the duration of intubation with early tracheotomy placement (Whited 1984). Furthermore, avoidance of traumatic or repeated intubations or inappropriately large tube size is essential. Medical management of GERD, bacterial infection, and chronic medical conditions such as diabetes is also important (Gardner 2000). Prompt and appropriate management of external trauma is also essential to prevention of the development of stenosis.

Care must also be taken during endolaryngeal surgery to avoid epithelial defects that cross the anterior or posterior commissure, which can result in web formation. This is especially true for surgery involving the anterior commissure. For example, when treating recurrent respiratory papillomas that cross the anterior commissure, papilloma should be left on one side at the commissure to avoid web formation. If this is not possible, mucosal flaps can be created to cover the epithelial defect on at least one side (Rosen and Simpson 2008a).

The role of GERD in the development of glottic stenosis is controversial; however, it likely contributes by preventing normal healing after injury (Gardner 2000). Appropriate medical management with proton pump inhibitor therapy is likely indicated in patients with an injury that predisposes to the development of stenosis and in patients who have undergone surgical management to relieve stenosis, irrespective of whether or not they have the classical signs or symptoms of GERD (Hirshoren and Eliashar 2009).

Therapy

Medical Therapy

Treatment of the underlying cause of the stenosis is important for inflammatory and infectious etiologies. Corticosteroids can reduce edema and improve airway patency acutely but do not provide a definitive solution unless an inflammatory or autoimmune process is the cause. If this is the case, other immunosuppressive medications may also be indicated. Consultation with a rheumatologist is essential in these cases. Infectious etiologies should be treated with appropriate antimicrobial agents and given the rarity of these infections, an infectious disease specialist should be involved in the care of these patients.

The use of botulinum toxin has been recently described as a potential treatment for patients with PGS (Ekbom et al. 2010). By weakening the thyroarytenoid and lateral cricoarytenoid muscles, the posterior cricoarytenoid muscle has less opposition and can lead to a more lateralized position of the vocal fold(s), resulting in an improved airway. Although this technique had good success in treating patients with bilateral vocal fold paralysis, results in patients with PGS were mixed. One patient with PGS and unilateral CA joint fixation experienced a significantly improved airway, while another patient with bilateral CA joint fixation did not experience any improvement (Ekbom et al. 2010).

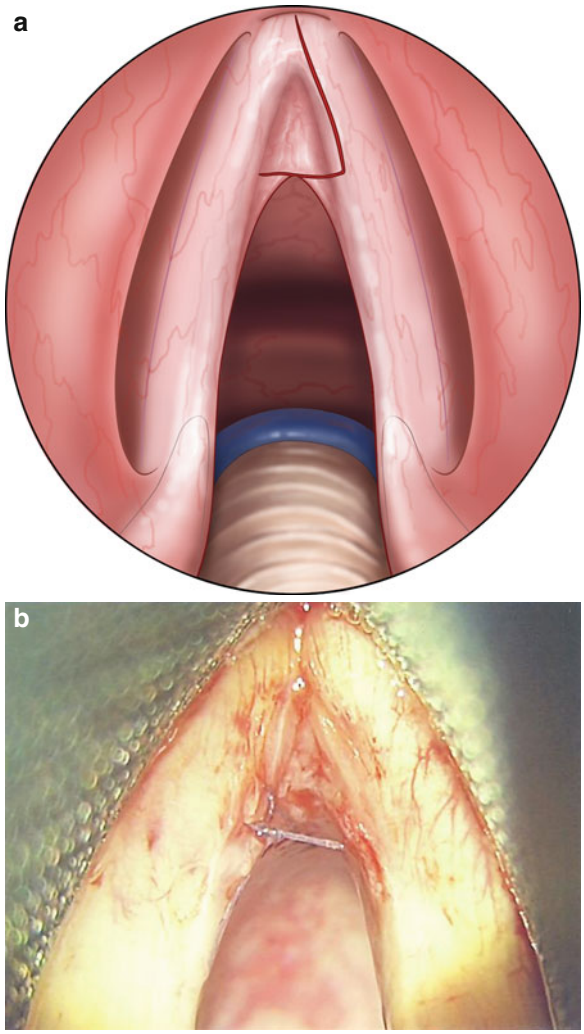
Surgical Therapy

Anterior Glottic Stenosis

Not all cases of anterior glottic stenosis require surgical management. Only in rare situations does anterior glottic stenosis result in significant airway compromise. In these cases, surgery is indicated. More often, patients' main complaint is dysphonia. The degree of dysphonia and each patient's vocal demands and goals will dictate the need for surgical intervention.

Endoscopic Approach Anterior glottic webs can be managed with suspension microlaryngoscopy and division of the web. This can be done with either the CO_2 laser or cold instruments. The web should be divided asymmetrically (Fig. 2a) such that the web itself can be used for mucosal coverage of one side of the anterior commissure (Rosen and Simpson 2008a; Shapshay and Valdez 2003). The resultant mucosal flap is then secured in place via placement of an endoscopic suture(s) (Fig. 2b).

Larger anterior glottic webs, those with an inadequate mucosal flap, or those that fail the above approach may need endoscopic placement of a keel in addition to division of the web. Several techniques have been described for endoscopic placement of keels (Rosen 2008; Shapshay and Valdez 2003). Keels are typically left in place for 10–14 days and are then removed under general anesthesia.



Adult Glottic Stenosis, Fig. 2 (**a**) Asymmetric division of anterior glottic web (Reprinted with permission from Rosen and Simpson 2008a). (**b**) Mucosal flap created from asymmetric division of anterior glottic web sutured in place to provide epithelial cover to the anterior right true vocal fold

Open Approach An anterior laryngofissure approach is indicated when there is coexistent subglottic stenosis, severe supraglottic stenosis, or when multiple endoscopic procedures have failed (Shapshay and Valdez 2003). The areas of web or stenosis are divided and a laryngeal stent or keel is placed and secured over a button to the overlying thyroid cartilage lamina or the skin of the neck. A tracheotomy will be required for the duration of the stent placement, which can be removed endoscopically after 2–6 weeks (Montgomery and Cheney 1996; Shapshay and Valdez 2003).

Posterior Glottic Stenosis

As with anterior stenoses, not all patients with PGS require surgery. The primary indication for surgical intervention is significant airway compromise, which can range from severe respiratory distress requiring urgent surgery to limited exercise tolerance appropriate for elective intervention. A secondary indication is patient desire for decannulation from an existing tracheotomy placed for airway obstruction.

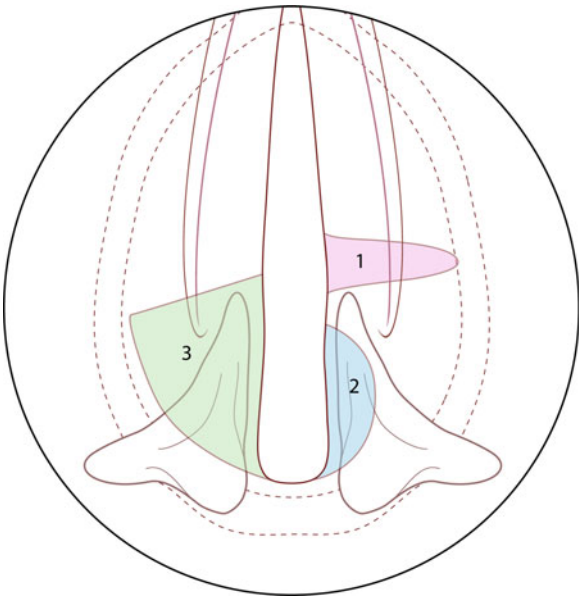
Any procedure directed to enlarge the glottic airway will sacrifice swallowing and voice outcome to some degree – patients must be made aware of this preoperatively. The guiding principle of these procedures is to conservatively enlarge the posterior glottic airway so as not to predispose to clinically problematic aspiration and to preserve the majority of the membranous true vocal fold, which is essential for voice production. A conservative approach is preferred to prevent these complications, knowing that the risk of restenosis will be slightly higher and that revision procedures may be required.

The surgical intervention with the least negative impact on voice and swallowing while providing an adequate airway is a tracheotomy. Patients must be made aware that a tracheotomy is an option, whether permanent or temporary to allow time for decision-making. Many patients, however, are resistant to the idea of having a permanent tracheotomy.

Endoscopic Approach

Lysis of Scar Band Simple Type 1 PGS – an interarytenoid scar band (Fig. 1c) – can be lysed with cold instruments or a laser. Care must be taken to avoid injuring the interarytenoid mucosa, which could result in scarring and worsened PGS.

Arytenoidectomy (Total or Medial) The classic CO_2 laser total arytenoidectomy was described by Ossoff et al. (1983) (Fig. 3). This involves vaporization of the arytenoid mucosa, the arytenoid cartilage, and a portion of the posterior true vocal fold, which results in a defect flush with the inner aspect of the cricoid cartilage. The large resultant defect does initially result in breathy dysphonia and aspiration of thin liquids. However, with time scar tissue does form, making the defect smaller and improving these symptoms while preserving enough airway enlargement for relief of the stenosis. The reported rate of decannulation was



Adult Glottic Stenosis, Fig. 3 Comparison of total arytenoidectomy, medial arytenoidectomy, and transverse cordotomy (Reprinted with permission from Rosen and Simpson 2008b). *1* Transverse posterior cordotomy; *2* Medial arytenoidectomy; *3* Total arytenoidectomy

86% (Ossoff et al. 1990). Numerous modifications of this procedure have been described in an attempt to reduce the significant negative impact on voice and swallowing and to provide more predictable healing, and thus, airway improvement results (Gardner 2000).

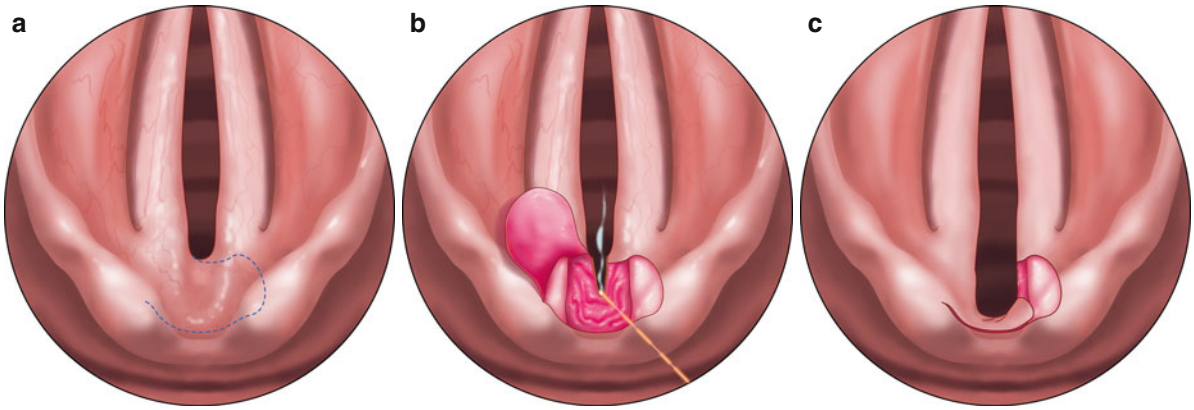
Crumley described medial arytenoidectomy (Crumley 1993), a procedure in which the medial body of the arytenoid and the overlying mucosa are removed using a laser to increase the size of the posterior glottic airway, while preserving the vocal process of the arytenoid and the membranous true vocal fold. This procedure achieves a 1–2 mm improvement in the airway size while preserving the phonatory glottis, thus minimizing the negative impact on phonation compared to total arytenoidectomy. Subsequent studies have confirmed the effectiveness of medial arytenoidectomy in terms of airway improvement, along with minimal negative impact on voice and swallowing (Bosley et al. 2005). Other authors have described preservation of the medial arytenoid mucosa, which can be endoscopically sutured laterally after the cartilage has been resected (Gardner 2000). This offers a more predictive healing response as opposed to leaving the underlying tissue exposed to heal secondarily.

Posterior (Transverse) Cordotomy The posterior (transverse) cordotomy involves making a transverse incision, typically using a laser, through the true vocal fold, just anterior to the vocal process of the arytenoid (Kashima 1991) (Fig. 3). The lateral end of the incision should extend to the inner aspect of the cricoid cartilage. To achieve this, the incision often extends into the false vocal fold tissue. Classically, the vocal process is preserved and by avoiding cartilage exposure, the risk of postoperative granuloma formation can be reduced (Rosen and Simpson 2008b). However, if a larger airway is required, the vocal process can be removed and/or the procedure can be combined with a medial arytenoidectomy. The posterior cordotomy can be performed unilaterally or bilaterally, depending on the degree of airway improvement required. When compared to medial arytenoidectomy, posterior cordotomy seems to perform similarly with regard to airway improvement and impact on voice and swallowing (Bosley et al. 2005).

Microflap Technique Both inferiorly (Dedo and Sooy 1984; Goldberg 2000) and laterally based (Rosen et al. 2008) microflap techniques have been described for managing type 2 or 3 PGS – that is, at least one CA joint should be mobile. In all of these techniques, a mucosal flap is elevated off of the interarytenoid scar tissue (Fig. 4). The underlying scar tissue is then removed or divided to mobilize the CA joint(s). The mucosal flap is redraped and endoscopically sutured in place to prevent new scar tissue formation. These procedures require the presence of a tracheotomy during the postoperative recovery to allow for adequate healing of the flap.

These techniques provide the advantage of airway improvement without compromising swallowing or the structure of the true vocal fold, thus maximizing voice outcome. Good results with these techniques have been reported in small groups of selected patients (Dedo and Sooy 1984; Goldberg 2000).

Open Approach The indications for open repair of PGS include failed endoscopic procedures, laryngeal trauma with significant disruption of the cartilaginous framework, and inability to adequately expose the glottis endoscopically. For all open procedures, patients should have a tracheotomy during the postoperative period.



Adult Glottic Stenosis, Fig. 4 Microflap technique for repair of posterior glottic stenosis (Reprinted with permission from Rosen et al. 2008). (**a**) Incision for laterally based microflap. (**b**) Elevation of flap and division and/or excision of underlying interarytenoid scar tissue. (**c**) Redraping of microflap to provide epithelial cover of interarytenoid space

Anterior Laryngofissure The classic approach to the posterior glottis is via an anterior laryngofissure, which provides excellent exposure. Care must be taken to divide the thyroid cartilage precisely in the midline to avoid injury to the membranous vocal folds. Montgomery described elevation of a mucosal flap in the posterior commissure, allowing excision of the posterior glottic scar tissue and the typically fibrosed interarytenoid muscle (Montgomery 1973). This allows for mobilization of the CA joints. The mucosal flap is then redraped and sutured in place. Other authors have described using free grafts instead of creating a pedicled mucosal flap – mucosal, skin, and perichondrocutaneous grafts have all been described (Gardner 2000; Hoasjoe et al. 1997).

Typically, a conforming laryngeal stent is placed and secured to the overlying thyroid lamina or neck skin between 1 and 6 weeks depending on the severity of the stenosis and the extent of the repair. It can then be removed endoscopically under general anesthetic, at which time any granulation tissue can be excised or vaporized with a laser.

Arytenoidectomy (see below) can also be combined with this procedure to provide further enlargement of the posterior glottis. If the cartilaginous framework of the larynx has been significantly disrupted, more complex reconstruction may be required (Shapshay and Valdez 2003).

Arytenoidectomy A total or subtotal arytenoidectomy can be completed via open approaches. The most direct approach is an anterior laryngofissure. The arytenoid can also be approached laterally via an approach similar to that used for arytenoid repositioning surgery. The posterior border of the thyroid cartilage lamina is exposed and the pyriform sinus mucosa is carefully dissected away from the cricoid cartilage and posterior cricoarytenoid muscle, exposing the muscular process of the arytenoid cartilage.

Complete Glottic Stenosis

Management of complete glottic stenosis can be complex and is directed by the underlying etiology. Traumatic injuries may require open reduction and fixation of any laryngeal fractures. An anterior laryngofissure is usually required to allow excision of the stenosis, mucosal or skin grafting, and placement of a conforming laryngeal stent (Shapshay and Valdez 2003).

Adjuvant Treatment

Antibiotics The use of antibiotics in the perioperative setting is generally recommended to prevent perichondritis and chondritis, which can lead to new scar formation and restenosis. However, the evidence for their benefit is mixed in both animal and human studies (Hirshoren and Eliashar 2009).

Intralesional Corticosteroids Corticosteroids delay the synthesis of collagen in the early stages of scar formation and increase the lysis of collagen in the later stages. Thus, intralesional corticosteroid application may have some benefit in preventing restenosis after surgery. However, as with antibiotics, the evidence

supporting their use from animal and human studies is conflicting (Hirshoren and Eliashar 2009).

Mitomycin C Mitomycin C is an alkylating agent that leads to cross-linking of DNA and is used as an antineoplastic drug for the treatment of several solid tumors. It has also been shown to inhibit fibroblast proliferation and the wound-healing response when applied topically (Hirshoren and Eliashar 2009). Several studies have shown a significant reduction in the incidence of restenosis with the topical application of mitomycin C during the surgical treatment of laryngotracheal stenosis in both animal and human studies (Hirshoren and Eliashar 2009; Perepelitsyn and Shapshay 2004). It is typically used at a dose of 0.4 mg/mL. However, there is controversy as to the subgroups of patients who are most likely to benefit and the potential side effects. Some animal studies have suggested that mitomycin C is beneficial only for fresh scar tissue and not for more mature stenosis (Hirshoren and Eliashar 2009). Studies in humans have found that fibrinous debris can accumulate at the application site, leading to airway obstruction. However, this complication was most often seen with higher does ($\geq$10 mg/mL) (Hirshoren and Eliashar 2009).

Cross-References

- ▶ Difficult Airway
- ▶ Hoarseness and Pediatric Voice Disorders
- ▶ Subglottic and Tracheal Stenosis in Adults
- ▶ Vocal Cord Surgery

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Advancement Flaps

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Synonyms

Advancement technique; Advancement tissue flap; Bilateral pedicle advancement; Bilateral single pedicle advancement; Bilateral unipedicle advancement; Bipedicle advancement; Island pedicle advancement; Single pedicle advancement; Subcutaneous island pedicle advancement; Unilateral advancement; Unilateral pedicle advancement; Unipedicle advancement; V to Y advancement; V to Y subcutaneous island pedicle advancement

Definition

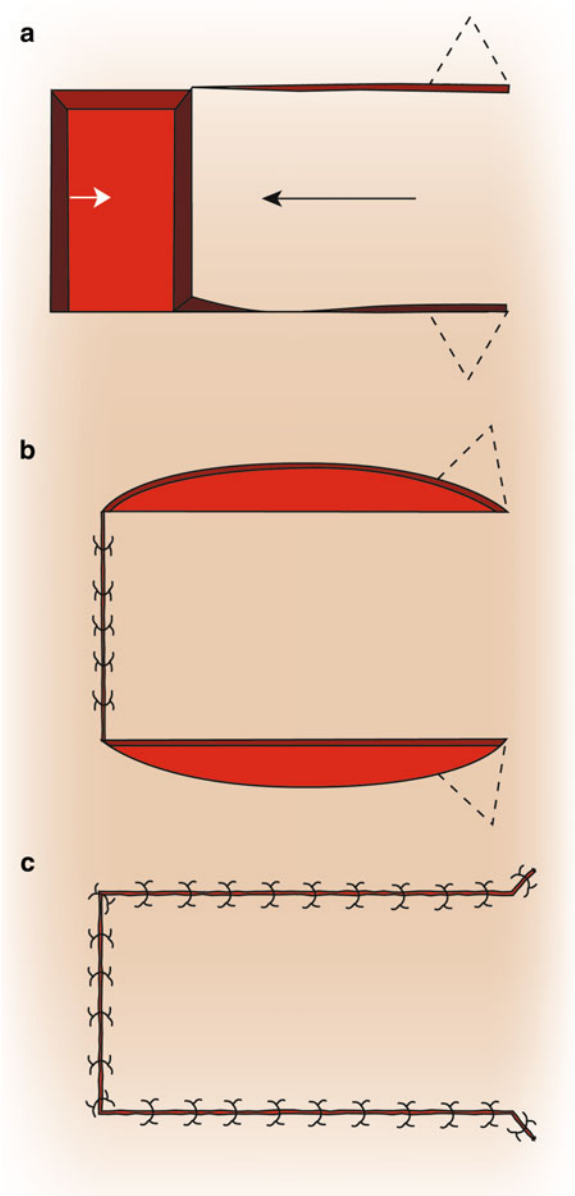
Advancement flap: Flap created by mobilizing adjacent tissue in a linear vector into the primary defect.

Principle

Most local tissue flaps used in the head and neck have some degree of advancement. Even ▶ *rotation flaps* have a component of advancement in relation to their pivot point. A pure advancement flap involves movement of tissue in a single vector into a defect. The most basic advancement is a simple linear closure where the opposing margins of a defect are undermined and brought together primarily. With larger defects, incisions are used to create an advancement flap that allows sliding movement of the flap along with its pedicle into the defect. One margin of the defect becomes the leading edge of the sliding donor flap.

It is important to recognize both primary and secondary movement in the advancement flap. The movement of the donor flap into the area of the defect is considered the primary movement. Secondary movement is the displacement of the remaining skin surrounding the defect toward the center of the defect (Fig. 1). It occurs in the direction opposite that of the primary movement (Baker 2007; Hilger and Boahene 2009). The degree of secondary movement is dependent on the intrinsic elasticity and redundancy of the remaining soft tissue margins of the defect as well as the tension of the closure itself. Secondary movement is facilitated by adequate undermining of the surrounding soft tissues. Additionally, in planning a flap advancement, it is crucial to consider secondary movement since undue tension could distort associated structures of the face. For these reasons, advancement flaps are best used in areas of tissue redundancy.

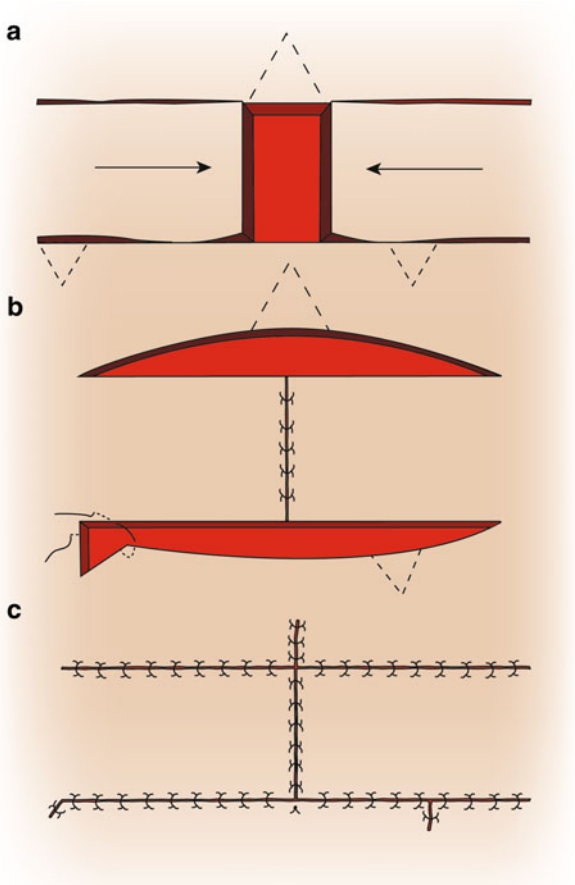
Before starting the reconstruction one needs to remember basic principles. Complete tumor removal either by Mohs micrographic surgery or other traditional techniques should be confirmed. Definitive efforts at repair without assurance of complete tumor eradication should be avoided. The future diagnosis of an incompletely excised tumor may be significantly delayed if hidden by a reconstructive tissue flap. One must also consider the principle of aesthetic subunits and aim for preservation of subunit boundaries where appropriate for optimal cosmetic outcome. Adequate preparation of the recipient bed is also imperative. Beveled edges are deepened since excess tissue bulk can interfere with flush approximation. Squaring off the donor defect is beneficial, since angulated flaps and defects ultimately exhibit less pin-cushioning compared to rounded flaps and defects. Advancement flaps generally have a flap length to width ratio of 2:1 to 3:1 depending on the facial site and author; however, distal tissue perfusion pressure is the ultimate determinate of flap viability (Bardach et al. 1982; Dzubow 1986; Braun and Cook 2005; Baker 2007; Hilger and Boahene 2009). Excessive flap tension should be



Advancement Flaps, Fig. 1 *Single pedicle advancement flap*. (**a**) The direction of the secondary movement (*white arrow*) is opposite that of the primary movement (*black arrow*). (**b, c**) Advancement of the flap results in apposed tissue edges of unequal length that may be addressed with excision of Burow's triangles

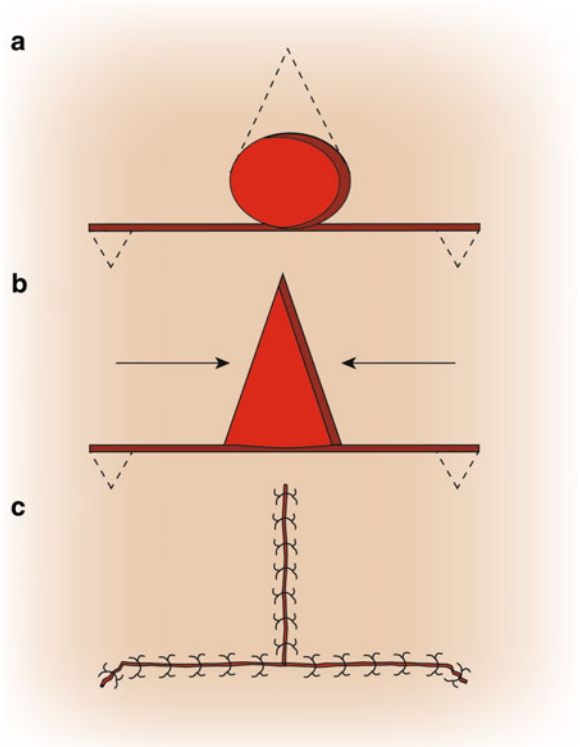
avoided since distal blood flow may become compromised, risking distal flap necrosis.

Once the incisions are created, the advancement flap undergoes sliding movement into the defect. This new tissue orientation causes the formation of soft

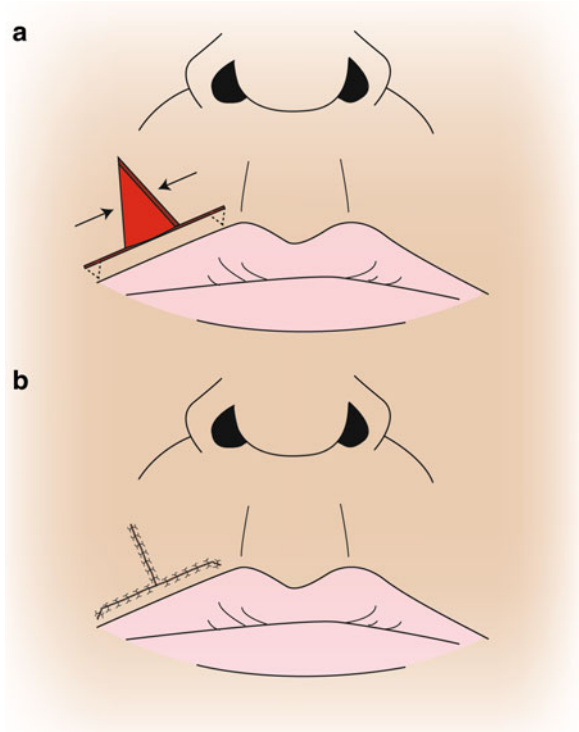


Advancement Flaps, Fig. 2 *Bilateral single pedicle advancement flap (H-plasty)*. (**a, b, c**) The coverage of the defect is shared between two pedicles that move toward each other. After advancement has been completed, Burow's triangles (if present) may be excised anywhere along the length of the flaps

tissue redundancies or standing cones of tissue called Burow's triangles. These are usually found at the base of the flap pedicle and form due to the unequal lengths of opposing tissues. When present, the redundancies require excision and closure. Excision of these triangles further facilitates movement of the flap. One should anticipate the formation of Burow's triangles; however, these should not be excised until after advancement. In some cases, the author advocates leaving soft tissue redundancies intact for future planned revision in a second in-office procedure. This approach maximizes flap viability since these redundancies tend to be located at the base of the vascular pedicle and removal could potentially compromise vascularity to the distal portion of the flap.



Advancement Flaps, Fig. 3 *O-T or A-T advancement flap (T-plasty).* (**a, b, c**) The O-shaped defect is fashioned into an A-shape to accommodate bilateral advancement. A T-plasty is essentially half of an H-plasty. After advancement has been completed, Burow's triangles (if present) may be addressed



Advancement Flaps, Fig. 4 *A-T advancement flap (T-plasty) in the philtrum of the lip.* (**a, b**) A cutaneous defect of the upper lip is fashioned into an A-shape. The long limb of the T-plasty is oriented in parallel with the lip vermilion

Purpose

The advancement technique is useful at all levels of soft tissue reconstruction.

Indication

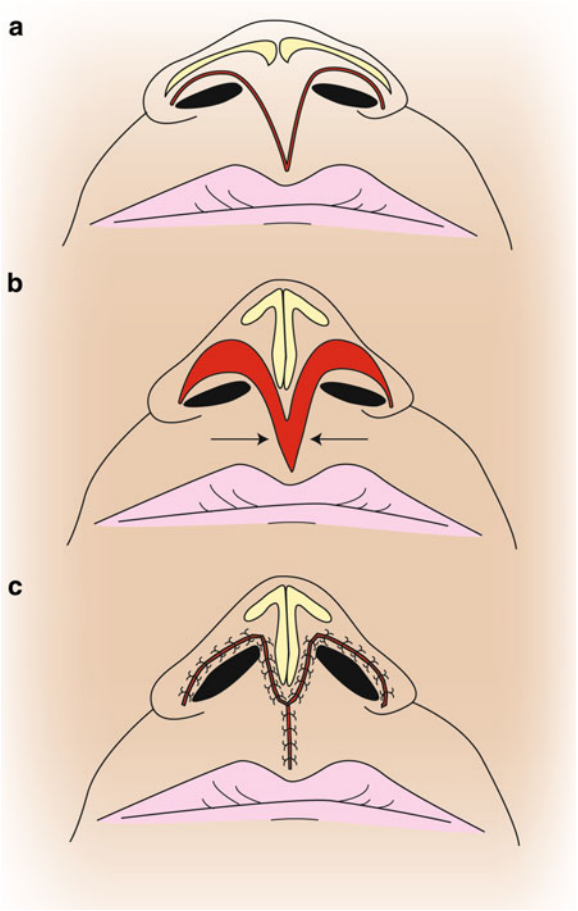
Advancement flaps can be created in many ways, the most basic of which is a simple linear closure. Classic examples of advancement flaps are the single pedicle, bilateral single pedicle, A-T, V-Y, and subcutaneous island pedicle. They can be applied throughout the face, especially in the lip, cheek, eyelid, and forehead regions. The relaxed skin tension lines in these regions allow for good camouflage. The advancement flap technique may be applied to both axial and random vascular pattern flaps (Honrado and Murakami 2005; Chu et al. 2010).

Simple Linear Closure

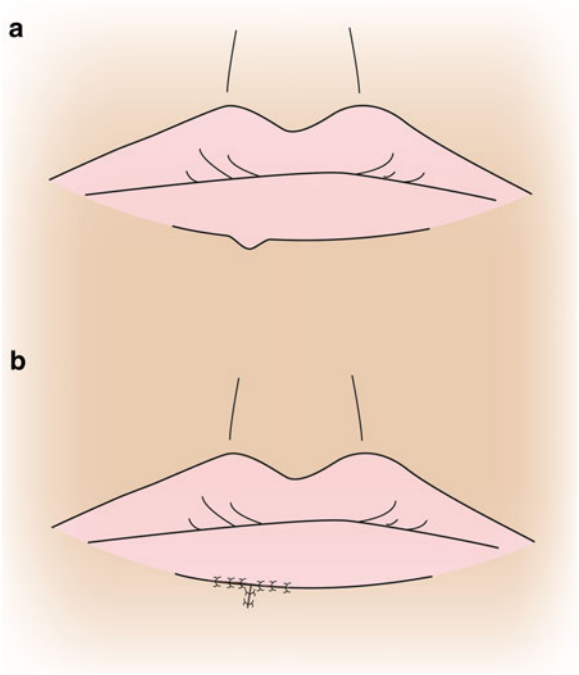
Proper and sufficient undermining may allow the surrounding soft tissue enough movement for successful primary simple linear closure. As with any local reconstruction, undermining of the involved soft tissues is recommended prior to committing to a flap plan. This allows one to explore the capabilities of the soft tissue character and thus plan for the most ideal reconstruction prior to making any obligating incisions. The more elastic and redundant the soft tissue, the more coverage can be obtained. This applies to all ▶ *local flap* reconstructions.

Single Pedicle Advancement Flap

The single pedicle advancement flap is the next most basic example of advancement after simple linear closure. After optimal undermining of the soft tissues,



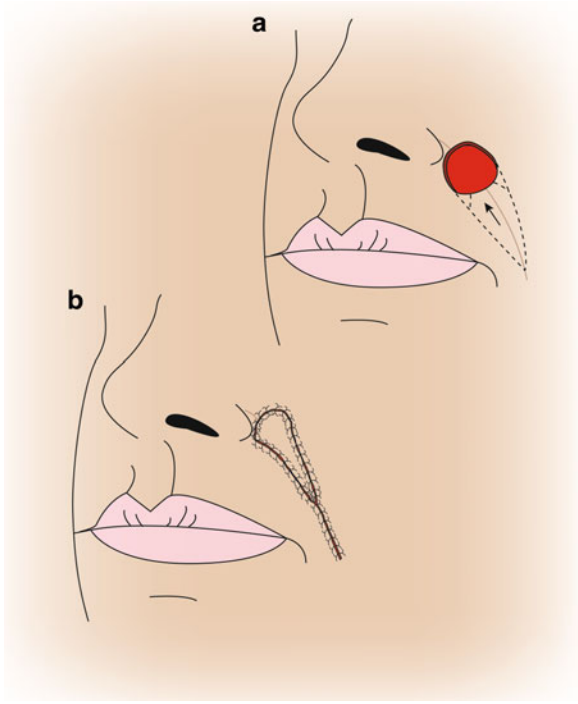
Advancement Flaps, Fig. 5 *V-Y advancement flap for columellar lengthening*. (**a, b, c**) The V-Y flap is useful for lengthening the columella in cleft lip nasal reconstruction. Central philtral skin is advanced superiorly into the base of the columella, while the medial edges of the resultant secondary defect at the philtrum are approximated to each other



Advancement Flaps, Fig. 6 *V-Y advancement flap for release of scar*. (**a, b**) The V-Y flap is useful for release of scar that distorts lip vermilion

parallel incisions are made, creating a flap with sliding action into the defect. A pure single pedicle advancement flap involves completely linear movement of tissue. The tissue pedicle is advanced in one direction toward and over the defect in a single vector. One margin of the defect becomes the leading edge of the flap. This technique is sometimes referred to as a U-plasty. The flap is then advanced and soft tissue redundancies or Burow's triangles are formed, due to the unequal lengths of the apposed tissue edges (Fig. 1). With single pedicle advancement flaps, two soft tissue redundancies or Burow's triangles are formed, one on each side of the pedicle. This should be contrasted to flaps with a rotational component where one single large Burow's triangle is formed. Unlike ▶ *rotational flaps*, in which a Burow's triangle must be excised at the base of the pedicle, the Burow's triangles that form in a pure advancement flap may be addressed anywhere along the length of the flap (Baker 2007). In these cases, one may then consider placement of the Burow's triangle in a relaxed skin tension line or in between facial subunits in order to better camouflage the excision. Although the formation and location of the Burow's triangle may be anticipated, it should not be excised until after the tissue has been advanced. Alternatively, if the Burow's triangle is small, it may be addressed by using a serial bisecting suture technique or serially "halving" the closure. This allows for even distribution of the redundant soft tissue over the greater length of the defect (Jackson 1997; Baker 2007).

Single pedicle advancement flaps are well suited for the forehead where the long horizontal incisions may be placed in or at least parallel to the native forehead creases, hairline, or eyebrows. They also camouflage

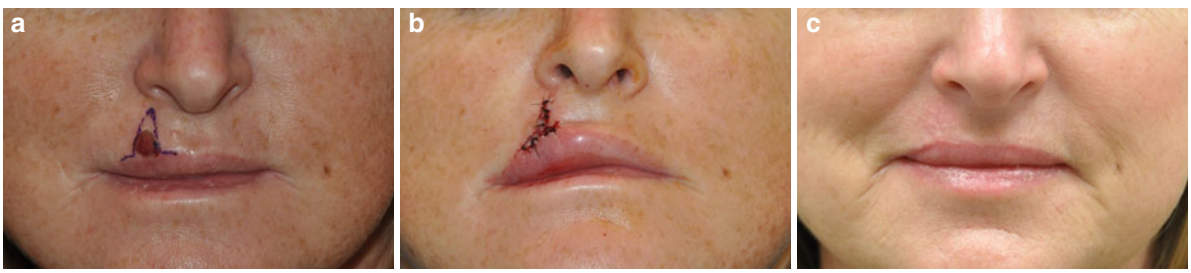


Advancement Flaps, Fig. 7 *Subcutaneous V-Y island advancement flap*. (**a, b**) An island of tissue adjacent to the defect is elevated with a centrally located subcutaneous pedicle. The island is advanced into the defect, creating a secondary defect, which is closed on itself

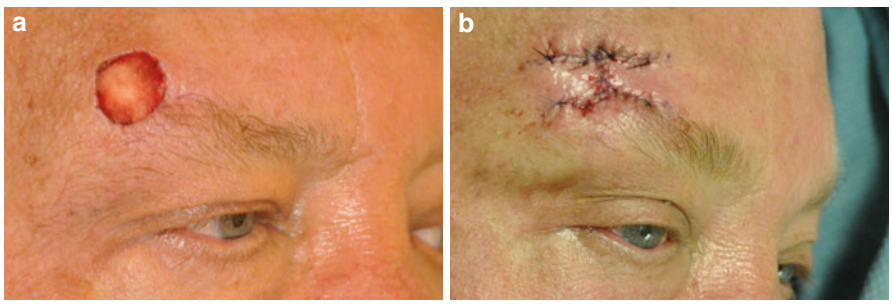
well in the lip, preauricular area, or medial cheek. The maximal length to width ratio of the single pedicle advancement flap is typically 3:1. Although the classic advancement flap includes two parallel incisions, modifications of this flap and incorporation of a rotational component are easy to design based on the position of relaxed skin tension lines and borders of aesthetic units.

Bilateral Single Pedicle Advancement Flap

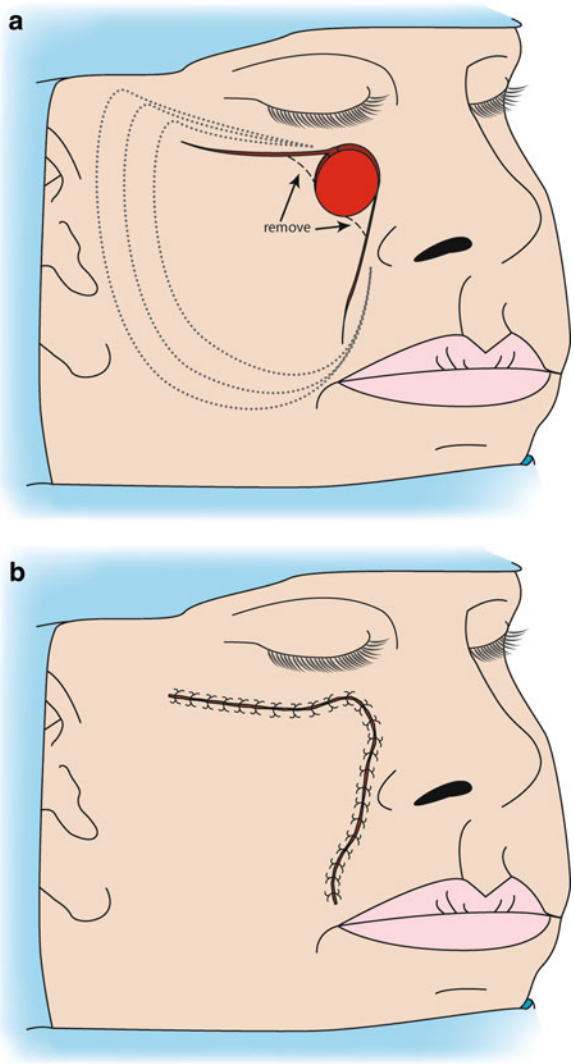
Bilateral single pedicle advancement flaps are useful when a unilateral or single pedicle advancement flap is insufficient for complete closure of a defect. The fundamental technique and principles are similar to those for the unilateral single pedicle advancement. In bilateral advancement, the two single pedicle advancement flaps are created on opposite sides of the defect and moved toward each other. Each flap covers a share of the defect, and the shares do not have to be equal. As stated previously, excision of any Burow's triangles should take place only after the advancement of tissue has been completed, and should be performed only if needed. The Burow's triangles may be addressed anywhere along the length of the flap (Fig. 2) and are ideally positioned with respect to aesthetic subunits. Like single pedicle advancement flaps, placement in forehead, hair-bearing regions, or between aesthetic subunits is also



Advancement Flaps, Fig. 8 *O-T flap, upper lip*. (**a, b**) A cutaneous malignancy is excised via Mohs micrographic surgery. The O-shaped defect is fashioned into an A-shape and T-plasty advancement performed. (**c**) Postoperative result at 4 months



Advancement Flaps, Fig. 9 *Bilateral unipedicle advancement flap*. (**a, b**) A cutaneous malignancy adjacent to the eyebrow is excised via Mohs surgery. The incisions of the bilateral advancement flap are oriented in the skin creases of the forehead



Advancement Flaps, Fig. 10 *Cheek advancement flap*. (**a, b**) Defects of the medial cheek are managed well with wide undermining and advancement. The amount of undermining and advancement-rotation depends on the elasticity and redundancy of the tissues as well as the size of the defect. The *dotted lines* demonstrate a few possibilities for the extent of undermining

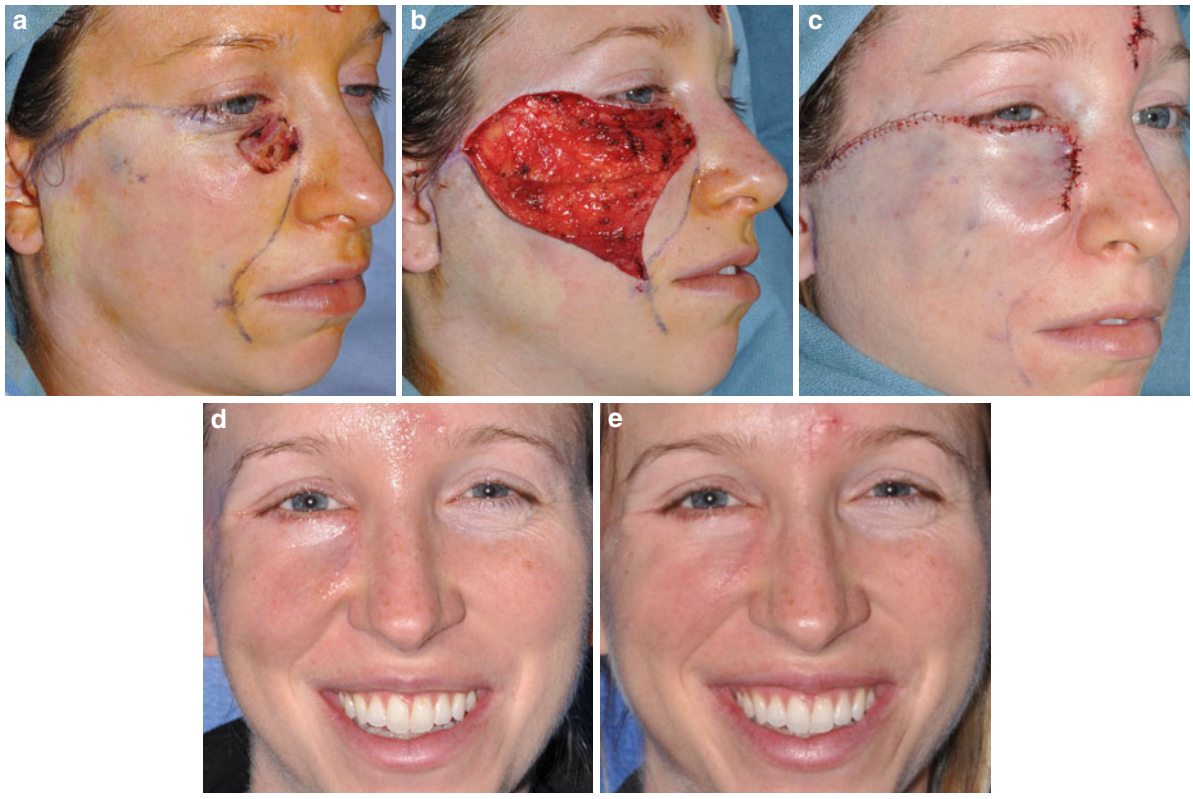
ideal here. A disadvantage of this flap is the potentially long suture line necessitating strategic placement of incisions. Since a bilateral single pedicle advancement flap may result in an H-shaped or T-shaped incision, they are sometimes referred to as H-plasty or T-plasty.

The A-T flap or O-T flaps are types of T-plasty and modifications of the bilateral advancement flap. T-plasty can be thought of as half of a bilateral advancement flap (Krishnan et al. 2005). In an A-T flap, a triangular defect is closed by advancing tissue from either side of the defect. In an O-T flap, the initial defect is circular and is ultimately fashioned into a triangular shape to be closed like an A-T flap (Fig. 3). Unlike the classic bilateral advancement flap where two parallel incisions are made, in T-plasty only one continuous bilateral advancement incision is made in an almost tangential fashion on one side of the defect. This ultimately forms the horizontal limb of the "T." A soft tissue redundancy forms on the opposite side of the circle and is removed via excision leaving an "A"-shaped defect. The sides of the "A" are then approximated to each other and this section then makes the vertical portion of the "T" suture line. The T-plasty is advantageous because it results in fewer final incision lines. It is particularly useful near the philtrum of the lip (Fig. 4) or in the forehead where the vertical limb can be camouflaged in the median or paramedian line. The horizontal limb would sit at the vermilion of the lip in the former, and in a forehead crease or brow margin in the latter (Sherris and Larrabee 2010). Studies into the biomechanics of the A-T flap have demonstrated that the height of the "A" should be twice the height of the original defect, with the tangential base incisions one defect diameter in each direction, and undermining to three times the diameter of the defect (Stevens et al. 1999).

V-Y Flap

This is a unique advancement flap in which a V-shaped flap is pushed into a defect or area in need of length, with primary closure of the donor area and a resultant Y-shaped suture line. Unlike other advancement flaps that require pulling the donor flap into the recipient site, the V-Y advancement flap achieves its advancement by pushing the donor flap into the recipient site (Baker 2007). This allows for the flap to move into the recipient site under very low tension. The secondary donor defect is then closed on itself, forming the common limb of the Y. It is very useful in two situations: First, when lengthening or release of a contracted scar is needed, and second, when used as a subcutaneous island pedicle flap.

The V-Y flap is extremely well suited for lengthening the columella in cleft lip repair (Baker 2007) (Fig. 5). A superiorly based V-shaped flap is created from the soft tissue of the central philtrum. The V-shaped flap is pushed superiorly, raising the height of the columella, and the remaining medial edges of this now secondary defect at the philtrum are approximated to each

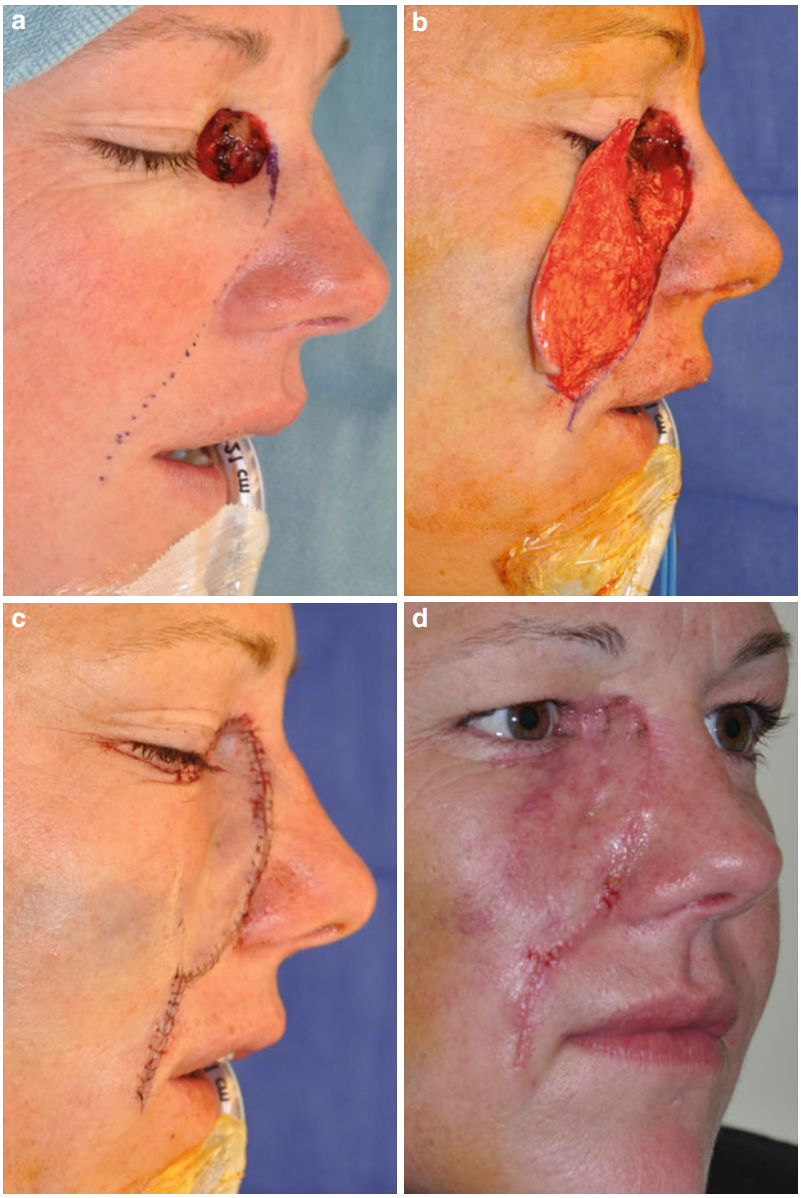


Advancement Flaps, Fig. 11 *Cheek advancement flap*. (**a**) A cutaneous malignancy is excised with a resultant medial cheek defect. (**b**) Wide soft tissue undermining allows for excellent mobility. The inferiorly based tissue flap is flipped inside-out in this photo. (**c**) The incision is extended out to the preauricular area to allow for adequate advancement. Deep tacking sutures to the maxillary periosteum reduce flap tension. (**d**) Postoperative result at 2 weeks. (**e**) Postoperative result at 2 months

other, transforming the incision line from a V to a Y. The V-Y flap is also helpful for releasing contracted scar that are causing distortion of facial structures (Fig. 6).

Alternatively, the V-Y flap can also be created as a subcutaneous island pedicle flap. This design is particularly useful in the medial cheek along the melolabial crease or on the nose at the alar groove or lateral tip (Leonhardt and Lawrence 2004; Li et al. 2006). Recently the V-Y flap has been utilized in the lower eyelid with good success (Marchac et al. 2009). Here, the nutrient pedicle consists of subcutaneous fat and possibly muscle and fibers of the superficial musculoaponeurotic system (Braun and Cook 2005). This subcutaneous pedicle may offer increased vascular supply when compared with alternative random pattern flap repairs. However, it is still a random pattern flap and thus is subject to the limits of tissue perfusion. In comparison to axial pattern flaps that have a named and preserved dominant nutrient vessel, the island pedicle flap remains at risk for flap necrosis and failure making careful operative planning and technique paramount (Borbely and Kovacs 1986).

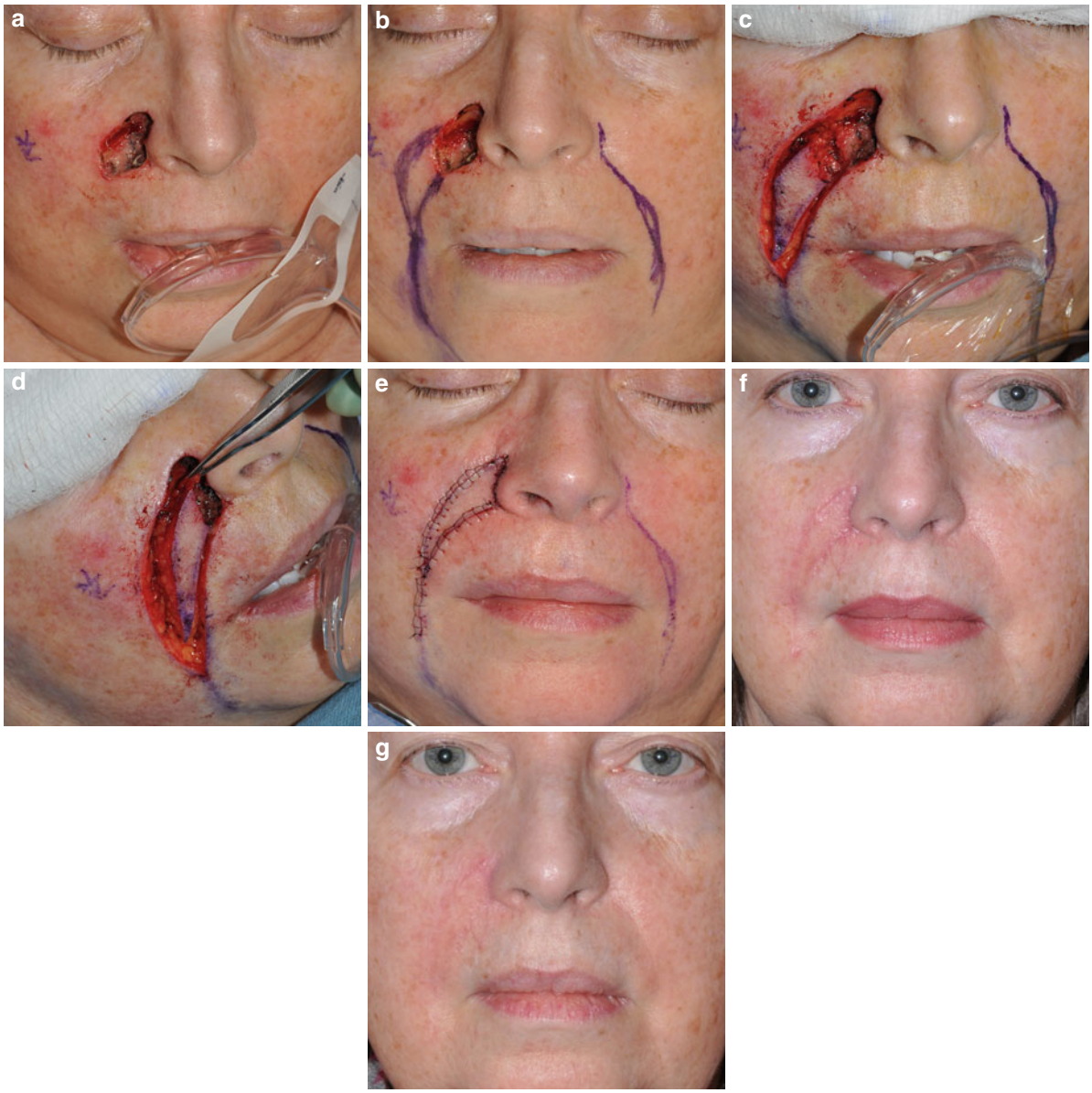
In the subcutaneous island design, a triangular island of tissue is fashioned to slide into the surgical defect (Fig. 7). One margin of the initial defect becomes the leading edge of the island of tissue. The opposite edge of the island is incised from the surrounding tissue in a V-shape. Thus, the island of skin is completely separated from the surrounding skin. When planning the flap design, the width of the leading border of the flap is equal to the diameter of the defect at its widest point and the length of the island is designed approximately twice the length of the defect. The tissues are undermined and a nutrient vascular pedicle remains attached centrally to the underlying subcutaneous tissues. This creates an island of skin



Advancement Flaps, Fig. 12 *Nasofacial Melolabial advancement flap*. (**a**) A cutaneous malignancy is excised with a resultant large defect of the medial canthal area. (**b, c**) An incision is created in the nasofacial sulcus down to the melolabial crease. A small back-cut is made at the level of the oral commissure for further advancement. After wide undermining the tissue is advanced into the defect. (**d**) Postoperative result at 1 week

that is free at its periphery but maintains an uninterrupted vascular supply from beneath. It is important not to separate the underlying subcutaneous tissue from the island of skin significantly, maintaining at least one third of the skin island intact with the underlying tissue to provide adequate vascularity. The triangular-shaped island is then advanced into the surgical defect creating a secondary defect at the apex of the flap. The limbs of the V-shaped secondary defect are approximated to each other in a linear fashion. Thus, the incision line is transformed from a V to a Y. As with any local flap, one should attempt to position the incisions in or parallel to relaxed skin tension lines or aesthetic subunit borders.

