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The recommendations found in this report are based on a detailed literature review and if possible on a consensus among the members of the working group in charge of the guideline, all the authors doing it as honestly as possible. This is not to say that these recommendations are the best and only mean to work correctly.

On the other hand, these recommendations will be temporary. New research, new ideas, new discoveries will certainly modify quite rapidly and largely these guidelines.

Levels of evidence and grades of recommendations

The levels of evidence and grades of recommendations are used as defined in Belgium by the Consensus Committee of the INAMI-RIZIV:

+ levels of evidence

– I a: one or more systematic reviews (meta-analysis)
– I b: large randomized controlled trial (RCT) with significant results (sufficient quality)
– II: – small meta-analysis or small RCT with uncertain result (insufficient quality)
  – cohort, case-controlled or cases series (identified by a group of experts)
– III: expert opinion without explicit critical appraisal

+ grades of recommendations

– A: corresponds to levels I a and I b (RCT or meta-analysis)
– B: corresponds to level II (observational study or case series)
– C: corresponds to level III (expert opinion)

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Otosclerosis

Th. Somers, F. Declau**, R. Kuhweide*** and Th. Robillard*****

*ENT Department, Sint-Augustinus Hospital, Antwerp; **ENT Department, Sint-Vincentius Ziekenhuis, Antwerp; ***ENT Department, Sint-Jan Ziekenhuis, Brugge; ****ENT Department, Clinique Sainte-Elisabeth, Namur.

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Abstract. *Otosclerosis.* Otosclerosis is the most common cause of progressive conductive and mixed hearing loss.[1-3] Its diagnosis is usually unproblematic and based on the combination of normal otoscopy, a typical audiogram, and absence of stapedial reflexes. In atypical cases, investigation with high-resolution imaging is recommended. In case of conductive hearing loss and depending on the severity of the symptoms, three treatments are available.[2] Watchful waiting is advised for patients with very slight hearing losses without social discomfort, and a hearing aid can be provided to patients with hearing problems but unwilling to undergo surgery. Surgery is the treatment of choice for the conductive component and is preferred because of its high success rate and low complication rate. Because surgery is always elective, in-depth counselling of the patient is important.[1,2]

Definition, Etiology, Epidemiology

Otosclerosis is the most common cause of stapes fixation.[1,2] It is primarily a disease of the bone that encases the cochlea and labyrinth. Histologically, otosclerosis is characterized by progressive focal dysplasia with destruction (the so called "otospongiosis" stage), remodelling, and finally sclerosis of the endochondral bone of the labyrinthine capsule (the so called otosclerosis stage).[2] The disease mostly starts in the anterior part of the oval window, the so-called fissula ante fenestram and extends to the annular ligament and stapes, where it causes bony ankylosis of the stapes, which results in increased stiffness of the ossicular chain and conductive hearing loss. A thick ossification of the entire oval window, also known as obliterative otosclerosis, is accompanied by severe conductive hearing loss. The inner ear structures are often uninvolved, but sometimes, advanced otosclerosis of the labyrinthine capsule occurs without conductive hearing loss. In those cases, progressive, degenerative changes in the inner ear occur, with atrophy of the spiral ligament, and they cause an additional sensorineural hearing loss.

In rare cases, the otosclerotic foci affect wide areas of the petrous bone. Patients with so called "malignant" otosclerosis become progressively deaf.[2]

The typical natural history of otosclerosis is characterized by a slow progressive conductive hearing loss. When the cochlear otic capsule is also involved, a concomitant sensorineural hearing loss develops. The disorder is usually bilateral, but the progression rate is different for the two ears, and otosclerosis may present as a unilateral conductive or mixed hearing loss.

The onset of the hearing loss mostly occurs after the third decade. Less than 3% of new cases are diagnosed during childhood.[2]

Females appear to be affected at twice the rate of males. During pregnancy, otosclerosis frequently becomes apparent or aggravates, which suggests that female hormones play an important role in the pathophysiology. Up until now, however, no hard evidence could prove increased incidence of otosclerosis in subjects that take oral contraceptives.[2,4]

A definite racial predisposition exists: otosclerosis is more common in Caucasians, has a lower prevalence among Asians, and is rage among native Americans.

Otosclerosis is a disorder in which both genetic and environmental etiological factors are involved.[5] A limited number of large families showing an autosomal dominant inheritance pattern for otosclerosis have been described. Most subjects with otosclerosis, however, occur in small families with unclear inheritance pattern or are sporadic, which suggests a multifactorial aetiology for otosclerosis. Among caucasians, clinical otosclerosis has a reported prevalence of 0.3% and is the most common cause of conductive hearing impairment. Histological

otosclerosis even has a prevalence of 3.5% among white adults and affects usually both temporal bones symmetrically.

Otosclerosis represents a heterogeneous group of genetic diseases in which genes are involved in regulating bone homeostasis of the otic capsule. It has been hypothesized that bone dysplasia in otosclerosis results from the lack of physiologic inhibition of bone turnover in the otic capsule due to environmental and genetic factors. Many environmental factors have been implicated in the aetiology of otosclerosis, including infectious causes such as measles virus, hormones (related to puberty, pregnancy and menopause), and nutritional factors (fluoride intake).

Large autosomal dominant otosclerosis families have been analysed for gene identification studies, but the first gene responsible for otosclerosis has yet to be cloned. However, five chromosome loci, OTSC1 - OTSC5, have been identified, supporting the hypothesis of genetic heterogeneity. OTSC1 was mapped to chromosome 15q25-q26 in an Indian family in which hearing loss began in childhood. The OTSC2 locus was mapped to a 16 cM region on chromosome 7 (7q34-36) in a large Belgian family detected by our institution (Sint-Augustinus Hospital). More recently, the OTSC3 locus was mapped on chromosome 6 in a large Cypriot family (6p21.3-22.3). The OTSC3 locus covers the HLA region, consistent with reported associations between HLA-A/HLA-B antigens and otosclerosis. OTSC4 was recently found in an Israelian family. A fifth locus for otosclerosis, OTSC5, was mapped to chromosome 3q22-24 in a large Dutch family. Note that genetic heterogeneity has also been demonstrated for nonsyndromic sensorineural hearing loss.[5]

Diagnostic Management

The diagnosis of otosclerotic hearing loss is usually unproblematic.[1,2,4,6]

A positive family history is found in about 50% to 60% of the cases. Clinical bilateral affection is common (85%-90%). Tinnitus, which is mostly low-pitched (~ 75%), is also a common symptom of otosclerosis. The exact mechanism underlying tinnitus in otosclerosis, however, is unclear. Tinnitus is most common in those patients with severe hearing loss. It is frequently encountered in the older age group and in those with an early age of onset and cochlear involvement.

Many patients (20%-78%) with otosclerosis have increased understanding of speech during a cocktail party, the so called paracusis of Willis. This phenomenon occurs because the conductive hearing loss attenuates the background noise and renders the dynamic range of the ear at the level of the speaker's voice, thus effectively increasing the signal to noise ratio. Vestibular disturbance and postural instability are present in more than a quarter of the patients with otosclerosis (25%-55%) and tend to be rather mild, except in co-existing endolymphatic hydrops.[4,6]

Three types have been described:

1. Periods of unsteadiness and dysequilibrium (20 min – 6 h) with normal caloric response, and without nystagmus.
2. Periods of postural instability.
3. Menièriform attacks with increased tinnitus, fluctuating hearing loss, caloric tests are normal or show hyporeflexia.

Otoscopy reveals a normal eardrum with an air filled middle ear.

The sign of Swartze, which refers to a reddish blush on the promontory, is a rare finding and reflects abnormal vascular shunts between otosclerotic foci and the vessels of the promontory.

Tuning fork tests are very helpful for evaluating a patient with otosclerosis. During Weber's test, sound lateralizes to the ear with the greatest degree of conductive loss and during Rinne's test, sound will be heard louder when delivered on the mastoid tip compared to delivering via the ear canal.[1,2,6]

Audiometric testing in otosclerosis reveals a conductive or mixed hearing loss. In its early stages, the conductive loss tends to be confined to lower frequencies (Figure 1A). In advanced stages, conductive loss also occurs at higher frequencies (Figure 1B) and a perceptive component may also appear (Figure 1C). A conductive loss of about 40 dB in the low frequencies with a reduction of the gap towards 2 kHz is typical, because stapes fixation reduces the elasticity of the ossicular chain. An interesting finding in otosclerosis is the deterioration of bone conduction thresholds at middle to high frequencies, which sometimes disappears after successful surgery: the so-called Carhart notch, which can reach up to 25 dB at 2 kHz (Figure 1D). A possible cause is the absence of middle ear resonance, in humans at 2000 Hz, together with reduced perilymph oscillation due to the immobile footplate.[2]

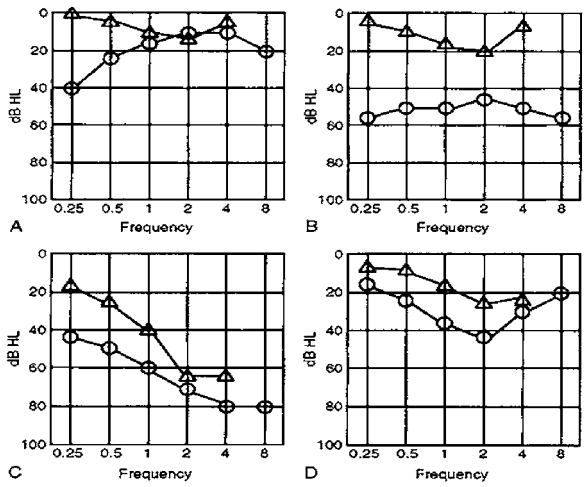


Figure 1
Audiometric findings in otosclerosis. **A:** conductive hearing loss at low frequencies during early stage otosclerosis. **B**: advanced stage conductive hearing loss. **C**: advanced stage high frequency perceptive hearing loss. **D**: Carhart notch at 2 kHz.

Speech audiometry shows a normal increase in speech discrimination when sound intensity increases. Reduced speech discrimination indicates inner ear involvement, and should be further investigated.

Tympanometry is generally normal, but sometimes a diminished compliance (a smaller peak) is observed.[2,4,6]

The stapedial reflex is absent and this sign is particularly interesting in unilateral forms.

The "on-off" effect, which refers to a reduction of the acoustic impedance at onset and offset of the sound stimulus, is a poorly understood finding at early stage of stapes fixation.

High-resolution computed tomography (HRCT) is currently the radiologic method of choice in assessing the labyrinthine windows and otic capsule. On HRCT images, otosclerotic foci are visualized as hypodense or radiolucent foci. Most common HRCT findings in surgically confirmed otosclerosis are foci anterior to the oval window (in the *fissula ante fenestram*), pericochlear lucency, and foci in the footplate of the stapes. Absence of foci on HRCT images does not rule out stapes fixation by a sclerotic focus. In severe mixed hearing loss, a peri-cochlear demineralisation can be observed as a characteristic radiolucency giving a "halo" appearance to the otic capsule.[2,4,6]

Although fenestral otosclerosis remains largely a clinical diagnosis, HRCT is recommended in atypical cases (e.g. children, atypical audiogram, concomitant vertigo) in order to exclude inner ear deformities (e.g. large vestibular aqueduct, inner ear dysplasias...). A large patent cochlear aqueduct or no partition between the inner ear and the fundus of the internal auditory canal should alert the surgeon for a potential perilymph gusher. HRCT is also recommended in revision cases and in far advanced cases with (sub)total deafness especially if cochlear implantation is planned.

MRI is recommended in asymmetric audiograms to exclude concommitant retrocochlear disease (e.g. a vestibular schwannoma). On MR images of ears with otosclerosis, slight-to marked contrast enhancement can be seen, which are interpreted as inflammatory hypervascularization.[2]

Some otologic diseases can mimic the clinical picture of otosclerosis, and their presence only becomes apparent during an exploratory tympanotomy.[4,6]

- Sequelae of otitis media with intact eardrum: ossicular discontinuity, tympanosclerosis
- Post-traumatic stapes fixation
- Malleus head fixation
- Minor malformations of the middle ear: monopodic stapes, aplasia of stapessuperstructure, footplate ossification with coexisting aplasia of the annular ligament, ossification of the stapedial tendon, persistence of a stapedial artery
- Abnormal perilymph pressure
- Paget's disease
- Osteogenesis imperfecta: patients with blue sclerae should be suspected and questioned about bone fractures in the past.

Therapeutic Management

Conservative therapy

- No treatment is advised when air conduction thresholds are lower than 30 dB HL.
- In patients with moderate to severe hearing loss, and unwilling or unable to undergo surgery, hearing aids often yield good results when cochlear function is well preserved.[1,4]

- Osseo-integrated bone-anchored hearing aids have occasionally been used as an alternative for patients with otosclerosis with very large air-bone gaps and who did not benefit sufficiently from traditional hearing aids.[2]
- In cases of cochlear otosclerosis with progressive sensorineural hearing loss one may also consider the use of sodium fluoride, calcium and vitamin D. The beneficial effects of sodium fluoride are best documented. The rationale of its use is based on epidemiological data and randomized trials. An increased prevalence of stapedial fixation in areas where the levels of fluoride are low has been observed. Several double-blind prospective studies have confirmed that sodium fluoride does stabilize hearing in sensorineural hearing loss, while the controls who did not receive treatment continue to experience a deterioration in their hearing. Fluoride probably transforms active otospongiotic lesions into more dense inactive otosclerotic lesions.[2]
- The daily recommended dose of fluoride is 50 mg. When the hearing stabilizes and radiological evidence of recalcification exists, some authors would give a maintenance dose of 25 mg. Others claim that prolonged fluoride administration does not seem to be superior to a shorter treatment period (1-2 years).[2,4]

Surgery

- Stapes surgery should be performed by surgeons who have special interest in otology, and have sufficient experience in middle ear surgery. Performing stapes surgery from time to time should be avoided. In approximately 90% of the cases, surgery results in a dramatic and prolonged hearing gain with closure of the air-bone gap to within 10 dB.[1,2,4]
- Stapes surgery is most appreciated by patients who experience hearing problems in everyday life. This is mostly the case when Rinne's test is "negative" and air conduction thresholds are at 30 dB HL or worse.[2,6]
- In bilateral cases, the operation should be carried out on the ear with the highest degree of hearing loss.[1]
- If the average bone conduction thresholds are more than 30 dB lower than those at the contralateral better hearing ear, the patient will most probably notice little or no hearing improvement after surgery.[1,2,4]
- When the air-bone gap is small, the potential risk of an intervention should be considered.
- Local or general anaesthesia can be used according to the patient's and the surgeon's preference.
- The small hole technique (stapedotomy) is preferred above the stapedectomy technique which is associated with a slightly higher risk for inner ear damage. Micro-instruments, microdrill or laser are used to make the calibrated hole. Laser stapes surgery has, to a certain extent, reduced technical difficulties. It must be emphasized, however, that the available techniques (different lasers and microdrills) are only as good as the surgeons that handle them.[1,2,4]
- The diameter of the stapedial prostheses varies between 0.4 mm and 0.6 mm. No significant difference in hearing results are found for prostheses as long as the diameter is comprised between 0.4 mm and 0.6 mm.[2,4]
- In profound hearing loss due to cochlear otosclerosis a cochlear implant (with or without cochlear drill out) may be warranted.[2,6]

Indications for surgery

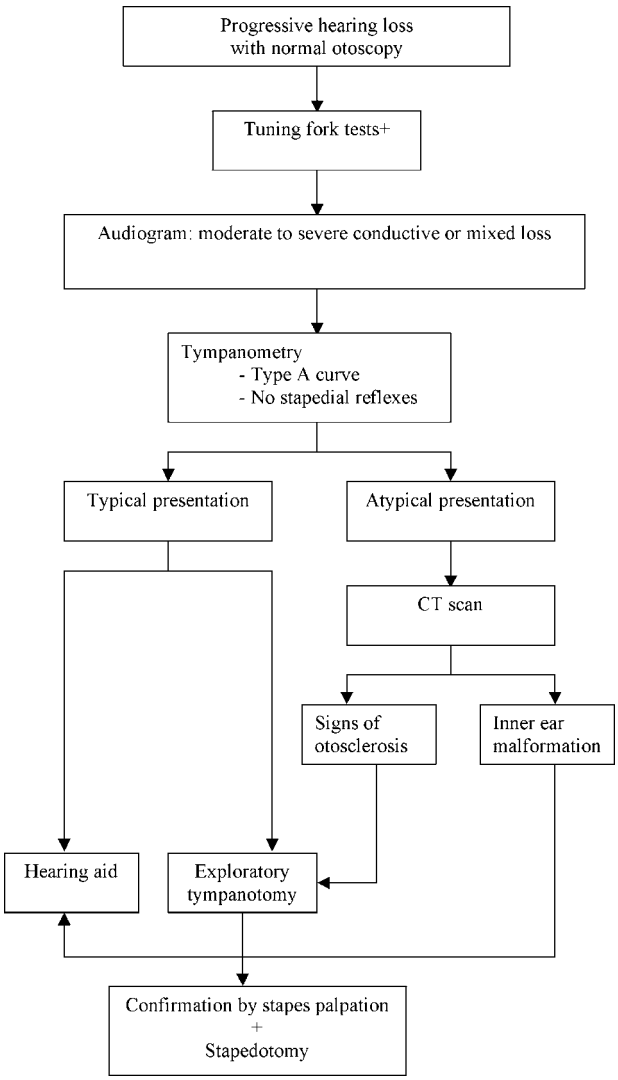
- The patient should be in reasonably good health, especially if general anaesthesia is planned.[1]
- The age of the patient is not a factor in the decision on surgery but one should be cautious in children (exclude inner ear malformations) and in elderly patients. In children, it is prudent to fit hearing aids first and not carry out the operation until both the affected adolescent and also his/her parents insist on the operation. A certain degree of caution may also be indicated in elderly patients. Individual studies (not confirmed by others), suggest that elderly patients develop a high frequency hearing loss postoperatively more often than younger patients.[2]
- The worst ear, based on the patient's statement and not necessarily on the audiogram, should be chosen for surgery.[1,2,4,6]
- Tuning fork tests should always be used to confirm the audiometric findings. If bone conduction is heard louder than air conduction with a 512 or 1024 tuning fork, the individual is a suitable candidate for surgery.[1,2]

- The minimal average air conduction loss should be at least 30 dB according to some[1] and at least 40 dB according to others.[2] The minimum air-bone gap should be 15 dB, as averaged in speech frequencies for some, others would not operate before a 20 dB air-bone gap.[2] More importantly the patient should experience his hearing loss as disturbing in everyday life before surgery is offered.[1]
- Indications for surgery are essentially the same whether the hearing loss is unilateral or bilateral. If for binaural disease, the stapedotomy at the first ear yields good hearing gain, the second ear can also be operated after a waiting period of about six months to one year, because useful binaural hearing is always preferred by patients. Useful binaural hearing enables patients to localize sound, and hear a talker better in a noisy environment, and this occurs when average air conduction thresholds of the two ears are no more than 30 dB apart.[1,2,4,6]
- In unilateral otosclerosis, the postoperative hearing thresholds often do not reach the thresholds of the completely healthy ear, so that subjective hearing gain is less spectacular.
- Stapes surgery must in theory not be carried out in patients with only one functional ear because of the small possibility (about 1%) of sensorineural loss.[1,2] The exception would be in a patient fully informed of the risk and aware that in this case the only alternative would be a cochlear implantation. Few experienced surgeons, however, are willing to perform this intervention because of the medico-legal implications.[4]
- Tinnitus is not a contra-indication for stapedotomy, and low-tone tinnitus may disappear after a well-performed stapedectomy.
- According to a large study at the House institute, stapedectomy does not increase the risk of inner ear barotraumas in scuba-divers and sky-divers. These activities may be pursued with relative safety following stapes surgery, provided adequate Eustachian tube function has been established.[2]
- In high performance pilots, Katzav *et al*.[6] found that flight status can be reinstated without endangering flight safety 3 months after stapes surgery.

Contra-indications for surgery

- Poor physical health.
- Balance problems, such as active endolymphatic hydrops or a fluctuating hearing loss.
- Pre-existing tympanic membrane perforation.
- Active external or middle ear infection.
- Inadequate air-bone gap confirmed by an audiogram and the 512 Hz tuning fork test.
- Inner ear malformations as visible on HRCT.

Decision algorithm



Counselling of candidates for surgery

Stapedectomy is an elective operation. In-depth counselling of the patient and providing preoperative information is hence of utmost importance. The mechanics of the hearing loss should be explained in detail, preferably with a suitable illustration.

Patients should be assured that it is very unlikely that they will become totally deaf. Patients who are suitable for stapes surgery should be told that they have the option of wearing hearing aids, and if they have any doubt about the decision to have surgery, they should be encouraged to have a trial period with hearing aids unless they are already wearing them.

Hearing improvement is strongly determined by the preoperative bone conduction level, and the patient must be aware of the degree of improvement that can be expected. The expected result as well as all possible risks, such as further or even total hearing loss, taste disturbance, dizziness, the effect on tinnitus, and the very small possibility of a partial or total facial paralysis, should be clearly explained.

The main problem of stapes surgery is the possible development of postoperative deafness, of which the incidence is estimated at 1%. The patient should be clearly informed about this serious complication.

Slight postoperative symptoms of vertigo occur fairly often in the first days after stapedectomy but less after stapedotomy. Tinnitus that is present preoperatively will not necessarily disappear, but often becomes less pronounced or even disappears altogether after surgery, probably because it is masked by the improved hearing. When hearing is worse after stapedectomy, tinnitus will likely increase.

The patient should be also informed that in rare cases a revision operation might be necessary. Persistence of conductive loss for at least 3-4 months after surgery may indicate a dislodged prosthesis, fixation of the malleus or incus, or necrosis of the distal end of the incus to which the prosthesis was attached. Re-exploration may be warranted, though results with revision surgery are less successful than with primary surgery.

Temporary dysfunction of the chorda tympani may occur in 15% to 30% but only in about 1% a slight dysgeusia persists permanently.

Iatrogenic lesions of the facial nerve after stapedectomy have occasionally been reported, mostly in cases with an abnormal anatomy of the nerve in the middle ear. Sometimes secondary, probably inflammatory, facial nerve paralysis occurs after a latent period of a few days, and is always reversible within a few weeks.

Addendum
Information to patients (Adapted from the information sheet given at the University of Minnesota)

What is otosclerosis?

Otosclerosis is an abnormal, microscopic growth of bone in the walls of the inner ear and causes the stapes bone to become frozen in place or “fixed” in the oval window. Normally the stapes, the smallest bone in the body, vibrates freely to allow the transmission of sound into the inner ear. When it becomes cemented to the surrounding bone it prevents sound waves from reaching the inner ear fluids, and hearing is impaired.

Occasionally the otosclerotic bone involves other structures of the inner ear so that, in addition to preventing sound from entering the ear, it causes a distortion or difficulty in understanding the speech of others, regardless of how loudly they talk. In such cases there is not only the “conductive” deafness already discussed, whereby sound waves are obstructed in reaching the inner ear, but in addition, “sensorineural” or “nerve” deafness, in which the function of the inner ear itself has been impaired.

Otosclerosis affects the ears only and not other parts of the body. When this condition is present, both ears are usually involved. It occurs more frequently in women and usually begins in young adulthood. Although otosclerosis tends to run in families, it does so irregularly; parents with otosclerosis do not necessarily transmit it to their offspring.

How is it treated?

There is no known medicine available for treating the stapes fixation due to otosclerosis. Although a hearing aid can be worn successfully by most patients, they prefer natural hearing if that is possible. Surgery has been found to be the most effective method of managing the stapes fixation due to otosclerosis.

The stapes operation is done using an operating microscope. The surgeon will first fold forward approximately one-half of the ear drum so that he can reach the area where the stapes is located. Part of the stapes is then removed with

fine instruments or/and the laser. A hole is made in the remaining footplate of the stapes. A "prosthesis" about 4 mm to 5 mm in length and between 0.4 mm and 0.6 mm in diameter then is introduced and secured in place to bridge the gap created by removal of the stapes.

Can I have the operation and what are my chances of its success?

An examination by an ear specialist, including a hearing test, is necessary to determine if you are a candidate for the operation. As you can imagine, there are many different causes of deafness; and in fact, not even all patients with otosclerosis are candidates for stapes surgery.

In some cases further imaging by CT scan can be recommended.

The chances of obtaining a good result from this operation are about 90%. This means that about 9 out of 10 patients will get an improvement of hearing up to the level at which their inner ear is capable of functioning. If the inner ear functions normally, then normal hearing can be restored. Approximately 7% of all patients have only partial recovery of hearing and 2% remain at the same level as before surgery. The main risk is a 1% chance of developing inner ear hearing loss following the procedure due to factors as yet not entirely understood. For this reason, only one ear is operated upon at a time, and the worst ear is always done first.

What should I be aware of before the operation?

If you would catch a cold one week or less prior to the date scheduled for your operation, you should report this to your doctor. For this operation a local anaesthetic or a general anaesthesia can be used depending on the patient's and surgeon's preference.

Because the stapes is so small, the operation is performed with the aid of a microscope. Under local anaesthesia you may notice improved hearing while still in surgery and notice a decrease later. Do not become alarmed, as this is due to ear packing, swelling, and fluid build-up from surgery. It may be several weeks before the full effect of surgery can be determined, as far as hearing is concerned. You may have occasional periods of dizziness during the first few days.

What can I expect after the operation?

The evening after the operation you should lie quietly on the unoperated ear. Do not be alarmed if you have some dizziness for the first few days after the operation.

The surgery usually takes about one hour.

Please do not:

- Blow your nose
- Remove any packing from your ear

Discharge instructions:

1. Do not get water in the ear
2. No strenuous exercise
3. Do not remove any packing
4. Notify your doctor of fever greater than 37°C, excessive pain, excessive drainage, or drainage that has an odour

Some possible side effects

Stapedectomy is a well established and proven operative procedure with a 90% or greater success rate. Potential but unusual side effects include:

1. Change in sense of taste on the same side of the tongue
2. Vertigo: usually resolves spontaneously
3. Lack of hearing improvement
4. Perforation of the tympanic membrane
5. No change in tinnitus
6. Intolerance of very loud noises

The authors wish to thank the other members of the subcommittee for reading this guideline on otosclerosis and their appreciated comments: Duterme J-P., Franceschi D., Maisin J-P., Thill M-P., Van den Abeele D.

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Th. Somers
University ENT Department
Sint-Augustinus Hospital
Oosterveldlaan 24
B-2610 Wilrijk, Belgium
E-mail: thomas.somers@gvagroup.be

CME questions

1. Epidemiology: find the false statement.

   A – Otosclerosis is usually characterized by a slow progressive conductive hearing loss
   B – Females are affected more often
   C – Oral contraceptives causes a higher incidence of otosclerosis
   D – The prevalence is lower among Asians
   E – Has a histological prevalence which is ten fold the clinical prevalence

2. Diagnosis: find the false statement.

   A – A positive family history is found in about half of the patients
   B – Vestibular disorders do not occur with otosclerosis
   C – During Weber's test sound lateralizes to the ear with the greatest air-bone gap
   D – The on-off effect as recorded during tympanometry with stapedial reflex testing is an interesting finding of early stage otosclerosis
   E – Ct scanning can not always detect an otosclerotic focus confirmed by surgery

3. Surgery: which condition can also be operated by a stapedotomy?

   A – Abnormal high perilymph pressure
   B – Ossicular discontinuity
   C – Malleus head fixation
   D – Congenital absence of oval window
   E – Osteogenesis imperfecta

4. Which treatment modality is never used today for otosclerosis?

   A – Cochlear implantation
   B – Stapes surgery
   C – Sodium fluoride
   D – Hearing aid
   E – Middle fossa approach to decompress the internal auditory canal

5. Surgery should not be recommended in patients when:

   A – The hearing loss becomes difficult in everyday life
   B – Audiometric and tuning fork tests are inconsistent
   C – The worse hearing ear is considered
   D – Average bone conduction is better than 30 dB
   E – CT scanning does not show an otosclerotic focus

6. Which is not a clear contra-indication?

   A – Patient older than 70 years
   B – Poor physical health
   C – Active middle ear inflammation
   D – Inner ear malformation as visible on high resolution CT imaging
   E – Active Menière's disease

Answers: 1C; 2B; 3E; 4E; 5B; 6A

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Ménière's disease

P. H. Van de Heyning, C. F. J. De Valck*, A. Boudewyns*, T. Cammaert**, S. Casteleyn***, N. Deggouj***, F. Gordts****, G. Forton*,*****, Ph. Lefebvre****** and Th. Robillard********

*University of Antwerp, Antwerp University Hospital, Antwerp; **Department of Otorhinolaryngology, St Lucas General Hospital, Ghent; ***Department of Otorhinolaryngology, University Hospital St Luc UCL, Brussels; ****Department of Otorhinolaryngology, University Hospital Free University, Brussels; *****Department of Otorhinolaryngology, Heilig Hart General Hospital, Roeselare; ******Department of Otorhinolaryngology, Sart Tilman University Hospital University, Liège; *******Department of Otorhinolaryngology, Clinique Sainte-Elisabeth, Namur

Key-words. Guidelines; Ménière's disease; inner ear; treatment.

Abstract. *Ménière's disease.* Ménière's disease is an idiopathic inner ear disorder characterized by endolymphatic hydrops (ELH), vertigo attacks, sensorineural hearing loss, tinnitus and pressure sensation in the affected ear. The disorder has to be differentiated from known causes of ELH and from other disorders provoking similar symptoms. Ménière's disease can seriously affect quality of life, and medical support is often necessary on a life long basis. The treatment modalities are counselling, preventive measures and life style adaptation, drug therapy, tinnitus coping, provision of hearing devices, and sometimes surgery. We review the indications for these modalities, and the evidence level of their beneficial effect.

1. Definition

In Ménière's disease, also called idiopathic endolymphatic hydrops (ELH), the endolymphatic compartment of the inner ear expands.[1] The clinical picture comprises recurrent spontaneous episodes of rotatory vertigo, fluctuating sensorineural hearing loss (SNHL), and tinnitus with or without aural fullness on the affected side. Patients suffering from Ménière's disease typically experience the vertigo attacks as the most debilitating symptom due to its unpredictable nature. The vertigo attacks may last from several minutes to several days. During attacks, patients experience neurovegetative symptoms and are usually unable to pursue normal life. After an attack, patients are exhausted and may experience disequilibrium for days. During active disease, most patients have a seriously diminished quality of life and anxiety or depression often develop. In a prospective study of 243 patients, Havia and Kentala found that the proportion of patients reporting severe or very severe attacks increased with the duration of the disease.[2]

Patients with long-standing Ménière's disease in which vertigo attacks ceased, also report reduced quality of life because of a significant sensorineural hearing loss and tinnitus.[3] A limited number of patients affected with Ménière's disease exhibit sudden falls without loss of consciousness or associated vertigo: the so called 'otolithic crises of Tumarkin' or drop attacks.

Up to 25% of the patients with Ménière's disease may eventually require a surgical procedure to control the vertigo attacks.

2. Epidemiology

Throughout the world, the reported incidence and prevalence of Ménière's disease varies by a factor of 10. In the US, the prevalence is about 200 per 100.000 persons and the incidence about 15 per 100.000 persons per year. Prevalence estimates obtained from Japanese and Scandinavian populations yielded much lower figures: 20 and 45 per 100.000 persons, respectively. Ménière's disease typically starts between the age of 20 and 50 years with a diagnosis rate proportional to the age of 60. Men and women are probably equally affected. In about 1/2 to 2/3 of the cases, Ménière's disease affects only one ear. In bilateral cases, the second ear is mostly affected within five years after onset of the disease.[4]

3. Pathophysiology

Per definition, the cause of Ménière's disease is unknown. ELH is commonly believed as the result of an abnormal fluid balance in the inner ear that can be

caused by many factors. New insights into normal cell biology will reveal new pathophysiologic pathways leading to ELH.

Dunnebier *et al.*[5] developed a guinea pig model for Ménière's disease by slight destruction of the endolymphatic sac and stimulation of the endolymph production with aldosterone. Different aspects of cochlear physiology in this animal model have been studied. Warmerdam *et al.*[6] found an abnormal endocochlear potential but, surprisingly, no increased pressure in the scala media. The same research group found that the resistance for fluid flow through the cochlear aquaduct, which connects the scala tympani with the cerebrospinal fluid space, depends on the position of the round window membrane, which can be manipulated with the Meniett device and aquaporin involvement.[6]

3.1. *Classification of ELH*

ELH in temporal bones of patients with Ménière's disease was for the first time observed by Hallpike and Cairns in 1938.[7] Ever since, ELH plays a central role in our hypotheses about the pathophysiology of Ménière's disease: a vertigo attack is believed to result from an acute volume increase of the endolymphatic compartment with rupturing of the membranous labyrinth and release of high amounts of K^+ in the perilymphatic space. Repeated rupturing of membranes is believed to cause progressive destruction of the labyrinth with eventually a profound deafness and disappearance of the vertigo attacks.

Based on clinical case reports and temporal bone studies, Schuknecht and Gulya proposed a classification of ELH according to aetiology. They distinguished embryopathic, idiopathic and acquired ELH. Embryopathic ELH results from a prenatal developmental disorder, and is associated with morphological anomalies like Mondini's malformation or a decreased space between the posterior semicircular canal and the subarachnoid space. Acquired ELH may occur after trauma of the labyrinth, infection, inflammation, auto-immune processes, and genetically mediated involution. ELH provoked by food substances or allergens could be classified as acquired.[8]

3.2. *Endolymphatic Hydrops and Ménière's disease*

ELH can explain a great deal of Ménière's disease, but many questions remain. An alternative view is that Ménière's disease reflects a neuroganglionitis and that ELH is merely an epiphenomenon.[9]
Improved imaging of the inner ear and fundamental research will be necessary to better understand Ménière's disease.

3.2.1. Evidence for ELH

Histological studies of temporal bones of patients with Ménière's disease provide strongest evidence for ELH. These studies consistently find that ELH is more pronounced in the cochlea and sacculus than in the utriculus and semicircular canals.[9-10]

Other data in support of ELH is based on electrocochleography (ECoG). Patients with Ménière's disease often (50-70%) have a large summating potential that can be reduced after administration of hyperosmotic substances.[11] In animal models, blockage of the endolymphatic canal or foreign protein deposition in the perilymph causes an ELH that is associated with hearing loss at low frequencies.

Morphological temporal bone features that limit extension of the endolymphatic sac or circulation of fluid are predisposing for ELH. These features include a decreased distance between the posterior semicircular canal and the subarachnoid space, a lack of visualisation of the endolymphatic duct on MRI, and an apical and middle cochlear segment displacement related to a reduced endolymphatic sac volume.[12]

3.2.2. Evidence against ELH

The absence of ELH in temporal bones of some Ménière's disease subjects, and the presence of ELH in some subjects who did not have Ménière's disease, place the significance of ELH for Ménière's disease in doubt.[10] Histopathologic findings other than ELH are found in temporal bones of patients with Ménière's disease: perilymphatic fibrosis, loss of spiral ganglion cells innervating the apical cochlea, and axonal degenerations. ELH is present in animal models of Ménière's disease, but these animals do not exhibit vestibular symptoms, and perilymphatic fibrosis is not found in their temporal bones.[9] In addition, few patients with Ménière's disease who received a cochlear implant, showed fluctuations of hearing performance. Moreover, hyperosmotic or diuretic agents, which are supposed to reduce hydrops, do not improve the subjective and objective symptoms in all patients with Ménière's disease.[11]

3.3. *Other pathophysiological factors*

Many factors can trigger a crisis of Ménière's disease symptoms. It

has been suggested that food and air-born allergens can trigger a crisis, but up until now, corresponding antibodies have not been detected. For some patients intake of caffeine, alcohol, or chocolate increases the frequency of attacks. Sometimes, a middle ear infection triggers an attack, and even weather changes can trigger an attack.

