

Ear accidents in scuba diving

Guidelines

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The ear is a primary organ affected in diving, with specific diseases, diagnostic approaches, and treatment. Ear-related issues in diving are associated with two main pathophysiological mechanisms, which often lead to confusion and difficulty in differential diagnosis:

- Dysbaric diseases or barotrauma: Caused by changes in volume and pressure (Boyle's Law), leading to mechanical trauma through vacuum formation (during descent) or overpressurization (during ascent).
- Decompression sickness (DCS) or desaturation disease: Linked to the dissolution of gases in the body (Henry's Law), resulting in intravascular and intratissue bubble formation.

1- Ear Barotrauma (BT):

1-1- Middle Ear Barotrauma (MEBT) is the most common diving accident (1 to 2 % of dives). Although usually not serious, it can hide other forms such as the **inner ear BT (IEBT)** which should always be considered.

Context:

- Always occurs during the descent
- Difficulty to equalize pressure
- Pressure equalization not carried out or carried out incorrectly

Causes:

- Permanent Eustachian tube obstruction
- Temporary Eustachian tube obstruction, e.g., due to *rhinitis, ear infections, pharyngitis, sinusitis*
- Lack of experience, delayed pressure equalization
- Yo-yo diving, freediving

Symptoms:

- Ear pain
- Conductive hearing loss ("cotton ear", autophony)
- Low-pitch tinnitus (ringing in the ear)
- +/- Transient vertigo
- +/- Otorrhagia

Gold standard:

- **Otoscopy** (Haines & Harris classification)

Audiometry:

- Conductive hearing loss

Treatment:

- Treat ears through the nose. Aerosols or ultrasound nebulizer (e.g., physiologic saline, vasoconstrictors, steroids)

Prevention:

- No dive when suffering a cold AND no Valsalva possible
- Begin equalizing ears using Valsalva immediately upon going into the water

- Stop descent or even ascend a few meters if equalization is difficult (irreversible tube blockage)
- Caution with vasoconstrictors or anaesthetic ear drops
- Learning equalizing maneuvers (in water or by Otovent)
- Treat mucous oedema of Eustachian tube caused by strong mucosal inflammation, laryngopharyngeal reflux and allergic rhinitis correlation. Prescription of steroid by nasal spray or seawater nose wash
- Consider balloon dilation of the Eustachian tube if needed.

Haines & Harris classification		Estimated return to dive
Grade 0:	Homogenous greyish-yellowish discoloration of the tympanic membrane (TM); slight protrusion, subjective symptoms	
Grade 1:	Slight injection and swelling of TM around malleus	Diving might still be feasible within a week (complete resolution)
Grade 2:	Increased diffuse injection with loss of contours of the malleus of TM; inversion of TM	
Grade 3:	Intense injection of the entire TM, blistering of the TM	Six weeks (blood reabsorption)
Grade 4:	Blood blisters of TM; hemotympanum	
Grade 5:	Perforation; muffled TM	Three months (healed perforation)

1-2- Inner ear barotrauma (IEBT) is much rarer (< 10% of auricular BT) but carries a risk of audiometric sequelae and vestibular damage. The main mechanism is pressure transmission (piston) from stapes to the inner ear, potentially causing a round window rupture (“explosive” and “implosive” Goodhill’s theory), or stapedovestibular dislocation. Both is a risk for **perilymphatic fistula**.

Context:

- Always occurs during descent (except in cases of alternobaric vertigo)
- Inadequate Valsalva maneuver (i.e., performed too late and/or with excessive force)

Symptoms:

- Cochlear symptoms (**high-pitched tinnitus** + sensorineural hearing loss)
- Vestibular symptoms

Otoscopy:

- In 50% of cases, there is no associated MEET and the appearance of the tympanic membrane does not correlate with inner ear involvement (most often stage 2 to 3)

Audiometry:

- Sensorineural hearing loss (pure tone audiometry with deficit most often in high frequencies, positive Rinne test and negative Weber test)

Treatment:

- This is a medical emergency, requiring normobaric or hyperbaric oxygen therapy, rehydration, vasodilators and corticoids.