The advantages of the V-Y island pedicle advancement flap include the amount it can be advanced, up to 3–4 cm in the melolabial fold, and that it creates no Burow's triangles (Jackson 1997). The number of incisions created in this flap is thus minimized in comparison to other types of advancement flaps. Another advantage of the V-Y island pedicle advancement flap is that no additional tissue is excised.

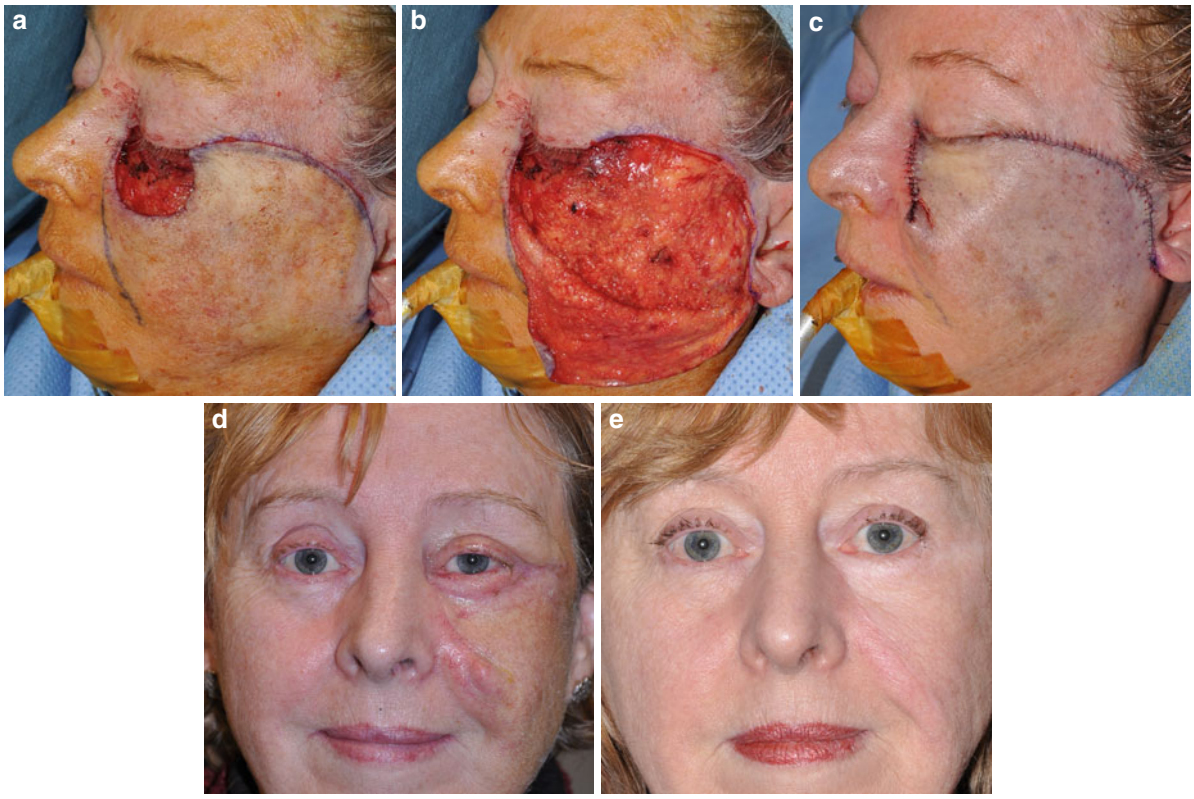


Advancement Flaps, Fig. 13 *Subcutaneous V-Y Island advancement flap, cheek.* (**a**) A cutaneous malignancy is excised with a resultant medial cheek defect near the melolabial fold and alar base. (**b**) The planned tissue island is oriented within the melolabial fold. (**c**) The island is elevated with an intact subcutaneous central pedicle. (**d**) Undermining of the island periphery in the subcutaneous plane allows for excellent advancement into the primary defect. (**e**) The incisions and secondary defect are closed in a V-Y fashion. (**f**) Postoperative result at 1 month. (**g**) Postoperative result at 3 months

Applications

Lip

In most cases, surgical defects up to one half the length of the lip may be handled with full-thickness excision and primary closure. Central defects of the upper and lower lip are usually very amenable to bilateral single pedicle advancement flaps or T-plasty (A-T or O-T) flaps (Fig. 8). The incisions are made along the vermilion border and a second, parallel incision may be made in the mental crease for lower lip defects, or just below the nasal sill for upper lip defects if needed.



Advancement Flaps, Fig. 14 *Eyelid advancement flap*. (**a**) A cutaneous malignancy involving the lower eyelid and cheek is excised leaving a large resultant defect. A transverse subciliary incision is made just beneath the eyelash line along the length of the lower eyelid. A musculocutaneous flap is created from the entire eyelid with the incision extending laterally past the lateral canthus. (**b, c**) Wide undermining allows for excellent mobility and advancement. Note the retained Burow's triangle of the lower medial cheek at this stage. (**d**) Postoperative result at 2 weeks, prior to removal of Burow's triangle at 4 weeks. (**e**) Postoperative result at 1 year

Forehead

Pure advancement flaps can be applied very well in the forehead. The multiple horizontal lines of the relaxed skin tension lines are favorable for either unilateral or bilateral single pedicle advancement (Fig. 9).

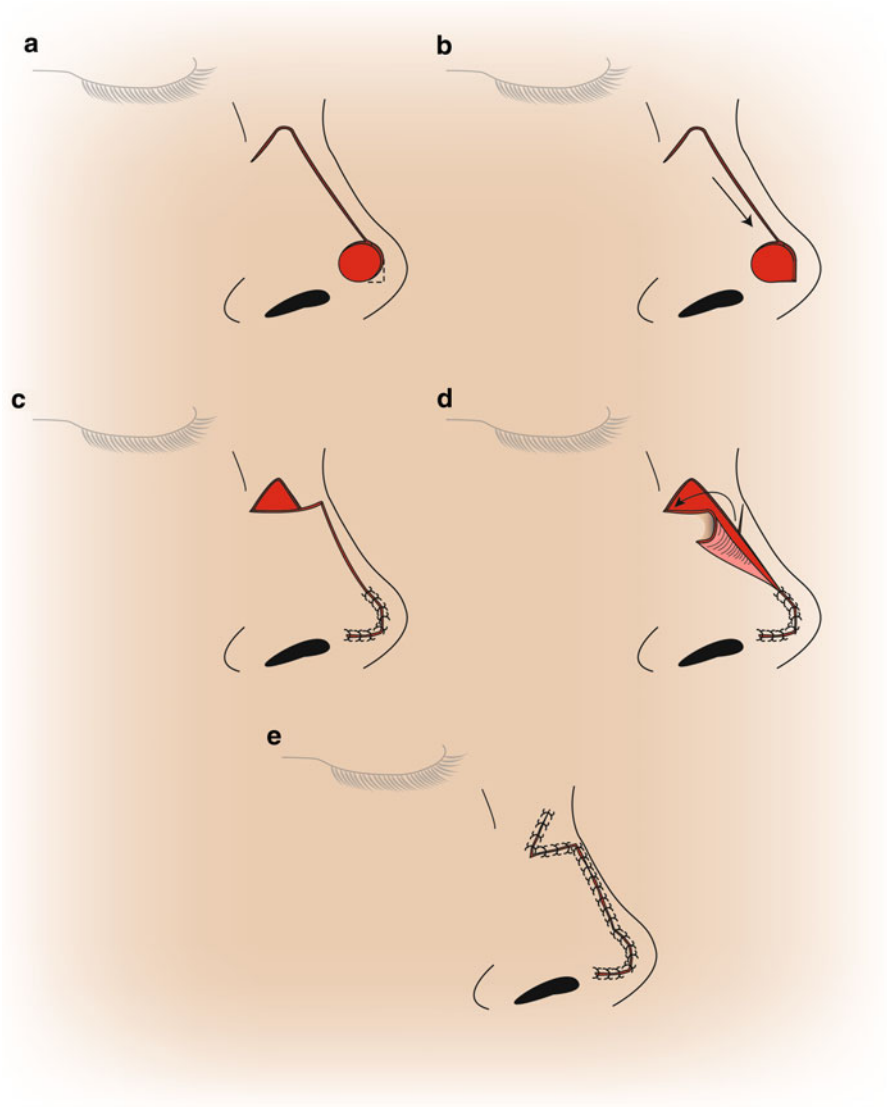
Cheek

Advancement flaps work well in the cheek, where increased elasticity and mobility allow for wide undermining and closure of larger defects of the medial cheek (Figs. 10 and 11). There is an element of rotation in most cheek advancement flaps. Larger defects of the cheek may require further recruitment of tissue turning the cheek advancement into a cervicofacial advancement flap (Chu and Byrne 2009). For defects close to the nasofacial sulcus, flaps under higher tension may be tacked to the periosteum of the maxilla or nasal bones in order to decrease tension at the incision and avoid dehiscence. If necessary, an incision in the nasofacial sulcus may be extended inferiorly, down into the melolabial crease (Fig. 12). Also, consideration must always be given to avoiding excessive inferior pull on the eyelid to prevent ectropion.

The V-Y subcutaneous island pedicle advancement flap is ideal for reconstruction of medial cheek defects near the melolabial fold and alar base. The triangular-shaped island is fashioned with the triangle's apex in the melolabial fold and the triangle's base at the inferolateral border of the defect. The primary direction of advancement is superiorly, and within or parallel to the melolabial fold (Fig. 13).

Eyelid

A lower eyelid defect limited to the anterior lamellae alone, and measuring less than or equal to 0.5 cm in diameter may heal well by secondary intention (Sherris



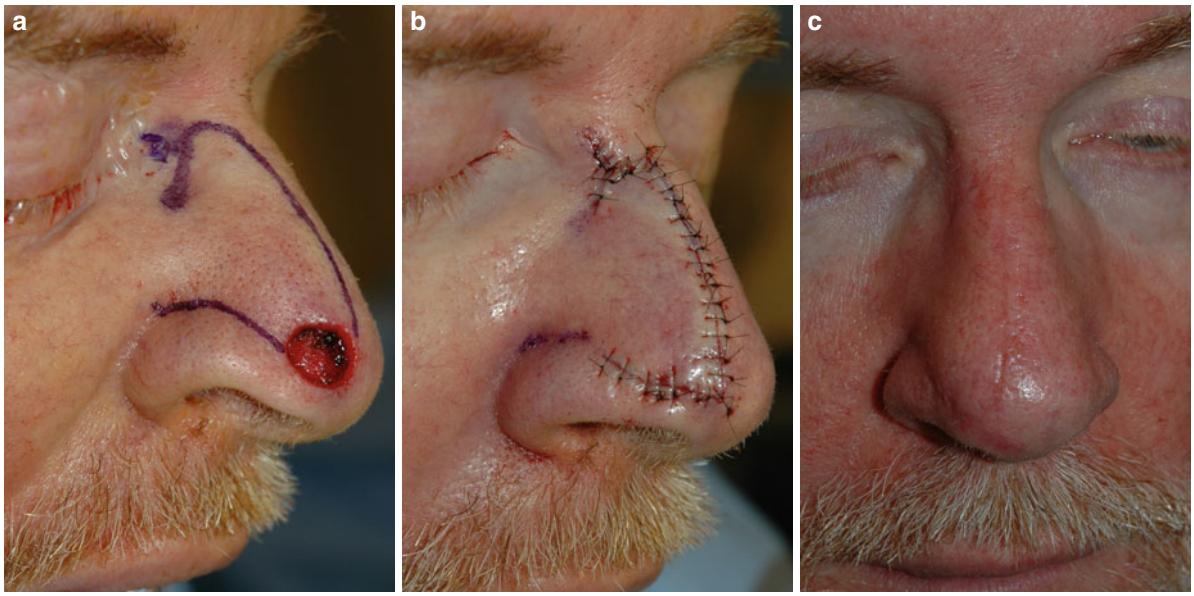
Advancement Flaps, Fig. 15 *Sliding nasal advancement flap with Z-plasty closure of secondary defect*. (**a**) The incision is planned along the nasal dorsum with a back-cut oriented toward the cheek and medial canthal area. (**b**) After undermining, the flap is advanced into the defect. The recipient site margin is angulated at the corner in order to prevent a pincushion deformity. (**c, d, e**) The flap is advanced, creating a secondary defect at the area of the back-cut which is managed here with a modified z-plasty

and Larrabee 2010). If the defect is greater than 0.5 cm, an advancement flap may be considered for repair. A transverse subciliary incision is made 2 mm beneath the eyelash line along the length of the lower eyelid (Khan 1991). A musculocutaneous flap is created from the entire eyelid. One must dissect the musculocutaneous flap free of any attachments to the orbital septum beneath so as to avoid any distortion of the eyelid or fat pads. For larger defects, it may be necessary to extend the incision laterally past the lateral canthus to utilize skin from the temple, or medially along the nasofacial sulcus to utilize the medial cheek skin (Fig. 14).

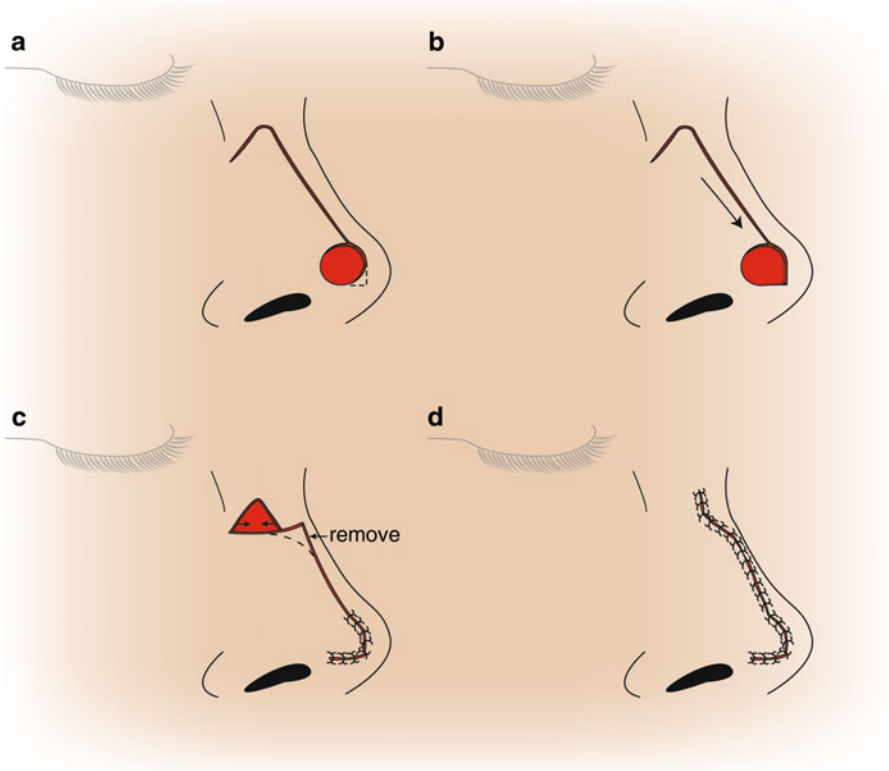
Marchac et al. has recently used the V-Y advancement flap in a series of lower eyelid reconstructions with favorable results (Marchac et al. 2009).

Nose

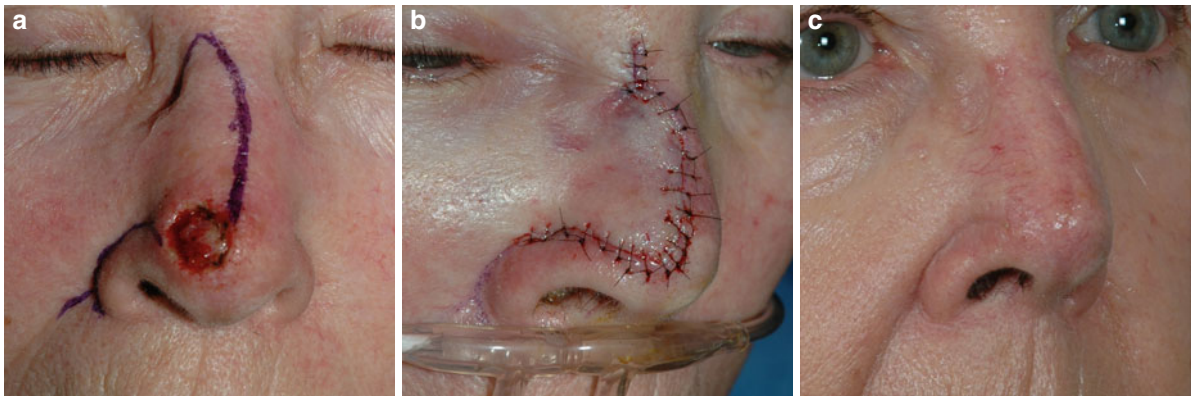
Typically, the nasal skin offers poor laxity and redundancy. But for small dorsal, sidewall, or tip defects a modified unilateral advancement flap utilizing recruitment from the nasal dorsum or glabella may be considered (Cervelli et al. 2007). This can be thought of as half of a T-plasty. If restricted to the nasal dorsum it is more appropriately called a nasal dorsal flap or sliding nasal advancement flap (Baker 2007;



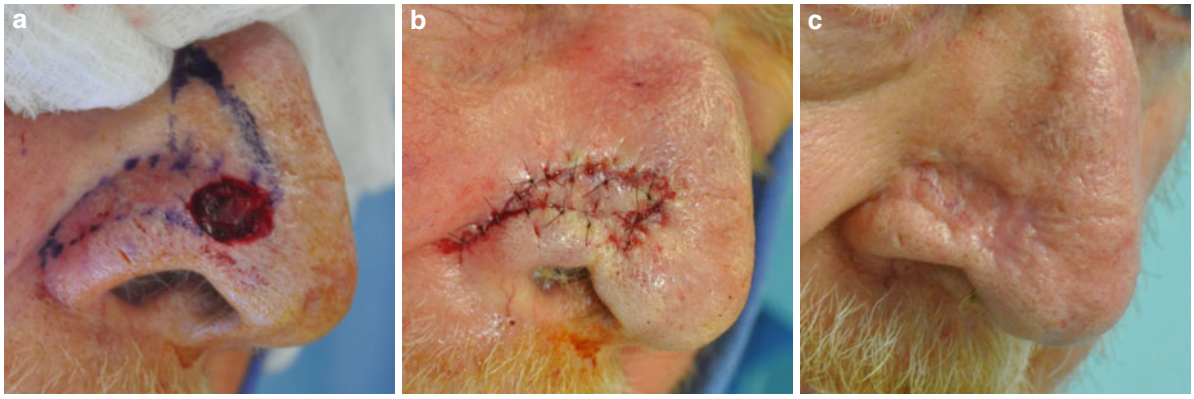
Advancement Flaps, Fig. 16 *Sliding nasal advancement flap with Z-plasty closure of secondary defect.* (**a**) A cutaneous malignancy is excised from the lateral nasal sidewall and tip area. (**b**) Final result. (**c**) Postoperative result at 2 months



Advancement Flaps, Fig. 17 *Sliding nasal advancement flap with V-Y closure of secondary defect.* (**a**) The incision is planned along the nasal dorsum with a back-cut oriented toward the cheek and medial canthal area. (**b**) After undermining, the flap is advanced into the defect. The recipient site margin is angulated at the corner in order to prevent a pincushion deformity. (**c, d**) The flap is advanced, creating a secondary defect at the area of the back-cut which is managed here with a V-Y closure



Advancement Flaps, Fig. 18 *Sliding nasal advancement flap with V-Y closure of secondary defect*. (**a**) A cutaneous malignancy is excised from the lateral nasal sidewall and tip area. (**b**) Final result. (**c**) Postoperative result at 2 months



Advancement Flaps, Fig. 19 *Subcutaneous V-Y island advancement flap, nose*. (**a**) A cutaneous malignancy is excised with a resultant defect in the anterior alar groove. (**b**) Final result. (**c**) Postoperative result at 5 months

Murakami 2010). A superior back cut toward the medial canthus or cheek may be necessary depending on the size of the defect and tissue laxity. This creates a secondary defect that can be managed with either a z-plasty as preferred by Murakami (Figs. 15 and 16) or V-Y technique (Figs. 17 and 18). Murakami advises a defect to be less than or equal to 1 cm if one is to consider this technique. When tissue is recruited up to the glabella, it can also be called a glabellar flap as originally described by Rieger (Rieger 1967; Sherris and Larrabee 2010). In this case, Baker advises the defect be less than or equal to 2–2.5 cm depending on the conditions. These advancement flaps also have a pivotal element to them, essentially making them advancement-► *rotation flaps*. A curvilinear incision adds more rotation, allowing greater tissue length to be recruited. As with all local flaps, respecting the subunit boundaries in planning the incisions allows for a more favorable aesthetic outcome.

The subcutaneous island pedicle advancement also works well for defects 1.5 cm or less in the anterior alar groove or lateral tip (Hauben 1989; Leonhardt and Lawrence 2004). Here, the subcutaneous pedicle consists of subcutaneous fat and nasalis muscle (Fig. 19).

Contraindications

Advancement is challenging in areas of low elasticity or redundancy. The scalp is a classic example of tissue with poor mobility and inability for recruitment. Rotation is necessary in the scalp to achieve closure and often in pinwheel or multiple fashion. See ► Rotational Flaps.

Advancement flaps are also contraindicated in large defects where the pull necessary for adequate closure creates anatomic distortion, such as the lower lid, nasal ala, and oral commissure. Ectropion and excessive nasal retraction should be avoided at all costs. Asymmetry of eyebrows or hairline although not ideal may be tolerated in some individuals.

Advantages/Disadvantages

Advancement flaps are an essential part of the facial plastic surgeon's armamentarium for cutaneous repair. They are advantageous in their versatility to be used in the repair of a wide variety of surgical defects at almost any anatomic site. Advancement flaps offer several major benefits, some of which are common to other types of flaps. Most importantly, advancement flaps are a relatively simple way to reduce tension on the incision, which reduces the risk of scar widening and wound breakdown. The V-Y subcutaneous island pedicle flap in particular, offers a high degree of tissue advancement and few incisions. Advancement flaps can also offer favorable cosmetic results with excellent matching of texture, color, and thickness since tissue is recruited locally. With careful planning, the resultant scars can be well camouflaged within natural aesthetic subunits. Disadvantages do exist. Advancement flaps should only be used in areas with laxity or redundancy. Relative to other types of flaps, they may provide comparably less movement, and as with any ► *local flap* closure, they can result in noticeable scars.

Acknowledgment The authors would like to recognize the artistic talent of Eden Palmer. We thank Eden for contributing her illustrations to this work.

Cross-References

► Local Flaps
► Rotational Flaps
► Transposition Flap

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Advancement Technique

► Advancement Flaps

Advancement Tissue Flap

► Advancement Flaps

Aesthetic Subunits of Nose

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Definition

The aesthetic subunits of the nose are regions defined by light and shadow which are often related to underlying histology and anatomy. The subunits consist of three paired units – the ala, soft tissue facets, and sidewall, as well as three unpaired units – the dorsum, tip, and columella.

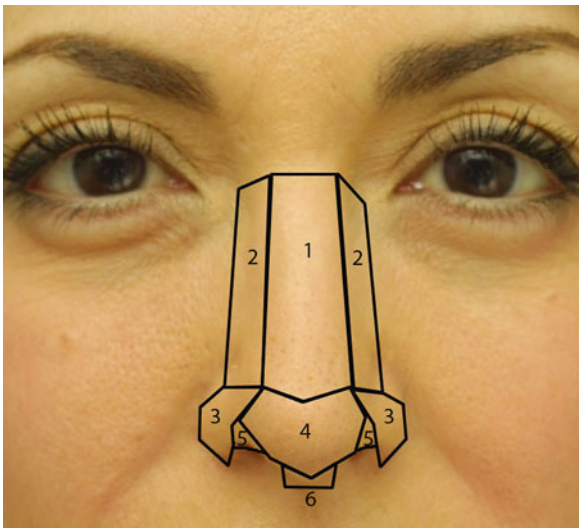
Background

The concept of dividing the nose into subunits is useful in aesthetic evaluation of the nose as well as reconstruction of nasal defects. The division of the nose into aesthetic subunits is a continuation of the division of the entire face into aesthetic units. At the most basic level, reconstruction of facial defects aims to replace like with like. In other words, a tissue defect of the face should be replaced or repaired with tissue of a similar color, texture, shape, volume, and consistency. The observation that the face could be divided into units based upon characteristics of the skin and the underlying tissue, as well as transition lines between units based upon hairlines and preexisting skin creases, was proposed by Gonzalez-Ulloa et al. (1954) in the 1950s. This idea was extended to the nose, itself an entire facial aesthetic unit, by Burget and Menick (1985) who together described the basic subunits of the nose that are still in use today.

Basic Characteristics

The division of the nose into subunits is based upon the topography of the nose and by corollary the soft tissue, cartilaginous, and bony components underlying the skin (Fig. 1). The borders of the subunits can be visualized using properly angled light and the resultant shadows delineating the transition between subunits. The nose is divided into three paired and three unpaired subunits. The paired subunits are the lateral walls, alar lobules, and soft triangle facets. The unpaired midline subunits are the dorsum, the tip, and the columella. While the original work on facial aesthetic units was based upon skin creases and histology, nasal subunits are based on underlying structures. In the instance of the nasal tip subunit, the underlying domal portion of the LLCs creates the framework that results in what is visualized as the subunit (Jewett 2007) – in this case the limits of which are the columella inferiorly and the supratip depression superiorly where the nasal dorsum subunit begins. The lateral limit of the nasal dorsum subunit corresponds with the suture line between the nasal bone and the frontal process of the maxilla. Superiorly it ends with the beginning of the forehead aesthetic unit at the nasion. The nasal sidewall subunit begins medially with the nasal bone/frontal process of maxilla suture line as previously described and ends with the cheek-nose junction. The inferior limit of the nasal sidewall is the superior limit of the alar subunit defined by the alar crease. This region is characterized by an abundance of fibrofatty tissue and a lack of underlying cartilaginous framework (Jewett 2007). A small area of soft tissue situated inferiorly between the alar and nasal tip subunits is known as the soft triangle facet.

Since aesthetic nasal subunits are defined by an area of skin and its associated underlying soft tissue and structures, it is useful to describe the soft tissue and structural anatomy of the nose. The bony structure of the nose consists of paired nasal bones forming the bony dorsum of the nose; the frontal process of the maxilla on either side forms the bony nasal sidewall. Superiorly, the nasal bones and



Aesthetic Subunits of Nose, Fig. 1 Subnits of the Nose. 1 Dorsum, 2 Sidewall, 3 Ala, 4 Lobule, 5 Soft triangle facet, 6 Columella

frontal process of the maxilla articulate with the frontal bone. Inferiorly, the nasal bones articulate with the superior limit of the upper lateral cartilages (ULC), which are continuous with the cartilaginous septum medially. The caudal one third of the nose is composed of the nasal ala, tip, and columella. The cartilaginous framework of this region is formed by the paired lower lateral cartilages (LLC). The lower lateral cartilages can be subdivided into three crura – the medial, intermediate (or middle), and lateral crura. The length, strength, and shape of the LLCs are most important to tip support and the external appearance of the ala and nasal tip. The LLC attachments to the caudal septum inferiorly and inferior border of the ULC's superiorly provide additional major tip support.

Nasal subunits are convex, flat, or concave. Often, a convex subunit is bordered by a flat or concave subunit. The surface topography and its variation plays as important a role in a subunit as does its underlying anatomy. The greater the disparity of the surface topography between adjacent subunits, the better scars and flap transitions are hidden at their junctions. The convex subunits are the tip and ala. The concave subunit is the soft triangle. The dorsum and columella are either flat or convex. The sidewall is either flat or concave.

Clinical Correlates

The concept of nasal subunits is important when considering the reconstruction of nasal defects. Like in facial defects, it is recommended that incisions be placed along borders of subunits to camouflage the resultant scar. Burget and Menick suggested that defects involving greater than 50% of a subunit should be repaired with complete resection of the subunit for superior aesthetic outcomes, whereas defects of less than 50% could undergo satisfactory reconstruction without removal of healthy tissue within the affected subunit (Burget and Menick 1985). There are many reconstruction options and techniques available which are beyond the scope of this chapter.

The other major contribution of Burget and Menick is that the reconstructive surgeon may take advantage of the healing characteristics of flaps and grafts when repairing a total subunit defect. Flaps generally heal by contracting centripetally as they heal, becoming more convex; grafts heal by flattening further as they contract. Scars heal by contraction, generally depressing as they heal. Flaps are best used to reconstruct naturally convex subunits (tip and ala) and may be used to repair flat subunits (dorsum, columella). Full thickness skin grafts effectively repair flat or concave subunits (soft triangle, sidewall). There is no role for split-thickness skin grafts in nasal surface reconstruction. The "50% rule" takes best advantage of these healing characteristics and avoids scar depressions at the edges of the repair within a subunit.

Although adhering to the "50% rule" and other tenets of reconstruction based upon nasal subunits is accepted, other authors have advocated for alternative approaches to address some of the drawbacks of the subunit approach, such as the sacrifice of healthy tissue. Moreover, some very effective reconstructive techniques, such as the bilobed flap, necessarily violate subunit boundaries. Rohrich et al. encourage maximal preservation of healthy tissue (Rohrich et al. 2004). They advocate for the preservation of healthy tissue within a subunit when the scar can be adequately camouflaged within the subunit. This can often be achieved with scar revision using ablative procedures such as dermabrasion. Other authors advocate for modification of the subunit method based on patient-specific factors such as skin texture, color, contours,

actinic damage, and medical conditions (Singh and Bartlett 2003).

The aesthetic subunits of the nose are based upon the histology and anatomy underlying the skin. Reconstruction of defects based upon these boundaries can often result in improved aesthetic results. Although adhering to the rule of nasal subunits can be helpful in the planning for reconstruction of nasal defects, modification or abandonment of the subunit approach is acceptable if a superior aesthetic outcome can be achieved when doing so.

Cross-References

- ▶ Nasal Reconstruction
- ▶ Nasal Valve
- ▶ Polly Beak Deformity

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Age-Related Hearing Loss

- ▶ Presbycusis

Ageusia

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Definition

The complete loss of taste resulting from radiation therapy to the head and neck.

Cross-References

- ▶ Dental Evaluation in Head and Neck Cancer Patient

Aggressive Papillary Middle Ear Tumors (APMET)

- ▶ Endolymphatic Sac Tumors

AIDS

- ▶ Head and Neck Manifestations of AIDS

Airway Anomalies in the Neonate

- ▶ Congenital Laryngeal and Tracheal Anomalies

Airway Management

- ▶ Emergency Airways

Airway Management of Otolaryngologic Patient

► Anesthetic Techniques for Otolaryngologic Patient

Alar Notching

► Alar Retraction

Alar Retraction

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Synonyms

Alar notching; Rim retraction

Definition

Alar retraction is defined as a cephalic elevation of the alar margin, which may result in excess nostril show.

Etiology

Alar retraction can be congenital or acquired. Congenital alar retraction may be present as an isolated familial trait or may present as part of a larger craniofacial syndrome. Facial clefts can be associated with alar hypoplasia (Dutton and Bumsted 2001).

Acquired alar retraction may be a post-traumatic or postsurgical complication. Trauma to the lower nose may result in tissue loss or unfavorable scarring and alar retraction. Postoperative alar rim retraction is a described complication following nasal skin cancer repairs and primary and secondary rhinoplasty. Iatrogenic alar rim retraction is typically due to over-resected or malpositioned lower lateral crura. The frequency of alar retraction after primary rhinoplasty ranges from 7% to 14%. Nasal alar excision, performed in skin cancer resection, may lead to scarring and resultant alar rim retraction (Becker and Park 2008).

Anatomy

The nasal alae function as the superior and lateral walls of the nostril and frame the external nasal valve. The ala contains skeletal muscle and fat sandwiched between nasal mucosa and thick, sebaceous skin. The anterior and superior borders of the ala are supported by the lower lateral cartilage. The nostrils contain a dilator and constrictor muscle; however, the muscular constrictor naris serves little function. The major alar muscle is the dilator naris, which originates on the lower lateral cartilage and inserts into the skin. Contraction of the dilator naris helps to open the nasal passage.

The alae are compliant and delicate. During respiration, the alae are mobile. They may narrow and flare during the respiratory cycle. The alae may be easily distorted during surgery as they lack an osseocartilagenous framework. Scarring and narrowing of the ala following surgery may compromise the external nasal valve function (Bruintjes et al. 1998).

Pathophysiology

Primary alar retraction is a result of abnormal development of the lower lateral cartilages, structures that help to define the alar rim. Long, arched, as well as cephalically malpositioned lower lateral cartilages can cause the alar rim to appear retracted.

Acquired alar retraction is among the most common complications encountered after rhinoplasty. The lower lateral cartilages may be resected to narrow and define the nasal tip; however, over-resection of the lower lateral cartilages negatively impacts alar aesthetics and function. Alar retraction, pinching, bossae, asymmetry, and even nasal valve collapse can occur if less than 6 mm of the lateral crura remain

after excision (Myers 2008). In these cases, scarring outweighs the cartilaginous structural support system. Excision of vestibular mucosa in primary rhinoplasty may also contribute to scar contracture (Becker and Park 2008).

There is a subset of people with thin alar rims who may experience alar contraction despite the appearance of adequate lower lateral cartilages. Becker et al. notes that 20% of the population has a thin alar rim and advises cephalic resection be avoided in this population to minimize alar retraction and external nasal valve collapse (Becker and Park 2008). The thin alar rim is unable to withstand the strong contractive forces of postoperative scarring.

Alar retraction from excess lateral crura excision can be further complicated by alar notching if combined with inappropriate interdomal suturing, vertical dome division, upper lateral cartilage resection, and scroll resection (Gruber et al. 2010; Gubisch and Eichorn 2009). These maneuvers can cephalically distort the lower lateral cartilages leading to increased alar retraction. Caudal alar cartilage excision is risky and may produce unwanted alar contouring and even notching.

Clinical Evaluation

Though some patients may seek isolated alar retraction repair, each surgical candidate should undergo a full preoperative rhinoplasty evaluation. The evaluation includes presurgical history, physical examination, and preoperative photography.

A preoperative evaluation of alar retraction is essential for surgical planning. A proper history includes discussing the cause of the alar retraction, the expectations of outcome, and any past attempts at treatment or therapy. The patient's psychiatric health and surgical candidacy should be considered. A review of social history should identify tobacco and cocaine abusers, as these both may significantly negatively impact surgical outcomes. Physical exam should identify alar skin thickness, lower lateral cartilage support, overall symmetry, nostril shape, alar base proportion and columella to alar rim proportion. Sites of previous nasal surgery such as rhinoplasty and septoplasty should be examined. A shortage of cartilage or skin prompts the surgeon to consider potential donor sites for graft harvest. The most common donor sites used in alar retraction repair include the nasal septum, the auricle, and the rib.

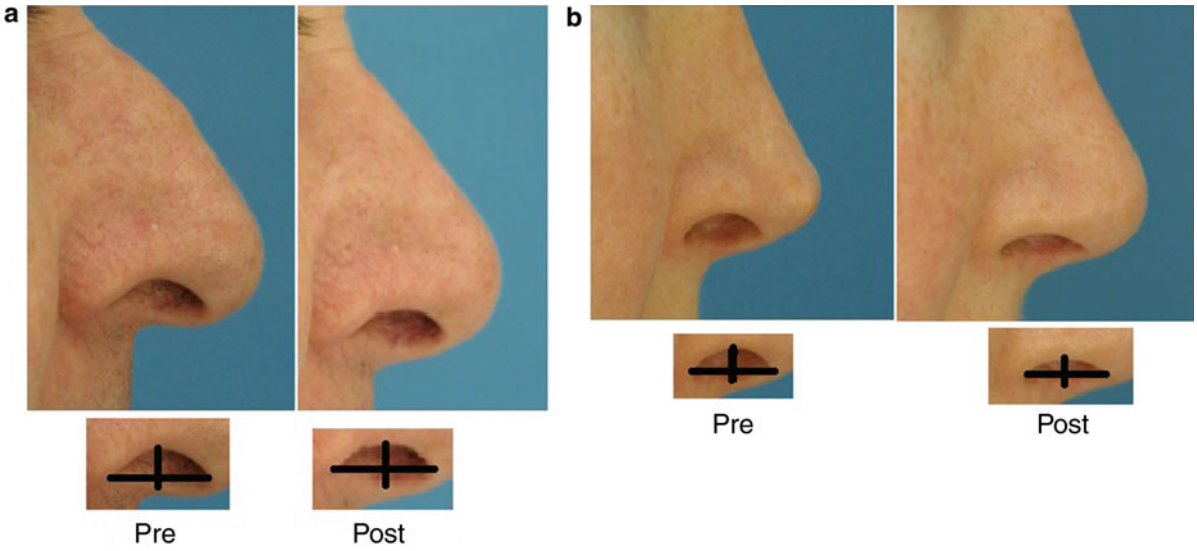
The photographic frontal and base views allow for an appreciation of alar symmetry, alar position, nostril shape, and tip shape. The frontal view of the alar rim should show a gentle curve, which is classically described as a "gull in flight" (Rees 1980). An exaggeration of this curve is suggestive of alar retraction. Alar rim retraction is evaluated best on the lateral view. The relationship of the alar rim to the columella must be assessed for proportionality. Normally, the columella is 2–4 mm below the rim of the ala, which is known as columellar show (Papel 2009; Becker and Park 2008). Deciding on the etiology of the ala-columellar disproportion is essential. Primary alar retraction leads to excess columellar show; however, primary columellar excess may masquerade as alar rim retraction. This distinction is essential because alar rim retraction and columellar excess are managed differently. Gunter and Rohrich explain that by drawing a line from the anterior most point of the nostril to the posterior most point of the nostril, the normal alar-columellar relationship can be evaluated. The distance from the most superior portion of the alar rim to this line should be equal to the distance from the most inferior area (see Fig. 1). If the superior segment is larger, alar retraction exists. If the inferior segment is larger, there is columellar excess (Gunter and Rohrich 1996). Ultimately, the preoperative evaluation should gauge the severity of the alar retraction to allow for a surgical plan.

Indications

Indications for the surgical correction of alar rim retraction include aesthetic deformity and nasal airway obstruction secondary to external nasal valve collapse.

Contraindication

Contraindications to alar rim repair are the same as those for rhinoplasty. Patients with poor general health, unstable psychiatric care as well as unrealistic expectations should be counseled appropriately. Patients with recent rhinoplasty should be encouraged to wait 1 year to evaluate the final outcome prior to intervention. The risk of necrosis and cartilage



Alar Retraction, Fig. 1 *Above – Operative Photos:* (**a**) *Left:* Male Preoperative; note alar retraction. *Right*: Male Postoperative, treated with rim grafts to force the nostril edge inferiorly. (**b**) *Left*: Female Preoperative; note alar retraction. *Right*: Female Postoperative, treated with an alar batten graft to force the rim inferiorly and support the deficient lateral crus. *Below – Alar-Columellar Relationships*: After a horizontal line connecting the anterior and posterior most segment of the nostril is determined, a perpendicular line connecting the most superior and inferior aspect of the nostril is drawn. Comparing the superior and inferior segments allows for determination of the alar-columellar relationship. In both cases, the preoperative evaluation shows superior limb excess indicating alar retraction

composite graft failure is increased in patients who abuse tobacco as well as cocaine. Though smoking is not an absolute contraindication, smoking cessation counseling should be included in the preoperative dialogue.

Therapy

Though the primary therapeutic goal is to improve alar retraction, the surgeon may address additional goals such as alar notching, nasal valve support, and alar symmetry. The major therapeutic modalities include nonsurgical injections and surgical repair, which often involves the placement of an autologous graft.

Nonsurgical Treatment

Although dermal fillers may produce minimal improvement of very mild alar retractions, they are painful and of marginal benefit as long-term solutions.

Surgical Treatment

Surgical therapy to correct alar rim retraction involves cartilage repositioning or grafting. The most common grafts include alar batten grafts, alar rim grafts, and composite grafts. Autologous grafts are preferable and are often harvested from the nasal septum, auricle, or rib. Synthetic grafts are rarely chosen due to the increased risks of extrusion and infection. Grafts serve both a structural and volume-occupying purpose. Grafts lower the retracted alar rim, support the nasal valve, and improve the contour and symmetry of the alar rim (Boahene and Hilger 2009).

For mild to moderate deformities, alar batten grafts and alar rim grafts, also known as marginal grafts, are considered. Alar batten grafts support the alar sidewall and can displace the alar rim downward. Traditionally, alar batten grafts may be placed cephalical or caudal to the lateral crus. For the purpose of treating alar retraction, the caudal edge of the graft is placed caudal to the caudal edge of the lateral crus. Alar batten grafts are harvested most commonly from septal cartilage, with auricular and costal cartilage as alternate choices.

The technique of alar batten graft placement must be given special consideration in patients with comorbid deformity in addition to alar retraction. If alar retraction is combined with a pinched supra-alar tip, the convex side of a contoured cartilage graft can be oriented laterally to widen the nasal tip. If the patient suffers from comorbid nasal valve collapse, nasal

valve support can be improved by extending the alar batten graft over the bony aspect of the pyriform aperture (Fig. 1b). In patients with short nasal length, an alar batten graft may be combined with an extended spreader graft.The spreader graft lengthens and caudally rotates the nose while the alar batten graft caudally displaces the alar cartilage.

For mild alar retraction (less than 2 mm), alar rim grafts are good options (Fig. 1a). They can straighten alar notching as well as prevent future retraction. The alar rim graft is inserted in a pocket fashioned along the rim, caudal to the marginal incision. The leading anterior edge of the graft may be softened by gently crushing with a Brown-Adson, forceps. It can be stabilized in its pocket by sewing it to the marginal incision. Alar rim grafts can be used alone or in combination with alar batten grafts.

When alar retraction occurs with cephalic malposition of the lateral crus, then caudal repositioning of the crus is the best treatment choice. This may be performed with or without further stabilization of the lateral crus with either alar batten (overlay) grafts or lateral crural strut (underlay) grafts. If the retraction is not sufficiently improved, alar rim grafts may then be placed for additional correction.

There are a subset of patients with severely retracted ala who will not be corrected by the combination of an alar rim and alar batten graft; such patients require more significant grafting. Auricular composite grafts, composed of skin and cartilage, add tissue bulk and downwardly displace the alar rim. The graft is harvested from concha cymba. To insert the graft, the intranasal vestibular mucosal is incised and the graft is placed in a surgically formed pocket that forces the alar rim caudally. The skin replaces the deficient, scarred vestibular skin and the cartilage provides structural support that prevents cephalic rotation of the alar margin with healing. The graft is suture-secured at its periphery with dissolvable sutures, but also sutured through-and-through the lateral alar skin to tightly adhere the graft to its bed and improve early revascularization. These sutures are removed 1 week later.

Postoperative Course and Prognosis

Postoperative Course

No particular additional care is required other than routine postoperative care except in patients with alar strut grafts and composite grafts. If an alar strut graft has been used, it is helpful to stent the alar with a rolled silicone rubber sheet for 1 week. Patients may require longer stenting if there is excessive edema or bulkiness of the graft. After a composite graft has been placed, stenting will prevent trauma to the graft during the initial healing phase.

Prognosis

The long-term complication rate of alar retraction following primary rhinoplasty may be 7–14% and the complication rate is estimated to be doubled following secondary rhinoplasties (Becker and Park 2008). Rohrich et al. described that alar cartilage grafting corrected 91% of alar retraction or collapse in primary rhinoplasty and 73% of patients in secondary revision cases (Rohrich et al. 2002). In cases of failure, revision always remains a possibility given the variety of available surgical techniques.

Conclusion

Alar retraction is a complex problem due to the subtle interplay of cartilage, skin, and soft tissue at the alar margin. The spectrum of repair ranges from injectables (a poor choice) to cartilage and composite grafts to lateral crural repositioning and often employs more than one modality. The outcome of repair reliably improves both nasal aesthetics and function.

Cross-References

- ▶ Acquired Nasal Deformity and Reconstruction
- ▶ Aesthetic Subunits of Nose
- ▶ Nasal Function

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Allergen

► Otolaryngologic Allergy/Immunology

Allergic Antibody

► Otolaryngologic Allergy/Immunology

Allergic Fungal Rhinosinusitis

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Synonyms

Allergic fungal sinusitis

Definitions

1. *Allergic bronchopulmonary aspergillosis (ABPA)* is an immunologic pulmonary disorder caused by hypersensitivity to *Aspergillus fumigatus*.
2. *Eosinophilic mucin* is a lamellated collection of inspissated inflammatory debris with sheets of eosinophils and Charcot – Leyden crystals. In AFRS, this mucin contains characteristic branching noninvasive fungal hyphae.
3. *Eosinophils* are granulocytic bi-lobed leukocytes characterized by large numbers of coarse refractile cytoplasmic granules that stain with the acid dye eosin and play an important role in allergy and some parasitic conditions.
4. *Modified radioallergosorbent (mRAST)* test is a radioimmunoassay test to detect specific IgE antibodies responsible for hypersensitivity.
5. *Superantigens* are microbial or viral toxins that are extremely potent polyclonal T-cell mitogens that do not require prior processing and presentation by antigen presenting cells.

Etiology

Allergic fungal rhinosinusitis (AFRS) affects 5–10% of chronic rhinosinusitis (CRS) patients, which in turn has a prevalence of 13–14% in the USA (Schubert 2009). AFRS is seen in immunocompetent individuals, often in adolescents and young adults, with a mean age at diagnosis of 22 years. It has a male preponderance with a male to female ratio of 1:6. Incidence of AFRS is also influenced by geographical factors. Recent studies have identified a high prevalence of AFRS in desert areas, such as Arizona, Southern California, and Saudi Arabia.

As its name suggests, AFRS has been traditionally ascribed to an allergic reaction to fungi, but the biology and pathophysiology remain controversial. Earlier studies assumed that *Aspergillus fumigatus* was the primary etiologic mold based on the morphological appearance of fungal hyphae identified histologically. In the USA, the pigment forming Dematiaceous family ("phaeohyphomycosis") consisting of such genera as *Bipolaris, Curvularia, Alternaria,* and *Cladosporium*, with a small fraction caused by *Aspergillus* (Luong and Marple 2004) represent the common fungi that play a role in AFRS. This observation is geographical as different fungi are responsible for AFRS in other parts of the world (Schubert 2009). Currently, the identification of a specific fungal agent within the sinuses of diseased patient seems to have no bearing on the

treatment or prognosis of the patient with AFRS, since current treatments do not highlight antifungal agents.

The exact pathophysiology of AFRS remains unclear and controversial; however, the heavy presence of fungi within the accumulated eosinophilic mucin made fungi the target of much research as the potential etiologic agent. Manning and Holman investigated the clinical relationship between fungal allergy and AFRS. They prospectively compared skin testing and fungal-specific IgG and IgE levels of 8 AFRS patients who had culture-positive *Bipolaris* and 10 chronic rhinosinusitis (CRS) patients. They found a 100% presence of positive skin testing to *Bipolaris* antigen challenge and elevated *Bipolaris*-specific IgE and IgG serum levels in the AFRS patients, while 80% of the CRS patients were negative on both tests (Manning and Holman 1998), suggesting a role of fungal hypersensitivity in the pathophysiology of AFRS. However, atopy by itself is clearly not sufficient to cause AFRS as elevated IgE levels to common AFRS etiologic molds is seen in patients without AFRS.

Immunologic characterization of sinonasal mucosal tissue from CRS with nasal polyp including AFRS patients shows elevated T helper 2 (Th2) cytokines such as IL-4, IL-5, and IL-13 (Bachert et al. 2000). In addition, eosinophils, also associated with the Th2 response, have a notably elevated presence within these diseased tissues. Should fungi be important in the immunologic response in AFRS, it was hypothesized that a Th2 response should be triggered in the memory T cells of these patients when challenged with fungi. A recent study demonstrated that peripheral blood mononuclear cells from AFRS and not from healthy control patients when challenged in vitro with common etiologic fungal antigens do have memory for the fungi and incite secretion of Th2 cytokines (Luong et al. 2009). From the above studies, we can conclude that AFRS patients have fungal hypersensitivity, often to the fungi identified within their sinus cavity, and show immunologic memory to fungi. However, a causal relationship of fungi to AFRS cannot be made from the above observations.

Recent studies have emphasized the concept of the unified airway and approximately 60%–80% of CRS with nasal polyp (CRSwNP) patients have been shown to have asthma in various studies. Lab studies have demonstrated that director and effector Th2 cells including eosinophils play a pathogenic role in both asthma and CRS (Jani and Hamilos 2005). As such, insight into the pathophysiology of asthma may provide better understanding of CRS.

The relationship of protease exposure and human allergic respiratory disease was first recognized in occupational exposure to microbial and plant proteinases. This link between protease and allergic respiratory disease remained even after controlling for age, sex, and smoking (Brant et al. 2009). Protease activity has been shown to accompany the antigenic activity of many allergens including dust mites, ragweed, and fungi (Kheradmand et al. 2002; Porter et al. 2009).

Given the limitations of understanding causal relationships of chronic diseases in humans, studies on allergic asthma have moved to mouse models. The classic model for allergic asthma involves first sensitizing mice to the antigen ovalbumin with intraperitoneal injections. This sensitization step allows the intranasal introduction of ovalbumin to overcome the tolerogenic mechanisms of the lungs and to develop chronic inflammation of airway lamina propria, intraepithelial eosinophil accumulation with Th2 responses, and marked airway hyperreactivity to methacholine. Interestingly, intranasal proteinase exposure alone without the non-physiologic sensitization step can incite the same pulmonary characteristics as that seen in the classic model for allergic asthma (Porter et al. 2009). This development suggests a possible causal relationship of fungi in the development of inflammatory lower respiratory disease. However, the immunological pathways activated by proteases leading to the observed inflammatory changes remain unknown.

Using the same protocol for antigen challenge as that used to establish the classic allergic asthma model, a murine model for CRS, demonstrating chronic eosinophilia in the sinonasal mucosa, was established with an initial intraperitoneal injection of whole-organism-derived fungal antigen followed by recurrent nasal challenge with this fungal antigen over 1 month (Lindsay et al. 2006). However, based on the recent establishment of an asthma mouse model utilizing only intranasal challenge of fungal protease antigen, similar sinonasal mucosal inflammation may also be incited with fungal protease.

In addition to fungi, a significant amount of research has focused on bacteria, specifically superantigens, as an etiologic factor in CRS. Superantigens are able to

nonspecifically activate a large polyclonal population of T cells, thereby inciting a massive immune response which can lead to inflammatory conditions. Bacteria, a source of superantigens, have been observed frequently together with fungi in diseased sinuses of CRS patients (Ferguson et al. 2007). In AFRS, *Staphylococcus aureus,* a prodigious superantigen-producer, is commonly found together with fungi and may serve as a factor in the pathophysiology of AFRS.

Although supporters of the theory that either fungi or superantigens alone or together are orchestrating the immune response which ultimately results in the clinical presentation of AFRS, opponents argue that both *S. aureus* and fungi are ubiquitous in the environment and would thus suggest that another factor (s) must be triggering the disease process. At this time, it appears that the best explanation for the pathogenesis of AFRS is that it is multifactorial, and its treatment is aimed broadly at the inflammatory cascade.

Clinical Presentation

The central characteristic of AFRS is the development of eosinophilic mucin with fungal elements within the sinonasal space. The mucin is composed of degradation products from eosinophils (namely, eosinophil cationic protein, eosinophil peroxidase, and major basic protein) as well as degranulated eosinophils and fungal elements. The eosinophilic mucin is often described as having a "peanut butter" texture; the material is typically thick and tenacious. Over time, the eosinophilic mucin will expand sinus cavities and erode bone. In advanced cases, sinus cavities, expanded by eosinophilic mucin, will encroach into the intracranial space and orbit.

Patients with AFRS normally present with signs and symptoms characteristically associated with chronic rhinosinusitis that include nasal obstruction, rhinorrhea, postnasal discharge, and sinus pressure. Given the presence of nasal polyps, many complain of hyposmia or anosmia. A history of nasal discharge described as clumps or thick may suggest eosinophilic mucin. Facial dysmorphia is a slow progression and often goes unrecognized by the patient and family members, but expanded ethmoid sinuses from impacted eosinophilic mucin can cause facial changes including hypertelorism.

In addition to the eosinophilic mucin, another unique clinical feature of AFRS is a common unilateral or asymmetric presentation. Although bilateral presentation is also frequent, AFRS, unlike other subsets of CRS, can present unilaterally.

Similar to the presenting symptoms, physical findings on examination are also variable, ranging from nasal airway obstruction with polyps, mucosal edema, and presence of eosinophilic mucin to gross facial disfigurement and orbital or intracranial abnormalities.

The slow accumulation of eosinophilic fungal mucin imparts unique characteristics to the disease. Eosinophilic fungal mucin can become trapped within the involved paranasal sinus cavities which can cause bone remodeling and expansion of sinuses into surrounding structures causing proptosis, hypertelorism (more often seen in children than adults), intracranial extension without tissue invasion, and vision loss due to compression of the ophthalmic nerve.

It is unknown whether bone-destroying enzymes produced by the fungus or mediators of the immune response such as major basic protein or pressure from the accumulating mucin is responsible for the bony erosion.

Diagnosis

Diagnostic Criteria

A number of criteria for the diagnosis of AFRS have been proposed. The Bent and Kuhn criteria for AFRS are the most widely accepted and serves as the basis for the recent consensus clinical guidelines for the definition of AFRS (Meltzer et al. 2006):

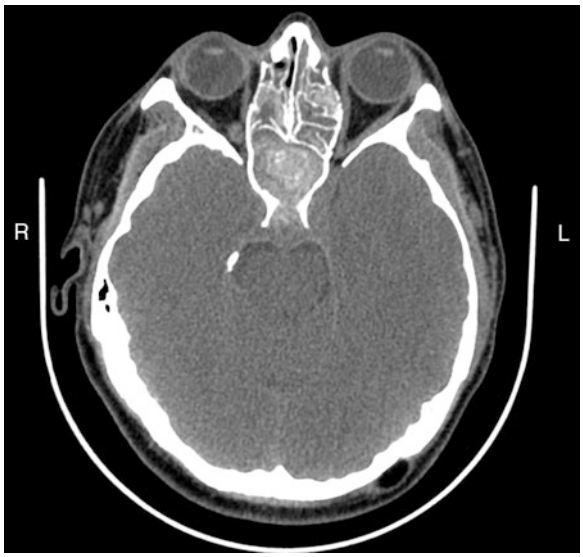
- Presence of at least one of the following clinical symptoms: anterior and/or posterior drainage, nasal obstruction, decreased sense of smell, and facial pain/pressure/fullness for at least 12 weeks
- Mucin within sinus cavity with presence of fungal hyphae and degranulating eosinophils
- Endoscopic evidence of inflammation within sinus cavity
- CT or MRI consistent with rhinosinusitis
- Evidence of fungal-specific IgE either with positive skin test to fungal antigen challenge or elevated fungal-specific serum IgE levels
- No histologic evidence of invasive fungal disease when risk factors present

The above criteria highlight the importance of histologic features in the diagnosis of AFRS. Grossly,

eosinophilic mucin is thick, tenacious, and highly viscous in consistency (peanut butter, axle grease) and its color may vary from light tan to brown or dark green. Histologic examination of the mucin reveals a constellation of characteristic findings, including branching noninvasive fungal hyphae, sheets of eosinophils, and elongated eosinophilic bodies (Charcot-Leyden crystals) that represent the product of eosinophilic degradation.

These above mentioned histological findings require special staining to identify the variety of components within eosinophilic fungal mucin, such as hematoxylin and eosin (H&E) staining that accentuates the mucin and eosinophils, and Grocott-Gomori methenamine silver (GMS) and other silver-based stains are absorbed by fungal elements which are then visualized as black or dark brown bodies.

Fungal cultures of eosinophilic mucin may provide some supportive evidence and are helpful in the diagnosis and subsequent treatment of AFRS. The sensitivity of fungal cultures is variable (between 64% and 100%) (Manning and Holman 1998).Thus, the histological appearance of eosinophilc mucin remains the most reliable indicator of AFRS.



Allergic Fungal Rhinosinusitis, Fig. 1 Axial CT sinus without contrast illustrating the hyperintense signal within the ethmoid and sphenoid sinuses consistent with accumulation of eosinophilic mucin

CT Scan of Paranasal Sinuses Without Contrast

A number of characteristic CT findings are associated with AFRS. For one, the diseased sinuses impacted with eosinophilic mucin appear opacified with areas of hyperattenuation that may take various patterns such as serpiginous, ground-glass appearance, or star-filled sky. Current evidence points to the accumulations of heavy metals (e.g., iron, manganese, and magnesium) and calcium salt precipitation within inspissated eosinophilic mucin as the most likely causes of these radiographic findings.