Auto-immune disorders of the inner ear can provoke ELH with rapidly progressive bilateral symptoms that respond to immuno-suppressive treatment. Ménière's symptoms are observed in some genetic cochleovestibular disorders, especially DFNA9.[13] Above all, psychosomatic factors play an important role in Ménière's disease: increased stress can trigger a crisis and disturbances in the personal of professional life are associated with a reactivation of the disease.

4. Diagnostic management

4.1. *Diagnostic criteria for Ménière's disease (recommendation A)*

The committee on Hearing and Equilibrium of the American Academy of Otolaryngology-Head and Neck Surgery suggested guidelines for reporting and evaluation of therapy in Ménière's disease (Committee AAO-HNS 1972, 1985, and 1995).[1] Nowadays, these guidelines are widely accepted and provide a solid framework that is applicable in the clinic. According to the guidelines, diagnosis of Ménière's disease is based on clinical symptoms and exclusion of identifiable "other causes". Four degrees of diagnostic certainty are defined: certain, definite, probable and possible Ménière's disease

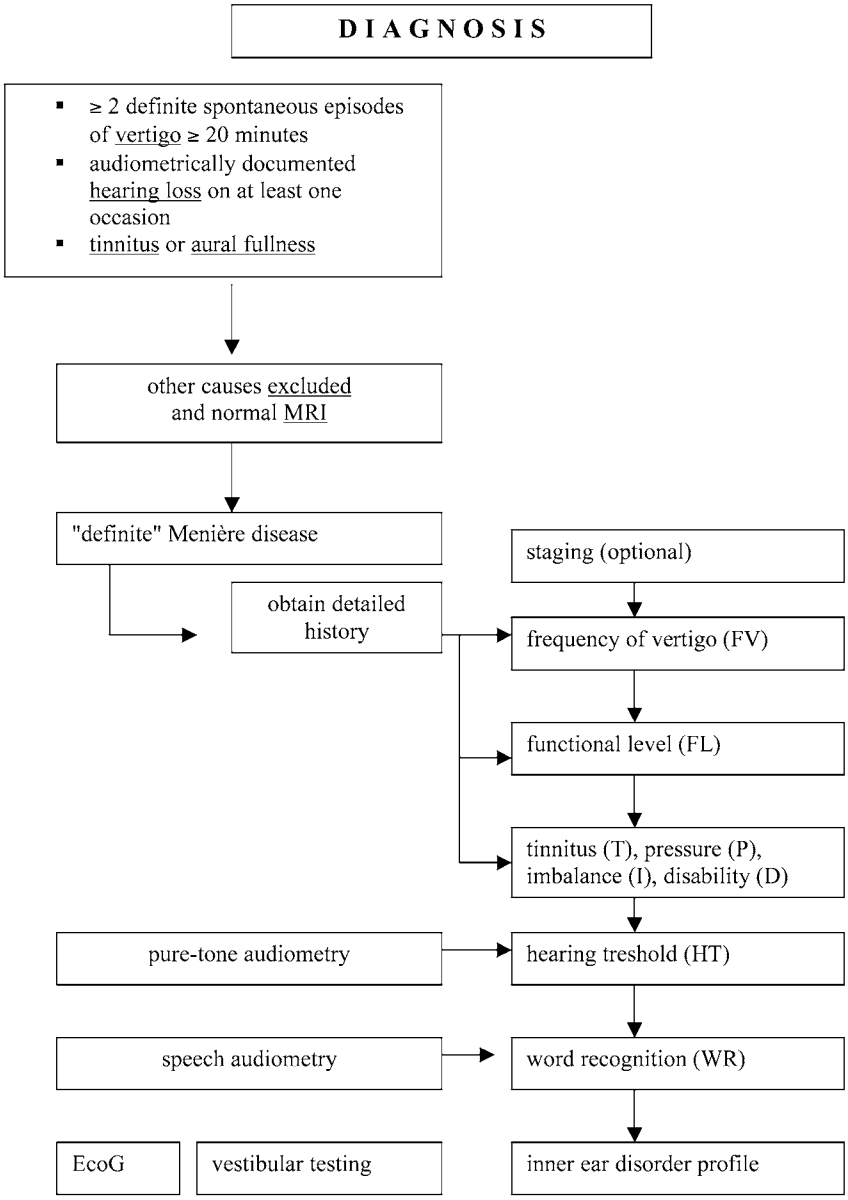

Figure 1
Diagnostic algorithm

(Table 1). Additional evidence for ELH can be provided with electrocochleography, auditory and vestibular testing.

Table 2 lists "other causes" of Ménière-like diseases that must be excluded using any diagnostic technique available (e.g. microscopic otoscopy, medical imaging including contrast enhanced MRI and high definition CT scan, virtual endoscopy, hematological, serological, biochemical and genetic tests). Taking into account the numerous reports of pathological findings in Ménière's disease, it is the opinion of the authors that at least once during the course of the disease a MRI scan with gadolinium enhancement of the posterior fossa should be performed (recommendation B). Associated

Table 1

Diagnostic criteria of Ménière's disease

(Following Committee AAO-HNS 1995)
Certain Ménière's disease Definite criteria and histopathologic evidence of ELH (E.g., postmortem analysis).
Definite Ménière's disease $\geq$ 2 definite spontaneous episodes of vertigo lasting longer than 20 minutes. Audiometrically documented hearing loss on at least one occasion. Tinnitus or aural fullness.
Probable Ménière's disease Idem but only one occasion.
Possible Ménière's disease Episodic vertigo without documented hearing loss. Sensorineural hearing loss (fluctuating or fixed) with disequilibrium.
For all classes other causes excluded

Table 2

Differential diagnosis for Ménière's disease

Inner ear disorders
Congenital disorders
Semicircular canal dehiscence
Large Vestibular Aqueduct Syndrome
Infections
Bacterial and viral labyrinthitis
Vestibular neuritis
Inflammations
Auto-immune inner ear disorder
E.g. syphilis
Cogan syndrome
Benign Positional Paroxysmal Vertigo
Vascular
Genetic and metabolic
DFNA9
Otosclerosis
Post-traumatic and post-surgery
Perilymphatic fistula
Central Nervous System pathology
Cerebellopontine angle tumours
Vestibular Schwannoma
Petroclival meningeoma
Endolymphatic sac tumours
Epidermoid cysts
Other tumours
Neurovascular conflict with N VIII
Demyelinizing disorders
E.g., multiple sclerosis
Vertebrobasilar insufficiency
Migraine and vestibular migraine
Side effects of drugs and toxic polluents

pathology needs to be assessed e.g. thyroid disease or auto-immune pathology.

It is good practice to challenge the diagnosis of Ménière's disease repeatedly during the course of the disease. Differential diagnosis with migraine associated vertigo, auto-immune inner ear disorders, neuro-vascular conflict in the cerebello-pontine angle and vertebro-basilar insufficiency may be difficult.

4.2. *Guidelines for a multidimensional description*

4.2.1. Basic reporting (recommendation A)

The standard guidelines of the AAO-HNS imply a multidimensional description of Ménière's disease. The basic elements are pure-tone sensitivity, word recognition, number of vertigo attacks lasting at least 20 min, and functional level rating. Researchers are of course free to quantify other aspects of the disease such as tinnitus, aural fullness, quality of life, OAEs, ECoG. Reporting raw data prior to statistical processing is recommended. Characterising patients with Ménière's disease using the basic elements is not only useful for research purposes but also helps in making the best treatment choice.

4.2.1.1. Hearing threshold (HT)

Hearing loss is an important qualifier of Ménière's disease. The AAO-HNS guidelines advise the use of the arithmetic mean of the pure-tone thresholds at 0.5, 1, 2, 3 kHz. If 3 kHz is not available, it can be replaced by the mean of 2 and 4 kHz.

Based on hearing loss, patients can be categorized into four stages (Stage 1: HT $\leq$ 25 dB; Stage 2: HT between 26-40 dB; Stage 3: HT between 41-70 dB; Stage 4: HT > 70 dB). The frequency profile of the hearing loss is not taken into account for diagnosis. A SNHL that predominates low frequencies is often found in patients with Ménière's disease, but is insufficient to label as possible Ménière's disease because only a

minority of the patients with low frequency hearing loss without vertigo attacks develop definite Ménière's disease.

4.2.1.2. Word recognition (WR)

Concerning reporting the speech discrimination performance for monosyllabic words, maximum phoneme score expressed in percent is the metric of choice.

4.2.1.3. Frequency of vertigo (FV)

When considering the frequency of the vertigo attacks, the patient's complaints should be evaluated over a period of 6 months. The average number of rotatory spells lasting at least 20 minutes is commonly used as the index for reporting FV.

4.2.1.4. Functional level (FL)

In any patient-centered treatment, quality of life is a central concern. The AAO-HNS guidelines provide a 6 grade functional level scale relevant to Ménière's disease: the patient is asked to mark the description which fits best with his/her condition (Table 3).

4.3. *Reporting additional characteristics (recommendation B)*

Apart from the basic elements of the AAO-HNS guideline, additional metrics that quantify other symptoms of the disease may be reported: semi-quantitative data on tinnitus (T), pressure (P), imbalance (I), disability (D), indexes of ECoG, vestibulo-ocular reflex, postural stability, and quality of life questionnaires for patients suffering from vertigo.

4.3.1. Tinnitus, pressure and imbalance-dizziness

Initial guidelines of the International Prosper Ménière's Society suggested grading of tinnitus, pressure, and imbalance according to a 7 grade scale: the inner ear disorder profile.

Two reporting instruments for complaints that are difficult to quantify prevail: the visual analogue scale (VAS) and validated quality of life (QOL) questionnaires. With the VAS, the patient indicates a value between 0 (no symptom awareness) and 10 (maximal imaginable intensity). In Ménière's disease, the VAS is mainly used for tinnitus and ear pressure. Disease specific QOL questionnaires are available for dizziness and for tinnitus.

Recently, Kato *et al.*[14] used an 18-item questionnaire for evaluating the outcome of endolymphatic sac decompression in patients with Ménière's disease.

4.3.2. Electrocochleography

During ECoG, sound evoked electrical activity near the cochlea is recorded. This technique is not widely available and therefore not included as a basic element of the AAO-HNS guidelines. Nevertheless, ECoG can ascertain the presence of ELH (recommendation B). From the recorded signal, two metrics are extracted: the amplitude of the action potential (AP) and the amplitude of the summating potential (SP). The SP/AP-ratio is most useful for the diagnosis of ELH but normative data differ with stimulus parameters and equipment. With click stimuli, following values are indicative for hydrops:

– Extratympanic ECoG (ET-ECoG) (click stimulation): SP/AP ratio > 0.42.
– Transtympanic ECoG (TT-ECoG) (click stimulation): SP/AP ratio > 0.35.

With pure tone bursts stimulation and TT-ECoG, an SP < -2 μV is suggestive for ELH.[15]

Some authors claim that the diagnostic value of ECoG can be enhanced by administration of dehydrating substances prior to the recordings. For most of the patients with fluctuating hearing loss, ECoG is crucial in establishing the diagnosis of ELH.

Middle ear infection, effusion, liquorrhea, and former surgery

Table 3

Functional level according to AAO-HNS

Regarding your current state of overall functioning, not just during attacks, check the ONE that best applies:
1. My dizziness has no effect on my activities at all.
2. When I am dizzy, I have to stop what I am doing for a while, but it soon passes and I can resume activities. I continue to work, drive and engage in any activity I choose without restriction. I have not changed any plans or activities to accommodate my dizziness.
3. When I am dizzy, I have to stop what I am doing for a while, but it does pass and I can resume activities. I continue to work, drive and engage in most activities I choose, but I have had to change some plans and make some allowance for my dizziness.
4. I am able to work, drive, travel, take care of a family or engage in most essential activities, but I must exert a great deal of effort to do so. I must constantly make adjustments in my activities and budget my energies. I am barely making it.
5. I am unable to work, drive or take care of a family. I am unable to do most of the active things that I used to. Even essential activities must be limited. I am disabled.
6. I have been disabled for one year or longer and/or I receive compensation (money) because of my dizziness or balance problem.

may constitute a contra-indication for TT-ECoG. In case of a contralateral deaf ear, use of ECoG should be conservative.

4.3.3. Vestibular testing

As with all other single disease parameters, vestibular testing cannot establish the diagnosis itself, but is useful for differential diagnosis, and for determining the functional status of the labyrinths. Dynamic posturography, gait and balance tests assess the vestibulospinal reflexes. Vestibular findings in patients with Ménière's disease are highly variable and well documented.[16]

5. Therapeutic management

Nowadays, no cure for Ménière's disease has been proven. Nevertheless, different treatment modalities can significantly improve the patient's quality of life. Management of Ménière's disease is focussed on the vertigo attacks: reducing the symptoms during an attack, and reducing the chance for new attacks.

5.1. *Treatment of attacks*

In case of an attack, treatment aims at reducing the rotational sensation and neurovegetative symptoms. A number of drugs can be given (recommendation B): anti-emetic drugs (e.g. domperidone), vestibulosedative anti-histamines (e.g. meclizine), and central sedative drugs with vestibulo-suppressive and anti-emetic effect (e.g. diazepam, sulpiride, dihydrobenzperidol, and phenothiazine) (evidence based medicine (EBM) Level II). Because of nausea and vomiting, intra-rectal or parenteral administration is often necessary. No studies demonstrate superiority of one of those products for an acute attack.

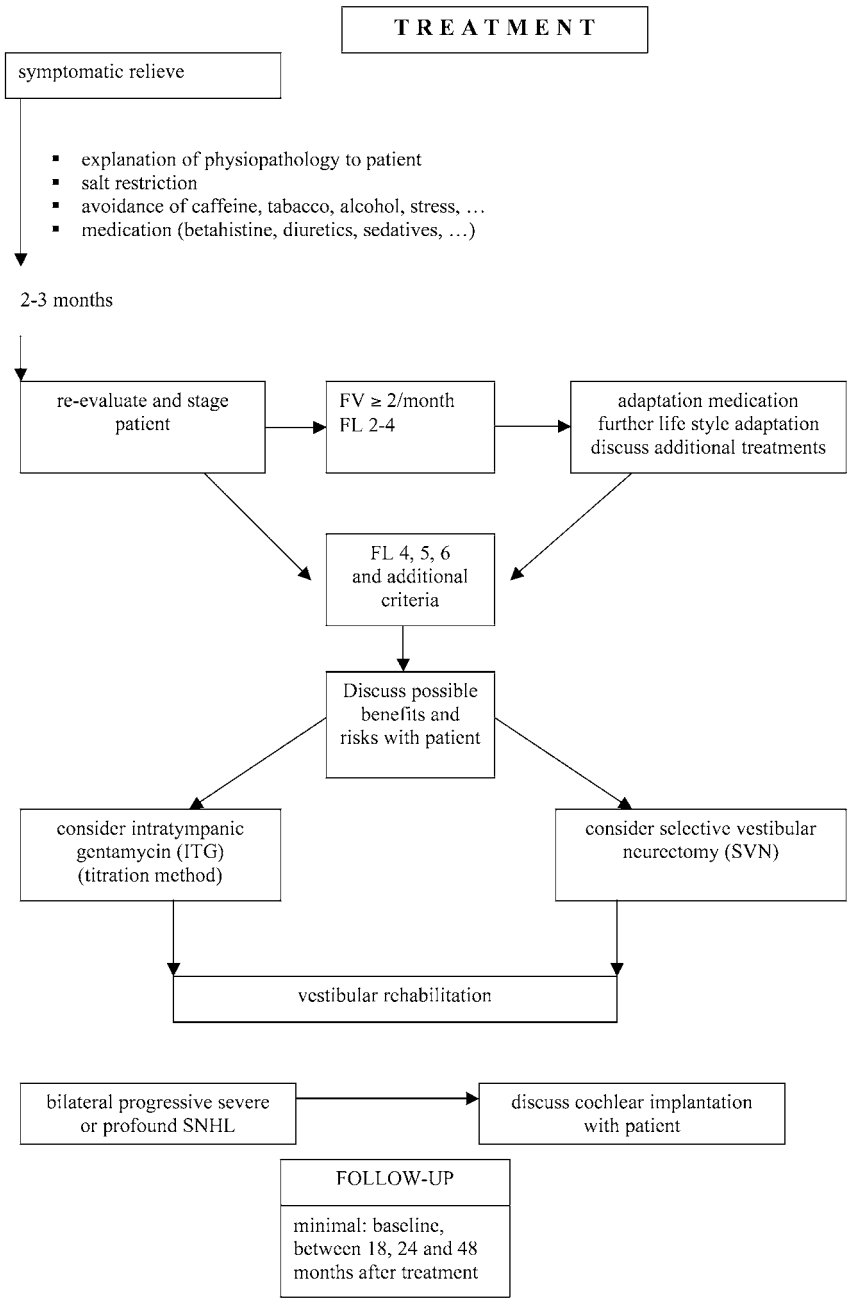

Figure 2
Treatment algorithm

Fattori *et al.*[17] administered hyperbaric oxygen during the early stages of the disease and found a long term protective effect. His findings, however, are under debate (EBM III; recommendation C). Findings from animal research also supports the use of hyperbaric oxygen therapy.

5.2. *Long term treatment*

Apart from treating vertigo attacks, medical support for patients with Ménière's disease can aim at reducing the number of vertigo attacks, compensating the

vestibular deficit, improving the patients coping strategies, and providing hearing aids. Practically, the physician provides information on the disease, suggests life style changes, prescribes medication and rehabilitation, and sometimes performs surgery.

5.2.1. Counselling and life style adaptations (EBM level II; Recommendation B)

During counselling, the physician has to explain gently what the patient may expect from the disease, and from medical support. Patients with basic knowledge about their illness will be able to cope more efficiently with a disease.

The physician should inform that the natural course of the disease is highly variable, that the diagnosis is described in terms of chance, that current knowledge is very limited, and that periodic evaluations are necessary. The coordinates of patient associations can be given.

Life-style adaptations consist of reducing salt, caffeine, alcohol, tobacco, and improving coping styles. Working in shifts should be avoided, and regular sleeping habits should be respected. Many patients can very well designate the event that provoked a vertigo attack. In exceptional cases, psychological support may be indicated.

5.2.2. Chronic drug therapy

Drug therapy plays an important role in the treatment of most patients with Ménière's disease. Since the late 80's, solid comparative studies reported the success of betahistine in reducing the frequency and severity of vertigo attacks without impairing vestibular compensation (EBM II; recommendation B).

In the same period some studies reported also the benefit of diuretics (EBM level II; recommendation B). However, it is still controversial whether acetazolamide is also a beneficial diuretic (recommendation C).

It is important to know that in case of pregnancy or lactation, betahistine cannot be given (class D product) and that antidiuretics are to be avoided (class C product: to be used if unavoidable, no teratogenic effects known). When subsequent to an acute attack, imbalance is a dominant complaint, mild vestibular sedatives (e.g. cinnarizine) may help.[18]

In case of bilateral Ménière's disease, inflammatory influences should be suspected, and systemic glucocorticoids may be necessary for a short period. It has recently been proven that glucocorticoids do not only influence inflammation, but also fluid dynamics via interaction with Na^+-pumps in the semicircular canals.[19] In case of reponse to glucocorticoids, an auto-immune inner ear disorder with ELH has to be suspected.

The presumed beneficial effect of intra-tympanic corticosteroid application is transient, and recently a working group decided to exclude this therapy modality for Ménière's disease.[20]

If the physician has the impression that anxiety and inefficient coping with stress dominate a patient's complaints, gaba-antagonist (e.g. alprazolam and serenase) can be administred for a short period.

5.2.3. Vestibular rehabilitaton (recommendation C)

Vestibular rehabilitation improves central compensation of a peripheral vestibular deficit and its resulting motion intolerance (EBM level I). Ménière's disease patients also benefit from this therapy. When a patient with Ménière's disease develops benign paroxysmal positional vertigo, a canalith repositioning procedure should be attempted (recommendation B). In case of nausea and oscillopsia due to nystagmus, prism spectacles of Utermohlen can be prescribed.

5.2.4. Incapacitating vertigo resistant to drug treatment

If the aforementioned drug treatments fail to control the vertigo attacks (e.g. FV $\geq$ 2/month, FL 2-4), other therapeutic modalities can be proposed. As previously mentioned, treatment effect should be evaluated over a period of at least 6 months.

First we will describe four treatment modalities that are useful for intractable Ménière's disease and that are not based on destruction of the peripheral vestibular system. The effect and most appropriate timing of these modalities are still under investigation, and thus, our recommendations are based on individual experience (no EBM; no recommendation).

1. Transtympanic pressure treatment (Meniett™, Medtronic Inc. USA) with tympanostomy tube initially yielded promising results, but the effects may be limited to reducing the duration of the attacks, and are less effective when administered during end-stage disease.[21]
2. Repetitive administration of hyperbaric oxygen has recently been introduced by Fattori *et al*.[17] who found long term protective effects.

3. Endolymphatic sac decompression has been criticized heavily, but is frequently performed in the USA.[14]
4. Franz *et al*.[22] revisited the hypothesis that middle ear muscles play a role in the etiology of Ménière's disease and found that tenotomy of the musculus tensor tympani and stapedius had a long term protective effect for patients with Ménière's disease.

Treatment modalities that destroy the peripheral verstibular system gained EBM level I evidence for incapacitating (FL 4, 5, 6) Ménière's disease. Vestibular deafferentiation can be achieved with intra-tympanic gentamycin application (ITG), labyrinthectomy, and selective vestibular neurectomy (SVN).

The advantage of ITG is its mildly invasive nature, and high success rate. The dosing and titration regimen determine the outcome and complication rate. The main bottle-neck of ITG is the inability to estimate the permeability of the round window membrane, and hence the optimal gentamycin dosage.

SVN yields maximal control of the vertigo attacks (> 95%), but is a relatively invasive otoneurosurgical procedure. Labyrinthectomy is somewhat less effective than SVN and excludes cochlear implantation if necessary. After an ablative procedure, vestibular rehabilitation is required as it supports central compensation (EBM II).

The pros and cons of ablative procedures must be notified to the patient:

– Persistent, troublesome disequilibrium in 20% of cases after surgical procedures.[23]
– A higher risk for SNHL with ITG (15% all procedures) compared to SVN (less than 10%).[24]

Improvement was observed in half of the patients to such an extent that SVN was not longer necessary 6 weeks after proposing a SVN and explaining the risks and benefits.[25] Relative contra-indications for ablative procedures are contralateral Ménière's disease, contralateral vestibular areflexia and any other visual, proprioceptive or CNS pathology that impairs vestibular function.

5.2.5. Hearing loss with Ménière's disease

Up until now, no proven therapy can reduce the loss of cochlear function in Ménière's disease. We, however, believe that preventive measures and life style adaptations offer the best perspectives. For many patients, when vertigo attacks ceased, hearing loss is the major problem. From an audiological point of view, the hearing loss has all characteristics of a SNHL: increased thresholds, recruitment, and reduced frequency selectivity. When compared to SNHL due to age, loudness recruitment associated with Ménière's disease is more pronounced. As a consequence, amplications gains preferred by patients with Ménière's disease differ from those with a common SNHL.

In many cases, speech recognition scores of aided hearing are disappointingly low. In case of bilateral profound SNHL due to bilateral Ménière's disease, good results were achieved with cochlear implantation. For unilateral profound SNHL, a bone anchored hearing aid (BAHA) may improve the hearing capabilities. With BAHAs, preliminary data demonstrate significant improvement of severe tinnitus in unilateral profound SNHL due to Ménière's disease.

Different tinnitus treatments are available and can be offered (e.g. tinnitus retraining therapy), but results focussed on patients with Ménière's disease have not been reported.

6. Patient information

6.1. *Counselling*

Comprehensive information of all aspects of Ménière's disease should be provided and is highly appreciated by all patients with Ménière's disease. A realistic picture of the disease and reassurance has to be given, because many patients experience considerable anxiety in the period prior to diagnosis.

More difficult, but necessary, is dealing with what is known, not known, and uncertain. As medicine progresses, underlying pathologic processes will be uncovered, and reassessments will be necessary. It is also useful to inform close family members, as the occurrence of repeated attacks is sometimes misinterpreted. Patient groups can offer appropriate information and support to individuals with Ménière's disease and their family. The Flemish Ménière's disease patient group has as website: www.meniere.be. The French Ménière's disease patient group is: Entraide Ménière ASBL, 87 rue des Floralies Bt77, 1200 Bruxelles, tel. 02 762 91 83, E-mail entraidemeniere@hotmail.com, website www.entraidemeniere.be.

6.2. *Follow-up*

The diagnosis of Ménière's disease is based on history, measuring of hearing loss, and

exclusion of "other causes". The history of the complaints and self-appraisal guides the therapy. For this reason, a detailed baseline and semi-quantitative documentation of complaints is instrumental for optimal treatment:

– frequency, duration, severity of vertigo attacks
– imbalance assessed on the dizziness handicap inventory
– hearing difficulties and hyperacousis
– tinnitus disability
– pressure sensation in the ear

Also secondary or associated complaints have to be assessed:

– depression and anxiety
– headache

Aspects concerning work limitation and driving capabilities have to be discussed. So-called "safety functions" are not allowed until the disease is under control. Patients sometimes need some time off work. Especially when severe Tumarkin otolithic crises occur, patients may not drive a car for at least 3 months after the last attack.

Treatment of vertigo comprises three steps

Step 1: counselling and life style adaptation
Step 2: chronic drug therapy and vestibular rehabilitation
Step 3: (partial) destruction of the vestibular epithelium input

Special attention is paid to hearing and tinnitus.

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Prof. Dr. Paul Van de Heyning.
Univ. Dept. ORL
Antwerp University Hospital
Wilrijkstraat 10
B-2650 Edegem, Belgium
E-mail: Paul.van.de.Heyning@uza.be

CME questions

1. The diagnosis of Ménière's disease is based on the clinical triad of symptoms consisting of recurrent vertigo, hearing loss and tinnitus or ear pressure combined with one of the following elements: (please indicate).

   A – Fluctuating low-tone sensorineural hearing loss
   B – Exclusion of other diagnoses (e.g. with MRI)
   C – Positive Electrocochleography
   D – Vestibular hypo-reflexia

2. Concerning the underlying pathophysiology of Ménière's disease: which statement is not true?

   A – Vertigo attacks can be caused by intra-labyrinthine membrane ruptures
   B – In endolymphatic hydrops there is mainly a volume increase of the endolymphatic compartment without measurable pressure increase
   C – Ménière's disease is always accompanied with endolymphatic hydrops and vice versa
   D – Endolymphatic sac dysfunction is a factor in Ménière's disease

3. Secondary endolymphatic hydrops may arise in following disorders except one: please indicate:

   A – Acoustic neuroma
   B – Otosclerosis
   C – DFNA9 Coch gene mutation
   D – Migraine associated dizziness

4. Definite Ménière's disease at first presentation is treated as follows. Indicate what is wrong (one statement).

   A – Salt, caffeine and alcohol
   B – Stress reduction
   C – Intra-tympanic gentamycin therapy
   D – Chlorothiazide treatment

5. Several conditions form the indication for ablative vestibular treatment. Indicate what is wrong (one statement).

   A – Profound sensorineural hearing loss
   B – Vertigo attacks not responding substantially to medical treatment during a 6 month period
   C – Comprehensive patient information on the aim and adverse effects of the treatment
   D – Moderate to severe degree of handicap (as assessed by the functional level scale)

Answers: 1B; 2C; 3D; 4C; 5A

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Tinnitus

A. Englebert, Th. Robillard*, C. Gilain**, M-P. Thill***, A. Boudewyns**** and P. Van Cauwenberge******

*Clinique Sainte Elisabeth, ENT dept., Namur; ** Cliniques Universitaires de Mont-Godinne, ENT dept.,Yvoir; ***CHU Saint-Pierre, ENT dept, Bruxelles; ****UIA, University Hospital, ENT dept, Antwerp; *****UGent, Department of Otorhinolaryngology, Gent

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Abstract. *Tinnitus.* This article is based on a review of the literature and the experience of some experts. Its goal is to present an overview of the physiopathology of tinnitus and perspectives of treatment based on recent publications. Tinnitus is a problem of society, affecting about 10% of the population. The causes of tinnitus are extremely diverse. Objective tinnitus is generally pulsatile and from arterial or venous origin; subjective tinnitus can be generated at any level of the auditory pathways. Approach to tinnitus includes qualification through anamnesis and specialized questionnaires, and thorough audiological characterization. Sometimes, imaging is indicated as it can reveal the cause of the tinnitus in case of a vascular abnormality or a retro-cochlear tumour. Among the various medications prescribed for tinnitus, only anti-depressants proved to be efficient when secondary depression is present. Hearing aids are useful for hearing impaired patients but the efficiency of tinnitus maskers is not proved. Tinnitus Retraining Therapy is very promising but results must be confirmed by future studies. Studies about neurostimulation are in progress. In the future, better understanding of the physiopathology of tinnitus will lead to new treatments.

Foreword

When one studies the literature of tinnitus, many different approaches are found but no study meets the EBM level I criteria. Therefore, any guideline on tinnitus management should be considered as a support rather than a strict protocol with information about what must be done to diagnose or treat.

Definition

Tinnitus (from the Latin *tinnire*, which means to ring or to tinkle) refers to the sensation of any sound perceived in the head or in the ears without an evident external stimulus.[1] Two main types can be identified: objective tinnitus which is caused by sounds generated somewhere in the body and subjective tinnitus, which is the perception of meaningless sounds without any physical sound being present.[2] Tinnitus should be differentiated from auditory hallucinations, which are perceptions of meaningful sounds, such as music or speech and are generally considered as a symptom of psychiatric or neurological disease.

Prevalence

Throughout life, most people occasionally experience tinnitus, and a high proportion of normal hearing subjects experiences tinnitus in a sound proof booth (64% in a group of 120 normal hearing volunteers). Studying the prevalence of tinnitus is difficult because tinnitus is subjective and therefore not amenable to straightforward quantification. Nevertheless, the epidemiological aspects of tinnitus are well established: tinnitus is highly prevalent throughout the world, and increases with age, amount of hearing loss, and amount of noise exposure.[3] According to the US National Centre for Health Statistics, tinnitus affects up to 30% of the adult population, with 6% of these individuals reporting incapacitating symptoms.[4] A British National Study of Hearing in 1978 found that at least 8% of persons with tinnitus, experience it as a moderate to severe annoyance or causing interference with sleep. Only 0.5% of them reported tinnitus as severely reducing their ability to lead a normal life and as causing depression and anxiety. A large scale Swedish study reported somewhat higher figures: 2.4% of the adults report that their tinnitus annoys continually. In 1996 the US National Centre for Health Statistics found that the prevalence of tinnitus was 3%, when all ages were considered. In fact the prevalence was 1% under the age of 45 and 9% over the age of 65.

Etiology

The possible aetiologies of tinnitus are extremely diverse. Table 1 gives an extensive listing of conditions that are possibly associated with tinnitus. In many of these diseases, tinnitus is not the major complaint. In a small number of patients, the tinnitus is a pulsatile sound that synchronizes to the heartbeat or the respiration. For these patients, tinnitus is likely to be caused by a vascular abnormality and can sometimes be cured. For most patients, however, tinnitus is associated with a (neuro)otologic disease. All pathologic states of the ear can actually be associated with tinnitus.

Physiopathology

Tinnitus most probably does not reflect a single entity but rather a diverse group of functional changes in the central auditory pathways. Different models have been proposed.[5]

One influential view stresses the analogy between tinnitus and chronic pain. As chronic pain, tinnitus is a phantom perception that can be caused by any lesion along the auditory pathways. Such lesions eventually cause down regulation of intracortical inhibition and tinnitus. For example, the loss of hair cells in a region of the cochlea will reduce the spontaneous neural activity of the corresponding auditory nerve fibres. This may result in a reduction of lateral inhibition at more central levels and lead to hypersensitivity and hyperactivity of a population of neurons at cortical level.[6]

Another model of tinnitus, the model of Jastreboff,[7] (see appendix 1) integrates two fundamental properties of the human central

Table 1
Etiologies of tinnitus

OBJECTIVE TINNITUS

1. Pulsatile tinnitus

1.1. Arterial etiologies
- 1.1.1. Atherosclerotic carotid artery
- 1.1.2. Intracranial and extra cranial arteriovenous malformations
- 1.1.3. Arterio-venous fistulas
- 1.1.4. Atherosclerotic subclavian artery
- 1.1.5. Atherosclerotic occlusion of the contralateral common carotid artery
- 1.1.6. Fibromuscular dysplasia of the internal carotid arteries
- 1.1.7. Carotid artery dissection
- 1.1.8. Intrapetrous carotid artery dissection
- 1.1.9. Brachiocephalalic artery stenosis
- 1.1.10. External carotid artey stenosis
- 1.1.11. Ectopic intratympanic carotid artery
- 1.1.12. Persistent stapedial artery
- 1.1.13. Aberrant artery in the stria vascularis
- 1.1.14. Microvascular compression of the eighth nerve
- 1.1.15. Increased cardiac output (anemia, thyrotoxicosis, pregnancy)
- 1.1.16. Aortic murmurs
- 1.1.17. Paget's disease
- 1.1.18. Otosclerosis
- 1.1.19. Hypertension, antihypertensive agents
- 1.1.20. Vascular neoplasms of skull base and temporal bone
- 1.1.21. Tortuous carotid and vertebral arteries

1.2. Venous etiologies
- 1.2.1. Pseudotumor cerebri syndrome or benign intra cranial hypertension syndrome or idiopathic intra cranial hypertension in association with:
  - Obesity
  - Anemia (iron deficiency or pernicious)
  - Polycythemia
  - Steroids
  - Deficiency: Addison's disease, steroid withdrawal
  - Excess: Cushing's disease, iatrogenic
  - Hypoparathyroïdism
  - Hyperthyroidism
  - Pituitary adenoma
  - Uremia
  - Cystic fibrosis
  - Vitamins (deficiency of vitamin D, excess of vitamin A)
  - Medications: steroids, dilantin, chlorpromazin, lithium, tetracycline, trimethoprim-sulfamethoxazole, amiodarone, growth hormone, oral contraceptives, indomethacin, nalidixic acid
- 1.2.2. Jugular bulb abnormalities
- 1.2.3. Hydrocephalus associated with stenosis of the Sylvian aqueduct
- 1.2.4. Increased intracranial pressure associated with Arnold-Chiari malformation
- 1.2.5. Abnormal condylar and mastoid emissary veins
- 1.2.6. Venous hum or idiopathic or essential pulsatile tinnitus

2. Non pulsatile tinnitus
2.1. Patulous eustachian tube
2.2. Palatal myoclonus
2.3. Spasm of stapedius or tensor tympani muscle
2.4. Temporomandibular joint disorders (Clicking sounds)
2.5. Spontaneous otoacoustic emissions

Table 1
Continuation

SUBJECTIVE TINNITUS

1. Outer ear

1.1. Impacted cerumen/wax
1.2. External otitis
1.3. Foreign body
1.4. Exostosis or stenosis of the external auditory canal

2. Middle ear

2.1. Tuba dysfunction; barotrauma
2.2. Acute otitis media; glue ear
2.3. Chronic suppurative otitis media; cholesteatoma; perforated tympanic membrane; ossicular lesions
2.4. After middle ear surgery
2.5. Otosclerosis

3. Inner ear

3.1. Infection (labyrinthitis)
3.2. Autoimmune diseases
3.3. Trauma
  – Noise-induced hearing loss
  – Shock
  – Baro traumatism with perilymphatic fistula
3.4. Presbyacusis
3.5. Drugs ototoxic (aminoglycoside antibiotics, salicylates, loop diuretics, non steroidal, anti-inflammatory drugs, quinine, chemotherapy agents: e.g. platins, vincristin)
3.6. Intoxication with lead, mercury, carbon monoxide
3.7. Sudden deafness
3.8. Meniere's disease
3.9. Micro vascular causes: general vascular causes, hematologic factors, metabolic and endocrinian factors (diabetes, hyperlipidemy, hyperuricemy, hypo or hyper thyroïdism), cervical distortions and cervical osteoarthritis

4. Auditory nervous system

4.1. Vestibular schwannoma (acoustic neuroma)
4.2. Other retrocochlear/cerebellar-pontine-angle tumours (meningioma)
4.3. After neuritis
4.4. Vasculo-nervous conflict (V/VIII) / vascular loop
4.5. Cerebral tumours;
4.6. Infectious: meningitis; encephalitis; sequel of Lyme disease; syphilis;
4.7. Closed Head injury
4.8. Multiple sclerosis
4.9. Vascular accident
4.10. Migraine (aura)
4.11. Lesion of the temporal lobe
4.12. Auditive hallucinations (psychiatry)

5. Others

5.1. Temporomandibular joint dysfunction and dental disorders
5.2. Cervical causes; whiplash
5.3. Psychological / psychiatric disorders (anxiety, depression, alcohol abuse, schizophrenia)
5.4. Inadequate emotional answer to stimulus
5.5. Hormonal cycle
5.6. Toxaemia

nervous system: the conditioned response paradigm (first demonstrated by Pavlov) and habituation. Habituation is the decrease in the strength of a behavioural response that occurs when a stimulus is repeatedly presented. This model suggests that the auditory pathways play a role in the initial generation of tinnitus, but the perception and the reinforcement of the phantom perception is maintained by extra-auditive pathways, especially the limbic system (playing an important role in our emotions) and the autonomic nervous system. The Tinnitus Retraining Therapy is based on the model of Jastreboff.