In the presence of IEBT, **consider a perilymph fistula** if:

- (Sub)cophosis
- No recovery within 8 days
- Portmann score > 7

Portmann Score	
Vertigo:	
To the effort	3
Postural	2
Others	1
Instability	1
Deafness	
Fluctuating	2
Mixed	1
Sensorineural	1
Tinnitus	1
Trauma	
Typical*	3
Atypical**	1
Pre-existing sensorineural hearing loss which getting worse	2
Fistula sign or Valsalva +	3
Hypo excitability (VNG)	1
CT scan	
Pneumolabyrinth Pathognomonic	
Ossicular fracture/dislocation	2
Round/oval window density	2
Petrous fracture	2
Inner ear malformation	2

Diagnostic:

- Tullio sign: Vertigo and/or nystagmus triggered by sound (80 dB at 250 and 500 Hz)
- Positional audiometry: difference > 20 dB

Treatment:

- Surgery may be required, though it is not urgent (50% resolve spontaneously, by spontaneous closures within 8 days)

2- Inner ear decompression illness (IEDCS)

IEDCS is caused by formation of gas bubbles in the vascular or tissue sectors during and after ascent. Bubbles are the results of desaturation of nitrogen. The inner ear is particularly vulnerable due to its terminal blood supply and two compartments (endolymph and perilymph), which facilitate in-situ degassing *in situ* degassing. There is a strong association between right-left shunt (PFO) and the onset of IEDCS (80% of cases).

Symptoms: during ascent or after the dive (80% within one hour after the dive)

- Mainly vestibular (rarely purely cochlear, < 10 % of cases)
- Harmonious vestibular syndrome +/- sensorineural hearing loss
- Right-side involvement in 80 % of cases (probably for anatomical factors)

Investigations:

- Vestibular assessment: Assessment of nystagmus (frenzel glasses) upon admission (emergency department), Video Nystagmography (VNG) or Head Impulse Test (HIT) during hospitalisation and follow-up
- Cochlear assessment: Pure tone audiometry
- Petrous MRI: Useless

Treatment:

- Immediate evacuation to a hyperbaric center is required

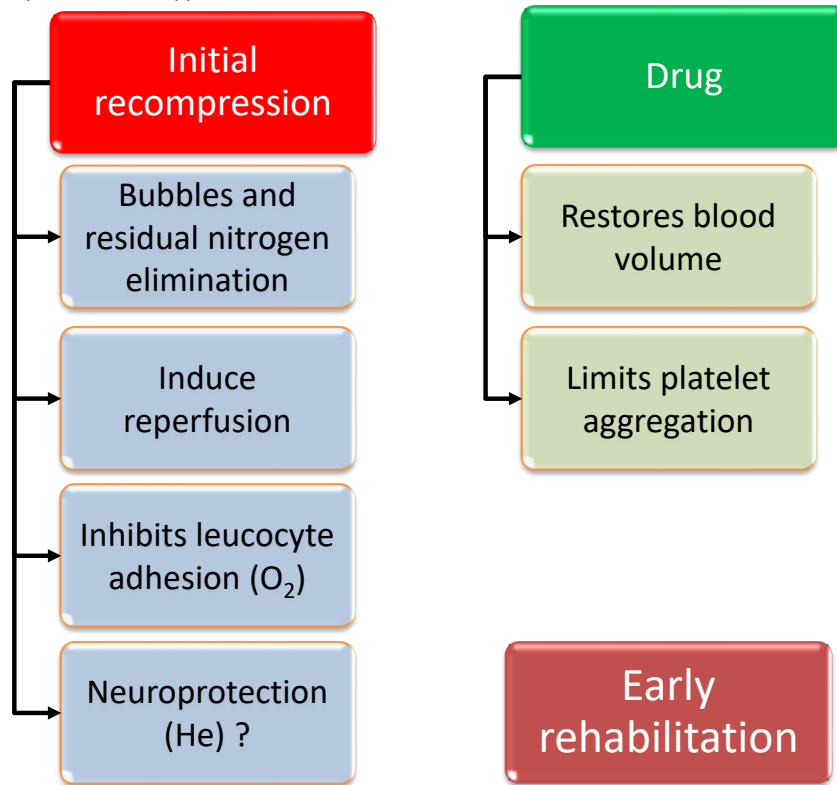
Hyperbaric oxygen therapy: Modality of oxygen administration at a pressure higher than atmospheric pressure, which leads to:

- Increase dissolved oxygen (reduces tissue anoxia), accelerating elimination of the diluent gas (nitrogen) dissolved in tissue

- Specific beneficial effect on ischemia-reperfusion and endothelial dysfunction via leukocytes and NO
- Mechanical action of pressure on the bubble (Boyle-Mariotte's law)
- Increase dissolution of bubble gases by increasing pressure (Laplace's law)

Any objective or subjective neurological symptoms, even if no longer present, requires emergency recompression.