As mentioned above, the impacted mucin can cause expansion of affected sinus cavities. CT imaging of AFRS patients may reveal expansion, remodeling, or thinning of involved sinus walls (Robson et al. 1989). Bony erosion may allow expansion of mucin through the defect into surrounding structures. Erosion into the intracranial cavity has been reported in up to 20% of patients. Other sites of extension include the nasopharynx and pterygomaxillary space and intraorbital areas (see Fig. 1).

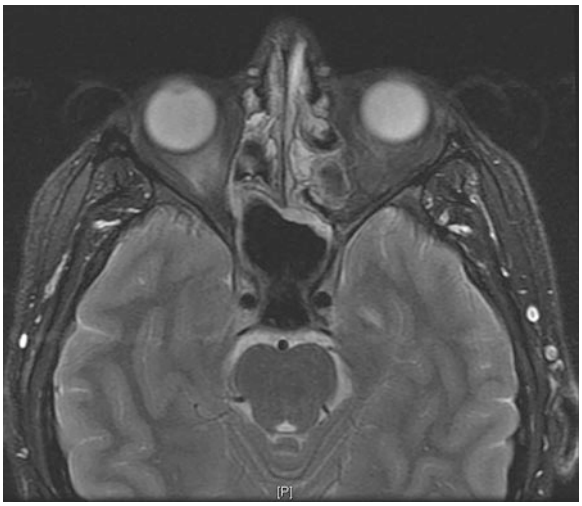
Magnetic Resonance Imaging (MRI)

MRI can provide vital information when the diagnosis is contentious or when the degree of intracranial extension needs to be confirmed. High protein and low water concentrations cause a decreased signal on T1- and T2-weighted MRI images because of protein cross-linking and slower macromolecular motion resulting in a dropped signal over the eosinophilic mucin. This effect is more pronounced on T2-weighted images (see Fig. 2).

Laboratory Studies

The diagnosis of AFRS requires documentation of IgE-mediated hypersensitivity to fungi. In addition, other laboratory studies can help differentiate AFRS from other CRSwNP subsets.

Immunologic testing for allergens, specifically molds, is one means of assessing fungal hypersensitivity. There are in vitro (radioimmunoassay) and in vivo (skin testing) methods of testing. Patients with AFRS generally demonstrate elevated serum antigen-specific IgE levels to multiple fungi. The reason for allergy to multiple fungi has been postulated to relate to either a common fungal epitope or a genetic predisposition toward fungal allergy in patients with AFRS. Skin testing (in vivo) may provide even greater sensitivity ratings than radioimmunoassay in patients with AFRS (Mabry et al. 1999).



Allergic Fungal Rhinosinusitis, Fig. 2 Axial T2 MRI of the same patient and level in Fig. 1 illustrating the drop signal associated with eosinophilic mucin in AFRS

Total immunoglobulin E has been proposed as a useful indicator of AFRS clinical activity and is generally elevated, often to more than 1,000 U/ml.

Differential Diagnosis

The presence of eosinophilic mucin without evidence of fungus within the mucin of CRS patients is termed eosinophilic mucin rhinosinusitis. It is unclear if this represents a different clinical entity or an entity along the spectrum of the same disease as AFRS.

AFRS is distinguished from CRSwNP by the presence of eosinophilic mucin containing viable fungal hyphae (as demonstrated by fungal staining or culture) and evidence of IgE-mediated hypersensitivity to one or more fungi. Patients may have typical symptoms related to nasal polyps combined with production of semisolid mucus.

Given the shared sinonasal symptoms, AFRS has to also be differentiated from aspirin-exacerbated respiratory disease (AERD). Common in AFRS patients, AERD patients often have lower respiratory inflammatory disease and nasal polyps. However, in AERD, there may be a history of exacerbation of disease with aspirin intake. Objective testing with aspirin challenge will clearly reveal hypersensitivity to aspirin.

Another subset of CRSwNP patients that AFRS needs to be differentiated from is cystic fibrosis (CF). CF represents a clinical manifestation of a defect in the sodium-chloride channel and has a largely neutrophilic cellular profile in local tissue. As a consequence, respiratory secretions are unusually thick. Although the gross description of the mucus is different between CF and AFRS patients, some CF patients can also develop AFRS. CF is diagnosed objectively through sweat test or genetic testing.

Prophylaxis

Studies are underway to understand the gene activation pattern of AFRS patients but to date no means exist to identify high-risk populations or individuals to prevent the occurrence of AFRS. The concept of prevention of development of AFRS in prone populations is in its infancy.

Given the high recurrence rate for AFRS despite surgery and complete clearance of the eosinophilic mucin, management is aimed at preventing or delaying recurrence of disease. Regular postoperative care including endoscopic nasal debridement, saline nasal irrigations, topical intranasal steroids, and systemic steroids play an important role in prevention. These measures aim to maintain low sinonasal fungal load and also suppress the inflammatory response. The effectiveness of antifungals, either topical or systemic, remains uncertain, lacking adequate controlled studies in this specific patient population. Studies on the long-term effects of immunotherapy suggest poor effect on the recurrence rate (Marple et al. 2002).

Therapy

The AFRS pathophysiology suggests that atopy, continuous antigenic exposure, and inflammation all play a key role. Addressing all three components of disease process provides the best chance of long-term disease control. This comprehensive approach to management is initiated with surgical clearance of eosinophilic mucin from diseased sinuses and long-term management through immunomodulation.

Surgical Therapy

Complete surgical removal of impacted mucin with restoration of sinus aeration and mucociliary clearance remains the cornerstone of AFRS surgical

management. Surgery is conservative but complete, relying completely on endoscopic techniques. It is believed that surgery helps decrease the levels of the etiologic agent and theoretically can decrease the stimulus triggering the robust immune response. Similar to the goal of functional endoscopic sinus surgery for other CRS diseases, surgery provides access to the diseased sinonasal mucosa for possible topical therapy.

Preoperatively, use of prednisone at 0.5 mg/kg/day for 1 week before surgery decreases intranasal inflammation and nasal polyp volume and reduces bleeding during surgery. This dosing is continued after surgery for at least 1 week until the first postoperative follow-up appointment.

Medical Therapy

Postoperative care begins immediately following surgery with nasal saline irrigation and continuation of systemic steroids. Regular clinic visits are required to allow inspection of the operative site and debridement of crusts and retained debris.

Corticosteroids. Corticosteroid therapy for long-term management of AFRS bears its origins from the success of this strategy in the treatment of ABPA. The potent anti-inflammatory and immunomodulatory effects of corticosteroids appear to be well suited to control recurrence of disease. Postoperative steroids delay the recurrence and time to revision surgery. Topical corticosteroids are accepted as standard therapy in the postoperative treatment of AFRS, but they provide limited benefit before surgery as the nasal access is restricted. However, after surgery, they may be effective in controlling local inflammation. The well-recognized benefits of systemic corticosteroids are counterbalanced by numerous potential adverse effects, including growth retardation, diabetes mellitus, hypertension, psychotropic effects, gastrointestinal side effects, cataracts, glaucoma, osteoporosis, and aseptic necrosis of the femoral head. The adverse effect profile of systemic corticosteroids warrants careful consideration when they are used for a prolonged period to control the disease process. Steroid therapy is tapered based on endoscopic findings, not symptomatic improvement.

Kuhn and Javer proposed that systemic steroids be tapered according to the mucosal stage (Kuhn and Javer 2000). Using the Kuperferberg staging system (see Fig. 3), postoperative systemic steroids are started at 0.5 mg/kg/day. The dosing is then reduced after 4 days by 0.1 mg/kg/day (or approximately 10 mg). Prednisone is then weaned in 4 day cycles by 10 mg/day until the patient is at 20 mg/day. The patient is maintained at that dose until mucosal stage 0 is obtained, which may take over a month to obtain. It is then recommended to continue at 20 mg/day prednisone for another 4 months to maintain the patient at this mucosa stage 0. After that period, the prednisone can then be weaned to 10 mg/day and maintained for at least 2 months where mucosa remains at stage 0, at which point systemic steroids can be stopped. As the systemic steroid is being weaned, topical nasal steroids are re-introduced. Needless to say, there are different views on the role, timing, and length of systemic steroid therapy use in AFRS.

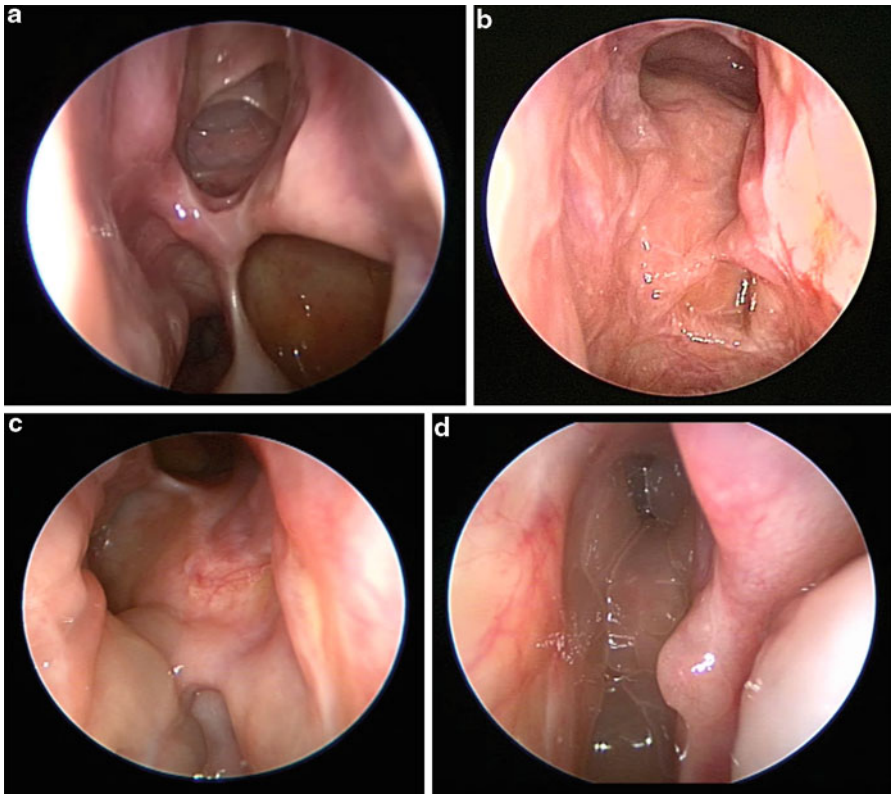
Nasal saline irrigations. Nasal saline irrigation is a mainstay therapy to reduce mucus stasis, specifically after surgery. Thinning the viscosity of mucus is also believed to enhance mucociliary clearance, although there is no supporting scientific evidence to validate the use of mucolytics such as guaifenesin. Nasal irrigations can also help to reduce fungal and bacterial concentration in sinonasal cavities.

Antimicrobials. Both systemic and topical antifungals have been tried in an attempt to decrease the fungal antigenic burden within the sinonasal cavities, but convincing data of their effectiveness are lacking. Culture-directed antibiotics are utilized to control acute exacerbations, similar to management of other CRS patients.

Immunotherapy. Studies on the effect of immunotherapy in the long-term maintenance of AFRS are few and hampered by the small sample size, but these studies suggest no benefit in the control of recurrence rates. However, control of allergic rhinitis to other antigens as well as fungi poses a theoretical benefit in management of AFRS. Currently, administration of immunotherapy to patients with AFRS is targeted to those with allergic rhinitis non-fungal antigens. The duration of therapy is recommended for the same duration as that recommended for patients with allergies in general, that is, 3–5 years. The rationale is to reduce the allergic inflammatory milieu felt to be conducive to AFRS relapse.

Antihistamines. These may reduce some of the IgE-mediated effect of AFRS. However, the drying effect of these agents may supersede their potential benefits. Hence their role is controversial.

Other anti-inflammatory agents. Agents such as leukotriene receptor antagonists and macrolide antibiotics may have a role, although data are lacking.



Allergic Fungal Rhinosinusitis, Fig. 3 Kuperferberg mucosal endoscopic staging system. (**a**) Stage 0; (**b**) Stage 1; (**c**) Stage 2; and (**d**) Stage 3

Prognosis

The potential for AFRS recidivism ranges from 10% to 100%. Recurrence can be in the form of mucosal edema, polyps, scarring, eosinophilic mucin, or fungal debris. AFRS recidivism appears to be influenced by long-term postoperative therapy. Thus, there is a need for emphasis on postoperative care and regular follow-up aimed to manage signs of early recurrences.

Cross-References

- ▶ Acute and Chronic Rhinosinusitis
- ▶ Medical Management of Chronic Rhinosinusitis
- ▶ Sinusitis

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Allergic Fungal Sinusitis

▶ Allergic Fungal Rhinosinusitis

Allergic Rhinitis

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Synonyms

Allergic rhinosinusitis; Allergic sinusitis; Allergies; Hay fever

Definition

Allergic rhinitis is a nasal disorder consisting of itching, sneezing, rhinorrhea, and nasal congestion induced by allergen exposure due to an IgE-mediated inflammation in the nasal mucosa (Bousquet et al. 2008).

Allergic rhinitis has been subclassified based upon the pattern of sensitivity. **Seasonal allergic rhinitis** denotes a sensitivity to tree, grass, or weed pollens, with symptoms present only during certain seasons of the year. **Perennial allergic rhinitis** denotes sensitivity to allergens that may be present throughout the year including animal dander, insects or mites, and molds. **Occupational allergic rhinitis** denotes symptoms that are induced by workplace exposures. The newer Allergic Rhinitis and Impact on Asthma (ARIA) classification scheme takes into account the frequency of symptoms. In this system, rhinitis is classified as intermittent or persistent. By definition, **persistent allergic rhinitis** denotes the presence of symptoms more than 4 days a week and for more than 4 consecutive weeks. Symptoms that are present for fewer than 4 days a week or for less than 4 weeks are classified as **intermittent allergic rhinitis**. In addition, the ARIA classification scheme includes a measure of the severity of disease: allergic rhinitis is either "mild" or "moderate/severe." **Moderate/severe allergic rhinitis** is differentiated from **mild allergic rhinitis** by the presence of sleep disturbance, impairment of daily activities, impairment of school or work, and the presence of "troublesome symptoms" (Bousquet et al. 2008).

Etiology

Risk factors for the development of allergic rhinitis include genetic predisposition, exposure to high levels of allergens, reduced exposure to a diverse microbial environment, and exposure to airway irritants and air pollutants. Allergic rhinitis is strongly associated within families. Atopy represents the most common phenotype and is associated with food allergy, eczema, asthma, as well as allergic rhinitis. Gene polymorphisms associated with allergic rhinitis (IL-13, filaggrin) and with allergen-specific IgE or skin test reactivity (IL-4 receptor and IgE receptor R1) have been implicated and are not specific to just allergic rhinitis but are also implicated in asthma and eczema (Genuneit et al. 2009).

Although "allergic" rhinitis is distinguished from nonallergic rhinitis and nonallergic rhinitis eosinophilic syndrome (NARES) by the lack of evidence by skin-prick testing or in vitro identification of allergen-specific IgE, it is now recognized that "local allergy" or "entopy" may occur in allergic rhinitis (Powe et al. 2010). Local production of IgE and allergen-specific B-cells producing IgE within the nasal mucosa and positive testing by intranasal provocation can occur in the absence of positive skin or blood allergy testing. Additionally, alternative non-IgE dependent mechanisms

may exist in nonatopic individuals that result in local mucosal hypersensitivity. Since provocation testing is not used routinely in clinical practice and presents logistical challenges, the extent of this entity remains uncertain. However, local allergy is an evolving concept in our understanding of allergic rhinitis.

The role of environmental "irritants" in the initiation and promotion of allergic rhinitis is becoming more apparent. The correlation of environmental tobacco smoke (ETS) and the development of allergic disease is well known. Seminal studies with diesel exhaust particles demonstrate an adjuvant effect or amplification of allergic mechanisms (Nel et al. 1998). Whether these agents promote the primary sensitization process is yet unproved but suspected. However, in asthma, the evidence is more compelling, and thus, it is likely that environmental oxidants such as ETS, diesel exhaust particles, and ozone likely promote the early development of allergic rhinitis.

The hygiene hypothesis has provided the most relevant information as to the dramatic rise in all allergic diseases, including allergic rhinitis. Important observations in predominantly farming communities in Europe have shown protective effects for the development of allergic disease when children are exposed to a diverse microbial environment (Ege et al. 2011). Many additional studies have also supported these findings with the following protective factors identified: day care attendance, presence of pets early in life, and less exposure to antibiotics.

Clinical Presentation

Allergic sensitization is felt to occur early in life to predominantly indoor allergens such as dust mite and animal dander, and new sensitizations can occur throughout life with subsequent exposures. Two or more seasonal allergen exposures may be required to develop sensitization. Sensitization occurs in the presence of high levels of allergen exposure, with the appearance of allergen-specific IgE occurring often prior to the onset of typical allergic rhinitis symptoms. Consequently, clinical manifestations of allergic rhinitis due to aeroallergens are rare under the age of 2 years (Bousquet et al. 2008). However, exaggerated symptoms with weather changes and upper respiratory infections may herald the onset of evolving allergic rhinitis in young children and infants.

The cardinal symptoms of allergic rhinitis consist of itchy, sneezy, runny nose with other associated symptoms including nasal congestion and nasal airway obstruction. In addition to the classic symptoms of rhinitis, patients may have a variable constellation of associated symptoms involving the eyes, ears, throat, and sinuses. Common associated symptoms include itchy, irritated, watery eyes, sore throat, postnasal drip, sinus pressure, headache, ear fullness, and cough (Schatz 2007). Symptoms are classically induced within 15 min of allergen exposure (pet dander, dust mite, mold, cockroach, pollens) but may be chronic and variable. Symptoms may be intermittent or chronic depending upon exposure and the pattern of allergic sensitivity. In general, allergic rhinitis symptoms tend to be worse in the morning, particularly with indoor allergen sensitization such as dust mite. Rhinitis symptoms are often associated with nonspecific stimuli such as weather changes and may be exaggerated with upper respiratory infections. The distinction between true allergic rhinitis and rhinitis in response to other environmental stimuli is sometimes challenging. Often, parents have difficulty distinguishing exacerbations of allergic rhinitis from infectious rhinosinusitis.

In allergic rhinitis, parents are usually able to identify a seasonal predisposition for their child's symptoms and may be able to identify allergic triggers. Rhinitis symptoms should directly correlate with exposure to allergens, and effective allergen avoidance can result in dramatic improvement in symptoms. A common occurrence among pollen allergic individuals is the relative loss of symptoms when relocating to new regions. However, new sensitizations occur, and symptoms tend to resume after some years in the "new" environment indicating sensitization to "new" or related allergens.

Allergic rhinitis is a significant source of chronic morbidity and reduced quality of life. Allergic sufferers may have sleep disorders, emotional problems, and impairment in activities and social functioning. This can lead to impaired school performance. In children, the effects of allergic rhinitis on social, intellectual, and emotional development should be taken into consideration in treatment.

Diagnosis

The diagnosis of allergic rhinitis is based upon history, physical exam, and diagnostic testing. History is the

most important source of diagnostic information. One key feature of the diagnosis is an association of reproducible or consistent symptoms with exposure to allergen sources, such as pet dander, occurrence in certain environments (e.g., the park), or certain times of the year (e.g., spring). Certain symptom patterns may be associated with the patient's particular sensitivity, e.g., early morning rhinitis symptoms with dust mite allergy or locations with increased levels of allergens within homes with pets, moldy rooms, etc. Allergic rhinitis in children is associated with other atopic disorders: conjunctivitis, food allergy, eczema, and asthma. The presence of any of these conditions in a child with rhinitis symptoms increases the likelihood of allergic rhinitis. There is a strong familial predisposition to allergic rhinitis and atopic disease in general; thus, a family history of atopic disease in first degree relatives should be obtained.

Detailed History Elements for Rhinitis Patients

Dominant symptoms
Duration of symptoms
Frequency of symptoms: intermittent, persistent, and acute exacerbations
Alleviating and exacerbating factors: e.g., smoke
Associated symptoms: e.g., sinuses, eyes, throat, and snoring
History of asthma, eczema, oral allergy syndrome, and food allergy
Allergen exposure: e.g., home environment, hobbies, sports, and pets
Family history of atopy
Medication use: type, duration, compliance, and efficacy
Impact on quality of life

The physical exam should provide correlative findings, but there is often a discordance between physical findings and symptoms. Classically, the turbinates are edematous and often appear pale with a glistening thin clear discharge, referred to as "boggy". They may also appear congested with a bluish hue due to venous congestion. However, an erythematous appearance, more often associated with infectious rhinitis, is not unusual. Other features include infraorbital venous congestion known as "allergic shiners" and a horizontal nasal supratip crease caused by excessive rubbing. Many patients have concomitant allergic conjunctivitis with watery eyes, conjunctival edema, erythema, and Dennie's lines (creases/wrinkling of the medial lower eyelid). A positive response to pharmacologic agents also strengthens the diagnosis, e.g., reduction of pruritus with antihistamines.

Specific allergen testing can provide confirmatory evidence of sensitization, but results must be correlated with the history to avoid misinterpretation. The most common method of aeroallergen testing is via skin-prick testing, whereby standardized extracts of allergens are introduced into the epidermis with a prick technique. A resulting wheal that is 3 mm or greater compared to an appropriate negative control is generally considered positive. Alternatively, in vitro testing can identify the presence of serum IgE directed against allergens. The advantages of in vitro testing in children are that testing can be completed with a single blood draw and medications do not affect the test results. One significant drawback of in vitro testing is in the interpretation of the results. Careful studies have not yet been performed that correlate allergen-specific IgE level with skin-prick testing and nasal provocation. For example, the detectable level for most in vitro techniques is reported at 0.35 kU/L. These careful studies have been performed for food allergy in children, and the IgE levels that provide a high positive predictive value range from 2 to 30 kU/L for different food allergens. One study reported that a level of 2 kU/L generally correlates with the 3-mm skin-prick test, but more careful and deliberate studies are lacking. In addition, higher levels of measured allergen-specific IgE correlate with increasing confidence of true allergic sensitization but not with greater severity of symptoms. In general, both in vitro testing and skin testing are felt to have good negative predictive value. However, a positive test result must be correlated with the history as false positive results (i.e., sensitizations that do not cause symptoms) are common (Bernstein et al. 2008).

Direct nasal allergen challenge with subsequent measurement of symptoms and objective measures of nasal function (rhinomanometry) are gaining in popularity, but present logistical barriers, e.g., only one allergen at a time, can be used. Therefore, direct allergen challenge is not routinely used for clinical diagnostic purposes.

In children, it is frequently difficulty to distinguish an exacerbation of allergic rhinitis from a viral URI or bacterial sinusitis. A nasal mucus smear with Hansel staining for nasal eosinophilia is one additional tool that may be used to distinguish allergic inflammation from, in particular, bacterial sinus infections.

Differential Diagnosis

Rhinitis signs and symptoms can be caused by a variety of nonspecific irritants and infectious agents. Infectious rhinosinusitis is the most common mimic of allergic rhinitis. In particular, viral upper respiratory infections are common and frequent in pediatric patients and produce symptoms that are very similar to allergic rhinitis. The differentiation of recurrent viral URI, chronic rhinosinusitis, and allergic rhinitis can be very difficult and may require a longitudinal relationship with the patient and family. A recent study of viral URI showed that infants and toddlers have on average 5 viral URIs per year, with a very broad range of incidence; approximately 10% of children had over 10 episodes per year (Chonmaitree et al. 2008). Children in day care are felt to have a higher rate of URIs because of increased exposures. Respiratory viral illnesses can circulate in families, and one viral respiratory illness may overlap with another such that some children seem to "always be sick." It is tempting for families to ascribe this problem to allergy. In general, the frequency of viral respiratory illness decreases as the school-age child develops immunity, and in older children, the distinction between allergic rhinitis and infectious rhinosinusitis becomes easier. Distinguishing clinical features such as acute onset of symptoms associated with fever, malaise, and purulent nasal secretions may help in distinguishing infectious etiologies.

Compared to adult populations, children with chronic rhinitis are more likely to have allergic rhinitis. Nonallergic rhinitis subtypes such as vasomotor rhinitis, gustatory rhinitis, nonallergic rhinitis with eosinophilia (NARES), and aspirin-exacerbated respiratory disease (AERD) would be very uncommon in young children.

Prophylaxis

Prophylaxis or preventive maneuvers fall within several parameters. Since the etiology of allergic rhinitis and atopy include both genetic and environmental factors, only environmental factors can be manipulated. Early life exposures to allergens, microbial flora, and environmental pollutants are the primary target of intervention. Evidence exists that exposure to high levels of indoor allergens (dust mite, cat, etc.) promotes allergic sensitization. However, intervention targeting these exposures has met with limited success in decreasing the overall incidence of atopic disease. However, once allergic symptoms have manifest, reduced exposure to allergens clearly reduces symptoms and continues to be a mainstay of management. Thus, reduction of water intrusion and humidity, control of pet dander, and use of "dust-free" bedding are reasonable interventions to control allergen exposure within the home.

The hygiene hypothesis provides the most compelling evidence to explain the overall increase in atopic disease and its interaction with behavioral and cultural changes within society. Studies have demonstrated a protective effect of early life exposure to a diverse microbial environment via increased exposure to animals (pets and farm animals), the day care environment (increased number of URIs), reduced use of antibiotics, and diet (probiotics with lactobacillus). Thus, although these have not been translated in to concrete recommendations, counseling parents against an overly "sterile" environment may be reasonable.

Exposure to chemical agents and air pollution clearly worsens the symptoms of allergic rhinitis. Whether these agents promote sensitization is less clear. Some studies have demonstrated increased IgE with exposure to tobacco smoke and oxides of nitrogen (e.g., NO_2). Other air pollutants, ozone, fine particulates, sulfur dioxide, and chemical household cleaners have been shown to worsen symptoms. Evidence is more compelling that these air pollutants as well as chemical pesticides promote the development of asthma, but it is reasonable to consider that these may also contribute to the development of allergic rhinitis. Thus, attention to combustion sources in homes, increased ventilation, avoidance of the use of chemical aerosols (cleaners, pesticides, air fresheners, scented candles, etc.) is a practical approach to environmental modification.

Pharmacologic interventions clearly improve the symptoms of rhinitis, but it is not likely that prophylactic therapy with antihistamines and topical nasal steroids prevents the development and progression of

allergic rhinitis. Thus, early pharmacologic intervention is not recommended. Alternatively, there is some evidence that immunotherapy to current allergen sensitizations may prevent the acquisition of new sensitizations. However, it is currently not recommended to employ early use of immunotherapy as a prophylactic measure.

Therapy

Treatment of allergic rhinitis involves a three-pronged approach of environmental avoidance, pharmacotherapy, and immunotherapy. In theory, avoidance of relevant allergens can prevent the symptoms of allergic rhinitis. However, sensitizations initially develop because individuals are frequently exposed to particular allergens; thus, it is difficult in practice to avoid exposures. In certain cases, elimination of pets, control of household pests (e.g., cockroaches), or intensive efforts to eliminate dust mite habitat may yield clinically noticeable improvements. But for pollen sensitivities, minimizing exposure may be impossible or would require dramatic changes in lifestyle. Possible recommendations include avoidance of specific allergens; reduction of indoor humidity; discontinuation of indoor air fresheners, scented candles, and chemical aerosols (cleaners, disinfectants, insecticides, etc.); improvement of indoor ventilation (esp. kitchen and bathrooms); and avoidance of environmental smoke (tobacco, wood fires, barbecue, vehicle exhaust, etc.). As outdoor pollutants also exacerbate rhinitis, attention to community warnings for outdoor exposures is important. While allergen avoidance and environmental modification efforts are frequently recommended and beneficial, they are rarely sufficient for the treatment of allergic rhinitis.

Pharmacotherapy

A wide variety of effective medications are available for the treatment of allergic rhinitis. The choice of medication depends upon multiple factors. Dominant symptoms, pattern and frequency of symptoms, cost and accessibility, approval for use in certain age groups, patient compliance and ease of administration, side effect profile, and response to previous treatment are examples of some of the considerations that may impact prescribing choices.

The simplest and safest "medication" for allergic rhinitis is intranasal saline that can be administered as a simple spray, aerosol, or lavage. Saline decreases the viscosity of nasal secretions, removes deposited allergens and particulates, improves mucociliary clearance, and may reduce nasal obstruction via clearance of obstructing mucus. Saline is particularly helpful if thick anterior or posterior rhinorrhea are prominent complaints.

Nasal obstruction may be managed with the use of decongestant medications. Oral decongestants (e.g., pseudoephedrine, phenylephrine) act as vasoconstrictors that reduce nasal congestion and thus improve the nasal airway. In general, pseudoephedrine is more effective than phenylephrine. Common side effects of these medications include insomnia, irritability, and palpitations. In the USA, these agents are not recommended for children under the age of 6 because of rare reports of psychosis, hallucination, and death when given in excessive doses or with certain other medications (Wallace et al. 2008). Topical intranasal vasoconstrictors (e.g., oxymetazoline, phenylephrine) are even more effective for reducing nasal congestion and improving nasal airway obstruction. However, these agents are not appropriate for long-term daily use due to tachyphylaxis and the potential for developing rebound nasal congestion and rhinitis medicamentosa.

Mast cell stabilizers (e.g., intranasal cromolyn sodium) inhibit mast cell degranulation, thus attenuating the early phase allergic response. They also have an anti-inflammatory effect that attenuates the late phase response. These agents are effective for the treatment of allergic rhinitis but are not as effective as other nasal spray options (e.g., steroids). The mast cell stabilizers are considered to be very safe, with a favorable side effect profile. However, their use is limited by the need for dosing prior to exposure and the need to dose these medications three or four times a day for maximum efficacy (Wallace et al. 2008).

Antihistamines have long been a mainstay for the treatment of allergic rhinitis. These agents bind the H_1 receptor and block the pharmacologic effects of histamine (vasodilation, nerve irritation, and increased vascular permeability) that lead to the cardinal symptoms of allergic rhinitis. However, as a general rule, while very effective for pruritus, these agents are not considered effective for nasal congestion and nasal airway obstruction. Thus, they are often formulated in combination with pseudoephedrine. Antihistamines can be administered orally, which is an advantage in

children. They have a rapid onset of action that makes them an appropriate option for patients with intermittent symptoms. Oral antihistamines are not as effective as intranasal steroid sprays. And older generation antihistamines may have deleterious side effects related to CNS penetration and anticholinergic effects. The sedation, psychomotor performance impairment, and thickening of nasal secretions associated with these older agents limit their usefulness. In addition, these first generation antihistamines decrease mucociliary clearance and may promote persistent serous otitis media; thus, they are generally not recommended during URIs in very young children and when used, should only be used intermittently. Newer generation agents (cetirizine, levocetirizine, fexofenadine, loratadine) have a more favorable side effect profile and are the currently recommended agents (Wallace). Even the newer agents may have some "drying" effect and decrease mucociliary clearance. The efficacy of antihistamines can be boosted by using a topical intranasal formulation. These agents (e.g., olopatadine, azelastine) have been shown to be more effective than oral antihistamines and may have comparable efficacy with nasal steroid sprays. Azelastine nasal spray is currently approved in the USA for treatment of children as young as 5, and olopatadine is approved down to the age of 6. Both of these intranasal antihistamines have a rapid onset of action and are appropriate for intermittent or daily use. Unlike the oral antihistamines, these agents are effective for the treatment of nasal congestion. Studies in adults have shown benefit with the combination of a nasal steroid and an intranasal antihistamine, making them a good option for combination therapy in patients with severe disease. Sensory characteristics may limit the usefulness of intranasal antihistamines; both have an unpleasant taste, and azelastine causes sedation (Wallace et al. 2008).

The cysteinyl leukotrienes are important inflammatory mediators in allergic rhinitis as well as asthma. Leukotriene modifying agents include synthesis inhibitors (e.g., zileuton) and receptor antagonists (zafirlukast, pranlukast, montelukast). In the USA, there is one leukotriene receptor antagonist (montelukast) approved for the treatment of allergic rhinitis. Montelukast is approved for use down to the age of 6 months and is available as a tablet, chew tab, and granules. Montelukast is considered to be more effective with symptoms of nasal congestion and obstruction, and there may be an additive benefit of combining montelukast with an oral antihistamine. This agent is an option for children who will not tolerate a nasal spray and may be particularly appropriate for rhinitis patients who also have asthma (Wallace et al. 2008).

Intranasal steroids are considered to be very effective medications that treat all of the symptoms of allergic rhinitis, including congestion. Some studies have also shown a benefit in ocular symptoms. A wide variety of agents are available, and all are considered to have equivalent efficacy. These agents have a delayed onset of symptom relief that is dependent upon the pharmacologic mechanism of action of steroids (3–12 h). In general, the symptom relieving effects of these agents are dependent on regular daily dosing. These agents are not generally felt to cause systemic steroid side effects, though theoretically growth suppression can occur particularly when used in conjunction with medium- to high-dose inhaled corticosteroids for asthma in children. Therefore, it is reasonable to monitor growth in children who are treated with nasal steroids for prolonged periods, and the minimally effective dose should be used. As a class, these agents have an excellent safety profile, and most side effects are mild local reactions: burning, irritation, and epistaxis (Wallace et al. 2008).

Immunotherapy

Specific allergen immunotherapy is the only treatment approach that has been shown to alter the natural course of the disease. Appropriate immunotherapy induces measurable immunologic changes, has a variety of clinically beneficial effects, and may have persistent benefits after immunotherapy is discontinued. Immunotherapy against a variety of allergens (pollens, mites, molds, animal danders, insects) has been shown via randomized placebo-controlled trials to reduce medication requirements and symptoms, in both children and adults. Immunotherapy in children may have particular benefits. Immunotherapy may prevent the development of new allergen sensitivities (Cox et al. 2011). There are also studies that have shown that immunotherapy has the potential to prevent the later development of asthma in children with isolated allergic rhinitis (Cox et al. 2011). There is no established age at which immunotherapy becomes a treatment option. In general, subcutaneous injection immunotherapy (SCIT) is

started in children who are 5 years or older. Injection immunotherapy is not usually used in younger children because of the trauma of repeated injections and difficulty managing possible systemic reactions. An emerging "new" treatment option is sublingual immunotherapy (SLIT). SLIT is also considered to be effective for the treatment of allergic rhinitis in children, with multiple randomized, placebo-controlled trials demonstrating efficacy. While the comparative efficacy of SCIT and SLIT is unknown (Radulovic et al. 2010), SLIT has many advantages in the pediatric population. These include the convenience of home administration, better safety profile with rare reports of anaphylaxis, and avoidance of repeated injections. SLIT is commonly used in Europe but is not yet a widely accepted treatment approach in the USA. Clinical trials in the USA are ongoing, and multiple sublingual immunotherapy tablet products may be available soon.

Prognosis

While allergic rhinitis is generally considered to be a disease of youth, the clinical course can be quite variable. Some individuals will have atopy manifest at an early age beginning with food allergy and eczema, then progress to develop allergic rhinitis and asthma (the so-called allergic march). Others will "grow out of" their asthma at some point, while allergic rhinitis tends to persist into adulthood. In general, over the lifespan, the symptoms of allergic rhinitis become milder (Bousquet et al. 2008).

Epidemiology

The prevalence of allergic rhinitis is a matter of significant uncertainty because of the difficulties in accurately diagnosing the condition on large survey-based studies. Early sensitization to indoor allergens and perennial rhinitis is common in very young children. However, seasonal rhinitis is more common in older children and adolescents, while perennial rhinitis may be more common in adults (Bousquet et al. 2008). Over the past several decades, the prevalence of allergic rhinitis has appeared to increase in children, especially in countries that formerly had a low prevalence (Bousquet et al. 2008). IgE sensitization to aeroallergens based on testing can be detected in 40–50% of the populations of the USA, Australia, and Europe. However, not all individuals with positive allergy tests have clinically significant symptoms (Bousquet et al. 2008). The Tuscon epidemiologic study found that 42% of children were diagnosed with rhinitis by the age of 6 (Wright et al. 1994). However, other single site studies that have examined the prevalence of AR in children have found a prevalence ranging from 0.5% to 44% depending upon the country, population, age group, and methods of study (Bousquet et al. 2008). The ISAAC (International Study of Asthma and Allergy in Childhood) studies of the prevalence of allergic disease probably provide the best estimate of worldwide prevalence of allergic rhinitis in children. The prevalence of rhinoconjunctivitis ranged from 0.8% to 14.9% in 6–7-year-olds and from 1.4% to 39.7% in 13–14-year-olds in different centers throughout the world (Bousquet et al. 2008).

Cross-References

- ▶ Allergic Fungal Rhinosinusitis
- ▶ Reactive Airway Disease
- ▶ Rhinitis

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Allergic Rhinosinusitis

▶ Allergic Rhinitis

Allergic Sinusitis

▶ Allergic Rhinitis

Allergies

▶ Allergic Rhinitis

Allergy

▶ Otolaryngologic Allergy/Immunology

Allergy Shots

▶ Otolaryngologic Allergy/Immunology

Ameloblastic Carcinoma

▶ Ameloblastoma

Ameloblastoma

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Synonyms

Ameloblastic carcinoma; Benign jaw tumors; Metastasizing ameloblastoma; Mural ameloblastoma; Odontogenic ectomesenchyme; Odontogenic tumors; Unicystic or multicystic ameloblastoma

Definition

Ameloblastoma is a benign but locally aggressive odontogenic neoplasm of jaws (Carlson 2004; Carlson and Marx 2006; Mendenhall et al. 2007).

Etiology

Ameloblastoma is an odontogenic tumor of the jaw. This group of tumors includes a complex and diverse group of pathologies with unique histopathologic and clinical behaviors. These tumors demonstrate varying extent of inductive interactions between the odontogenic ectoderm and ectomesenchyme. Odontogenic tumors can be classified based on the germ layer of origin: epithelial, ectomesenchyme, and mixed (both epithelial and ectomesenchymal elements) (Regezi et al. 1978, 2003). Table 1 presents the modified classification from the 1992 WHO (World Health Organization); it subdivides odontogenic tumors based on the cell of origin into epithelial, mixed, and ectomesenchymal (Neville et al. 2002; Philipsen and Reichart 2002). Ameloblastoma originates from odontogenic epithelium.

Ameloblastoma is one of the more significant odontogenic tumors and accounts for approximately 10% of all jaw tumors. It usually occurs in the vicinity of the molars, posterior body, and ramus of the mandible. It has the appearance of a well-defined uni- or multilocular radiolucency. There may be an impacted molar tooth associated with the lesion. The tumor can

Ameloblastoma, Table 1 Classification of odontogenic tumors

A. Tumors of odontogenic epithelium
1. Ameloblastoma
a. Malignant ameloblastoma
b. Ameloblastic carcinoma
2. Calcifying epithelial odontogenic tumor
3. Adenomatoid odontogenic tumor
4. Squamous odontogenic tumor
5. Clear cell odontogenic carcinoma
B. Mixed odontogenic tumors
1. Ameloblastic fibroma
2. Ameloblastic fibro-odontoma
3. Ameloblastic fibrosarcoma
4. Odontoameloblastoma
5. Compound odontoma
6. Complex odontoma
C. Tumors of odontogenic ectomesenchyme
1. Odontogenic fibroma
2. Granular cell odontogenic tumor
3. Odontogenic myxoma
4. Cementoblastoma

arise from the dental lamina rests, dental enamel organ, epithelial lining of an odontogenic cyst, or basal cells of the oral mucosa. Ameloblastoma may be classified into four groups based on different clinical behavior and radiographic presentation:

1. Conventional solid or multicystic (86%)
2. Unicystic (13%)
3. Peripheral (1%)
4. Malignant ameloblastoma and ameloblastic carcinoma (<1%)

This classification provides useful information with regard to the biologic behavior of the four variants and the appropriate surgery for curative intent. In general, the solid or multicystic variant is believed to be the most aggressive one; relatively less aggressive behavior is associated with the unicystic variant (Gardner and Corio 1984; Carlson and Marx 2006).

Clinical Presentation

Due to their individual differences in clinical, histopathological, and radiographic presentation, the various types of ameloblastoma are discussed separately as follows.

Solid or Multicystic Ameloblastoma

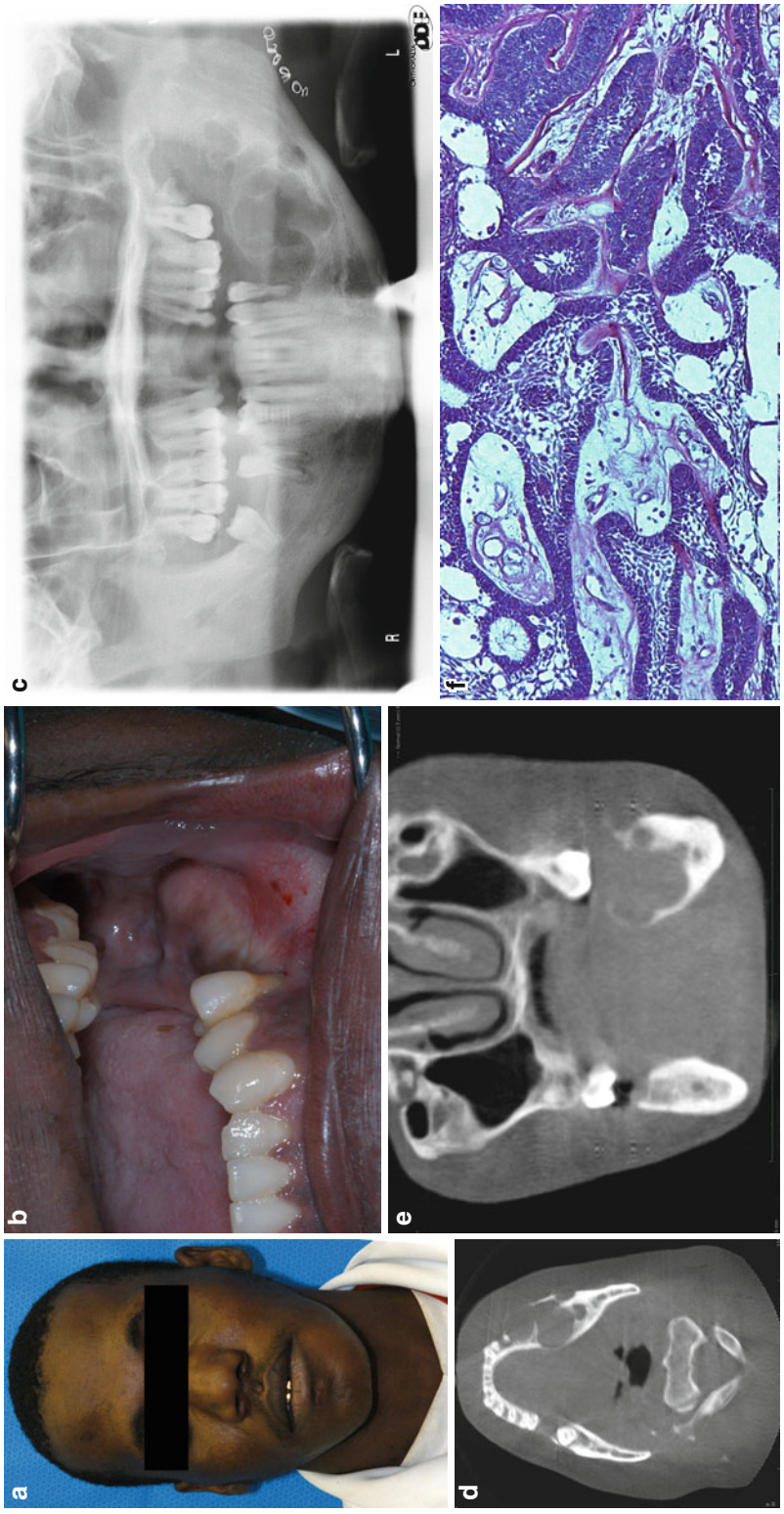
This type occurs over a wide age distribution, with rarity in the first decade and relatively uncommon in the second (Ord et al. 2002; Fregnani et al. 2010). The tumor shows quite equal predilection from third to seventh decades of life. Racial predilection is controversial with some suggestion for increased prevalence in African-Americans. About 80% of lesions occur in the posterior mandible, most commonly in the third molar region and ascending ramus. The remainder occurs in the posterior maxilla (Nastri et al. 1995; Jackson et al. 1996). Smaller lesions are asymptomatic and are typically diagnosed only through routine panoramic radiographs taken as part of a dental evaluation. A painless expansile mass in the posterior mandible is the most common presentation. Pain and inferior alveolar nerve involvement is uncommon, unless the lesion is infected or causes pathological fracture. The lesion, although classified as benign, is locally aggressive and can erode vast regions of mandible.

The characteristic radiographic presentation is that of multilocular radiolucency described as "honey comb" or "soap bubble" appearance depending on the size of loculations. Expansion of the buccal or lingual cortex and eventual perforation will occur with time. Adjacent root resorption is common and often the third molar (wisdom) tooth is associated with the radiolucent lesion. Although a multiloculated radiolucency is suggestive of ameloblastoma, a variety of other odontogenic and nonodontogenic lesions may show similar presentation (Carlson 2000). Eversole and colleagues documented a desmoplastic variant of ameloblastoma primarily occurring in the anterior maxilla. It has a mixed radiographic presentation due to osseous metaplasia of the fibrous septa resembling any other fibro-osseous lesion (Neville et al. 2002). The clinical, radiographic, and histologic presentations of multicystic ameloblastoma are shown in Fig. 1.

Unicystic Ameloblastoma

The unicystic ameloblastoma was originally described by Robinson and Martinez in 1977. Based on clinical, radiographic, and histopathologic features, the unicystic ameloblastoma has been considered as a separate entity. Although the initial studies reported less aggressive nature than solid tumors, current literature disputes this concept (Gardner and Corio 1984; Neville et al. 2002).

In contrast to the solid or multicystic ameloblastoma, unicystic ameloblastomas occur at a younger age. The peak incidence is in second decade of life and posterior mandible is the most common site



Ameloblastoma, Fig. 1 Clinical, radiographic, and histologic presentation of multicystic ameloblastoma. (**a**) Frontal photograph showing facial asymmetry due to expansion of left mandible. (**b**) Intraoral photograph revealing buccal cortical expansion with missing teeth typical of osteolytic lesions. (**c**) Panorex showing multiloculated radiolucent lesion on the left mandible with resorption of left second premolar root surfaces. (**d**) Axial section showing buccal and lingual cortical expansion with perforation. (**e**) Coronal section showing similar findings. (**f**) Histopathologic section revealing plexiform ameloblastoma with anastomosing cords of odontogenic epithelium

(Philipsen and Reichart 1998). It appears as a well-defined circumscribed radiolucency around the crown of unerupted tooth, which resembles a dentigerous cyst. The clinical and operative findings are consistent with an odontogenic cyst, but slightly different histopathologic findings, which will be discussed later, characterize the lesion as an unicystic ameloblastoma.

Whether the unicystic ameloblastoma arises de novo or it is the neoplastic transformation of cystic epithelium has long been debated with the possibility that both mechanisms are likely to occur. Dentigerous cyst can transform into true neoplasms, with one study showing up to 17% of ameloblastomas were associated with existing dentigerous cyst (McMillan and Smillie 1981). However, this percentage varies by study (Paul et al. 1969; Taylor et al. 1971; Hansasuta 1972). Malignant transformation is considerably less than ameloblastic transformation. Figure 2 shows the clinical, radiographic, and histologic presentation of unicystic ameloblastoma.

Peripheral Ameloblastoma

The peripheral ameloblastoma is uncommon accounting for about 1% of all ameloblastomas. It arises from the dental lamina rests of oral mucosa or the basal epithelial cells (Wettan et al. 2001). It presents as a painless sessile or pedunculated lesion of the gingiva or the alveolar mucosa usually less than 1.5 cm in diameter. They occur over a wide age range, with peak incidence in fifth decade. Although these tumors do not invade the underlying bone, longstanding lesions have the potential to "cup out" bone in the jaws (Neville et al. 2002).

Malignant Ameloblastoma and Ameloblastic Carcinoma

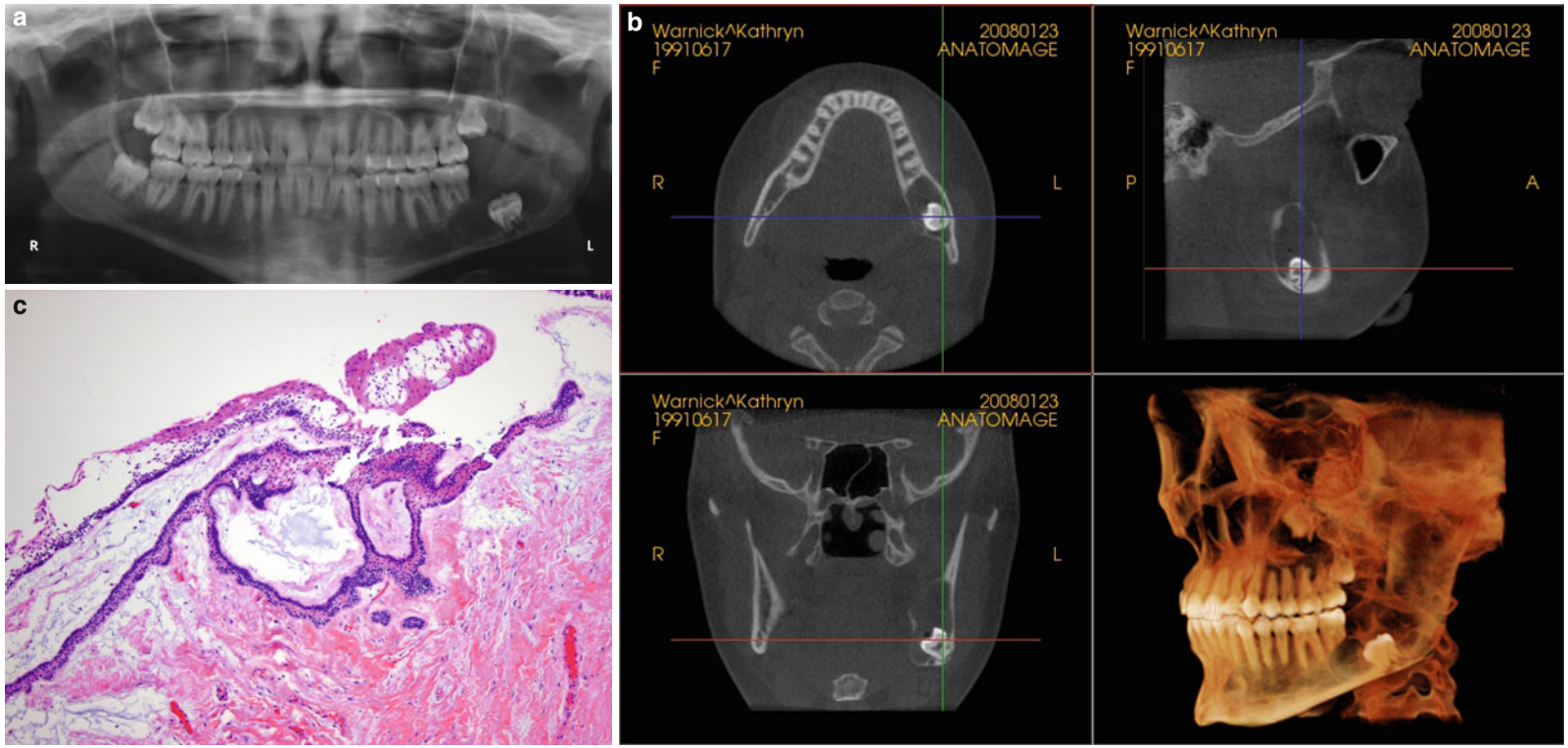
Malignant behavior can occur in less than 1% of all ameloblastomas. Malignant ameloblastoma refers to the presence of tumor in both a primary lesion and in metastatic deposits (Kunze et al. 1985; Laughlin 1989; Henderson et al. 1999). Ameloblastic carcinoma refers to a tumor that has cytologic features of malignancy in a primary tumor, recurrent lesion, or a metastatic deposit. Malignant ameloblastoma have been observed between 4 and 75 years with a mean age of 30 years. The metastasis is not usually apparent until 10 years after treatment (Newman et al. 1995; Hayashi et al. 1997). Ameloblastic carcinomas tend to develop later in life with the mean age at sixth decade of life. The most common sites of metastatic disease are the lungs, followed by the cervical lymph nodes and visceral organs (Gilijamse et al. 2007). Lung metastases have sometimes been regarded as aspiration phenomena, yet the peripheral location of many of these deposits supports hematogenous spread. Metastasis is more likely to arise from solid or multicystic tumors rather than unicystic ones (Slootweg and Muller 1984; Veness et al. 2001; Neville et al. 2002; Van Dam et al. 2010). The radiographic findings of malignant ameloblastomas are the same as the nonmetastasizing types. Ameloblastic carcinomas are often more aggressive lesions with ill-defined margins and cortical erosions noted radiographically (Gold 2000; Neville et al. 2002).

Diagnosis

Appropriate clinical exam and imaging is necessary in establishing a diagnosis. Initial imaging usually involves a plain film panoramic radiograph. This lesion typically appears as a uni- or multicystic radiolucent lesion. Most often the lesion involves the posterior mandible with or without association with an impacted molar tooth.

Helical computed tomography (CT) allows precise assessment of the extent of bony involvement and violation of cortical borders. This is important for determining where supraperiosteal dissection is necessary to maintain at least one uninvolved anatomic tissue layer on the tumor specimen and to plan the most appropriate reconstruction. In-office cone-beam computed tomography (CBCT) can be utilized for planning resection margins. However, this modality has several limitations compared to helical CT. Contrast cannot be administered, rendering of soft tissues is of poorer quality, and the data set is not as high quality for performing virtual surgery or fabrication of stereolithography models.

Histopathologic diagnosis is essential for accurate classification and for directing appropriate therapy. For larger lesions, an incisional biopsy for routine histology is carried out first to establish a diagnosis and definitive treatment plan. This can be done in the office setting under local anesthesia and intravenous sedation. Consultation with an oral pathologist or head and neck pathologist is important in formulating a diagnosis.



Ameloblastoma, Fig. 2 Clinical, radiographic, and histologic presentation of unicystic ameloblastoma. (**a**) Panorex showing unilocular radiolucency involving the unerupted third molar and resorption of adjacent tooth roots. (**b**) Axial, sagittal, coronal, and 3D preoperative images. (**c**) Histopathologic section revealing mural type with fibrous wall of cyst being infiltrated to varying depths with follicular ameloblastoma

Ameloblastoma, Table 2 Histological types of ameloblastoma

Histologic pattern	Description
Follicular	Stellate reticulum is located within the center of the odontogenic island and exhibits foci of cystic degeneration
Plexiform	Stellate reticulum is located outside of the odontogenic rest with anastomosing cords of odontogenic epithelium
Acanthomatous	Islands of squamous differentiation of the odontogenic epithelium is present
Granular cell	Tumor islands exhibit cells that demonstrate abundant granular eosinophilic cytoplasm
Desmoplastic	Tumor contains extremely dense collagenized stroma
Basal cell	Nests of uniform basaloid cells are present, with a strong resemblance to basal cell carcinoma

The histologic features of ameloblastomatous proliferation were described by Vickers and Gorlin. These include hyperchromatism of basal cell nuclei of the epithelium lining the cystic cavities, palisading of the basal epithelium in a columnar configuration with polarization of their nuclei away from the basal lamina, cytoplasmic vacuolization of the basal cells, epithelial proliferation of bud-like extensions into the connective tissue of the cyst wall; epithelial nests seemingly detached from these extensions; hyperplasia of the cystic lining with lack of epithelial cohesiveness (Vickers and Gorlin, Cancer 1970). Histologic patterns include follicular, plexiform, acanthomatous, granular cell, desmoplastic, and basal cell types. Follicular and plexiform are the most common types (Neville et al. 2002) (Table 2).

Unicystic ameloblastoma has a pattern of epithelial proliferation that has been described in dentigerous cysts of jaws and does not exhibit all of the classic histologic criteria as described by Vickers and Gorlin (Robinson and Martinez 1977; Gardner 1981; Gardner and Corio 1983; Haug et al. 1990). Three different histopathologic variants have been described: luminal, intraluminal, and mural types. The *luminal* type is the simplest lined by ameloblastic epithelium showing a hyperchromatic polarized basal layer. The supporting connective tissue wall is uninvolved by the proliferating epithelial element. The *intraluminal* type has ameloblastic nodules projecting from the cyst lining into the cavity. The pattern of epithelial proliferation is essentially plexiform and resembles that seen in the solid plexiform ameloblastoma. The *mural* type has its fibrous wall infiltrated to varying depths with follicular or plexiform tumor. The epithelial elements may or may not be connected to the epithelial lining of the cystic component and there is variation in the amount of epithelial proliferation (Sciubba et al. 1999).