Until recently, fundamental knowledge on tinnitus was based on animal research.

Recently, it became possible to study the neurophysiology of tinnitus in humans in a non invasive manner with magneto encephalography, positron emission tomography (PET), and fMRI. Magneto encephalographic (scalp recorded variations of the magnetic fields in relation with neuronal depolarisation) studies on humans with tinnitus suggest a relation between tinnitus and brain plasticity.

They find altered cortical tonotopy in patients with tinnitus as is also observed in the somatosensory cortex of amputees who experience phantom pain. Those similarities are in favour of the hypothesis that tinnitus may be an auditory phantom phenomenon.[8]

PET studies measure the metabolic brain activity via a radiotracer and find that tinnitus and residual inhibition are related to networks of auditory higher–order processing, memory and attention.[9] It is a very sensitive technique that can also be used in

cochlear implanted patients. Disadvantages are the use of radioactive substances and the lack of equipped centres. Recently, also the fMRI technique, has been used to study tinnitus, and first reports are promising.[10] Our understanding of the neurophysiological mechanisms that lead to a phantom auditory perception and the associated debilitating consequences of this sensory experience is continuing to improve. Tinnitus appears to be significantly affected in a complex way by somatosensory, limbic and motor influences. Effective treatments will certainly emerge from these new insights.[11]

Diagnostic work-up

Questioning

A full diagnostic work-up for tinnitus includes extensive anamnesis. Table 2 lists a number of questions relevant to tinnitus: context of the tinnitus and specific aspects of tinnitus. Different groups developed, mostly for research purposes, specific questionnaires to estimate quantitatively the impact of tinnitus on daily living. Those questionnaires are of certain interest in the follow-up op the patient but in either case can not replace the anamnesis. The Tinnitus Handicap Inventory (THI) yields a psychometrically robust measure of tinnitus handicap based on self-report of the patient.[12,13] The higher the score, the more distressing the tinnitus. With a score between 0 and 16, the handicap is considered slight, being heard only in quiet environments and easily masked. In contrast, a score of 78 to 100 is considered catastrophic, with all tinnitus aspects experienced as severe. These patients need specialized counselling, and psychological problems are commonly associated. According to our experience, the THI questionnaire is most practical from an administrative perspective, and is used frequently (see Appendix 2). The subjective tinnitus severity scale (also available in French) consists of 16 questions to be answered with yes or no, yields a metric of tinnitus severity on a 16 point scale, and enables classification into mild, intermediate or severe tinnitus. In case of hyperacousis, the “questionnaire de sensibilité auditive” which measures the impact of hyperacousis on concentration, social life and emotional life can be used. The Hospital Anxiety and Depression scale is useful to explore anxiety and depression associated with tinnitus.[14,15]

Table 2

Context of the tinnitus

- Hearing loss? Hyperacusis? Vertigo? Otalgia? Otorrhoe? Ear surgery? Headache? Nasal symptoms?
- Noise exposure: (profession, hobby)
- Internal diseases (diabetes, dysthyroïdism, oncological)
- Vascular diseases (arteriosclerosis, hypertension, hypercholesterolemia ...)
- Psychiatric diseases
- Temporo-mandibular joint
- Cervical spine
- Drug abuse: tobacco, alcohol
- Medication (present and old); Ototoxic agents (quinine, aminoglycosides, loop diuretics, chemotherapy ...)
- Previous tinnitus treatments: hearing aid, acupuncture, homeopathy, hypnosis
- Personal and familial history

Specific aspects of tinnitus

Time course: onset, gradual or sudden, constant, intermittent, fluctuating
trigger
localisation: right ear – left ear – both ears – head
Pulsatile or not
Perceived quality: pure-tone, high or low frequency, humming, hissing...
Pitch
Loudness
Presence of real silence
Can the patient modulate her/his tinnitus?
Awareness of tinnitus in percentage of waking hours
Annoyance of the tinnitus
Impact on sleep
Impact on activities (work, concentration, reading, sports, social, other...)
Effect of noise on tinnitus (louder, softer)
Patient’s beliefs about tinnitus (will get worse, will go on for ever, there is no treatment, a tumour, become deaf)

Physical examination

An otological examination with otomicroscopy is required. Depending on the anamnesis, examination of the neck with carotid auscultation, of the temporal joint and otoneurological examination, particularly if complaints of dizziness are associated, are also indicated.

Audiological testing

Audiologic tests play a central role in the diagnostic work-up of tinnitus. Pure-tone hearing thresholds and speech discrimina-

tion should always be obtained, and guide further investigations. In many clinics, audiological characterization of tinnitus has become common practice. Results of these measurements reveal the variety of tinnitus, can sometimes be correlated with pure-tone thresholds, but are poorly correlated with the amount of tinnitus distress.[16]

Seventy-five per cent of the patients match their tinnitus pitch at or above 4000 Hz (median: 6000 Hz). 70% of the loudness matches are between 0 and 6 dB sound level (SL). Loudness matches are useful to confirm the genuine perception of tinnitus especially when compensation is sought for tinnitus in the context of occupational hearing damage or automobile injuries. In litigation cases, the loudness match of pretended tinnitus must be determined on at least five separate occasions. When the variation of the loudness matches does not vary by more than 3 dB, tinnitus perception is probably genuine, because it is extremely difficult to remember the loudness of a tone accurately.

Table 3 gives an extensive listing of tests that can be of some interest in the evaluation of tinnitus.

Laboratory tests

In our tinnitus working group, we could not obtain consensus concerning the laboratory tests that should be routinely performed in patients with tinnitus. However, considering Table 1 and all the pathologies that can be involved in patients complaining of tinnitus, some laboratory tests should be performed depending of the medical history, circumstances and other symptoms associated. For indication, Table 4 presents a series of tests that seem to be sometimes of interest in tinnitus evaluation.

Imaging

- Magnetic resonance imaging (MRI) should be considered in patients with unilateral tinnitus or/and those with asymmetric hearing loss.
- A CT scan of the temporal bone and the posterior fossa can still be useful in case MRI is not possible, and in case of suspected middle ear pathology.
- In case of unilateral pulsatile tinnitus, for detection of carotic artery stenosis, a duplex ultrasound is reliable. Others etiologies (aterio-venous malformations, jugular bulb and carotid abnormalities, chemodectome ...) are diagnosed by MRI, angio Mri or CT. Arteriography is seldom indicated.

Treatment

Guidelines for a constructive tinnitus treatment relationship (Recommendations Level C)

1. **Express sympathy and care**. Tinnitus patients often hope that cure is possible. Whatever you advise, you must not leave patients without hope. Never tell patients “There is nothing I can do” or “You must learn to live with it”. Because of the rapid

Table 3

Audiometry
- Pure tone audiometry (standard frequencies and high frequencies if possible), air and bone levels
- Loudness discomfort level
- Speech audiometry

Tympanometry
- Tympano ossicular compliance
- Acoustic reflexes: to be considered especially if suspicion of otosclerosis (because of the high intensity of the stimulation, there is a risk of majoration of tinnitus, particularly in patients suffering from hyperacusis)

Otoacoustic emissions
- Spontaneous otoacoustic emissions
- Sound evoked (clicks, two-tone)
- Transient otoacoustic emissions with controlateral masking

Auditory brainstem response (BERA)
In case of unilateral tinnitus, unilateral hearingloss, auditory neuropathy.

Vestibular evaluation
If complains of dizziness and / or abnormal neurotological examination

Tinnitus testing
+ Pitch match frequency (by adaptive method using supra liminar pure tones or narrow band stimulations)
+ Tinnitus loudness match (TLM) (ascending method in best hearing ear)
+ Minimum masking level (MML) (defined as the lowest sound intensity that renders tinnitus inaudible In the majority of the patients, MML occurs between 0 and 9 dB SL)
+ Residual inhibition testing (RI) (refers to the temporary disappearance of tinnitus after presentation of a masking sound, and can be complete or partial; e.g., MML plus 10 dB for 60 seconds).

Table 4

+ Complete blood count
+ Lipids
+ Ionogram
+ Uremia
+ Fluorescent treponema antibodies (FTA) ; Lyme disease
+ Thyroid hormones
+ Viral serology : EBV, CMV, herpes zoster and simplex

progress in tinnitus research, new therapies will emerge. You must convince patients that, even if current techniques fail, tinnitus research is daily making progress and that one day it will help them.

2. **Establish your interview as a dialog**. Do not simply see the patients, but interact with them. First, find out how tinnitus affects the individual and know the specific nature of their difficulties to select appropriate treatments. Second, encourage patients to ask questions and answer those questions honestly and completely. Third, be forthright in admitting incomplete knowledge when such exists.

3. **Develop a relax yet attentive interview format**. Do not distance yourself with unnecessary barriers (seating at a long distance, white coat). Encourage a spouse, a friend, or a family member to attend the session.

4. **Use an interviewing approach** that allows you to give your undivided attention to the patient. Provide adequate time for thorough interviewing, allowing large opportunities for patients to explain and comment their tinnitus history, and to ask questions.

5. **Provide clear explanations** of all your procedures in layman's language. Explain carefully the options of therapy. It is important to indicate both positive and negative aspects, using layman language but be careful to avoid any tone of condescension.

6. **Remember the quality of life.** Develop a broad concern about all aspects of the patient's problems (family difficulties, noisy work environment, signs of deafness or brain disorder).

Medications

No drug has proved effective in curing tinnitus (Evidence level III). In his review of 69 randomized clinical trials (RCTs), Dobie concluded that "no treatment can yet be considered well established in terms of providing replicable long-term reduction of tinnitus impact, in excess of placebo effects".[17] In randomized clinical trials, placebo effects are strong and are attributed in part to the medical attention provided to the patient.[18]

1. Tricyclic antidepressants are likely to be beneficial
An RCT with subjects suffering from depression and chronic tinnitus found that, when compared to placebo, the tricyclic antidepressant nortriptyline significantly improved tinnitus related disability, reduced tinnitus loudness, and symptoms of depression at 6 weeks, but found no significant difference in tinnitus severity.[19]

2. Benzodiazepines did not prove effective in controlling tinnitus.[20]
Prescription of benzodiazepines should be tempered because withdrawal intensifies tinnitus and causes supplementary distress.[21]

3. Antiepileptic drugs
One RCT found no significant difference between carbamazepine (150 mg 3 times daily for 30 days) versus placebo for tinnitus severity.[14] Three other studies also failed to show benefit.[22]

4. Nicotinamide, vitamine B3
One RCT found no significant difference between nicotinamide versus placebo for tinnitus severity at 30 days.[19]

5. Cinnarizine
One RCT found no significant difference between cinnarizine versus placebo for tinnitus severity.[19]

6. Zinc
One RCT found no significant difference between zinc versus placebo for tinnitus severity at 8 weeks.[19]

7. Baclofen
One RCT found no significant difference between baclofen versus placebo for tinnitus severity.[19]

8. Ginkgo Biloba is likely to be ineffective or even slightly harmful.
One systematic review and an RCT found no significant difference of tinnitus symptoms with ginkgo biloba versus placebo, and another study reported stomach upset, dizziness and dryness.[19]

9. Tocainide is likely to be ineffective or even harmful.
One RCT found no significant difference with tocainide versus placebo in improving symptoms, but found evidence that tocainide caused significantly more adverse effects after 30 days treatment (rash 25%, dizziness 12%, tremor 8%).[19]

Randomized clinical trials of flecainide and mexiletine were marked by adverse drug effects in up to 70 percent of the participants, and by dropout rates of about 50 percent.[17]

Hearing aids

When hearing impairment is present, hearing aids should be advised, as they mask the tinnitus through amplification of ambient sounds. Some patients attribute their hearing problems to tinnitus. For them, providing hearing aids often results in improvement of tinnitus distress[1] (Recommendation level C).

Tinnitus maskers

Maskers look similar to hearing aids and deliver broadband noise in the external auditory meatus. The instruments generate an external, constant sound that can be controlled by the patient, and allow concentration rather than distraction by sounds from televisions, etc. They reduce tinnitus distress by diverting attention, replacing tinnitus by another noise, under control.[23] The sound produced by a tinnitus masker is not a white noise. Although tinnitus maskers have been widely prescribed, no evidence supports their use. Only one randomized clinical trial (RCT) was found (75 people suffering from tinnitus but without hearing loss). The RCT compared two types of tinnitus masking devices versus a non-blinded control group and found that either type of device improved symptoms compared to no device[24] (Evidence level II).

The philosophy of tinnitus maskers is very different than the one of tinnitus retraining therapy (TRT®) where a white noise is used and where the intensity of the noise stimulation remains always under the level of masking.

Tinnitus Retraining Therapy

Regarding clinical evidence, this technique has to be covered in future updates. (Evidence level III). For Hazell *et al.*[7], TRT® is primarily a long-term treatment rather than a temporary palliative. This therapy exploits two approaches: psychological and prosthetic. The first is more important, and aims to remove inappropriate beliefs and fears about tinnitus, which enhance tinnitus intrusiveness. The role of the ENT doctor is fundamental, as he provides important information. The prosthetic approach used in TRT® consists of providing background sound (white noise's generators) that does not mask the tinnitus. Such sounds gradually decrease the brain's oversensitivity to auditory signals. The modalities of this treatment are quite different if tinnitus is isolated, or associated with hearing loss and/or hyperacusis. When tinnitus is associated with hearing loss, the white noise's generator can be built in a hearing aid.

<u>The retraining programme:</u>

- change patient's beliefs
- reduce signal detection
- lower arousal level
- increase plasticity and decrease contrast by using sound therapies
- face object of disaffection without reaction

It is important to use teaching material and stories to illustrate different aspects of the retraining model. These factors will tailor counselling to each individual patient and his level of comprehension. The first consultation is of fundamental importance.

Other treatments

Acupuncture
An analysis of six RCTs failed to demonstrate any efficacy.[25]

Low Power Laser
One RCT found no significant difference of tinnitus severity between low power laser and placebo after one month of therapy.[19]

Electromagnetic stimulation / ear canal magnets have unknown effectiveness.
Four small RCT found insufficient evidence for effects of magnetic and electromagnetic stimulation.[19]

Hyperbaric oxygen has unknown effectiveness
No systematic reviews or RCT were found.[19]

Psychotherapy has unknown effectiveness.
One systematic review found insufficient evidence in favour of cognitive behavioural treatment, relaxation therapy, counselling, education, hypnosis, biofeedback, or stress management compared with other or no treatment in people with chronic tinnitus.[19]

Hypnosis has unknown effectiveness*
One RCT found no significant difference of tinnitus severity after three months of hypnosis versus counselling.[19]
* However, the trial may have lacked power to exclude clinically important effects.

Surgical treatments remain controversial.

Although some reports claim improvement of tinnitus after micro vascular decompression of the auditory nerve, the use of surgical treatments, including nerve section, remains controversial.[26,27]

Conclusion

Research has progressed our comprehension of the physiopathology of tinnitus. Nevertheless, many factors remain unclear. What has to be stressed is certainly the necessity of audiological investigation and to provide time enough for a good anamnesis. Tinnitus is a very frequent problem of which the etiology remains often uncertain, and the possible presence of a VIIIth cranial nerve schwannoma must be kept in mind, particularly in cases of unilateral tinnitus. In those cases, an MRI scan has to be done. When pulsatile tinnitus is present, vascular pathologies should be searched for. It is now well accepted that tinnitus reflects an unlucky brain adaptation to many possible disturbances within or outside the auditory pathways. Therefore the therapeutic approach has to take into account auditive and psychological aspects. The TRT, at present, seems to be one form of treatment giving certainly good results in some cases. A lot of treatments have been proposed but in the majority, correct evaluations disprove their efficiency. In case of depression related to tinnitus, antidepressive drugs have been proved useful. In the future, refined comprehension of tinnitus will certainly lead to new approaches of treatment.

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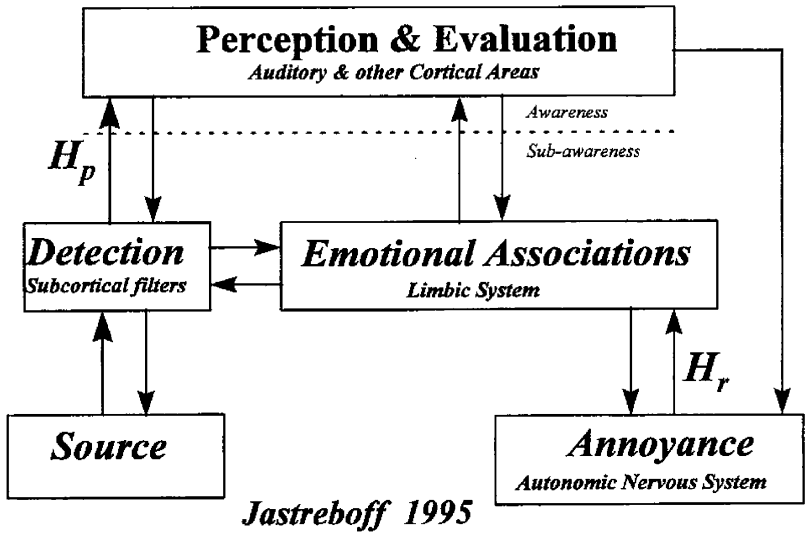
A. Englebert
Dept. of Otorhinolaryngology
Clinique Sainte Elisabeth
Place Louise Godin, 15
B-5000 Namur, Belgium
E-mail: ann.englebert@skynet.be

APPENDIX 1
Schema Jastreboff's Model



APPENDIX 2

Tinnitus Handicap Inventory
The purpose of the scale is to identify the problems your tinnitus may be causing you. Check "Yes", "Sometimes" or "No" for each question.

F1. Because of your tinnitus, is it difficult for you to concentrate?
F2. Does the loudness of your tinnitus make it difficult for you to hear?
E3. Does tinnitus make you angry?
F4. Does your tinnitus make you feel confused?
C5. Because of your tinnitus, do you feel desperate?
E6. Do you complain a great deal about your tinnitus?
F7. Because of your tinnitus, do you have trouble falling to sleep at night?
C8. Do you feel as though you cannot escape your tinnitus?
F9. Does your tinnitus interfere with your ability to enjoy your social activities such as going out to dinner, to the movies, etc?
E10. Because of your tinnitus, do you feel frustrated?
C11. Because of your tinnitus, do you feel that you have a terrible disease?
F12. Does your tinnitus make it difficult to enjoy life?
F13. Does your tinnitus interfere with your job or household responsibilities?
E14. Because of your tinnitus, do you find that you are often irritable?
F15. Because of your tinnitus, is it difficult for you to read?
E16. Does your tinnitus make you upset?
E17. Do you feel that your tinnitus problem has placed stress on your relationship with members of your family and friends?
F18. Do you find it difficult to focus your attention away from your tinnitus? And on other things?
C19. Do you feel you have no control over your tinnitus?
F20. Because of your tinnitus, do you feel tired?
E21. Because of your tinnitus, do you feel often distressed?
E22. Does your tinnitus make you feel anxious?
C23. Do you feel you can no longer cope with your tinnitus?
F24. Does your tinnitus get worse when you are under stress?
E25. Does your tinnitus make you feel insecure?

Item are classified as pertaining to the functional (F) subscale, emotional (E) subscale or catastrophic (C) subscale. Answers of "yes" are scored 4 points, "sometimes" 2 points and "no" receives O points.

APPENDIX 3[28,29,30]

Algorithm : Tinnitus

Il all cases, history, microscopic otoscopie, audiological testing

UNILATERAL TINNITUS

Non pulsatile

– With conductive hearing loss → etiological treatment- if necessary, temporal bone TDM

– With neurosensoral hearing loss → cerebello- pontine MRI

- normal: see tinnitus + hearing loss treatment (*)
- pathologic: etiological treatment + **

– Without hearing loss → cerebello- pontine MRI

- normal: see tinnitus treatment (**)
- pathologic: etiological treatment and (**)

Pulsatile

1) Arterial pressure measure and thyroid test control

2) Tympanoscopy

– Retro tympanic mass → temporal bone TDM
→ if indicated, surgery

– Normal → Neck Duplex ultrasound
Cerebral Angio-IRM
Neck TDM

Bilateral tinnitus

Non pulsatile

If normal hearing → **

If conductive hearing loss → etiological treatment - if necessary, temporal bone TDM

If neurosensoral hearing loss

– Symetric hearing loss → *

– Asymmetric hearing loss → cerebello- pontine MRI
  - normal: see tinnitus + hearing loss treatment (*)
  - pathologic: etiological treatment + **

Pulsatile

1) Arterial pressure measure and thyroid test control
2) Neck Duplex ultrasound and Cerebral Angio-IRM

*: Hearing aid trial (except in cases of hyperacusis).
**: See different therapeutic approaches described in the text in the paragraph treatment.

CME QUESTIONS

1. What is the most pertinent exam for a patient with a persisting unilateral tinnitus without hearing loss?

   A – OAE
   B – BERA
   C – Temporal bone CT scan
   D – MRI
   E – Vestibular testing

2. Which of the drugs has Evidence Based efficacy?

   A – Cinnarizine
   B – Benzodiazepines
   C – Tricyclic antidepressants
   D – Ginkgo biloba
   E – Zinc

3. What is the worst thing to say to a patient suffering from tinnitus?

   A – I am not competent in this kind of therapy
   B – There is nothing that can be done for you. You will have to learn to live with it
   C – We will treat you but we do not know if it is curable
   D – This medical problem is not heavy
   E – Be quiet, I will probably cure you

4. What is the prevalence of incapacitating tinnitus in the population?

   A – 1 to 3%
   B – 3 to 7%
   C – 7 to 10%
   D – 10 to 16%
   E – 16 to 30%

5. Recruitment:

   A – Is responsible for hyperacusis
   B – Causes any discomfort to the patient
   C – Should always be treated with sound generators
   D – Is independent from hyperacusis
   E – Is the basis of phonophobia

6. Sound used in TRT®

   A – Must be provided by sound generators
   B – Must be set at the threshold of hearing
   C – Should not mask tinnitus
   D – Must be heard only one hour a day
   E – Must not be heard each day

7. Audiological testing should always include

   A – Otoacoustic emission
   B – Acoustic reflexes
   C – Auditory brainstem response
   D – Pure-tone audiometry
   E – Speech audiometry

8. The following therapies are advisable to supplement TRT®

   A – Xanax
   B – Anti-depressants
   C – Dietary constrains with suppression of alcohol, caffeine, salt
   D – Techniques of relaxation
   E – Zinc

9. In the different Jastreboff categories, which therapeutic element is always essential?

   A – Relaxation techniques
   B – White Noise Generators
   C – Directive counselling
   D – Psychological aid
   E – Hearing aid

10. In a pluridisciplinary medical team, which association is most appropriate?

    A – ENT, audiologist, psychotherapist
    B – Audiologist, psychotherapist
    C – ENT, dietician, psychotherapist
    D – ENT, psychotherapist
    E – ENT, audiologist

Answers: 1D; 2C; 3B; 4C; 5D; 6C; 7D; 8D; 9C; 10A

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Sudden hearing loss

P. Levie, O. Desgain*, C. de Burbure**, P. Germonpré***, J-P. Monnoye*, M-P. Thill****, M. Barthelemy*****, V. Monnoye*, R. Kuhweide******, J. Claes******* and Th. Robillard*********

*ENT Department, Cliniques Ste Anne-St Remi, Brussels; **Pathology, St Luc Teaching Hospital, Université Catholique de Louvain, Brussels; ***Center for Hyperbaric Oxygen Therapy, Military Hospital, Brussels; ****ENT Department, Centre Hospitalier Universitaire St Pierre, Brussels; *****ENT Department, CHU de Charleroi, Charleroi; ******ENT Department, Algemeen Ziekenhuis St-Jan, Brugge; *******ENT Department, Universitair Ziekenhuis Antwerpen, Universitaire Instelling Antwerpen; ********ENT Department, Clinique Sainte Elisabeth, Namur

Key-words. Guidelines; sudden deafness; management

Abstract. *Sudden hearing loss.* This update on the latest studies and management policies for patients suffering from sudden sensorineural hearing loss (SSHL) represents a cooperative effort of Belgian ENT surgeons from various corners of the country. SSHL has an incidence ranging from 5 to 20 cases per 100,000 persons per year, and is a relative medical emergency, as only 30% to 65% of the patients recover spontaneously.[1-3] Nowadays, treatment varies a great deal between countries and hospitals. The various etiologies and therapeutic modalities are reviewed, and evidence levels are indicated. Finally, diagnostic and therapeutic organigrams are proposed along with a Belgian therapeutic cocktail in view of conducting a large Belgian study on the management of SSHL.

Introduction

Sudden sensorineural hearing loss (SSHL) is defined as a sensorineural hearing loss that settles within less than 3 days, and that is at least 30 dB over three consecutive frequencies ranging between 0.125 to 8 kHz in comparison to the contralateral side.[3] The incidence of SSHL ranges between 5 and 20 cases per 100,000 persons per year. SSHL represents about 1% of all sensorineural hearing losses.[1,3]

Etiology of SSHL[3-5]

The cause of the sudden hearing loss is mostly unknown. Based on presumptive evidence, a few hypotheses have been put forward:

– The “viral hypothesis” (in 30% to 40% of the cases, an upper respiratory tract infection precedes, within a month, the hearing loss).
– The “vascular hypothesis” (micro-emboli, micro-thrombosis, slowing of the cochlear blood flow following increase of blood viscosity by a “sludge” effect -intravascular red blood cell aggregation in case of stasis, spasm, systemic hypotension and intralabyrinthic hemorrhage).
– The “immunological hypothesis” (antibodies directed against epitopes present in the inner ear).
– The “pressure origin” (hydrops is sometimes exclusively confined to the cochlea).

Sometimes, the cause of SSHL can be identified, and a specific treatment initiated.

The etiology of SSHL can be classified into categories: (1) viral and infectious, (2) autoimmune, (3) traumatic, (4) vascular, (5) neurological, (6) tumoral, (7) ototoxic and (8) pressure related. There are multiple conditions within each of these categories that have been associated with sudden hearing loss.

The following is a partial list of reported causes of SSHL:

Infectious: meningococcal meningitis, herpes viruses (simplex, varicella zoster), cytomegalovirus, mumps, HIV, mycoplasma, toxoplasmosis, syphilis, measles (rubeola), rubella, Lyme disease.

Autoimmune: lupus erythematosus, polyarteritis nodosa, Cogan’s syndrome, Wegener granulomatosis, relapsing polychondritis, Behçet syndrome, Kawasaki disease, temporal arteritis (Horton disease).

Traumatic: perilymphatic fistula, temporal bone fracture, barotrauma, blast injury ...

Vascular: vertebrobasilar vascular attack, stroke, sickle cell disease, decompression, sicknes from SCUBA diving ...

Neurological: multiple sclerosis, migraine ...

Tumoral: vestibular schwannoma (acoustic neuroma), leukemia, myeloma, metastasis to internal auditory canal, meningeal carcinomatosis ...

Ototoxic causes: amikacin, vancomycin, erythromycin, cisplatin ...

Pressure attack: hydrops, Ménière's disease ...

History and physical examination

SSHL is a relative medical emergency, and diagnostic workup and management should be started without delay. The primary objective is to rule out treatable causes. It is important to find out the detailed circumstances of the hearing loss and the time course of its onset. The presence of associated symptoms, such as tinnitus, vertigo or dizziness, aural fullness, and otalgia should also be specifically asked about, along with details of previous or concurrent viral infections, previous otologic surgery or the use of ototoxic drugs. Any history of trauma, diving, flying and intense noise exposure should be noted. Past medical history of other diseases associated with SSHL should also be obtained such as diabetes, autoimmune disorders, malignancies, neurological conditions, and hypercoagulation state. Otoscopic findings should be normal. The Ramsay-Hunt zone should be inspected for the presence of vesicles which appear in case of a varicella zoster reactivation. An audiogram (pure tone, speech and tympanometry including stapedial reflex testing) should be performed for all patients with SSHL. In case of vertigo, an electronystagmography (ENG) or a videonystagmography (VNG) must also be performed. A brainstem evoked response audiometry (BERA) should be proposed though not too early, in order to avoid noise injury. If BERA responses cannot be evoked due to profound hearing loss, or if the BERA is pathological, a magnetic resonance imaging (MRI) scan is recommended at least one month after onset in order to look for the presence of tumors in the cerebello-pontine angle or multiple sclerosis. In the presence of associated symptoms such as vertigo, an MRI examination should be performed systematically. Certain authors, in fact, recommend an MRI examination in all cases because a vestibular schwannoma (acoustic neuroma) is found in about 2% of SSHL and has even been described with partial hearing recovery.[6]

Blood tests should be based on the history and the suspected diagnosis. An extensive set of tests should not be performed systematically in view of costs and lack of specificity. Following laboratory tests can be useful: hemoglobin (Hb), hematocrit (Htc), red blood cell count (RBC), white blood cell count (WBC), platelets, C-reactive protein (CRP), serological test for Lyme disease *(Borrelia burgdorferi)* and syphilis (*Treponema pallidum* hemagglutination assay, TPHA). Specific and efficient drugs for the two latter diseases exist, and outcome improves with earlier onset of therapy. Herpes serology is not of great interest as the test is not sensitive enough, quite expensive and its results usually arrive too late in terms of treatment. Practically, the diagnosis of herpes is mainly clinical (vesicles in Ramsay-Hunt zone).

Finally, in case of bilateral or recurrent episodes of sudden hearing loss, immunological tests looking in particular for anti-cochlear antibodies should be requested.

Disease progress and prognosis

In a prospective study by Mattox and Simmons, 65% of the patients with SSHL recovered spontaneously and independent of medical management.[2]

Factors affecting prognosis are:

– Amount of hearing loss: most authors concur in saying that the greater the loss, the worse the prognosis.[1,5]

– Delay of therapy onset: most authors again agree that the shorter the delay, the greater the chances of recovery. Pajor *et al*.[7] quantitatively expressed the chance of recovery as function of the delay of therapy onset: 66% for a delay shorter than 7 days, 25% for a delay between 8 and 14 days, and 16% for a delay between 15 and 30 days. Mosnier *et al*.[1] report similar results for total and partial recovery rates: < 7 days: 70%; 7-30 days: 50% and for more than 30 days: 10%. Thus, treatment should ideally start before 7 days, and hearing improvement can occur within 30 days of hearing loss onset. However, because most of the spontaneous recoveries occur within the first few days, it is difficult to establish with certainty that early therapy is the real cause of improved recovery with faster

therapy onset. For Tran Ba Huy,[8] treatment delay between 1 to 6 days does not appear to influence the final degree of hearing loss.

– Microvascular lesions: Hirano *et al*.[9] demonstrated that patients with diabetes, hypercholesterolemia and high blood pressure have a poor prognosis.

– Age: according to Hirano *et al*.,[9] prognosis worsens above the age of 60. This author suggested that the age effect is related to the higher amount of patients with microvascular lesions above the age of 60. Mosnier *et al*.,[1] however, did not find that age affected prognosis because he placed a prognostic threshold at 40 years of age (too young to see a difference between the two groups of patients).

– Frequency profile of the hearing loss: according to Mosnier *et al*.,[1] ascending or horizontal curves have a better prognosis than descending or V-shaped curves. Fetterman *et al*.[10] do not find any differences with respect to the shape of the audiometric curve. Tran Ba Huy[8] also found that ascending audiometric curves have better prognosis. Audiometric curves that slope down at high frequencies have less favorable prognosis, especially when the hearing loss is pronounced.

– Presence of vertigo: Pajor *et al*.[7] found a recovery rate of 51% for sudden hearing losses without vertigo, whilst only 33% for SSHL with associated vertigo. According to the findings of Nakashima,[11] the association of vertigo and predominantly high frequency hearing loss has the worst prognosis. However, Fetterman *et al*.[10] and Mosnier *et al*.[1] didn't observe this relation.

– Tinnitus: no significant correlation.[1] Certain authors suggested that the presence of tinnitus facilitates recovery, but statistical analyses are not significant.[1]

– Prognosis is worse when SSHL affects an ear that had already been damaged due to chronic excessive noise exposure.[5]

– Otoacoustic emissions: The presence of otoacoustic emissions is associated with a good prognosis. In some patients with SSHL, otoacoustic emisions can be registered when the hearing loss is up to 35-40 dB HL. According to Nakashima *et al*.,[11] this observation suggests that in some cases of SSHL, external hair cells function normally.

Current treatment modalities

When the cause of SSHL is known, management can be focused. The majority of SSHL cases, however, have no identifiable cause. In this paper, we will limit our discussion to the management of patients with idiopathic SSHL.

SSHL management is a subject of controversy: high spontaneous recovery rate and low incidence hinder the validation of empirical treatment modalities. Various treatments have been proposed. A review of the literature confirms that only few of those have proven efficacy. The following review is based on recent peer-reviewed articles evaluated by the authors, and rated between Ia and III according to Belgian evidence levels (BEL).

Anti-inflammatory and immunosuppressive drugs

In the eighties, double-blind studies were performed concerning the treatment of SSHL with oral steroids.[12,13] Treatment consisted of oral steroid therapy (dexamethasone) tapered over 10-12 days.[12] A significant effect on hearing recovery in patients with a hearing loss between 40 and 90 dB HL was found.[12] The overall recovery rate for patients treated with dexamethasone during twelve days was 89%, compared to 44% recovery without steroids.[13] However, recovery was defined as a hearing improvement of more than 50% of the initial loss at three frequencies relevant to speech understanding.[13] In 1996, Hughes *et al*.[3] recommended treatment with prednisone 1 mg/kg/day for at least 10 days and up to one month (BEL III).