Treatment principles at the hyperbaric centre:

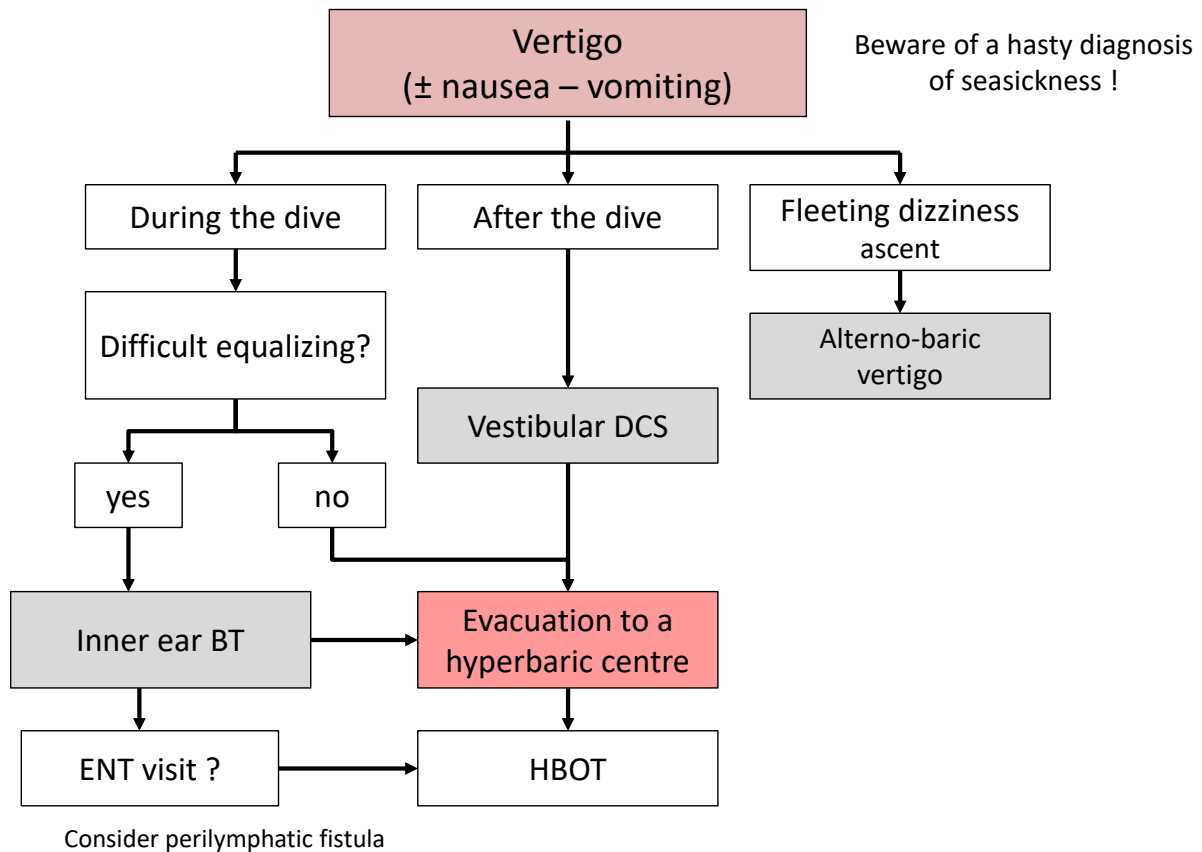


Initial recompression is generally done at 2.8 ATA (18 msw) with pure oxygen, though some centers use deeper tables with Helium at 4.0 ATA (30 msw).

3- Differential diagnosis problem

Several elements can be helpful to differentiate the diagnoses of IECDS from IEBT:

Inner ear Decompression Syndrome	Inner ear Barotrauma
<ul style="list-style-type: none"> - Mainly vestibular symptoms - Asymptomatic latency phase - Yo-yo or saturation diving - Right-Left Shunt - Right ear 	<ul style="list-style-type: none"> - Mainly cochlear symptoms - Occurring during the dive or immediately after exit - Difficulty of equalizing pressure in the ears - Pain - Free diving



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