Peripheral ameloblastoma histopathologic features show islands of ameloblastic epithelium that occupy the lamina propria underneath the surface epithelium (Sciubba et al. 1999; Neville et al. 2002).

Differential Diagnosis

A multilocular lesion of the posterior mandible with or without bony expansion is typical for ameloblastoma but not pathognomonic. The differential diagnosis for such a lesion includes an odontogenic cyst or tumor, a nonodontogenic tumor (benign or malignant), vascular lesions, and bony metastasis (Cohen and Bhattacharyya 2004).

Prophylaxis

A true prophylaxis for ameloblastoma which is a benign and locally aggressive odontogenic neoplasm of jaws is not available. It usually presents as an asymptomatic slow-growing painless lesion that is identified as an incidental finding on radiographic examination. Due to the possibility for development of a dentigerous cyst and even an ameloblastoma in association with an impacted tooth, consideration should be given to removal/extraction of impacted teeth, particularly third molars (wisdom teeth). A radiolucent lesion, particularly in the posterior mandible, many times warrants a surgical biopsy.

Therapy

The literature is replete with case reports/series demonstrating various treatment options for ameloblastoma ranging from enucleation and curettage to resection with wide local margins (Marx 1993;

Pogrel 1993; Carlson and Marx 2006; Goh et al. 2008). However, there is a lack of randomized controlled trials comparing various surgical modalities. Moreover, there is little data showing the effectiveness of adjunct therapy in management of ameloblastoma. It is generally agreed that a more aggressive treatment is indicated for solid or multicystic ameloblastoma, than the unicystic ameloblastoma.

Solid or Multicystic Ameloblastoma

Ablative Surgery

Because this tumor is generally considered benign and slow growing, some advocate a more conservative surgical approach, such as enucleation and curettage/peripheral ostectomy (Salmassy and Pogrel 1995; Sampson and Pogrel 1999; Sachs 2006; Sammartino et al. 2007; Sannomiya et al. 2008). Carlson and others advocate a more aggressive approach for the solid or multicystic variant. This includes resection with linear and anatomic barrier margin principles (Feinberg and Steinberg 1996; Carlson and Marx 2006). This is due to the fact that this tumor is highly destructive, tends to recur years later if undertreated, has the potential to metastasize, and can be fatal on rare occasion (Daramola et al. 1980; Carlson and Marx 2006). Recurrence rates have been reported from 55% to 90% for ameloblastomas of all types that had been treated by curettage (Shatkin and Hoffmeister 1965).

The solid or multicystic ameloblastoma tends to infiltrate between intact cancellous bone trabeculae at the periphery of the tumor before bone resorption becomes evident on radiograph. The actual tumor margin therefore extends beyond the radiographic or clinical margin (Kramer 1963). In a series of 82 ameloblastoma resections, Carlson found that tumor extended from 2 to 8 mm (mean 4.5 mm) histologically beyond the radiographic margin of the specimen (Carlson 2004). He concluded that a 1–1.5-cm bony linear margin provides a margin-free specimen and is curative if soft tissue margins are negative as well (Carlson and Marx 2006).

Tumor in the maxilla is more problematic compared to the mandible. The thin maxillary bone provides less of an anatomic barrier and the complex midface anatomy can make clearing a margin much more difficult than tumor involving the mandible. Once tumor has spread beyond the confines of the maxillary bone and involves adjacent structures, the chances of a surgical cure drop considerably (Carlson and Marx 2006).

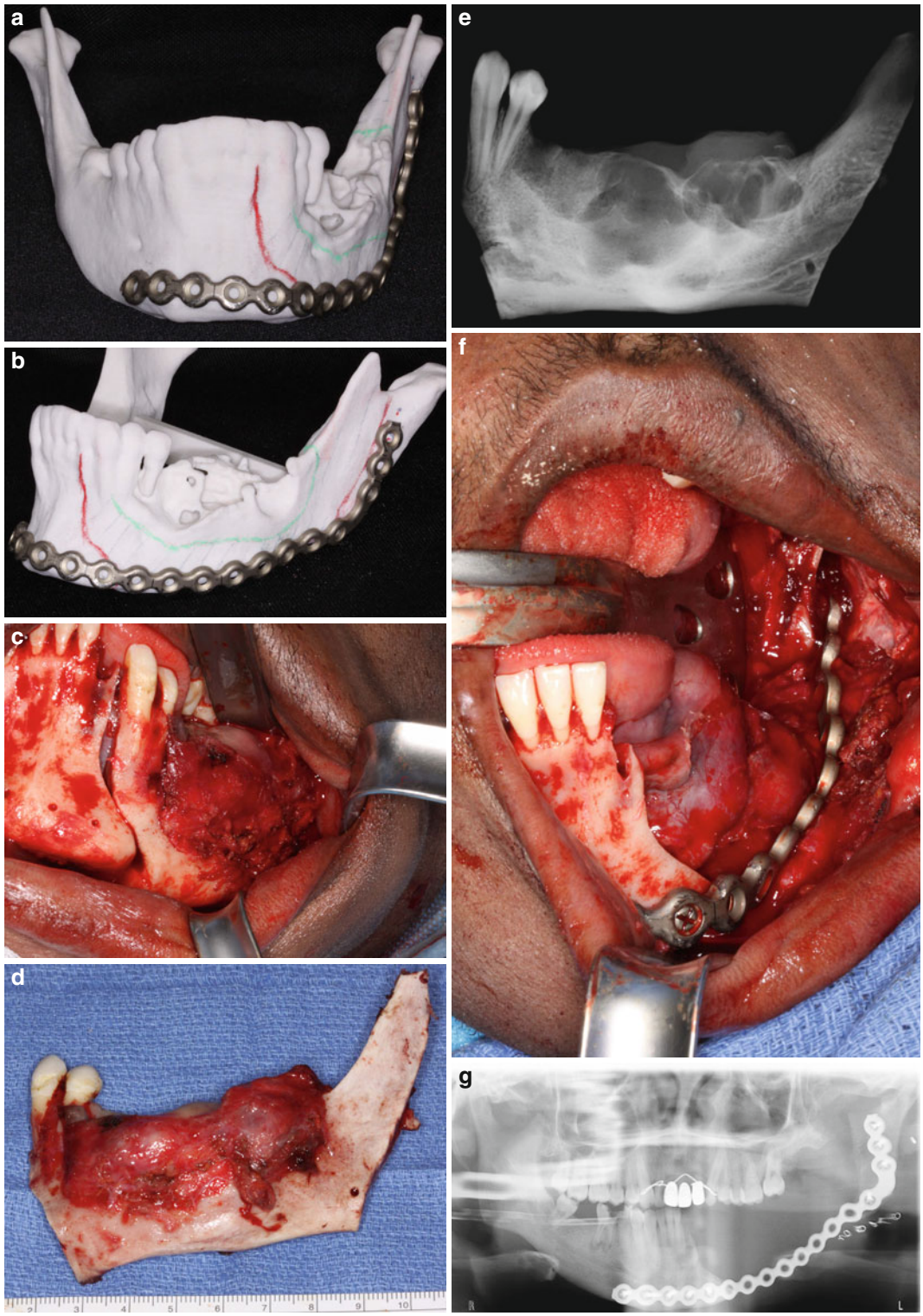
Segmental resection is typically necessary with 1–1.5-cm bone margins. In addition, tumor involving the posterior body/ramus may obviate need for disarticulation of the condyle from the glenoid fossa. This will make joint reconstructive and rehabilitation of jaw range of motion more difficult. In any area of cortical perforation, the mandible should be approached with supraperiosteal dissection. Soft tissue should be submitted for frozen sections intraoperatively to assure clear margins. A stereolithographic model to plan the resection and reconstruction can be helpful. Figure 3 shows the treatment planning, intraoperative, and gross specimen of multicystic ameloblastoma.

In the medically compromised or elderly patient, one can consider less aggressive surgery such as enucleation or en bloc resection with less than ideal margins. This seems reasonable if persistent or recurrent disease is unlikely to result in significant morbidity. Various adjunctive therapies have been advocated and can be considered in this situation to minimize the chance of persistent disease beyond resection margins. Cryotherapy has been advocated after tumor removal to achieve additional cell death by thermal injury beyond the resection margins (Pogrel 1993). In a similar manner, Carnoy's solution, which is a fixative, has also been advocated. But it is no longer available in the United States in its original formulation because one of its ingredients, chloroform, is carcinogenic. Further it has a caustic effect on adjacent tissues including nerves and possible systemic toxicity. The efficacy of cryotherapy and Carnoy's solution is not well documented. Figure 4 shows en bloc resection and cryotherapy

Reconstructive Surgery

Maxillary defects can be more difficult to manage with grafting techniques compared to those in the mandible. Obturator appliances were the standard some years ago although today microvascular free flaps are allowing for more predictable tissue reconstruction.

The reconstructive options for mandibular defects include primary and secondary bone grafting. In primary reconstruction, a vascularized or a non-vascularized graft is placed based on the size and soft tissue considerations of the defect. In secondary reconstruction, a reconstruction bone plate is placed during resection followed by a return in 3–4 months for secondary bone graft reconstruction. There is some debate as to the best method for bone reconstruction of the



Ameloblastoma, Fig. 3 (continued)

mandible. Both have been advocated. Each modality has benefits and drawbacks and indicated uses.

Free Bone Grafts

Both cortico-cancellous block and particulate grafts can be utilized. The anterior or posterior iliac crest is the usual donor site for such grafts (Goh et al. 2008). The volume of bone required is one factor that dictates the donor site. Posterior iliac crest can give up to 100 ml of bone while anterior crest only provides up to 50 ml of bone (Wilk 2004; Goh et al. 2008). The posterior crest in general has a lower complication rate with less reported gate disturbance, sensory disturbance, and hematoma/seroma formation (Marx 1993).

Cortico-cancellous block grafts offer the advantage of providing sufficient width and height to allow for subsequent implant reconstruction. Survival depends on revascularization from the recipient site through creeping substitution—a process of resorption and deposition of new bone. The graft should be rigidly fixated to prevent micro-movement that could jeopardize graft viability. These grafts do best in smaller defects not greater than 5 cm and that have a good soft tissue bed (Goh et al. 2008). The soft tissue bed is typically adequate due to fact that minimal soft tissue is usually resected and adjunctive radiation therapy is not commonly used.

Particulate bone cancellous marrow (PBCM) grafts have the advantage of superior osteogenic potential due to the osteocompetent cells present in the cancellous marrow. A two-phase osteogenesis occurs as transplanted cells form new random osteoid which is subsequently resorbed and remodeled into mature bone. However, due to the inherent lack of structural integrity, this type of graft requires a crib to maintain its physical dimensions and provide mechanical stability. Allogeneic and autogenous cribs as well as bone plates can be used for this purpose (Goh et al. 2008). A costochondral graft can be used in association with this graft to reestablish articulation if the condyle has been resected.

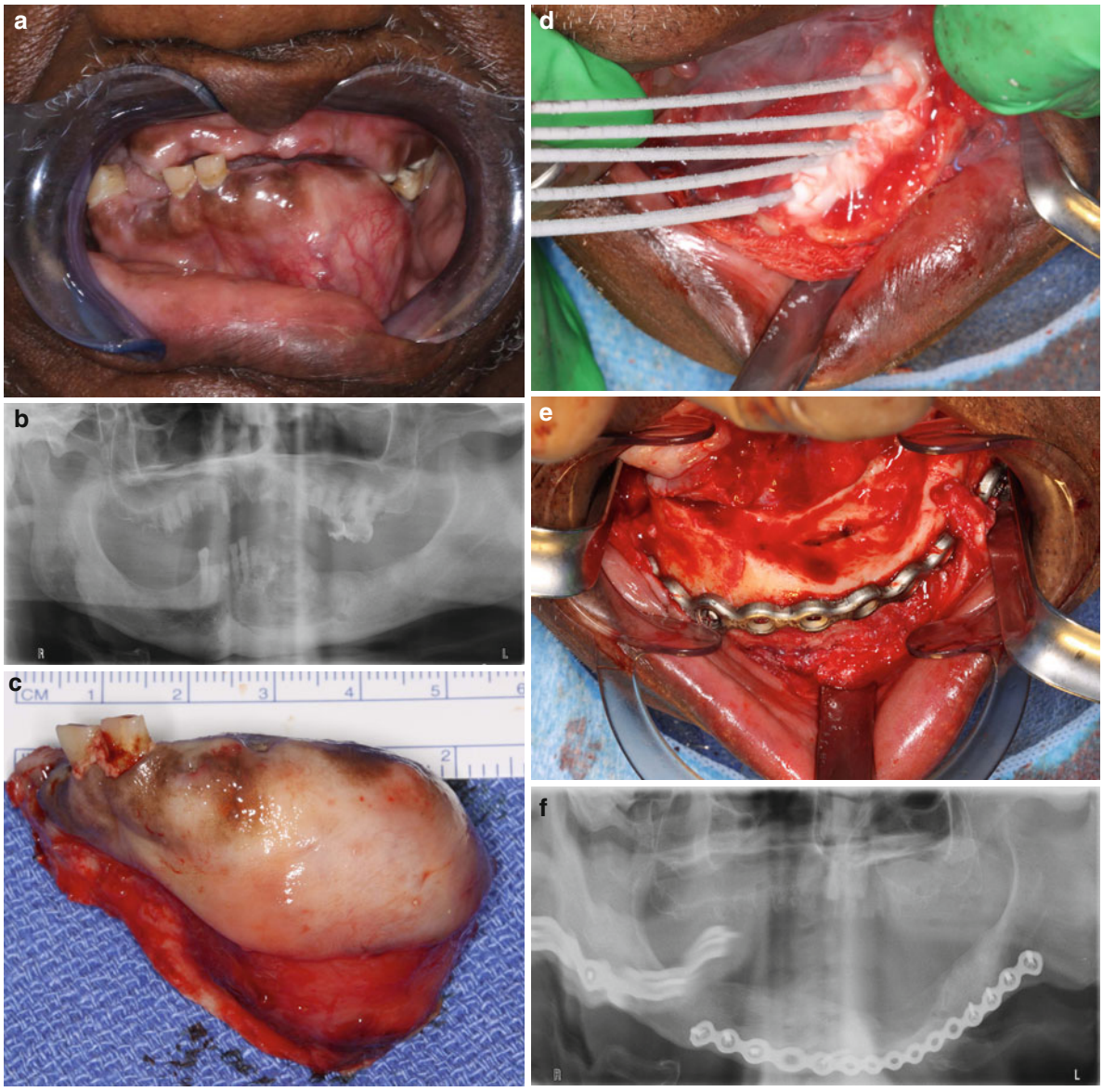
Advantages of the PBCM include the ability to attain adequate height and width to support dental implants for occlusal rehabilitation, and this graft can be used to bridge mandibular defects of any length. Disadvantages include remodeling resorption, wound dehiscence, and infection with loss of the graft. Complications can also arise from the bone plate or crib (Goh et al. 2008). These grafts are not as predictable for reconstruction of the symphysis region due to propensity for wound dehiscence and plate exposure in this region. Figure 5 shows a free bone graft reconstruction for mandibular defect.

Microvascular Free Flaps

A free tissue graft can be transferred with an intact blood supply with microvascular anastomosis. Bone alone or a composite graft can be used. The most common donor sites used include the fibula, radial forearm, scapula, and iliac crest. Each donor site differs in the quality and quantity of available bone and soft tissue, quality of the vascular pedicle, and ability to shape and place implants for occlusal rehabilitation (Goh et al. 2008).

Microvascular free flaps for mandibular reconstruction can be considered the gold standard today (Kelly et al. 2004; Gonzalez-Garcia et al. 2008). There are situations in which free flaps offer a clear advantage over non-vascularized grafts. These include a defect size greater than 6 cm, a defect involving the symphysis region, and a defect in which significant overlying soft tissue must be excised to clear a margin. For instance, if floor of mouth mucosa is exonerated, a composite graft with soft tissue to reconstruct the floor of mouth can be utilized. Complications with

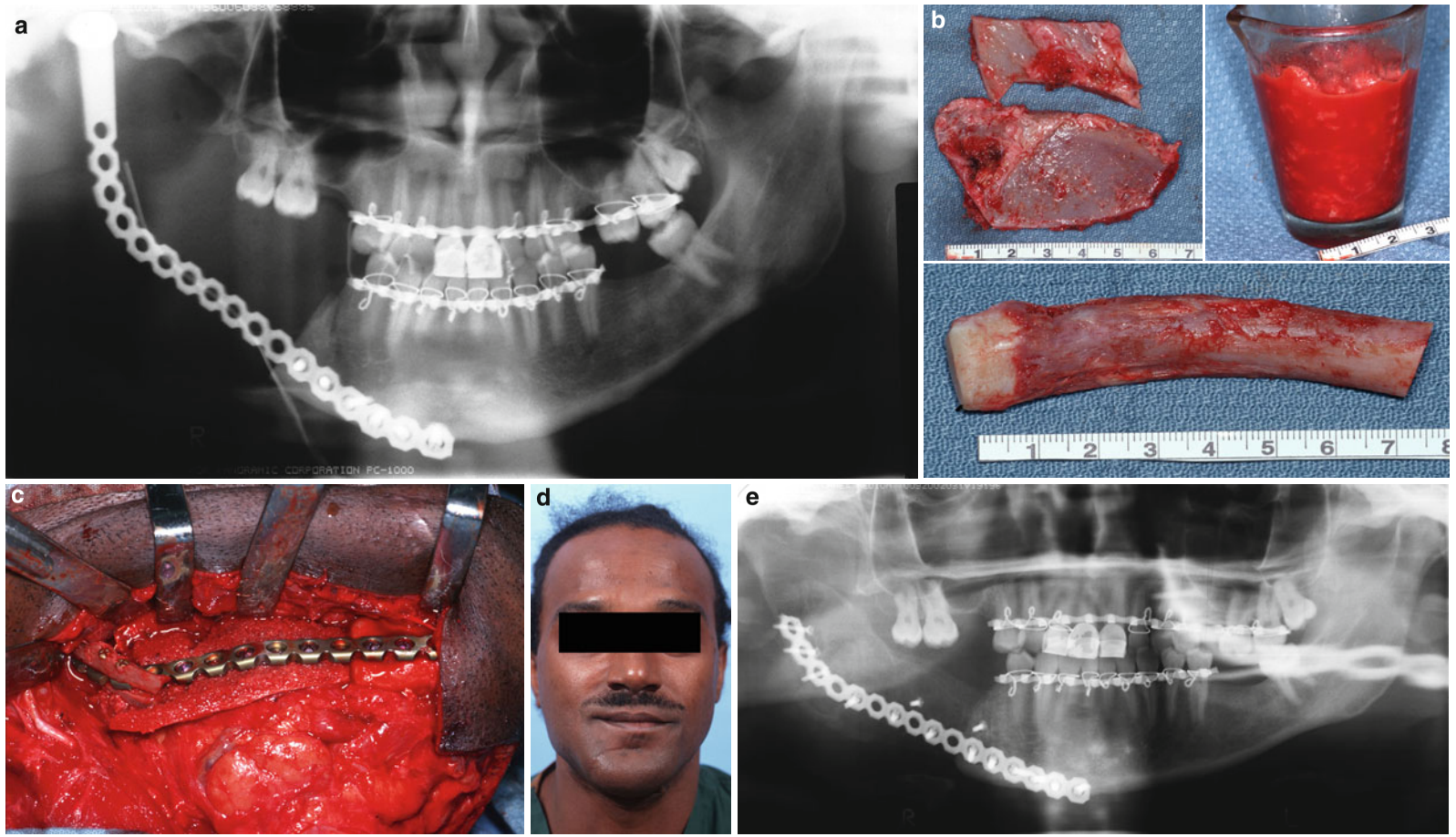
Ameloblastoma, Fig. 3 Treatment planning, intraoperative, and gross specimen of multicystic ameloblastoma. (**a**) Frontal view of stereolithographic (SLA) model with secondary reconstruction plate adapted. The lesion and resection margins of about 1 cm are outlined. (**b**) Lateral view of SLA model with adapted reconstruction plate and resection margins. (**c**) Intraoperative view of anterior osteotomy adjacent to the canine tooth. An incisor tooth is removed so that there is a ledge of bone at the resection margin. This aids in preventing mucosal dehiscence in this area. (**d**) Resected specimen with supraperiosteal dissection where the cortex has been perforated. (**e**) Intraoperative radiograph of the specimen to confirm clear margins. (**f**) Pre-adapted secondary reconstruction plate secured in place with at four bicortical screws in each segment. Note that the plate was properly positioned and drill holes and screws placed in each segment before resection in order to ensure that proper segment alignment and occlusion were maintained after the resection. (**g**) Postoperative panoramic X-ray confirming reconstruction plate placement. Note the proximal condylar segment in glenoid fossa, and pre-resection occlusion was maintained



Ameloblastoma, Fig. 4 En bloc resection and cryotherapy. (**a**) Intraoral photograph showing expansion of alveolar ridge. (**b**) Radiolucent lesion of the anterior mandible. (**c**) Gross specimen following en bloc resection. (**d**) Multiple cryoprobes being utilized simultaneously. At least three freeze/thaw cycles are recommended. (**e**) Prebent reconstruction plate utilizing an SLA model fixated to prevent a pathological jaw fracture with function. Note the intact lower border of mandible, and the mental nerve, which was preserved. (**f**) Postoperative panoramic X-ray documenting the resection and plate positioning

these grafts such as resorption and infection can be greatly reduced compared to other methods due to an intact blood supply (Goh et al. 2008).

The fibula is currently the most popular free flap for mandibular reconstruction and has the widest application. The flap is based on the peroneal artery and associated veins. The pedicle is adequate in length and diameter. Because the blood supply is both intraosseous and segmental, multiple osteotomies can be made to allow reshaping for improved contour. It can provide up to 30 cm of bone length, which is adequate to reconstruct any size defect. However, the height of the bone is inadequate relative to a dentate mandible. This can be problematic when dental



Ameloblastoma, Fig. 5 Secondary reconstruction using free bone graft. (**a**) Panorex showing previous ameloblastoma resection that involved the right body, ramus, and condyle. A primary reconstruction plate with a condylar prosthesis was placed at the time of the resection. (**b**) Posterior iliac crest block graft and particulate cancellous bone marrow (PCBM) and rib graft harvested. (**c**) The block graft is secured to the reconstruction plate at the body region, while the rib graft restores the ramus condyle unit. PCBM is packed around the block graft and reconstruction plate to improve bone regeneration. (**d**) Three month postoperative view with acceptable facial symmetry and well-healed lip-splitting incisions (used for the resection surgery). (**e**) Three month postoperative panorex showing stable graft union. Case courtesy of Edward Ellis, III, DDS, MS, Chairman, Department of Oral and Maxillofacial Surgery, University of Texas Health Science Center, San Antonio, Texas

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implants are planned for occlusal rehabilitation (Goh et al. 2008). Proponents of PBCM grafts point this out as a main reason to choose the non-vascularized graft over a fibula free flap. The use of a "double barrel" flap has been described to improve height and overcome this problem (Horiuchi et al. 1995).

The radial forearm is not commonly used for mandibular reconstruction due to restrictions associated with its relatively small size. The iliac crest was the main free flap used for mandibular reconstruction in the 1980s but today has been supplanted by the fibular free flap. Its advantages are an adequate bone size that is suitable for implants and ability to use in someone with peripheral vascular disease who may not be a candidate for a fibula flap. Disadvantages include a significant donor site deformity if bicortical bone is removed, herniation of the abdomen, and potential for permanent gait disturbance (Goh et al. 2008).

Virtual Surgery Resection Planning

Computer-assisted virtual surgical planning with CT-based models can be utilized for planning the surgical resection with appropriate margins and subsequent reconstruction. This is especially so when dealing with more complex cases, such as a recurrent tumor. Virtual planning can be assisted by third parties who specialize in providing this type of service, such as Medical Modeling, Inc., Golden Colorado. Planning is typically based on three-dimensional CT models. Interactive software is used for segmentation of the CT data, viewing 3D and planar images, and carrying out virtual surgery. Additive manufacturing (i.e., rapid prototyping) is then used to fabricate stereolithographic models and cutting guides to transfer the virtual plan to the operating room. Stereolithographic models are used to prebend bone reconstruction plates. Cutting guides are used intraoperatively to resect the tumor, ensuring adequate margins, and to harvest the bone flap and create osteotomies for contouring the graft to fit into the resection defect. Figure 6 shows a sample case for virtual surgical planning.

Radiotherapy

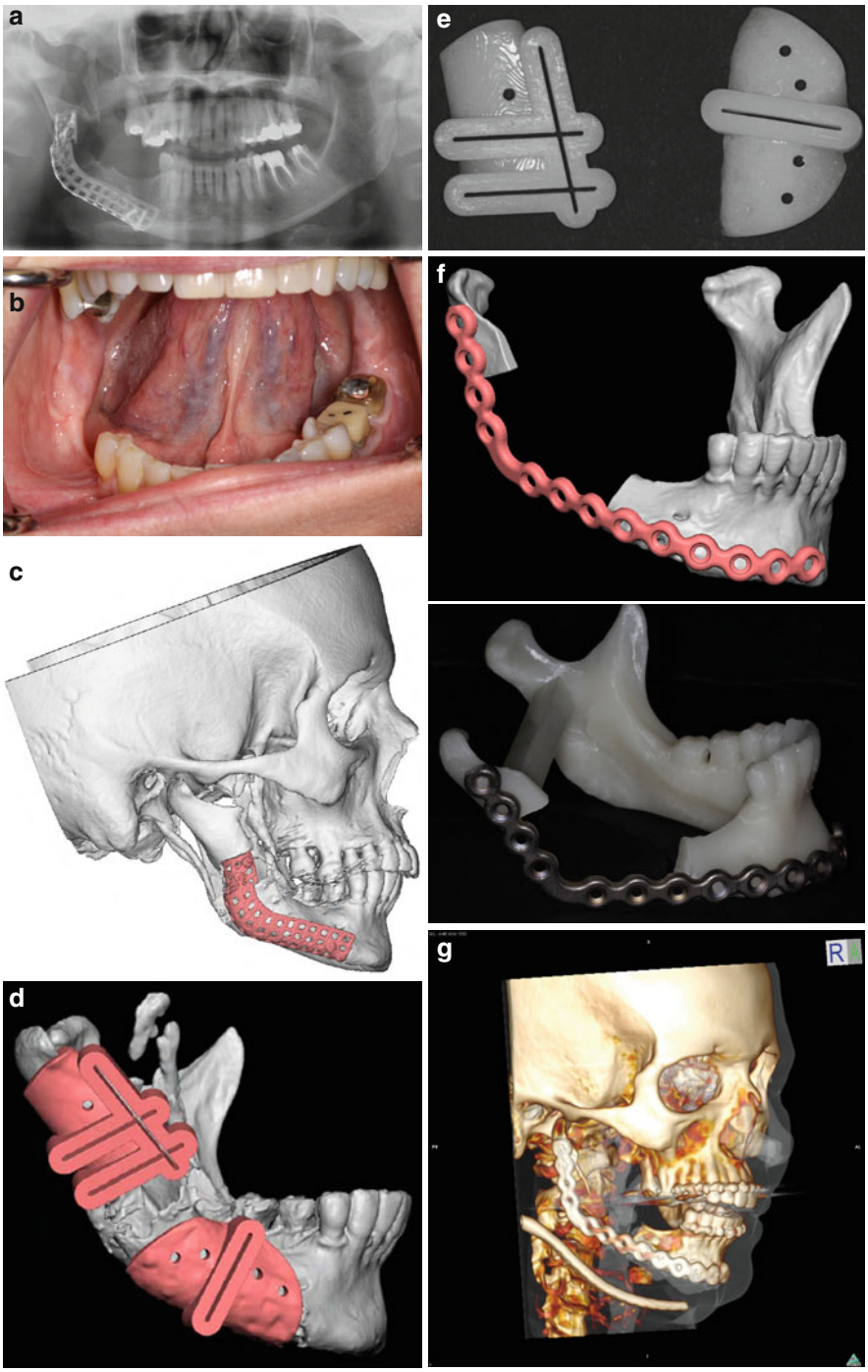
There is a lack of well-documented evidence in the literature concerning the relative radioresponsiveness or radioresistance of ameloblastomas, although they are generally considered radioresistant. Radiotherapy has been primarily reserved for patients with recurrent and/or incompletely resectable tumors. Most of the studies lack acceptable histopathologic proof of the diagnosis, adequate radiotherapeutic data, and/or follow-up information; many predate the use of megavoltage irradiation. Shatkin et al. reported on 24 patients treated for ameloblastomas between 1918 and 1963 at the Roswell Park Memorial Institute (Buffalo, New York). Only two of the total twenty-four patients were treated with radiotherapy; dose-fractionation schedules were not available (Shatkin and Hoffmeister 1965). Sehdev and coworkers reported on 92 patients with ameloblastoma treated between 1920 and 1970 at the Memorial Sloan Kettering Cancer Center. Nine of the patients were treated with radiotherapy for gross disease; dose-fractionation schedules were not available (Sehdev et al. 1974). Atkinson et al treated 10 patients with megavoltage irradiation. Six of seven patients treated by radiation alone had good locoregional control. All three patients treated by surgery and radiation had no disease recurrence (Atkinson et al. 1984). The outcomes of radiotherapy from recent reports are summarized in Table 3.

Currently, no clear indications for radiotherapy have been established in literature. The conclusions from the few studies available show that ameloblastoma is not an inherently radioresistant tumor as it was thought initially. However, radiotherapy should be considered for incompletely resected tumors with a positive margin which is not amenable to re-resection and as a treatment option for large maxillary ameloblastomas encroaching on vital structures. Dose-fractionation is similar to the management of oral squamous cell carcinomas (Huvos et al. 1985; Gardner 1988).

Unicystic Ameloblastoma

Ablative Surgery

In most cases, radiographic findings suggest the lesion is a dentigerous cyst because of the cyst's association with the crown of an unerupted tooth. Histopathologic diagnosis and accurate classification of this variant is essential for directing the appropriate therapy. The surgeon should open such a lesion that has the appearance of a cyst and look for luminal proliferation of tumor. This can add to proper classification. If complete excision of the lesion is planned, frozen sections with multiple sections through many levels of the specimen should occur to properly subclassify the variant of unicystic



Ameloblastoma, Fig. 6 Virtual surgical planning. (**a**) Preoperative panorex showing recurrent ameloblastoma with hardware failure; a pathologic fracture was clinically appreciated. This is the third recurrence over approximately 30 years. (**b**) Intraoral photograph. (**c**) 3D reconstruction confirming panorex findings. (**d**) Surgical cutting guides planned virtually using CMF Surgicase® software. (**e**) Cutting guides milled using rapid prototyping technology. (**f**) Virtual planning showing reconstruction plate placement following resection. Plate prebent on SLA model. (**g**) Postoperative 3D reconstruction confirming resection and plate positioning. Fibula free-flap performed by Kristen Otto, MD and Gina Jefferson, MD, Department of Otolaryngology and Head and Neck Surgery, University of Mississippi Medical Center, Jackson, Mississippi

ameloblastoma. If only an incisional biopsy is carried out, the specimen can be sent for routine histology. Consultation with an oral pathologist or head and neck pathologist is important in identifying the subclass.

Recurrence rates for unicystic variant have been reported from 10% to 29%. Unfortunately, little is reported in the literature on recurrence and prognostic factors (Adekeye and Lavery 1986; Abaza et al. 1989; Gold 2000). It appears that when the lesion is

Ameloblastoma, Table 3 Outcomes of radiotherapy

Study	Recurrence	Extent of disease	Dose	Fractionation	Outcome
(Atkinson et al. 1984)	1 out 10 patients	7 gross, 3 microscopic	30–50 Gy	6–25 fractions	6 out of 7 treated by radiation only had good local regional control; All 3 patients treatment by surgery and radiation had no recurrence
(Philip et al. 2005)	2 out 2 patients	2 gross	63–66 Gy	35–39 fractions	Both patients had recurrent disease and died at 2.1 and 10 years, respectively
(Miyamoto et al. 1991)	1 out 1 patient	1 gross	54–63 Gy	30–35 fractions	Good local and regional control. Died of recurrent disease at 7.5 years

a luminal or intraluminal variant and occurs in younger patients (in their second and third decades of life), recurrence is less likely (Robinson and Martinez 1977; Gardner and Corio 1984). Enucleation and curettage is effective for the luminal and intraluminal variants (Carlson 2004).

Management of the mural variant is controversial because persistence may be higher with a more conservative curettage. If this diagnosis is made postoperatively (after an enucleation and curettage of the entire cyst), then close indefinite follow-up with appropriate radiographic imaging of the patient is an option. If an incisional biopsy is performed first, resection with appropriate margins may be chosen to minimize the chance of having a persistent tumor that later manifests as a recurrence.

There are three circumstances that warrant resection of a unicystic ameloblastoma. Recurrent unicystic ameloblastoma following an adequate enucleation and curettage warrants more aggressive resection. The mural unicystic variant is probably more aggressive than the luminal and intraluminal variants due to the presence of tumor in the cyst wall and its closer proximity to surrounding bone. It seems logical to manage these tumors with a surgery that is similar to that for solid or multicystic ameloblastoma. Finally, large tumors with significant expansion of cortical walls can be resected. Enucleation and curettage will essentially result in a resection and leaves the jaw at high risk for pathologic fracture (Carlson 2004; Lau and Samman 2006).

Reconstructive Surgery

If a simple enucleation and curettage is carried out, bone grafting may not be necessary. This is particularly true for a younger patient with good inherent regenerative potential. Larger size defects may require reconstructive procedures usually at the time of cyst removal. Placement of an inferior border reconstruction plate may be warranted to prevent a pathologic jaw fracture under function in the immediate postoperative period if a significant portion of the mandible is destroyed. A PBCM graft can be used to obliterate a larger size bony defect. If placed transorally, contamination with oral flora is thought to negatively affect graft success. However, in the presence of an adequate soft tissue bed and an immunocompetent patient, transoral placement of a particulate autogenous marrow graft can lead to predictably favorable result (Benson et al. 2006).

Peripheral Ameloblastoma

The peripheral ameloblastoma is managed by a wide local excision. When surgical margins are negative for tumor, a cure is highly likely (Carlson 2004).

Malignant Ameloblastoma and Ameloblastic Carcinoma

The prognosis of patients with malignant ameloblastoma appears to be poor. There is limited literature available that documents cases of malignant ameloblastoma with long-term follow-up. However, the basic principles in the management of conventional ameloblastoma and oral squamous cell carcinoma apply in their management. Surgical ablation with a minimum of 1–1.5-cm margins for the primaries accompanied with removal of fibrofatty contents of the neck for the treatment of cervical lymphatic metastases and a complete staging of cancerous process is critical. Radiation therapy can be used as primary or adjuvant therapy. Primary radiotherapy is usually reserved for those with significant comorbidities or when the primary tumor is unresectable.

Prognosis

In general, the solid or multicystic variant is believed to be the most aggressive one and have the highest rate of recurrence if undertreated. Tumors resected with adequate surgical margins have very low incidence for recurrence. A relatively less aggressive behavior and lower recurrence rate is associated with the unicystic variant (Gardner and Corio 1984; Carlson and Marx 2006).

Pathogenetically, the proliferative capacity of ameloblastomas has been positively correlated with the number of PCNA-positive cells. PCNA is a cell cycle antigen and has been used for the evaluation of the proliferative ability of many types of tumors (Kim and Yook 1994; Piattelli et al. 1998). Although no differences have been observed between the different histological types, a significant increase in the PCNA + cells were observed in recurrent tumors compared to nonrecurrent tumors. The nuclear PCNA positivity of the unicystic ameloblastoma was notably lower than the positivity of the solid or multicystic ameloblastoma. The overexpression of *BCL2* and *BCLX*, as well as the expression of IL-1 and IL-6 supports the aggressive behavior of the ameloblastoma (Slootweg 1995; Regezi et al. 2003).

Epidemiology

The incidence of ameloblastoma accounts for approximately 10% of all jaw tumors. A breakdown among the various categories of ameloblastoma yields a relative distribution of conventional solid or multicystic (86%), unicystic (13%), peripheral (1%), and malignant ameloblastoma and ameloblastic carcinoma (<1%). Multicystic is encountered over a wide age range with equal predilection in both sexes. Some studies indicate greater predilection to Afro-Americans while others indicate no racial preference. More than 80% of lesions tend to occur in the posterior mandible in the ramus third molar area. About 15% occur in the maxillary posterior region with remainder elsewhere. Unicystic ameloblastoma has a younger predilection with about 50% of tumors occurring during the second decades of life. The location is similar to multicystic occurring predominantly in the posterior mandible. Malignant ameloblastomas have been observed between 4 and 75 years with a mean age of 30 years. The metastasis is not usually apparent until 10 years after treatment (Newman et al. 1995; Hayashi et al. 1997). Ameloblastic carcinomas tend to develop later in life with the mean age at sixth decade of life. The most common sites of metastatic disease are the lungs, followed by the cervical lymph nodes and visceral organs (Gilijamse et al. 2007).

Cross-References

- Ameloblastoma
- Fibula Free Flap
- Free Tissue Transfer in Head and Neck
- Intensity Modulated Radiation Therapy

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Aminoglycoside

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Definition

Class of bactericidal antibiotic with high potential for ototoxicity. Targets the ribosomal RNA subunits of a bacterial cell.

Cross-References

► Sensorineural Hearing Loss (Ototoxicity)

Anamnesis

► Hearing Exam

Anaplastic Carcinoma of Skin

► Merkel Cell Cancer of Head and Neck

Anesthesia Considerations in Head and Neck Surgery

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Introduction

The first public demonstration of ether anesthesia took place in the Bullfinch Amphitheater of the Massachusetts General Hospital in 1846. Dr. William Morton anesthetized a patient with diethyl ether while Dr. John Warren excised a vascular tumor from the left side of the patient's neck and jaw. Anesthesia for head and neck tumor surgery was at the very beginning of surgical anesthesia. Since 1846, much has changed and yet much remains the same. While airway management in general and for head and neck surgery has undergone remarkable advancement, it is still the airway which demands special focus. The goal of airway management is simple: to provide the most expeditious form of management that has the lowest potential for injury and the greatest potential for control of the airway. Establishing, maintaining, and protecting an airway in the face of abnormal anatomy and simultaneous surgical intervention test the skills and patience of any anesthesiologist.

Surgical procedures for otorhinolaryngology will challenge the creativity and skills of the finest anesthesiologist. On a routine basis, the anesthesiologist will provide mask anesthetics, spontaneous or jet ventilation, controlled hypotension, and extubations during

deep levels of anesthesia. Most of these cases will be performed with little or no muscle relaxation. The patient population will vary from neonates to the elderly, with a significant number of pediatric cases.

The three main tasks of the anesthesiology team are (1) to keep the patient safe, (2) to keep the patient comfortable, and (3) to provide for good operating conditions during the preoperative, intraoperative, and immediate postoperative periods. The component qualities of an anesthetic are loss of consciousness, amnesia, analgesia, and muscle relaxation/paralysis. Anesthesia can be general, regional, or local; general anesthesia is provided for most head and neck surgeries, thus the need for airway management.

In a routine setting, the patient receives a general anesthetic, and the anesthetic "take-off" follows after a thorough preoperative history and physical. The patient is then brought into the operating room and positioned supine. Standard monitors are placed, as described later in this section. Preoxygenation occurs with 100% inspired oxygen to denitrogenate the patient's functional residual capacity. At that point, anesthesia is induced and the airway is managed appropriately. After intubation or other airway control, invasive monitors or additional intravenous access may be placed, and the surgery is allowed to commence.

Advances in Monitoring

There are serious legal and financial consequences of failed airway management. Fortunately, adverse outcomes related to poor airway management have decreased in frequency with the standardization of anesthetic monitoring. The American Society of Anesthesiology Standards for Basic Anesthetic Monitoring statement was first released in 1986 and further amended in 1998 and 2005. These standards call for continual evaluation of the patient's oxygenation, ventilation, circulation, and temperature during all administered anesthetics. Practically speaking, the standard mandates continuous oxygen analysis of the anesthetic circuit, pulse oximetry, end-tidal capnometry, tidal volume measurement, electrocardiography, and temperature, as well as intermittent (no less frequent than every 5 min) measurement of arterial blood pressure and heart rate. In addition, the routine use of the neuromuscular blockade (NMB) monitor (also called the "twitch" monitor) to assess degree of muscle paralysis and return of muscle strength after pharmacological reversal of paralyzing agents significantly contributed to improved patient safety. Compared with earlier eras, this document made the important leap of elevating pulse oximetry and capnometry to standards of care, thus allowing more rapid, accurate recognition of oxygen desaturation and rapid recognition of previously unrecognized esophageal intubation.

The consequences of this change were staggering. Respiratory system adverse events (including airway mishaps) accounted for 36% of claims in the ASA Closed Claims Project data set for the 1970s, but this percentage decreased to 14% of claims in the 1990s after implementation of the routine use of capnometry and pulse oximetry. Claims related to death or brain injury likewise had a similar drop in the percentage that was attributable to respiratory adverse outcomes. Caused in part by continuous pulse oximetry and capnometry, anesthesiology has been a leader in the patient safety movement in the past decade.

Anesthesia Pharmacology Overview

This sectio n provides a brief introduction to the array of drugs used by anesthesiologists to facilitate anesthesia and maintain control of the airway. An in-depth discussion of these agents is not within the scope of this entry; however, certain features of these drugs that are particularly applicable to airway management are highlighted.

Induction Agents and Volatile Anesthetics

In most adult patients, a peripheral intravenous line is started preoperatively to administer fluid and drugs. Therefore, most adult patients receive an intravenous induction of anesthesia. The most commonly used intravenous induction agents are thiopental, propofol, etomidate, and ketamine. Each of the intravenous induction agents has the advantage of quick onset, producing unconsciousness within 1–2 min when given in standard induction doses. Of note, thiopental and propofol are both associated with negative inotropic effects and a related drop in blood pressure when used for induction of general anesthesia. Etomidate's effects are considered to be more hemodynamically stable, but this drug has the drawbacks of potential

adrenal suppression and myoclonic activity. Thiopental, propofol, and etomidate all produce apnea along with unconsciousness. In contrast to the other three agents, ketamine is notable for not producing apnea with administration. The maintenance of spontaneous ventilation with ketamine is an important consideration in the management of patients with potentially difficult airways and other subsets of patients presenting for surgery. In addition, ketamine has the advantage of being able to be given intramuscularly in patients without intravenous access. The major disadvantages of ketamine include emergence delirium and the sympathomimetic effects of the drug, and thus can cause tachycardia and hypertension, which limit its role in the treatment of patients with cardiovascular disease. Additionally, ketamine produces exaggerated secretions, and an antisialogogue such as glycopyrrolate should be coadministered if the airway is not secured immediately after induction.

For most adults, the volatile anesthetic agents (e.g., isoflurane, sevoflurane, and desflurane) are used for maintenance of anesthesia rather than induction. Their role in induction of anesthesia is limited by slower onset of activity and patient inability to tolerate the scent of the anesthetic gas. However, in pediatric anesthesia, wherein most patients are intolerant of intravenous placement before coming to the operating room, "mask inductions" with volatile agents is common. Sevoflurane is typically the agent used for mask induction because it is considered less noxious than the other agents. All of the volatile agents have the significant advantage of maintaining spontaneous respiration while producing unconsciousness.

Adjuncts to Induction: Sedatives and Opioids

Benzodiazepines are also commonly given in the immediate preoperative period for their anxiolytic and amnestic effects. Midazolam is the most commonly used benzodiazepine because it has onset of activity in 2–4 min. In larger doses, benzodiazepines can also be used as induction agents themselves. In sedative doses, the benzodiazepines do not typically produce significant respiratory depression. However, in combination with opioids, the respiratory depression can be synergistic. Furthermore, the response to benzodiazepines can be idiosyncratic, and a sedative dose can produce unconsciousness and apnea in sensitive patients.

Opioids are used intraoperatively to provide analgesia and a balanced anesthetic. When given as part of anesthetic induction, they are useful in blunting the sympathetic response to laryngoscopy and intubation. They also have a role during sedation of patients because they can produce a sense of well-being, with decreased responsiveness to noxious stimuli. Commonly used opioids are fentanyl, sufentanil, remifentanil, morphine, and hydromorphone. Opioids produce a dose-dependent central respiratory depression with increased $Paco_2$ and diminished respiratory drive. This respiratory depression can often be offset in the awake patient by asking the patient to consciously breathe deeply. However, the combination of opioids with benzodiazepines can result in a patient with central apnea who is unresponsive to instructions to breathe. Both opioids and benzodiazepines can be antagonized at the receptor level by naloxone and flumazenil, respectively.

Lidocaine is sometimes used as adjunct during anesthetic induction, although not in doses large enough to be an induction agent itself. Propofol can cause venous irritation during administration, and pretreatment with lidocaine into the same vein may decrease patient discomfort. In addition, lidocaine does have its own anesthetic effects and may decrease sympathetic response to laryngoscopy and intubation. Doses are kept to 1–1.5 mg/kg to avoid potential toxicity of local anesthetics, which are described later.

Paralytic Agents

Paralysis of the patient eases endotracheal intubation by relaxing the jaw and stopping vocal cord motion. Furthermore, paralysis is often necessary for the surgical procedure itself. There are two classes of paralytics, depolarizing agents and nondepolarizing neuromuscular blockers.

The depolarizing agent used in the United States is succinylcholine. Succinylcholine acts at the acetylcholine receptor in the neuromuscular junction, activating the receptor but then occupying it and therefore prolonging the refractory period before the muscle can contract again. The drug eventually diffuses away from the receptor and is metabolized and deactivated by pseudocholinesterase. Succinylcholine does produce fasciculation of the muscle, which can cause postoperative myalgia. In addition, the original opening of the receptor causes potassium efflux from the muscle, which raises the serum potassium

transiently by approximately 0.5 mEq/L. This increase in potassium is exaggerated in patients with upregulated amounts of acetylcholine receptors, such as after differentiation caused by stroke or other central nervous system injury. In patients with already elevated serum potassium levels, succinylcholine can precipitate ventricular dysrhythmias.

The major advantage of succinylcholine is its very fast onset of action. Paralysis sufficient for endotracheal intubation can be reliably produced within 45–60 s. Another advantage is its short duration of action because clinical paralysis usually dissipates within 5 min of an intubating dose. It has been thought that this quick return of strength would allow resumption of spontaneous respirations if positive-pressure ventilation were not successful. However, a past study shows that deleterious oxygen desaturation may occur before resumption of spontaneous respirations. In addition, the small percentage of patients who are pseudocholinesterase deficient will have prolonged paralysis after administration of succinylcholine. Vigilant use of the NMB monitor has led to increased diagnosis of patients with atypical cholinesterase activity, which varies with the population but is cited to be 1:2,800 in the general population in the United States, with a 1:1 male/female ratio.[3] Confirmatory blood laboratory diagnosis is made by determining the patient's dibucaine number. Succinylcholine has also been identified as the most common muscle relaxant trigger for malignant hyperthermia (MH). Primary contraindications for the use of succinylcholine include known or suspected MH, increased intracranial pressure, increased intraocular pressure, and elevated potassium. Although not contraindicated in patients with pseudocholinesterase deficiency, administration should be monitored with the NMB monitor to verify full return of strength before extubation.

The other group of paralytics is the nondepolarizing neuromuscular blockers. These drugs work in the neuromuscular junction by preventing the binding of acetylcholine to its receptor and subsequent muscle contraction. There are many different nondepolarizing agents, clinically distinct because of their different times of onset, durations of action, and different routes of metabolism. None of these agents work as quickly as succinylcholine. In the patient in whom there is a contradiction to the use of succinylcholine, the nondepolarizer of choice for rapid-sequence intubation is rocuronium, which has an onset of action between 60 and 75 s. However, when given in doses sufficient for intubating conditions, the effects of rocuronium persist for 30–40 min (and cannot be pharmacologically reversed for 20–30 min), which can be a major problem if the initial attempts to intubate the trachea are unsuccessful. Establishment of mask ventilation is then essential, and although the risk of aspiration is now greater, there are no other options available to the practitioner.

Local Anesthetics

Local anesthetics are discussed here because of their use surgically as an adjunct for analgesia and because of their use for topical and regional anesthesia of the airway in awake patients. Lidocaine and bupivacaine are the most commonly used local anesthetics for local infiltration or nerve blocks at our institution. The surgeon must be aware of the maximum dose allowable, given the risk of local anesthetic toxicity, manifested first by central nervous depression and seizures, followed by cardiovascular dysrhythmias, and potentially ventricular fibrillation. The maximum dose of lidocaine is 5 mg/kg and up to 7 mg/kg can be given safely if epinephrine is used in the solution to slow uptake through subcutaneous tissues into the central circulation. A 2% lidocaine solution contains 20 mg/mL of lidocaine, so a 70-kg patient should receive no more than 17.5 mL of this solution. The effects of intravenous lidocaine administered during induction are additive to the amount of lidocaine absorbed from local infiltration, topical application, or regional block, so communication between the anesthesiology and surgical teams is crucial to avoid potentially toxic overdoses. The maximum dose of bupivacaine is 2–3 mg/kg, with the upper end of the range reflecting the addition of epinephrine to the solution during local infiltration. As a word of caution, toxic effects are seen with much lower doses of local anesthetics administered directly into the circulation, so careful aspiration must be done before injection of these drugs during infiltration or regional blocks. Injection into the carotid artery during extraoral glossopharyngeal block can produce immediate seizures and loss of consciousness.

Cocaine is also used for topicalization of the airway during head and neck surgery. The advantage of cocaine applied to the nasal mucosa is its vasoconstrictive properties in addition to its anesthetic properties. However, the side effects of cocaine include tachycardia and

hypertension, which can be particularly deleterious in patients with coronary artery or other cardiovascular disease. The addition of phenylephrine to lidocaine jelly offers similar vasoconstrictive properties with fewer risks than cocaine. In addition, cocaine has significant addictive properties, so its use during surgery must be intensively monitored.

Antihypertensives

Airway management in the last decade has been radically advanced by the increased understanding of the pathophysiology of ischemia and the judicious perioperative use of antihypertensives for patients at increased risk of ischemic events. Intraoperative hypertension and tachycardia can be a direct response to agents used in topicalization of the airway for awake airway management techniques, specifically cocaine, epinephrine in lidocaine mixtures, and phenylephrine in lidocaine mixtures. In the asleep patient, translaryngeal intubation of the trachea stimulates laryngeal and tracheal receptors, resulting in marked increase in the elaboration of sympathomimetic amines. This sympathetic stimulation results in tachycardia and an increase in blood pressure. In normotensive patients, this increase is approximately 20–25 mm Hg; it is much greater in hypertensive patients. This increase in blood pressure results from vasoconstriction, owing to unopposed alpha stimulation in hypertensive patients taking β-blocking agents.

The most commonly used antihypertensives for intraoperative control of hypertension and tachycardia related to airway management include the β-blockers esmolol and metoprolol, and the α- and β-blocker labetalol. Most blood pressure and heart rate changes occur about 15 s after the start of direct laryngoscopy and become maximal after 30–45 s. Esmolol is especially effective in blunting these responses because of its almost immediate onset of action, ease in titration, and short action of duration with half-life of 9 min. Labetalol is comparable in attenuating hemodynamic effects but is less immediate in onset of action and has a half-life of 5 h.

Standard Induction Versus Rapid-Sequence Induction

After the patient with an expected routine airway is monitored and anesthesia is induced, the next step is appropriate management of the airway.

An important question to ask before this point is whether the patient is at risk for aspiration of gastric contents into the airway, an event that can be potentially catastrophic. The patient's risk of aspiration of gastric contents helps determine whether the patient should be managed with rapid-sequence induction (RSI) and intubation or with a nonrapid sequence of events. The increased risk of aspiration is due to the presence of gastric contents and is the reason anesthesiologists are concerned about the length of time patients have been without food or drink before surgery. The ASA has published guidelines for preoperative fasting that are based on the time required for gastric emptying in healthy patients. As surgeons, your familiarity with these guidelines can prevent the delay or cancellation of elective surgery.

The summary of fasting recommendations is 2 h for clear liquids, 4 h for breast milk, and 6 h for other food or beverage, including infant formula and milk. In patients with delayed gastric emptying, such as diabetic gastroparesis, further fasting may be necessary for reduced risk of aspiration. In addition to adherence to fasting guidelines, pharmacologic agents given preoperatively may reduce risk of aspiration and include clear antacids (30 mL of 0.3-M sodium citrate), anticholinergic agents (atropine or glycopyrrolate), metoclopramide (to stimulate gastric emptying and to increase lower esophageal sphincter tone), and H_2-receptor antagonists (cimetidine or ranitidine) to decrease further secretion of additional acid.

In patients without increased risk of aspiration, a controlled and stepwise approach is taken with induction and intubation. After monitoring and preoxygenation, general anesthesia is induced. Once the patient is unconscious, positive-pressure mask ventilation is performed. Only after successful mask ventilation is established is a paralyzing agent given. This stepwise approach to the airway increases patient safety because, even if intubation cannot be performed successfully, it is known that the patient can be mask ventilated and oxygenated while the paralytic wears off or alternative intubation techniques are readied. The ability to ventilate a patient is more crucial than the ability to intubate a patient, and bag-valve-mask ventilation is a lifesaving skill that every anesthesiologist must master. After successful mask ventilation, the paralytic is given, and intubation is performed after the paralytic takes effect.

RSI and intubation are done for patients with an increased risk of aspiration, such as a patient with a full stomach or a patient with a significant history of gastroesophageal reflux. During an RSI technique, mask ventilation is not done because it can fill the stomach with air and increase the risk of aspiration even further. Instead, the paralytic agent is given immediately after the induction agent. Cricoid pressure is held throughout, and the patient is not ventilated for the time it takes the paralysis to take effect.

Proper preoxygenation allows most apneic patients to maintain oxygen saturation during this minute. The patient is intubated once paralysis is achieved, usually by means of direct laryngoscopy. After confirmation of proper endotracheal tube placement by end-tidal CO_2 and auscultation of bilateral breath sounds, the endotracheal tube cuff is inflated, and cricoid pressure can be released.

The risk of an RSI is that intubation may not be successful and the ability to mask ventilate the patient has not been previously established. The most dangerous result of failed RSI could be a paralyzed patient who cannot be ventilated or intubated.

Therefore, the stepwise approach to the induction of anesthesia and establishment of mask ventilation before paralysis is the safer and preferred technique for a patient without increased risk of aspiration and without an expected difficult airway. The stepwise approach for a patient with risk for aspiration and with an expected difficult airway requiring general anesthesia is awake versus RSI, with immediate backup in the event of failed intubation.

Anesthesia for Common Otolaryngology Situations

Endoscopy

Endoscopy includes laryngoscopy (diagnostic and operative), microlaryngoscopy (laryngoscopy aided by an operating microscope), esophagoscopy, and bronchoscopy. Endoscopic procedures may be accompanied by laser surgery.

Preoperative Considerations

Patients presenting for endoscopic surgery are often being evaluated for hoarseness, stridor, or hemoptysis. Possible causes include foreign body aspiration, trauma to the aerodigestive tract, papillomatosis, tracheal stenosis, obstructing tumors, or vocal cord dysfunction. Thus, a meticulous preoperative physical examination and medical history, with particular attention to potential airway problems, must precede any decisions regarding the anesthetic plan. In some patients, flow-volume loops or special radiographic studies (e.g., tomograms, computed tomography, or magnetic resonance imaging) may be available for review. Many patients will have undergone indirect laryngoscopy by the surgeon in clinic and the importance of discussing the findings and plans with the surgeon preoperatively cannot be overemphasized.

The most important questions that must be answered are whether the patient will be easy to ventilate with a face mask and easy to intubate with direct laryngoscopy. If either is in doubt, the patient's airway should be secured prior to induction by using an alternative technique such as described in the Chap. 5 Case Discussion (e.g., use of a fiberoptic bronchoscope or a tracheostomy under local anesthesia). It should be stressed that even securing an airway with tracheotomy does not necessarily prevent intraoperative airway obstruction due to surgical manipulation and techniques.

Sedative premedication is contraindicated in any patient with any significant degree of upper airway obstruction. Administering glycopyrrolate (0.2–0.3 mg intramuscularly) 1 h before surgery may prove helpful by minimizing secretions, thereby facilitating airway visualization.

Intraoperative Management

The anesthetic goals for endoscopy include profound muscle paralysis to provide masseter muscle relaxation for introduction of the suspension laryngoscope and an immobile surgical field, adequate oxygenation and ventilation during surgical manipulation of the airway, and cardiovascular stability during periods of rapidly varying surgical stimulation.