In a recent double blind prospective study, Cinamon *et al*.[14] suggested that prednisolone 1 mg/kg/day had no therapeutic advantage over a placebo (BEL Ib). However, Alexiou *et al*.[15] performed a retrospective study in 2001 concerning the use of 500-1000 mg of prednisolone for three days, and found that glucocorticoids should be recommended for the treatment of SSHL, particularly for patients with hearing loss in the lower and middle frequencies (BEL Ib).

Vasodilators / rheologic agents

Many vasodilators have been used for treating SSHL.

Procaine, just as other local anesthetics, causes arteriolar vasodilation. Procaine hydrochloride in the form of intravenous infusions is advocated for the treatment of SSHL by several authors (vasoactive therapy ...)[16] However, a double-blind clinical study has concluded that procaine therapy is not superior to a placebo (BEL II).[16]

A recent retrospective study showed that the use of low

molecular-weight heparin could improve hearing in SSHL. Considering the side-effects of this treatment, it should be used with caution (BEL III).[17]

In a preliminary report, Gersdorff *et al.*[18] concluded that 12 g of piracetam administered as an intravenous infusion over 15 minutes significantly increased the chance of complete recovery for patients with SSHL (BEL III).

Hemodilution

A hematocrit drop leads to a reduction of blood viscosity and a reduction of venous return resistance, and hence to an increased cardiac output. At micro-circulatory level, a drop in hematocrit values results in a higher perfusion rate and higher oxygen delivery. Optimum oxygen delivery is reached at a hematocrit value of 30%. Therapeutic hematocrit reduction has to be performed in a hospital environment because severe hypotension can occur, even several hours after administration of the drugs (BEL II).[19]

Antiviral agents

Animal models of viral labyrinthitis were developed by Stokroos *et al.*,[20] and treatment with a combination of prednisolone and acyclovir resulted in higher recovery of hearing compared to either drug alone.

Combining acyclovir with prednisolone, however, has no established beneficial effect in humans with SSHL, as reported by Westerlaken *et al.*[21] and Tucci *et al*.[22] A critical factor for success with acyclovir is the delay of treatment onset: the mean delay of treatment onset in two studies on SSHL was 4 days, whereas antiviral therapy must be started within 3 days after onset of the disease. Thus, as discussed by Kuhweide *et al.*,[23] if started early, the combination of acyclovir and prednisolone might yet prove to be effective for SSHL, and is certainly reasonable if clinical signs of varicella zoster virus (Herpes zoster oticus, Ramsay-Hunt) are present (BEL III).

Diuretics

The use of diuretics may be indicated when endolymphatic hydrops is suspected, even in the absence of vertigo. For these patients, Claes *et al.*[24] suggest the use of hydrochlorothiazide (25-50 mg/day) or acetazolamide (500 mg/day), or a combination of hydrochlorothiazide 25 mg with triamterene 50 mg in association with a salt free diet during 3 months. They also strongly recommend adding betahistine 16 mg $\times$3/day. Patients are also recommended to avoid coffee, alcohol, smoking and stress, which are known triggers for vertigo attacks in Ménière's disease (BEL III).

Hyperbaric oxygen therapy (HBO)

Breathing 100% oxygen at supra-atmospheric pressures increases the amount of oxygen in the arterial circulation, and favors oxygen supply to tissues, even when vascularisation is compromised. During HBO, an important pO_2 rise in the endolymph and perilymph has been measured. During an HBO session, which lasts 90 minutes and which is administered with a frequency of one per day, a patient is placed in a pressure chamber and breathes 100% oxygen at 2.5 atmospheres, through a mask or oxygen hood.
A control audiometry must be performed after 10 sessions. When the patient's hearing does not improve, treatment is not prolonged. When hearing improves, HBO is prolonged for 5 days or even longer until thresholds stabilize. The atmospheric pressure increase during a HBO session can be problematic for patients with Eustachian tube dysfunction. Tympanometry can be performed prior to a HBO session to check Eustachian tube function. When middle ear and environmental pressure cannot be equalized, tympanostomy tubes must be placed. HBO appears to be effective up to three months following the onset of the hearing loss. In general, HBO is prescribed in cases where drug therapy has not resulted in significant improvement of hearing thresholds (BEL III).[25]
In cases of (suspected) decompression sickness, HBO treatment is the first treatment of choice; in these cases, commencing HBO treatment as soon as possible is mandatory. Special treatment schedules are used for emergency treatment of diving pathology, the description of which is beyond the scope of this review.

Other agents and procedures

Some studies have shown that carbogen, a combination of 95% oxygen and 5% carbon dioxide, increases the partial pressure of oxygen in perilymph. However, recent studies have failed to prove any benefit from carbogen therapy (BEL Ib).[26]

Fibrinogen and LDL apheresis has recently been found to be effective in the treatment of patients with SSHL. Indeed, a multicenter study reports that a single fibrinogen/LDL apheresis lasting for 2 hours could be used as an alternative to infusion treatment and prednisolone for

10 days. Patients with plasma fibrinogen higher than 8.68 µmol/l would appear to have a higher degree of improvement, especially if serum LDL concentrations are also raised. Apheresis for SSHL is common practice in Germany (BEL Ia).[27]
Recently, studies have proven the efficiency of some vitamins and oligoelements.

A prospective double blind study found that the combination of 167 mg of oral magnesium and steroids improves hearing in patients with SSHL more than steroids alone (BEL Ib).[28]

The use of the antioxidant vitamin E for reducing cochlear damage has been proposed. Animal studies suggest that ototoxic drugs, noise exposure, and inflammation in the cochlea cause damage through release of free oxygen radicals. In animal models on ototoxicity, vitamin E has been shown to prevent cell damage. In clinical studies, the combination of steroids, carbogen, magnesium and vitamin E (twice a day 600 IU) yielded better results than without vitamin E (BEL II).[29]

Suggested therapeutic management

No single treatment has proven absolute efficacy for SSHL, and a variable amount of recovery has been reported depending on the treatment protocol and study. Thus, from a medico-legal point of view, it is careful to treat a patient with idiopathic SSHL. The main difficulty lies in the poorly understood pathophysiologic processes of the disease. However, hypotheses on the possible etiologies exist, and we would like to propose a therapeutic approach that covers the main causes, that is feasible, and that avoids side-effects and economic burden (work absence, treatment and hospitalization costs ...).

We recommend outpatient treatment because no study proves that hospitalizing a patient improves recovery rate.

The following "Belgian" therapeutic cocktail has not been studied previously but all components are proven effective, and substance interaction is unlikely. The various components of this cocktail were selected with the objective of covering as many etiologies as possible. We would like to submit a proposal for a large national double-blind prospective study on the effects of this "Belgian cocktail" versus for example steroids.

The authors of this review agree that every patient should be treated as soon as possible. Furthermore, we propose two determinants in deciding on the treatment modality for SSHL: delay of therapy onset and frequency profile of the hearing loss (curve type):

- for the ascending curves (highest loss at low frequencies), we propose treatment with triamterene combined with an oral steroid. If the hearing loss is due to hydrops, recovery may be expected within a week. If full recovery is not achieved at the end of a week, the Belgian cocktail should be administered, and hearing should be measured every week.
- for the other audiometric curve types, the treatment modality should depend upon the delay since the onset of the hearing loss. If the delay is less than one month, the drugs listed below could be used:
  - steroids: prednisolone 1 mg/kg
  - piracetam: 3×3 1200 mg/day (10.8 g/day)
  - vitamin E: 2×600 IU/day
  - magnesium: 167 mg/day
  + Audiometry once a week.

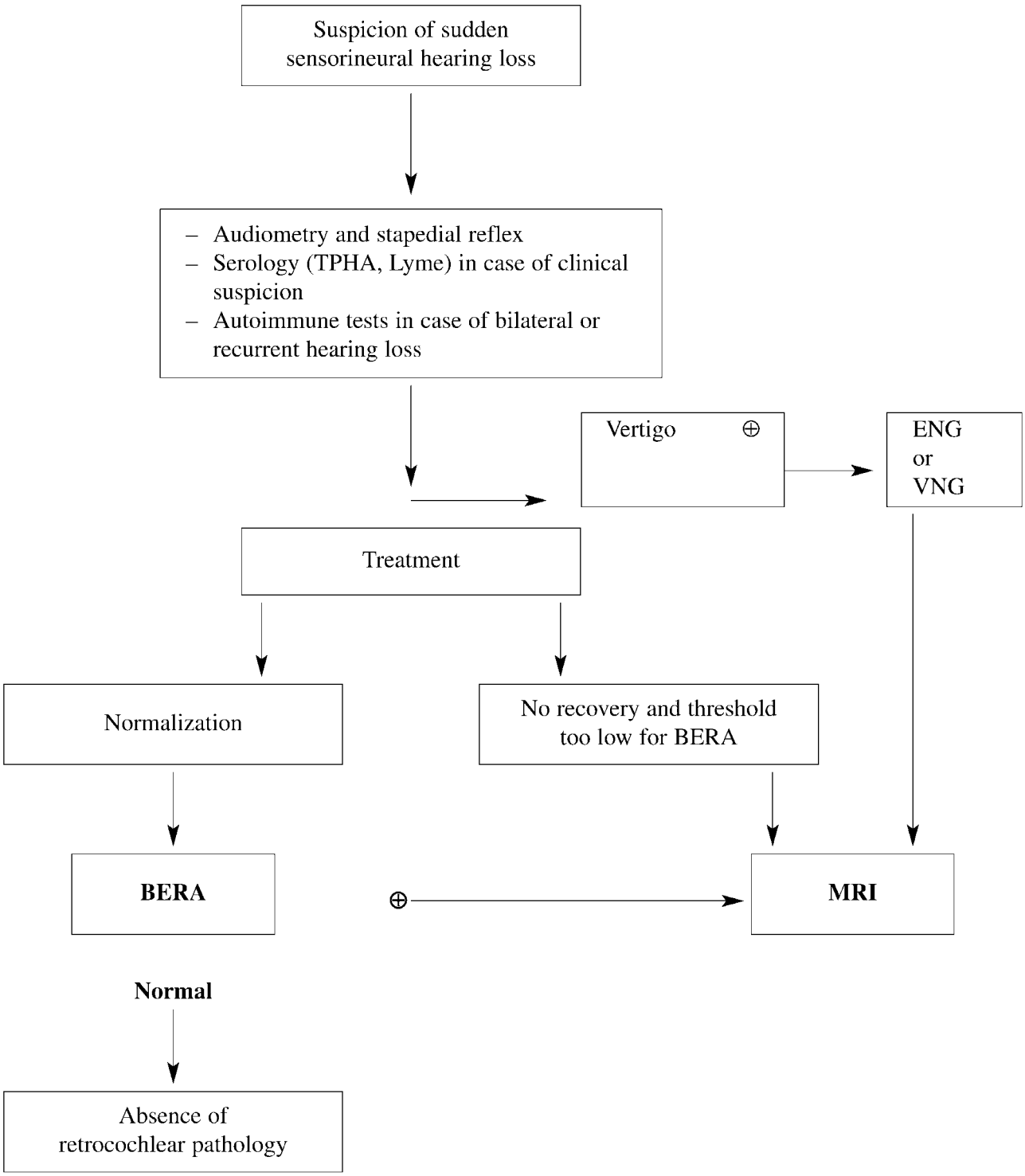
If the onset of hearing loss is less than 3 days, we recommend to add acyclovir (5×800 mg/day for 7 days), particularly if clinical sign of herpes reactivation such as auricular vesicles and facial weakness, and perhaps also pain and rotatory vertigo are present. When hearing thresholds do not improve after one week of treatment, continuation of the "Belgian cocktail" is recommended.

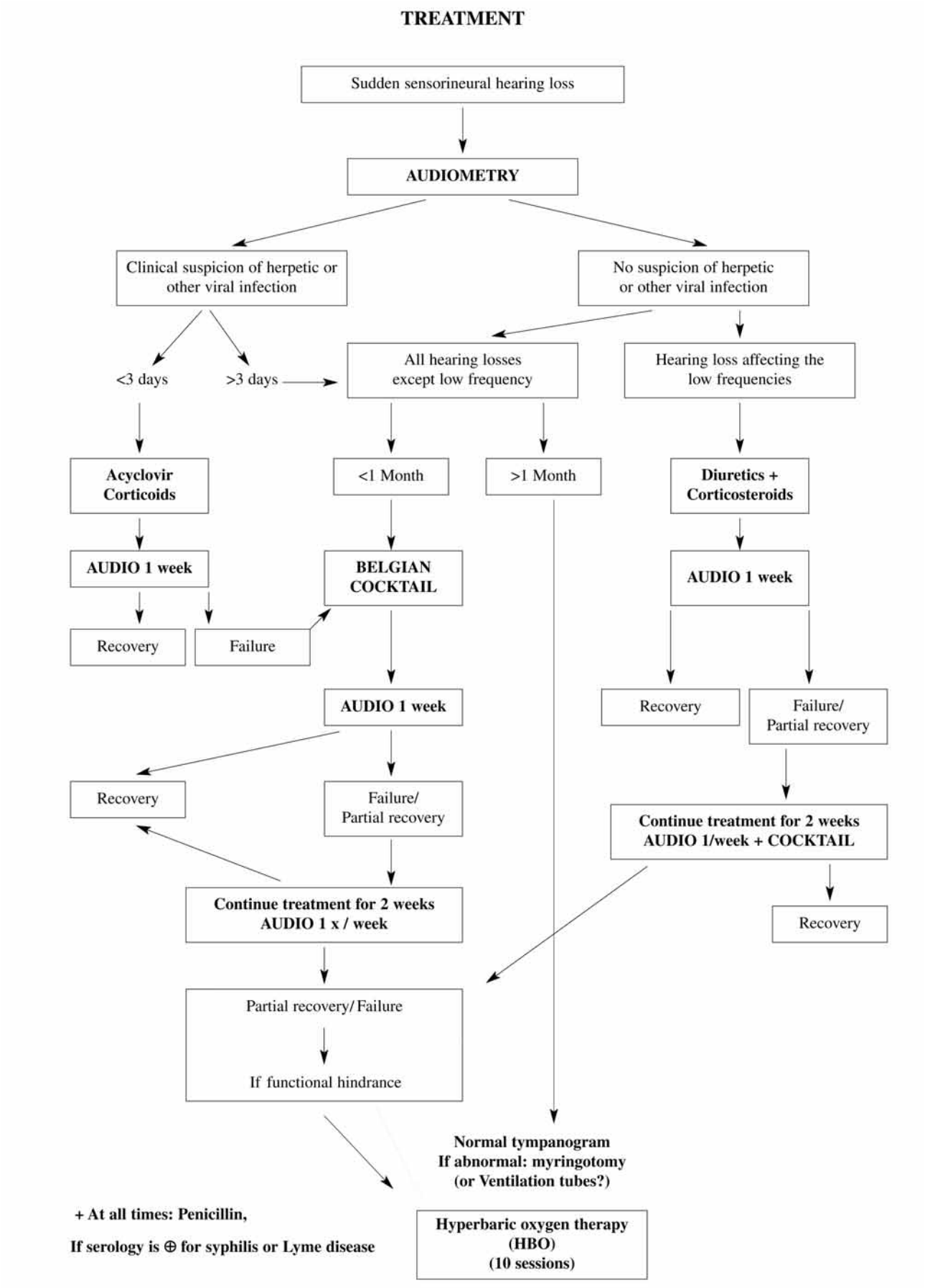
If the onset of hearing loss is more than one month ago, or if the first treatment regimen has failed, HBO should be proposed. In general, medical treatment is administered first, but as soon as a month has passed, HBO is mandatory. However, no benefit can be gained from HBO more than 3 months after onset of SSHL. Upon completion of 10 HBO sessions, the patient's hearing should be checked and in case of treatment failure, HBO therapy stopped. In case of improvement, more HBO sessions are prescribed, five at a time, until stabilization of the thresholds.

If barotrauma is the cause of SSHL, we propose HBO as first choice treatment. A myringotomy with ventilation tube is necessary because pressure changes during the HBO session might further damage the inner ear when the round window is ruptured due to the barotrauma.

The "Belgian SSHL-cocktail", thus, consists of different tablets, some of which are prescribed as a generic preparation:

DIAGNOSIS


Suspicion of sudden sensorineural hearing loss
– Audiometry and stapedial reflex
– Serology (TPHA, Lyme) in case of clinical suspicion
– Autoimmune tests in case of bilateral or recurrent hearing loss
Vertigo ⊕
ENG or VNG
Treatment
Normalization
No recovery and threshold too low for BERA
BERA
⊕
MRI
Normal
Absence of retrocochlear pathology


TREATMENT
Sudden sensorineural hearing loss
AUDIOMETRY
Clinical suspicion of herpetic or other viral infection
No suspicion of herpetic or other viral infection
<3 days
>3 days
All hearing losses except low frequency
Hearing loss affecting the low frequencies
Acyclovir Corticoids
<1 Month
>1 Month
Diuretics + Corticosteroids
AUDIO 1 week
BELGIAN COCKTAIL
AUDIO 1 week
Recovery
Failure
AUDIO 1 week
Recovery
Failure/ Partial recovery
Recovery
Failure/ Partial recovery
Continue treatment for 2 weeks AUDIO 1/week + COCKTAIL
Continue treatment for 2 weeks AUDIO 1 x / week
Recovery
Partial recovery/ Failure
If functional hindrance
Normal tympanogram
If abnormal: myringotomy
(or Ventilation tubes?)
+ At all times: Penicillin,
If serology is ⊕ for syphilis or Lyme disease
Hyperbaric oxygen therapy (HBO)
(10 sessions)

R/ vitamine E acetate 50%: 800 mg capsules (60)
1 capsule 3 times daily
R/ magnesium aspartate dihydrate: 725 mg capsules (60)
1 capsule 3 times daily
R/ piracetam 1200 (any company)
R/ medrol 32

Patient information

We do not recommend hospitalisation but we do advise patients not to expose themselves to a noisy environment. We explain that although we will try to find the diagnosis, often no cause can be found. Infection or a central cause are to be excluded first. We also point out that a weekly evaluation of hearing is necessary to decide on the next treatment. Contra-indications to therapeutic management are looked for, specifically with regard to corticoids. The other components have virtually no contra-indications (cf. compendium). When HBO is necessary, possible contra-indications for this treatment are discussed with the hyperbaric physician (most of these are relative contra-indications). Finally, we give a prognosis based on the various criteria discussed above.

Final take-home notes

In summary, sudden hearing loss without detectable cause is a relative medical emergency (3 days in case of Herpes zoster and one week for the other cases). Audiometry should be performed to confirm the diagnosis. Treatment should be started without delay and treatment modality should depend on the delay of treatment onset, frequency profile of the hearing loss, and clinical signs of infection with Herpes viruses, Lyme disease (Borrelia burgdorferi) or Treponema pallidum. Finally, retrocochlear pathology has to be excluded by performing BERA and/or MRI.

Conclusion

The diagnosis of sudden hearing loss is easily obtained by audiometry. It is important to determine the exact onset date of the hearing loss. On the other hand, a wide range of causes exists, and the exact etiology often remains unknown despite extensive investigations. Several hypotheses exist, which is our rationale for a cocktail of drugs covering the main causes of sudden deafness according to disease duration. We hope to set up a double-blind study to determine whether this cocktail could benefit patients in the long-run.

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Dr. Patrick Levie
Clinique Ste Anne-St Remi
Boulevard Graindor 66
B-1070 Brussels, Belgium
E-mail: patrick.levie@skynet.be

CME questions

1. Sudden sensorineural hearing loss (SSHL):

   A – presents as a conductive hearing loss
   B – presents as a perceptive hearing loss
   C – its etiology is often immunological
   D – is always viral in origin
   E – never recovers spontaneously

2. Sudden sensorineural hearing loss:

   A – represents 1% of the sensorineural hearing losses
   B – only affects the elderly
   C – an RSV viral episode is always preceding
   D – can reveal an acoustic neuroma
   E – is always accompanied by tinnitus

3. During anamnesis and clinical examination of a patient with SSHL, one finds:

   A – occasionally the cause
   B – often a family history of hearing loss
   C – a slightly red tympanic membrane
   D – a history of glue ear during childhood
   E – intake of antibiotics in the weeks preceding the hearing loss

4. Prognosis appears less favorable in the following situations:

   A – hearing loss affecting the high frequencies
   B – with a delay greater than a month
   C – presence of vertigo
   D – age over 60
   E – presence of microvasculature pathologies (diabetes, hypertension, hypercholesterolemia, ...)

5. The “Belgian cocktail” must be suggested in the following cases:

   A – suspicion of Herpetic infection
   B – only if the delay is <3 weeks
   C – only if the delay is >3 weeks
   D – in case of HBO failure
   E – in case of hearing loss affecting the low frequencies

6. Etiological assessment of sudden hearing loss:

   A – systematic blood test
   B – blood test if there is a suspicion of syphilis
   C – blood test if there is a suspicion of Lyme disease
   D – blood test if there is a suspicion of Herpes
   E – blood test if there in case of recurrent hearing loss

7. In clinical studies, the following treatments have shown to improve sudden sensorineural hearing loss with ascending curves:

   A – corticosteroids
   B – heparin
   C – hemodilution
   D – HBO
   E – diuretics

8. In case of hearing loss with an ascending curve:

   A – hydrops can be suspected
   B – start the treatment by associating corticosteroids with a diuretic
   C – do not hesitate to start immediately with HBO
   D – a higher chance of an acoustic neuroma and an MRI must be requested
   E – recovery must be rapid, and if the patient does not show any signs of improvement after a week, then do not hesitate to administer the Belgian cocktail

9. Which of the following statements are true?

   A – Do not hesitate to give acyclovir in case of viral infection irrespective of the delay
   B – Do not hesitate to give acyclovir in case of viral infection as long as the delay does not exceed 3 days
   C – Suggest the Belgian cocktail in case of treatment failure one week after acyclovir (in case of viral infection)
   D – In case of descending hearing loss, suggest HBO immediately
   E – In all cases, suggest HBO as soon as the delay is 3 weeks

10. Which of the following statements are false?

    A – Only ask for an MRI in cases with vertigo and abnormal ENG
    B – Request an MRI in cases with a hearing loss around 60 dB
    C – Hydrops excludes the presence of a retrocochlear pathology
    D – Recovery of hearing excludes retrocochlear pathology
    E – There are no contraindications to HBO

Answers: 1B; 2AD; 3A; 4ABCDE; 5B; 6BCE; 7AE; 8ABE; 9BCE; 10ABCDE

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Bone Anchored Hearing Aids (BAHA)

G. E. J. Forton and P. H. Van de Heyning***

*E.N.T. department, Heilig Hart General Hospital, Roeselare; **University E.N.T. department, University Hospital, Antwerp

Key-words. BAHA; Bone Anchored Hearing Aid; conductive hearing loss; unilateral deafness

Abstract. *Bone Anchored Hearing Aids (BAHA).* The bone anchored hearing aid or BAHA is a small vibrator that can be reversibly plugged onto a titanium screw that is implanted behind the ear. It transduces sound into vibration of the screw and stimulates the cochleae by means of the bone conduction pathway. The main indications are conductive hearing loss or mixed hearing loss with a moderate perceptive component when classical hearing aids cannot be worn, and rehabilitation of unilateral deafness. The indications, contra-indications, surgical technique and results are discussed in this paper.

Introduction

Most patients with hearing loss can be successfully fitted with a conventional hearing aid which involves the placement of an occlusive ear mould in the external ear canal. For some hearing impaired persons, however, the fitting of a conventional hearing aid is problematic in spite of favourable audiological criteria. For example, in patients with stenosis of the external ear canal due to congenital middle ear malformation or agenesis, an ear mould cannot be placed.[1] Also, hearing impaired persons with chronic suppurative otitis media (CSOM) suffer from ear discharge that often exacerbates when an occlusive ear mould is placed. Another group of patients for whom a conventional hearing aid is often problematic are those with a canal wall down mastoidectomy cavity. They have a wide external ear canal and acoustic feedback frequently occurs. In some otological conditions, thus, the occlusive ear mould of the conventional hearing aid is the major bottleneck in restoring hearing. For these patients, a bone anchored hearing aid (BAHA) does not imply occlusion of the external ear canal and offers a valid alternative to conventional hearing aids.

More recently, the indications for a BAHA have been extended to include unilateral deafness. For these patients, the BAHA is implanted at the deaf side, and bone conduction routes sound to the functional cochlea. Compared to a conventional contralateral routing of sound (CROS) hearing aid, patients report high satisfaction with the BAHA.

Principles

The BAHA stimulates the cochlea through bone conduction, in a similar way as a tuning fork does (see Figure 1). Because the external and middle ear are bypassed, pathological conditions of these structures do not interfere with hearing as they would with a conventional hearing aid.

Bone conduction stimulation of the cochlea results from several physical phenomena:[2]

- sound radiation in the external ear canal (predominantly at high frequencies)
- inertion of the tympano-ossicular chain and the inner ear fluids (predominantly at low frequencies)
- compression of the inner ear spaces (predominantly at mid frequencies)

For bone anchored hearing aids, the latter two phenomena are quantitatively most important and hearing gain will eventually be limited by the amount of sensorineural hearing loss. Sound radiation in the ear canal does occur with a BAHA, but this sound energy reaches the inner ear strongly attenuated due to the pathologic state of the middle ear that indicates the use of the BAHA. As sound waves propagate through the bones of theskull, the contralateral cochlea is stimulated as well, which is a second benefit of the BAHA, as will be discussed forthwith.

By using a percutaneous titanium bone-integrated fixture, the BAHA overcomes the limitations

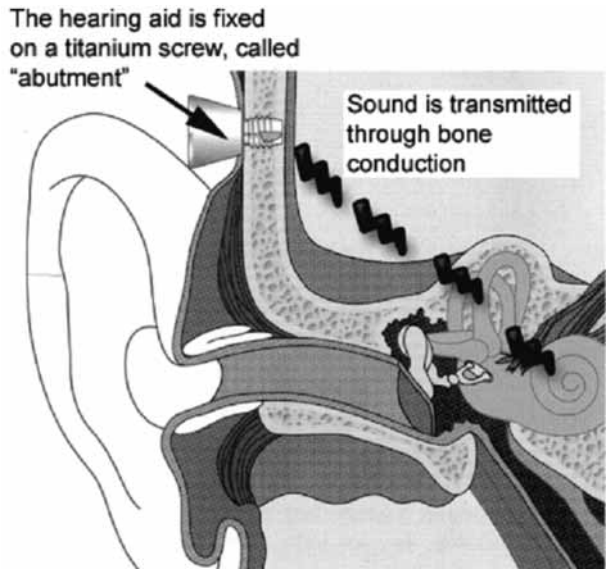

Figure 1
Scheme of BAHA

of transcutaneous devices such as a bone conduction hearing aid incorporated in a headset or spectacles. Most interestingly, acoustic feedback or Larsen's effect does not occur with the BAHA .

Indications and patient selection criteria

1. *Audiological indications*

- A BAHA can be used in all cases of conductive hearing loss,[3] even with an additional sensorineural hearing loss of up to 45 dB HL. For the BAHA Compact, the average bone conduction threshold should be better than or equal to 45 dB HL (measured at 500 Hz, 1 kHz, 2 kHz and 3 kHz). Recently, a BAHA with digital sound processing, the BAHA Divino, has been released. Its maximal amplification is identical to the BAHA Compact, but is has automatic gain control (AGC) capability and two microphones: an omnidirectional microphone and a directional front-facing microphone. The BAHA Cordelle II is a body worn device and has the more powerful K-amp amplifier, which yields an output that is on average 13 dB stronger than the BAHA Classic.
- A maximum speech discrimination score better than 60% (phonetically balanced CVC-words scored on phonemes).
- For single sided deafness,[4,5] the pure tone average air conduction threshold of the hearing ear should be better than or equal to 20-25 dB HL (measured at 500 Hz, 1 kHz, 2 kHz and 3 kHz).
- Using a test band or rod, the candidate can evaluate the sound quality and possible gain of the BAHA device prior to implantation. Pure tone and speech audiometry can be carried out and thus realistic expectations are obtained.

2. *Otological indications*

- Congenital malformations with agenesis or atresia of the middle or external ear. In cases of microtia or a completely absent pinna, an epithesis can be provided with two additional fixation points.[3]
- Chronically draining ears that do not allow use of an air conduction hearing aid, such as mastoidectomy cases with poor sound transmission and recurrent problems of humidity, discharge or infection in case of occlusion by a hearing aid or recurrent external otitis.[3]
- Patients with unilateral conductive hearing loss (and not appropriate for or refusing surgical correction) or unable to be aided by conventional air conduction hearing devices.[3]
- Congenital or acquired unilateral total deafness,[5,6,7] e.g. after acoustic neurinoma surgery where preservation of hearing was not possible.

3. *Contraindications*

- An average bone conduction threshold worse than 60 dB HL (measured at 500 Hz, 1 kHz, 2 kHz and 3 kHz).
- Mentally retarded or uncooperative patients; drug addicts…
- Very small children (<2 years). In the USA, the lower age limit is 5 years.

Surgery

Since Anders Tjellström performed the first three screw implantations in 1977, the surgical procedure and the equipment have evolved significantly. The operation nowadays usually consists of a one-stage procedure, carried out under general or local anaesthesia in the outpatient clinic. Currently, two types of incisions and surgical approaches are used, though the

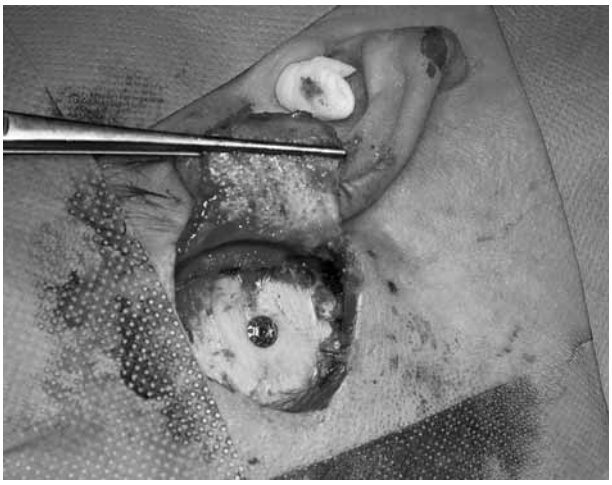

Figure 2
Horseshoe-shaped incision with elevated and thinned skin flap. Fixture screw in place.

details of the actual implantation are identical in both procedures.[8]

The first approach uses a horseshoe-shaped skin flap that is mobilized somewhat posterosuperior to the pinna (see Figure 2). The flap is elevated and thinned as much as possible before closure. When available, a dermatome can be used for thinning the skin. No subcutaneous fat tissue or hair follicles may remain. The second approach uses a single, straight incision via which the surrounding skin is undermined and thinned. We observed faster wound healing with the straight incision and abandonned the horseshoe-shaped skin flap.

The actual drilling site has to be chosen carefully, especially in small children or in post-radiotherapy cases. Detailed spiral CT studies can be helpful in these particular cases, where sometimes a two-stage procedure is preferred. There are two types of self-tapping fixation screws: their lengths are 3 and 4 mm respectively. After drilling a 3 mm deep hole, the presence of solid bone is assessed. If there is solid bone, then the drilling continues to a depth of 4 mm and the 4 mm fixture is used. This is usually the case.

During the second stage, after osseo-integration of the screw, the skin is again incised and thinned and, subsequently, the abutment is screwed onto the fixation screw.

The so-called osseo-integration takes about 3 to 4 months in healthy individuals, but in most centers, the fixture screw is loaded for the first time approximately two months after surgery. In cases of very thin bone or after radiotherapy, a longer waiting time is warranted.

Results

When reporting the outcome of a BAHA, several issues have to be considered: implantation success, skin tolerance, audiometric performance, and finally, overall patient satisfaction. Most studies report high success rate of osseo-integration (>90%). As to complications, they are rare and generally limited to skin reactions. Loss of the fixture is reported to happen sporadically. Previously irradiated bone, bone disease and very thin cortical bone are a negative prognostic factor, but not a contra-indication.[8,9]

Several clinical studies comparing the audiometric performance of the Bone Anchored Hearing Aid to those of air conduction hearing aids have been carried out. Especially patients with a pure conductive hearing loss and a limited sensorineural loss up to 45 dB (0.5–3 kHz) are very satisfied, although sensorineural losses up to 60 dB (0.5–3 kHz) can be fitted using a body-worn device connected to the transducer (Cordelle II). If not otherwise stated, the conclusions of these studies are mainly based on data from patients suffering from CSOM. All studies almost unanimously agree on a number of facts:

1. Neither conventional air conduction hearing aids, nor bone anchored hearing aids rehabilitate hearing impaired patients to the level of normal hearing people. Although this might seem an obvious observation, it is important to convey this message to the patient prior to implantation to ensure they have realistic expectations.[10]
2. Both air conduction hearing aids and bone anchored hearing aids yield very similar audiometric performances. Both were effective in improving aided free field hearing thresholds. The best improvement in hearing was observed between 1 and 2 kHz. In tests of temporal acuity, the BAHA scored slightly better, though not statistically significant.[10,11]
3. In terms of subjective improvement using validated question-

naires, the BAHA scored better. Almost all patients preferred their BAHA to the air conduction device they used beforehand. Of course, one has to take into account that the problems these patients had with their conventional hearing aids encompass the indication for switching to BAHA.[11,12]

4. Ninety-seven percent of all patients confirmed reduced occurrence of ear discharge and discomfort.[1]
5. In cases of single sided deafness, studies demonstrate strongly positive patient reactions to the BAHA system. Although source localization was not improved, subjective benefit (quality of life) was reported consistently. Also, an objective improvement in speech recognition in noise was reported (except for the condition where the talker is at the side of the hearing ear). This suggests that reducing the head shadow by use of a BAHA has overall postive effects on hearing, compared to uniloateral hearing. The results with BAHA were also consistently better than those with conventional CROS devices.[4-7,13] One recent review, however, comments on the validity of these studies, since they invariably consist of small numbers of patients, who have not always tried CROS devices for a long enough period according to the authors.[14]
6. Bilateral fitting of BAHA has been carried out on a limited scale. The results show that sound localization, speech recognition in quiet and in noise is significantly better compared to the monaural BAHA group.[15-17]

To our opinion, the recommendations formulated regarding the indications for BAHA surgery are based on good and consistent scientific evidence and can therefore be considered as grade A.

Conclusion

The Bone Anchored Hearing Aid is a valuable solution for a selected group of patients who cannot be satisfactorily helped by either functional surgery or a conventional hearing aid. Level A scientific evidence is at hand illustrating the effectiveness and safety of the procedure, as well as a significant improvement of speech discrimination and quality of life. Although an elegant and minimally invasive procedure, an operation is nonetheless required. Belgian social security reimburses the costs of the operation and the titanium implants. Furthermore, a partial reimbursement of the sound processor is provided, similar to a classic bone conduction hearing aid. The gain in quality of life significantly outweighs the inconveniences associated with this type of hearing aid.