Muscle Relaxation Intraoperative muscle relaxation can be achieved by either a continuous infusion of succinylcholine or intermittent boluses of intermediate-duration nondepolarizing neuromuscular blocking agents (NMBAs) (e.g., rocuronium, vecuronium, cisatracurium). A disadvantage of a succinylcholine drip is the potential of developing a phase II block during unexpectedly long procedures. On the other hand, an intermediate-duration

nondepolarizing block may prove difficult to reverse and may delay return of protective airway reflexes and extubation. These problems may be avoided by administering an intermittent bolus or continuous infusion of mivacurium or cisatracurium, short-acting nondepolarizing NMBAs. It should be noted that although profound relaxation is needed until the very end of the surgery, rapid recovery is important since endoscopy is often an outpatient procedure.

Oxygenation and Ventilation Several methods have successfully been used to provide oxygenation and ventilation during endoscopy. Most commonly, the patient is intubated with a small-diameter (4.0–6.0 mm) tracheal tube through which conventional positive pressure is administered. Standard tracheal tubes of this size, however, are designed for pediatric patients. They therefore tend to be too short for the adult trachea, with a low-volume cuff that will exert high pressure against it. A 4.0-, 5.0-, or 6.0-mm microlaryngeal tracheal (MLT) tube (Mallinckrodt Critical Care) is the same length as an adult tube, has a disproportionately large high-volume low-pressure cuff, and is stiffer and less prone to compression than a regular tracheal tube. The advantages of intubation include protection against aspiration and the ability to administer inhalational anesthetics and to continuously monitor end-tidal CO_2.

In some cases (e.g., those involving the posterior commissure), intubation with a tracheal tube may interfere with the surgeon's visualization or performance of the procedure. A simple alternative is insufflation of high flows of oxygen through a small catheter placed in the trachea. Although oxygenation may be maintained for brief periods in patients with good lung function, ventilation is inadequate for longer procedures unless the patient is allowed to breathe spontaneously.

Another possibility is the intermittent-apnea technique, in which periods of ventilation with oxygen by face mask or tracheal tube alternate with periods of apnea, during which the surgery is performed. The duration of apnea, usually 2–3 min, is determined by how well the patient maintains oxygen saturation as measured by a pulse oximeter. Hypoventilation with hypercarbia and pulmonary aspiration are risks of this technique.

A more sophisticated approach involves connecting a manual jet ventilator to a side port of the laryngoscope. During inspiration (1–2 s), a high-pressure (30–50 psi) source of oxygen is directed through the glottic opening and entrains room air into the lungs (Venturi effect). Expiration (4–6 s duration) is passive. It is crucial to monitor chest wall motion constantly and to allow sufficient time for exhalation to avoid air trapping and barotrauma. A variation of this technique is high-frequency jet ventilation, which utilizes a small cannula or tube in the trachea, through which gas is injected 80–300 times per minute. High-frequency jet ventilation requires an intravenous anesthetic. Capnography will tend to greatly underestimate the $PaCO_2$ during jet ventilation due to constant and sizable dilution of alveolar gases.

Cardiovascular Stability Blood pressure and heart rate often fluctuate strikingly during endoscopic procedures for two reasons. First, many of these patients have a long history of heavy tobacco and alcohol use that predisposes them to cardiovascular diseases. In addition, the procedure is, in essence, a series of stress-filled laryngoscopies and intubations, separated by varying periods of minimal surgical stimulation. Attempting to maintain a patient at a constant level of anesthesia invariably results in alternating intervals of hypertension and hypotension. Providing a modest baseline level of anesthesia allows supplementation with short-acting anesthetics (e.g., propofol, remifentanil) or sympathetic antagonists (e.g., esmolol) as needed during periods of increased stimulation. Alternatively, regional nerve block of the glossopharyngeal nerve and superior laryngeal nerve would minimize intraoperative swings in blood pressure. Invasive monitoring of arterial blood pressure should be considered in patients with a history of hypertension or coronary heart disease, even if the surgeon anticipates a short procedure.

Laser Precautions

Laser (*l*ight *a*mplification by *s*timulated *e*mission of *r*adiation) light differs from ordinary light in three ways: it is monochromatic (i.e., it possesses one wavelength), coherent (it oscillates in the same phase), and collimated (it exists as a narrow, parallel beam). These characteristics offer the surgeon excellent precision and hemostasis with minimal postoperative edema or pain. Unfortunately, they also introduce some major hazards into the operating room.

The potential uses and side effects of a laser vary with its wavelength, which is determined by the medium in which the laser beam is generated. For example, a medium of CO_2 gas produces a long wavelength laser (the CO_2 laser has a 10,600-nm wavelength), whereas a medium of yttrium-aluminum-garnet (YAG) gem results in a shorter wavelength (the YAG laser can emit at 1,064- or 1,320-nm wavelength). As wavelength increases, absorption by water increases and tissue penetration decreases. Thus, the effects of the CO_2 laser are much more localized and superficial than those of the YAG laser.

General precautions include evacuation of toxic fumes (laser plume) from tissue vaporization; these may have the potential to transmit microbacterial diseases. Depending on the wavelength of laser being used, all operating room personnel should wear some type of eye protection, and the patient's eyes should be taped shut. The greatest fear during laser airway surgery is a tracheal tube fire. This can be avoided by using a technique of ventilation that does not involve a flammable tube or catheter (e.g., intermittent apnea or jet ventilation through the laryngoscope side port). Some procedures, however, require a tracheal tube because of the expected duration of the case, location of the lesion, or preexisting lung problems in the patient. In these cases, using a tracheal tube that is relatively resistant to laser ignition may be warranted. In an effort to protect tracheal tubes from laser ignition, tubes can be wrapped with a variety of metallic tapes; however, they should be used with caution. There are commercially available flexible stainless steel tracheal tubes that resist laser strikes. If laser beams hit the tube, they are defocused, decreasing the chance of damage to healthy tissue. There are double cuffs at the distal end to seal the airway. Therefore if the upper cuff is struck by laser and the saline escapes, the lower cuff will continue to seal the airway. The technology for the tube was developed by the National Aeronautics and Space Administration (NASA), another civilian benefit of the space program.

It should be emphasized that no cuffed tracheal tube or any currently available tube protection is completely laser proof. Therefore, whenever laser airway surgery is being performed with a tracheal tube in place, the following precautions should be observed:

1. Inspired oxygen concentration should be as low as possible (many patients tolerate an FIO_2 of 21%).
2. Nitrous oxide supports combustion and should be replaced with air (nitrogen) or helium.
3. The tracheal tube cuffs should be filled with saline dyed with methylene blue to dissipate heat and signal cuff rupture. A cuffed tube will minimize oxygen concentration in the pharynx. The addition of 2% lidocaine jelly (a 1:2 mixture with saline) into the proximal cuff can seal small laser-induced cuff leaks, potentially preventing combustion.
4. Laser intensity and duration should be limited as much as possible.
5. Saline-soaked pledgets (completely saturated) should be placed in the airway to limit risk of ignition.
6. A source of water (e.g., 60-mL syringe) should be immediately available in case of fire.

These precautions limit, but do not eliminate, the risk of an airway fire; anesthesiologists must always be prepared for that eventuality.

Nasal and Sinus Surgery

Common nasal and sinus surgeries include polypectomy, endoscopic sinus surgery, maxillary sinusotomy (Caldwell-Luc procedure), rhinoplasty, and septoplasty.

Preoperative Considerations

Patients undergoing nasal or sinus surgery may have a considerable degree of preoperative nasal obstruction caused by polyps, a deviated septum, or mucosal congestion from infection. This may make face mask ventilation difficult, particularly if combined with other causes of difficult ventilation (e.g., obesity, maxillofacial deformities).

Nasal polyps are often associated with allergic disorders such as asthma. Patients who also have a history of allergic reactions to aspirin should not be given any nonsteroidal anti-inflammatory drugs (e.g., ketorolac). Nasal polyps are a common feature of cystic fibrosis.

Because of the rich vascular supply of the nasal mucosa, the preoperative interview should concentrate on questions concerning drug use (e.g., aspirin) and any history of bleeding problems.

Intraoperative Management

Many nasal procedures can be satisfactorily performed under local anesthesia with sedation. The anterior ethmoidal nerve and sphenopalatine nerves provide sensory innervation to the nasal septum and

lateral walls. Both can be blocked by packing the nose with gauze or cotton-tipped applicators soaked with local anesthetic. The topical anesthetic should be allowed to remain in place at least 10 min before instrumentation is attempted. Supplementation with submucosal injections of local anesthetic is often required, particularly if scar tissue is present from prior surgery. Use of an epinephrine-containing solution or cocaine (usually a 4% or 10% solution) will shrink the nasal mucosa and potentially decrease intraoperative blood loss. Intranasal cocaine (maximum dose, 3 mg/kg) is rapidly absorbed (reaching peak levels in 30 min) and may cause detrimental cardiovascular effects.

General anesthesia is often preferred for nasal surgery because of the discomfort and incomplete block that may accompany topical anesthesia. Special considerations during induction include using an oral airway during face mask ventilation to mitigate the effects of nasal obstruction, intubation with a reinforced or preformed **r**ight-**a**ngle **e**ndotracheal (RAE) tube (e.g., an oral RAE tube, Mallinckrodt Critical Care), and tucking the patient's padded arms to the side. Because of the proximity of the surgical field, it is important to tape the patient's eyes closed to avoid a corneal abrasion. One exception to this is during endoscopic sinus surgery, when the surgeon may wish to periodically check for eye movement during dissection because of the close proximity of the sinuses and orbit. Similarly, NMBAs are strongly suggested because of the potential neurological or ophthalmic complications that might arise if the patient moves during sinus instrumentation.

Techniques to minimize intraoperative blood loss include supplementation with cocaine or an epinephrine-containing local anesthetic, maintaining a slightly head-up position, and providing a mild degree of controlled hypotension. A posterior pharyngeal pack is often placed to limit the risk of aspiration of blood. Despite these precautions, the anesthesiologist must be prepared for significant blood loss, particularly during the resection of vascular tumors (e.g., juvenile nasopharyngeal angiofibroma).

Ideally, extubation should be smooth, with a minimum of coughing or straining, as these will increase venous pressure and tend to increase postoperative bleeding. Unfortunately, strategies that accomplish this goal also tend to increase the risk of aspiration (e.g., deep extubation).

Head and Neck Cancer Surgery

Surgery for cancer of the head and neck includes laryngectomy, glossectomy, pharyngectomy, parotidectomy, hemimandibulectomy, and radical neck dissection. An endoscopic examination often precedes these procedures, while the timing of a tracheostomy depends on the patient's preoperative airway compromise. Some procedures may include reconstructive surgery, such as the transplantation of a free microvascular muscle flap.

Preoperative Considerations

The typical patient presenting for head and neck cancer surgery is elderly and has a long history of heavy tobacco and alcohol use. Preexisting medical conditions that often need preoperative evaluation and optimization include chronic obstructive pulmonary disease, coronary artery disease, chronic alcoholism, aspiration pneumonia, and malnutrition.

Airway management may be complicated by an obstructing lesion or preoperative radiation therapy that has further distorted the patient's anatomy. As always, if there is serious doubt regarding potential airway problems, an intravenous induction should be avoided in favor of awake direct or fiberoptic laryngoscopy (cooperative patient) or an inhalational induction, maintaining spontaneous ventilation (uncooperative patient). In any case, the equipment and personnel required for an emergency tracheostomy must be immediately available. Elective tracheostomy under local anesthesia is a prudent option, particularly if indirect laryngoscopy shows that the lesion is susceptible to dislodgment during intubation.

Intraoperative Management

Monitoring Because of the substantial blood loss associated with many of these procedures and the prevalence of coexisting cardiopulmonary disease, these patients often require arterial cannulation for blood pressure, blood gas, and hematocrit monitoring. If a central venous line or pulmonary artery catheter is deemed necessary, antecubital or femoral veins provide the best access. Arterial lines and intravenous cannulas should not be placed in the arms if a radial forearm flap is planned. A minimum of two large-bore intravenous lines should be secured and a urinary catheter (preferably with temperature-monitoring capability) placed. Inspiratory gases should be heated and humidified, and a forced-air warming blanket

should be positioned over the lower extremities to help maintain normal body temperature. Intraoperative hypothermia and consequent vasoconstriction can be particularly detrimental for perfusion of a microvascular free flap.

Tracheostomy Intraoperative tracheostomy is often a part of head and neck cancer surgery. During ventilation with 100% oxygen, the tracheal tube and hypopharynx should be thoroughly suctioned to limit the risk of aspiration of blood and secretions. After dissection down to the trachea, the tracheal tube cuff is deflated to avoid perforation by the scalpel. When the tracheal wall is transected, the tracheal tube is withdrawn so that its tip is just cephalad to the incision. Ventilation during this period is difficult because of the large leak through the trachea. A sterile wire-reinforced tracheal tube or J-shaped laryngectomy tube is placed in the trachea, connected to a sterile breathing circuit, and sutured to the chest wall. As soon as correct positioning is confirmed by capnography and chest auscultation, the old tracheal tube may be removed. An increase in peak inspiratory pressure immediately after tracheostomy usually signals a malpositioned tube, bronchospasm, or debris in the trachea.

Maintenance of Anesthesia The surgeon may request the omission of NMBAs during neck dissection or parotidectomy to identify nerves (e.g., spinal accessory, facial nerves) by direct stimulation and to preserve them. A mild hypotensive technique may be helpful in limiting blood loss. Cerebral perfusion pressure may be severely compromised, however, when the tumor involves the carotid artery (decreased cerebral arterial pressure) or jugular vein (increased cerebral venous pressure). Furthermore, a head-up tilt may increase the chance of venous air embolism. Following reanastomosis of a microvascular free flap, blood pressure should be maintained at the patient's baseline level. Vasoconstrictive agents (e.g., phenylephrine) should be avoided because even though systemic blood pressure increases, flap perfusion decreases due to vasoconstriction of graft vessels. Likewise, vasodilators (e.g., sodium nitroprusside or hydralazine) should be avoided due to decreased perfusion pressures.

Transfusion Blood loss can be rapid and substantial. Transfusion decisions must balance the patient's medical problems with the possibility of an increased posttransfusion cancer recurrence rate as a result of immune suppression. Rheological factors make a relatively low hematocrit (e.g., 27–30%) desirable when microvascular free flaps are performed. Diuresis should be avoided during microvascular free-flap surgery to allow adequate graft perfusion in the postoperative period.

Cardiovascular Instability Manipulation of the carotid sinus and stellate ganglion during radical neck dissection (the right side more than the left) has been associated with wide swings in blood pressure, bradycardia, arrhythmias, sinus arrest, and prolonged QT intervals. Infiltration of the carotid sheath with local anesthetic will usually ameliorate these problems. Bilateral neck dissection may result in postoperative hypertension and loss of hypoxic drive because of denervation of the carotid sinuses and bodies.

Maxillofacial Reconstruction Orthognathic Surgery

Maxillofacial reconstruction is often required to correct the effects of trauma (e.g., LeFort fractures) or developmental malformations, for radical cancer surgeries (e.g., mandibulectomy), or for obstructive sleep apnea. Orthognathic procedures (e.g., LeFort osteotomies, mandibular osteotomies) for skeletal malocclusion share many of the same surgical and anesthetic techniques.

Preoperative Considerations

Patients undergoing maxillofacial reconstruction or orthognathic surgical procedures often pose the greatest airway challenges to the anesthesiologist. Preoperative airway evaluation must be detailed and thorough. Particular attention should be focused on jaw opening, mask fit, neck mobility, micrognathia, retrognathia, maxillary protrusion (overbite), macroglossia, dental pathology, nasal patency, and the existence of any intraoral lesions or debris. If there are any anticipated signs of problems with mask ventilation or tracheal intubation, the airway should be secured prior to induction. This may involve fiberoptic nasal intubation, fiberoptic oral intubation, or tracheostomy. Nasal intubation with a preformed tube (nasal RAE) or a straight tube with a flexible angle connector is usually preferred in dental and oral surgery. The tracheal tube can then be directed

cephalad and connected to breathing tubes coming over the patient's head. On the other hand, nasal intubation should be carefully considered in LeFort II and III fractures because of the possibility of a coexisting basilar skull fracture and cerebrospinal fluid leak.

Intraoperative Management

Reconstructive and orthognathic surgeries can be associated with substantial blood loss. Strategies to minimize bleeding include a slight head-up position, controlled hypotension, and local infiltration with epinephrine solutions. Because patients' arms are typically tucked at their sides, at least two intravenous lines should be established prior to surgery. This is particularly important if one line is used for delivery of an intravenous anesthetic or hypotensive agent. An arterial line can be helpful during high-blood-loss cases, particularly as a surgeon leaning against the patient's arm may interfere with noninvasive blood pressure cuff readings. An oropharyngeal pack is often placed to minimize the amount of blood and other debris reaching the larynx and trachea. Because of the proximity of the airway to the surgical field, the anesthesiologist's location is more remote than usual. This increases the likelihood of serious intraoperative airway problems such as tracheal tube kinking, disconnection, or perforation by a surgical instrument. Airway monitoring of end-tidal CO_2, peak inspiratory pressures, and esophageal stethoscope breath sounds assumes increased importance in such cases.

At the end of surgery, the oropharyngeal pack must be removed and the pharynx suctioned. Although it is not unusual for there to be some bloody debris during initial suctioning, repeat efforts should be less productive.

If there is a chance of postoperative edema involving structures that could potentially obstruct the airway (e.g., tongue), the patient should be carefully observed and perhaps should be left intubated. Otherwise, extubation can be attempted once the patient is fully awake, and there are no signs of continued bleeding. Patients with intermaxillary fixation (e.g., maxillomandibular wiring) should have appropriate cutting tools at their bedside in case of vomiting or other airway emergencies.

Ear Surgery

Frequently performed ear surgeries include stapedectomy (usually under local anesthesia), tympanoplasty, and mastoidectomy. Myringotomy with insertion of tympanostomy tubes is the most common pediatric surgical procedure.

Intraoperative Management

Nitrous Oxide Because nitrous oxide is more soluble than nitrogen in blood, it diffuses into air-containing cavities more rapidly than nitrogen (the major component of air) can be absorbed by the bloodstream. Normally, changes in middle ear pressures caused by nitrous oxide are well tolerated as a result of passive venting through the eustachian tube. Patients with a history of chronic ear problems (e.g., otitis media, sinusitis), however, often suffer from obstructed eustachian tubes and may rarely experience hearing loss or tympanic membrane rupture during nitrous oxide anesthesia.

During tympanoplasty, the middle ear is open to the atmosphere and there is no pressure build-up. Once the surgeon has placed a tympanic membrane graft, the middle ear becomes a closed space. If nitrous oxide is allowed to diffuse into this space, middle ear pressure will rise, and the graft may be displaced. Conversely, discontinuing nitrous oxide after graft placement will create a negative middle ear pressure that could also cause graft dislodgment. Therefore, nitrous oxide is either entirely avoided during tympanoplasty or discontinued prior to graft placement. Obviously, the exact amount of time required to wash out the nitrous oxide depends on many factors, including alveolar ventilation and fresh gas flows but 15–30 min is usually recommended.

Hemostasis As with any form of microsurgery, even small amounts of blood can obscure the operating field. Techniques to minimize blood loss during ear surgery include mild (15°) head elevation, infiltration or topical application of epinephrine (1:50,000–1:200,000), and controlled hypotension. The use of controlled hypotension in ear surgery is somewhat controversial because of its inherent risks and questionable necessity. Because coughing on a tracheal tube during awakening (particularly during head bandaging) will increase venous pressure and may cause bleeding, a deep extubation may prove helpful.

Facial Nerve Identification Preservation of the facial nerve is an important consideration during some types of ear surgery (e.g., resection of a glomus tumor or

acoustic neuroma). During these cases, intraoperative paralysis with NMBAs may confuse the interpretation of facial nerve stimulation and should be avoided.

Postoperative Nausea and Vomiting Because the inner ear is intimately involved with the sense of balance, ear surgery may cause postoperative dizziness (vertigo), nausea, and vomiting. Induction and maintenance with propofol have been shown to decrease postoperative nausea and vomiting in patients undergoing middle ear surgery. Prophylaxis with decadron prior to induction, with administration of a 5-HT_3 blocker prior to emergence, should be considered.

Anesthesia for Otolaryngology

► Anesthetic Techniques for Otolaryngologic Patient

Anesthetic Techniques for Otolaryngologic Patient

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Synonyms

Airway management of otolaryngologic patient; Anesthesia for otolaryngology; Ear, nose, throat surgery: anesthetic management

Definition

Anesthesia for otolaryngology entails the development and implementation of a safe and suitable anesthetic plan for patients undergoing ear, nose, throat, or head and neck procedures. It is determined by the preoperative assessment and examination of the patient and the type of surgery. An understanding of airway anatomy, physiology, and knowledge of the wide variety of procedures is important. The ability to establish and maintain an unobstructed airway is a priority in otolaryngology. It is also necessary for the anesthesiologist to communicate and work closely with the surgeon because often times they are both working within the same area which can be challenging.

Characteristics

Anesthesia for Ear Surgery

Simple external ear and some middle ear procedures involving the tympanic membrane and stapes are suitable for local anesthesia with or without sedation. The decision to use local anesthesia with or without sedation over general anesthesia is based on numerous factors including patient cooperation, duration of procedure, patient preference, patient understanding, and surgical preference. Young children and uncooperative adults usually require general anesthesia due to the risks involved with sudden intraoperative movements.

External ear surgeries involve removal of simple lesions, foreign bodies in the external auditory canal, preauricular abnormalities, exostoses, and complex reconstruction of the external auditory canal. Four sensory nerves supply the external ear: the greater auricular nerve which is a branch of the cervical plexus which innervates the posteromedial, posterolateral, and inferior auricle; the lesser occipital nerve which innervates a small portion of the helix; the auricular branch of the vagus nerve innervates the concha and most of the area around the auditory meatus; and the auriculotemporal nerve innervates the anterosuperior and anteromedial aspect of the auricle. A regional field block around the auricle is done via four injection sites; the needle is advanced so that the anesthetic is infiltrated on all four sides of the auricle (Cousins and Bridenbaugh 1998). In addition to a local anesthetic injection to the peripheral nerves, sedation during the surgical procedures can be done with titration of agents such as midazolam, propofol, fentanyl, and/or remifentanil.

The use of an operating microscope in nearly all surgeries of the external, middle, and internal ear make general anesthesia the safer option. General anesthesia is defined as a state of unconsciousness resulting from anesthetic drugs (Miller et al. 2009). After general anesthesia induction the airway can be managed in several ways. The face mask can be used for simple short procedures such as a myringotomy and tube

insertions; this is one of the most frequently performed outpatient pediatric surgeries. General anesthesia delivered via a face mask requires the patient to maintain spontaneous ventilation, therefore a mask induction is done and the use of paralytics is contraindicated. The use of a face mask requires the anesthesiologist to maintain a tight seal in order to improve oxygenation, anesthetic delivery, and monitoring. The tight seal needs to be achieved in spite of frequent repositioning of the patient's head for surgical access. A laryngeal mask airway (LMA) can also be used during general anesthesia. The advantages of an LMA over a face mask are a better seal and ability to more accurately monitor gases (Miller et al. 2009). A tracheal tube is another option and safely provides a more secure airway particularly during the rotation and movement of the head. In addition, it is safer for the patient over a face mask or an LMA if field avoidance is required for surgery and the anesthesiologist has no direct and immediate access to the airway. The cuffed tracheal tube also provides protection from blood, debris, and gastric contents.

Clinical Aspects and Special Considerations During Ear Surgery

During ear surgeries and in particular middle ear surgery, the use of nitrous oxide is typically avoided. Nitrous oxide diffuses from blood to air cavities and can easily displace tympanic membrane grafts due to rising or negative middle ear pressure. The amount of nitrous oxide that diffuses into the air space depends on the concentration and length of time the patient is exposed to nitrous oxide while under anesthesia. If used, it should be discontinued 30 minutes prior to the tympanic membrane graft placement.

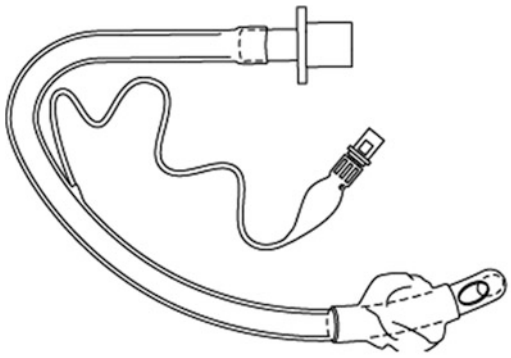
Due to the close proximity of the facial nerve during surgeries in the middle ear, inner ear, and mastoid, it is important to identify and monitor the facial nerve intraoperatively in order to avoid iatrogenic injury. The nerve is mapped with electrodes that result in an audible/visual response when the nerve is stimulated during surgery. For this reason, paralytics should be avoided since they can alter and/or eliminate nerve activity response.

Postoperative nausea and vomiting is common after inner ear surgery. It is important to administer prophylactic treatment with medications such as *dexamethasone*, serotonin antagonists such as *ondansetron*, and gastrokinetic agents such as *metoclopramide*.

Anesthesia for Nasal Surgery

Local anesthesia with or without sedation is suitable for septoplasty, procedures on the anterior septum, turbinectomy, polypectomy, and reduction of simple nasal fractures. The anterior ethmoidal nerve and sphenopalatine nerves provide sensory innervation to the septum, nasal cavity, and lateral walls. The nerve block is done by initially spraying the nasal mucosa with topical local anesthesia; this provides analgesia in order to tolerate the nerve blockade. The anterior ethmoidal nerve is anesthetized by passing a cotton-tipped applicator containing a local anesthetic along the dorsal surface of the nose until the anterior cribriform plate is reached. Regional blockade of the palatine nerves can be accomplished by blocking the pterygopalatine ganglion from which both palatine nerves arise (Morgan et al. 2006). This is accomplished noninvasively by taking a cotton-tipped applicator soaked in local anesthetic and passing it along the upper border of the middle turbinate to the posterior wall of the nasopharynx. Both cotton applicators must be left in place for 5–10 min in order for the nerve block to be effective. Along with local anesthetics, nasal vasoconstrictors are commonly used to reduce the size of the nasal mucosa and potentially decrease intraoperative blood loss. Commonly used vasoconstrictors include cocaine, epinephrine, and phenylephrine. Cocaine has both local anesthetic and vasoconstrictor properties. It is usually a 4% or 10% solution and the safe maximum recommended dose is 3 mg/kg. Epinephrine and phenylephrine are also commonly used and are usually combined with lidocaine.

General anesthesia is used for more complex or longer procedures including sinus surgery, rhinoplasty, septorhinoplasty, nasolacrimal surgery, anterior skull base procedures, and craniofacial procedures. It may also often times be preferred during simple procedures over local anesthesia with sedation due to the discomfort and the potential for an incomplete block. Nasal blockage and obstruction in many of these patients can make airway management difficult. An oral airway should be used in order to facilitate face-mask ventilation. An oral right-angle endotracheal (RAE) tube can be used for securing the airway (Fig. 1) (Morgan et al. 2006). It is an endotracheal tube that has a preformed right-angle bend at the level of the teeth in order to exit the mouth away from the surgical field during nasal surgery. In addition to an endotracheal tube, a throat pack is also inserted in order to prevent blood and



Anesthetic Techniques for Otolaryngologic Patient, Fig. 1 Oral right-angle endotracheal tube (Morgan et al. 2006, p. 841)

debris from contaminating the lower airway. A tracheal tube provides a more secure airway, the ability to paralyze a patient in order to deliver positive pressure ventilation and prevent patient movement for optimum safety. A flexible LMA may also be used for airway management during general anesthesia and if placed correctly can provide better protection from blood and debris by diverting it laterally due to its placement above the glottic airway. The flexible LMA has a wire-reinforced, flexible airway tube that allows it to be positioned away from the surgical field while minimizing the loss of seal; the wire-reinforced tube resists kinking and cuff dislodgement. It is particularly useful in adult and pediatric procedures where the surgeon and anesthesiologist are working in the same area, such as those involving the head and neck. It acts as a barrier for the glottis and trachea against contamination by blood and secretions from above, making it useful for intraoral and nasopharyngeal surgical procedures.

Clinical Aspects and Special Considerations During Nasal Surgery

Intraoperative bleeding can be minimized by the use of nasal vasoconstrictors, avoiding high blood pressures and maintaining the head of the bed slightly elevated. During general anesthesia a throat pack is placed in the posterior oropharynx in order to absorb the blood generated from the surgical procedure. The throat pack is removed at the end of the case and thorough suctioning is done by the anesthesiologist in order to clear additional blood and debris. Prior to extubation an orogastric tube may be inserted and suctioned to evacuate the stomach of any swallowed blood.

Extubation can be done when the patient is fully awake and following commands; this will allow the patient to clear and protect their airway once extubated. The disadvantage of an awake extubation is the discomfort experienced by the patient which may cause bucking, coughing, increased blood pressure, and increased risk of bleeding. A "deep" extubation, removing the endotracheal tube or LMA while the patient is still partially or fully anesthetized but spontaneously breathing, avoids coughing and increased risk of bleeding. The disadvantages of a "deep" extubation are that the patient is not fully awake to protect their airway and it may be difficult to manage if the patient has preexisting obstructive sleep apnea (OSA).

Anesthesia for Upper Airway Surgeries

Tonsillectomy and Adenoidectomy

The preoperative assessment should focus on identifying patients with obstructive sleep apnea (OSA), bleeding disorders, loose teeth, and/or active respiratory tract infections. Patients with OSA may present with varying degrees of obstruction ranging from snoring to periods of apnea. They are at increased risk for respiratory complications and may be difficult to mask ventilate. Children with severe OSA have an increased risk of desaturation, laryngospasm, and developing airway obstruction during induction. In patients who present with an upper respiratory tract infection, the surgery is typically postponed until symptoms resolve due to their greater risk of perioperative complications (Miller et al. 2009).

A tonsillectomy and adenoidectomy is a surgical procedure done under general anesthesia. Mask induction is used in uncooperative children or adults with difficult intravenous access. If the patient has OSA, there may be a delayed inhalational mask induction. Elevating the head of the patient may alleviate the soft tissue obstruction that arises from the enlarged tonsils. An intravenous standard induction is done with a combination of drugs including induction agents, narcotics, benzodiazepines, and paralytics in order to reduce airway irritability. The airway is protected and maintained using two techniques: an oral RAE tracheal tube positioned "south" in the midline away from the surgical field or placement of a flexible LMA. The

advantages of an endotracheal tube are that it provides a more secure airway, is less likely to be compressed by a mouth gag, is less likely to dislodge during the operation, and when compared to an LMA occupies less space in the oropharynx which provides for a better surgical field. The disadvantages of an endotracheal tube are the required use of paralytics, less optimal protection against airway soiling when compared to the flexible LMA, and the increased risk of laryngospasm and stridor post extubation. Advantages of a flexible LMA for airway management are the avoidance of paralytics, better barrier against airway soiling, potentially smoother emergence, less airway trauma, and less risk of laryngospasm. The disadvantages are that it is a less secure airway and may create a suboptimal surgical field. Manipulation of the mouth gag by the surgeon can dislodge the LMA or cause obstruction.

At the end of the case, it is the responsibility of the anesthesiologist to inspect the oropharynx and ensure that all blood, secretions, and debris have been cleared. The endotracheal tube can be removed while the patient is still under the effects of general anesthesia in order to minimize discomfort and post-extubation laryngospasm. Conversely, patients who are extubated when fully awake and following commands are better able to protect their airway on their own which is a benefit especially for those with a preexisting history of OSA. Post-extubation laryngospasm and stridor can be minimized by the use of topical lidocaine into the airway, intravenous lidocaine, propofol, and intravenous magnesium (Miller et al. 2009). The LMA is typically removed when patients follow commands and the cuff remains inflated in order to ensure removal of all secretions and debris from oropharynx.

Clinical Aspects and Special Considerations During Tonsillectomy and Adenoidectomy

Postoperative bleeding usually occurs within 6 h of surgery and is more common in adults. Signs suggesting significant blood loss are tachycardia, excessive swallowing, sweating, pallor, restlessness, hypotension, and difficulty breathing indicating airway obstruction. It is important for patients to have adequate peripheral intravenous access and be adequately resuscitated in the recovery room. Hemoglobin, hematocrit, and a coagulation panel should be checked and supplemental oxygen should be provided. If anesthesia is required, a rapid sequence induction should be done due to the significant amount of blood that has likely been swallowed. This will also provide a faster method of securing the airway and there will be a less likelihood of aspirating blood. A difficult airway should be anticipated given the concomitant increased edema and bleeding from recent surgery.

The use of perioperative steroids reduce morbidity by decreasing post-op nausea and vomiting, improving ability to tolerate a diet sooner, particularly in the pediatric population (Steward et al. 2001). Perioperative antibiotics in patients result in earlier return to normal diet and activity but have not been shown to decrease postoperative pain (Iyer et al. 2006).

Oral Cavity, Oropharyngeal, and Supraglottic Procedures

Standard induction and airway management techniques can be applied to patients with small lesions and no visible or clinical evidence of airway compromise. In patients with large lesions such as a partially occluding vascular tumor, peritonsillar abscess, or an expanding tongue base mass, a standard intravenous induction may cause a complete airway obstruction due to loss of soft tissue muscle tone. Face-mask ventilation may be difficult in these patients and may require an oral airway, nasal airway, or a jaw thrust maneuver to expand the tongue base forward. When inserting an airway or laryngoscope, one should be extremely cautious to avoid trauma, bleeding, or rupture of the lesion as this may put the patient at risk for aspiration of blood, tissue, or even pus from an abscess. If the lesion is large enough that severe airway obstruction is a concern, an awake fiber-optic intubation with local and topical anesthesia can be done. In these patients the glottis and lower airway are normal and the difficulty is encountered in bypassing the lesion in the upper airway. Additional techniques include awake tracheostomy with local anesthesia.

The indications for a nasotracheal intubation are intraoral, oropharyngeal, or dental procedures, and also when unable to obtain oral access due to trauma or trismus. A thorough preoperative assessment and airway examination is done prior to induction of anesthesia. Mechanical dilatation may be done through the nasal passage by inserting nasopharyngeal airways that are incrementally larger in size; this may however cause trauma and epistaxis. In addition, the nasotracheal tube may be submerge in warm water for several minutes prior to induction in order to

make it more malleable. The nasotracheal tube has a shorter diameter and is longer than a standard oral endotracheal tube. It should be lubricated and the nasal cavity may be topicalized with local anesthesia and vasoconstrictors. The tube is passed through either naris along the floor of the nasal pharynx until reaching the larynx. At that point with the aid of direct laryngoscopy the tube is advanced past the vocal cords using Magill forceps.

Anesthesia for Laryngeal Procedures and Endoscopic Procedures

Laryngeal procedures can vary from removal of minor vocal cord lesions to resection of obstructive tumors that may be causing severe airway compromise. The preoperative assessment should focus on standard airway assessment, identifying location and size of lesion by reviewing imaging available, anesthetic techniques used on previous procedures, history of obstructive sleep apnea, and symptoms such as hoarseness, dysphagia, and stridor.

Endoscopy includes diagnostic laryngoscopy or operative laryngoscopy, microlaryngoscopy which is laryngoscopy aided by an operating microscope, esophagoscopy, endoscopic sinus surgery, and bronchoscopy. The anesthetic goals during endoscopic procedures include providing adequate oxygenation and ventilation in spite of surgical manipulation and instrumentation within or around the airway, maintaining hemodynamic stability during variable periods of surgical stimulation, and lastly creating an optimal surgical field with the appropriate level of muscle paralysis either by intermittent doses of intermediate acting nondepolarizing neuromuscular blocking agents or by a continuous infusion of short-acting neuromuscular blocking agents (Morgan et al. 2006). There are two broad classifications of anesthetic techniques that may be employed during endoscopy: a closed system in which a cuffed endotracheal tube is used and an open system in which an endotracheal tube is not used (Miller et al. 2009). The decision to use either technique depends on the patient's existing condition, size and location of the lesion, laser use, and surgical plan.

The advantages of a closed system are establishing a secure airway, protection against aspiration, maintaining oxygenation and ventilation intraoperatively, delivery of inhalational anesthetics, and the ability to monitor end-tidal CO_2. The disadvantages are the limited surgical visibility and access in the operative field, the increased airway pressures as a result of smaller lumen tubes, and the risk of an airway fire if a laser is used during surgery. Patients may be intubated with a standard smaller diameter cuffed endotracheal tube (4.0–6.0 mm) or with a microlaryngeal tracheal tube which is the same length as an adult tube with a high volume to low pressure cuff; it is also stiffer which makes it less likely to be compressed during endoscopy.

The advantages of an open system are better surgical visualization of lesion and it is a safer option during laser surgery; however the disadvantages are the inability to secure a definitive airway and the risk of aspiration. There are several techniques to achieve an effective open system. These techniques include insufflation with spontaneous ventilation, intermittent-apnea technique, and jet ventilation.

The insufflation technique is done on a spontaneously breathing patient undergoing brief diagnostic or therapeutic procedures and for removal of lesions that are not obstructive (Miller et al. 2009). Inhalational induction is followed by topical anesthesia of the larynx and trachea. Insufflation of anesthetic gases and oxygen can be delivered either via a catheter above the larynx, a nasal airway, or a shortened tracheal tube inserted nasally. There should be an oral suction catheter in order to minimize operating room pollution due to volatile anesthetics.

The intermittent-apnea technique involves periods of ventilation with oxygen by face mask or tracheal tube followed by periods of apnea usually lasting 2–3 min as tolerated. Technique is not appropriate for patients with a difficult airway and limited respiratory or cardiac reserve.

Jet ventilation is a technique in which a jet of oxygen is delivered through a small catheter at certain rates to maintain lung expansion, alveolar ventilation, and oxygenation. The technique can be subdivided into manually versus mechanically, high- or low-frequency jet ventilation which differ in the rate at which oxygen is delivered, and the site at which the gas emerges – supraglottic, subglottic, or transtracheal under local anesthesia. The technique involves preoxygenation of the patient, intravenous induction, laryngoscopy and topicalization of the larynx, and lastly ventilation of the patient either by inserting an LMA or using a face mask until the surgeon is ready to begin instrumentation of the airway (Miller et al. 2009). Anesthesia during the procedure is maintained through a continuous

intravenous infusion. A jetting needle is attached to the laryngoscope (supraglottic) or a catheter is inserted (subglottic or transtracheal) to begin the jet ventilation at the optimal location. The high-frequency jet ventilators have automatic interruption of flow when preset pause pressure limits are reached. The main disadvantages of jet ventilation are the risk of barotrauma resulting in pneumomediastinum, pneumothorax, or subcutaneous emphysema and the inability to measure end-tidal CO_2. It is important to monitor the patient's respiratory pattern, chest movements, respiratory sounds, oxygen saturation on the monitor, and the endoscopic images throughout the procedure in order to be sure the jet ventilation technique is effective.

Laser Surgery and Safety

Endoscopic procedures may be accompanied by laser surgery. Laser surgery provides precision in targeting airway lesions with reduced postoperative edema. The greatest risk when there is an endotracheal tube in place is a tube fire. For some procedures an endotracheal tube is required due to the length of the case, location of the lesion, and/or preexisting lung problems in the patient. The only nonflammable laser-safe endotracheal tube is the all-metal cuffless tube. Most laser-safe tubes have laser-resistant properties around the shaft but may still ignite particularly around the unprotected cuff. Tracheal tubes may also be wrapped with metallic tape in order to prevent them from igniting. In spite of this, no cuffed tracheal tube or any currently available tube protection is completely laser proof. For safety reasons all precautions should be observed during endoscopic laser surgery which includes inspired oxygen to be the lowest tolerated to maintain adequate saturation (patients may tolerate FIO_2 of 21%), air should be used instead of nitrous oxide, the laser intensity and duration should be kept to a minimum while remaining effective, and the tracheal tube cuff may be filled with saline-dyed methylene blue to dissipate heat and signal if cuff rupture occurs.

If an airway fire occurs the airway-fire protocol should be followed immediately. The anesthesia circuit must be disconnected in order to stop ventilation of the lungs; the endotracheal tube should be removed and submerged in water to extinguish the fire; the patient should be ventilated with 100% oxygen via a face mask then reintubated with a standard tracheal tube; a bronchoscopy should be done in order to assess airway damage and remove possible debris; serial chest x-rays and arterial blood gases should be obtained; and a bronchial lavage, steroids, and antibiotics should be considered for severe burns.

In addition to airway fires, laser surgery can also cause atmospheric contamination from vaporization of tissues. The resultant smoke and particles can deposit in the alveoli. This is preventable by the use of a smoke evacuator and special masks. Other risks include inadvertent perforation of tissue or transection of blood vessels by misdirected laser energy, venous gas embolism, and ocular injury which can be prevented by use of protective eyewear on everyone in the operating room including the patient. The airway-fire protocol is given below.

1. Disconnect the circuit from the tracheal tube
2. Extubate the patient
3. Submerge the tracheal tube and other flaming material in water
4. Ventilate the patient with oxygen via face mask
5. Reintubate the patient
6. Perform a bronchoscopy in order to survey the airway damage and remove any debris
7. Obtain a chest x-ray and arterial blood gas
8. Consider a bronchial lavage, steroids, and antibiotics

Anesthesia for Lower Airway Surgeries

Glottic, Subglottic, and Tracheal Lesions

In procedures involving a glottic, subglottic, or tracheal lesion the anesthetic management is determined by the effect the lesion has on the airway patency. If the lesion is not causing any symptoms or signs of airway compromise, then standard anesthetic techniques can be applied. If the lesion is compromising the airway, then an awake fiber-optic intubation can be done. Topicalization with local anesthetic is often difficult and the fiber-optic bronchoscope can be challenging to pass through the obstructing lesion. Additional options include jet ventilation via a transtracheal catheter that is inserted below the level of the lesion under topical anesthesia while the patient is awake. Once placement is confirmed, intravenous anesthesia and jet ventilation are started. Supraglottic jet ventilation can be done in the presence of laryngeal tracheal stenosis. In patients with lower tracheal masses or lesions the difficulty is not in visualizing the larynx with direct laryngoscopy, but rather in passing the endotracheal tube into the trachea depending on the level of the obstruction; a rigid bronchoscope may be used to secure the airway.

Stridor

Stridor is an abnormal high-pitched sound resulting from turbulent air flow in a partially obstructed upper airway. It can be indicative of serious airway obstruction from severe conditions such as epiglottitis or other infections, a foreign body lodged in the airway, airway edema due to instrumentation of the airway, allergic reaction, laryngospasm, congenital airway abnormalities, or bilateral vocal cord paralysis.

Epiglottitis

Epiglottitis is an infection caused by *Haemophilus influenzae* which results in acute inflammation of the epiglottis, arytenoids, and aryepiglottic folds. The onset of symptoms is acute and can rapidly progress from sore throat to complete obstruction and respiratory failure (Baresh et al. 2009). Patient are usually 2–7 years old and present with stridor, sore throat, fever, dysphagia, muffled voice, drooling, and respiratory distress, and often favor the "tripod" position. It is important not to stimulate the patient or examine the airway while the patient is awake because this may lead to further airway compromise. The management of epiglottitis involves inhalation mask induction in the operating room; a direct laryngoscopy is done once the patient is deeply anesthetized while maintaining spontaneous ventilation. A tracheostomy tray should be available and open with the appropriate personnel ready should an emergent surgical airway be required. Once the airway is secure with an endotracheal tube, the patient is transferred to the intensive care unit for monitoring and further management.

Vocal Cord Innervation and Paralysis

The external branch of the superior laryngeal nerve innervates the cricothyroid muscle. The cricothyroid muscle tenses the vocal cords; injury to the superior laryngeal nerve will result in loss of tension in the vocal cords. The recurrent laryngeal nerve provides motor innervation to all other intrinsic muscles of the larynx which includes adductors and the posterior cricoarytenoid which is the only abductor of the vocal cords. Nerve damage can result from a stroke or surgical trauma during thyroid, parathyroid, or other neck surgeries. A unilateral injury is more common and can be either partial affecting only the abductor fibers (which are more commonly injured) or complete affecting both abductor and adductor fibers in which the vocal cord assumes a paramedian position. Bilateral complete recurrent laryngeal nerve palsy results in both vocal cords assuming a paramedian position. A bilateral partial nerve palsy only affecting the abductor fibers will cause bilateral adducted vocal cords which can critically obstruct airflow and may require an emergent surgical airway.

Foreign Body Aspiration

An aspirated foreign body can lodge in the larynx, trachea, main bronchi, or smaller airways. Patients may present acutely with difficulty breathing, dry cough, hoarseness, stridor, or wheezing depending on the location of the foreign body. Extreme caution must be taken to prevent dislodgment of the foreign body which may cause a partial obstruction to become a complete airway obstruction. The patient should be taken emergently to the operating room where the management involves an inhalation mask induction maintaining the patient's spontaneous ventilation. Sedation should not be given to the patient prior to induction (Baresh et al. 2009). Once a deep level of anesthesia is achieved, a direct laryngoscopy is done in order to topicalize the upper airway with local anesthesia. A bronchoscope is inserted to visualize and remove the foreign body. An intravenous anesthetic is used to maintain the patient adequately anesthetized during the procedure. The rigid bronchoscope has important advantages over the flexible bronchoscope. The larger diameter of the rigid bronchoscope facilitates the passage of various grasping devices and the ability to deliver oxygen and volatile anesthetics if inhalational maintenance of anesthesia is chosen over intravenous. Postoperative care requires close observation for airway edema and respiratory difficulties. Humidified oxygen, intravenous steroids, and antibiotics should be considered as part of the postoperative management.

Laryngospasm

A laryngospasm is an uncontrolled involuntary muscular contraction of the vocal cords. It is an exaggeration of the protective glottic closure reflex in response to irritants such as gases, food, gastric contents, blood, or surgical debris. The closure may persist in spite of the removal of the irritant and it manifests as stridor that can progress rapidly to complete airway obstruction. It occurs more commonly during a light plane of anesthesia such as during induction or emergence. It is more likely to occur after otolaryngologic procedures where there is increased surgical debris and blood. The management

of laryngospasm is immediate suctioning followed by positive pressure ventilation with 100% oxygen delivered via a tightly sealed face mask. If this technique does not work and the patient begins to desaturate, then an intravenous anesthetic such as propofol should be administered to the patient in order to deepen the level anesthesia. If the laryngospasm remains refractory to positive pressure ventilation and other means, a small dose of fast-acting muscle relaxant succinylcholine (0.1–0.5 mg/kg) should be administered.

Anesthesia for Head and Neck Surgery

Head and neck surgery includes laryngectomy, glossectomy, pharyngectomy, pharyngolaryngectomy, parotidectomy, radical neck dissection, and hemimandibulectomy. A complete preoperative assessment and examination should be done prior to anesthesia. It is important to note that many patients often have long-standing history of alcohol and tobacco use along with other preexisting medical conditions. Patients may also have a history of having undergone radiation or chemotherapy prior to surgery which may further compromise airway patency. In the preoperative assessment, it is important to determine whether the patient's airway will be difficult to manage; if a difficult airway is anticipated a standard intravenous induction should be avoided. Safe alternatives include an awake direct or fiber-optic laryngoscopy with adequate topical and regional anesthesia, awake fiber-optic intubation with adequate topical and regional anesthesia, an inhalation induction maintaining spontaneous ventilation, awake transtracheal catheter placement followed by jet ventilation, or a tracheostomy done under local anesthesia.

Clinical Aspects and Special Considerations During Head and Neck Surgery

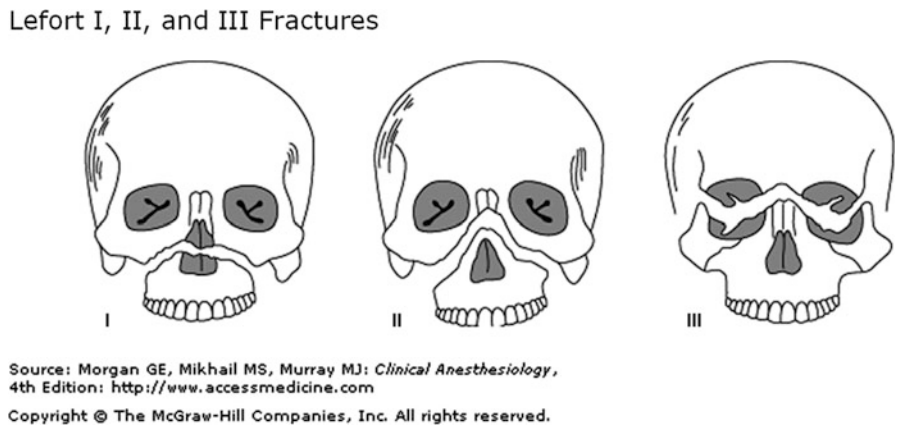
Head and neck surgical procedures tend to be long in duration and significant blood loss can occur. An intra-arterial cannula should be inserted for blood pressure, blood gas, and hematocrit monitoring. Adequate peripheral access should be obtained and central venous cannulation with central venous pressure monitoring obtained if it is deemed necessary. Hypotension to minimize blood loss is helpful and can be achieved with inhalational agents and continuous infusion of agents such as remifentanil. During radical neck dissection, surgical manipulation of the carotid sinus can produce severe bradycardia, hypotension, and even asystole. The treatment is surgical cessation of manipulation, intravenous atropine, and in some instances local anesthetic to the carotid sheath in order to prevent symptoms. In procedures involving the parotid gland, the facial nerve will need to be monitored in order to prevent iatrogenic injury.

Tracheostomy

A tracheostomy may be done under general anesthesia or under local anesthesia in an emergent situation when other routes of securing the airway have failed or are not an option. When done under general anesthesia, the patient's oropharynx and tracheal tube should be suctioned to prevent aspiration. After surgical dissection has reached the trachea, the endotracheal tube cuff is deflated and the tube is withdrawn so that the tip is above the incision site. A new tracheal tube is inserted at the tracheal incision site and once placement is confirmed the original endotracheal tube can be removed. A tracheostomy done under local anesthesia is technically challenging for the surgeon and is poorly tolerated by the patient. It is more commonly done in an emergency and sedation should be avoided in order to avoid complete airway obstruction in a patient with an unsecured airway. An increase in airway pressures after a tracheostomy can indicate a misplaced tracheal tube, bronchospasm, or debris in the trachea (Morgan et al. 2006).

Anesthesia for Facial Trauma

Facial trauma or injury can involve the mandible, the midface, and Le Fort fractures which are a classification system involving the maxilla (Fig. 2) (Morgan et al. 2006). These patients have a significant risk of bleeding and aspiration of bone fragments, soft tissue, loose teeth, and blood. Preoperative assessment and airway examination are paramount in developing an anesthetic plan. If a difficult mask ventilation or difficult airway is anticipated, an airway should be secured while the patient is awake and prior to general anesthesia induction. This can be done via an awake fiber-optic oral or nasal intubation with topical and local anesthesia or a tracheostomy under local anesthesia. Orotracheal intubation is indicated when there is intranasal damage. Nasal intubation is contraindicated in Le Fort II and III fractures because they may be associated with a basilar skull fracture and CSF rhinorrhea. There may be significant blood loss



Anesthetic Techniques for Otolaryngologic Patient, Fig. 2 Le Fort fracture classification system (Morgan et al. 2006, p. 844)

intraoperatively, and adequate bilateral peripheral intravenous access should be obtained prior to the start of the surgical procedure. An intra-arterial cannula may be inserted for blood pressure, blood gas, and hematocrit monitoring. An oropharyngeal pack placed during the procedure is removed at the end, and the anesthesiologist should thoroughly suction the posterior oropharynx prior to extubation in order to minimize the risk of aspiration. Some patients may have increased risk of postoperative airway edema due to the surgical procedure or duration of procedure. These patients should remain intubated until there is minimal risk of airway compromise and it is safe to remove the endotracheal tube.

Cross-References

- Adult Glottic Stenosis
- Anesthesia Considerations in Head and Neck Surgery
- Emergent Airway
- Head and Neck Cancer Pain Management
- Hoarseness and Pediatric Voice Disorders
- Reactive Airway Disease
- Sleep Apnea in Children
- Subglottic and Tracheal Stenosis in Adults
- Thyroidectomy, Complications
- Total Laryngectomy and Laryngopharyngectomy
- Tracheostomy
- Traumatic Injury to Larynx, Trachea, and Esophagus
- Vocal Cord Surgery

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Aneuploidy

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Definition

Aneuploidy is the presence of an abnormal number of chromosomes within a cell.

Cross-References

► Field Cancerization

Angiitis

► Vasculitides

Angiogram

► Angiography

Angiography

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Synonyms

Angiogram; Arteriography; Contrast injection; Contrast study

Definition

The word angiography derives from the Greek word *angeion* meaning "vessel" and *graphein* meaning "to write or record."

Catheter angiography is an invasive diagnostic procedure whereby a radiopaque contrast agent is injected into the lumen of a vessel (generally arterial, but sometimes venous or lymphatic). The study created is an angiogram. A study of the arterial system is called an arteriogram, one of the venous system is a venogram, and one of the lymphatic system is a lymphangiogram. Noninvasive types of angiography include computed tomographic angiography and magnetic resonance angiography.

Purpose

The purpose of an angiographic study is to visualize the anatomy (branching pattern, size, extent) of the system being studied with the intent of identifying normal and abnormal characteristics.

Principle

History

The technique of angiography was conceived by Egas Moniz in 1926 as a way to localize brain tumors by examining the alteration in the normal cerebral vasculature (Lima 1950). The first stage of his investigations consisted of finding a radiopaque substance that was sufficiently safe to inject. Strontium bromide was initially used, followed by sodium iodide. In 1931Thorotrast was introduced as the contrast medium. The injection of contrast in these early days was performed directly into the internal carotid artery with temporary ligation of the vessel proximally, but this evolved into injection into the common carotid artery.

Technique

The current technique for cerebral angiography involves the percutaneous cannulation of the common femoral artery. Other arteries are rarely used, for example, the carotid artery (when this vessel has been exposed for proximal control during clipping of a proximal internal carotid artery aneurysm) or the

brachial artery. The procedure begins with adequately counseling the patient and obtaining informed consent. The patient is transported to the angiography suite and an anxiolytic such as midazolam is administered intravenously. A local anesthetic such as 1% lidocaine is then infiltrated over the common femoral artery in the vicinity of the femoral head. This location facilitates hemostasis after the sheath is removed since the artery can be compressed against this bony landmark. It is often helpful to obtain a spot AP image to localize the optimal injection site (approximately 2 cm below the inguinal ligament). Once adequate local anesthesia has been achieved, an 11-blade knife is used to create a small skin incision and the subcutaneous tissue spread with a hemostat. The artery is then accessed using the Seldinger technique with an 18 g single-wall needle and suitable guide wire. Alternatively, a micropuncture kit can be used. Generally, a 5Fr femoral sheath is adequate for most diagnostic studies. If an intervention is planned, a 6Fr sheath is preferable. Once the sheath is properly placed it is flushed and connected to a continuous stream of heparinized saline.

The selection of catheters and wires for angiography is largely a personal choice. An initial aortic arch injection can be performed by placing a pigtail catheter in the ascending aorta and connecting to the power injector. This injection is not necessary for every diagnostic study but can be very helpful (and can save time) in patients with severe tortuosity or anomalous origin to their vessels. The selective injection of the great vessels is done by advancing the chosen wire ahead of the catheter and into the ascending aorta. The wire is then pulled back into the catheter and the catheter gently rotated while pulling the catheter and wire back as a unit so that the distal curve is pointing cephalad. This action facilitates the placement of the tip of the catheter at or in the origin of the vessel to be interrogated. The wire is then advanced ahead of the catheter to minimize intimal injury to the vessel. The catheter can then be positioned where needed in the arterial tree (e.g., right brachiocephalic, right subclavian, right common carotid, right internal carotid, right external carotid, left common carotid, left internal carotid, left external carotid, left subclavian, or left vertebral artery injections).

A superselective study can be achieved by using a coaxial technique (a smaller, flimsier catheter within a sturdier one) to inject more distal vessels. An example is when the respective feeding vessels of an arteriovenous malformation are to be imaged or embolized, a guide catheter is placed in the proximal ICA (for example) and the microcatheter advanced into a distal branch of the middle cerebral artery.

Once the catheter is properly positioned the contrast is injected and the angiogram recorded. Nonionic contrast agents are better tolerated and less risky than ionic agents when imaging the head and neck vessels. Depending on the purpose of the angiogram, the vessel being injected, and the disease being studied, the image intensifier can be angled relative to the patient's head to optimize visualization.

Indications

The initial indication for which angiography was developed was the intracranial localization of lesions that resulted in a shift of the arterial tree away from the lesion. The development of the CT scan and later the MRI largely supplanted angiography for this purpose. The current indications for angiography of the head and neck are varied and include the definition of normal vascular anatomy and the identification of abnormal pathology. Some of the more common reasons for angiography are briefly discussed below.

Intracranial Hemorrhage

A pattern of spontaneous intracranial hemorrhage on a CT scan that is suspicious for an underlying vascular lesion may prompt a workup that includes an angiogram. This pattern can be a subarachnoid hemorrhage (cerebral aneurysm), non-hypertensive intracerebral hemorrhage (arteriovenous malformations), or spontaneous subdural hematoma (dural arteriovenous fistula).

Cerebral Aneurysms

Cerebral aneurysms can present as ruptured, that is, a subarachnoid hemorrhage, or unruptured. Unruptured aneurysms can be incidental, that is, asymptomatic, or symptomatic (e.g., third nerve palsy). The classic presentation of a subarachnoid hemorrhage is a sudden severe headache and the vast majority of patients undergoing an angiogram for this

disease will have had a CT scan. This study should be carefully reviewed to gain clues as to the possible location of the ruptured aneurysm. It is advisable to inject the suspicious vessel first in case there is deterioration of the patient's status. It is also essential to obtain a complete four-vessel study (i.e., bilateral carotid arteries and bilateral vertebral arteries). Also acceptable is a three-vessel study with retrograde flow from one vertebral artery to the contralateral vertebral artery such that both posterior inferior cerebellar vessels are seen. Approximately 15–20% of patients will have multiple aneurysms underscoring the need for a complete study. Up to 15% of patients will have an aneurysmal negative subarachnoid hemorrhage, most commonly a perimesencephalic pattern on the CT scan. Most practitioners will obtain a follow-up cerebral angiogram 1–4 weeks after an initial negative study.

Arteriovenous Malformations

Arteriovenous malformations can be incidental or asymptomatic, or symptomatic. Symptomatic AVMs may result from hemorrhage or other symptoms such as seizures or vascular steal. The arteriogram remains the gold standard in the diagnosis of AVMs. The hallmark is an early draining vein (one that is visible in the arterial phase of the angiogram). The angioarchitecture including the arterial feeders, the nidus, the venous drainage, as well as any associated feeding aneurysms, intranidal aneurysms, venous aneurysms, or strictures can be readily identified. While an internal carotid or vertebral artery injection is likely to readily reveal the AVM, a superselective study is frequently needed to clearly identify the third or fourth order vessels that are contributing to the lesion. The latter studies are especially important when embolization is being considered.

Cerebral Vasospasm

Angiographic vasospasm of the cerebral vessels will develop in up to two-thirds of patients who present with subarachnoid hemorrhage while clinical vasospasm develops in about one-third. This can be manifest as focal weakness, lethargy, confusion, agitation, or coma. The risk of vasospasm is related to the amount of subarachnoid blood in the basal cisterns and can occur from 3 days to 3 weeks after the hemorrhage but generally peaks around day 7 and wanes by day 14. A cerebral angiogram can be performed to assist with the diagnosis of vasospasm but can also be critical in its treatment by way of angioplasty or infusion with a vasodilatory substance.

Atherosclerotic Disease

Atherosclerotic disease of the great vessels can result in transient ischemic attacks, embolic strokes, and its attendant neurologic symptoms. An arteriogram can reveal features such as stenosis of the carotid or other great vessels, ulcerations, dissections, occlusions, or pseudoaneurysms. It is important to place the diagnostic catheter proximal enough in the diseased vessel so that the catheter placement does not result in iatrogenic embolic or dissection. While carotid Duplex ultrasound MRA and CTA are all more commonly performed to diagnose carotid stenosis, angiography remains the gold standard. A variety of trials such as the North American Symptomatic Endarterectomy Trial (NASCET 1991) and the Asymptomatic Carotid Atherosclerosis Study (ACAS) relied on an accurate measurement of stenosis on angiography. The most common method used can be expressed as the formula: Percent stenosis $= (b–a)/b \times 100\%$, where a is the minimal diameter of the stenosis and b is the normal diameter of the vessel well beyond the bulb. The NASCET trial showed that carotid endarterectomy and medical therapy was superior to medical therapy alone in patients with high grade (defined as 70–99%) stenosis.

Non-atheromatous Vasculopathy

A variety of disorders that are non-atherosclerotic may affect the craniocerebral vessels (Osborn 1999). Extracranial vasculopathy can cause narrowing or enlargement of the great vessels. The former group includes congenital hypoplasia, acute and chronic dissection, and fibromuscular dysplasia. Dissections occur as a result of blood penetrating the arterial wall and can be traumatic or nontraumatic. The most common angiographic finding is a relatively smooth narrowing of the cervical carotid artery sometimes called a "string sign." Fibromuscular dysplasia is most commonly found in middle-aged women and results from a thickening of one of the layers of the vessel wall (most commonly the medial layer). The angiographic appearance is dependent on the exact histologic type but the most common appearance is multifocal

stenoses that alternate with areas of mural dilatation ("string of beads"). Other possible findings can include aneurismal formation, septae, or diverticula. Enlargement of the great vessels can occur with pseudoaneurysms, collagen vascular disease, Takayasu's arteritis, neurofibromatosis type 1, Marfan's syndrome, and Kawasaki's disease. Takayasu's arteritis is a primary arteritis of unknown etiology that typically affects young and middle-aged women. Smooth tapered narrowing and occlusions, or dilatation of the origins of the great vessels are seen on angiography. Cystic medial necrosis is the most common arterial lesion seen in Marfan's syndrome. Spontaneous dissection of the craniocephalic arteries is uncommon and ectasia and tortuosity are sometimes also seen. Kawasaki's disease is a febrile vasculitis of childhood that mainly affects the coronary vessels but can also involve the great vessels. Stenosis, thrombosis, and aneurysms are seen.

Intracranial vasculitides include primary central nervous system angiitis, systemic vasculitis with CNS involvement (e.g., polyarteritis nodosa, Wegener's granulomatosis and Behcet's disease), systemic diseases that can cause CNS angiitis (e.g., systemic lupus erythematosus, rheumatoid disease, and scleroderma), and CNS disorders with secondary vasculitis (e.g., meningitis, septic emboli, and sarcoid). Intracranial vasculopathies include inherited disorders (e.g., NF-1, Ehlers-Danlos disease and sickle-cell disease), moya-moya disease, drug-related vasculopathy, tumor emboli, radiation-induced vasculopathy, and posterior reversible encephalopathy syndromes (e.g., eclampsia and chemotherapy). Despite the variety of intracranial vasculitides and vasculopathies, the angiographic appearance is similar in each. Areas of multifocal narrowing alternating with dilated segments are typically seen. Moya-moya (idiopathic progressive arteriopathy of childhood) may be acquired or inherited and results in stenosis or occlusion of the distal ICAs with extensive collateralization from the perforating lenticulostriate and thalamoperforators. This collateralization can resemble a "puff of smoke" for which the disease is named.

Tumors

Cervical and cerebral angiography may be useful in some patients harboring tumors of the brain, skull base, and paranasal sinuses. The study can be used to evaluate vessels that are coursing around or through the tumor or to evaluate the vascularity of the lesion. The course and state of the surrounding vasculature (e.g., carotid arteries or venous sinuses) is important in determining the risk of a surgical resection. Assessment of collateral flow is important in determining the risk involved should vessel sacrifice become necessary to prevent life-threatening bleeding. On occasion, a vessel bypass may be prudent prior to resection of complex or invasive skull base tumors. Another important use of the preoperative angiogram is to assess to vascularity of the lesion and the need for preoperative embolization. This technique can reduce the blood loss during surgical resection.

Vascular tumors that lend themselves particularly well to preoperative embolization include convexity and skull base meningiomas, schwannomas, hemangiomas, glomus tumors, juvenile angiofibromas, and olfactory neuroblastomas. Meningiomas that arise from the arachnoid cap cells can occur in a multitude of locations including the convexity and the skull base. Schwannomas arise from the nerve sheath of peripheral, spinal, or cranial nerves. The angiographic appearance varies but vascularity is usually moderate or low with displacement of the local vasculature. In addition to the tumor blush, enlarged discrete tumor vessels can sometimes be identified. Glomus tumors (also known as paragangliomas or chemodectomas) are neuroendocrine tumors that arise from neural crest derivatives but secretory activity is rare. The most common types are glomus jugulare (arising in the jugular fossa and presenting with 9th, 10th, and 11th cranial nerve symptoms), glomus tympanicum (occurring from Jacobson's nerve in the middle ear and sometimes causing pulsatile tinnitus), carotid body tumors (arising at the carotid bifurcation), and glomus vagale types. The angiographic appearance is that of a well-circumscribed vascular mass with intense blush. Juvenile angiofibromas are vascular benign tumors that occur almost exclusively in boys of adolescent age. They arise around the sphenopalatine foramen and usually present with nasal obstruction and/or epistaxis. Angiographically, the internal maxillary artery is the feeding vessel and an intense prolonged vascular blush is typical. Malignant tumors involving the skull base are especially prone to encasing

the carotid arteries and may occasionally invade them. The angiographic appearance can include vessel displacement, constriction (encasement), pseudoaneurysm formation, or occlusion.

Epistaxis

Nosebleeds can result from hypertension, trauma, predisposing conditions such as hereditary hemorrhagic telangiectasias, benign tumors (such as juvenile angiofibromas), or invasive malignant tumors (such as squamous cell carcinomas). While the diagnostic angiogram will often not show frank extravasation indicating active bleeding from the source (especially if the nares have been packed to prevent exsanguination), careful examination of the study will often show signs such as focal or segmental vasospasm, irregularity, or pseudoaneurysms.

Venous Sinus Thrombosis

Thrombosis of one or more of the major venous sinuses can result in venous hypertension, cerebral edema, and hemorrhage. While MR venography can noninvasively reveal this diagnosis, an angiogram is rarely indicated to confirm the diagnosis.

Contraindications

Relative contraindications to the use of angiography include renal insufficiency and known contrast allergy. The use of a variety of nonionic contrast agents has reduced the incidence of contrast reactions. In addition, patients can be premedicated with steroids and Benadryl to minimize allergic reactions. For patients with renal insufficiency and in whom an angiogram is deemed essential, premedication with mucomyst and post-procedure dialysis can be entertained.

Advantage

The major advantage that catheter angiography holds over other forms of vascular imaging such as CT angiography, MR angiography, or Doppler sonography is that it is still considered the "gold standard" for vascular assessment. 3-D rotational angiography can now be achieved on the more modern units and this certainly enhances the visualization of the anatomy. The fact that flow can be assessed adds another dimension that is lacking with CT angiography.

Disadvantage

Potential disadvantages of angiography include limitations of the technique and the risks associated with the technique. A major limitation of angiography is the fact that the angiogram may occasionally not show the full extent of a vascular lesion. Since the study results from contrast filling the lumen of the vessel or lesion, any extraluminal features will not be captured. Any example is a partially thrombosed aneurysm that may be much larger than the angiographic study suggests. Another example is a dissection that may result in significant intramural pathology but minimal reduction in caliber of the lumen. In both these cases the diagnosis may be missed unless a high index of suspicion is maintained. Supplemental studies such as an MRI will be useful in these cases.

Since catheter angiography is by definition an invasive study with attendant risks, whenever possible, these risks should always be discussed with the patient and family before the procedure. Risks associated with angiography include but are not limited to contrast allergy, hematoma formation at the entry site, vessel dissection, vessel perforation, transient ischemic attacks, strokes, and worsening of impaired renal function. These risks are higher (up to 1%) in certain populations of patients such as the elderly and those with chronic untreated hypertension which predisposes to vessel tortuosity. Earnest et al. prospectively studied 1,517 consecutive angiograms and found an overall risk of 8.5%, a neurologic risk of 2.6%, and permanent neurological risk of 0.33%. The incidence of permanent neurologic deficit in patients referred for evaluation of symptomatic cerebrovascular disease was 0.63%. Older age, increased serum creatinine concentration, and the use of more than one catheter all were significantly associated with serious neurologic complications (Earnest et al. 1984). Another prospective study by Heiserman et al. found that cerebral angiography was associated with a 1% overall incidence of neurologic deficit and a 0.5% incidence of persistent deficit (Heiserman et al. 1994). All

complications occurred in patients presenting with a history of stroke/transient ischemic accident or carotid bruit.

Two common preventable causes of transient ischemic attacks or strokes are clot and air embolic. Both can be readily minimized by using proper catheter flushing techniques, continuous heparinized drips, and anticoagulation when appropriate. For example, when performing a coil embolization procedure of an aneurysm, the patient is generally heparinized to achieve an activated clotting time of 1½ to 2 times baseline prior to inserting the microcatheter. Similarly, a patient is treated with Plavix and aspirin for several weeks prior to intravascular stent placement.

Cross-References

- ▶ Arteriovenous Malformations
- ▶ Epistaxis
- ▶ Skull Base Neoplasms

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Angioma Arteriale

- ▶ Arteriovenous Malformations

Angiomatous Malformation

- ▶ Arteriovenous Malformations

Angiosome

- ▶ Classification of Flaps

Angiosomes

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Synonyms

Vascular territory

Definition

Taylor and Palmer introduced the concept of angiosomes to describe the anatomical territory of a source artery in the skin and deep tissues. The angiosome was found anatomically to be composed of multiple three-dimensional composite blocks of tissue supplied by particular source arteries. Detailed studies of the entire body have revealed over 370 angiosomes. A good understanding of angiosome is essential in safely planning flap incisions to maximize flap survival. It also forms the basis of composite tissue transfer. It also gives information that may help explain the etiology and treatment of head and neck arteriovenous vascular malformations. In the head and neck, no fewer than 13 angiosomes of the head and neck, supplied by the branches of the external carotid, internal carotid, and subclavian arteries, have been defined, mapping their three-dimensional territories in the skin, the deep soft tissues, and the bones.

Cross-References

- ▶ Delay of Flap
- ▶ Perforator Flaps

Anosmia

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Definition

Loss of the ability to smell

Introduction

Anosmia – loss of the ability to smell – has significant safety, nutritional, and quality-of-life consequences. Nearly all patients presenting with "loss of taste" have, in fact, decreased smell function. Most food flavors, such as cola, coffee, strawberry, pizza, and vanilla, are largely dependent upon stimulation of the olfactory receptors from volatiles that arise from the rear of the oral cavity during chewing and swallowing (so-called retronasal olfactory stimulation). Such "taste" sensations disappear when the olfactory epithelium is severely damaged. What is left intact are only sensations from taste buds (e.g., sweet, sour, salty, bitter, metallic, and umami (monosodium glutamate–like) sensations) and free nerve endings of the trigeminal nerve (e.g., coolness, warmth, sharpness, and irritation).

In a study of 750 consecutive patients presenting with mainly decrements in the ability to smell, 68% reported altered quality of life, 46% changes in appetite or body weight, and 56% adverse influences on daily living or psychological well-being (Deems et al. 1991). In another study of 445 such patients, at least one hazardous event, such as food poisoning or failure to detect fire or leaking natural gas, was reported by 45.2% of those with anosmia, 34.1% of those with severe hyposmia (lessened smell function), 32.8% of those with moderate hyposmia, 24.2% of those with mild hyposmia, and 19.0% of those with normal olfactory function (Santos et al. 2004). In a longitudinal study of 1,162 non-demented older persons, mortality risk was 36% higher in those with low than with high scores on a smell test after adjusting for such variables as sex, age, and education (Wilson et al. 2011). Of particular importance to the physician is that smell dysfunction is among the early "preclinical" or "presymptomatic" signs of Alzheimer's disease (AD) and Parkinson's disease (PD) (Doty 2003).

In addition to anosmia and hyposmia, strange and distorted smells, sometimes described as "chemical- or garbage-like," can occur either in the absence of an odorant (phantosmia) or when an odorant or warm air is smelled (dysosmia or parosmia). When having a fecal-like character, such distortions are termed "cacosmia." Most cases of dysosmia or phantosmia are due to less-than-complete damage to the olfactory receptors within the lining of the upper regions of the nose, although in some cases tumors and other central nervous system lesions can be involved. In some instances, foul smells can arise from bacterial infections within the nose or sinuses. Olfactory agnosia – the inability to recognize odors by an otherwise intact olfactory system – may occur secondary to some brain lesions, although distinguishing this problem from other forms of dysfunction is challenging. Hypersensitivity to odorants (hyperosmia) has been reported, although many persons claiming hypersensitivity are experiencing dysosmias and show decrements in function upon testing.

Numerous factors can produce anosmia or associated aberrations in the ability to smell, including age, smoking behavior, reproductive state changes, poor nutrition, toxic exposures, head trauma, CNS lesions, and numerous diseases (Table 1). Women generally perform better on smell tests than do men. Age is a major correlate of smell dysfunction, with significant decrements occurring in over 50% of those between 65 and 80 years of age and in 75% of those 80 years of age and older (Fig. 1) (Doty et al. 1984a). Such losses help to explain why many elderly find food distasteful and succumb to nutritional deficiencies and, in rare instances, natural gas poisoning.

Upper respiratory infections, head trauma, and chronic rhinosinusitis are the three most common causes of chronic smell loss (Deems et al. 1991). The next three most common causes are congenital, iatrogenic, and toxic chemical exposures. These etiologies can result in decreased number of receptor cells, damage the olfactory epithelium with associated replacement from islands of respiratory-like epithelium. Increased susceptibility to such damage can come from a number of sources, including age-related

Anosmia, Table 1 Disorders and conditions associated with compromised olfactory function, as measured by olfactory testing

22q11 deletion syndrome	Lubag
AIDS/HIV infection	Medications
Adenoid hypertrophy	Migraine Myasthenia gravis
Adrenal cortical insufficiency	Multiple sclerosis
Age	Multiple system atrophy
Alcoholism	Multi-infarct dementia
Allergies	Narcolepsy with cataplexy
Alzheimer's disease	Neoplasms, cranial/nasal
Amyotrophic lateral sclerosis	Nutritional deficiencies
Anorexia nervosa	Obstructive pulmonary disease
Asperger's syndrome	Obesity
Ataxias	Obsessive compulsive disorder
Attention deficit/ hyperactivity disorder	Orthostatic tremor
Bardet-Biedl syndrome	Panic disorder
Chemical exposure	Parkinson's disease
Chronic obstructive pulmonary disease	Parkinson dementia complex of Guam
Congenital	Pick's disease
Creutzfeldt-Jakob disease	Posttraumatic stress disorder
Cushing's syndrome	Pregnancy
Cystic fibrosis	Pseudohypoparathyroidism
Degenerative ataxias	Psychopathy
Diabetes	Radiation (therapeutic, cranial)
Down syndrome	REM behavior disorder
Epilepsy	Refum's disease
Facial paralysis	Renal failure/end-stage kidney disease
Frontotemporal lobe degeneration	Restless leg syndrome
Gonadal dysgenesis (Turner's syndrome)	Rhinosinusitis/polyposis
Guamanian ALS/PD/ dementia syndrome	Schizophrenia
Head trauma	Seasonal affective disorder
Herpes simplex encephalitis	Sjogren syndrome
Hypothyroidism	Stroke
Huntington's disease	Tobacco smoking
Iatrogenesis	Toxic chemical exposure
Kallmann syndrome	Upper respiratory infections
Korsakoff psychosis	Usher syndrome
Leprosy	Vascular disorders (e.g., aneurysms, hemorrhages)
Liver disease	Vitamin B12 deficiency

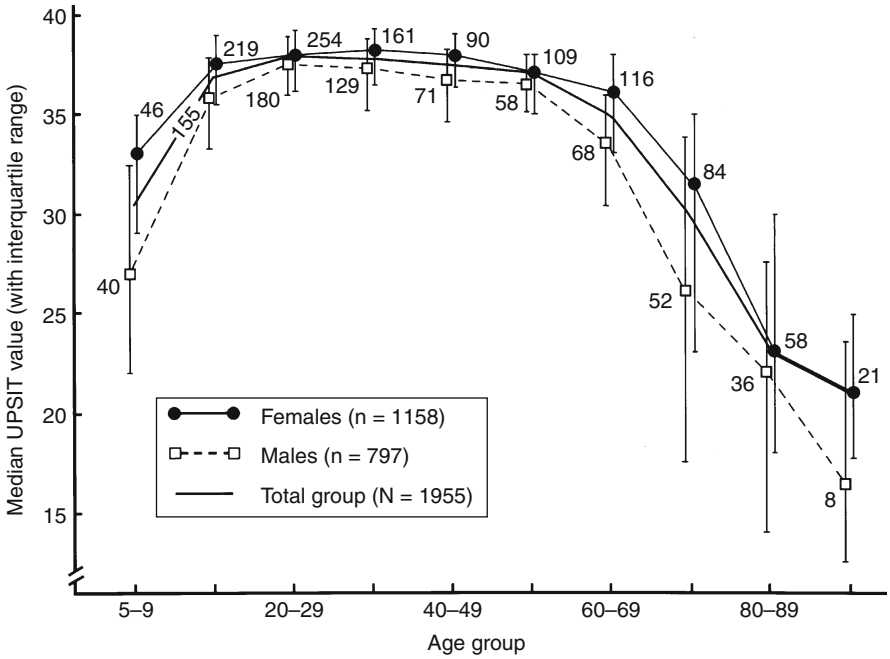
changes in nasal function and normal defense mechanisms, as well as the reduction or inhibition of mucociliary transport by disease, drugs, diet, or genetic factors.

Many idiopathic cases of anosmia and other forms of smell dysfunction probably reflect unrecognized viral infections, since most viral infections are either entirely asymptomatic or so mild that they go unrecognized. Thus, the number of serologically documented influenza or arboviral encephalitis infections exceeds that of acute cases by several hundredfold. In a manner conceivably analogous to vaccine-related cases of Bell's palsy and Guillain-Barré syndrome, smell dysfunction has been reported to occur after some influenza vaccine inoculations, perhaps reflecting a subtle but defining influence on an already compromised olfactory epithelium.

Neurotropic viruses, such as herpes simplex types 1 and 2, poliomyelitis, vesicular stomatitis, rabies, mouse hepatitis, Borna disease, and canine distemper can, under certain circumstances, enter the brain after encorporation into the olfactory receptor cells. Such viruses can produce smell dysfunction and may potentially catalyze neurodegenerative disease. Some viruses that are not ordinarily neurotropic may become so after entering the nose. When the NWS strain of influenza virus is inserted into the nose of mice, it spreads through the olfactory and trigeminal nerves and invades the brain. However, when intraperitoneally injected, the viral antigen is restricted to the meninges, choroid plexus, ependymal cells, and perivascular locations within the brain parenchyma (Reinacher et al. 1983).

A significant development in neurology was the realization that Alzheimer's disease (AD), Parkinson's disease (PD), and some other neurodegenerative diseases are associated with smell loss early in their development (Doty 2003). In many cases, such loss precedes the defining clinical phenotype by years. Smell testing can aid in differential diagnosis, since a number of disorders often confused with AD or PD are unaccompanied by considerably less or no olfactory dysfunction, including major affective disorder, essential tremor, progressive supranuclear palsy (PSP), and vascular parkinsonism. The relative severity of olfactory dysfunction in a range of neurodegenerative diseases and in schizophrenia is shown in Table 2.

It is generally believed that loss of smell function from head trauma typically reflects coup contrecoup movement of the brain that shears off or otherwise damages the olfactory fila at the level of the cribriform plate. In most cases, scar tissue forms, precluding



Anosmia, Fig. 1 Scores on the University of Pennsylvania Smell Identification Test (UPSIT) as a function of subject age and sex. Numbers by each data point indicate sample sizes. Note that women identify odorants better than men at all ages (From Doty et al. 1984a. Science 226:1421. Copyright © 1984 American Association for the Advancement of Science)

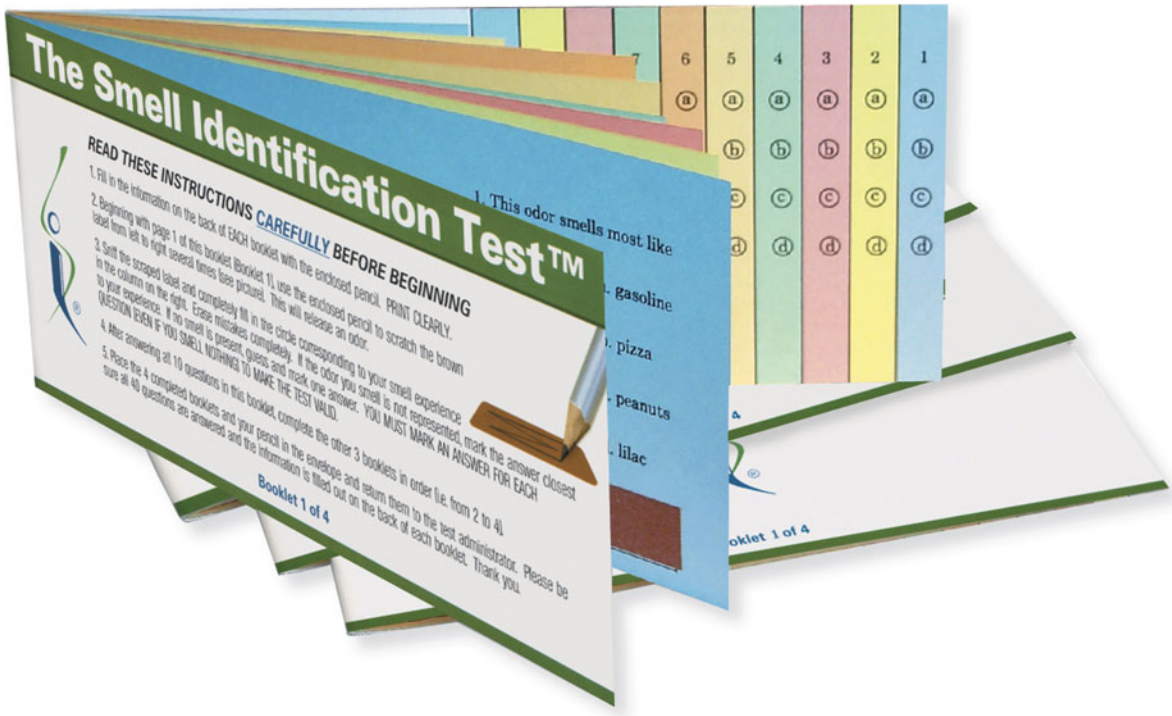
Anosmia, Table 2 Relative degree of olfactory dysfunction in various neurological diseases on an arbitrary scale. Key: ++++ marked loss, +++ moderate loss, ++ some loss, + mild loss, *0* normal. Most of the values are based on relatively small patient numbers except for idiopathic Parkinson's disease. *SCA* spinocerebellar atrophy

Disease	Relative severity of smell loss
Idiopathic Parkinson's disease, Alzheimer's disease, dementia with Lewy bodies, Guam pd-dementia complex. Idiopathic rapid eye movement sleep behavior disorder	++++
Huntington's disease, Down syndrome	+++
Multiple system atrophy (type-P), pallidopontonigral degeneration, schizophrenia, X-linked dystonia-parkinsonism (lubag)	++
Motor neurone disease, SCA2 PD, Friedreich's ataxia, corticobasal degeneration, frontotemporal dementia	+
Major affective disorder, essential tremor, vascular parkinsonism, MPTP-induced parkinsonism, idiopathic dystonia, progressive supranuclear palsy	**0** or +

reconnection of axons from regenerating receptor cells. Fractures of the cribriform plate or other elements of the skull are not a prerequisite for the smell loss.

Clinical Evaluation

The first step in establishing etiology is to obtain a thorough clinical history. The nature of the symptoms should be established (e.g., type, time of onset, duration, and fluctuation patterns), as well as events that may have precipitated symptom onset (e.g., viral infections, head trauma, initiation of new pharmaceuticals, exposure to pesticides, medical interventions, alcohol use in the context of Wernicke and Korsakoff syndromes). Information regarding allergies, head trauma, smoking habits, drug and alcohol abuse (e.g., intranasal cocaine, chronic alcoholism), medical or dental interventions, and exposures to pesticides and other toxins are informative. The possibility of cumulative effects cannot be discounted. Determining the medications that the patient was taking before and at the time of symptom onset is frequently useful, particularly in cases where distortions of smell or taste are present, as are comorbid medical conditions (e.g., renal failure, liver disease, hypothyroidism, diabetes, epilepsy, and dementia). Delayed puberty in association with anosmia suggests the possibility of Kallmann's syndrome. Questions related to memory, parkinsonian signs, and seizure activity (e.g., automatisms, occurrence of blackouts, auras, and déjà vu) should be posed. The possibility of malingering should



Anosmia, Fig. 2 The University of Pennsylvania Smell Identification Test (known commercially as the Smell Identification Test) (Doty et al. 1984b). This test is comprised of 40 microencapsulated odorants located next to forced-choice questions on each page of ten-page booklets. Most human quantitative olfactory studies have used this test. Copyright © 2004, Sensonics, Inc., Haddon Heights, New Jersey

be considered, particularly if litigation is involved. *Intermittent loss* usually implies an obstructive disorder, such as from rhinosinusitis or other inflammatory problem. *Sudden loss* alerts the practitioner to head trauma, ischemia, infection, or a psychiatric condition. *Gradual loss* can be a marker for the development of a progressive obstructive lesion, cumulative drug effects, or simply presbyosmia or presbygeusia. Although losses secondary to head trauma are most commonly abrupt, in some cases the loss appears over time or only becomes apparent to the patient after a long interval.

Quantitative olfactory testing, which often is performed at the same time as the medical history is taken, is essential in determining the validity of a patient's complaint, the extent of dysfunction, the efficacy of therapies, and the likelihood of malingering. Numerous tests are available to this end, the most common of which is the University of Pennsylvania Smell Identification Test (UPSIT; Fig. 2). The latter is a self-administered microencapsulated (scratch and sniff) test that establishes both absolute and relative (i.e., age- and sex-related percentiles) function or dysfunction. In addition to such testing, neurological and otorhinolaryngological (ORL) examinations, along with appropriate brain and sinonasal imaging, aid in the evaluation of patients with chemosensory complaints. A focus of the neurological exam should be made on cranial nerve function, with particular attention to possible skull base and intracranial lesions. Smell loss may be associated with intracranial mass lesions that induce papilledema and optic atrophy, as in the Foster Kennedy syndrome. Nasal polyps, masses, and adhesions of the turbinates to the septum may compromise the flow of air to the olfactory receptors, since less than a fifth of the inspired air traverses the olfactory cleft in the unobstructed state. Blood serum tests are helpful in identifying associated conditions

such as diabetes, infection, heavy metal exposure, nutritional deficiencies (e.g., B6, B12), allergies, and thyroid, liver, and kidney disorders.

Treatment and Management

Medical and surgical interventions are available for most patients with obstructive or inflammatory disorders (e.g., allergic rhinitis, glossitis, polyposis, intranasal or intraoral neoplasms). In cases of rhinosinusitis, for example, an oral taper of prednisone can initially be used to mitigate general inflammation. This can be followed by topical administration of a steroid nasal spray or drops in the inverted head position, increasing the likelihood of the material reaching the olfactory epithelium. Medications that induce chemosensory distortions can often be discontinued and other types of medications or modes of therapy substituted. Some antioxidants, such as alpha-lipoic acid, may be effectual in cases of hyposmia, hypogeusia, dysosmia, dysgeusia, and burning mouth syndrome, although strong scientific evidence for efficacy is lacking. Except in the case of frank deficiencies, zinc and vitamin A therapies are unlikely to show benefit in olfactory disturbances, although such therapies may improve taste dysfunction secondary to hepatic deficiencies.

A recent report that theophylline improved smell function was not double blinded and lacked a control group (Henkin et al. 2009b), failing to account for the fact that some meaningful improvement occurs without treatment. Similar problems are inherent in claims of efficacy for acupuncture and transcranial magnetic stimulation (TCMS) (Henkin et al. 2009a). Indeed, the percentage of patients reportedly responsive to the treatment in most such studies is essentially the same as expected without treatment. In a longitudinal study of 542 patients presenting to the University of Pennsylvania Smell and Taste Center with smell loss from a variety of causes, modest improvement occurred over an average time period of 4 years in about half of the participants (London et al. 2008). Nonetheless, normal age-related function returned in only 11% of the anosmic and 23% of the hyposmic patients. The amount of dysfunction present at the time of presentation, not etiology, was the best predictor of prognosis. Other predictors were patient age and the time between dysfunction onset and initial testing.

There are reports that antiepileptics and some antidepressants (e.g., amitriptyline) may help some chemosensory disturbances, particularly following head trauma. However, there is clear evidence that amitriptyline can distort taste function, possibly from its anticholinergic effects. One study reported that donepezil (acetylcholinesterase inhibitor) improved odor identification scores in patients with AD and that the test scores correlated with clinician-based impressions of cognitive change, suggest to the authors that tests of smell identification function may be useful in assessing treatment responses to this medication (Deshpande et al. 1999). It is of interest that repeated exposure to odorants may increase sensitivity to them in both humans and animals, providing a rational basis for therapies in which multiple odors are repeatedly smelled (Hummel et al. 2009). That being said, double-blind studies with appropriate controls are lacking to confirm the effectiveness of this approach.

An important but overlooked element of therapy comes from chemosensory testing itself. Confirmation or lack of conformation of loss is beneficial to patients, particularly ones who come to believe they may be "crazy" as a result of unsupportive family members or medical practitioners. Quantitative testing places the patient's problem into overall perspective and, when considerable function is present, patients can be informed of a more positive prognosis. It is extremely therapeutic for an elderly person to know that, while his or her smell function is not what it used to be, it still falls above the average of his or her peer group. It is unfortunate that many such patients are simply told by their physician they are getting old and nothing can be done for them, often exacerbating or leading to depression and decreased self-esteem.

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Anotia

► Microtia and Atresia

Anterior Lamellae

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Definition

Portion of the eyelid at the eyelid margin composed of skin and orbicularis oculi muscle.

Cross-References

► Ectropion

Anterior Petrosectomy Petrous Apicectomy

► Surgical Approaches and Anatomy of the Lateral Skull Base

Anterior Skull Base Surgery, Approach

► Craniofacial Resection

Anterior/Extended Craniofacial Resection

► Craniofacial Resection

Antibiotics and Medical Management of ABRS

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Synonyms

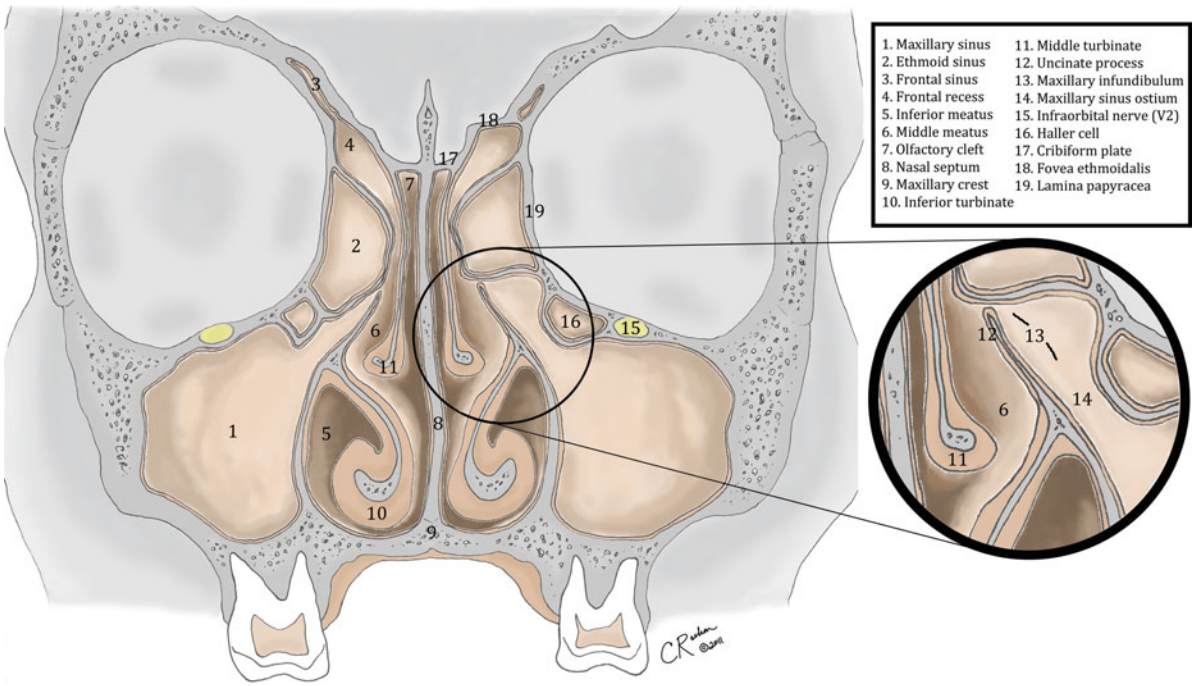
Rhinosinusitis; Sinusitis

Definition

Acute bacterial rhinosinusitis (ABRS): inflammation of the nasal passages and paranasal sinuses from bacterial pathogens.

Introduction

The diagnosis of rhinosinusitis reflects inflammation involving the nasal passages and connected paranasal



Antibiotics and Medical Management of ABRS, Fig. 1 Nasal cavity and paranasal sinuses; *inset*: detail of osteomeatal complex

sinuses (Fig. 1) from a variety of causes including allergic, idiopathic, viral, bacterial, and fungal etiologies. Uncomplicated acute rhinosinusitis excludes any extension of inflammation or infection to neurologic, ophthalmalogic, or adjacent soft tissue sites outside of the paranasal sinuses. Acute rhinosinusitis is traditionally defined by duration as symptoms including persistent purulent nasal drainage with nasal obstruction or facial pressure lasting for up to 4 weeks, subacute as symptoms lasting between 4 and 12 weeks, and chronic rhinosinusitis lasting longer than 12 weeks (Rosenfeld et al. 2007) (see ▶ Acute and Chronic Rhinosinusitis). Four or more episodes of acute rhinosinusitis with full resolution between episodes is defined as recurrent acute rhinosinusitis. Acute rhinosinusitis is further divided into acute bacterial rhinosinusitis (ABRS) and acute viral rhinosinusitis (AVRS). Another classification by Meltzer et al. (2004) defined four categories of acute likely bacterial rhinosinusitis, chronic rhinosinusitis without and with polyps, and classic allergic fungal rhinosinusitis.

Acute bacterial rhinosinusitis originates from dysfunction of the normal mucociliary clearance in the nasal cavity and sinuses or obstruction of the sinus ostia that leads to decreased clearance of mucus and debris with eventual filling of the sinus cavities. This ciliary dysfunction can be congenital or acquired. Many factors can contribute to an acquired ciliary dysfunction, including allergic, nonallergic, or infectious causes that provoke mucosal inflammation and ciliary dysmotility. Other factors include anatomic variations that increase the risk of sinus obstruction – narrowed ostia, septal deviation, nasal polyposis, or enlarged turbinates. Ciliary stasis prevents movement and clearance of mucus within blocked sinuses, leading to negative intrasinus pressures and hypooxygenation, which only further decrease ciliary activity. This internal milieu of the static sinus promotes bacterial growth and may lead to acute bacterial rhinosinusitis.

Epidemiology

Rhinosinusitis is a common disease, acutely affecting approximately 30 million patients in the USA each year in 2006, or nearly 13% of the population (Ahovuo-Saloranta et al. 2008). Acute sinusitis is the chief complaint in two of every hundred ambulatory outpatient visits and accounts for 15–21% of all

antibiotics prescribed in adult outpatient care settings (Ahovuo-Saloranta et al. 2008). Costs relating to direct care in addition to loss of productivity, work days, and disability total approximately $6 billion annually (Anand 2004). Given its prevalence, economic impact, and treatment difficulties, evidence-based management of acute rhinosinusitis is important to maximize the risk-benefit balance of available treatments and improve clinical outcomes.

History

Acute bacterial rhinosinusitis is frequently preceded by a viral upper respiratory tract infection (URTI). Resulting inflammation of the mucosal lining of the sinonasal cavities leads to closure of the narrow sinus ostia, obstructing normal mucous flow from the sinuses and causing a buildup of pressure and fluid. Frequently, patients with acute viral rhinosinusitis (AVRS) have symptoms similar to those of acute bacterial rhinosinusitis, including nasal obstruction, facial pressure, and rhinorrhea. Facial pressure occurs primarily over the anterior face and maxilla, in the periorbital or frontal area, or may present as a diffuse headache. Approximately 40% of these patients will have reversible mucosal thickening or other abnormalities on imaging, however 80% of patients with symptoms of acute rhinosinusitis will resolve without antibiotic treatment within 2 weeks, compared to a 90% improvement rate with antibiotic treatment (Ahovuo-Saloranta et al. 2008), and only 0.5–2.0% of cases of AVRS transition into ABRS (Pearlman and Conley 2008).

Clinical Features

Distinguishing patients with bacterial rhinosinusitis from uncomplicated URTI or AVRS is important to determine appropriate treatment. This can be difficult with multiple overlapping symptoms, but differences between them can be found in the pattern and timeline of disease (Table 1). Symptoms of acute viral rhinosinusitis – facial pain or pressure, rhinorrhea, and nasal obstruction – are self-limited and usually resolve within 10–14 days without worsening, while acute bacterial rhinosinusitis tends to last longer and worsen over time, occasionally improving before worsening again (known as "double worsening") and more often produces purulent rhinorrhea, instead of the thinner clear rhinorrhea common in AVRS (Rosenfeld et al. 2007). Other symptoms supporting a diagnosis of acute bacterial sinusitis include impairment of smell, cough, headache, fever, or aural fullness (Rosenfeld et al. 2007). Early in the course of acute rhinosinusitis (within the first 4 days), differentiating symptoms and timeline between ABRS and AVRS is difficult, and a diagnosis of AVRS is presumed.

Antibiotics and Medical Management of ABRS, Table 1 Symptoms distinguishing AVRS and ABRS

AVRS	ABRS
Self-limited symptoms <10–14 days	Extended symptoms >10 days
Facial pain/pressure	Facial pain/pressure, particularly if unilateral
Clear rhinorrhea	Purulent rhinorrhea (thick, colored, opaque)
Nasal obstruction	Nasal obstruction
	"Double-worsening" of symptoms
	Maxillary tooth pain, particularly if unilateral
	Hyposmia/Anosmia
	Cough
	Fever
	Headache
	Aural fullness

Evaluating patients presenting with signs and symptoms of acute bacterial rhinosinusitis involves gathering both subjective and objective information to gauge where each patient is in the timeline of the disease process. A full head and neck physical examination can detect facial tenderness, the presence and quality of rhinorrhea, or the presence of postnasal rhinorrhea along the posterior pharyngeal wall or cobblestoning of the mucosa indicative of inflammation from chronic postnasal drip or allergic inflammation. Soft tissue swelling over the maxillary or frontal sinuses, any neurologic or visual deficits may indicate extension of infection to surrounding sites. Rhinoscopy and/or nasal endoscopy of the nasal cavities, frontal recess, sphenoethmoidal recess, olfactory cleft, and middle meatuses allows for a thorough evaluation for turbinate or nasal cavity mucosal inflammation, purulent discharge, or polyps. Assessment of pain in patients with symptoms of ABRS provides an objective measurement of a key clinical marker of infection and reason

for seeking medical care. Multiple pain scales are available, including the visual analog pain Scale, faces pain scale, or qualitative scales, and repeated measurements over multiple visits assist in focusing early management on treating pain in parallel with treating the infection. Additional assessments include the Sinonasal Outcome Test (SNOT-20), a 20-question self-assessment questionairre that evaluates the impact of rhinosinusitis pathology of various quality-of-life categories, and also may be useful to monitor therapeutic response (Rosenfeld et al. 2007).

Tests

Bacterial cultures may provide additional information in the setting of acute rhinosinusitis if purulent rhinorrhea is present to sample for culture. Nasal endoscopy after appropriate mucosal decongestion including evaluation of the middle meatus provides a more reliable method of detecting purulence to diagnose ABRS and allows for endoscopic-guided cultures (Rosenfeld et al. 2007). Particularly in patients with recurring acute rhinosinusitis episodes or patients previously unresponsive to antibiotic treatments, cultures can identify causative pathogens and direct more effective antibiotic therapy.

Radiology testing is not recommended in the setting of acute rhinosinusitis unless complicated acute rhinosinusitis (orbital, intracranial or soft tissue abscess) or an additional contributing diagnosis (benign or malignant neoplasms) is suspected (Rosenfeld et al. 2007). If completed, imaging including plain films, computed tomography (CT), or magnetic resonance imaging (MRI) often shows evidence of mucosal inflammation with thickening or increased enhancement with contrast, but may not give additional useful information for diagnosis beyond what is available through a physical examination. Currently, a noncontrast dedicated sinus CT with 1 mm cuts available in both the axial and coronal planes is the gold standard for imaging (see ▶ Facial Nerve Imaging, CT and MRI).

Differential Diagnosis

Acute viral rhinosinusitis (AVRS)
Complicated acute bacterial rhinosinusitis
Subacute rhinosinusitis
Chronic rhinosinusitis
Nasal polyposis
Nasal tumor (see ▶ Benign Sinonasal Neoplasms)
Allergic fungal sinusitis (see ▶ Allergic Fungal Rhinosinusitis)
Invasive fungal sinusitis

Etiology

The most common bacterial pathogens isolated in acute bacterial rhinosinusitis include several key aerobic bacteria: *Streptococcus pneumonia*, in 20–43% of ABRS cases, *Haemophilus influenzae* in 22–35%, *Moraxella catarrhalis* in 2–10% (Rosenfeld et al. 2007), and less commonly group A beta-hemolytic streptococci and *Staphylococcus aureus* (more common in sphenoid sinusitis than other sinuses) (Brook 2010). Staphylococcus is also more commonly seen in patients with previous sinus surgery. Anaerobic bacteria including *Pseudomonas aeurginosa* may eventually dominate an acute bacterial infection if it persists into a chronic infection, but are uncommon in ABRS unless an ondotogenic source is involved. Odontogenic rhinosinusitis frequently occurs through extension of infection from molar or premolar dental sources through bony defects and thin mucosa into the maxillarly sinuses. Polymicrobial ABRS occurs in approximately 3% of odontogenic cases, with anaerobes comprising 90% of isolated pathogens, reflecting oral bacterial flora (*Prevotella, Porphyromonas, Peptostreptococcus* spp.) (Brook 2010). Approximately one-third of all acute rhinosinusitis infections involve multi-pathogen infections (Brook 2010), with other potential etiologies including fungi and viruses, and rare involvement of enteric bacteria. Recent increases have been seen in *H. Influenzae* rates in ABRS relative to *S. Pneumoniae* due to the impact of the 7-valent pneumococcal vaccine introduced in the USA in 2000 (Brook 2010). Methicillin-resistant *S. aureus* (MRSA) infections were documented in 2.7% of ABRS infection in 2006 (Huang and Hung 2006). Normal nonpathogenic bacterial flora of the nasal cavity, including Staphylococcus aureus, Staphylococcus epidermidis, alpha- and gamma-streptococci, Propionibacterium acnes, and facultative diphtheroids, may inhibit pathogenic bacterial

growth and decrease risk of acute bacterial rhinosinusitis (Brook and Gober 1999).

In specific populations, etiologies of ABRS may include less common pathogens that are important to consider in diagnosing and appropriately treating these patients. Immunocompromised patients are frequently affected by rhinosinusitis, including patients with neutropenia, diabetics, HIV, or patients requiring intensive care settings. Fungal (*Aspergillus,* mucor, rhizopus, alternaria) and *Pseudomonas* infections are common causes of rhinosinusitis in patients with neutropenia. Diabetic patients are most often affected by fungi, *S. Aureus*, streptococci, and Gram-negative enteric bacteria. HIV-positive patients may present with multiple causative pathogens including *S. Aureus, P. Aeruginosa*, streptococci, anaerobes, and fungi (Aspergillus, Cryptococcus, Rhizopus), while advanced immunosuppression patients may have rare parasitic rhinosinusitis (*Microsporidium*, *Cryptosporidium*, *Acanthamoeba*), cytomegalovirus, atypical mycobacteria, and *Mycobacterium kansasii* (Brook 2010).

Nosocomial rhinosinusitis can occur during extended stays in intensive care unit (ICU) settings, involving transoral or particularly prolonged transnasal intubation or nasogastric tube use. Nasotracheal intubation poses a higher risk of nosocomial rhinosinusitis, developing in approximately one-fourth of patients nasally intubated for more than 5 days (Brook 2010). Commonly-recovered organisms include *Pseudomonas aeruginosa* and other gram-negative rods (*Enterobacter* spp., *K. Pneumoniae, P. Mirabilis, Serratia marcescens*), although it is unclear whether these bacteria are pathogenic or simply colonizing a dysfunctional sinonasal environment with potential nosocomial foreign bodies present and impaired mucociliary clearance.

Odontogenic rhinosinusitis is a relatively common cause of maxillary sinusitis, involved in approximatey 10–12% of cases (Brook 2010), due to the close anatomic proximity of the maxillary molar roots and the maxillary sinus floor. These infections more commonly present with anaerobic and polymicrobial infections. Predominant bacteria recovered from odontogenic infections are anaerobes (AGNB, *Peptostreptococcus,* and *Fusobacterium* spp.) and aerobes (alpha-hemolytic streptococci and *Staph aureus*), generally reflecting the species seen in normal oral flora (Brook 2005).

Treatment

AVRS Treatment

In early acute rhinosinusitis, with a presumptive diagnosis of AVRS, treatment is supportive and aimed at reducing mucosal edema to improve nasal obstruction, rhinorrhea, sinus ventilation, and clearance, and providing analgesic treatment to reduce facial pain and pressure. This includes evaluating the level and quality of pain with available scales, followed by treatment with analgesics to address the often significant discomfort as well as ensuring sufficient follow-up, in order to address potential analgesic masking of clinical worsening. Additional non-antibiotic treatments for acute rhinosinusitis include nasal saline irrigations, intranasal topical steroids or systemic steroids, antileukotriene agents, antihistamines, and multiple types of complementary medicine. Overall, evidence of effectiveness for these adjunctive treatments varies from providing symptomatic relief to minimal or no impact on the course of the disease (Chan and Kuhn 2009).

Saline irrigations offer benefits of thinning mucus and improving mucociliary clearance with minimal cost or risk. Rabago et al. demonstrated significant improvement of rhinosinusitis symptoms with hypertonic saline nasal rinses by Rhinosinusitis Disability Index (RSDI) and a Single-Item Sinus-Symptom Severity Assessment (SIA) scoring, and reduction of the amount of analgesics, nasal sprays, and antibiotics used (Rabago et al. 2002). In one study from Ural et al., isotonic saline rinses significantly increased mucociliary clearance time in acute rhinosinusitis, however hypertonic saline rinses improved clearance time in only chronic sinusitis patients (Ural et al. 2009). Mucolytics (e.g., guaifenesin) are often used to thin mucus consistency, although minimal evidence supports their efficacy.

Systemic or topical nasal decongestants (e.g., pseudoephedrine, phenylepinephrine, oxymetazoline hydrochloride) theoretically decrease mucosal edema to improve sinus ventilation and mucus clearance, and have been shown to improve acute rhinosinusitis symptoms (Meltzer et al. 2005), although no randomized controlled trials strongly support their effect on the course of rhinosinusitis (Rosenfeld et al. 2007). Repetitive or prolonged use of topical decongestants beyond 3 days can increase the risk of rebound nasal congestion, rhinitis medicamentosum, or tissue

vasoconstriction with necrosis. Decongestants should be used with caution in patients with unstable hypertension, coronary artery disease, benign prostatic hypertrophy or glaucoma.

Antihistamines have been used to treat AVRS and ABRS through an antiinflammatory and drying effect (Rosenfeld et al. 2007), and second-generation H1 antagonists can also provide some specific benefit in patients with a history of allergic rhinitis, although no clinical studies confirm any benefit of antihistamines.

First-generation H1 antagonists may worsen sinus clearance by thickening mucus, and have potential side effects including drowsiness. Leukotriene inhibitors include leukotriene D4 receptor blockers (e.g., zafirlukast, montelukast) and 5-lipooxygenase inhibitors (e.g., zileuton). These agents limit the effects of leukotrienes, which are responsible for triggering the inflammatory cascade leading to increased mucous production and vascular permeability with subsequent mucosal swelling.

Topical intranasal glucocorticoids (e.g., fluticasone, betamethasone, proprionate, budesonide, mometasone) are used to relieve the generalized mucosal inflammation responsible for rhinosinusitis in order to improve sinonasal drainage and mucociliary clearance. If used early in the clinical course of rhinosinusitis, steroid-induced reduction of the inflammatory process and mucosal edema could potentially lessen the severity and duration of symptoms, restore normal drainage pathways and prevent ABRS. Recent studies have evaluated topical nasal glucocorticoids in ABRS with and without simultaneous antibiotic treatment, summarized by a recent Cochrane review examining evidence from meta-analysis of three separate studies (Zalmanovici and Yaphe 2007). Intranasal corticosteroids were shown to have a moderate effect, with a higher chance of resolving ABRS symptoms than placebo (73% vs. 66.4%; risk ratio (RR) 1.11; 95% CI 1.04–1.18). Intranasal application of glucocorticoids is most effective in the head-down position directing the spray laterally to increase dosing to the middle meatus and minimize septal irritation. Potential side-effects of intranasal steroids include nasal mucosal drying, epistaxis, sore throat, and cough. Systemic steroids are not used commonly in the treatment of ABRS, but show efficacy for treatment of chronic rhinosinusitis with nasal polyps (CRS) in decreasing mucosal edema and nasal polyp size (Dykewicz and Hamilos 2010).

Complementary medicine is becoming more commonly used in the treatment of rhinosinusitis, with up to 30% of patients utilizing alternative herbal therapy for chronic rhinosinusitis prior to seeking conventional medical intervention (Guo et al. 2006). Common types of complementary medicine include herbalism (use of plant remedies), homeopathy (use of diluted extracts), acupuncture (use of needles to affect physiologic function), aromatherapy (use of aromatic oils), chiropractic (treatment by spinal manipulation), osteopathy (treatment of underlying mechanical disorders), and bioresonance (treatment with electromagnetic energy). A meta-analysis examining the effects of herbal remedies in ten randomized controlled trials (Brown et al. 2009) determined some effectiveness from Sinupret (an herbal preparation including extracts of Gentiana lutea root, Primula veris flower, Rumex sp., and Sambucus nigra flower) and bromelain (a stem and fruit extract from pineapple, Ananas comosus) for symptoms of acute and chronic sinusitis. Positive effects were found in Myrtol, Esberitox, Cineole and Bi Yuan Shu as well (Brown et al. 2009). One small study showed efficacy of Shea butter (from oil of the African Shea butter tree seed, *Butyrosperum parkii*) for nasal decongestion when applied to the upper lip. Echinacea is thought to improve viral rhinitis symptoms by activating T and B lymphocytes, and although several meta-analyses found positive effects, some studies have shown no effect (Asher et al. 2001). Commerically available formulations of Echinacea also vary widely in amount and type of active compounds, further complicating effective studies (Asher et al. 2001).

ABRS Treatment

Once the diagnosis of ABRS is made, therapeutic decisions depend on probable infecting agents, potential antibiotic resistance, the patient's allergy profile, and an individual's response to treatment. Evidence for immediate initiation of antibiotic therapy versus continuation of supportive therapy is unclear, and deferring antibiotic therapy during a period of watchful waiting can be considered since spontaneous resolution of ABRS occurs in over 60% of patients (Rosenfeld et al. 2007). For patients with mild symptoms (mild-to-moderate pain, low-grade fever), supportive treatment may be sufficient, with antibiotics added for any worsening symptoms or failure to improve after 1 week. Patients presenting with more

severe symptoms (moderate-to-severe pain, fever >101°F) or symptoms for more than 7 days should be treated with an antibiotic (Pearlman and Conley 2008).

A 2009 Cochrane review of antibiotics for acute maxillary sinusitis (Ahovuo-Saloranta et al. 2009) evaluated data from five placebo-controlled studies and 51 studies studying effects between different antibiotics. Placebo-controlled studies included five studies with a total of 631 subjects receiving either antibiotics or placebo and evaluated for clinical failure, defined as lack of cure or improvement at 7–15 days follow-up. Collectively, this analysis found a slight statistically significant difference favoring the use of antibiotics with a relative risk (RR) of 0.66 (95% CI 0.44–0.98). However, the review points out that the clinical difference was equivocal since the majority of subjects showed improvement regardless of group (80% in placebo group and 90% in antibiotic group). Based on this data, antibiotics appear to have a small treatment benefit in uncomplicated sinusitis lasting for more than 1 week, but 80% of patients treated without antibiotics will improve within 2 weeks (Ahovuo-Saloranta et al. 2009).