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Glen E. J. Forton, M.D., Ph.D.
E.N.T. Department
Heilig Hart General Hospital
Wilgenstraat 2
B-8800 Roeselare, Belgium
E-mail: gforton@hhr.be

CME questions

1. BAHA is not indicated for:

   A – Unilateral radical cavity with large conductive hearing loss
   B – Bilateral agnesia of the outer ear canal
   C – Bilateral mild to moderate sensorineural hearing loss
   D – Unilateral deafness

2. In cases of normal healing, the patient can start wearing the hearing aid on the abutment after:

   A – Two weeks
   B – Eight weeks
   C – Six months
   D – Immediately

3. Which of the statements are correct?

   A – A BAHA does not improve speech-in-noise discrimination
   B – A BAHA partly eliminates the head shadow and conveys spectral and temporal information by transcranial sound transmission to the contralateral ear in case of an only hearing ear, thus improving speech-in-noise.
   C – A BAHA is much less efficient than a conventional hearing aid in cases of unilateral deafness
   D – A BAHA needs a mobile stapes in order to work properly

4. Which contra-indication is correct?

   A – An average bone conduction threshold worse than 90 dB HTL (measured at 500 Hz, 1 kHz, 2 kHz and 3 kHz)
   B – An average bone conduction threshold better than 60 dB HTL (measured at 500 Hz, 1 kHz, 2 kHz and 3 kHz)
   C – Unilateral deafness
   D – An average bone conduction threshold worse than 60 dB HTL (measured at 500 Hz, 1 kHz, 2 kHz and 3 kHz)

5. Which statement is correct?

   A – BAHA patients are generally more happy with conventional hearing aids
   B – Larsen's effect remains an important problem with BAHA
   C – BAHA patients almost unanimously prefer the BAHA to their conventional hearing aid
   D – BAHA patients often complain about vibrations in their ear

Answers: 1C; 2B; 3B; 4D; 5C

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Implantable electro-mechanical devices for sensorineural hearing loss

J. Claes and P. H. Van de Heyning

University deptartment ENT, Antwerp University Hospital, University of Antwerp

Key-words. Hearing loss; treatment; implantable devices

Abstract. *Implantable electro-mechanical devices for sensorineural hearing loss.* Implantable electro-mechanical devices are a valuable solution for patients with sensorineural hearing loss who do not tolerate a conventional hearing aid. The currently available devices are the result of technological progress and clinical experiments over the last 30 years. The advantages observed during early clinical trials are nowadays confirmed. Some issues – specifically the coupling of the device to the human auditory system – are still open for improvement.

Introduction

Conventional hearing aids have important limitations, even for properly selected patients and after rigorous adaptation. Many patients with sensorineural hearing loss (SNHL) avoid the use of a conventional hearing aid despite their needs for better hearing. Apart from psychological factors, distortion of the amplified sound is often cited as a major reason for this attitude. Also, the presence of a hearing aid in the external ear canal is experienced as uncomfortable, cosmetically unacceptable, and stigmatizing. Occlusion of the external ear canal may cause external otitis and wax accumulation. Acoustic feedback phenomena occur at high frequencies and high intensities. A small receiver, inherent to the design of a hearing aid, heavily distorts low frequencies. These phenomena degrade speech understanding and limit hearing gain achieved with conventional hearing aids. Many of the limitations of conventional hearing aids are related to the physics of sound, and hence fundamental and difficult to overcome.

A hearing aid that does not involve the delivery of amplified sound in the external ear canal, and that is totally hidden would probably meet the needs of a large group of patients with hearing loss. Middle ear implants offer these advantages and have successfully remediated hearing loss of patients with SNHL and conductive or mixed hearing loss.

Advantages over conventional hearing aids and principles of functioning

Implantable electro-mechanical devices transduce sound into mechanical vibration that, in most cases, is directly applied to the ossicular chain. They are therefore often referred to as “direct drive” transducers. The mechanical vibration can be generated by a piezoelectric element, an electromagnetic coil, or even hydrostatic force. These transducers are implanted in the middle ear, and do not imply use of an occlusive ear mould and a small speaker, and therefore appear user-friendly and promise better quality of hearing.

Direct application of force to the ossicular chain is a relatively new project in otologic clinics, and many questions with practical implications arose. How does the normal human ossicular chain vibrate? What is the effect of a mass load on this vibration? What should be the optimal direction of the force applied to the ossicular chain? How well, on the long term, will the implant integrate in the tissues of the ossicular chain? These notions are equally or even more important than considerations of technical and surgical feasability when a coupling system is designed, and are currently under evaluation.

Types of implants currently available in Belgium for clinical implantation

Two types of implants are currently available in Belgium for clinical use under FDA and/or CE approval. The Vibrant Soundbridge (VSB, Vibrant MED-EL Hearing Technology, Innsbruck, Austria – Figure 1) is a semi-implantable device consisting of three parts: an external audio processor, an internal receiver, and an electromagnetically driven

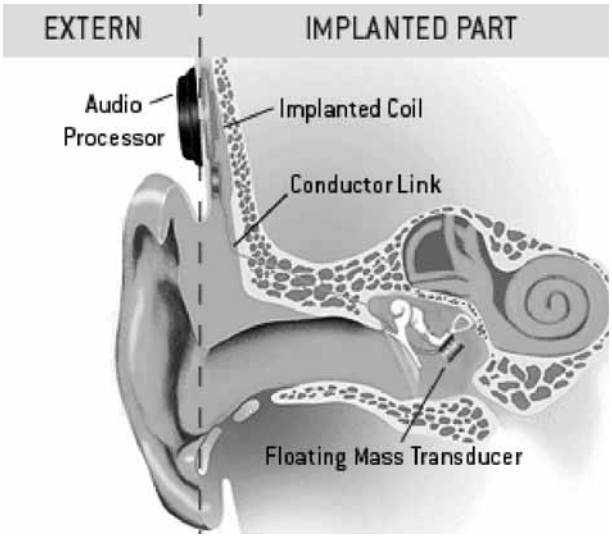

Figure 1
The Vibrant Soundbridge system

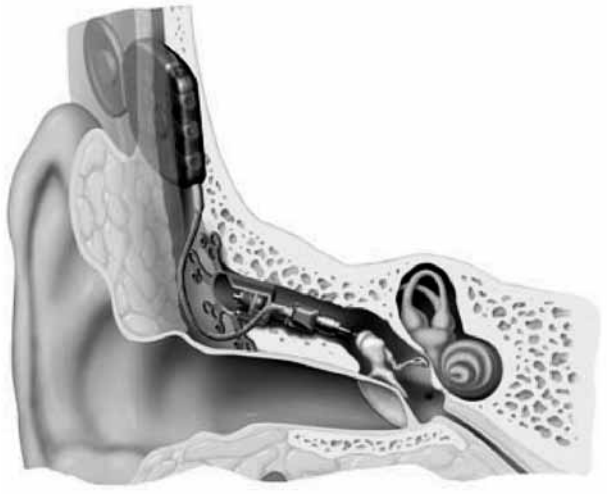

Figure 2
The MET system

transducer, which is attached to the long process of the incus. The transducer of the VSB is also called a floating mass transducer; it contains a mass that can freely move within the coil. The internal receiver of the device is implanted in a recessed seat in the temporal fossa, similar to a cochlear implant. A wire links the internal receiver to the floating mass transducer. A mastoidectomy with posterior tympanotomy is necessary for exposition of the long process of the incus, to which the floating mass transducer is attached. The audio processor is worn externally like the external coil of a cochlear implant, it is coupled to the internal receiver by a transdermal telemetry system.

The Otologics Middle Ear Transducer (MET, Otologics, Boulder, Colorado, USA – Figure 2) consists of an external audio processor which is worn on the skin behind the ear, and an internal receiver-transducer that drives an aluminum oxide probe that is coupled to the incus body. The electromagnetic transducer is mounted into an atticomastoidectomy cavity, and acts as a piston on the ossicular chain via a hole that is made in the body of the incus with a laser. The receiver is embedded in a temporal fossa seat much like is done in cochlear implant surgery.

Otologics has recently developed a fully-implantable ossicular stimulator named Sonäta. The system uses the same direct drive on the incus body as the MET, but it has a microphone that is positioned subcutaneously, and a battery and sound processor that are also implanted under the temporal skin. The battery can be charged transcutaneously.

A third system, DACS or Direct Acoustic Cochlear Stimulation (Cochlear Acoustics, Lausanne, Switzerland) is in phase IV post approval investigation in Europe. The system has an implantable part that provides an artificial incus process on which a stapes prosthesis, comparable to those used in stapedotomy, can be attached. An external sound processor drives the implant.

A fourth system, the Soundtec Direct Hearing System (Soundtec Inc., Oklahoma City, Oklahoma, USA), currently only available in the USA, consists of an external and an internal portion. The external part carries a microphone and a sound processor connected to an electromagnetic coil, it can be worn in the ear canal or behind the ear with a custom ear canal mold in which the coil is incorporated. The internal part is a magnet that is attached to the incudo-stapedial joint. It can be implanted through a transmeatal tympanotomy.

Patient selection criteria

Today, only adult patients are selected for Vibrant Soundbridge implantation. They should have a sensorineural hearing loss, which is not of retrocochlear origin. Middle ear anatomy must be normal and there should be no air-bone gap greater than 10 dB at two or more frequencies at 0.5, 1, 2 and 4 kHz. The hearing loss must be stable in time. The use of a conventional hearing aid must be

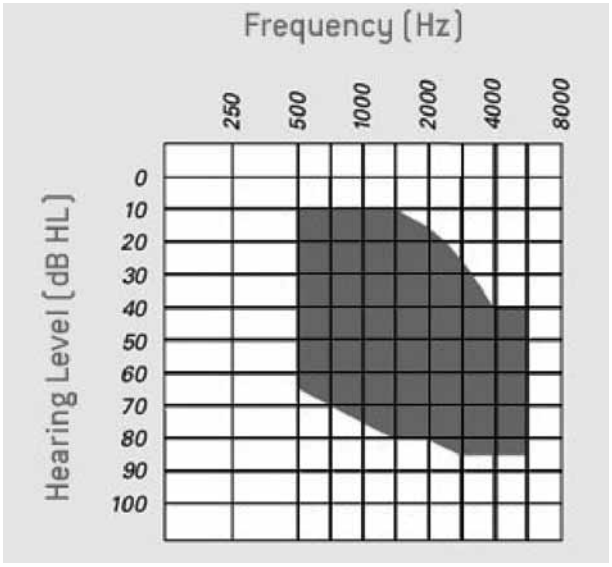

Figure 3
Audiologic selection criteria for Vibrant Soundbridge

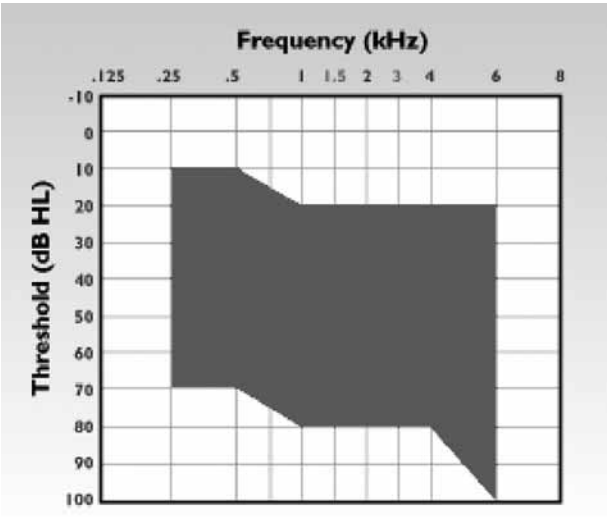

Figure 4
Audiologic selection criteria for MET.system

contraindicated for medical reasons or rejected by the patient after optimal fitting and a reasonable period of use. The pure tone unaided hearing levels of the fitted ear must lie within the boundaries given in Figure 3. Speech understanding should be at least 50% in open-set word tests at the most comfortable listening level. A combination of the Vibrant Soundbridge floating mass transducer with a stapedotomy prosthesis is under investigation. This modification would extend the selection criteria to mixed type hearing losses. A number of personal communications have been made by several surgeons who apply the floating mass transducer to the round window niche in difficult-to-treat middle ear cases. (Colletti V, MEMRO 2006, Zurich, personal communication).

The selection criteria for the MET implant include adult patients with SNHL, no signs of conductive or retrocochlear hearing loss, and no history of recurrent otitis media. The hearing loss must be stable, of post-lingual onset and lie within the limits given. Patients should have realistic expectations of their hearing gain (Figure 4). The range of hearing loss that can be remediated by the Sonäta is identical to that of the MET system. A combination of the system with a partial ossicular replacement prosthesis in titanium is under investigation. This combination would extend the indications to mixed hearing loss with a normally functioning stapes, such as certain congenital malformations of the ear and certain post-surgical chronic otitis cases. No results of these latter options have been published today.

The DACS system does not require a functional middle ear, and can be implanted without compromise to residual hearing or residual middle ear function. It would therefore be applicable to sensorineural as well as mixed type hearing losses. Clinical experience with the system, however, is limited today.

As in all prosthetic rehabilitation of hearing, selection of patients must also take into account the effect of "dead regions" in the cochlea, where the absence of hair cells precludes successful amplification of sound, be it acoustic or by direct vibration of the ossicular chain.[1] Also, normal hearing at low frequencies may contra-indicate a middle ear implant since a low frequency and low intensity rumble may, as it does in conventional non-digital hearing aids, disturb the user.

Results

Several studies by different centers in the USA and in Europe report the results after implantation of the Vibrant Soundbridge (VSB) system.[2-4] These reports conclude that most of the patients clearly benefit from the VSB, with however a subgroup of patients experiencing low gain (at threshold or at conversational sound level) that could not be explained by their amount of preoperative

hearing impairment. Speech recognition scores after implantation are comparable to those obtained with conventional hearing aids, with however a large spread of results. A large French multicenter clinical study with 125 VSB implantees reports that 83% of the patients were either satisfied or very satisfied with the device.[5] Unsatisfactory results in some of the patients are attributed to problems with positioning and fixation of the floating mass transducer,[6] as well as to suboptimal programmation of the audioprocessor. By measuring sound in the external ear canal, a reverse transfer function can be established, and the proper functioning of the implant and its coupling to the ossicular chain can be objectively assessed during or after the operation.[7] The sound quality after implantation is generally rated as undistorted, and hearing with the implant results in better speech understanding even in situations with loud background noise.[4]

Also the long term results seem to be very interesting as the first implanted patients in 1996 continue to be satisfied with their device.[8] Studies comparing patient satisfaction between the VSB and the conventional hearing aids seem to favor the first.[9,10] The fixation site of the floating mass transducer at the lenticular process of the incus appears to show changes comparable to those after stapes surgery.[11] We must however accept that selection criteria for implantable hearing devices do not only depend on pure audiometric selection criteria.[12]

Experimental acoustic studies found that a floating mass transducer reduces stapes displacement in the temporal bone model. This might have an effect on high frequency hearing function, especially when the device is switched off.[13]

The evidence level of conclusions found in the literature on VSB implants can be classified as level II.

For the MET implant system, the first results of multicenter clinical studies are now available. For 282 patients implanted in Europe and the USA, group mean postoperative bone and airconduction thresholds (unaided) did not change significantly from preoperative levels. Postoperative air conduction thresholds decreased slightly in some patients, due to the mass loading effect of the coupled transducer. Sufficient gain was achieved to reach target prescription levels for patients with moderate to severe hearing loss. Audiometric and subjective assessment indicates that patients do as well or better with the MET Ossicular Stimulator than with their conventional hearing aid.[14] However, at this time (august 2005) only one multicenter study with this device is available. We therefore classify the results studies of the MET system at level III of evidence.

Conclusion

After a long period of experimental studies and research, the implantable electro-mechanic hearing devices for SNHL are now on the verge of broad clinical application. The first clinical results are very promising and the currently used devices are safe and functional. They will probably become a good alternative for those patients who are dissatisfied with their conventional hearing aid. It is also clear that some changes in technical aspects of implantation – especially in the design of the ideal coupling between transducer and ossicular chain – are needed before these hearing aids will become widely accepted.

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J. Claes
Univ dept ENT
Antwerp University Hospital
University of Antwerp
E-mail: jos.claes@uza.be

CME questions

1. Middle ear implants are applicable for:

   A – patients with middle ear conductive hearing loss
   B – patients in whom the chronic otitis precludes the use of conventional hearing aids
   C – patients with unilateral total deafness
   D – patients with sensorineural hearing loss and a normal middle ear
   E – patients with bilateral total deafness

2. An advantage of MEI over conventional hearing aids is:

   A – receivers can be larger because they do not have to fit in the external ear canal
   B – there is no feedback fenomenon (Larsen's effect)
   C – they are invisible since they are implanted
   D – they perform better in the high frequency range

3. The widespread application of MEI is limited by:

   A – the cost
   B – the surgical procedure that is necessary
   C – the incompletely resolved issue of coupling the device to the ossicular chain
   D – the limited number of indications for their use

4. When an implanted MEI it is switched off, the hearing of the patient when compared to the pre-implantation levels:

   A – is identical
   B – is much worse
   C – is probably worse in the high frequency range
   D – is probably worse in the low frequency range

5. The functional results of MEI are, in comparison to conventional hearing aids:

   A – systematically worse
   B – systematically better
   C – partly unpredictable because of technical shortcomings in the frequency characteristics of direct drive systems
   D – partly unpredictable because of technical shortcomings in the coupling of devices to middle ear structures

Answers: 1D; 2B; 3C; 4C; 5D

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Rhinosinusitis in children

P. A. R. Clement and S. Vlaminck***

*Department of Otolaryngology, Head and Neck Surgery, Academic Hospital, Free University Brussels (A.Z.-V.U.B.), Brussels; **Department of Otolaryngology, St. Jan General Hospital, Bruges

Key-words. Consensus; paediatric sinusitis; management

Abstract. *Rhinosinusitis in children.* The definition of rhinosinusitis (RS) in children is based here on category IV reports. The diagnosis of RS is mainly made on clinical grounds helped by endoscopic investigation. Indications for additional investigation and radiological examination are outlined. Medical treatment with antibiotics is advised when bacterial infections and complications are present. There is insufficient evidence for the use of antibiotics for uncomplicated common colds in children. The strength of evidence for recommendations is mainly A-based, unless otherwise specified. There is a paucity of studies (with a rather low numbers of participants) in children. The absolute and relative indications for surgical intervention are outlined. Decisional algorithms are presented for acute and chronic rhinosinusitis in children.

I. Definition and epidemiology of rhinosinusitis in children

Rhinitis and **sinusitis** usually coexist and are concurrent in most individuals; the correct term is now ***rhinosinusitis***.[1]

Clinical definition of rhinosinusitis in children

- inflammation of the nose and the paranasal sinuses characterised by:
  - blockage/congestion
  - discharge: anterior/post-nasal drip
  - facial pain/pressure
  - impairment/loss of smell

  and either
- endoscopic signs:
  - polyp(s)
  - mucopurulent discharge from middle meatus
  - oedema/mucosal obstruction primarily in middle meatus

  and/or
- CT changes:
  - mucosal changes within ostiomeatal complex and/or sinuses

Classification in paediatric rhinosinusitis is based on the consensus meeting in Brussels.[1] To summarise:

1. **Acute rhinosinusitis** is an infection of the sinuses usually initiated by a viral infection, in which the complete resolution of symptoms (assessed on a clinical basis only) without intermittent upper respiratory tract infections may take up to twelve weeks. It can be subdivided into severe and non-severe (Table 1).
   According to the subcommittee on the management of sinusitis and the committee on quality improvement of the American Academy of Pediatricians (SMS/CQIAAB), the common predisposing event that sets the stage for acute bacterial sinusitis is a viral upper respiratory infection that results in viral sinusitis and can lead to an "acute bacterial rhinosinusitis" (ABRS). In 80% of cases, this acute bacterial rhinosinusitis is induced by an upper respiratory infection that starts a diffuse mucositis followed by bacterial superinfection. Allergy is responsible for the remaining 20% of acute bacterial sinusitis. According to the SMS-CQI-AAP guideline[2], an acute bacterial rhinosinusitis is an infection of the paranasal sinuses lasting less than 30 days in which symptoms resolve completely. According to Mucha *et al.*[3] ABRS should be considered after a viral upper respiratory infection, when the symptoms worsen after 5 days, are present for longer than 10 days or out of proportion to those seen in most viral infections. A typical evolution of this kind is more obvious in adolescent children and adults than in very young children.
   To cover the gap between acute and chronic sinusitis the SMS-CQI-AAP guideline[2] introduced, for children also, the concept of "subacute bacterial sinusitis" as an infection of the paranasal sinuses lasting between 30 and 90 days,

Table 1
Symptoms and signs of non-severe and severe sinusitis in children

Non-severe	Severe
Rhinorrhoea (of any quality) Nasal congestion Cough Facial pain and headache and Irritability (variable)	Purulent rhinorrhea (thick, coloured, opaque) Nasal congestion Facial pain and headache

in which symptoms resolve completely. The Brussels Consensus Meeting[1] did not recommend the term subacute sinusitis since the difference between acute and subacute is very arbitrary and does not imply a different therapeutic approach in children.
Recurrent acute sinusitis involves episodes of bacterial infection of the paranasal sinuses, separated by intervals during which the patient is asymptomatic. The SMS/CQI-AAP guideline[2] states that these episodes last less than 30 days and are separated by intervals of at least 10 days.

2. **Chronic rhinosinusitis** in children is defined as a non-severe sinus infection with low-grade symptoms persisting for more than twelve weeks.
Chronic rhinosinusitis with frequent exacerbations or acute bacterial sinusitis superimposed on chronic sinusitis. These are patients with residual respiratory symptoms who develop new respiratory symptoms. When treated with antimicrobials, these new symptoms resolve, but underlying residual symptoms do not.

The members of the Brussels Consensus meeting[1] noted that medical treatments such as antibiotics and nasal steroids may modify symptoms and signs of acute and chronic sinusitis and it is sometimes difficult to differentiate between infectious rhinosinusitis and allergic rhinosinusitis on clinical grounds alone in children.

II. Epidemiology

In the USA the annual incidence of viral rhinosinusitis is estimated to be 6 to 8 episodes in children and 2 to 3 episodes in the adult population.[4] Wald[5] states that colds are much more frequent in children than in adults and that the range of reported frequency for URI in young children is between 6 and 8 per year, while adults experience two or three colds a year. Between 5 and 10% of cases of viral rhinosinusitis are thought to be complicated by clinically evident acute bacterial rhinosinusitis.

Van der Veken[6] showed in a CT scan study that there was sinus involvement in 64% of children with a history of chronic purulent rhinorrhoea and a nasal obstruction. An MRI study of a non-ENT paediatric population[7] found an overall prevalence of sinusitis signs in children of 45%. This prevalence increases in the presence of a history of nasal obstruction to 50%, to 80% when bilateral mucosal swelling is present on rhinoscopy, to 81% after a recent upper respiratory tract infection (URI), and to 100% in the presence of purulent secretions. Kristo *et al.*[8] also found a similar overall percentage (50%) of abnormalities on MRI in 24 schoolchildren. They included, however, a follow-up after 6 to 7 months, and found that about half of the abnormal sinuses on MRI findings had resolved or improved without any intervention.

A very extensive prospective study was performed by Bagatsch *et al.*[9] who followed the total paediatric population (24,000 children), representing 30% of a newly developed residential area in the neighbourhood of Rostock (former DDR) with 80,000 residents, who were followed for 1 year by the only available medical centre in that area. Eighty-four percent of the children aged between 0-2 years, 74% of those between 4 and 6 years, and 80% of those over 7 years of age had one or more episodes of URI in that period. In a closer look at the 0 to 5 year old group, 72% of those children staying in day care centres and 27% of those staying at home had one or more episodes of URI. Of the 84% of children aged 0 to 3 years (n = 4.103), 32% suffered from rhinopharyngitis. The peak of this disease was located in November to February. Lind[10] and Bjuggren *et al.*[11] also found a much higher prevalence of up to 100% for maxillary sinusitis in children staying in day care centres compared with the same age group staying at home or older children in schools. Sometimes, children in day care centres also induce recurrent sinusitis in the adults watching over them (= “young child to young adult sick sinus syndrome”).[12]

All these epidemiological studies yield important information about pathophysiology and

clinical relevant factors for the prevalence of rhinosinusitis in children:

1. There is a clear-cut decrease of the prevalence of rhinosinusitis after 6 to 8 years of age. This is the natural history of the disease in children and is probably related to an immature immune system in the younger child.[6,13,14]
2. In temperate climates there is a definite increase in the occurrence of chronic rhinosinusitis in children during the autumn and in the winter, so the season seems to be another important factor.
3. The prevalence of chronic or recurrent sinusitis is much higher in younger children in day care centres than in children staying at home.

III. Pathophysiology

Although viruses are rarely recovered from sinus aspirates[15,16] most authors agree[17] that viral infections are the trigger for rhinosinusitis. Evidence supports the idea that nasal fluid containing viruses, bacteria and inflammatory mediators might be blown into the sinuses during a cold.

Although CT scan abnormality can be seen up to several weeks after the onset of a URI, one can assume that only 5 to 10% of URIs in early childhood are complicated by acute sinusitis.[18,19,20]

The factors predisposing to ostial obstruction can be divided into those that cause mucosal swelling, and those due to mechanical obstruction. Mucosal swelling is mostly induced by URI but it can be caused by systemic diseases such as cystic fibrosis, allergy, immune disorders and primary ciliary dyskinaesia. Local insult such as facial trauma, swimming and or diving can contribute to poor antral drainage and ventilation. The most common mechanical factors in children are choanal atraesia, adenoid hyperplasia, extreme anatomical variations of septum and of the lateral nasal wall, foreign bodies and tumours (juvenile angiofibroma) or pseudotumours (polyps, antrochoanal polyp, meningoencephalocoeles).

IV. Diagnostic management

1. *Clinical examination*

   – Anterior rhinoscopy: remains the first step but is inadequate on its own.
   – Endoscopy: is more useful not only for diagnosis but also for exclusion of other conditions such as polyps, foreign bodies, tumours and septal deviations. Moreover, it allows for direct sampling of the middle meatus in certain conditions.[21]

2. *Microbiology*

   Microbiological assessment is usually not necessary in children with uncomplicated acute or chronic rhinosinusitis. The indications for sinus punction are:

   1. severe illness or toxic conditions in a child;
   2. acute illness in a child that does not improve with medical therapy in 18 or 72 hours;
   3. an immunocompromised host;
   4. the presence of superative (intra-orbital, intracranial) complications (orbital cellulites excepted).

   Culture specimens obtained from the middle meatus or from the ethmoidal bulla are often more likely to show positive results than culture specimens obtained from the maxillary antrum.

3. *Imaging*

Imaging is not necessary to confirm a diagnosis of rhinosinusitis in children. Transillumination of the sinuses is difficult to perform and unreliable in children. The value of ultrasound is controversial.

– Plane sinus X-rays are insensitive and their usefulness is limited for both diagnosis and guiding surgery in children. The marginal benefits are insufficient to justify the exposure to radiation in children.[22]
– CT scanning remains the imaging methodology of choice because it can resolve both bone and soft tissue[23] and provides good visualisation of the ostiomeatal complex, the corner-stone of the diagnosis of sinusitis.[24]

Indications:

1. severe illness or toxic conditions in a child;
2. acute illness in a child that does not improve with medical therapy in 18 or 72 hours;
3. an immunocompromised host;
4. the presence of suppurative (intra-orbital, intracranial) complications (orbital cellulites excepted);
5. if surgery is being considered.

4. *Additional investigation*

Additional investigation in the presence of recalcitrant rhinosinusitis: underlying conditions such as allergy, immunodeficiency, cystic fibrosis, ciliary immotile disorders, and gastro-oesophageal reflux have to be considered. Of these, respiratory allergy is perhaps the most frequent. In children with chronic or recurrent acute rhinosinusitis with a suggestive history and/or physical examination findings, then, allergic assessment (skin-prick, nasal smear, radioallergosorbent testing, or trial of treatment) should be performed in patients who continue to have clinical difficulties, despite avoidance and simple pharmacological measures. Immunological assessment (complete blood cell count, quantitative immune globuline levels, IgG subclass levels in serum and anti-pneumococcic antibody titres) is also advised.

V. Therapeutic management

1. *Medical treatment*

a) **Common cold**

A study of the delayed use of antibiotics for symptoms and complications of respiratory infections indicates that antibiotics have no effect on the common cold. The use of antihistamines, decongestants, antitussives, expectorants, singly and in combination, are meant to provide symptom relief, but no studies are available in children and infants that have demonstrated any benefit. Their use is not recommended because of the potential of enhanced toxicity. Transmission of the common cold is best prevented by frequent hand-washing and avoiding touching one's nose and eyes.

b) **Acute rhinosinusitis**

The most common bacterial species isolated from the maxillary sinuses of patients with ABRS are *Streptococcus Pneumoniae, Haemophilus Influenzae and Moraxella catarrhalis,* the latter being more common in children.[22]
Antibiotherapy only should be considered in

– severe illness or toxic conditions in children;
– suspected or proven suppurative complications (parenteral antibiotics are preferred);
– severe acute rhinosinusitis;
– non-severe acute rhinosinusitis in a child with protracted symptoms to whom antibiotics can be given on a individualised basis (presence of asthma, chronic bronchitis, acute otitis media, immunocompromised children,...).

The duration of the antimicrobial therapy should be at least 10 to 14 days, and can be prolonged to 1 month if the symptoms have clearly improved but not resolved completely. However, if the symptoms are unchanged at 72 hours or worsen at any time, the clinician should either change antibiotics or obtain a specimen of sinus secretions for culture and make a thorough re-evaluation of the child's condition.
This recommendation is based on experience in adults. Hamory *et al*.[25] found negative cultures (n = 81) with symptoms of acute sinusitis after a 10-day course of treatment with an antibiotic to which the micro-organism was susceptible in 42 out of 44 (95%) repeated sinus aspirates. Since 1981, the percentage of β lactamase-positive strains has shown a steady increase from 6% to 17% in 1991.[26] Depending on the country and the local situation, amoxicillin can usually still be used as a good first-line antibiotic in non-severe cases. If the local prevalence of lactamase-positive strains is high, then an appropriate β lactam-resistant antibiotic such as amoxicillin-clavulanate or cefuroxime can be used for at least 10 days.

c) **Chronic rhinosinusitis**

There is no evidence – since the role of bacteria in CRS remains unclear – supporting the use of antibiotics. Van Buchem *et al*.[14] followed 169 children with a runny nose for 6 months, treating them only with decongestants or saline nose drops. They did not find a single child who developed a clinically serious disease, which proved that complications of rhinosinusitis in a child are not very common. The only long-term follow-up of the treatment of children with chronic maxillary sinusitis (n = 141), which compared oral amoxicillin combined with decongestive nose drops, drainage of the maxillary sinus (antral lavage), a combination of the two previous regimens, and placebo, was performed by Otten *et al*.[27] They found that the therapeutic effects of these four forms of treatment did not

differ significantly or have a significant curative effect. Antibiotics should not be administered in a child under the age of seven with a chronic runny nose but who is otherwise completely healthy.

d) **Chronic rhinosinusitis with frequent exacerbations**

In chronic rhinosinusitis with frequent exacerbations, an initial course of 2 weeks of oral antimicrobial treatment is advised. If there is no response within 5-7 days, the antibiotic should be changed. If there is again no response within 5-7 days a specimen of sinus secretion should be obtained for culture or a non-infectious condition should be considered. If, however, the patients respond rather slowly, a second two-week course can be prescribed. In rare cases, when there is a clear-cut improvement but symptoms still persist, a third course can be given before considering surgery. Parenteral antimicrobial therapy may be administered before considering surgery.

2. *Surgical treatment*

a) **Adenoidectomy**

One study[28] performed on 78 children showed a significant improvement ($p < 0.01$) of sinusitis signs on X-ray examination six months after surgery compared with a control group. Accordingly, in cases where chronic sinusitis is accompanied by clear-cut signs of adenoid hypertrophy resulting in nasal obstruction, snoring and speech difficulty, adenoidectomy should be performed before more extensive surgery is considered. In a retrospective study, Vandenberg *et al.*[29] showed, in 48 children after adenoidectomy or adenotonsillectomy, a clear-cut improvement in the symptoms of rhinosinusitis i.e.: rhinorrhoea, nasal congestion, mouth breathing and frequent antibiotic use. The importance of adenoidectomy is further underscored by Ungkanont *et al.*[30] in a prospective study in 37 children with chronic rhinosinusitis, showing a statistically significant reduction in episodes per year of acute rhinosinusitis and reduction in obstructive symptoms.

b) **Antral lavage**

In children with chronic rhinosinusitis, irrigation of the maxillary sinus does not lead to better results after 3 weeks compared with a control group[31] or there is no statistically significant increase in the success rate.[22]

c) **Nasal antral window in inferior meatus**

Lund[23] demonstrated that, especially in children under the age of 16 years, there is a higher rate of closure of these antral windows. She concluded that the inferior meatus in children is smaller than in adults, making it impossible to achieve an adequate antrostomy. Lusk *et al.*[22] and Muntz *et al.*[24] were therefore able to show that, in a six-month follow-up, the success rate of the nasal antral window procedure dropped to 27%. All patients remained symptomatic, and 28% needed further functional endoscopic sinus surgery.

d) **The Caldwell-Luc operation**

Is contra-indicated in children.[16,23]

e) **Functional endoscopic sinus surgery (FESS)**

Functional endoscopic sinus surgery (FESS) should be individually tailored to each case. An international consensus was reached in 1996[1] concerning the indications for FESS in children (Table 2).

Extensive sphenoidectomy is usually not necessary in children. Anterior ethmoidectomy (with removal of the uncinate process with or without maxillary antrostomy, opening of the bulla, no dissection posterior to the basal lamella) is often sufficient. It is only in children with massive polyposis due to cystic fibrosis that extensive spheno-ethmoidectomy yields better and more enduring results than limited surgery.

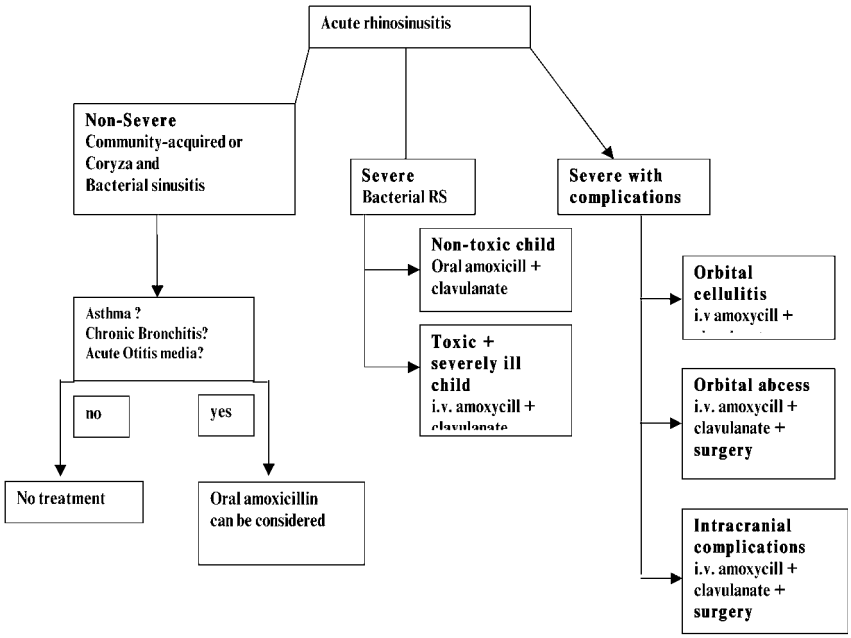
In a meta-analysis of FESS in children, Hebert *et al.*[32] (focusing on the number of patients per study, length of follow-up, prospective versus retrospective, the separation or exclusion of patients with significant underlying systemic disease) showed – in 8 published articles (832 patients) – positive outcome rates ranging from 88 to 92%. The average combined follow-up was 3.7 years. So they concluded that FESS is a safe and effective treatment for chronic sinusitis that is refractory to medical treatment.

Similar results were published in a more recent study by Jiang *et al.*[33] and Fakhri *et al.*[34] showing a postoperative improvement in 84% of cases treated with FESS

(n = 121). For this indication, Bothwell *et al*.[35] conducted a retrospective age-matched cohort outcome study using qualitative antropomorphic analysis of 12 standard facial measurements in follow-up over 13.2 years. They found no statistically significant difference in outcome in terms of facial growth between 46 children who underwent FES surgery and 21 children who did not.

VI. Decisional algorithms

Evidence-based diagram for therapy in children with acute rhinosinusitis[38]



Evidence-based diagram for therapy in children with chronic rhinosinusitis

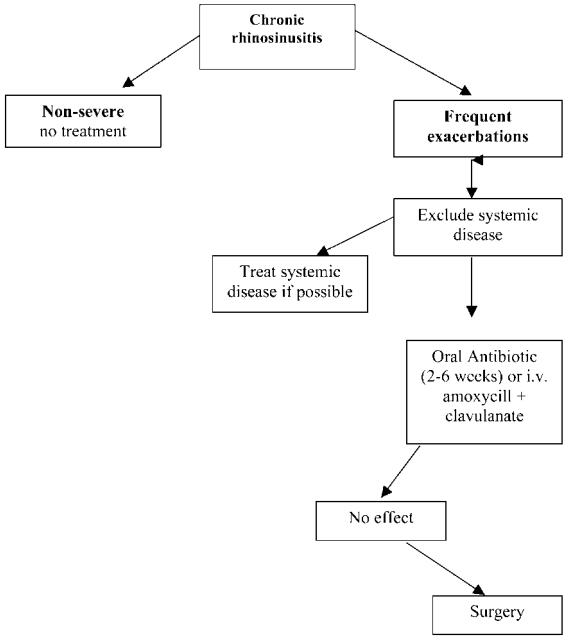


Table 2
Indications for surgery in children with rhinosinusitis

Absolute indications
1 Orbital abscess
2 Intracranial complications
3 Antrochoanal polyp
4 Mucocele or mucopyocele
5 Fungal sinusitis
6 Massive polyposis in cystic fibrosis

Possible indications
After optimal medical management and exclusion of systemic disease, persistent chronic rhinosinusitis with frequent exacerbation

Conclusion

In conclusion one can state that rhinosinusitis in children is a very common disease. Medical therapy should be restricted to well-defined conditions and surgical therapy should only considered in exceptional cases.

VII. Patient information

Rhinosinusitis is an inflammation of the mucosa of the nose and paranasal sinuses, mainly provoked by viral infections, without any need for antibiotic treatment. The development of the sinuses and hence the inflammatory changes depend on the age of the child. Factors such as bacterial superinfection, respiratory tract allergy, gastro-oesophageal reflux and immunological disorders have to be considered.

The doctor should be consulted when severe illness, fever, rhinitis, facial pain and headache are present.

The diagnosis is mainly made by clinical examination. Endoscopic inspection of the nose might

be necessary to refine the diagnosis.

In cases of severe illness or frequent exacerbation, antibiotic treatment should be considered, where appropriate based on sampling secretions for bacteriological identification.

When complications occur or symptoms worsen after 5 days or the rhinosinusitis lasts longer than 10 days with persistent acute symptoms, further evaluation is needed. Underlying conditions will be examined when frequent exacerbation or chronic rhinosinusitis persists. CT scan is the gold standard for radiological investigation.

Adenoidectomy might first be considered when persistent nasal obstruction, nasal discharge and serous otitis media seem to be linked. In exceptional cases, functional endoscopic sinus surgery (FESS) can be considered when medical treatment fails. It should be tailored to the specific indications and needs of each case, after possible underlying conditions have been ruled out or treated.

If you have further questions, please consult your medical doctor.

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P. A. R. Clement
Academic Hospital - V.U.B.
(A.Z.-V.U.B.)
Department of Otolaryngology,
Head and Neck surgery
Laarbeeklaan 101
B-1090 Brussels, Belgium
E-mail: knoctp@az.vub.ac.be

Guidelines

- Sinus and Allergy Partnership: Antimicrobial treatment guidelines for acute bacterial rhinosinusitis. *Otolaryngol Head Neck Surg*. 2004;130 (1 suppl): 1-45.
- American Academy of Pediatrics, Subcommittee of Management of Sinusitis and Committee on Quality Improvement. Clinical Practice Guideline: management of sinusitis. *Pediatrics*. 2001;108: 798-808.

CME questions

1. The classification (acute, subacute, chronic...) in paediatric RS is based on

   A – Category of evidence I
   B – Category of evidence III
   C – Category of evidence IV
   D – None of the above
   E – Differs from country to country

2. What is correct in the following statements about acute bacterial RS?

   A – The condition is always clinically evident with the presence of purulent secretions
   B – Can only be proved by correct sampling methods for culturing
   C – Is never the result of a viral upper respiratory infection
   D – Occurs mainly in allergic patients
   E – Is obvious in the five first days of upper respiratory infection

3. What is correct in the following statements about chronic RS (CRS)?

   A – A viral inflammation persisting more than 12 weeks
   B – Severe sinusitis persisting for more than 12 weeks
   C – Low-grade symptoms in non-severe rhinosinusitis persisting for more than 12 weeks
   D – Recurrent bacterial infections with symptom-free intervals lasting more than 12 weeks
   E – All of the above

4. Look for the wrong statement

   A – The annual incidence in the USA of viral RS is estimated to be 6 to 8 episodes/year
   B – There is a clear fall in the prevalence of RS after the age of 6 to 8 years
   C – Sometimes adults induce recurrent RS in children in day care centres
   D – Young children who stay at home have much less chronic or recurrent RS
   E – In temperate climates, children are prone to chronic RS in the autumn and winter

5. After a recent upper respiratory tract infection (URI) with presence of purulent secretions

   A – MRI is likely to find signs of sinusitis in 45% of patients
   B – In more than 50% of patients
   C – In more than 64% of patients
   D – In more than 80% of patients
   E – In all patients

6. Routine investigation in children with mild uncomplicated RS requires

   A – Endoscopic nasal investigation
   B – Microbiological assessment
   C – Plane X-rays
   D – Blood-sampling for immunological work-up
   E – Simple clinical investigation without any treatment

7. Antral lavage in children with acute bacterial RS is necessary

   A – Whenever a bacterial infection is suspected
   B – When clinical signs get worse after 5 days of uri
   C – When acute symptoms of URI exceed ten days
   D – In severely ill children who do not improve with medical therapy
   E – In view of possible surgical intervention

8. CT imaging in children is necessary when

   A – You want to confirm a diagnosis of rhinosinusitis
   B – To acquire additional information to complement X-rays, which are inadequate
   C – To evaluate the approximate age of the child
   D – To prove an allergic condition
   E – None of the above reasons

9. The use of antibiotics in children with CRS should be considered

   A – When purulent nasal secretions are present, even without fever and in non-toxic cases
   B – Suspected or proven suppurative complications
   C – At the explicit request of the parents when there is a positive antibiogram
   D – In a preventive fashion for day-care purposes
   E – Persistent non-severe symptoms lasting for more than five days

10. Endoscopic sinus surgery in children

    A – Is indicated when adenoidectomy has failed
    B – Should be individually tailored
    C – Is indicated when a Caldwell-Luc operation has failed
    D – Is indicated whenever a CT scan shows signs of chronic inflammation
    E – Is indicated in all the circumstances above

Answers: 1C; 2B; 3C; 4C; 5E; 6E; 7D; 8E; 9B; 10B

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Taste disorders

S. Collet, Ph. Rombaux**, P. Eloy* and B. Bertrand**

*Department of Otorhinolaryngology, Head and Neck Surgery, Cliniques Universitaires de Mont-Godinne, Yvoir; **Department of Otorhinnolaryngology, Head and Neck Surgery, Cliniques Universitaires Saint Luc, Brussels

Key-words. Taste; taste disorders; dysgeusiae; guidelines

Abstract. *Taste disorders*. The guidelines presented in this review relate exclusively to disorders of the physiological sensation of taste i.e. the disorders of the perception of the four basic tastes: sweet, salt, sour and bitter.
Despite the low prevalence of dysgeusia and the difficulty of making a precise diagnosis of the aetiologies, a precise and complete evaluation of the problem is important because of the significant impact on patients' nutrition and quality of life.
These guidelines also propose include recommendations for good practice based on a review of the relevant literature using Medline.
It should be kept in mind that:

1. From a diagnostic point of view, an elaborate anamnesis, including drug intake and nutritional elements and a detailed clinical examination, are very often adequate to elucidate the problem. Gustometry objectivates the complaint and localises the site of the defect. Complementary investigations should be determined on the basis of the diagnostic hypothesis: cultures, sialometry and salivary biopsy, or imaging to investigate lesions in the taste pathways or in the central nervous system and blood.
2. From a therapeutic point of view, the treatment should be confined to the aetiology as much as possible. If this is not possible, the administration of zinc gluconate is recommended because it can significantly improve the gustatory function. In all cases, the help of a dietician is recommended.

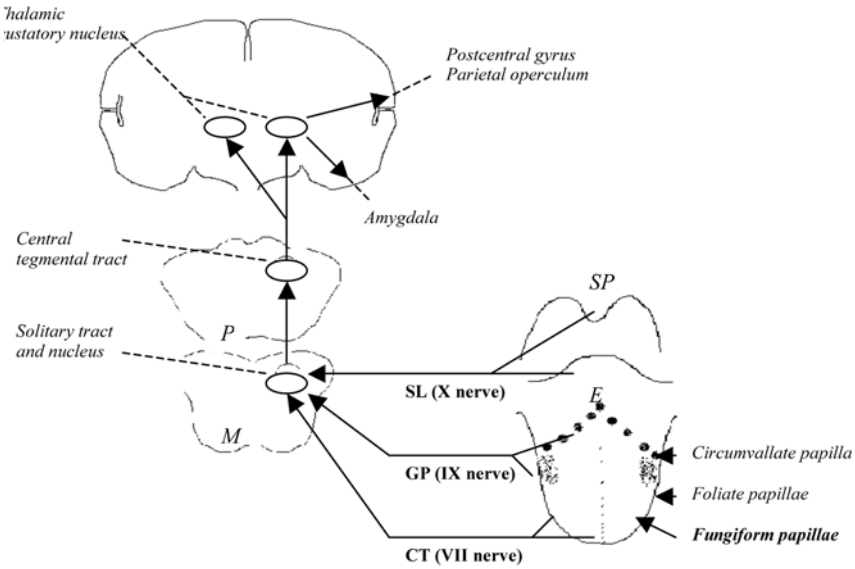
Introduction

Taste results from the sensation born in the taste buds, i.e. in the calceiform, foliate and fungiform gustative papillae found on the tongue, the palate, the posterior wall of the pharynx and the epiglottis, when taste molecules transported by saliva come into contact with the microvilli of the taste cells. The sensation is then transmitted, depending on the stimulation site, either via the chorda tympani to the facial nerve or to the glossopharyngial nerve, and finally to the upper branch of the vagus nerve (Figure 1). Classically, there are four basic tastes: sweet, salty, sour (acidic) and bitter. They condition alimentary behaviour and the rejection of toxic substances. They also initiate certain biological reactions indispensable to the equilibrium of the internal environment, such as the secretion of insulin.

A taste problem may be qualitative and/or quantitative. A qualitative problem consisting of an erroneous perception of the stimulus is called a parageusia. A quantitative problem relating to the perception threshold may be defined as an ageusia, a hypogeusia or a hypergeusia. Gustative hallucinations are also possible.

It is important to highlight the difference between the physiological phenomenon of "taste", and the common sense of the word "taste", meaning "flavour", which results not only from the stimulation of the taste buds, but also from the stimulation of heat-sensitive and tactile trigeminal receptors on the tongue and on the olfactory mucous membrane during retrochoanal movement accompanying deglutition. Taken together, these stimuli form a sensory image, the perception of which also depends on the type of stimulus and the affective context. The sensory image plays an important role that varies from person to person.

This discussion deals exclusively with disorders of the physiological sensation of taste. It provides a guide for good diagnostic and therapeutic practice on the basis of a review of the literature up to January 2005 using Medline. By contrast with research dealing with other ENT pathologies, this review mainly found expert opinions and studies conducted in a non-randomised and uncontrolled



CT: chorda tympani; GP: glossopharyngeal nerve; SL: superior laryngeal nerve; E: epiglottis; SP: soft palate; M: medulla; P: pons.

Figure 1
Taste Pathways

way, corresponding to level III of evidence-based medicine. There are probably two reasons for this. The first is the low prevalence of this complaint. In a study conducted in a chemosensory clinical ENT population, Pribitkin *et al.*[1] found only 10 patients out of 1176 who presented with a hypogeusia (0.85%), whereas 371 experienced a profound olfactory deficit (32%). Secondly, there is the multiplicity and multi-disciplinary nature of possible aetiologies (see Tables 1 and 2). According to the review of Kitagoh *et al.*[2] (n = 119), the most frequent aetiologies are idiopathic in 37.8% of cases (n = 45/119); related to the side-effects of medication in 32% (n = 38/119) of cases or linked to a zinc insufficiency in 30.2% (n = 36/119) of cases. According to the review of Osaki *et al.*[3] (n = 39 patients), aetiologies of hypogeusia listed by decreasing order of frequency are: iron deficiency (28%, n = 7/25), oral candidosis (24%, n = 6/25), xerostomia (24%, n = 6/25), psychiatric pathology (12%, n = 3/25) and, finally, idiopathic in 12% (n = 3/25). Parageusiae are of psychiatric origin in 57% of cases (n = 8/14), linked to oral candidosis in 21% of cases (n = 3/14), the side-effect of medication in 14% of cases (n = 2/14) and linked to a hyposalia in 7% of cases (n = 1/14).

Guidelines for the diagnosis of taste disease

Proving the aetiology of a dysgeusia is not an easy matter because of the number of anatomical and functional structures involved, the multi-disciplinary nature of the aetiologies, and the extreme difficulty of dealing with a rare condition. A sound knowledge of the anatomy and physiology of the gustative system associated with an elaborate anamnesis and a thorough examination of the oral cavity are the keys. Chemical and electrical gustometry, as well as semi-objective tests, provide information about the nature of the complaint and often about the location of the defect. Complementary investigations should then be ordered depending on the diagnostic hypothesis.

A complete anamnesis has considerable diagnostic value: a checklist adapted from Cullen *et al.*[4] is given in Table 3. A precise description of the type of dysgeusiae is an important step in arriving at a diagnosis: in the case of a dysfunctional taste receptor, it involves one or perhaps two taste archetypes; in the case of a neurological disorder, the disorder involves all four taste archetypes, and is localised in the innervation area of the implicated nerve; gustative hallucinations are found in the context of psychiatric pathologies or damage to the central nervous system.

Medication must be checked very thoroughly because it may be the cause of gustatory disorders.[2,3]

The evaluation of nutritional consequences, of the dysgeusia, and of its impact on quality of life should also be considered during the anamnesis.[5]

The clinical examination is based on the checklist suggested in Table 4 adapted from Cullen *et al.*[4]

Semi-objective report

A review of the literature worldwide demonstrates that gustometry can be a precious source of diagnostic information. However, there are few references which deal with this type of investigation and both the technique used and the protocol are frequently specific to the individual authors. This lack of standardisation, associated with a wide variability in the individual thresholds and the lim-

Table 1
Causes of taste dysfunction

Category of disorders	**Localisation and types**	**Description**
Epithelial pathways	Oral mucosa and tongue	Autoimmune disease, discoloured lesions, amyloidosis, infection, local injury, chemotherapy and radiotherapy, neoplasia
	Gingival, dental and periodontal structures	
	Salivary gland disorders	
	Gastro-oesophageal reflux disease	
	Sinus abnormalities	
Peripheral neural pathways	Facial nerve	Infection, neoplasia, trauma, inflammatory disease, degenerative disease
	Vagus nerve	
	Glossopharyngeal nerve	
Central pathways	Central lesion	Neurovascular stroke or arteriovenous malformation, neoplasia, CNS infection, multiple sclerosis
	Psychiatric	Bulimia, conversion disorder, depression, malingering, schizophrenia
	Genetic	Riley-Day syndrome, hereditary spinocerebellar degeneration, Turner's syndrome
Systemic dysfunction	Medications	c.f. table 2
	Nutritional	Blood transfusion, cancer-related wasting syndrome, chronic renal failure, HIV wasting syndrome, liver disease, malnutrition, zinc and copper deficiency, vitamin deficiency (B3, B12, C)
	Endocrine	Adrenocortical insufficiency, Cushing's syndrome, cretinism, diabetes, hypopituitarism
Special circumstances		Ageing
		Pregnancy
		Burning mouth syndrome

ited number of studied patients, explains the differences in the standards published until now.

Chemical gustometry is a rapid and non-expensive test. Solutions in increasing concentrations of citric acid, glucose, sodium chloride and quinine are applied to the tongue with the aid of a dropper or taste strips.[6] Chemical gustometry tests the functioning of the receptor cells for each of the archetypical tastes. It is particularly useful in diagnosing dissociated dysgeusiae. Although rather imprecise in terms of determining the exact extent of the stimulated zone, it can nonetheless provide topographical information about the taste receptors: quinine is preferentially recognised in the circumvallate papillae and the foliate papillae, the innervation of which depends on the glossopharyngeal nerve; citric acid, glucose and sodium chloride are recognised in the anterior portion of the tongue, the innervation of which depends on the chorda tympani.[7] In the case of a nerve lesion, the identification of the thresholds will be overestimated within the limits of the topography of the innervation.[8]

In addition to the difficulty of localising the stimulation, Bergdahl *et al*.[9] identified other factors that may influence the results, and therefore the interpretation and the reproducibility, of the test: the learning process, the temperature of the stimulus, olfactory contamination, the individual profile and degree of sensitivity, physiological factors such as the menstrual cycle, anxiety or depression, and the use of certain medications (anti-asthmatic, anxiolytic).

Electrogustometry is a fast and easy test. Electro-anodic stimulation with a continuous current causes hydrolysis of the saliva. The resultant liberation of ions stimulates the gustative chemoreceptors.

Table 2

Drugs that may affect taste according to Hawkes[16]

Antihelminthic	Levamisole
Antithyroid	Carbimazole, methylthiouracil, propylthiouracil
Antiseptic	Chlorhexidine
Anti-inflammatory	Penicillamine, colchicines, gold salts, nonsteroidal anti-inflammatory drugs
Antimitotic	Bleomycin, α-interferon, interleukine-2, methotrexate, vincristine, doxorubicin, chlorambucil, procarbazine, cisplatin, 5-fluorouracil
Antifungals	Amphotericin B, griseofulvin
Antibiotics	Tetracycline, sulfonamides, penicillins, cephalosporins, ethambutol
Anti-protozoal	Metronidazole, pentamidine
Antiviral	Idoxuridine, zidovudine, didanosine, protease inhibitors
Calcium channel blocker	Nifedipine, amlodipine, diltiazem
Anti-cholinergic	Benxheol, tricyclic antidepressants, oxybutynin
Diuretic	Acetazolamide, amiloride, frusemide, hydrochlorthiazide
Anti-arrhythmic	Amiodarone, procainamide, propranolol
Oral hypoglycaemic agents	Phenformin, glipizide
Anti-epileptic	Phenytoin, carbamazepine
Antipsychotic/antidepressant	Trifluoperazine, lithium carbonate, amitryptiline, clomipramine, paroxetine, sertraline
Drugs for Parkinson disease	Levodopa, pergolide, bexhexol, selegiline
Miscellaneous	Theobromine, theophylline, quinine, strychnine, sumatriptannasal spray, metoclopramide, cimetidine, disulfiram, pesticides, lead, industrial solvents and paints

Table 3

Dysgeusia: checklist for history

1	Is smell also affected?
2	Description: ageusia, hypogeusia, hypergeusia, parageusia, phantogeusia?
3	One or more tastes?
4	Localisation: bilateral or unilateral? Anterior or posterior?
5	Timing: continuous or intermittent?
6	Onset: sudden or gradual?
7	Precipitating event: surgery, trauma, chemotherapy, radiotherapy ...
8	Others symptoms: facial numbness, dysphagia, hoarseness, pain on swallowing, dry mouth, dry eyes, pain, burning, numbness in tongue, vesicules on tongue, dental procedures ...
9	Medication
10	Past medical health: diabetes, endocrine disease, Bell's palsy, gastro-oesophageal reflux...
11	Social and occupational history for smoking, work exposure to toxins

The intensity of the stimulation is increased until a metallic sensation is detected. This defines a threshold of detection which is representative of the overall function of the taste buds and gustative nerve paths and therefore helps to discriminate between ageusia and hypogeusia. When this test is used in the different zones of the oral cavity, the advantage is that the precise point of stimulation is known and the affected nerve is located quickly.

Four points from Gomez's study, which included a large number of normal patients (n = 147), are worth keeping in mind when interpreting the results:

– the thresholds on the right side may be lower than those on the left. According to the author, this is due to the specialisation of the right-hand hemisphere of the brain in matters of taste perception;
– the thresholds are higher in the region of the lingual V than in the region of the tongue or the soft palate;
– a difference between the thresholds on the two sides of 19.5 µA ± 4.5 µA for an average threshold of 38.5 µA ± 5.5 µA is admissible;

Table 4

Dysgeusia: checklist for physical examination

1	Oral cavity	Tongue: number, size, distribution of papillae health of mucosae: mycosis saliva: quantity and quality condition of teeth nasopharyngeal mass gustatory function: methylene blue staining of the tongue (taste pores innervated remain blue), topical anaesthesia applied to the tongue (persistent dysgeusia after anaesthesia in case of phantom taste), thermal stimulation (persistent cold sensation in the area of the foliate papillae in case of glossopharyngeal nerve integrity)
2	Ears	SOM, previous surgery, hearing tests
3	Eyes	Dry eyes, Schrimer strip test
4	Neck	Masses, thyroid enlargement, previous neck surgery
5	Nervous system	Cranial nerves examination, cerebellar and sensory motor function, psychiatric impression

– a threshold difference of at least 50% from one side to the other is considered pathological.[10]

The reproducibility of this technique is considered controversial in the literature on the basis of a small number of studies involving a limited number of patients. It is weak according to Lobb *et al*.[11] (n = 2, 80 examinations over 3 months) who observes variable results from one session to the next or from one side to the other for one and the same subject. It is improved, according to Gomez, if the subject is familiarised through pre-examination stimulation (n = 4, 100 measures, variations of 0.4 to 0.5 µA, confidence interval of 5%).[10] This drawback was not experienced by Kuga *et al*.[12] who found no statistically significant reduction of the thresholds after a third examination of 30 patients. Doubts about the reproducibility of this examination mean that some circumspection is required when it is used in the evaluation of dysgeusia.

Objective examinations

As a result of their burdensome nature, objective examinations will be reserved for patients for whom the clinical and gustometric tests do not permit the establishment of aetiology:

– *culture* is proposed when a fungal or a bacterial buccal infection is suspected;
– *sialometry and salivary biopsy* to exclude salivary dysfunction;
– the use of *imaging* depends on the diagnostic hypothesis. CT is appropriate when there is a suspected post-traumatic fracture or erosion of bone in the area of the middle ear. MRI is the examination of choice when evaluating the cortical structures and the pons in search of an ischaemic, haemorrhagic, demyelinating, tumorous or epileptic pathology;
– *a blood test* should also be ordered. It will focus on the blood count (anaemia, effects of medication), sedimentation rate (vasculitic disease, malignancy), B12 and folate level (nutritional state), glucose (diabetes and pituitary disease), thyroid function (myxoedema), electrolytes (renal disease, Addison's or Cushing's disease), liver function tests (cirrhosis), and autoimmune tests (Sjörgen's disease);
– *evoked taste potentials* were recorded for the first time by Kobal[13] in 1985 with acetic acid and afterwards with chloroform (sweet), ammonium chloride (salty) and thujone (bitter). They are likely to provide objective grounds for the results, but they are still in the experimental stage owing to the difficulty of obtaining pure taste stimulation and to the presence of the gag reflex for the territory innervated by the glossopharyngeal nerve.

Guidelines for treatment of taste disease

Treatment can be limited to the aetiology: administration of zinc in the case of zinc deficiency, equilibration of diabetes, buccal and dental care, psychiatric treatment in case of depression...

Zinc administration would appear to be helpful in the treatment of idiopathic dysgeusia. Heckmann *et al*.[14] demonstrated that zinc gluconate (140 mg/day for 3 months) improves general gustatory function and general scores (n = 50) independently of the level of zinc in serum.[14] No "fundamental" treatment such as vitamin B or corticoids has been demonstrated to be efficacious as yet.[15,16]

The help of a dietician may be valuable in guiding patients in the control of what they eat and in the development of compensatory

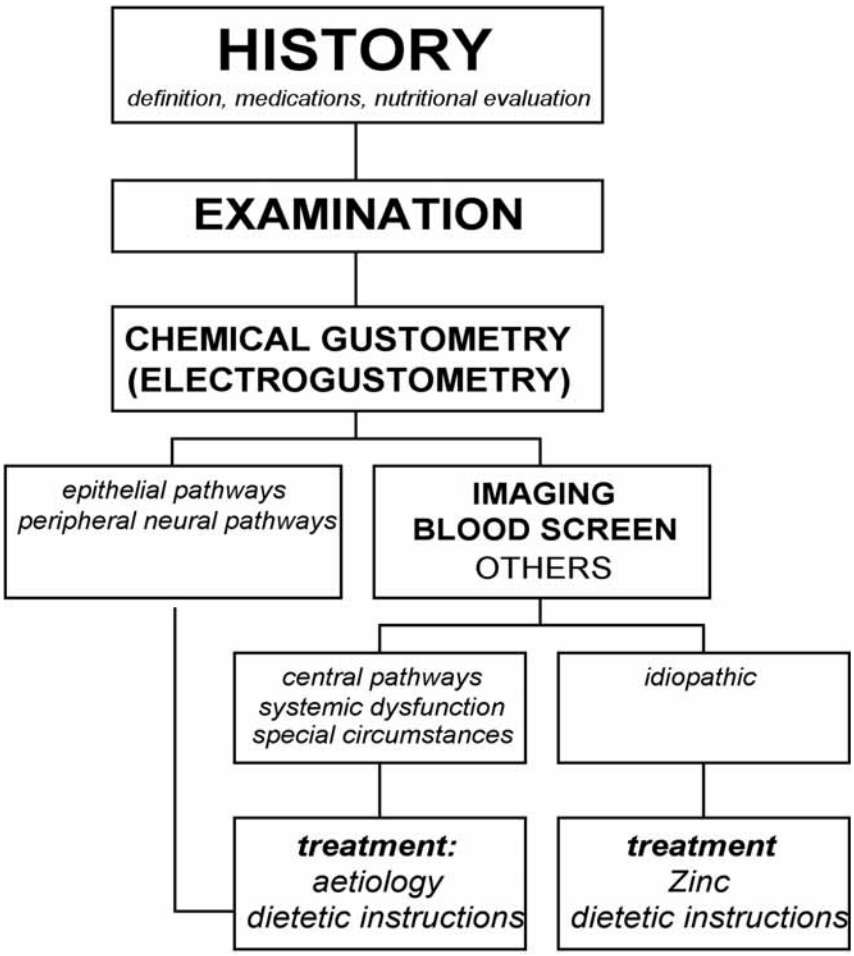


Figure 2
Algorithm for taste disorders

mechanisms such as the visual and olfactory aspects of their food in order to maintain nutritional and quality of life status.

The support of a psychologist may occasionally be necessary, for example for professionals whose sense of taste is essential for their job.

Conclusion

Figure 2 contains a diagnostic and therapeutic algorithm, based on the literature review, for the isolated taste disorders. From a diagnostic point of view, an elaborate anamnesis and a detailed clinical examination are required. Gustometric tests should be used to support the diagnosis. Imaging and blood screening should be reserved for the most difficult cases only.

From a therapeutic point of view, the treatment should focus on the aetiology when it can be proven. The help of a dietician is often necessary.

Acknowledgements

P. Rombaux and S. Collet are indebted to the encouragement of Professor Thomas Hummel, who reviewed this paper and helped us in the elaboration of these Belgian guidelines for taste disorders. He gave them the opportunity to study the German guidelines on the website www.uni-duesseldorf.de/AWMF/ll/017-052.htm.

Patient information

It is important to start by explaining what taste is.

In the medical sense of the word, taste is the sensation born in the taste receptors in the oral cavity when eating or drinking. There are four recognisable tastes: sweet, salt, sour and bitter. So the taste of a strawberry ice cream, for example, is in medical terms no more than the perception of its sweet properties.

In the common sense of the word, taste consists not only of the stimulation of the taste receptors by food and drink, but also of the perception of texture and temperature by the tongue and, especially, the smell of the foodstuff as perceived during chewing and swallowing. These stimuli form a complex sensation, the perception of which also depends on the characteristics of the foodstuff and emotional associations; the sensation is particular to each individual. So the taste of a strawberry ice cream, in the common sense of the word, corresponds not only to the perception of sweetness but also to the perception of texture, temperature and smell. It is appreciated all the more because the ice cream may be consumed in good company and recall, for example, pleasant childhood memories.

This information deals exclusively with the medical definition of taste and targets people with taste disorders in particular.

Your problem may be:

- either a modification of the perception of one or more of the four tastes of foodstuffs

(for example, you are not able to tell whether crisps are salty, even if you add more salt);

- the perception of an erroneous taste sensation, whether or not in the presence of a foodstuff (for example, a strawberry ice cream causes a salty sensation or you have a permanent salty sensation in your mouth).

This situation is sometimes difficult to live with.

The reasons for your disorder can be numerous but not always recognisable.

In order to help us understand the situation, you will be submitted to specific taste tests after a thorough clinical examination and, depending on the diagnostic hypothesis, to blood tests or scans.

This point cannot be emphasised enough: the treatment of your problem will be limited to the causes if they can be diagnosed objectively. The help of a dietician is important to guide you in watching what you eat and to teach you ways to improve your pleasure in eating. This may include:

- the appearance of your meals;
- starting by smelling your food before putting it in your mouth;
- choosing foodstuffs with different textures,
- the use of aromatic herbs, ...

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Dr. Stéphanie Collet
Department of Otorhinolaryngology, Head & Neck Surgery,
Université Catholique de Louvain,
Cliniques Universitaires
de Mont Godinne,
B-5530 Yvoir, Belgium.
E-mail: stephanie.collet@orlo.ucl.ac.be

CME Questions

1. Taste in the common sense of the word corresponds to the perception of a sensation resulting from:

   A – The stimulation of gustatory receptors
   B – The stimulation of gustatory and olfactory receptors
   C – The stimulation of gustatory, trigeminal and olfactory receptors
   D – The stimulation of gustatory and trigeminal receptors
   E – The stimulation of olfactory receptors and gustatory receptors bathed in a saliva of certain quality

2. The taste buds are innervated by:

   A – The chorda tympani (VII) and the lingual nerve (V3)
   B – The chorda tympani (VII) and the glossopharyngeal nerve (IX)
   C – The chorda tympani (VII), the glossopharyngeal nerve (IX) and the upper branch of the vagus nerve (X)
   D – The chorda tympani (VII), the lingual nerve (V3) and the upper branch of the vagus nerve (X)
   E – The chorda tympani (VII), the lingual nerve (V3) and the glossopharyngeal nerve (IX)

3. The prevalence of dysgeusia in an ENT population is:

   A – <1%
   B – 1–5%
   C – 6–12%
   D – 15–20%
   E – 20–30%

4. One of the following aetiologies is not responsible for parageusiae:

   A – Psychiatric pathology
   B – Paraneoplasic syndrome
   C – Buccal candidosis
   D – Hyposialia
   E – Side-effect of medication

5. One of the following aetiologies is not responsible for hypogeusia:

   A – Iron deficiency
   B – Buccal candidosis
   C – Xerostomia
   D – Psychiatric pathology
   E – Pregnancy

6. One sentence is wrong.

   A – Chemical gustometry tests the functioning of the gustative and olfactive receptors
   B – Chemical gustometry confirms a dissociated dysgeusia
   C – Chemical gustometry can localise the damaged nerve
   D – The results of chemical gustometry can be disrupted by the temperature of the stimulus, olfactory contamination and the use of anxiolytics
   E – The results of chemical gustometry depend on good cooperation from the patient

7. One sentence is wrong.

   A – In electrical gustometry, the detection of a metallic sensation defines a gustative threshold of detection
   B – Electrical gustometry can localise the affected nerve
   C – The reproducibility of electrical gustometry is controversial in the literature
   D – Olfactory contamination can disrupt the results of electrical gustometry
   E – Electrical gustometry can be impossible to interpret in patients with Sjörgen's syndrome

8. Guidelines for the treatment of taste disease. One sentence is wrong.

   A – The aetiology should be treated if possible
   B – Zinc administration should be used in the treatment of idiopathic dysgeusia
   C – Prolonged chlorhexidin mouthwash should be used in the treatment of idiopathic dysgeusia
   D – Dietetic evaluation is indicated
   E – An evaluation of quality of life is indicated

9. Taste disorders after tonsillectomy. One hypothesis is wrong.

   A – Glossopharyngeal nerve damage
   B – Anorexic status known before the surgery
   C – Postoperative buccal candidosis
   D – Chlorhexidin mouthwash
   E – Povidone iodine mouthwash

10. Metallic taste for previous 24 hours in a woman aged fifty-four. One hypothesis is wrong.

    A – Onset of viral facial palsy
    B – Burning mouth syndrome
    C – Lyme's disease treated by tetracycline for the last 15 days
    D – Allopurinol for the last month
    E – Considerable passive smoking over a period of several years

Answers: 1C; 2C; 3A; 4B; 5E; 6A; 7D; 8C; 9E; 10E

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Sleep-disordered breathing

A. Boudewyns, O. Vanderveken*, B. Bertrand** and Ph. Rombaux****

*Department of Otorhinolaryngology, Antwerp University Hospital, Antwerp; **Department of Otorhinolaryngology, Cliniques Universitaires Mont-Godinne; ***Department of Otorhinolaryngology, Cliniques Universitaires Saint Luc, Brussels

Key-words. Sleep-disordered breathing syndrome; snoring; apnoea; nCPAP, upper airway

Abstract. *Sleep-disordered breathing.* Sleep-disordered breathing (SDB) constitutes a spectrum of diseases, with primary snoring as the mildest form and obstructive sleep apnoea-hypopnoea syndrome (OSAHS) as the most severe form. These disorders are primarily caused by a partial or complete collapse of the upper airway during sleep. Risk factors, clinical features and physical findings are discussed in this review paper together with the diagnostic criteria. Polysomnographic studies remain the gold standard in the diagnosis and preoperative assessment of SDB. Surgical treatment for snoring most commonly includes some form of velopharyngeal surgery. The application of nasal continuous positive airway pressure (nCPAP) is the first-line treatment for moderately and severe OSAHS. Upper airway surgery is indicated for mild OSAHS and can be considered in moderately and severe OSAHS patients who are unable to comply with general measures/and or with medical treatment. Oral appliances are indicated for patients with mild SDB or nCPAP intolerance. The management of SDB requires a multidisciplinary approach. A thorough diagnostic work-up and proper patient selection are essential to guarantee a successful treatment outcome.

Introduction

The term sleep-disordered breathing (SDB) refers to sleep-induced conditions that alter the normal ventilatory pattern during sleep. Other conditions such as asthma or restrictive pulmonary disease may worsen during sleep or cause sleep disruption but their presence is not limited to sleep and therefore they are not classified as SDB.

The physiological spectrum ranges from partial upper airway (UA) collapse with an increase in UA resistance, manifested as snoring, flow limitation and hypopnoea, to complete UA collapse and apnoea.

Definitions

Snoring

Snoring is an inspiratory noise produced by the vibration of pharyngeal soft tissues.

Primary snoring is defined as snoring without sleep disruption and the absence of insomnia or excessive daytime sleepiness.

Habitual snoring is defined as snoring that occurs for >5 nights/week.