Guidelines for treatment of adult sinusitis by the American Academy of Otolaryngology in 2007 recommended initial treatment of uncomplicated ABRS with a narrow-spectrum antibiotic like amoxicillin, trimethoprim-sulfamethoxazole, or macrolides (Rosenfeld et al. 2007). However, awareness of predominating bacterial pathogens and trends in antibiotic resistance within local communities is important in tailoring empiric antibiotic therapy. With increasing antibiotic resistance, endoscopic middle meatus cultures for antibiotic sensitivities can improve treatment efficacy. Broader-spectrum antibiotics (amoxicillin-clavulanate, quinolones (levofloxacin, moxifloxacin), second- and third-generation cephalosporins (ceforoxime-axetil, cefpodoxime proxetil, cefdinir) provide coverage for narrow-spectrum treatment failures, patients with comorbidities or risk factors for antibiotic resistance, and more severe infections, including severe symptoms or complications. In cases of ABRS, where initial treatment with amoxicillin or an equivalent narrow-spectrum antibiotic fails to improve symptoms after several days of treatment, a change in antibiotic therapy should be considered. Use of antibiotics in the previous month increases the potential of a resistant infection, and warrants a broader-spectrum antibiotic choice. If no response is achieved on secondary antibiotic treatment, middle meatus cultures can provide direction for antibiotic choices, and contributing factors or other differential diagnoses must be considered. Patients with severe or worsening symptoms should be monitored closely for progression to complicated rhinosinusitis (see ▶ Sinusitis), which can include orbital, intracranial, and bony extension of infection (Giannoni and Weinberger 2006). Parenteral antibiotics are generally reserved for patients with complications of rhinosinusitis, organisms resistant to oral therapy, or severe immunocompromise. Recommended length of antibiotic therapy for ABRS is at least 14 days, or continuation of therapy 7 days beyond symptom resolution, whichever is longer, although no controlled studies have thoroughly evaluated optimal duration (Brook 2010). Longer durations of antibiotic dosing increase the patient's exposure and may also increase the risk of medication side effects like gastrointestinal irritation or allergic reactions. On the other hand, incomplete treatment can contribute to the development of antibiotic resistant organisms.

Specific populations may require alterations in antibiotic treatment for ABRS and deserve specific attention. ABRS patients with penicillin allergies may be effectively treated with a macrolide, trimethoprim-sulfamethoxazole (TMP-SMX), clindamycin, or tetracyclines (Dykewicz and Hamilos 2010). Antibiotic dosing in pregnant women requires consideration of pregnancy safety categories, since all antibiotics cross the placental blood barrier and expose both the mother and fetus to any potential adverse effects. Pregnant women should avoid tetracyclines and aminoglycosides (FDA pregnancy category D), and sulfonamides, quinolones and vancomycin (FDA pregnancy Category C), but may receive amoxicillin, clindamycin, erythromycin, ampicillin, penicillin (FDA pregnancy Cateogry B) without any concerns for pharmacologic risk to the pregnancy. Cephalosporins are considered Category B, but are not first-line agents during the first trimester of pregnancy due to a paucity of data on effects during this period (Dashe and Gilstrap 1997). In immunocompromised patients, a broad variety of pathogens may cause acute sinusitis and should be considered when choosing therapies. These include fungus, *S. aureus*, *Pseudomonas*

aeruginosa, or even rarer pathogens (Brook 2010). In these patients in particular, culture-directed therapy is useful, with inclusion of tissue biopsies if the clinical picture presents any potential for a fungal infection. Fungal infections in immunocompromised patients require a high level of clinical suspicion for efficient diagnosis and treatment, particularly in cases of invasive fungal infections. Increasingly, methicillin-resistant *S. aureus* (MRSA) is appearing in cultures of ABRS infections, and treatment of MRSA ABRS presents a specific challenge. Rates of MRSA in acute maxillary sinusitis increased between 2001 and 2006 from 3% to 9% (Brook 2010), and although vancomycin was previously considered the gold standard of treatment, reports of vancomycin resistance are now appearing. Children with exposure to daycare settings have a higher risk of penicillin-resistant *Streptococcus pneumoniae* and should receive high-dose amoxicillin as initial therapy (Pearlman and Conley 2008). One additional population to consider is patients who have recently received antibiotics (in the previous 4–6 weeks), and have an increased risk of treatment failure or antibiotic resistance. In these cases, fluoroquinolones, high-dose amoxicillin-clavulanate and ceftriaxone are useful. For patients in this situation with penicillin allergies, consider trimethoprim-sulfamethoxazole or macrolides to provide coverage without allergic reaction potential (Pearlman and Conley 2008).

Cross-References

- ▶ Acute and Chronic Rhinosinusitis
- ▶ Allergic Fungal Rhinosinusitis
- ▶ Benign Sinonasal Neoplasms
- ▶ Facial Nerve Imaging, CT and MRI
- ▶ Sinusitis

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Antibody

- ▶ Otolaryngologic Allergy/Immunology

Antigen

▶ Otolaryngologic Allergy/Immunology

Aphthous Stomatitis

▶ Stomatitis

Apopilosebaceous Unit

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Synonyms

Hair follicle unit

Definition

Hair follicle unit consisting of the hair follicle and its associated arrector pili muscle, and apocrine and sebaceous glands.

Cross-References

▶ Pinna and External Auditory Canal, Anatomy

Appelbaum Prosthesis

▶ Ossicular Chain Reconstruction in Children

Apraxia of Speech

▶ Speech Development and Disorders

Arnold's Nerve

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Definition

The auricular branch of the vagus nerve.

Cross-References

▶ Pinna and External Auditory Canal, Anatomy

Arteriography

▶ Angiography

Arteriovenous Malformations

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Synonyms

Angioma arteriale; Angiomatous malformation; AVMs; Vascular harmartoma

Definition

An arteriovenous malformation (AVM) is an abnormality of the vasculature whereby arteries form fistulous connection with veins without an intervening capillary bed. It is the most common type of symptomatic vascular malformation which includes cavernous malformations, developmental venous anomalies, and

capillary telangiectasias. They are generally categorized as harmartomas (a focal malformation resulting from faulty development in an organ; composed of an abnormal mixture of tissue elements, or an abnormal proportion of a single element normally present in that site).

Epidemiology

The vast majority of AVMs are congenital in origin, although rare reports of de novo lesions have been reported. They are thought to arise between 3 and 8 weeks of gestation and resemble normal anastomoses in early embryogenesis. A minority of AVMs may be acquired secondary to trauma, radiation, or other type of injury. The majority of AVMs are sporadic but some occur in a familial pattern. Notable examples are those occurring in patients with Hereditary Hemorrhagic Telangiectasia (HHT a.k.a. Rendu-Osler-Weber syndrome) and in Wyburn-Mason syndrome. The frequency of AVMs in a large autopsy series was 1.4% (Olivecrona and Riives 1948) and the incidence rate in another series (excluding autopsies) was 1.11 per 100,000 (Brown et al. 1996).

Brain AVMs are most commonly located in the supratentorial region (90%) and the parietal lobes are the most commonly involved when located supratentorially (39% of lesions). Other less common locations are the cerebellum, brainstem, and intraventricular region. Most AVMs occur singly but multiple AVMs are more likely to occur with HHT.

AVMs may also occur as a subset of cutaneous vascular malformations which include hemangiomas (which are true neoplasms) and vascular malformations. Cutaneous vascular malformations are congenital lesions and can further be subdivided into high-flow lesions (arterial, arteriovenous, and arteriolymphovenous malformations and arteriovenous fistulas) and low-flow lesions such as capillary, venous, and lymphatic malformations.

History

The first detailed description of cerebral vascular malformations was by Virchow in 1863 in his classic Die Kranhaften Geschwulste (Virchow 1863). He and other early investigators wrestled with the controversy as to whether these lesions represented true neoplasms or developmental anomalies. In 1928, Cushing and Bailey published the classic monograph *Tumours arising from the blood-vessels of the brain* in which they synthesized the previous literature and proposed separating vascular malformations and vascular neoplasms such as hemangioblastomas (Cushing and Bailey 1928). With intraoperative and pathologic evidence that intervening brain parenchyma was present within the tangle of vessels, they concluded that these lesions are in fact malformations. The technical limitations of the time and poor outcomes after the tentative surgical exploits led Cushing to be pessimistic concerning the resection of these lesions. Notably, they described the first radiotherapy for an AVM in a patient who initially presented with seizures who underwent a craniotomy for an "angioma arteriale." This attempt at removal was met with significant blood loss and hypotension, and thus, the procedure was aborted. The patient subsequently recovered from an initial hemiplegia and received a series of X-ray treatments. Three years later, a second exploration was performed for aphasia and altered mental status and Cushing found that the lesion was completely thrombosed.

Clinical Features

AVMs may be incidental (i.e., asymptomatic), but they are the most frequently detected symptomatic vascular malformation. They usually present before age 40 but are uncommon in children. The most common presentation is intracranial hemorrhage occurring in 65% of AVMs (Brown et al. 1997). This hemorrhage is usually in a deep intracerebral pattern often with a component of subarachnoid or intraventricular extent. This is consistent with the classic morphology of an AVM as a wedge-shaped lesion with the base oriented toward the surface and the apex oriented toward the ventricle. More superficially located lesions may occasionally present only with subarachnoid hemorrhage and ependymal AVMs only with intraventricular hemorrhage. Seizures of various types are the second most common presentation seen in 28% of patients with AVMs (Perret and Nishioka 1966). Frontal or temporal lobe lesions have a higher risk of seizures with generalized seizures seen most often in the frontal lobe and

focal seizures seen most commonly in the parietal lobe. Other presenting symptoms of AVMs include headaches, seen in 15% of patients, and focal neurologic deficits seen in less than 5% of cases (Brown et al. 1988). Focal deficits in a patient without a hemorrhage may be caused by a "steal" phenomenon, or vascular maldistribution whereby the high-flow shunt prevents an adequate supply of blood to surrounding tissue, thus resulting in symptoms.

In a long-term follow-up study of AVMs with a mean follow-up of 23.7 years, the bleed rate for all hemorrhages was 4% per year (Ondra et al 1990). The lifetime risk of hemorrhage is a more complicated calculation based on actuarial analysis but a formula that closely approximates these calculations is: 105 − patient's age in years. The risk of hemorrhage of an AVM is dependent on multiple factors many of which can be identified on angiography. While at least one large study failed to find an association between size of AVM (Brown et al. 1988) and the risk of hemorrhage, others have demonstrated that smaller AVMs have a higher risk of presentation with an initial bleed but not with subsequent bleeds (Graf et al. 1983; Waltimo 1973). The presence of intranidal aneurysms is also associated with an increased risk of hemorrhage. Other factors that have been shown to be independent predictors of AVM hemorrhage by multiple logistic regression include a prior bleed, a ventricular or periventricular nidus, diffuse AVM morphology, elevated mean feeding arterial pressure, exclusively deep venous drainage, a single draining vein, venous stenosis, reflux into a dural sinus or deep veins, and the ratio of the number of afferent to efferent systems (Alleyne and Spetzler 1999). The risk of rehemorrhage after an initial bleed increases to between 6% and 17% to first year after hemorrhage but decreases to 2% per year thereafter (Graf et al. 1983; Fults and Kelly 1984).

Vein of Galen (VOG) malformations are a specific subgroup of vascular lesions occurring in the pediatric population and most of these are more properly classified as arteriovenous fistulae. This latter group also comprises dural arteriovenous fistulae. VOG malformations result from an arteriovenous fistula of the median prosencephalic vein (a precursor of the VOG) occurring at 6–11 weeks of gestation. The median prosencephalic vein fails to regress and becomes aneurysmal. In one classification system of these lesions (Yasargil 1988), type 1 is a small pure cisternal fistula between the VOG and either the pericallosal or posterior cerebral vessels; type 2 has multiple fistulous connections between the VOG and thalamoperforating vessels; type 3 is a mix of types 1 and 2; and type 4 is a parenchymal AVM (true AVM) with drainage into the vein of Galen. The clinical presentation varies with the age of the patient. The neonate can present with high-output cardiac failure and/or a cranial bruit, the infant can present with hydrocephalus due to venous hypertension or aqueductal stenosis and the child can present with developmental delay or hydrocephalus.

Tests

The arteriogram remains the gold standard in the diagnosis of AVMs. The hallmark is an early draining vein (one that is visible in the arterial phase of the angiogram). The angioarchitecture including the arterial feeders, the nidus, the venous drainage, as well as any associated feeding aneurysms, intranidal aneurysms, venous aneurysms, or strictures can be readily identified. While an internal carotid or vertebral artery injection is likely to readily reveal the AVM, a superselective study is frequently needed to clearly identify the third or fourth order vessels that are contributing to the lesion. The latter studies are especially important when embolization is being considered. Other radiographic tests that can identify AVMs include CT and CT angiogram, MR and MR angiogram. The CT is sensitive to acute blood and the addition of contrast can show the vessel tortuosity of the nidus or draining veins. It can also reveal calcification within the nidus, edema, gliosis or encephalomalacia around the nidus, or hydrocephalus. The CT angiogram will reveal the three-dimensional architecture of the lesion. The MR can be particularly useful in localizing the lesion relative to eloquent cortical tissue, deep structures such as the basal ganglia and corpus callosum, and the ventricular system. In select cases, a functional study such as positron emission tomography (PET), functional MRI (fMRI) may be indicated to help identify the relationship between functional cortex (such as primary sensory, motor, visual, and speech areas) and the AVM. Mini-WADA testing (e.g., superselective infusion of an anesthetic in a feeding vessel to rule out supply to functional tissue) can also be performed prior to definitive embolization.

Differential Diagnosis

The differential diagnosis of an AVM that presents with a hemorrhage includes a bleed of hypertensive etiology, amyloid angiopathy, mycotic aneurysm, cavernous malformation, or an underlying tumor (e.g., melanoma, metastasis, or glioblastoma). The differential diagnosis of an AVM that is unruptured but has tortuous vessels includes a variety of hypervascular lesions such as hemangiomas, hemangioblastomas, hemangiopericytomas, meningiomas, and glomus tumors.

Etiology

The vast majority of AVMs are congenital in origin although rare reports of de novo lesions have been reported. They are thought to arise between 3 and 8 weeks of gestation and resemble normal anastomoses in early embryogenesis. A minority of AVMs may be acquired secondary to trauma, radiation, or other type of injury. The underlying molecular mechanisms of AVM formation remain unclear. One popular theory based on the work of multiple investigators suggests that these lesions may arise as a result of aberrant vasculogenesis of the developing capillary bed and then arteriovenous shunting with vessel recruitment can then result in growth of the lesion. Local factors such as venous hypertension may contribute to the development of AVMs. Other specific factors thought associated with AVM formation include endothelin-1, vascular endothelial growth factor (VEGF), and transforming growth factor-beta (TGF-β) (Jafar et al. 1999).

Treatment

The decision whether or not to treat an AVM and the selection of a treatment modality can be a rather complex one. Given the natural history of only 3–4% risk of hemorrhage per year, the decision to intervene must be weighed carefully against the risk of intervention. The primary goal of treatment is to reduce or eliminate the risk of hemorrhage, control seizures, and reversal of neurological deficit. Options for treatment include surgical resection, endovascular embolization, stereotactic radiosurgery, or a combination.

Surgical excision represents the definitive treatment and has the advantage of an immediate decrease or elimination of the risk of hemorrhage. The major disadvantage is, of course, the risks incurred during the craniotomy. These risks can be predicted using the Spetzler–Martin grading scale which classifies AVMs based on size, location, and deep venous drainage (Spetzler and Martin 1986). A successful surgical resection begins with adequate preoperative planning. This includes patient counseling and consent, patient positioning, and planning the incision and the craniotomy. The flap should be large enough to gain adequate exposure of the entire AVM. Extreme care should be taken when removing the bone flap and opening the dura since any cortically based AVM is at risk for intraoperative rupture during this stage of the procedure. The technique of surgical resection involves dissecting the plane between the nidus and the surrounding brain. The feeding arteries are identified, coagulated, and cut sequentially to devascularize the nidus in a circumferential pattern. It is critical that the major draining vein or veins are not divided before the arterial feeders have been coagulated. An intraoperative angiogram can be useful to document that the AVM has been completely resected.

Endovascular embolization is usually used as a preoperative adjunct to surgical resection or occasionally to stereotactic radiosurgery. Embolization alone is generally used for palliation although rarely a cure can be achieved in small AVMs. The technique of embolization involves the insertion of a microcatheter into the nidus of the AVM. The embolysate, generally glue such as a cyanoacrylate or Onyx, is infused into the nidus. Care should be taken to avoid transmission of the embolysate to the venous outflow since this can precipitate an intraoperative bleed. Significant reflux of embolysate along the microcatheter should also be avoided since this can result in a retained microcatheter tip. If the AVM is large and has multiple feeding pedicles, it is preferable to perform a staged embolization to reduce the risk of bleeding from normal perfusion pressure breakthrough which is a result of sudden shifts of blood flow to surrounding areas of the brain that have impaired autoregulation (Spetzler et al. 1978). As a general rule, it is advisable to embolize the deeper feeding vessels that are less surgically accessible and then preserve the more superficial vessels for occlusion at the time of surgery. If an AVM is located near eloquent

cortex and it is uncertain if embolization would cause a neurological deficit, a mini-WADA test can be performed. With the patient awake, a short-acting local anesthetic can be infused superselectively in the feeding vessels in question while the patient is examined.

Stereotactic radiosurgery can comprise of Gamma knife, a variety of linear accelerator-based options (such as Novalis and Cyberknife), and proton beam radiosurgery. Gamma knife was developed by Lars Leksell in 1968 in Stockholm, Sweden. It utilizes gamma rays from 201 cobalt-60 sources. The gamma rays are made to converge on a target via a system of collimators. The treatment is initiated by affixing the head frame to the patient's head. An MRI is obtained with the frame in place. The planning is accomplished by the team (generally consisting of a neurosurgeon, radiation oncologist, and physicist) using the software. The radiation dose (e.g., 18–20 Gy to the 50% isodose line) is then administered. Cyberknife and Novalis are frameless linear accelerator systems that use electrons accelerated to a target to create a focused X-ray beam. Proton beam therapy requires a cyclotron to produce the protons. The Bragg Peak Effect allows protons to deliver full energy at beam energy defined depth with a steep drop-off.

Radiosurgery can be utilized as the primary form of treatment, as an adjunct for residual AVMs after surgical resection, or after embolization. The effect of radiosurgery is to cause thickening of the walls of the AVM nidus over time and eventual occlusion. Histologically certain time-sensitive changes are seen. At 33 months, a partial vaso-occlusion (36–74% of lumen) secondary to coagulation of cytoplasmic debris is identified. At 48 months, 86–96% luminal occlusion occurs, and at 64 months, complete luminal occlusion is seen (Tu et al. 2006). Angiographically, AVM obliteration occurs after 2 or more years, and during this time, the patient is subject to the risk of hemorrhage from the lesion. The success rate of embolization is over 70% for AVMs less than 3 cm in diameter but less than 50% for larger lesions. The technique does carry a roughly 10% risk of edema which can result in neurological deficit. The type and severity of the deficit is dependent on the exact location and size of the AVM and the dose of radiation. This edema usually develops between 6 and 24 months after treatment but can generally be controlled with steroids.

In conclusion, AVMs represent a group of generally congenital vascular lesions that can present a challenge to manage. Asymptomatic lesions should be carefully assessed to identify any angiographic or clinical factors that might predispose to a higher risk of rupture. The decision whether or not to treat can be complicated and should depend on the aforementioned factors, location of the lesion, occupation and wishes of the patient, and risks of treatment including surgical, endovascular, radiosurgical treatment, or a combination of methods. Occasionally, a detailed analysis may suggest that the overall risk of treatment may outweigh the risk of hemorrhage based on the known natural history of these lesions. In general, symptomatic lesions (including ruptured lesions) should be treated to decrease the future risk of hemorrhage if the treatment risk is acceptable, but the treatment strategy should be individualized.

Cross-References

- ▶ Angiography
- ▶ Differential Diagnosis of Adult Neck Masses
- ▶ Epistaxis
- ▶ Vascular Anomalies of Head and Neck

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Arteritis

► Vasculitides

Articulation Disorder

► Speech Development and Disorders

Aspiration

► Fine Needle Aspiration for Head and Neck Tumors

Aspiration Biopsy

► Fine Needle Aspiration for Head and Neck Tumors

Aspiration Cytology

► Fine Needle Aspiration for Head and Neck Tumors

Association Study

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Definition

Aids in the identification of genetic factors by investigating the co-occurrence of a disease and an allele of a genetic marker.

Cross-References

► Genetics of Presbycusis

Asthma, Diagnosis and Management

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Synonyms

Reactive airway disease; Recurrent bronchiolitis; Wheezy bronchitis

Definition

Asthma is a chronic inflammatory disorder of the airways causing recurrent episodes of coughing (particularly at night or early in the morning), wheezing, breathlessness and chest tightness in susceptible individuals. These episodes are usually associated with widespread but variable airflow

obstruction that is often reversible either spontaneously or with treatment (EPR-3 2007).

Epidemiology

Asthma is one of the most commonly encountered chronic medical conditions in children in both developed and developing countries. Current estimates show that approximately 300 million people worldwide have asthma (Masoli et al. 2004). In the USA alone, more than 22 million have asthma, approximately 6 million of whom are children (EPR-3 2007). There is a wide variation in asthma prevalence around the world with up to 15-fold differences between countries. Prevalence is generally high in developed countries (>15% in the UK, 15.1% in New Zealand, 14.7% in Australia, 14.6% in the Republic of Ireland, 14.1% in Canada, and 10.9% in the USA) (Masoli et al. 2004). Within countries, prevalence also varies between areas with prevalence being higher in urban than in rural areas.

Childhood asthma appears to be increasing in prevalence worldwide despite advances in its management and pharmacotherapy (Liu et al. 2004). In addition, this increase in prevalence has been showed to be associated with a concurrent increase in other allergic conditions such as eczema and rhinitis. The rate of asthma also increases as urbanization grows. Asthma prevalence is higher in African Americans than in whites or Hispanics. About one in six (17%) of non-Hispanic black children had asthma in 2009, the highest rate among racial/ethnic groups (CDC 2011). This group also had the greatest rise in asthma rates (almost a 50% increase) from 2001 through 2009 (CDC 2011). African Americans are also at higher risk for morbidities associated with asthma.

Without appropriate treatment, asthma can significantly limit individuals' activities and result in asthma exacerbations, which can lead to hospitalization and even death. Asthma accounts for about 500,000 hospitalizations/year (Akinbami 2006) and is among the top causes of hospitalization in children. In the USA, 185 children and 3,262 adults died from asthma in 2007 (CDC 2011). Death rates are higher for African Americans. Asthma accounts for approximately 13 million missed school days each year and 10.1 million missed work days for adults (Akinbami 2006). From an economic standpoint, asthma cost the USA about $3,300 per person with asthma each year from 2002 to 2007 in medical expenses, missed school and work days, and early deaths (CDC 2011).

History

Asthma has been in existence for thousands of years, perhaps dating back to ancient Egyptian times. The word asthma comes from the Greek word *aazein*, meaning "to pant" or "to gasp." It is believed that Hippocrates (ca. 460 BC–ca. 370) was the first to use asthma as a medical term. Galen (AD 129–199/217) described asthma symptoms and established that these symptoms were caused by bronchial obstructions.

It was in the early part of the twentieth century that modern treatment for asthma began with the development of bronchodilators. However, it was also around this time that asthma was largely thought to be a psychosomatic illness. The concept of asthma as an inflammatory condition was only recognized in 1960, and since that time anti-inflammatory medications have been increasingly developed for use in the management of asthma. In the later part of the twentieth century, there was also significant advancement in asthma research, including findings relating allergies and genetics to this disease.

Clinical Features

Asthma can present in all age groups from infancy to adulthood, but most cases of chronic asthma begin in the preschool age (Bisgaard and Bønnelykke 2010). In addition, the younger a child is at the onset of symptoms, the greater is the need to consider and work up for an alternative diagnosis.

Asthma is characterized by repeated episodes of wheezing, coughing, shortness of breath, and tightness in the chest. Recurrent wheezing and coughing are typically the most frequent presenting complaints. Physician-documented wheeze is helpful in the evaluation since parents may confuse upper airway congestion with true wheezing. The cough in asthma is often described as dry and is more prominent at night and in the early morning. Younger children may complain of chest discomfort as well. Symptoms are typically provoked by a variety of factors including exercise, laughing, tickling, cold air, stress, and exposure to

various airway irritants. Airway irritants include tobacco smoke, environmental allergens (such as dust mite, pollen, animal dander), and various respiratory viruses especially rhinovirus. Response to asthma therapy (including bronchodilators and inhaled or systemic steroids) in the past is an important clinical feature to elicit.

Asthma is a heterogeneous disorder with specific phenotypes based on patterns of natural history and allergic sensitization (Martinez 2002). In the preschool-aged child, two distinct clinical patterns are present: nonatopic viral respiratory infection-induced asthma and atopic asthma with persistent symptoms (Weinberger and Abu-Hasan 2006). The former is more common and symptoms occur exclusively following respiratory viral infections. Onset of symptoms occurs typically during infancy following an episode of respiratory syncytial virus bronchiolitis. Atopic asthma with persistent symptoms usually starts in the preschool age and is the common pattern during school age. Exacerbations also occur with respiratory illnesses, but these children often have symptoms between exacerbations. Most of these children have evidence for specific IgE to inhalant allergens (Weinberger and Abu-Hasan 2006).

There are features in a child's past medical, family, and environmental histories which may favor a diagnosis of asthma. Children born prematurely with a prolonged requirement for oxygen after birth are at higher risk for asthma symptoms. Severe respiratory virus syncytial (RSV) bronchiolitis during infancy has been shown to lead to recurrent respiratory symptoms in childhood. In fact, this is commonly the first episode of wheezing in infants who subsequently are diagnosed to have asthma (Weinberger and Abu-Hasan 2006). Children with other atopic conditions (such as atopic dermatitis, allergic rhinitis, and food allergies) and those with parental history of atopy have a greater risk for developing asthma. Exposure to environmental tobacco smoke (including maternal smoking during pregnancy) and other irritants are documented risk factors for asthma.

Physical examination of a child with asthma should include assessment of growth and careful examination of both upper and lower respiratory tracts. In addition, other signs of an atopic disease need to be sought. Inspection of the nose may show edema and rhinorrhea, which may suggest allergic rhinitis. The presence of nasal polyps is not frequent in asthma and should prompt investigation for cystic fibrosis. Examination of the lungs outside of an acute episode is often unremarkable. The respiratory rate, oxygen saturation, work of breathing, inspiratory to expiratory ratio, and auscultation are frequently normal. During an acute episode, wheezing may be heard. In more severe cases, tachypnea, retractions, hypoxia, and respiratory distress may be present. The presence of eczema or signs of allergic rhinitis increase the likelihood of asthma in a child with recurrent cough and wheeze, as 80–90% of school-aged children with asthma have an allergic diathesis (Castro and Kraft 2008).

There are certain conditions that also manifest with recurrent coughing mimicking asthma, which may coexist with asthma as well. These associated conditions include chronic rhinosinusitis, allergic rhinitis, gastroesophageal reflux disease, and vocal cord dysfunction (Liu and Covar 2008).

Chronic rhinosinusitis is common in children presenting with symptoms of asthma. It is thought that this condition may trigger asthma through a variety of mechanisms including (1) pharyngobronchial reflexes which are triggered by the drainage of inflammatory mediators and infected material from the sinuses into the pharynx, (2) drainage of inflammatory cells and mediators into the lungs, (3) impaired filtration of inspired air, and (4) local upper respiratory inflammation leading to pulmonary inflammation (Smart 2005). On the other hand, these two conditions may also be manifestations of a single disease ("one airway hypothesis") with common histopathology between the two areas (Smart 2005). It has been shown in several studies that medical management of chronic rhinosinusitis is associated with improvement in asthma symptoms and lung function (Smart 2005).

Allergic rhinitis is common in children with asthma. Several mechanisms are also thought to explain how this condition can aggravate asthma. These include (1) release of mediators via nasal allergen exposure causing bronchoconstriction and eosinophil influx into the lung; (2) postnasal drip causing coughing, bronchial smooth muscle contraction, and lower airway inflammation; and (3) impaired heating, humidification, and filtration of inspired air due to mouth breathing (Liu and Covar 2008). As with chronic rhinosinusitis, treatment of allergic rhinitis leads to improved asthma control.

Gastroesophageal reflux disease (GERD) is thought to cause recurrent episodes of coughing through two

mechanisms. First is by microaspiration of refluxed gastric contents. And the second is through vagally mediated neural reflexes from distal esophagitis. It can coexist with asthma, making asthma control more challenging. Asthma can also trigger reflux events especially during acute exacerbations. Some medications used in asthma can also worsen GERD.

Vocal cord dysfunction, also called paradoxical vocal fold motion, is a condition wherein the vocal cords adduct inappropriately during inspiration, and occasionally during exhalation, resulting in symptoms of wheezing (usually loudest over the trachea), shortness of breath, cough, and throat tightness. It is more common in older children and adolescents, and may be mistaken for difficult-to-control asthma as this condition responds poorly to asthma therapy. However, most patients with vocal cord dysfunction also have true asthma (Kercsmar 2006).

Tests

The diagnosis of asthma is based on a combination of clinical history, physical examination, and laboratory testing. Unfortunately, there is no single diagnostic test that is both highly sensitive and highly specific for asthma. In pediatrics, testing for asthma is further complicated by the inability of infants and young children to perform lung function testing. Although it is possible to measure lung function in these age groups through infant pulmonary function tests and impulse oscillometry, these techniques are mainly research tools at the current time and there no normative values based on large population studies (Castro and Kraft 2008). Thus, in infants and younger children, the diagnosis of asthma is based largely on clinical history and laboratory testing done to rule out an alternative diagnosis, as well as on the response to asthma therapy.

In school-aged children, pulmonary function testing can be done. Spirometry is one of the more important tests done in asthma and can usually be done at around 7 years of age. Some children as young as 5 years may also be able to perform this test. This involves the performance of a forced vital capacity maneuver consisting of maximal inspiration followed quickly by a forceful exhalation and continued exhalation until end of test (at least a 6-s period of exhalation). The parameters that can be measured include the amount of air exhaled during the first second (FEV1), the total amount of air exhaled (FVC), the ratio between FEV1 and FVC, and the airflow between 25% and 75% of vital capacity (FEF 25–75%). A decrease in the FEV1/FVC ratio is consistent with airway obstruction (such as what is seen in asthma) and the amount of decrease in FEV1 reflects the severity of the defect. The FEF 25–75% is thought to measure peripheral airway obstruction and is among the first parameters to be abnormal in asthma (Castro and Kraft 2008). Although the presence of an obstructive defect supports a diagnosis of asthma, a normal test does not rule it out. In fact, majority of asthmatic children who are asymptomatic at the time of pulmonary function testing may have normal spirometry.

Reversibility of airway obstruction can be tested with the use of a bronchodilator. A significant response is an increase of at least 12% in FEV1 (or 200 ml) following bronchodilator administration. Responsiveness to bronchodilator correlates with airway inflammation and supports the diagnosis of asthma. It has been recommended that response to bronchodilator be assessed even if the baseline FEV1 is normal (Castro and Kraft 2008).

Another pulmonary function test that can be done in children is the assessment of the different lung volumes through body plethysmography or helium dilution. Parameters that can be computed include the total lung capacity (TLC) and the residual volume (RV) which is the amount of air left in the lungs after complete exhalation. In asthma, the RV is elevated as a result of air trapping from airway obstruction. In addition, TLC may also be increased secondary to hyperinflation.

In children with symptoms of asthma but with normal lung function, measures of airway hyperresponsiveness can be used to support a diagnosis of asthma. Exercise and methacholine challenge are the two most commonly employed. Methacholine is a drug which triggers bronchoconstriction. Progressively higher doses of this drug are inhaled during a methacholine challenge (also called bronchial challenge test), and the FEV1 is measured after each dose. A drop of at least 20% in FEV1 at no more than 8 mg/ml of methacholine is considered a positive test, diagnostic of asthma. A negative test puts the diagnosis of asthma in doubt. In an exercise challenge, a drop in FEV1 of at least 15% is indicative of exercise-induced bronchospasm.

The use radiographic tests for asthma in children is more useful for excluding other causes of cough and wheezing, as there are no pathognomonic findings on a chest x-ray. Some features which may be seen in asthma include areas of atelectasis from mucus plugging, as well as some peribronchial thickening. Allergy testing by percutaneous skin prick testing or RAST testing is important to increase the probability of asthma as a diagnosis and to identify possible asthma triggers. Visualizing the airway through direct laryngoscopy and flexible bronchoscopy are useful in ruling out other causes of chronic cough and wheezing.

Differential Diagnosis

The differential diagnosis of asthma in children is broad and includes conditions affecting either the upper or lower respiratory tract, with obstruction involving large airways or both large and small airways (Table 1).

Asthma, Diagnosis and Management, Table 1 Differential diagnosis of asthma

Upper respiratory//large airway conditions
Allergic rhinitis
Rhinosinusitis
Vocal cord dysfunction
Laryngotracheomalacia
Congenital malformation (vascular ring/sling, laryngeal web)
Foreign body aspiration
Lower respiratory tract conditions//small airway conditions
Viral bronchiolitis
Chronic lung disease of prematurity
Gastroesophageal reflux
Aspiration syndromes
Diseases associated with bronchiectasis
Cystic fibrosis
Primary ciliary dyskinesia
Immune deficiency

As noted previously, allergic rhinitis and chronic rhinosinusitis may mimic and/or coexist with asthma. Patients with these conditions usually have persistent nasal congestion or postnasal drip. In approximately 50% of asthmatic children, evidence of rhinosinusitis can be demonstrated (Smart 2005). Vocal cord dysfunction (VCD) should be considered in the older child or adolescent with difficult-to-control asthma. In this condition, the vocal cords close inappropriately during inspiration. As with allergic rhinitis and chronic rhinosinusitis, VCD may be comorbid with asthma. The wheeze in vocal cord dysfunction may be more prominent in the neck area or anterior chest area, and children may complain more of difficulty taking a breath in (as compared to difficulty with exhalation). Diagnosis of VCD may be made by direct laryngoscopy during an acute episode showing the paradoxical vocal cord movement.

In infants and younger children, laryngotracheomalacia, congenital malformations (such as a vascular ring or sling compressing on the airway), and foreign body aspiration, should be ruled out. Laryngotracheomalacia can cause recurrent episodes of barky cough, wheezing, or stridor. Symptoms are usually worse with crying, activity, and concurrent respiratory infections, and improve when the infant is asleep. There is no change in symptoms with a trial of asthma therapy. Diagnosis can be made through bronchoscopy. Mechanical compression of the airway from a vascular ring or sling can cause persistent wheezing and stridor. Symptoms are also worse with crying and with an intercurrent respiratory infection. Diagnosis may be suggested in an esophagogram showing a filling defect in the flow of barium, but is confirmed through magnetic resonance imaging. Foreign body aspiration may present as acute onset of cough and unilateral wheezing. Alternatively, it may also present as chronic wheeze or non-resolving infiltrate. Inspiratory and expiratory films may show air trapping on the affected side. Diagnosis is made through bronchoscopy with removal of the foreign body.

Viral bronchiolitis in infants, particularly that caused by respiratory syncytial virus (RSV), may present similarly with wheezing, tachypnea, small airway inflammation and in some, respiratory compromise. Gastroesophageal reflux disease can manifest with a chronic cough and wheeze and may also be comorbid with asthma. Children with GERD may not manifest with typical symptoms seen in adults such as heartburn. Diagnosis is by 24-h pH probe monitoring. Endoscopy may also reveal findings consistent with GERD such as arytenoid edema, postglottic edema, or enlargement of lingual tonsil (Carr et al. 2001). Aspiration syndromes, either from a dysfunctional swallow or from GERD with microaspiration, can present with persistent episodes of cough and wheezing.

Cystic fibrosis occurs in 1 in 2,500 live births in populations of northern European descent. In addition to recurrent respiratory symptoms, affected children may also have failure to thrive, diarrhea, recurrent sinus, and ear infections. These children often fail to respond optimally to asthma management. Diagnosis is through determination of sweat chloride concentration. Patients with primary ciliary dyskinesia often present with a chronic productive cough. History reveals recurrent episodes of respiratory tract infections including sinusitis, otitis, and pneumonia. Diagnosis is made through examination of ciliary function and ciliary ultrastructure of samples from nasal mucosal brushings. Immunodeficiency is associated with other systemic symptoms (such as failure to thrive) and other sites of infection.

Etiology

The exact etiology of asthma is unclear, but it is known that interplay between genetic and environmental factors is involved. Twin studies have shown higher concordance in monozygotic twins compared with dizygotic twins even when they share the same environment. The concordance in identical twins, however, is not much over 50% (Weinberger and Abu-Hasan 2006). An atopic predisposition appears to be genetically determined. Environment also contributes to asthma, and this is further supported by the differences in asthma prevalence in different areas. Respiratory viruses, particularly rhinovirus, are associated with the development and exacerbation of asthma (Busse et al. 2010).

Airway inflammation is the basic pathophysiology in asthma. This airway inflammation leads to lower airway obstruction affecting both small and large airways. It results from a series of events involving several mediators in a predisposed individual. Components of airway inflammation and obstruction include bronchial hyperreactivity, mucus hypersecretion, bronchial smooth muscle contraction, smooth muscle proliferation and edema.

Treatment

Evidence-based guidelines have been developed by several groups to optimize the diagnosis and management of pediatric asthma and to improve awareness about this condition. These international guidelines are updated and revised periodically to incorporate the latest scientific advances. Among the more often cited guidelines include that released by (1) Global Initiative for Asthma (GINA), which is a collaboration between the National Heart, Lung, and Blood Institute (NHLBI), the National Institutes for Health (NIH), and the World Health Organization (GINA 2010); and (2) National Asthma Education and Prevention Program (NAEPP), which is coordinated by the NHLBI and NIH and publishes the Expert Panel Report (EPR) for the Diagnosis and Management of Asthma (EPR-3 2007). In the UK, the British Thoracic Society and the Scottish Intercollegiate Guidelines Network jointly produced the British Guideline on the Management of Asthma (BTS-SIGN 2009).

The goal of asthma management is to control the disease and prevent irreversible airway damage and mortality (Murphy 2007). Control of disease is defined by several parameters. This includes absence of chronic and troublesome daytime and nighttime symptoms, minimal need for rescue medications, no exacerbations requiring ED visits or hospitalizations, normal activity levels, (near) normal lung function, minimal adverse effects of therapy, and normal growth (EPR-3 2007, BTS-SIGN 2009). It is also very important that patients' and their families' expectations of and satisfactions with asthma care are met (EPR-3 2007). It is possible to obtain well-controlled asthma in 80% of asthmatic children (Guiang 2008).

The management of asthma includes both nonpharmacological and pharmacological therapy (Table 2). Nonpharmacological therapy includes education of the patient and family regarding the disease and its management. The identification and control of factors contributing to asthma severity is a key component of asthma therapy. This includes avoidance of allergen exposure, elimination of environmental tobacco smoke and other airway irritants, and treatment of comorbid conditions such as chronic rhinosinusitis and gastroesophageal reflux. Since asthma is a condition which can change over time and differ among individuals and by age group, regular assessment and monitoring are needed to optimize asthma management and monitor lung function.

Medications used in asthma are classified either as a rescue medication (quick-reliever medication) or as a controller (or preventer) medication. Rescue medications act quickly to treat acute symptoms and

Asthma, Diagnosis and Management, Table 2 Management of asthma

Nonpharmacological
Education of patient and family
Control of factors contributing to asthma exacerbations
Regular assessment and monitoring
Pharmacological
Rescue medications
Short-acting bronchodilators
Anticholinergic
Systemic steroids
Controller medications
Inhaled steroids
Leukotriene modifiers
Long-acting bronchodilators
Methylxanthines

exacerbations. Controller medications are used daily to achieve and maintain control.

A stepwise approach is used in the pharmacological management of asthma. Asthma severity is classified as either intermittent or persistent, with persistent asthma being further classified as mild, moderate, and severe. This classification of asthma severity is based on the frequency of symptoms, nighttime awakenings, need for rescue medications, exacerbations requiring oral systemic corticosteroids, and on lung function (EPR-3). Intermittent asthma requires only the use of rescue or quick-reliever medications as needed, while persistent asthma necessitates the use of controller or preventer medications.

Rescue medications include short-acting bronchodilators, anticholinergics, and systemic steroids. Inhaled short-acting bronchodilators (SABA), such as albuterol or levalbuterol, are used for the acute relief of symptoms. SABAs relax smooth muscle leading to bronchodilation, decrease in vascular permeability, increase in mucociliary clearance, and decrease in mucus secretion (Landau and Martinez 2008). Anticholinergic agents such as ipratropium bromide inhibit muscarinic cholinergic receptors and reduce intrinsic vagal tone of the airway leading to bronchodilation. Systemic steroids, though not quick acting, are considered as a rescue medication for use in moderate to severe exacerbations to hasten recovery and prevent recurrence of exacerbation.

Once criteria are met for persistent asthma (>2 days/week with symptoms, >2 nighttime awakenings/month, use of SABA >2×/week, and >/= 2 courses of corticosteroids/year), a daily controller medication is needed. Inhaled corticosteroids (ICS) are still the best long-term control treatment for asthma patients of all ages as they are the most effective anti-inflammatory medication available. They are the cornerstone of therapy in persistent asthma (Castro and Kraft 2008). ICS therapy results in reduction in symptoms, improvement in lung function, decrease in airway hyperresponsiveness, prevention of exacerbations, and possible prevention of airway remodeling. They have also been shown to lead to an improvement in quality of life. In the stepwise management of persistent asthma, low-dose ICS is the preferred starting medication. There are several ICS available, and each differs in potency as well as rate of absorption. ICS available include beclomethasone dipropionate, budesonide, fluticasone propionate, mometasone furoate, ciclesonide, flunisolide, and triamcinolone acetonide. If persistent asthma is not adequately controlled on low-dose ICS, step-up therapy includes either increasing the ICS dose or adding other controller medications including the leukotriene modifiers, long-acting bronchodilators, or theophylline.

Leukotriene modifiers inhibit release of mediators from mast cells, eosinophils and basophils. They produce bronchodilation, decrease vascular permeability, decrease mucus production, and decrease infiltration and activation of inflammatory cells (EPR-3 2007). This class of drugs includes the leukotriene receptor antagonist montelukast.

Long-acting bronchodilators have a duration of action of at least 12 h. These drugs are not recommended as monotherapy or as initial therapy for persistent asthma, but rather as combination therapy with ICS, in those children requiring a step-up in asthma care. Methylxanthines, such as theophylline, are primarily bronchodilators with limited anti-inflammatory effect with long-term use. They are rarely used as they have a low therapeutic benefit to potential toxicity ratio.

Before any step-up in therapy is done, it is important to evaluate compliance with medications, review technique of inhaler devices, and assess control of environmental and comorbid conditions. Once adequate asthma control is obtained for at least 3 months, consideration may be done to step down on asthma therapy. In the management of asthma, it is important to set expectations high since asthma is a disease which can be controlled.

Cross-References

- ▶ Allergic Rhinitis
- ▶ Chronic Rhinosinusitis

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Atelectatic Otitis

- ▶ Retraction Pockets, Treatment Algorithm

Atelectatic Retraction Pocket

- ▶ Retraction Pockets, Treatment Algorithm

Atopy

- ▶ Otolaryngologic Allergy/Immunology

A-Train

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Definition

Sinusoidal facial EMG pattern of high frequency and homogeneous appearance; the most sensitive and specific pattern for postoperative facial nerve dysfunction. It produces high-frequency sound of up to 210 Hz with amplitudes ranging from 100 to 200 μV, never exceeding 500 μV, with duration between milliseconds seconds.

Cross-References

▶ Intraoperative Neurophysiologic Monitoring of the Facial Nerve (VII)

Atresiaplasty

▶ Surgery for Congenital Aural Atresia

Atrium

▶ Mesotympanum

Atticotomy

▶ Mastoidectomy

Audiogram

▶ Audiometry

Audiologic Evaluation

▶ Audiometry

Audiometry

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Synonyms

Audiogram; Audiologic evaluation; Diagnostic hearing evaluation; Hearing testing; Pure tone audiometry; Specialized audiometry; Speech reception testing

Definition

Audiometry is a diagnostic test that provides information on the type of hearing loss and establishes frequency-specific hearing thresholds. Audiometry tests hearing sensitivity by delivering a sound stimulus in order to elicit a behavioral response. Audiometric testing is performed using a variety of techniques including pure tone audiometry, speech reception testing, and specialized audiometry techniques for pediatric patients.

Purpose

Hearing is a critical sense and a highly complex process involving a stimulus detector (▶ Middle Ear Anatomy), complex neural pathways, and sophisticated integration and processing centers in the central nervous system (▶ Middle Ear Physiology). An audiologic evaluation is indicated in a number of conditions in which there are suspected or known hearing loss, communication problems, infections, or other pathologic conditions of the temporal bone. Hearing loss can result from a number of problems along the hearing pathway. A battery of tests exists which allows for a comprehensive evaluation of the ear and hearing. Generally the tests selected are based on the clinical condition and can include audiometry, ▶ tympanometry, ▶ auditory brainstem response (ABR), acoustic reflex testing, ▶ electrocochleography (ECoG), and ▶ otoacoustic emissions (OAE). Audiometry is the primary method used to test hearing and provides information regarding the type and degree of hearing loss.

The primary goal of audiometry is to establish hearing thresholds across frequencies. *Threshold of hearing is defined as the minimum level of sound that evokes an auditory sensation* (ANSI 1972). During audiologic evaluation, threshold is the lowest intensity that the listener responds to at least 50% of the time (Katz 2002). Audiometric testing consists of multiple parts that are explained in greater detail in the following sections. For convenience, brief definitions related to audiometric testing are provided in Table 1.

Audiometry, Table 1 Audiometric terminology

Acoustic stimuli	A type of sound consisting of a pure tone, warble tone, or word presented to the listener at a known intensity to evoke a behavioral response
Air conduction	The delivery of a sound stimulus through air. Air conduction tests the outer, middle, and inner ear. Sound stimuli are typically delivered by headphones or inserts
Audiogram	The graphic display of hearing threshold measured in decibels as a function of frequency
Audiologic booth	Soundproof booth where audiologic testing is completed
Audiologist	(Au.D.; Ph.D.; M.S.; M.A.) Health-care provider specializing in identifying, diagnosing, treating, and monitoring disorders of the auditory and vestibular systems
Bone conduction	The delivery of a sound stimulus through a bone oscillator. Bone conduction bypasses the outer and middle ear and tests only the inner ear. Sound waves travel much faster through a solid (bone) medium than through gas (air)
Conductive hearing loss (CHL)	Hearing loss caused when sound waves are blocked from reaching the inner ear. The pathology is usually in the outer or middle ear and the inner ear is normal
Conditioned play audiometry (*CPA)*	Play-oriented activities used to reinforce a response to a stimulus. This technique is used in pediatric testing for ages 3–5 years
Frequency	Rate at which a sound wave vibration occurs, measured in cycles per second or Hertz, and frequently referred to as pitch
High frequency testing	Ultrahigh frequency testing, 9,000–20,000 Hz, is used primarily for ototoxic monitoring and tinnitus assessment. Circumaural headphones are used to test frequencies from 9,000 to 20,000 Hz, depending on the limits of the audiometer used
Masking	Masking is the delivery of a sound stimulus, through air conduction, to the non-test ear, allowing isolation of the test ear (the ear of interest). Masking is necessary in audiometric testing because sound delivered through bone conduction, and sound delivered through air conduction at a higher intensity, will stimulate both ears simultaneously. In order to isolate one ear and provide side-specific information, masking is employed
Pure tone audiometry(PTA)	A pure tone is a simple sound consisting of a single frequency. Pure tone audiometry tests the threshold at specific frequencies and may be tested using air or bone conduction. The PTA consists of an average of the thresholds at frequencies of 500, 1,000, and 2,000 Hz
Sensorineural hearing loss (SNHL)	Hearing loss that results from damage or dysfunction of the inner ear or neural pathways to the brainstem. In SNHL, sound is able to reach the inner ear but damage to the sensory cells of the inner ear prevents normal stimulation of the cochlea
Speech discrimination testing	Speech discrimination scores show how well a patient understands speech presented at a comfortable level (suprathreshold). This test is important because speech is a much more complex sound than pure tones. Speech discrimination testing guides further diagnostic testing and management. Several word lists have been developed but the most commonly used is a phonetically balanced list of monosyllabic words
Speech reception threshold (SRT)	Audiometric testing using speech stimuli instead of pure tones. Two syllable words with equal stress called spondee's are delivered at varying intensities and the level at which they are detected is the SRT. The SRT should be similar numerically to the PTA and serves as a confirmatory measure of the PTA
Sound field testing	Sound field technique is often used in pediatric testing because of physical and behavioral limitations. Sound field testing is a variation of audiometry completed through sound field speakers rather than the traditional head/earphones. The testing is nonspecific because the stimulus is available to both ears and the response tests the better hearing ear. During sound field testing, frequency-modulated (FM) tones, called warble tones, are used to avoid standing waves and areas in the booth where a pure tone can be diminished
Transducers	The method of delivering sound waves/stimulus to the ear. Supra-aural headphones and ear inserts deliver a sound to the outer ear. Bone-conducting oscillator delivers sound directly to the inner ear
Visual reinforcement audiometry (*VRA)*	Hearing testing in which visual reinforcement is used as a reward for responding to the stimuli. VRA is frequently used in pediatric testing

Principle/Procedure

Audiology Equipment

Audiometry testing requires specialized equipment that includes an audiometer and, ideally, an audiology booth. The audiometer is a machine that generates and delivers a sound stimulus to a patient through a transducer. Transducers can deliver sound through air conduction using headphones and ear inserts, or through bone conduction using a bone oscillator. The audiometer allows control of the sound stimulus intensity and pitch so that the lowest level of sound detectable at specific frequencies can be determined. Once a sound stimulus is delivered, the patient generates a behavioral response when it is detected. Adults voluntarily signal stimulus detection by pressing a button. For young children, the response may be a startle response, a change in expression, or turning toward the stimulus source. For each frequency, the lowest level of stimulus intensity (threshold) is recorded and plotted on an audiogram.

An audiology booth is an insulated room, in which the testing is conducted, that reduces ambient noise. The ideal location for audiometry is in a calibrated soundproof booth. Considerations for booth design include single- or double-walled construction, single- or double-sided booth, and type of transducer used to transmit the stimuli from the audiometer to the listener. Calibration of the equipment is essential for accurate results.

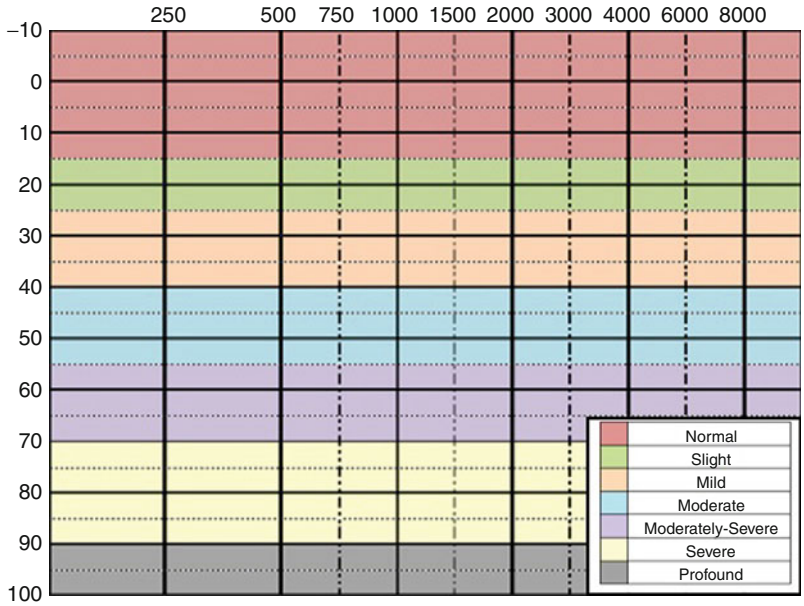
Audiometry Techniques

Audiometry techniques can be categorized into automatic and manual audiometry. Automatic audiometry is run by a computer program; the presentation level is determined by the listener response. An audiologist, who has control over the stimuli, runs manual audiometry. There are advantages and disadvantages to both systems. Automatic audiometry is often used to screen large numbers of people to detect abnormal hearing. This technique is often utilized with certain populations who may not complain of hearing loss but are at risk for hearing loss or the consequences of having undetected hearing loss are greater. Examples of automated audiometry screenings include school health assessments and groups with occupational noise exposure, such as in construction or the military. These tests provide an accurate assessment of hearing and allow rapid testing of large numbers in a short period. Manual audiometry is a more detailed examination and has the advantage of having a highly trained professional administering and interpreting the tests. If the results are unusual or inconsistent, then the audiologist can employ a number of quantifying and diagnostic techniques to ensure the most accurate testing. This method is more time consuming but is preferred for individuals with known or suspected hearing loss.

Pure Tone Audiometry

Acoustic stimuli are sounds used to determine hearing sensitivity (thresholds) and vary depending on the listener and the transducer. The most basic sound used for testing is a *pure tone*. Pure tones are sinusoidal sound waves that have only one frequency of vibration (Stach 2003). Pure tones are easily calibrated and are a reliable way to evaluate the hearing sensitivity. Pure tones are the most common stimulus used to test hearing in older children and adults. The pure tone frequencies are tested in octaves, which are doublings of frequencies. The primary pure tones tested and displayed on the audiogram include 250, 500, 1,000, 2,000, 4,000, and 8,000 Hz. These pure tones are selected to best represent the frequencies of spoken language. Pure tones are presented over a range of intensities to determine the lowest intensity (threshold), which can be detected. Intensity of a pure tone is measured in decibels (dB). In accordance to American National Standards Institute (ANSI) standards, the audiogram is plotted with decibels hearing level (dB HL) referencing average normal hearing levels. Thresholds, measured in decibels (dB), are plotted according to frequencies and graphically displayed on an audiogram (Fig. 1). The thresholds at 500, 1,000, and 2,000 Hz are averaged to find the *pure tone average* (PTA) of an individual ear. The pure tone average is cross-referenced with the speech reception threshold (SRT) for verification (Koike 2006). Pure tone testing can be done by conducting the stimulus through air or bone.

Pure tone air conduction (AC) is a primary audiometric testing method that delivers a pure tone stimulus (sound wave) through air using headphones or ear inserts. In normal hearing, a low intensity sound will conduct through the outer, middle, and inner ear and the sound will be detected (▶ Middle Ear Physiology). In someone with a hearing loss, a higher intensity stimulus will be necessary to overcome the hearing



Audiometry, Fig. 1 Audiogram with color-coded regions demonstrating the classification of hearing loss based on severity. Frequency on X-axis and intensity (dB) on Y-axis. The inset legend correlates color-coded region with type of hearing loss based on severity. For example, a hearing loss with thresholds falling in the range of blue is termed a moderate hearing loss

impairment; this will translate into a higher hearing threshold. The advantage of this technique is that it tests the sensitivity of the overall system but the disadvantage of air conduction is the inability to determine if hearing loss results from the outer, middle, or inner ear. Thresholds for air conduction, measured in decibels (dB), are plotted according to frequencies and graphically displayed on an audiogram. Air conduction is indicated on the audiogram by the use of color-coded symbols: red circles represent right ear thresholds and blue X's left ear thresholds. When the thresholds at each frequency are connected with a line, this is called the air conduction line and is displayed on an audiogram.

Pure tone bone conduction (BC) is another primary audiometric method, which delivers a pure tone stimulus through a bone-conducting oscillator. This oscillator transmits sound waves directly into the skull, which houses the cochlea or inner ear. This technique effectively bypasses the outer and middle ear and tests only the inner ear. Bone conduction testing is important for site of lesion testing. BC is used to determine type of hearing loss, conductive versus sensorineural. ▶ Conductive hearing loss (CHL) results when sound waves traveling through air are blocked from reaching the inner ear. If sound is delivered by bone conduction, the blockage is bypassed and a low level stimulus may be detected. A ▶ sensorineural hearing loss (SNHL) results from a problem in the cochlea; so, no matter how the sound is conducted, higher stimulus intensity is required to stimulate the inner ear. Thresholds for bone conduction are plotted according to frequency on an audiogram. Bone conduction testing is indicated on the audiogram by the use of color-coded brackets as outlined in Table 3. When the thresholds at each frequency are connected with a line, this is called the bone conduction line. The difference between the AC and BC lines is termed the air-bone gap. A CHL is identified when there is a significant air-bone gap. An air-bone gap of 15 dB HL or more indicates a CHL, whereas an air-bone gap of less than 15 dB HL is consistent with a SNHL (Stach 2003).

Masking

Masking is the delivery of a sound stimulus, through air or bone conduction, to the *non-test ear*, allowing isolation of the test ear (the ear of interest). Masking is necessary in certain situations when sound stimulates both ears, eliminating the ability to tell if the test ear or non-test ear is actually receiving the stimulus. *Interaural attenuation* is the reduction in the sound energy of a signal as it is transmitted by bone conduction from one side of the head to the opposite ear (Stach 2003).

When testing via bone conduction, the bone oscillator is placed on the mastoid process of the temporal bone or forehead. Vibrations delivered through the oscillator conduct to the inner ears nearly

simultaneously because bone has an inter-aural attenuation near 0 dB. This means that a very low intensity stimulus delivered by bone conduction passes to both ears because bone is such an excellent conductor. When this happens, responses are not ear specific, meaning the patient cannot tell which ear is being tested or which ear is detecting the stimulus. Masking is therefore needed to isolate each ear. Masking for bone conduction is required when the ABG is greater than or equal to 15 dB HL (Katz 2002).

Sound traveling through air has different characteristics than sound traveling through bone. Air conducts sound much less effectively and when sound energy encounters an interface, such as from air to fluid, which happens as sound moves from the middle ear to the inner ear, the vast majority of energy is dissipated and only the test ear is stimulated. However, when an intense stimulus is delivered by air conduction, enough energy may remain to stimulate the opposite ear. Masking for air conduction testing is necessary when the difference in thresholds between the ears is greater than or equal to the inter-aural attenuation of the transducer used (40 dB for supra-aural headphones; 60 dB for insert earphones) (Katz 2002).

Audiometry, Table 2 Classification of severity of hearing loss

Degree of hearing loss	Range (dB HL)
Normal hearing	−10 to 15
Slight	16–25
Mild	26–40
Moderate	41–55
Moderately severe	56–70
Severe	71–90
Profound	91+

Audiometry, Table 3 Commonly used symbols in audiometry

Symbols for	Right	Left	Other
Air conduction – unmasked	O	X	
Air conduction – masked	Δ	□	
Bone conduction – unmasked	<	>	
Bone conduction – masked	[	]	
Bone conduction – forehead			^
Minimal response level			M
Sound field threshold			S
Uncomfortable loudness level			U
No response	↙	↘	

Hearing Loss

Hearing loss is classified by type, severity, and configuration. There are three types of hearing loss, which include conductive, sensorineural, and mixed hearing loss. ▶ Conductive hearing loss results when an obstruction or dysfunction in the outer or middle ear blocks sound from reaching the inner ear. ▶ Sensorineural hearing loss results when sound reaches the inner ear but it cannot be detected or transmitted correctly to the auditory cortex. A ▶ mixed hearing loss occurs when components of both exist. Hearing loss can vary with the frequency of a sound. Hearing loss severity is determined by the dB scale of the audiogram. The classification of hearing loss severity is modified from Goodman (1965) and Clark (1981) and is outlined on Table 2 and Fig. 1. Terminologies used to describe the configuration of thresholds on an audiogram include but are not limited to: flat, sloping, rising, precipitous, cookie bite, corner, and notched.

Audiogram and Interpretation

The results of audiometric testing are typically provided in the form of an audiogram and a written report. An audiogram is the graphical depiction of frequency-specific hearing thresholds. The intensity of a frequency-specific stimulus, which elicits a response, is recorded on an audiogram (Koike 2006). Several symbols are necessary to distinguish how the testing is conducted. Symbols are used to represent the side of response (red for right, blue for left), the type of stimulus (air vs. bone conduction), and whether masking was performed. The standard symbols used to convey the specific details of testing are listed in Table 3.

Clinical Examples

Typical findings with audiometry include but are not limited to normal hearing, conductive, sensorineural, and mixed hearing losses. Table 4 lists the types of hearing loss with some of the pathologic conditions that may result in that type of hearing loss. Examples of the audiometric appearance of each type of hearing loss (normal, conductive, sensorineural, and mixed hearing loss) are illustrated in Fig. 2.

Speech Testing

Comprehensive audiometry includes speech testing. Speech reception threshold (SRT) testing refers to the lowest level at which the listener can correctly repeat

Audiometry, Table 4 Classification of hearing loss based on type with associated etiologies

Hearing loss	Examples of pathology
Conductive hearing loss	Otitis Media; Otitis Externa; TM perforation; Cholesteatoma; middle ear tumor; impacted cerumen; otosclerosis; Eustachian tube dysfunction
Sensorineural hearing loss	Congenital; Noise-induced; ototoxicity; presbycusis; chromosomal anomalies; vascular compression; autoimmune; cochlear malformations; meningitis; genetic; traumatic
Mixed hearing loss	Barotraumas; tumor; combined middle and inner ear pathology

spondaic words 50% of the time. The SRT should be within ±6 dB of the PTA for good agreement and no worse than ±13 dB (Katz 2002).

Spondaic Word Examples

Hotdog Baseball Mushroom Popcorn Bathtub Airplane Cowboy

Toothbrush Outside Ice-cream Sunset Birthday Railroad Playground

Speech detection testing (SDT) and speech awareness testing (SAT), along with picture pointing, are often used in pediatric cases. SRT, SDT, and SAT testing are conducted with a closed set of words (Katz 2002).

Word recognition (WR), commonly referred to as speech discrimination testing, primarily uses phonetically balanced, open-set word lists, which are presented at a suprathreshold (re SRT). Various word lists have been created (i.e., PB-K 50, NU-6, CID W-22, PB-50, California Consonant, etc.) and the presentation level of the stimuli is dependent on the list selected (Speaks et al. 1970; Katz 2002).

WR scores indicate therapeutic effects for hearing aids/amplification and can assist in retrocochlear site of lesion determination.

Specialized Audiometry

A variety of audiometry methods have been developed to enable ►pediatric hearing assessment and the "difficult-to-test" population. Behavioral observation audiometry (BOA), visual-reinforced audiometry (VRA), and conditioned play audiometry (CPA) were created for use with difficult-to-test patient populations, primarily the pediatric population. They can be used for pure tone or SDT/SAT testing via sound field, headphones, or earphones. Sound field testing is primarily used during pediatric audiometry or hearing aid testing. Stimuli are presented via loud speakers into the booth; therefore, testing is not ear specific.

BOA primarily is looking for a startle response, a change in behavior of the listener with the presentation of sound. VRA, on the other hand, involves a specific response (head turn) to the stimuli and is reinforced with a visual reward (lighting up of toys in blacked-out boxes). VRA is typically used for patients aged 6 months (if the patient can sit unassisted) to 2 years.

CPA involves listener response by means of "play," for example, placing a block in the bucket when the stimulus is heard. CPA is used for patients aged 3–6.

Results from an ABR testing can also be calculated and plotted onto an audiogram for patients who cannot be tested by traditional means.

Indication

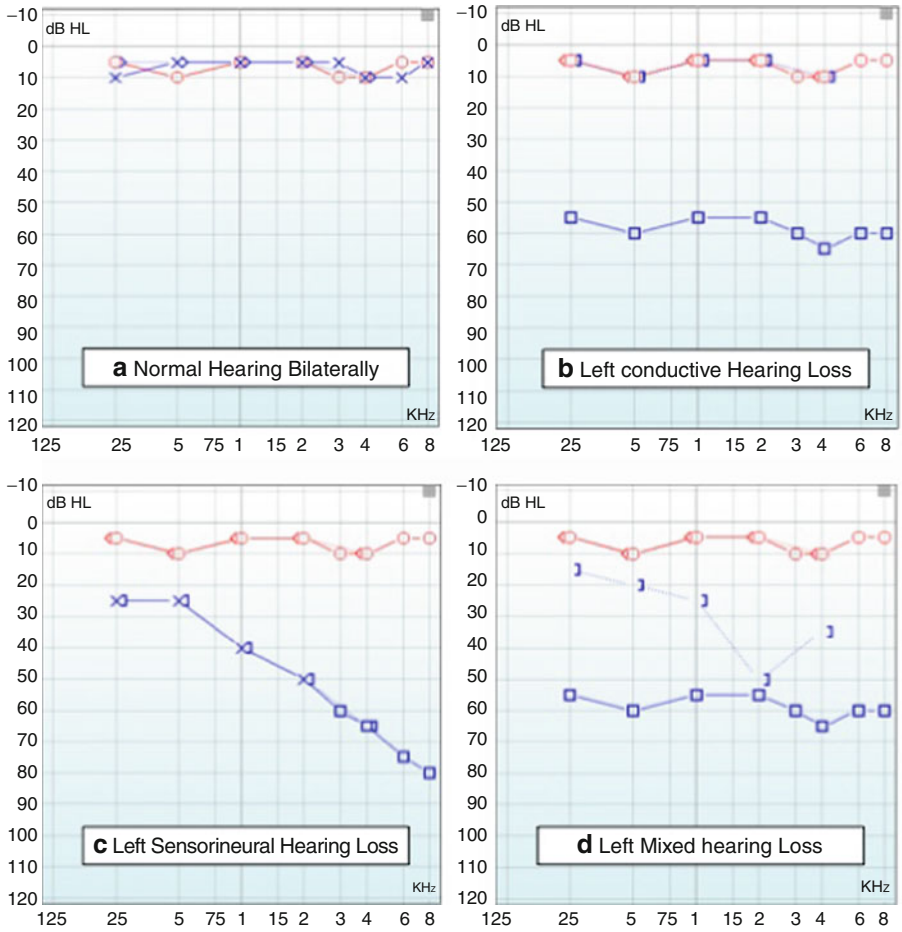
►Audiologic evaluation, including audiometry, is indicated in many situations and represents the standard of care for evaluating known or suspected hearing loss. Diagnostic testing is indicated for subjective complaints of hearing loss, vertigo, tinnitus, and other otologic complaints, occupational noise exposure, and exposure to ototoxic substances. Audiometry is indicated for a wide range of medical conditions affecting the ear and temporal bone to include genetic hearing loss, infections, and other disorders of the ear, hearing loss associated with aging, and anyone being considered for otologic surgery.

Contraindication

Audiometry is generally well tolerated and has no absolute contraindications.

Advantage/Disadvantage

Audiometry is a frequency-specific diagnostic (►Mixed Hearing Loss) test that allows the establishment of baseline hearing and guides appropriate therapy including surgical correction or use of amplification (hearing aids). It is more accurate, comprehensive, and quantifiable than a clinical assessment of hearing completed during an examination. Site of



Audiometry, Fig. 2 Audiograms representing normal, conductive, sensorineural, and mixed hearing loss. Audiogram A: Normal Audiogram. Right and left thresholds are less than 15 dB. Audiogram B: Right normal hearing. Left conductive hearing loss. Note the blue brackets in the normal range, representing bone conduction thresholds, and the blue X's representing air conduction thresholds. The gap between the two measure thresholds represents the air-bone gap characteristic of a conductive hearing loss. Audiogram C: Right normal hearing. Left sensorineural hearing loss. Note the absence of an air-bone gap. Audiogram D: Right normal hearing. Left mixed hearing loss characterized by an air-bone gap greater than 15 dB with both the air conduction line and bone conduction line being outside of the normal hearing range

lesion testing is incorporated into audiometry by means of air versus bone conduction testing, as well as with speech discrimination. Audiometry is a major component of audiologic evaluations, which can also include ▶ tympanometry, ▶ OAE, and ▶ ABR testing. Audiometry testing is difficult in pediatric and difficult-to-test patients. The testing requires approximately 30 min to complete. Audiometry is a peripheral test of the ear and does not test central systems. Furthermore, it does not test the vestibular system, central processing system, or provide diagnostic information for tinnitus. However, it should be completed in the evaluation of these disorders, as it yields significant information on the health or dysfunction of the inner ear, which may provide insight into these other disorders.

Cross-References

- ▶ Auditory Brainstem Response (ABR)
- ▶ Auditory System Exam
- ▶ Hearing Assessment in Infancy and Childhood
- ▶ Inner Ear
- ▶ Intraoperative Elctrocochleography (ECOG)
- ▶ Middle Ear Anatomy
- ▶ Middle Ear Physiology

- ▶ Mixed Hearing Loss
- ▶ OAEs
- ▶ Physiology of Cochlea
- ▶ Sensorineural Hearing Loss and Meningitis
- ▶ Tympanometry
- ▶ Vestibular and Central Nervous System, Anatomy

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Auditory Brainstem Implant, Surgical Devices

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Synonyms

ABI

Definition

An auditory brainstem implant (ABI) is a device designed to electrically stimulate the ventral and dorsal cochlear nuclei in patients that cannot benefit from a cochlear implant due to the absence of a cochlear nerve (Figs. 1, 2).

Auditory Brainstem Implant, Surgical Devices, Fig. 1 Auditory brainstem implant (Image Courtesy of Cochlear Americas ©2011)

Auditory Brainstem Implant, Surgical Devices, Fig. 2 Close-up of electrode array of auditory brainstem implant (Image Courtesy of Cochlear Americas ©2011)

Purpose

The ABI is used to electrically stimulate the ventral and dorsal cochlear nuclei. The purpose is to improve communication by providing auditory input to augment lip reading in patients with deafness.

Principle

History

The first ABI was implanted in 1979 at the House Ear Institute, and the multichannel ABI was approved by the FDA in July 2000 for patients with neurofibromatosis type 2 (NF2). Since this time, multiple institutions have developed ABI programs. In addition, the ABI has been used for patients with conditions other than NF2 causing deafness such as congenital cochlear nerve aplasia, labyrinthitis ossificans, cochlear nerve avulsion, and bilateral temporal bone fractures.

Anatomy

The ABI is placed adjacent to the ventral and dorsal cochlear nuclei. The cochlear nuclei are located on the superior surface of the lateral recess (foramen of Luschka) of the fourth ventricle. The identification of the lateral recess is essential for the accurate placement of the ABI. Since a large vestibular schwannoma may obscure brainstem anatomy, the surgeon must understand the relationship of surrounding structures to the lateral recess. The lateral recess can be located between the roots of the facial and glossopharyngeal nerves. The taenia is a white strip that transverses the superior aspect of the lateral recess and marks the surface of the ventral cochlear nucleus. The choroid plexus can be a useful landmark since it protrudes through the lateral recess from its origin in the fourth ventricle.

Surgical Procedure

For patients with NF2, the ABI is placed after removal of a vestibular schwannoma. Multiple cranial nerves are monitored including electrically evoked auditory brainstem response, facial nerve, and glossopharyngeal nerve. After the schwannoma has been removed, the lateral recess is identified using the landmarks previously described. Once the lateral recess is clearly identified, a cottonoid is placed to mark the location of the lateral recess. Identification of cerebrospinal fluid flow during a Valsalva maneuver can be used to confirm the location is indeed the lateral recess. The magnet in the receiver-stimulator is removed and replaced with a titanium marker to allow postoperative MRI. A well is created posterior to the craniotomy site to house the receiver-stimulator and electrodes. Two small suture holes are drilled on each side of the well and the receiver-stimulator is fixed using silk sutures.

Once the receiver-stimulator is secured, the cottonoid is removed and the paddle-like electrode is placed into the lateral recess using a Rosen needle or Bayonet forceps with the electrodes facing superior and adjacent to the surfaces of the ventral and dorsal cochlear nuclei. Complete insertion into the lateral recess provides the most consistent stimulation. Proper placement is confirmed using electrically evoked auditory brainstem response (EABR). Once the ABI is in place, monopolar cautery is no longer used to prevent damage to the implant or brainstem. Nonauditory stimuli such as facial and glossopharyngeal nerve stimulation are common. The electrode is relocated to maximize the number of electrodes providing auditory stimuli while minimizing the number of electrodes providing nonauditory stimuli. To prevent migration of the implant, Teflon is placed to hold the implant in the lateral recess until fibrosis allows more permanent fixation. The ground electrode is placed under the temporalis periosteum (Fayad et al. 2006).

In nontumor patients, a retrosigmoid craniotomy approach is preferred. The steps to implant the ABI are the same.

Postoperative Care

A mastoid dressing is placed for 3 days. The initially stimulation occurs in 4–8 weeks after edema has resolved to allow an adequate signal to reach the internal receiver-stimulator.

Initial Stimulation

Because nonauditory side effects are common and could theoretically cause life-threatening arrhythmias, the manufacturer recommends performing initial stimulation with monitoring and the ability to resuscitate the patient if necessary. The ABI is programmed in a similar fashion to a cochlear implant with some differences. Nonauditory sensations are much more common in ABI recipients when compared to a cochlear implant and patients are encouraged to report these sensations during initial or subsequent programming. During initial stimulation, patients rank pitch and most comfortable auditory stimulation through monopolar electrode pairs. This information is used to program the ABI to provide maximum benefit.

Outcomes in Patients with Neurofibromatosis Type 2

Speech recognition measures show the ABI to be inferior to a cochlear implant; however, most patients gain

significant improvement in communication through the use of an ABI and lip-reading compared to lip-reading alone. Open-set speech recognition occurs in a minority of patients and a limited ability to talk on a telephone occurs in less than 10% of patients. It is important for the otologist, audiologist, and patient to realize rehabilitation using the ABI is much slower than a cochlear implant and improvement in speech recognition testing has continued to show improvement greater than 9 years after implantation (Otto et al. 2006).

Outcomes in Nontumor Patients

Although the ABI is only approved for patients with neurofibromatosis type 2 (NF2) in the USA, multiple other centers around the world have implanted deaf patients that could not benefit from a cochlear implant. Overall nontumor (NT) patients perform significantly better than patients with NF2 (Sennaroglu et al. 2011). Coletti et al. showed a mean speech reception score of 59% in NT patients compared to a mean speech perception score of only 10% in patients with NF2 (Colletti et al. 2009a). The reasoning for this difference is unclear. Hypotheses include distorted brainstem anatomy from compression by the tumor or physiologic changes in the cochlear nucleus.

Complications

Surgical complications include facial paralysis, dysphagia, or stroke. Also cardiac arrhythmias including bradycardia or asystole may occur during intraoperative or postoperative stimulation of electrodes. Displacement of the electrode has been reported.

Indication

The most common indication for an ABI is after vestibular schwannoma removal in a patient with neurofibromatosis 2 (NF2). Other less common indications include congenital absence of cochlear nerves, bilateral labyrinthitis ossificans, bilateral cochlear nerve avulsion, or bilateral transverse temporal bone fractures precluding placement of a cochlear implant.

Contraindications

There are few contraindications for placement of an ABI in patients with NF2. Currently, the device is approved by the FDA for patients 18 years or older with NF2, so the device is not currently available for pediatric patients in the USA. Definitive identification of the lateral recess is necessary and may not be possible after removal of a large vestibular schwannoma. Prior radiosurgery or radiation therapy is not a contraindication for an ABI.

Advantage/Disadvantage

The ABI is currently the only option for patients without cochlear nerves and may provide increased sound awareness to facilitate communication. The procedure is generally safe in the hands of an experienced team comprised of a neurosurgeon, otologist, and an electrophysiologist.

Disadvantages include the possibility the patient will receive no benefit from the implant due to either excessive nonauditory stimuli or no auditory stimuli. Often a "sleeper" ABI is placed during removal of the first vestibular schwannoma even if the patients has serviceable hearing in the contralateral ear to allow another chance for an ABI in the contralateral ear if the initial ABI does not provide benefit. Disadvantages for the nontumor patients include the need for a craniotomy and the inherent risks associated with this.

Cross-References

- ▶ Benign Neoplasia-Schwannoma-Neurofibromatosis Type 2
- ▶ Vestibular and Central Nervous System, Anatomy

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Auditory Brainstem Implants (ABIs)

► Implantable Hearing Devices

Auditory Brainstem Response

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Definition

An electrical signal evoked from the brainstem in response to a presented sound.

Cross-References

► Vestibular and Central Nervous System, Anatomy

Auditory Brainstem Response (ABR)

► Central Auditory System, Anatomy

Auditory Midbrain Implants (AMIs)

► Implantable Hearing Devices

Auditory Nerve

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Definition

A sensory nerve that carries signals from the cochlea of the inner ear to the brain. It is part of the vestibulocochlear nerve, the eighth cranial nerve.

Cross-References

► Central Auditory System, Anatomy
► Cochlear Nerve, Anatomy
► Physiology of Cochlear Nerve
► Vestibular and Central Nervous System, Anatomy

Auditory Nerve Schwannoma

► Cochlear Schwannoma

Auditory Processing Disorder (APD)

► Acquired Auditory Processing Disorders
► Developmental Central Auditory Processing Disorders

Auditory System Exam

▶ Hearing Exam

Aural Atresia

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Definition

A congenital condition in which the external ear canal is missing or underdeveloped.

Cross-References

▶ Bone-Anchored Hearing Aids (BAHAs)
▶ Congenital Aural Atresia

Auricle

▶ Pinna and External Auditory Canal, Anatomy

Auricular Reconstruction

▶ Microtia and Atresia

Auriculo-branchiogenic Dysplasia

▶ Hemifacial Microsomia

Auriculotemporal Syndrome

▶ Frey's Syndrome

Autism

▶ Language Development and Disorders, Birth to 7 Years

Autoimmune Diseases

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Definitions

Systemic lupus erythematosus: An autoimmune disease in which organs and cells undergo damage mediated by tissue-binding autoantibodies and immune complexes.

Rheumatoid arthritis: A chronic multisystem disease of unknown cause causing persistent inflammatory synovitis, leading to bone erosion and cartilage destruction of the peripheral joints.

Sjögren's syndrome: An autoimmune disorder characterized by decreased lacrimal and salivary gland function which can present alone (primary SS) or in combination with autoimmune rheumatic disease (secondary SS).

Systemic sclerosis: A chronic systemic disorder of unknown etiology characterized by thickening of the skin and distinctive involvement of multiple internal organs, most notably the lungs, gastrointestinal tract, heart, and kidneys.

Relapsing polychondritis: An autoimmune disorder causing episodic recurring inflammation of cartilaginous structures with deposition of a high concentration of glycosaminoglycans.

Mixed connective tissue disease: A syndrome with features of systemic lupus erythematosus, polymyositis, and rheumatoid arthritis associated with the presence of high titers of autoantibodies to U1-RNP.

Introduction

Connective tissue diseases are a group of diseases in which the major histopathologic feature is inflammation of the collagen and elastin components of connective tissue. These disorders include multiple organ systems with varying and overlapping symptoms, signs, laboratory findings, and serology. The otolaryngologist must have an understanding of the constellation of findings of these disorders in order to diagnose them correctly and to best manage their head and neck manifestations.

Systemic Lupus Erythematosus

Systemic lupus erythematosus (SLE) is an autoimmune disease in which organs and cells undergo damage mediated by tissue-binding autoantibodies and immune complexes. Prevalence of SLE in the United States is 15–50 per 100,000 and is most common in African Americans. The predominant histopathologic feature is a variable amount of connective tissue and blood vessel inflammation with abundant fibrinoid deposits. Biopsies of affected skin show deposition of Ig at the dermal–epidermal junction, injury to basal keratinocytes, and inflammation dominated by T lymphocytes in the dermal–epidermal junction and around blood vessels. SLE is typically diagnosed with >=4 of the following criteria: malar rash, discoid rash, photosensitivity, oral ulcers, arthritis, serositis, proteinuria >0.5 g/day, seizures or psychosis without other causes, hemolytic anemia or leukopenia, positive anti-dsDNA, anti-Sm, and/or antiphospholipid antibodies; and abnormal titer of ANA by immunofluorescence. The specificity is 95% and the sensitivity is 75% with these diagnostic criteria (Hochberg 1997).

At its onset, SLE may involve one or several organ systems. Systemic symptoms, particularly fatigue, myalgias, and arthralgias, are present most of the time. SLE patients commonly have intermittent polyarthritis, characterized by soft tissue swelling and joint tenderness in the hands, wrists, and knees. Lupus dermatitis can be classified as discoid lupus erythematosus (DLE), systemic rash, or subacute cutaneous lupus erythematosus (SCLE). Discoid lupus erythematosus is a subtype of SLE in which cutaneous lesions result in significant scarring but with no visceral involvement. The most common SLE rash is a photosensitive, slightly raised erythema, occasionally scaly, on the face. It is most prominently located on the cheeks and nose (which is termed the "butterfly" rash), ears, chin, upper back, and extensor surfaces of the arms. Worsening of this rash often accompanies flare of systemic disease. SCLE consists of scaly red patches similar to psoriasis or circular flat red-rimmed lesions. Patients with these manifestations are photosensitive; most have antibodies to Ro (SS-A). Other SLE rashes include recurring urticaria, lichen planus–like dermatitis, bullae, and panniculitis. Rashes can be minor or severe and may be the major disease manifestation.

Nephritis is usually the most serious manifestation of SLE, particularly since nephritis and infection are the leading causes of mortality in the first decade of disease. Patients with glomerular damage usually have microscopic hematuria and proteinuria (>500 mg per 24 h); approximately one half develop nephrotic syndrome, and most develop hypertension. If diffuse proliferative glomerulonephritis (DPGN) is untreated, virtually all patients develop ESRD within 2 years of diagnosis. Therefore, aggressive immunosuppression is indicated (usually systemic glucocorticoids plus a cytotoxic drug) in these patients. There are many central nervous system (CNS) and peripheral nervous system manifestations of SLE; in some patients, these are the major causes of morbidity and mortality. These include cognitive dysfunction, headaches, seizures, and psychosis. The prevalence of transient ischemic attacks, strokes, and myocardial infarctions is increased in patients with SLE. The most common pulmonary manifestation of SLE is pleuritis with or without pleural effusion. Pericarditis is the most frequent cardiac manifestation; it usually responds to anti-inflammatory therapy and infrequently leads to tamponade. Sicca syndrome and nonspecific conjunctivitis are common in SLE and rarely threaten vision.

SLE most commonly presents in the head and neck with skin and mucosal lesions. A malar or "butterfly" rash is the first sign of the disease in 50% of patients. An erythematous maculopapular eruption on the head, neck, and/or chest may be pruritic and be precipitated by sun exposure. Oral ulcerations are superficial with an erythematous halo and may increase to 2 cm. Small, painful ulcerations on the oral or nasal mucosa are common in SLE; the lesions resemble aphthous ulcers.

Three to five percent of SLE patients present with ulceration or perforation of nasal septum due to vasculitis. Larynx and trachea involvement is rare: The vocal folds may be thickened or paralyzed, and cricoarytenoid arthritis and *subglottic stenosis* may be present. Acute enlargement of the parotid gland occurs in 10% of patients. Fifteen percent of the patients may present with cranial neuropathies. Neuropathies may involve the motor supply to the extraocular muscles, the sensory divisions of the trigeminal nerve, the motor divisions of the facial nerve, the vestibular portion of the eighth cranial nerve, or the optic nerve.

Among patients with fatigue, pain, and autoantibodies of SLE, but without major organ involvement, management can be directed to suppression of symptoms. Analgesics and antimalarials are mainstays of treatment. NSAIDs are useful particularly for arthritis and arthralgias, while antimalarials (hydroxychloroquine, chloroquine, and quinacrine) often reduce dermatitis, arthritis, and fatigue. A randomized, placebo-controlled, prospective trial has shown that hydroxychloroquine reduces the number of disease flares. If quality of life is inadequate in spite of these conservative measures, treatment with low doses of systemic glucocorticoids may be necessary. The mainstay of treatment for any inflammatory life-threatening or organ-threatening manifestations of SLE is systemic glucocorticoids (Hochberg 1997).

Rheumatoid Arthritis

Rheumatoid arthritis (RA) is a chronic multisystem disease of unknown cause. The characteristic feature of established RA is persistent inflammatory synovitis leading to bone erosion and cartilage destruction of the peripheral joints. The prevalence of RA is ~0.8% of the population (range 0.3–2.1%); women are affected approximately three times more often than men and the prevalence increases with age. The onset is most frequent during the fourth and fifth decades of life, with 80% of all patients developing the disease between the ages of 35 and 50. The incidence of RA is more than six times greater in 60- to 64-year-old women compared to 18- to 29-year-old women. In 1987, the American College of Rheumatology developed revised criteria for the classification of RA. Four of the following seven criteria are required for diagnosis: morning stiffness; arthritis of three or more joint areas; arthritis of the hand joints; symmetric arthritis; rheumatoid nodules; serum rheumatoid factor; and characteristic radiographic changes on hand and wrist radiographs (Arnett et al. 1988). These criteria demonstrate a sensitivity of 91–94% and a specificity of 89% when used to classify patients with RA compared with control subjects with rheumatic diseases other than RA.

Articular involvement is the underlying cause of head and neck manifestations of RA. RA affects the ossicular chain, the temporomandibular joint, cricoarytenoid joints, and the cervical spine. *Temporomandibular joint* dysfunction may be severe and lead to contractures of the muscles of mastication. RA is the most frequent cause of arthritis of the cricoarytenoid joint. Histologic abnormalities of the cricoarytenoid joints are present in 86% of patients with RA. Cricoarytenoid arthritis may manifest with neck pain, dysphagia, hoarseness, or aspiration. Hoarseness may also be caused by rheumatoid nodules that form within the vocal folds and by recurrent laryngeal nerve paresis or paralysis. Airway compromise may result in RA patients, requiring systemic steroids and emergent tracheostomy. High-frequency sensorineural hearing loss has been found in patients with RA which has been attributed to vasculitis, neuritis, and/or ototoxicity. Stiffness in the ossicular chain rarely results in conductive hearing loss, but does result in stiffness abnormalities detected on tympanometric testing (Ozturk et al. 2004).

Medical management of RA involves the use of NSAIDs and simple analgesics to control the symptoms and signs of local inflammation. These agents are rapidly effective at mitigating signs and symptoms, but they appear to exert minimal effect on the progression of the disease. Although low-dose glucocorticoids have been widely used to suppress signs and symptoms of inflammation, recent evidence indicates that they may also retard the development and progression of bone erosions. In addition, the use of low-dose glucocorticoids increases the anti-inflammatory effects of agents such as methotrexate as well as the protective effect of these agents on bone damage. Disease-modifying antirheumatic drugs (DMARDs) which include methotrexate, sulfasalazine, hydroxychloroquine, and penicillamine decrease elevated levels of acute-phase reactants in treated patients. Biologics, which include TNG-neutralizing

agents (infliximab, etanercept, and adalimumab), IL-1-neutralizing agents (anakinra), those that deplete B cells (rituximab), and those that interfere with T cell activation (abatacept) have been shown to have a major impact on the signs and symptoms of RA and also to slow progressive damage to articular structures. Immunosuppressive and cytotoxic drugs, including leflunomide, cyclosporine, azathioprine, and cyclophosphamide, have also been shown to ameliorate the disease process in some patients.

Sjögren's Syndrome

Sjögren's syndrome (SS) is the second most common autoimmune rheumatic disease after rheumatoid arthritis. Patients with SS demonstrate symptoms related to decreased lacrimal and salivary gland function and present with xerostomia, keratoconjunctivitis sicca, and parotid gland enlargement. SS can present alone (primary SS) or in combination with autoimmune rheumatic disease (secondary SS). Its prevalence is estimated to be 500,000 to two million patients in the United States. There is a 9:1 female preponderance, and onset is most commonly at 40–60 years of age. The European-American Consensus Group Modification of the European Community Criteria for Sjögren's Syndrome requires the presence of four of the following criteria, one of which must be either a positive biopsy finding or positive autoantibody screen: symptoms of dry eye; signs of dry eye (abnormal results of Schirmer or rose bengal test); symptoms of dry mouth; tests of salivary glandular function (abnormal flow rate, scintigram, or sialogram); positive minor salivary gland biopsy; positive autoantibodies (SS-A or SS-B) (Vitali et al. 2002). Laboratory findings associated with SS include diffuse hypergammaglobulinemia, which is found in 80% of SS patients. The levels of several autoantibodies are elevated, including that of rheumatoid factor, antinuclear antibodies, and antibodies to the extractable cellular antigens Ro/SS-A and La/SS-B. Anti-Ro/SS-A is not specific for SS and often occurs in other autoimmune disorders, particularly SLE. Patients with SLE who have anti-La/SS-B antibodies usually also have SS. Histopathologic findings in SS include focal lymphocytic infiltrates, located mainly around the glandular ducts of the salivary and lacrimal glands. Although it is known that both B and T lymphocytes are involved, the underlying pathophysiology remains elusive.

Patients with SS have symptoms related to salivary and lacrimal gland dysfunction. Lacrimal gland dysfunction results in dry eye, photosensitivity, erythema, eye fatigue, decreased visual acuity, and thick discharge from the eye. Salivary gland dysfunction results in xerostomia, increased frequency of dental caries, and change in the taste of food. The salivary glands normally produce 1–1.5 L of saliva daily. Saliva contains lysozyme, lactoferrin, lactoperoxidase, and histidine-rich polypeptides which inhibit bacteria and fungi. Salivary glycoproteins are also hypothesized to inhibit microbial attachment to oral epithelium. Thus, the mean number and proportion of *Streptococcus mutans* and *Lactobacillus* organisms, as well as *Candida*, are increased in the oral cavity of SS patients. One third of SS may demonstrate an enlarged parotid gland or other major salivary glands.

Other head and neck manifestations include a mild-to-moderate high-frequency *sensorineural hearing loss* believed to be related to immune complex deposition in the stria vascularis. In addition, a unique type of laryngeal lesion, termed the bamboo node which is a white or yellow transverse submucosal lesion localized to the middle third of the vocal fold, has been described in patients with autoimmune diseases, including SS. Thyroid abnormalities, such as Hashimoto's thyroiditis, are associated with Sjögren's syndrome. Antibody to thyroglobulin and thyroid microsomal antigens can be found in as many as one half of patients with Sjögren's syndrome. Nasal crusting and epistaxis, in addition to atrophy of the nasal mucosa, have been noted. Pulmonary symptoms include dry cough and dyspnea, attributed to desiccation of the mucosa of the tracheobronchial tree. Peribronchial lymphocytic infiltrates are seen histologically (Papiris et al. 1971). Esophageal dysmotility is common in Sjögren's syndrome patients. A decrease in aqueous saliva results in dysphagia and increased incidence of esophageal spasm.

Systemic manifestations include renal manifestations of interstitial nephritis and type I renal tubular acidosis and hematologic manifestations of normochromic, normocytic anemia. Lymphoma occurs in approximately 5% of patients with SS. Patients with SS in one study had a 44 times higher relative risk of lymphoma. Risks factors of SS patients for progression to lymphoma include persistent

enlargement of parotid glands, splenomegaly, lymphadenopathy, palpable purpura, leg ulceration, low levels of C4, mixed monoclonal cryoglobulinemia, and cross-reactive idiotypes of monoclonal rheumatoid factors (Voulgarelis and Moutsopoulos 2001). Most lymphomas in patients with SS are of B-cell lineage and are low- or intermediate grade and arise from extranodal areas such as the salivary glands, gastrointestinal tract, thyroid gland, lung, kidney, or orbit. Localized, low-grade lymphoma affecting exocrine glands may be managed by watchful waiting; disseminated lymphoma may be treated with combination chemotherapy.

Diagnostic tests for SS involve quantification of lacrimal and salivary gland function. The Schirmer test for the eye quantitatively measures tear formation via placement of filter paper in the lower conjunctival sac. If less than 5 mm of paper is wetted after 5 min, the test result is positive. Rose bengal scoring involves placement of 25 mL of rose bengal solution in the inferior fornix of each eye and having the patient blink twice. Slitlamp examination may then detect destroyed conjunctival epithelium caused by desiccation. The rose bengal score is the sum of scores assigned to damage found in three regions of the eye and can define the presence of keratoconjunctivitis. Sialometry measures unstimulated salivary flow into a calibrated tube for 15 min; normal flow is more than 1.5 mL. Sialometry, however, does not distinguish between causes of xerostomia. Parotid sialography and salivary gland scintigraphy may demonstrate gross distortion of the normal pattern of parotid ductules on sialogram, with marked retention of contrast medium. Scintigraphic findings in patients with SS include decreased uptake and release of technetium Tc 99 m pertechnetate, with the extent of decrease paralleling the degree of xerostomia and salivary flow rate. Minor salivary gland biopsy remains a highly specific test for the salivary component of SS. Focal lymphocytic sialadenitis (multiple, dense aggregates of 50 or more lymphocytes in perivascular or periductal areas in the majority of sampled glands) is a characteristic histopathologic feature of SS.

The treatment of SS is intended to limit and prevent the damage resulting from chronic xerostomia and keratoconjunctivitis. Two currently approved agents have a therapeutic effect on xerostomia and keratoconjunctivitis: pilocarpine and cevimeline. Pilocarpine and cevimeline stimulate the M3 and M1 receptor subtypes on acinar and ductal cells of the salivary and lacrimal glands. Pilocarpine is a parasympathomimetic agent, but has potential cardiovascular and pulmonary effects which may limit its use in patients taking B-blockers and in those with asthma. Intraoral candidiasis in SS patients should be treated with nystatin. NSAIDS are used to mitigate minor musculoskeletal symptoms and the use of disease-modifying antirheumatic agents such as hydroxychloroquine has not been found to have any clinical benefit. Corticosteroid use is limited to the treatment of severe extraglandular manifestations of SS. The frequent use of tear substitutes and punctal plugs may also prevent the development of keratoconjunctivitis, blepharitis, or corneal ulceration. Unfortunately, no treatment is currently available to decrease the glandular lymphocytic infiltration that is the underlying cause of exocrine gland dysfunction.

Systemic Sclerosis

Systemic sclerosis (SSc), also known as scleroderma, is a chronic systemic disorder of unknown etiology. SSc is characterized by thickening of the skin and distinctive involvement of multiple internal organs, most notably the lungs, gastrointestinal tract, heart, and kidneys. In the United States, the incidence is 9–19 cases per million per year. Like other connective tissue diseases, SSc shows a female predominance, greatest in the childbearing years and declining after menopause. While SSc can present at any age, the most common age of onset is in the range of 30–50 years.

SSc is characterized by a thickening of the skin (scleroderma) and distinctive involvement of multiple internal organs, most notably the lungs, gastrointestinal tract, heart, and kidneys. SSc is classified into two types. Diffuse cutaneous SSc (dcSSc) presents with progressive skin induration, starting in the fingers and ascending from distal to proximal extremities, face, and trunk. dcSSc patients are at risk for early pulmonary fibrosis and acute renal involvement. In the second type, called limited cutaneous SSc (lcSSc), patients generally have long-standing Raynaud's phenomenon before other manifestations of SSc appear. Skin induration is limited to the fingers (sclerodactyly), distal extremities, and face, and the trunk is not affected. A subset of SSc patients have prominent calcinosis cutis, Raynaud's phenomenon,

esophageal dysmotility, sclerodactyly, and telangiectasia, a constellation of findings termed CREST syndrome.

The histopathology of SSc displays widespread obliterative vasculopathy of small arteries and arterioles and fibrosis in the skin and internal organs. Perivascular cellular infiltrates may be detected in multiple organs prior to the appearance of fibrosis. In the skin, infiltrates are located in the reticular dermis and are composed primarily of $CD4^+$ T lymphocytes. In addition, $CD8^+$ T cells, monocytes/macrophages, plasma cells, mast cells, and occasionally B cells may be detected. Antinuclear autoantibodies can be detected in almost all patients with SSc. Autoantibodies directed against topoisomerase-I (Scl-70) and centromere are very highly specific for SSc, but are mutually exclusive.

Eighty percent of patients with systemic sclerosis have involvement of the head and neck. Patients present with tight skin, thin lips, and vertical perioral furrows and complain of a decreased ability to open their mouth. Dysphagia is the most common initial complaint. Esophageal pathology is extremely common in patients with SSc, as 80% of SSc patients demonstrate abnormal radiographic findings of the distal two third of the esophagus. Dysphagia is secondary to decreased esophageal innervation and smooth muscle atrophy. Gingivitis, periodontal thickening, and xerostomia may also occur.

No therapies have been shown to alter the natural history of SSc significantly. Glucocorticoids may decrease stiffness and aching in patients with early-stage dcSSc but do not influence the progression of skin or internal organ involvement. Furthermore, use of glucocorticoids in high doses is associated with an increased risk of scleroderma renal crisis. Thus, glucocorticoids should be avoided if possible. Because gastroesophageal reflux is very common, all patients with SSc should be treated for this complication. Significant reflux may occur in the absence of symptoms. Patients should be instructed to elevate the head of the bed and eat frequent small meals. Proton pump inhibitors and H2 blockers are effective and may need to be given in relatively high doses. Patients with Raynaud's phenomenon should be instructed to dress warmly, minimize cold exposure or stress, and avoid drugs that could precipitate or exacerbate vasospastic episodes. Calcium channel blockers such as nifedepine or diltiazem are commonly used but show only moderate benefit. *Dysphagia* to solids can be mitigated by using liquids to clear the esophagus (LeRoy et al. 1988).

Relapsing Polychondritis

Relapsing polychondritis (RP) is an autoimmune disorder causing episodic recurring inflammation of cartilaginous structures with deposition of a high concentration of glycosaminoglycans that are eventually replaced by granulation tissue and fibrosis. The incidence of RP has been estimated to be 3.5 cases per million in Rochester, Minnesota, and women are more commonly affected by men with the average onset of 47 years. Currently, diagnosis is made on the basis of chondritis in two of three sites: auricular, nasal, laryngotracheal; or one of those sites and two other features, including ocular inflammation, audiovestibular damage, or seronegative inflammatory arthritis (Michet et al. 1986). The pathogenesis is unknown, although there is a significant increase in the frequency of HLA-DR4 in RP patients. ESR may be elevated, along with moderate leukocytosis and mild-to-moderate anemia. Histologically, there is a loss of basophilic staining of cartilage, perichondral inflammation, and cartilage destruction and replacement by fibrosis.

RP patients can present with multiple systemic manifestations. Musculoskeletal findings include nonerosive arthritis which is intermittent, migratory, asymmetric, and seronegative. Pulmonary manifestations include tracheal and bronchial stenosis, thickening and calcification of the airway walls, obstructive bronchiectasis, and dynamic tracheal or bronchial collapse. Pulmonary function tests should be performed in all patients with RP to detect occult airway disease. Twenty-two percent of patients with RP have renal manifestations. Renal pathology includes mesangial expansion, IgA nephropathy, tubulointerstitial nephritis, and segmental necrotizing crescentic glomerulonephritis. Thirty-seven percent of RP patients have at least one associated dermatologic manifestation, most commonly oral aphthous ulcers and nodules on the limbs with an erythema nodosum appearance (Frances et al. 2001).

Head and neck manifestations include auricular and nasal chondritis. Auricular chondritis and nonerosive arthritis are the most common presenting symptom. Auricular chondritis presents with the sudden onset

of erythema and pain, and spares the lobule. Nasal chondritis affects the distal part of the nasal septum, which may lead to a saddle nose deformity. Chondritis is the presenting feature in 33% of patients, and it will develop in 90% of patients with the disease. Conductive hearing loss may develop due to collapse of the external auditory canal or chondritis of the Eustachian tube. Chondritis of the laryngotracheal cartilages occurs in more than 50% of patients, and may present with hoarseness, cough, inspiratory stridor, dyspnea, or wheezing. Airway obstruction may occur secondary to laryngeal edema, vocal fold palsy, and fixed subglottic or bronchial stenosis. Patients may develop episcleritis, scleritis, keratoconjunctivitis sicca, iritis, retinopathy, keratitis and/or optic neuritis.

Treatment has traditionally consisted of oral corticosteroids for mild-to-moderate auricular and nasal chondritis or arthritis, while higher doses have been used for patients with sensorineural hearing loss (SNHL), ocular involvement, respiratory compromise, and/or renal and vascular involvement. NSAIDS may be used for treatment of arthralgias and mild arthritis. Colchicine has been reported to be beneficial for auricular chondritis and the antileprosy medication dapsone may be used for more mild disease. Methotrexate and azathioprine have also been used in recalcitrant cases.

Mixed Connective Tissue Disease

Mixed connective tissue disease (MCTD) describes a syndrome with features of systemic lupus erythematosus, polymyositis, and rheumatoid arthritis. This overlap syndrome is generally associated with the presence of high titers of autoantibodies to U1-RNP. The characteristic initial presentation is Raynaud's phenomenon associated with puffy fingers and myalgia. Gradually, the limited cutaneous SSc features of sclerodactyly, calcinosis, and cutaneous telangiectasia develop. Skin rashes suggestive of systemic lupus erythematosus (malar rash, photosensitivity) or of dermatomyositis (heliotrope rash on the eyelids, erythematous rash on the knuckles) occur. While arthralgia is common, some patients develop erosive polyarthritis. Pulmonary fibrosis may develop. Other manifestations include esophageal dysmotility, pericarditis, Sjögren's syndrome, and renal disease, especially membranous glomerulonephritis. Laboratory evaluation indicates features of inflammation with elevated ESR and hypergammaglobulinemia. While anti-U1RNP antibodies are detected in the serum in high titers, SSc-specific autoantibodies are not found. In contrast to SSc, patients with MCTD often show a good response to treatment with glucocorticoids, and the long-term prognosis is better than that of SSc. Whether MCTD is a truly distinct entity or is, rather, a subset of systemic lupus erythematosus or SSc is controversial (Venables 2006).

Cross-References

- ▶ Dysphagia
- ▶ Sensorineural Hearing Loss
- ▶ Subglottic Stenosis (SGS)
- ▶ Temporomandibular Joint

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Autoimmune Inner Ear Disease (AIED)

- ▶ Autoimmune Sensorineural Hearing Loss

Autoimmune Sensorineural Hearing Loss

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Synonyms

Autoimmune inner ear disease (AIED); Immune-mediated cochleovestibular disease; Immune-mediated sensorineural hearing loss; Idiopathic progressive bilateral sensorineural hearing loss (IPBSNHL)

Definition

- Antigen: Substance that stimulates the immune system.
- Western Blot: This clinical test is performed by electrophoresing a suspected antigen onto a gel and incubating them for several hours with a dilute solution of the patient's serum. Positivity means the antigen and corresponding antibody exist in the patient's serum.
- FTA-ABS: Fluorescent treponemal antibody absorption testing for syphilis.
- Retrocochlear pathology: Etiologies that are more central than peripheral hearing end organ causing aural symptoms such as acoustic neuroma that can best be diagnosed with imaging.

Introduction

The hallmark of AIED is a rapidly progressive bilateral sensorineural hearing loss (SNHL) over weeks to months that responds to the administration of immunosuppressive agents such as corticosteroids. McCabe was the first person to formally describe it in 1979 as an autoimmune-mediated disease since his patients responded to steroid treatment (McCabe 1979).

Specific audiometric criteria for idiopathic progressive bilateral sensorineural hearing loss (IPBSNHL) include bilateral SNHL of at least 30 dB at any frequency with progression in at least one ear, defined as a threshold shift that is greater than 15 dB at any frequency or 10 dB at 2 or more consecutive frequencies or a significant change in discrimination score. This definition excludes patients with sudden SNHL occurring in less than 3 days.

AIED may be primary when the inner ear is the only organ involved or secondary when there is a generalized immune process involving multiple organs.

Epidemiology

It is a rare disorder. The exact incidence is not known. However, it is thought to be rarer than idiopathic SSNHL which occurs 10 in 100,000. Autoimmune inner ear disease most commonly affects middle-aged women, much like other autoimmune diseases. Of affected individuals, 65% are female and 35% male.

Pathophysiology

Animal studies performed in vivo as well as in vitro have shown that antigens can gain access to the immunocompetent cells in the endolymphatic sac and that the inner ear in general is capable of generating an inflammatory reaction to such antigens. Inner ear immune response can be a result of actions of antibodies, antibody complex, or immune cells. Such ability to surmount an immune response is an innate capability of the inner ear to protect itself from outside infection, but when reacting to itself can incur permanent damage to the end organ in a repetitive fashion.

The endolymphatic sac has been shown to harbor immunocompetent cells all the time whereas cochlea does not. This is presumably where the introduction of antigens induces a chain of immune responses. There follows a massive cellular infiltration to both scala tympani and scala vestibuli through the spiral modiolar vein. This cellular proliferation of macrophages, immunoglobulin bearing cells, and T-helper cells starts a cascade of reactions involving more immune mediators and maturation of cells. Concomitant to this cellular proliferation is an increase in extracellular matrix, most likely by fibroblast and endosteal cells lining scala tympani. These fibrotic tissues become first visible in 1 week, and when this progresses to osteoneogenesis, the first signs of labyrinthitis ossificans are in evidence by week 3. The inner ear is not very good at clearing this extracellular matrix. This lack of clearing mechanism

Autoimmune Sensorineural Hearing Loss, Table 1 Autoimmune syndromes associated with hearing loss

Disease	Affected organs	Associated symptoms
Cogan's disease (non-syphilitic interstitial keratitis)	Eye, vestibular system, cochlea	SNHL, vertigo, and tinnitus, ocular irritation
Wegener's granulomatosis	Sinopulmonary, vascular, renal, middle ear, rarely inner ear	CHL, serous otitis media, sinusitis, septal perforation, lung disease, SNHL, subglottic stenosis
SLE (systemic lupus erythematosus)	Skin, lung, kidney, brain, ear	Chronic otitis media, dizziness, SNHL, butterfly malar rash, arthritis, pleuritis, nephritis, neuritis
Rheumatoid arthritis	Joints, inner ear	Joint pain, SNHL
Polyarteritis nodosa	Kidney, viscera	SNHL, myalgia, arthralgia, abdominal pain
Relapsing polychondiritis	Cartilage of ear, nose, trachea, larynx	Recurrent chondritis of auricle, hearing loss
Susac syndrome (retinocochleocerebral vasculopathy)	Microangiopathy of brain, eye, ear	Impaired vision, headache, changed personality, hearing loss, confusion

and subsequent ossification leads to permanent damage resulting in sensorineural hearing loss. There is also an independent contribution from the degeneration of spiral ganglion as well (Harris and Ryan 1995).

There has been an extensive search for the offending agent that starts the autoimmune process. One such antigen that is inherent in cochlea is an inner ear antigenic epitope with a molecular weight of approximately 68-kdalton. This is detectable on Western blot analysis in guinea pigs and also in human ears (33% of human serum with progressive SNHL) with AIED (Orozco et al. 1990, Harris and Sharp 1990). Some studies have implicated that the presence of this antigen in the serum of patients may predict an active state of the disease and therefore a predictor for a good response to steroids. Rauch (Rauch et al. 1995) subsequently identified the 68-kd protein as heat shock protein 70 (HSP 70). Heat shock proteins are constitutively produced by host and pathogens and usually are upregulated in response to infection or other stresses. There is a commercial assay which tests for the presence of HSP 70. The clinical utility of this test is yet to be proven. Its specificity is rather high at 95% but sensitivity is low when used in general population.

Clinical Presentation

It usually presents as a progressive bilateral (79%) SNHL that is rapidly progressive over weeks or months. It could start as unilateral and fluctuating but eventual pattern is one that leads to relentless deterioration. It is associated with tinnitus and sometimes with vertigo and aural fullness. As many as 25–50% of patients have symptoms of tinnitus and aural fullness, which can fluctuate in severity. Approximately 50% of AIED patients have vestibular symptoms. Vestibular symptoms can include disequilibrium, ataxia, motion intolerance, positional vertigo, and episodic vertigo.

Systemic autoimmune diseases occur in 29% of patients. Some of these diseases are summarized in Table 1.

Diagnosis

Audiogram needs to be done with speech discrimination scores. It is important to compare it to an older one to see if there is a change. If treatment is started, a serial audiogram should be performed to track a progress.

ENG could be performed if the clinical picture is not clear. When the hearing loss starts out as a unilateral loss, an MRI with gadolinium should be performed to rule out a retrocochlear pathology.

There is no specific blood work. One can look for signs of inflammation or activity in other autoimmune markers to see correlation (Table 2).

Western blot analysis for antibodies to inner ear antigen has been advocated by some. Mosicki Moscicki et al. (1994) identified antibodies to 68 kDa antigen in 89% of patients with active progressive bilateral SNHL suggestive of AIED. Seventy five percent of the patients who tested positive responded to steroid therapy as compared to only 18% of those who tested negative. Harris's work found 32% of patients with presumed AIED were positive for HSP 70 (Harris and Sharp

Autoimmune Sensorineural Hearing Loss, Table 2 Blood-work for AIED

Other autoimmune markers	General test	Coagulopathy	Other mimicking conditions
ANA, anticardiolipin	CBC with differential	INR, PT, PTT	Hgb A1C
anti-dsDNA	ESR		HIV testing
RF	CRP		FTA-ABS
c-ANCA, p-ANCA	C50, C3 and C4		Lyme titer
anti-SSA/B antibodies, antiphospholipid antibodies	HSP 70		TSH

1990). He therefore concluded that the test is 95% specific for AIED, but rather insensitive when used in the general population, and states that "in a group of patients who have unexplained progressive deafness, there is about a 1/3 chance of there being an immune cause of the hearing loss" (Harris in Bailey's textbook).

Differential Diagnosis

Acoustic neuroma can present as a sudden unilateral sensorineural hearing loss. In fact, about 4–10% of idiopathic sudden sensorineural hearing loss is due to vestibular schwannoma, proven by MRI. Infections such as syphilis and lyme disorder must also be ruled out with serological testing.

The clinical spectrum of Meniere's disease (MD) and AIED overlaps significantly (Hughes et al. 1988). In fact, 33% of Meniere's disease patients have evidence of antibodies to the 68- to 72-kD antigen by Western blot assay. There seems to be a small proportion of MD that has autoimmunity as a part of pathophysiology for endolymphatic hydrop.

Other rarer causes that can lead to sensorineural hearing loss mimicking AIED are vascular insult, idiopathic SSNHL, metastatic disease with inflammation of dura, and multiple sclerosis.

Therapy

High-dose oral steroids such as prednisone (1 mg/kg) for 4 weeks have been the mainstay treatment. Treatment may be considered if the beginning of symptoms has been within 3 months. If the threshold has improved by 15 dB or more at one frequency or 10 dB at two or more consecutive frequencies, or if the discrimination is significantly improved, patients are considered steroid responders. Nonresponders are tapered off their medication whereas responders continue full-dose therapy until a plateau of recovery is reached. Some patients may need this maintenance therapy for longer than 6 months. Some patients become steroid dependent and cannot be weaned off of steroid and transitioned to methotrexate. Contraindications to steroid treatment include peptic ulcer disease, diabetes mellitus, glaucoma, hypertension, and history of tuberculosis. Overall steroid response rate is approximately 60%.

Other cytotoxic medications include methotrexate, cyclophosphamide, and azathioprine (Imuran). Harris et al. (2003) performed a prospective randomized study on patients who have already responded to a month of high-dose steroid and divided them into receiving either placebo or methotrexate. The authors found that methotrexate was not able to maintain the hearing improvements obtained by high-dose prednisone over time. McCabe advocated cyclophosphamide as an additional primary treatment to steroids. Cyclophosphamide has adverse effects that include myelosuppression, hemorrhagic cystitis, infertility, and increased risk of malignancy.

Drugs that block tumor necrosis factor (TNF) such as etanercept given as a subcutaneous injection weekly seem to be potentially effective in AIED (Rahman et al. 2001; Wang et al. 2003). Some of the reported complications include serious infections, nervous system disorders, and depression/personality disorders.

Luetje studied the use of plasmapheresis in patients with autoimmune inner ear disease. Improvement in auditory function occurred in six of eight patients, three of whom were able to discontinue immunosuppressive medication. This study was seriously underpowered.

Prognosis

The natural history for AIED is unknown. Patterns of response to corticosteroid therapy vary. Some patients have improvement in threshold, some have improvement in discrimination only, and some experience

improvement in both areas. Some patients with hearing loss fluctuation and progression before therapy show stabilization in hearing without actual improvement. Most responders slowly taper off the steroid dose, wean from steroids, and do well.

Conclusion

AIED, although rare, is an important disease entity since hearing loss is reversible with timely treatment. It is not an otologic emergency in the same sense as sudden SNHL. However, an adequate length of treatment with high-dose steroid with prolonged maintenance is required since hearing loss can be fluctuating even after a pulse of high-dose treatment.

Given similar presentations, a diagnosis of AIED should at least be entertained in any patients with a previous diagnosis of Meniere's disease (MD) now presenting with contralateral symptoms. This is an important consideration since many of surgical treatments for MD are ablative and cause irreversible hearing loss.

Cross-References

- ▶ Autoimmune Diseases
- ▶ Otologic Manifestations in Wegener Granulomatosis
- ▶ Otologic Manifestations of Lyme Disease
- ▶ Sudden Sensorineural Hearing Loss

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Autonomic Nervous System

- ▶ Vestibular and Central Nervous System, Anatomy

Autosomal Dominant

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Definition

Form of inheritance pattern with ability of an allele (not located on the X chromosome) to be expressed whether a single or pair of that allele exists.

Cross-References

- ▶ Sensorineural Hearing Loss-Congenital-Genetics

Autosomal Dominant Deafness

► Genetics of Hearing Loss

Autosomal Recessive

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Definition

Form of inheritance pattern with the ability of an allele to be expressed only if a pair of that allele is present.

Cross-References

► Sensorineural Hearing Loss-Congenital-Genetics

Autosomal Recessive Deafness

► Genetics of Hearing Loss

AVMs

► Arteriovenous Malformations

Axial Flaps

► Classification of Flaps

Axial Pattern Flap

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Definition

Axial pattern flap: Flap based on a named source artery.

Cross-References

► Advancement Flaps

Axonotmesis

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Definition

Usually the result of a more severe blunt or crush injury than neuropraxia. There is damage to the nerve fibers and myelin sheath that does not disturb the endoneurium, perineurium, or epineurium but is followed by complete peripheral (Wallerian) degeneration, distal and slightly proximal to the site of injury. Partial and complete nerve function recovery is possible and depends on distance of axon regrowth and whether the axon regrows within the same endoneurium.

Cross-References

► Sunderland Classification of Nerve Injury