Upper airway resistance syndrome

This disorder was originally defined as the combination of a clinical complaint (excessive daytime sleepiness) with both flow limitation, increased respiratory effort, and arousal just after the peak in negative inspiratory oesophageal pressure. Current thinking is that this is not a distinct syndrome but rather a subtle form of the sleep apnoea syndrome.[1]

The American Academy of Sleep Medicine[1] formulated the definitions for **sleep apnoea (hypopnoea) syndrome (SAHS)** (Table 1).

Pathogenesis

Sleep predisposes to disordered breathing, even in otherwise healthy individuals, because the ventilatory control system is compromised during sleep. Several factors affecting both the upper airway and ventilatory drive occur during sleep in normal subjects and may contribute to SDB.

The state of wakefulness is characterised by the tonic excitation of the respiratory centres which has been named the ‘wakefulness stimulus’. This waking neural drive results in an overall drive to the respiratory muscles and is crucial to the generation of rhythmic breathing. At sleep onset, the ‘wakefulness stimulus’ disappears, which implies that ventilation becomes dependent on chemoreceptor control. This results in a reduction of minute ventilation and an increase in upper airway resistance.

Table 1

Definitions for sleep apnoea (hypopnoea) syndrome (SAHS) (1)
To meet the diagnostic criteria for **obstructive sleep apnoea (hypopnoea) syndrome** (OSAHS), the individual must fulfil criterion A or B, plus criterion C.
A. Excessive daytime sleepiness that is not better explained by other factors. B. Two or more of the following that are not better explained by other factors: – choking or gasping during sleep; – recurrent awakenings from sleep; – unrefreshing sleep; – daytime fatigue; – impaired concentration. C. Overnight polysomnography demonstrates five or more obstructive breathing events per hour during sleep. These events may include any combination of obstructive apnoeas, hypopnoeas or respiratory-effort-related arousals.
An obstructive apnoea/hypopnoea event is defined as a transient reduction or complete cessation of breathing. For clinical purposes, it is not deemed necessary to distinguish between apnoeas and hypopnoeas since both have the same pathophysiology. These events must fulfil criterion 1 or 2, plus criterion 3 as described below: 1. A >50% decrease from baseline in amplitude of a valid measure of breathing during sleep. 2. A <50% amplitude reduction of a valid measure of breathing during sleep associated with either an oxygen desaturation of >3% or an arousal. 3. The event lasts 10 seconds or longer.
RERA event (respiratory effort-related arousal) is characterised by increasingly negative oesophageal pressure, terminated by a sudden change in pressure to a less negative level and an arousal. This event lasts 10 seconds or longer.
An **arousal** is defined as any shift in EEG frequency to alpha or theta for at least 3 seconds but not longer than 15 seconds.
The **RDI** (respiratory disturbance index) is the total number of respiratory events (apnoeas and hypopnoeas)/hour of sleep
Severity criteria
Mild: 5 to 15 events/hour of sleep Moderate: 15 to 30 events/hour of sleep Severe: more than 30 events/hour of sleep
Idiopathic central sleep apnoea syndrome
This condition is characterised by recurrent apnoeic episodes during sleep in the absence of respiratory effort and upper airway obstruction during the episode. These events usually result in desaturation, recurrent arousal and daytime symptoms.

The decrease in ventilatory drive and the concomitant increase in upper airway resistance will result in a decrease in tidal volume, which in turn may cause hypopnoea or apnoea with partial or complete upper airway obstruction.

Several studies have demonstrated that the UA of patients with SDB is more susceptible to narrowing and collapse when upper airway dilator activity decreases during sleep.

Two hypotheses have been formulated to account for this increased collapsibility.[2]

The neural hypothesis states that upper airway dilator activity is more reduced during sleep in OSAHS patients as compared to normals. According to the anatomical hypothesis, the sleep-related reduction in OSAHS patients is normal but it occurs in a pharynx that is structurally less stable (or abnormal). The two hypotheses are not mutually exclusive but most studies today support the anatomical hypothesis.

In recent years, it has been recognised that the majority of OSAHS patients have multiple sites of upper airway obstruction that may vary according to the sleep stage and/or sleeping position.[3] This knowledge has important implications for treatment selection. In order to be successful, it will be necessary to combine several surgical procedures, each targeting a particular site of the UA, or to choose a procedure that alters the properties of the entire UA.

The arousal response that accompanies apnoea termination is likely to be determined by respiratory and non-respiratory stimuli. OSAHS patients have a higher arousal threshold compared to

normals and this may further aggravate SDB.[4]

Prevalence of sleep-related breathing disorders

Janson *et al.*[5] administered questionnaires on sleep disturbances in a random population of 2202 subjects (aged 20-45 years) in four European cities (Reykjavik, Upsalla, Gothenburg and Antwerp). At all centres, 5% of the men and 2-3% of the women reported snoring every night. Snoring was positively correlated with age, male gender and body mass index in all areas.

The Wisconsin Sleep Cohort Study was a population-based prospective study using overnight polysomnography to investigate the epidemiological features of SDB. The results of this survey indicated that the estimated prevalence of SDB (defined as respiratory disturbance index (RDI) ≥5 events/hr) among employees between 30 and 60 years of age was 9 percent for women and 24 percent for men.[6] Two percent of women and 4 percent of men fulfil the minimum diagnostic criteria for sleep apnoea syndrome (RDI ≥5 events/hr and daytime hypersomnolence). In general population samples, the male/female ratio for SDB is 2-3/1, whereas a ratio of 10/1 is found in clinic-based studies.

There is however mounting evidence that 'sleep study OSAHS' as found in epidemiological studies is not the same as 'sleep clinical OSAHS', which presents because of significant symptoms. Symptomatic sleep apnoea in men meriting nCPAP treatment probably has a prevalence of 1-2%, depending on obesity prevalence.[7]

The prevalence of OSAS seems to increase with age, with peak values at the ages of about 50 to 60 years. There is, however, no consensus about whether OSAHS worsens over time in the absence of weight gain.

Clinical signs and symptoms

Snoring is the most constant symptom in patients with SDB. Heavy snoring is often a source of inconvenience and questioning the patient's bed partner can provide useful information about snoring and the nocturnal breathing pattern. In the mildest forms of SDB, snoring is an inspiratory noise associated with almost every breath. Snoring interrupted by quiet intervals representing apnoeas is a typical feature associated with OSAHS.

Excessive daytime sleepiness (EDS) is yet another major symptom of SDB. Excessive daytime sleepiness has been attributed to cerebral hypoxaemia and sleep fragmentation due to repeated arousals. Surprisingly, many patients will deny any significant daytime sleepiness. This may reflect tolerance to sleep fragmentation, personal tolerance to sleepiness as a negative trait, or the chronicity of the symptoms.

Habitual snoring and EDS are considered to represent the cardinal symptoms of SDB, although their absence does not exclude the disease. The relationship between these clinical complaints and disease expression is poorly understood. Snoring often occurs years before the onset of disease-related illness and many patients will deny any significant daytime somnolence.

In addition to these major symptoms, the patient may complain about morning headaches, nocturnal enuresis, altered state of consciousness, modifications of mood towards irritability and aggression, cognitive disturbances and a decrease of libido.

Consequences of SDB

Although no data from prospective case-control studies are available at present, SDB seems to be associated with increased morbidity and mortality that are attributed to the consequences and complications of the respiratory events occurring during sleep: sleep fragmentation, intermittent hypoxaemia and hypercapnia, increased intrathoracic pressure swings, cardiac arrhythmias, polycythaemia, decreased cerebral blood flow, pulmonary hypertension and endocrinological disturbances.

A link between excessive daytime sleepiness resulting from SDB and an increased risk of work and road accidents has been documented. Findley *et al.*[8] demonstrated a sevenfold increase in the risk of road accidents in OSA patients (RDI >5 events/hr) compared to normals.

The results of epidemiological studies investigating the relationship between SDB and cardiovascular morbidity and mortality are often affected by the presence of confounding factors such as obesity, gender, diabetes, hypertension etc. in patients with SDB. Sleep apnoea is an independent risk factor for arterial hypertension and cardiovascular disease.[9]

Diagnosis of sleep-related breathing disorders

The diagnosis of SDB is essentially based on history, clinical signs

and symptoms and full-night polysomnography (PSG).

History is taken by means of standard questionnaires for the evaluation of signs and symptoms, medical history, alcohol and tobacco consumption and use of medication.

Snoring can easily be documented using a visual analogue scale. The Epworth sleepiness score is widely employed to document the degree of excessive daytime sleepiness.[10]

The *general clinical examination* is usually quite normal. About 70% of the patients with SDB are found to be obese. In addition, increased neck circumference (>40 cm in men) is more often found in OSAHS.

An examination of the *ear, nose and throat* is recommended in each patient referred for SDB and may reveal anatomical abnormalities of the UA. Special attention should be paid to the pharyngeal dimensions and the pattern of upper airway narrowing should be documented using upper airway endoscopy with Müller's manoeuvre. In 2002, the Royal Belgian Society of ENT surgeons published a consensus paper on the details of the clinical ENT examination of patients with suspicion of sleep-disordered breathing and the reader is referred to this paper.[11]

A pulmonary function test is usually performed in patients admitted for PSG. Although lung function parameters are generally within normal limits, this examination is essential to exclude underlying lung disease.

Polysomnography

At present, we support the use of full PSG for the evaluation of subjects with complaints of socially disturbing snoring and/or excessive daytime sleepiness or other symptoms suggestive of SDB.[12] Nevertheless, we recognise that, in the future, the use of limited diagnostic procedures may be justified.

Treatment

The treatment of SDB disorders includes general measures, non-invasive devices, mandibular advancement devices, nasal continuous positive airway pressure and surgical procedures. In 2002, the Royal Belgian Society of ENT surgeons published a consensus paper on the surgical management of patients with SRBD and the reader is referred to this manuscript[13] (Figure 1).

After history and ENT clinical examination, a full PSG is required for patients with suspicion of SDB. When polysomnographic data are normal, a routine follow-up is proposed with general measures to achieve better sleep hygiene and to reduce risk factors. General measures include weight loss, alcohol and sedative avoidance, smoking cessation and sleep-position training for the patient, avoiding anteflexion of the head or lying on the back during sleep. Non-invasive treatments for SDB patients, including oral spray lubricant, nasal dilators (Nozovent®, Breathe Right®) to increase nasal patency, or a head-positioning pillow, did not prove beneficial when assessed using objective criteria in a polysomnographic study. However, as these devices are relatively inexpensive and have no side-effects, they can be used during a trial period, especially by the primary snoring patient.

Nasal continuous positive airway pressure (nCPAP)

Application of nCPAP is the first-line treatment for all OSAHS patients with moderate to severe disease.

The positive pressure acts as a pneumatic splint, opening up or preventing the collapse of the pharyngeal airway during sleep. Long-term CPAP treatment results in a decrease of UA oedema and an improvement of lung function parameters.[14] This treatment starts with clinical habituation and must be accepted by the patient. The effective mask pressure required to restore a normal ventilatory and sleep pattern is determined during a second PSG. A member of the sleep unit must evaluate long-term compliance with nCPAP therapy. The criteria for reimbursement of CPAP in Belgium are RDI >30/hr or RDI >20/hr and movement arousal index >30/hr.

Upper airway surgery and mandibular advancement devices (MADs)

Upper airway surgery or treatment by a mandibular advancement device might be considered for 1) patients with socially disturbing snoring (with or without daytime symptoms); 2) those with mild OSAHS or; 3) patients with moderate to severe disease in whom other non-invasive treatments have failed or have been refused.[15]

Mandibular advancement devices have gained increased attention and acceptance as a non-invasive alternative treatment for the management of SDB. The action of MADs, which are worn intra-orally at night to advance the lower jaw, is usually assumed to involve the enlargement of the retroglossal space by the anterior

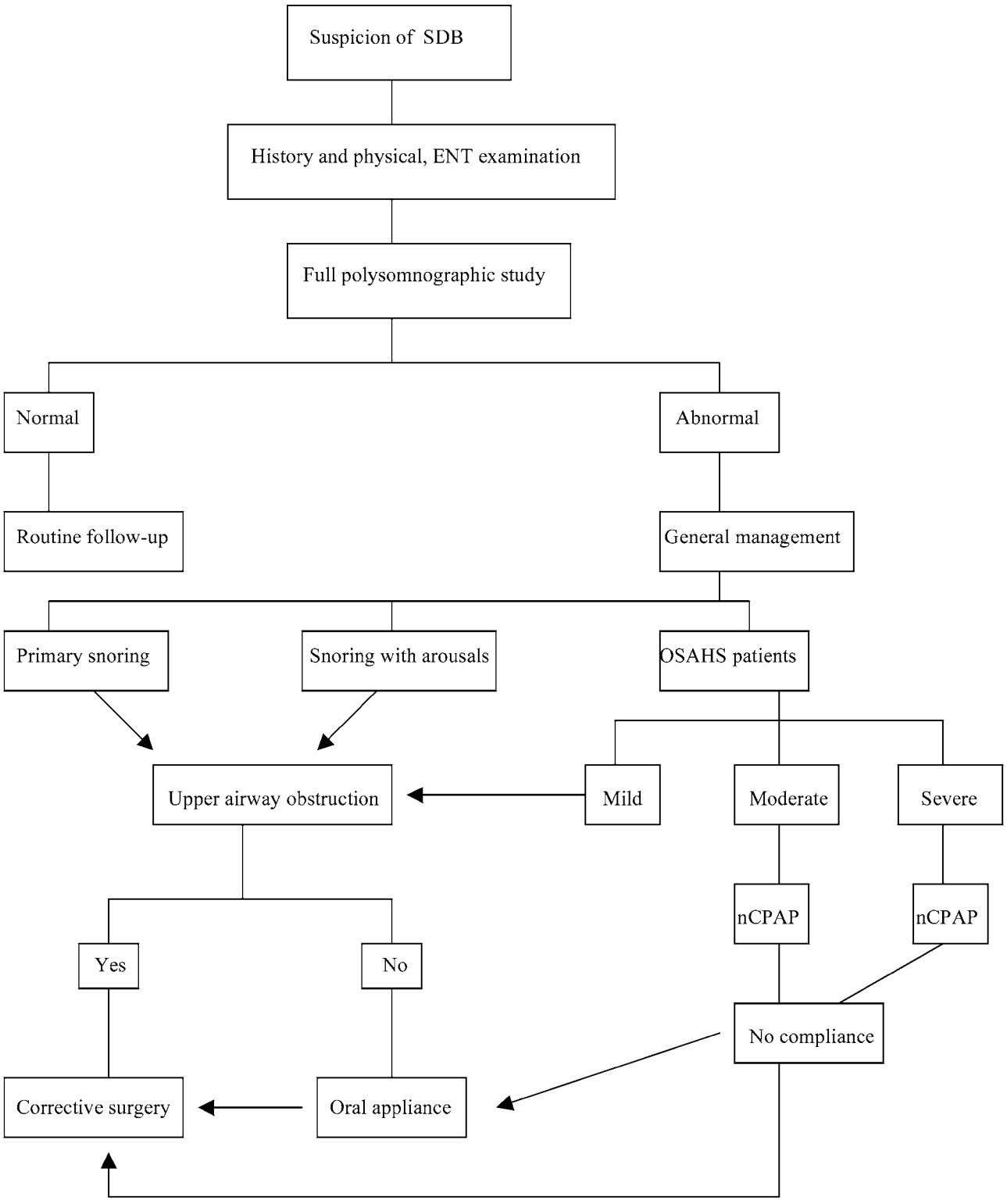

Figure 1
Management of patients suspected of sleep-disordered breathing. (Adapted from reference 13)

displacement of the tongue, the major muscle of which, the genioglossus muscle, inserts at the lingual surface of the anterior mandibular arch. By means of these anatomical changes, MADs can diminish collapsibility and thus reduce the severity of SBD by widening the cross-sectional dimension of the upper airway. A task force of the American Academy of Sleep Medicine recently published recommendations for the use of MADs in the treatment of SDB.[15]

Treatment with an MAD may be indicated in habitual snorers with or without associated daytime sleepiness, in snorers with arousals or in mild OSAS patients when no evidence of upper airway obstruction is observed or when there is retrognathia. Although MADs are not as effective as nasal continuous positive airway pressure (nCPAP) therapy, adaptation of an MAD may be indicated in subjects with moderately severe obstructive sleep apnoea (OSAHS) who do not tolerate or comply with their nCPAP device, or as a temporary alternative. MADs should also be considered as rescue treatment in patients with persistent SDB after uvulopalatopharyngoplasty (UPPP).

Corrective surgery for upper airway obstruction includes nasal, adenoid, velopharyngeal and retrobasilingual surgery. A detailed description of the various surgical techniques and their results can be found elsewhere.[16] At present, no data from randomised controlled trials are available comparing any surgical intervention for OSAHS with another surgical or non-surgical treatment modality.[17] Partner opinion is the best subjective measure of success in the treatment of snoring. Successful treatment of OSAHS is frequently defined as a postoperative reduction in AHI >50% and a postoperative AHI ≤20/hr or a postoperative apnoea index (AI) <10/hr. As there is often a discrepancy between objective and subjective results, it is mandatory to document the results of any surgical procedure for OSAHS or snorers with arousals by a postoperative PSG 3-6 months after the procedure.

Nasal surgery

Nasal surgery, including septo(rhino)plasty, inferior turbinate volume reduction (radiofrequency, microdebrider, turbinoplasty,...) and endoscopic sinus surgery, may be proposed to patients with SDB and increased nasal resistance. Although there is no good correlation between waking nasal resistance and the severity of SDB, the relationship between nasal disorders, especially nasal obstruction, and SDB is intimate.[18] Nasal obstruction may trigger sleep disorders in normal subjects and exacerbate them in snorers or OSAHS patients. Subjective analysis with questionnaires about snoring, daytime fatigue or excessive daytime sleepiness has revealed that the treatment of nasal disorders in SDB patients may be beneficial. However, objective data with pre- and post-therapy polysomnographic studies are far less encouraging. The success rate of isolated nasal surgery, for instance, seems to be less than 20%, although normalisation of nasal resistance is achieved in most cases.[19] Rhinological procedures may also be of interest for patients with poor compliance with nCPAP therapy due to nasal problems. An improvement in mask tolerance can be expected after medical or surgical treatment of nasal obstruction in these patients.

Velopharyngeal surgery

Velopharyngeal surgery is the cornerstone of the surgical management of SDB patients and essentially includes three different approaches: uvulopalatopharyngoplasty (UPPP), laser-assisted uvuloplasty (LAUP) and radiofrequency tissue volume reduction (RFTVR). The best candidates for velopharyngeal surgery are patients with a BMI of less than 28 kg/m^2 with a low (modified) Mallampati score, a low tonsil score, and without upper airway obstruction revealed at the retrobasilingual level. If a high tonsil score is observed during anterior pharyngoscopy, a tonsillectomy procedure must be performed during the velopharyngeal surgery. Velopharyngeal procedures are proposed to reduce soft palate vibration and with the aim of enlarging the velopharyngeal isthmus. They can be performed under general anaesthesia (UPPP) or under local anaesthesia (LAUP, RFTVR) and during single-stage sessions (UPPP) or multiple-stage sessions (LAUP, RFTVR).

Reductions in snoring to an acceptable level after surgery seem to be achieved in 60 to 80% of patients.[20] Cure rates tend to fall with time after surgery. These results are obtained with the three procedures, but there are major differences in the postoperative period since RFTVR is the least painful procedure[21] (Table 2).

Palatal implants have been introduced recently for the management of the snoring patient. These Pillar or palatal implants are inserted into the soft palate in order to increase the rigidity of the

Table 2
Post-operative pain and side-effects of velopharyngeal surgery

	UPPP	LAUP	RFTVR
Post-operative pain	severe (+/- 2 weeks)	severe (+/- 2 weeks)	moderate (+/- 1 week)
Narcotic drugs required	frequent	frequent	rare
Wound infection	frequent	rare	rare
Wound dehiscence	frequent	rare	rare
Bleeding	rare	rare	rare
Velopharyngeal fistula	rare	rare	rare
Posterior pillar narrowing	frequent	frequent	rare
Velopharyngeal stenosis	rare	rare	–
Problem with smell, taste	frequent	rare	rare
Pharyngeal dryness	frequent	rare	rare
Globus sensation	frequent	rare	rare
Voice change	frequent	frequent	rare
Pharyngonasal reflux	frequent	rare	rare

UPPP: uvulopalatopharyngoplasty, LAUP: laser-assisted uvulopalatoplasty, RFTVR: radio-frequency tissue volume reduction. (adapted from ref 21).

soft palate and subsequently to reduce snoring. Although clinical experience has been reported in only a limited number of patients, long-term results (up to 1 year) are promising in primary snorers, in whom there was a significant improvement in snoring and daytime sleepiness.[22]

The success rate for velopharyngeal surgery in unselected OSAHS patients is less than 40%.[23] Surgical success can be improved by proper patient selection based upon the pre-operative identification of the site(s) of UA obstruction.

Retrobasilingual surgery

Retrobasilingual surgery is also proposed for patients with SDB. One might consider procedures such as soft-tissue volume reduction using laser or radio frequency, or hard-tissue corrective management when mandibular osteotomy, genioglossus advancement or hyoid suspension are performed. These latter procedures are indicated for OSAS patients when compliance with nCPAP therapy is poor and when upper airway obstruction is demonstrated at the retrobasilingual level.

As many patients with SRBD have different levels of obstruction in their upper airway it seems logical to propose a multilevel surgical strategy. Combined UPPP and RFTVR of the tongue base, multilevel RFTVR in inferior turbinates, the velopharynx and the tongue base or combined nasal and velopharyngeal surgery are also accepted methods for the treatment of the SDBD patients. The risk of combining these procedures in one surgical setting must be taken into account, especially in OSAHS patients. The combination of nasal surgery (with postoperative nasal packing) and velopharyngeal or tongue base surgery in one setting might result in postoperative airway compromise.

Preoperative information about the site(s) of UA obstruction can be obtained with static methods such as cephalometry, computed tomography or magnetic resonance imaging, but dynamic studies are far superior. Sleep endoscopy during drug-induced sleep (propofol or midazolam) is a non-invasive method for identifying the site of UA collapse. When combined with polysomnographic and other clinical data, sleep endoscopy was found to be very helpful for providing individually tailored treatment advice.[24] Figure 2 sets out an approach for surgical treatment that takes the site of UA obstruction into account.

Conclusions

Sleep-disordered breathing and sleep medicine integrate many specialities such as neurology, pulmonology, oral surgery and otorhinolaryngology.

The otorhinolaryngologist performs airway evaluation before

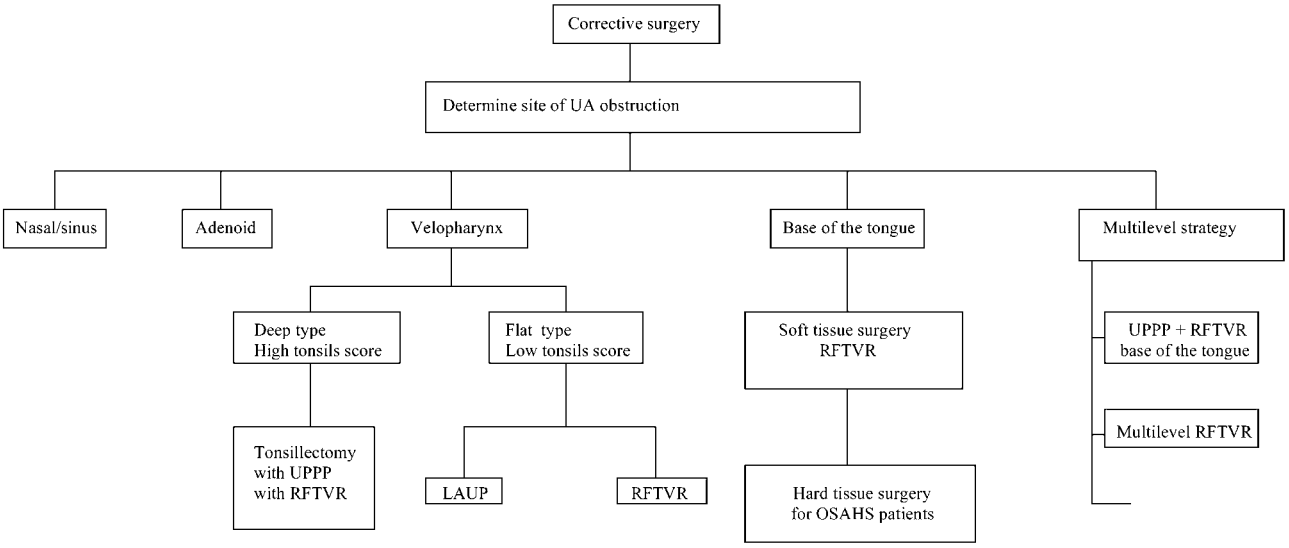

Figure 2
Options for UA surgery according to site of UA obstruction and clinical features

surgical treatment and the surgical treatment itself when indicated. We must also emphasise that the otorhinolaryngologist must have a working knowledge of the physiology of sleep and respiration and the health consequences of the sleep-related breathing disorders.

Finally, surgical modalities and tools are evolving that reduce postoperative discomfort without jeopardising outcomes.

Patient information

Sleep-disordered breathing encompasses different clinical situations: from primary snoring to obstructive sleep apnoea-hypopnoea syndrome. Snoring is caused by diffuse vibrations of the pharyngeal walls and suggests increased upper airway resistance during sleep. In about 5% to 10% of snorers, pharyngeal narrowing leads to complete occlusion and apnoea. Snoring is therefore a marker of obstructive sleep apnoea-hypopnoea syndrome (OSAHS), which is considered to be a risk factor for hypertension, cardiovascular disease or cerebrovascular disease. A sleep evaluation approach known as a 'polysomnographic study' is mandatory for patients with a clinical suspicion of apnoea or when a surgical correction of an upper airway obstruction is indicated for patients with sleep-related breathing disorders.

Treatment of non-apnoeic snoring begins with the identification and correction of risk factors (weight loss, smoking habit, avoidance of hypnotic medication,...). Velopharyngeal surgery and/or a rhinological procedure and/or a retrobasilingual procedure are proposed to reduce snoring and to enhance the sleep quality of both the patient and the bed partner. Velopharyngeal surgery is performed with different tools and instruments: uvulopalatopharyngoplasty (UPPP), laser-assisted uvulopalatoplasty (LAUP) or radio-frequency tissue volume reduction (RFTVR). Radio frequency is associated with less postoperative discomfort than other techniques. After these procedures, there is less snoring in 60% to 80% of cases.

For apnoeic patients, initial treatment includes nasal mask with continuous positive airway pressure (nCPAP). This treatment is associated with a high cure rate for sleep apnoea-hypopnoea syndrome patients and with a decreased risk of OSAHS-related comorbidity. Upper airway surgery or the use of a mandibular advancement device might be considered in those patients for whom CPAP treatment fails or is unacceptable after a therapeutic trial.

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An Boudewyns, M.D., Ph.D.
Antwerp University Hospital
Department of Otorhinolaryngology, Head and Neck Surgery
Wilrijkstraat 10
B-2650 Edegem, Belgium
Tel.: 03 821 33 85
Fax: 03 825 05 36
E-mail: An.Boudewyns@uza.be

CME Questions

1. What is incorrect in the following definition of sleep apnoea-hypopnoea syndrome?

   A – Five or more obstructive events per hour of sleep demonstrated with polysomnography
   B – And lasting more than 10 seconds
   C – With a > 50% decrease from baseline in amplitude of a valid measure of breathing during sleep
   D – Or a < 50% amplitude reduction of a valid measure of breathing during sleep associated with either an oxygen desaturation of > 3% or an arousal
   E – With an arousal defined as any shift in EEG to alpha or theta rhythm for at least 15 seconds

2. The prevalence in men of OSAHS is usually estimated to be approximately:

   A – 0.1%
   B – 2%
   C – 5%
   D – 10%
   E – 15%

3. What is incorrect regarding the following statement: Excessive daytime sleepiness is:

   A – A major symptom of SDB
   B – Attributed to cerebral hypoxaemia
   C – Attributed to sleep fragmentation due to repetitive arousals
   D – Related to the Epworth Sleepiness Scale
   E – Secondary to central apnoea in SDB patients

4. Respiratory events during sleep involve all the consequences and complications below, with one exception.

   A – Cardiac arrhythmias
   B – Intermittent hypocapnia
   C – Pulmonary hypertension
   D – Intermittent hypoxaemia
   E – Sleep fragmentation

5. Moderate to severe forms of OSAHS must be treated with

   A – nCPAP
   B – Nasal dilators
   C – Oxygenotherapy for every patient
   D – Hypnotic medications
   E – Oral corticoid

6. Which of the following does not apply to nasal surgery for SDB patients?

   A – Indicated for patients with nasal obstruction and poor nCPAP compliance
   B – Successful for > 80% of OSAHS patients
   C – Included in a multilevel strategy of upper airway obstruction treatment
   D – Indicated for patients with increased nasal resistance
   E – Sometimes associated with a worsening of OSAHS

7. Velopharyngeal surgery for SDB patients involves all these different approaches, with one exception:

   A – RFTVR
   B – UPPP
   C – LAUP
   D – Pillar implant
   E – Velopharyngeal stenosis

8. A second polysomnography after a treatment is mandatory in all these circumstances, with one exception:

   A – Primary snoring patient
   B – For moderate OSAHS
   C – For severe OSAHS
   D – To adapt nCPAP mask for OSAHS patients
   E – After surgical failure

9. Which examination is essential before a surgical procedure for SDB?

   A – MRI
   B – CT Scan
   C – Polysomnographic study
   D – Cephalometry
   E – Rhinomanometry

10. What is incorrect regarding the following statement: excessive daytime sleepiness …:

    A – RFTVR seems to be less painful for the patient than UPPP
    B – Velopharyngeal surgery is successful in 60-80% of primary snoring patients
    C – The best candidates for velopharyngeal surgery are patients with a BMI > 28 kg/m^2
    D – Tonsillectomy may help in the management of SDB patients
    E – Snoring cure rates tend to drop with time after surgery

Answers: 1E; 2C; 3E; 4B; 5A; 6B; 7E; 8A; 9C; 10C

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Management of thyroid nodules

J. P. Monnoye, M. Hamoir**, C. de Burbure***, G. Chantrain****, P. Gasmanne*****, P. Levie*, R. Loncke******, O. Desgain*, V. Monnoye* and Ch. Malherbe********

*Department of Otolaryngology, Cliniques Ste Anne-St Remi, Brussels; **Department of Otolaryngology, Head and Neck Surgery, St Luc University Hospital, Catholic University of Louvain, Brussels; ***Pathology, St-Luc University Hospital, Catholic University of Louvain, Brussels; ****Department of Otolaryngology, University Hospital St-Pierre, ULB, Brussels; *****Department of Otolaryngology, CHU Charleroi, Charleroi; ******Department of Otolaryngology, H. Hartziekenhuis, Roeselare; *******Internal Medicine Department, Endocrine-Metabolic Unit, Brussels

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Abstract. *Management of thyroid nodules.* These Belgian guidelines for ENT surgeons about thyroid nodules were elaborated in the light of personal practical experience and the recent advances in diagnosis and management described in the literature. Thyroid nodules are a common finding, particularly in women and in areas of iodine depletion. The prevalence in the general population averages 3 to 7% on palpation and almost 50% on ultrasound. The major difficulty facing the clinician is how best to assess and manage these thyroid nodules. The authors have attempted to simplify the assessment of thyroid nodules, to classify them, and to present the most common current therapeutic management options.

1. Introduction

The following guidelines are based on recent peer-reviewed articles evaluated by the authors to rate between Ia and III according to Belgian evidence levels (BEL).[1-9]

1.1. *Definition*

A thyroid nodule is a tumefaction of a part of the thyroid gland.

Its prevalence and incidence can vary greatly according to the investigations carried out, the population studied, gender, age as well as the patients' past medical history.

1.2. *Epidemiological overview*

The finding of thyroid nodules by simple palpation increases by 0.1% every year of life of the patient with a prevalence averaging 3 to 7% in the general population. Thyroid nodules are four times more common in women than in men and the prevalence increases in areas with iodine deficiency and ionizing radiation exposure.[10]

On ultrasonography the prevalence ranges from 19% to 46% in the general population, may be even higher at autopsy, and may reach 49.5% in clinically healthy people.[11]

1.3. *Classification of thyroid nodules*

Thyroid nodules are either benign or malignant and are further subdivided following on histopathology. Benign nodules are classified into adenomas, cysts and other benign lesions.[12] Malignant tumours are predominantly epithelial in nature, and are either classified into differentiated types which can be papillary, follicular or medullary carcinomas or into undifferentiated tumours such as insular and anaplastic carcinomas.

2. Benign nodules

2.1. *Adenomas*

2.1.1. Follicular adenoma is a common thyroid tumour, with a greater incidence in women than in men.

Around 90% of solitary thyroid nodules are adenomas, which may undergo haemorrhagic transformation, cystic or necrotic degeneration. Malignant transformation is rare. Most patients are euthyroid and consult for a painless tumefaction but rapid growth due to haemorrhage may cause neck pain.

At histopathology, a follicular adenoma is an encapsulated tumour that consists of cells reproducing the thyroid architecture. It is either round or oval and surrounded by a fibrous capsule. It is 4-5 times more frequent than cancer. Several types exist, namely: macrofollicular (colloid), microfollicular (fetal), trabecular (embryonic) and normofollicular.

2.1.2. Variants:

– A toxic adenoma is a benign thyroid tumour that has escaped pituitary control. It corresponds to a solitary nodule with autonomous function.
– Hürthle cell adenoma is a totally encapsulated tumour composed mainly of oncocytic cells (75%), and is synonymous with oxyphilic or Askenazy's adenoma.

2.2. *Cysts*

Cystic nodules account for 15 to 25% of thyroid nodules, are benign and are the result of degenerative changes either within the normal thyroid parenchyma or a nodular goitre. Malignant change can occur in 20% of nodules larger than 4 cm. Cystic nodules can appear rapidly as a mass that is often very sensitive.

2.3. *Other benign nodules*

Other benign nodules can be seen in Hashimoto's thyroiditis, de Quervain's thyroiditis and rarely in cases of infection.

3. Malignant nodules

3.1. *Well differentiated carcinomas*

Well differentiated carcinomas of the thyroid represent 80-85% of thyroid cancers. They are divided according to their histopathology into papillary, follicular and less commonly, medullary carcinomas.

3.1.1. Papillary carcinoma

Papillary carcinoma is the commonest thyroid cancer with 12,000 new cases per year in the United States. It is often multifocal, has a peak incidence between 30 and 40 years of age, is two to three times more frequent in women, and has a good prognosis. It presents as a firm, mostly non-encapsulated mass.

At histopathology, there are some purely papillary carcinomas, some with a follicular predominance, a diffuse sclerosing variant, tall and columnar cell variants, and they may also present as microcarcinomas. The histological criteria of a papillary carcinoma are the presence of papillae formed by cells bordering a fibrovascular axis, the presence of laminated calcified nodules (psammoma bodies, found in 50% of the cases), and voluminous pale nuclei with early lymphatic invasion.

Papillary carcinoma has the best prognosis among the various types of thyroid cancers with the risk of recurrence increasing after the age of 40. Microcarcinomas (smaller than 1 cm) have an excellent prognosis. Patients with extension outside the thyroid and distant and lymphatic metastases at diagnosis have a less favourable prognosis.[13]

3.1.2. Follicular carcinoma

Follicular carcinoma constitutes 10-20% of thyroid cancers. It is typically a solitary, encapsulated nodule with a greyish-white macroscopic appearance, and metastasizes by vascular invasion to the lung and bone. Follicular carcinoma with minimal invasion has an excellent prognosis, while the invasive form less so. It occurs at a later age than papillary carcinoma (50-60 years of age) and its prevalence increases by a factor of 2 in areas that are iodine deficient.

At histopathology, this malignant epithelial tumour of the thyroid has a follicular differentiation, which makes it difficult to distinguish from a follicular adenoma: differential diagnosis is based on signs of capsular and vascular invasion, a high mitotic index and the presence of metastases.

There are particular types of follicular carcinomas, such as *Hürthle cell carcinomas*, or follicular carcinomas with oxyphilic cells. They are in fact uncommon aggressive variants of follicular carcinomas and account for 3-6% of thyroid tumours.[14,15] They generally present as a hot solitary nodule at scintigraphy and are more frequent in women in their fifties. Malignancy indicators are clear vascular and capsular invasion.

3.1.3. Medullary carcinoma

Medullary carcinomas originate from the C cells of the thyroid gland and represent 5-10% of thyroid carcinomas. Parafollicular C cells do not capture iodine and are not regulated by TSH. A genetic enquiry has to be pursued in every case as there is a familial form transmitted in an autosomal dominant mode and in which both thyroid lobes can be affected from the start. The existence of specific tumour markers facilitates diagnosis.

Medullary carcinomas have a firm consistency at histopathology, their colour varies from brown-yellow to pale pink and they have regular nuclei and abundant granular cytoplasm. The diagnosis is confirmed by immunohistochemistry with anti-calcitonin antibodies and carcino-embryonic antigen.

Medullary carcinoma tends to metastasize to the cervical and mediastinal lymph nodes and less frequently to the lung, liver and

bone. In suspected familial cases of medullary carcinoma, the close relatives should have calcitonin levels measured as well as a pentagastrin test from the age of 5. The prognosis varies according to the age at first treatment and the 10-year survival rate is around 85% in patients under the age of 30 who have no metastases or lymphadenopathy and a tumour diameter less than 4 cm. For the other patients, the 10-year survival rate drops to 10%. The sporadic forms have a worse prognosis than the familial forms.

3.2. *Poorly differentiated carcinomas*

3.2.1. Insular carcinoma

The insular thyroid carcinoma usually presents as a nodule with or without an associated goitre.

At histopathological examination, insular carcinomas have a leveled architecture filled with cavities. The association of carcinoma cells of both follicular and papillary types is frequent, suggesting this type of carcinoma may well represent an intermediate stage in the differentiation process. This tumour also displays collagen-rich dense areas, which is the reason for which some have been wrongly diagnosed as medullary carcinomas. Thyroglobulin but not calcitonin is positive.

The prognosis is intermediate between those of well differentiated and anaplastic tumours. Local recurrence is frequent and metastases to the lung occur in 40% and to bone in 20% of the cases. Metastasis is often early and early aggressive treatment is warranted.

3.2.2. Anaplastic carcinoma

Anaplastic carcinoma of the thyroid is one of the most aggressive types and accounts for less than 5% of thyroid cancers. It usually occurs in patients above the age of 50 with a goitre or a thyroid nodule and has a peak incidence around 70 years of age. The tumour is rapidly invasive and metastasizes readily to the lung, bone, brain and liver.

The tumour is composed of giant fusiform or polygonal cells at histopathology. There is often a mixture of several cell types, along with keratinised, osteoblastic or sarcomatous cells. Epithelial structures are often present. Immunohistochemical studies have to be performed systematically. Keratin is the most useful epithelial marker and is present in 40-100% of the cases. Other antibodies will enable discrimination between lymphoma or more rarely a poorly differentiated follicular carcinoma, and a medullary carcinoma or an intrathyroid metastasis.

Survival is not modified by surgery, radiotherapy or chemotherapy, averages 2-6 months and rarely beyond 12 months.

3.3. *Other malignant tumours*

These consist mainly of sarcomas, lymphomas, histiocytosis, teratomas and metastases from the breast, kidney, lung, colon or a melanoma (see Table 1).

4. Management of a thyroid nodule[3,6,8,9,15,16]

– Anamnesis is essential, taking into account family history, gender, age (under 20, above 60 years of age), any past medical history of irradiation to

Table 1

TNM classification of thyroid carcinomas

TNM classification of thyroid carcinomas:[28]

TX: Primary tumour cannot be assessed
T0: No evidence of primary tumour
T1: The tumour is 2 cm (slightly less than an inch) or smaller
T2: Tumour is between 2 cm and 4 cm (slightly less than 2 inches)
T3: Tumour is larger than 4 cm or has extended slightly outside the thyroid gland
T4a: Tumour of any size and has grown beyond the thyroid gland to invade adjacent tissues of the neck
T4b: Tumour has grown either back to the spine or into adjacent large blood vessels

The values for **N** are:

NX: Regional (nearby) lymph nodes cannot be assessed
N0: No regional lymph node spread
N1: Spread to lymph nodes
N1a: Spread to lymph nodes in the neck (cervical lymph nodes)
N1b: Spread to lymph nodes in the upper chest (upper mediastinal lymph nodes)

The values for **M** are:

MX: Presence of distant metastasis (spread) cannot be assessed
M0: No distant metastasis
M1: Distant metastasis is present, involving non-regional lymph nodes, internal organs, bones, etc.
Separate stage groupings are recommended for papillary or follicular, medullary, and anaplastic (undifferentiated) carcinomas according to the age of the patient (under or above 45 years of age) (see association for online resources).

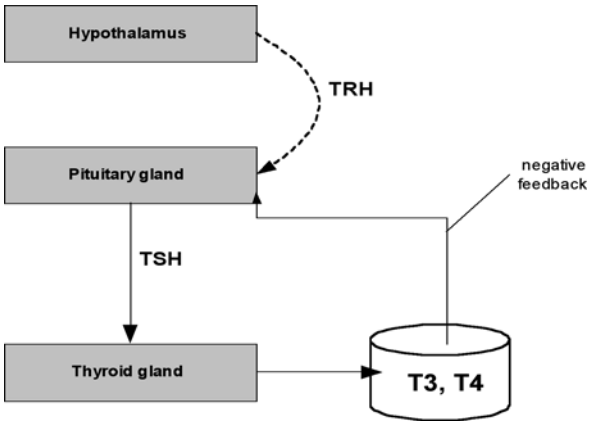

Figure 1
Regulation of thyroid hormone synthesis. TRH: thyrotropin releasing hormone, TSH: thyroid stimulating hormone (thyrotropin), T3: tri-iodothyronine, T4: thyroxine.

the cervical area, the presence of any pain, rapid nodular growth and compression symptoms.
- Clinical examination: by palpation, the size of the nodule can be assessed along with the presence of tenderness, induration, glandular fixation, plunging goitre, or lymphadenopathy.
- Paraclinical examinations have to be focused if only from an economical point of view.
- Biological assessment (TSH, T3 and T4) will enlighten the clinician about the functional state of the gland and on the eventual presence of a toxic adenoma.
- TSH: thyrotropin or thyroid stimulating hormone (TSH) stimulates thyroid secretion and is released by the thyrotropic cells of the pituitary gland. Its secretion is in turn regulated by the circulating levels of the thyroid hormones (see Figure 1).

The new ultra-sensitive measurement technique of TSH levels is currently available everywhere in Belgium. As TSH levels are low in almost all hyperthyroid conditions linked to a primary pathology, this measurement alone should theoretically indicate the diagnosis of hyperthyroidism.

- Antibodies: anti-thyroglobulin and anti-peroxidase antibodies, when present, direct the diagnosis towards an auto-immune pathology.
- Calcitonin and carcino-embryonic antigen are measured when there is a suspicion of medullary carcinoma of the thyroid. When positive, a phaeochromocytoma should be excluded by measuring urinary catecholamines. Pentagastrin tests are only useful in infraclinical familial medullary carcinoma or in the postoperative follow-up of patients.
- Thyroid ultrasonography is the most common examination performed and enables the study of the morphology of the thyroid, the description of a nodule that had been found by palpation, the distinction between solid and cystic nodules, whether it is isolated or associated with other nodules, its situation within the gland and enables the search for cervical lymph nodes. Ultrasonography enables the visualisation of solid nodules measuring at least 3 mm and fluid-filled nodules of at least 1 mm in diameter. Hypoechogenicity and an irregular shape increase the probability of a nodule being malignant. Its wider use has enabled the discovery of a large number of micronodules. When these are smaller than 1.5 cm, conservative management is proposed to the patient, whilst when the nodule size is above 5 mm, ultrasound guided fine-needle biopsy will be recommended.[17,18]
- Fine-needle aspiration (FNA) results will greatly depend on the experience of the operator as well as that of the pathologist. On average, two to three punctures will be performed on each nodule in order to get 5 to 6 glass slides. FNA is the most reliable and least invasive examination for the distinction between a benign and malignant nodule, and enables a better selection of patients requiring surgery.
  The FNA is reliable in 85-95% of the cases and has a 1-11% false negative and 1-8% false positive rate. The lesions are benign in 69% of FNA, are suspect in 10%, malignant in 4% and indeterminate in 17%.[14,19-22]
- Scintigraphy: This examination reflects mainly the functional aspect of the thyroid gland and does not distinguish between benign and malignant nodules with sufficient specificity. This functional evalua-

tion enables the distinction between cold nodules with low fixation from hot nodules that are hyperfixating. The majority of cold nodules is benign but 10% are malignant; only 4% of hot nodules are malignant.[23] Moreover, 33% of the echographic nodules, including the infracentimetric nodules, are not visible at scintigraphy.

Hyperfixating hot nodules will show up toxic adenomas as well as hyperthyroidism, toxic adenomas with preclinical hyperthyroidism, and Hürthle cell adenomas. The risk of malignancy in these is 4%. Hypofixating cold nodules represent 80% of thyroid nodules. As 10% of cold thyroid nodules are malignant, scintigraphy is recommended if TSH is low.

The most commonly used isotopes are iodine I^{131} and technetium Tc^{99}. Technetium is currently the main isotope used for the initial exploration of thyroid pathology. Results obtained by Tc^{99} are comparable to those from I^{131} in 98% of the cases. This examination is not routinely proposed to the patient in several European countries, although it is part of daily practice in Belgium.

- The CT scan is only useful when complex surgery is planned or in cases of major tissue invasion. The use of iodinated contrast medium is contra-indicated in cases of hyperthyroidism. An NMR is preferred though rarely performed.
- The PET-scan is used for searching for distant metastases.
- Genetic studies: a 6-gene array-based predictor model has recently been developed to diagnose benign versus malignant thyroid lesions. Due to its high sensitivity and specificity, this technique may prove useful to diagnose the malignant potential of thyroid nodules preoperatively.[24,25]

4.1. *Medical treatment*

Thyroxine

- For cold nodules: thyroxine is very often prescribed when surgery is not indicated, and most often when there is an associated goitre. It has little effect on the size of the nodules but decreases the size of the goitre as a whole and may prevent the apparition of further nodules, by rducing the metabolic activity of the thyroid gland. The dose has to be adapted so as to achieve low-normal TSH levels, taking into account tolerance and eventual associated pathologies. It is unnecessary if TSH is already inhibited. Thyroxine is also prescribed postoperatively in order to maintain euthyroidism and prevent the occurrence of new nodules in the remaining thyroid parenchyma, in cases of partial thyroidectomy. The aim is again to maintain low-normal TSH levels.
- For hot nodules: thyroxine is usually not indicated, and it is unnecessary if TSH is low or inhibited. In case of surgery (often a unilateral lobectomy), its prescription is recommended to ensure euthyroidism and to avoid hypertrophy of the residual lobe or hypothyroidism if the remaining lobe is too small.
- For carcinomas: thyroxine is frequently given to the patient following a surgical intervention. Should a treatment with radio-iodine be necessary, thyroxine should only be given at the end of the treatment. In case of a papillary carcinoma, the dose of thyroxine has to be adapted so as to obtain TSH levels just above the minimal levels. TSH levels must be reduced in case of a follicular carcinoma and normal but rather low in cases of medullary of anaplastic carcinomas. It is important not to give too much thyroxine in cases of carcinoma in order to prevent osteoporosis that could set in after several years of treatment.

Radio-iodine I^{131}

- This treatment is unnecessary in cases of medullary or anaplastic carcinomas.
- It is indicated in papillary and mainly follicular carcinomas although this is still a matter of debate.
- It is unnecessary when the papillary carcinoma is <1 cm, if it is localised and non-invasive and treated by a simple lobectomy. However, although its use is absolutely classic in case of follicular carcinoma, it is a little more controversial in papillary carcinoma treated by total thyroidectomy.
- It is usual to wait for one month prior to prescribing I^{131}, as TSH levels have to be >30 µU/ml. The usual dose is 100 mC.
- For papillary carcinomas, a single dose is usually sufficient.
- For follicular carcinomas, treatment has to be repeated every six months and always follows a weaning-off period of thyroid hormones. This con-

tinues until there is no fixation on a Total Body Scan.
– Thereafter, monitoring can be limited to thyroglobulin levels (with or without a Total Body Scan) following stimulation by TSH-rh (Thyrogen), which should enable continued treatment with L-Thyroxine (more comfortable but expensive).

Ideally this treatment should be repeated at six months, then after a year, two years and five years. Thyroglobulin levels must remain <1 ng/ml. If it is above 1 ng/ml, one should repeat the I^{131} Total Body Scan with a view to complementing the treatment.

Follow-up with cervical ultrasonography should also be performed.

It is important to note that I^{131} is also used in case of toxic nodules (with inhibited TSH and raised T3 levels) that do not require an operation (<3 cm, not causing any discomfort) and particularly when the patient is elderly or has too high an operative risk.

Calcium

– Calcium is indicated in cases of postoperative hypoparathyroidism and is either given per os or is depending on the severity. Hypoparathyroidism becomes persistent in +/- 2% of total thyroidectomies and calcium is often needed in association with vitamin D (Rocaltrol). This is constraining and expensive as calcium therapy is not reimbursed by the INAMI.

Fine-needle biopsy

– in the case of a cyst: the FNA procedure is often therapeutic, particularly when the cyst is haemorrhagic. It also yields a diagnosis on cytological examination. Should the cyst not disappear, ultrasonography should follow and a decision regarding surgery has to be made. Surgery is always indicated in cases of suspicious or positive cytology.
– In case of a cold nodule: ultrasound-guided fine-needle biopsy has become the most important examination in therapeutic management (see above).

External Radiotherapy

This treatment is reserved for anaplastic carcinomas, certain lymphomas and sarcomas as well as very particular cases of extensive differentiated carcinomas that do not fix I^{131}.

4.2. *Surgical management*

It is mandatory to obtain frozen sections of the tumour during the surgical intervention.

Total lobectomy plus isthmusectomy with recurrent nerve dissection and parathyroid gland exposure is the basic treatment of benign nodules.
It can also be performed for small unifocal papillary carcinomas as well as for minimal invasion follicular carcinomas.

Total thyroidectomy with careful dissection of the recurrent nerves and parathyroid glands (respecting vascularisation) is recommended in cases of multicentric papillary carcinomas either with lymphadenopathy or a poor prognosis as well as in follicular carcinomas that are either invasive or larger than 1.5 cm in diameter. A decrease in the recurrence risk within the contra-lateral lobe and easy patient follow-up will play in favour of total thyroidectomy.[26,27]

The morbidity of total thyroidectomy is low when it is performed by an experienced surgeon.

However, complications include recurrent nerve palsy and hypoparathyroidism, both of which can be either transient or permanent (approximately 2% for both).

In both medullary carcinoma and Hürthle cell carcinoma, total thyroidectomy is paramount.

In anaplastic carcinoma, surgery will depend on tumour size, since survival won't be modified by the procedure.

When reoperation is envisaged at a later stage, such as in toxic multi-nodular goitres and particularly in the presence of recurrent nerve palsy or hypoparathyroidism, it is well worth considering radio-iodine as a satisfactory alternative. Indeed, the risk of complications such as recurrent nerve palsy is doubled at reoperation.

Lymph node clearance

In follicular carcinoma, functional clearance is performed if lymphadenopathy is present.

In papillary carcinoma, homolateral lymph node clearance is performed if lymphadenopathy is found peroperatively (recurrent nerve chain, pre- and laterotracheal lymph nodes and the inferior part of the homolateral jugulo-carotid chain).

In medullary carcinoma, functional bilateral lymph node clearance, including the recurrent and jugulo-carotid chains is mandatory.

Conclusions

Rapid, efficient and financially sustainable diagnostic procedural steps are essential for the benefit

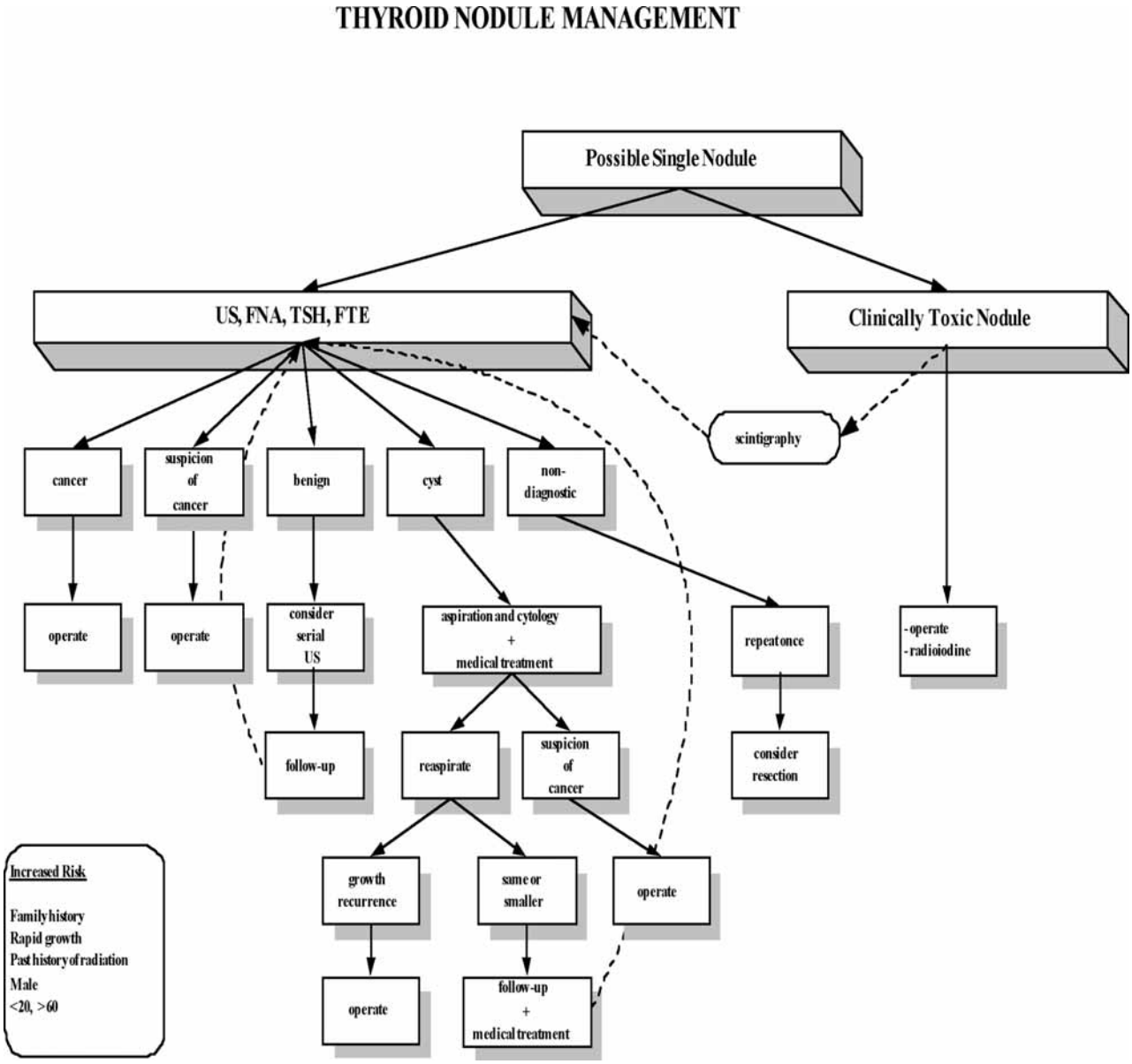

Figure 2
Management flow-chart of the thyroid nodule

of the patient and should consist of biological tests including TSH, T4, ultrasound and fine-needle aspirate (see Figure 2). In case of an uncertain diagnosis, a fine-needle aspirate can be repeated in order to decide on the most appropriate treatment. Only in a few particular cases should the other technical procedures (scintigraphy, further histological techniques,…) be proposed to the patient with a view to optimizing management.

Therapeutic management should be installed and followed-up by an endocrinologist. Surgical treatment should be performed by a cervical surgeon, ENT or other surgeon, whereas radiotherapy will usually be managed by the various disciplines involved.

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Dr. Jean-Paul Monnoye
Cabinet Messidor
217 avenue de Messidor
1180 Brussels, Belgium
Tel. : +32.2.3471027
Fax : +32.2.6333233
E-mail : jpmonnoye@skynet.be

CME questions

1. What percentage of the population will present with a thyroid nodule on palpation of the thyroid gland?

   A – 1%
   B – 5%
   C – 10%
   D – 20%
   E – 50%

2. What percentage of a solitary thyroid nodule will be an adenoma?

   A – 10%
   B – 20%
   C – 50%
   D – 70%
   E – 90%

3. Which is the most common type of thyroid carcinoma?

   A – Papillary
   B – Follicular
   C – Insular
   D – Anaplastic
   E – Medullary

4. Which type of thyroid carcinoma has the most favourable prognosis?

   A – Papillary
   B – Follicular
   C – Insular
   D – Anaplastic
   E – Medullary

5. The Hürthle cell carcinoma is usually classified among which type of thyroid carcinoma?

   A – Papillary
   B – Follicular
   C – Insular
   D – Anaplastic
   E – Medullary

6. What is the first test that should be performed when facing a patient with a thyroid nodule?

   A – Limited biological assay
   B – Complete biological assay
   C – Fine-needle aspiration
   D – Ultrasound examination
   E – Scintigraphy

7. What percentage of “cold” nodules are malignant tumours?

   A – 2%
   B – 5%
   C – 10%
   D – 15%
   E – 25%

8. The risk of developing a recurrent nerve palsy following reoperation increases by:

   A – 10%
   B – 25%
   C – 50%
   D – 75%
   E – 100%

9. Should the fine-needle aspiration cytology report be non-diagnostic, one has to:

   A – Operate
   B – Treat medically
   C – Re-aspirate
   D – Perform a scintigraphy
   E – Perform a CT-scan

10. In the presence of a thyroid nodule, which of the following presents a greater risk of having a carcinoma?

    A – A woman aged 20 to 60 years
    B – A man aged 20 to 60
    C – A multi-nodular goitre
    D – A hot nodule
    E – Hashimoto’s thyroiditis

Answers: 1B; 2E; 3A; 4A; 5B; 6A; 7C; 8E; 9C; 10B

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Tracheotomy: how to deal with it?

Ph. Deron, M. Hamoir** and C. Van Laer****

*Department of Head and Neck Surgery, Ghent University Hospital, Gent; **Department of Head and Neck Surgery, Head and Neck Oncology Program, Cliniques Universitaires St. Luc, Université Catholique Louvain, Brussels; ***Department of Otolaryngology, Head and Neck Surgery, Universitair Ziekenhuis Antwerpen, Universitaire Instellingen Antwerpen, Edegem

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Abstract. *Tracheotomy : how to deal with it?* Tracheotomy is one of the oldest surgical procedures and many different techniques are still in use. This guideline is focused on the indications, the choice of technique, open tracheotomy versus percutaneous tracheotomy, the complications, the materials and the management of the patient with a tracheotomy tube.

Introduction

Tracheostomy is one of the oldest surgical procedures and was already performed by the Egyptians in 3600 BC. The first successful tracheostomy was described in 1546 by the Italian physician, Antonio Musa Brasovala.[1,2] Since then, tracheostomy has had worldwide use as a basic surgical procedure. The first systematic step by step description was reported by Chevalier Jackson in 1909. During the last two decades, the introduction of percutaneous tracheostomy has challenged some indications for the surgical procedures.[3-5]

Even the name given to the procedure of cutting a hole in the trachea remains a matter of controversy. The terms “tracheotomy” and “tracheostomy” are used interchangeably although these words have different meanings. “Tracheotomy” (from the Greek word “tome” – to cut) implies the performance of a non-permanent type of surgery, whereas “tracheostomy” (from the Greek word “stomoun” – to furnish with an opening or mouth) implies a more permanent opening in the trachea. According to the International Organization of Standards, tracheotomy should be the correct name for the act of cutting a hole in the trachea whereas the actual hole and tube should collectively be called a tracheostomy.[6]

Many aspects of tracheotomy and tracheostomy have evolved in different directions through the years. Rather than producing an exhaustive list of the differences, this guideline is mainly focused on some specific issues and, in particular, the prevention of complications.

Indications

Table 1 summarizes the indications for tracheotomy. Prolonged intubation, a need for long-standing ventilatory support and management of bronchopulmonary secretions are indications, in which the otolaryngologist assists as a consultant in the intensive care unit or Neurology department. The gold standard for switching ventilation from translaryngeal to tracheal was around day 21 of intubation. A tendency towards earlier tracheotomy occurred due to the availability of percutaneous techniques. Consequently, several authors now advocate a more aggressive approach and consider carrying out a tracheostomy after 1 to 3 days of intubation if there is an anticipated need for mechanical ventilation beyond days 7 to 10.[3,5-11]

Additionally, a tracheotomy is indicated in the case of severe obstruction of the upper airway and as an adjunct to major elective head and neck or cardio-thoracic surgery.

Choice of technique

Once the decision is made to perform a tracheotomy, the technique has to be chosen. Most head and neck surgeons and Otolaryngologists are familiar with the open surgical technique. Because in some institutions percutaneous tracheotomy is performed almost exclusively in the intensive care setting by intensive care physicians without the assistance of head and neck surgeons, the technique of percutaneous tracheotomy is probably less known. This

Table 1

Indications for tracheotomy

1. Prolonged intubation; need for longstanding ventilatory support (reduce dead space or in neurological disorders)
2. Management of bronchopulmonary secretions – aspiration
3. Obstruction of the upper airway:
   - Benign or malignant tumours
   - Laryngotracheal injury
   - Congenital anomalies
   - Bilateral vocal cord paralysis
   - Maxillofacial trauma
   - Fixed foreign bodies in the upper airway
   - Inflammatory, infectious or allergic swelling not reacting to medical treatment
   - OSAS
4. Adjunct to major elective Head & Neck or Cardio-Thoracic surgery.

Table 2

Contra-indications for percutaneous tracheotomy

Absolute contra-indications:
- Difficult airway
- Non-intubated patient
- Emergency airway needed
- Inability to palpate cricoid and trachea:
  - Obesity
  - Neck masses
  - Tumour
  - Enlarged thyroid
  - Infection of soft tissues of the neck
  - Recent neck surgery
- Inability to extend the neck:
  - Kyphosis
  - Arthritis of the cervical spine
  - Cervical fusion
  - Documented or suspected spinal injury
  - Halo traction
- Children
- Superior vena cava syndrome
- Uncorrectable coagulopathy
- Haemodynamic instability
- High peak airway pressure

Relative contraindications:
- Scarring from previous neck surgery
- Previous neck surgery
- Correctable bleeding diathesis
- Irradiation induced tissue changes

situation has led to two major side effects. Firstly, most head and neck surgeons are reluctant to learn this technique. Secondly, head and neck surgeons are called to the intensive care unit only when complications occur. For these reasons, we believe that any resident in head and neck surgery should be trained in both procedures.[12] In this way, the head and neck surgeon would be able to select the best suitable procedure according to local or general circumstances. Aware of the performed procedure, he would be present on the spot to adequately tackle potential complications, whether immediate or delayed.

The contra-indications to the percutaneous technique need to be recognized. Table 2 provides an overview of the absolute and relative contra-indications to percutaneous tracheotomy. It is clear that a learning curve exists before becoming familiar with the technique. This implies that the presence of an experienced surgeon is mandatory when converting from percutaneous to open tracheotomy. Failure to recognize this last point may lead to disastrous situations!

Lastly, cricothyroidotomy or coniotomy may be the fastest means to obtain an airway under emergency circumstances. However, because cricothyroidotomy is associated with a higher incidence of both early and long-term sequelae, it is advisable to convert a coniotomy to a standard tracheotomy once the patient is stabilised and able to be transported to the operating theatre.

Open tracheotomy

Open tracheotomy is a surgical procedure performed under general anaesthesia and endotracheal intubation, as well as under local anaesthesia. Local anaesthesia with 1 or 2% lidocaine with epinephrine 1:200.000 is injected in a diamond shape around the planned incision.

Ideally the patient is placed in a dorsal decubitus position with the neck in extension. A rolled towel or sheet under the shoulders can help and a small pillow should stabilize the head. The skin incision is performed in a horizontal or a vertical plane. Each way has its advocates and review of the literature cannot help clarify which is the best. However, in an emergency situation, the vertical incision has the benefit of avoiding most of the veins in the superficial fascia of the neck and thus results in a less bloody surgical field.

Midline separation of the subhyoid muscles and exposition followed by division of the thyroid isthmus are standard surgical steps. Meticulous control of bleeding is required before opening the trachea, which in itself is still controversial.

Whereas some surgeons perform a horizontal incision in the tracheal cartilage, others prefer a vertical approach. Whereas some partly resect the anterior tracheal wall, others make a little inversed U-flap. Regardless of what is done, any injury to the cricoid cartilage or the remaining tracheal rings should be avoided. Finally, introduction of the tracheostomy tube into the trachea should be carried out with care.

In the paediatric population the trachea can only be incised in a vertical plane and no part of the anterior tracheal wall can be taken away. Safety sutures should be placed on both sides of the incision in order to facilitate introduction of the tube. Approximation of the skin incision at the end of the procedure should not be too tight. Fixation of the tracheotomy tube to prevent early extrusion ends the intervention.

Table 3

Complications of tracheotomy

General:
- Death
- Major haemorrhage
- Minor haemorrhage
- Pneumothorax
- Pneumomediastinum
- Tracheo-oesophageal fistula or laceration
- Paratracheal insertion
- Haematoma
- Accidental extubation
- Subcutaneous emphysema
- Tearing of the cannula cuff
- Hypotension, hypoxemia
- Loss of airway
- Resistance to insertion
- Laceration of the cricoid
- Injury to the recurrent laryngeal nerve
- Local wound infection
- Airway obstruction due to dried secretions in the cannula
- Non-airflow rhinitis
- Granuloma formation in the trachea
- Laryngo-tracheal stenosis
- Persistent tracheo-cutaneous fistula after decannulation

Specific to percutaneous tracheotomy:
- Failure to complete the procedure
- Puncture of the endotracheal tube
- Puncture of the bronchoscope

Percutaneous tracheotomy

Two techniques of percutaneous tracheotomy are currently widely used: the dilatational tracheotomy and the dilating forceps method.[1,4,5,11,12] Both techniques require general anaesthesia, are better performed under endoscopic vision and use a J-tipped guide-wire to locate the trachea.[1,4,5,11,12]

In the first technique, serial dilations are performed over a guide-wire to create a lumen wide enough to introduce the definitive tracheostomy tube. In the second technique, a dilation forceps guided by the guide-wire creates the necessary space.

Complications

Table 3 lists the possible per- and postoperative complications of tracheotomy. All surgeons must be aware of all these potential complications in order to both prevent and especially to recognize and treat them accordingly. In this way, permanent co-morbidity or even fatal outcome can best be avoided. Experience is critical to reduce the incidence of complications, and a tracheotomy procedure remains a step by step procedure, which must be respected.

Materials

A wide variety of commercially available tracheostomy tubes or cannulas exists. Each of these has its advantages and disadvantages, and each has its particularities and matched accessories. Numbering of the different types is unique to each manufacturer, so the real measures always need to be checked on each tube itself. The size of the outer cannula should not fill more than 2/3 of the tracheal lumen and the diameter of the trachea should approximate the width of the index finger. In male patients, the tracheal size ranges from 15 to 22 mm, in female patients from 13 to 18 mm. In the paediatric patient, the reader will find a table with measures according to age in the guideline “Management of stridor in neonates and infants”.[13]

Management of the patient with a tracheostomy tube

Correct management of the patient with a tracheotomy is critical to avoid temporary or more permanent complications.

In the early postoperative period, aseptic wound care should

prevent local wound infection, which, if not controlled, could end in painful granulation around the stoma.

When a cuffed cannula is to remain in place for a prolonged period, daily control of the cuff-pressure is necessary. Twenty to 25 cmH_2O should not be exceeded.

Most patients suffer from excessive tracheo-bronchial secretions early after tracheotomy and regular cleaning of the tube lumen and careful aspiration in the tracheo-bronchial tree are essential. In contrast, because of the lack of natural warming and humidification of the inspired air, some patients have dried secretions and encrustations in both the cannula and trachea. A heat and moisture exchanger is indicated in these patients. At times, external humidification or regular aerosols with mucolytics are necessary.

Most patients and, unfortunately, many medical care providers show aversion towards patients with a tracheotomy. Good practical and psychological support should certainly be organised in patients in whom tracheotomy is expected to be permanent. Most manufacturers have a set of accessories that can comfort the patient in this difficult situation (speaking valves, comfortable and re-usable neck laces, neck scarves, etc.).

Regular changing and cleaning of the inner cannula is needed to ensure a patent airway. The frequency varies from individual to individual. Most patients can take self-care of their inner cannula with some teaching. Changing and cleaning of the outer cannula has no appropriate timing and its frequency depends on signs of infection or other problems. Regardless of complications or problems, a good policy may be to change the outer cannula every 1 to 3 months.

In case of planned decannulation, it is imperative to check the airway for patency. Temporary and progressive size reduction and progressive capping of the cannula can help the patient with a long-standing tracheotomy prepare for re-use of normal transglottic breathing. A proper dressing, reaching the stomal edges and pressure-supported by the patient when coughing or speaking, will stimulate the spontaneous closure of the tracheo-cutaneous fistula. Surgical closure of the fistula may be necessary if the tracheotomy was present for longer than 16 weeks.

Conclusions

Tracheotomy is a surgical procedure that can lead to serious complications when performed by inexperienced physicians. The head and neck surgeon must be trained to perform both surgical and percutaneous procedures and be capable of selecting the best suitable procedure when a patient requires a tracheotomy.

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Dr. P. Deron
Department of Head & Neck Surgery
Ghent University Hospital
De Pintelaan 185
B-9000 Gent, Belgium
E-mail: philippe.deron@ugent.be

CME questions

1. Which condition is an absolute contra-indication to percutaneous tracheotomy?

   A – Diabetes
   B – Uncorrectable coagulopathy
   C – Correctable coagulopathy
   D – Palpable cricoid and trachea

2. When a cuffed cannula is to stay in place for a long period, the daily controlled cuff-pressure should be between:

   A – 10 to 15 cmH_2O
   B – 15 to 20 cmH_2O
   C – 20 to 25 cmH_2O
   D – 25 to 30 cmH_2O

3. The ideal diameter of the outer cannula to be inserted in a trachea can be estimated by measuring the width of his:

   A – Thumb
   B – Index finger
   C – Middle finger
   D – Ring finger

4. In the ideal situation for placement of a percutaneous tracheostomy:

   A – No endoscopist is needed
   B – A trained ENT-surgeon is present on the spot
   C – A trained ENT-surgeon is not necessary
   D – An anesthesiologist can take care of complications

5. In a paediatric tracheotomy, the incision of the trachea:

   A – Must be vertical
   B – Must be horizontal
   C – Is followed by the placement of traction sutures
   D – Is best done in a circular way

Answers: 1B; 2C; 3B; 4B; 5A