Ear nose and throat problems in diving

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Abstract

Problems with pressure equilibration and trauma to the ears and sinuses are often referred to as the most common medical problems in diving although in most cases relatively harmless. On the other hand damage to the inner ear is relatively rare but can cause severe vertigo, loss of orientation, nausea and vomiting which causes serious threat to survival under water. Despite the fact that ENT problems are both frequent and may be life threatening, it is difficult to find numbers on morbidity and mortality of ENT-problems in diving.
Careful FTD-assessment and good training of the diver can minimize the risk of encountering ENT related problems in diving.

Key words: oto-rhino-laryngology, diving accidents, sports-diving

The ear nose and throat, ENT- system is a gas filled system containing delicate sensory organs in the head and neck region. The fact that it is gas filled is the cause of many of the troubles in diving since changes in pressure calls for gas flux to compensate the volume changes in the gas due to the compressibility of the gas. If gas can not move freely, or the diver is unable to perform necessary manoeuvres to move the gas, pressure differences to ambient will appear, which may result in squeeze, oedema, rupture of blood vessels or mechanical damage.

Without any existing reference, to my knowledge, there are good reasons to believe that the inexperienced divers are more often involved in ENT-problems than the experienced divers. The reason being that the pressure equilibration is not always passive, but require skills that takes some time to achieve. A six months training in scuba diving in the Swedish navy resulted in a significant reduction of the active forcing pressure from 43.8 to 31.3 cm of H_2O, while the passive clearing remained almost the same 43.0 to 39.7 cm of H_2O according to Ornhagen and Roman (1). Furthermore physiological and sometimes patho-physiological variations, of the mucosal lining of the air containing structures, causes changes in the flow capacities of many times narrow canals. An inexperienced diver could not be aware of what these might lead to, while the experienced knows what type of unwanted complication can be the result, which makes him/her abort the dive. An example of this is a minor cold or allergic reaction that on land passes unnoticed, but may cause vestibular problems during diving that could jeopardize work efficiency and even survival under water.

In several publications the authors state that ENT-problems are the most common among medical problems in diving but data on incidence and morbidity is scarce.
Molvaer (2) reports that 46 % of all medical problems in saturation diving in the Norwegian sector are related to ENT-problems. However, as outlined below 95% of the ENT-problems in saturation diving are external otitis.

Among diving instructors and dive masters in recreational diving reporting a total of 3547 accidents and trauma during one year, at a questionnaire in a retrospective study, Ornhagen and Hagberg (3) found 26.3 % ENT related problems among males and 31.75 problems among females. This difference seemed to be related primarily to more reported pressure equilibration problems among females. Table 1 illustrates the different types of accidents and trauma.

Table 1. Distribution of reported medical problems, as a result of diving, among Swedish diving instructors and dive-masters, 1999. (Based on 3,4)

Type of accident or trauma	*Female*		*Male*	
	Number	*Percent*	*Number*	*Percent*
Headache	126	24.4	824	27.2
Physical traumas and strains	93	18.0	777	25.6
Ear problem	46	8.9	198	6.5
Sinus problems	37	7.2	180	5.9
Tooth and jaw problems	32	6.3	180	5.9
Motion (sea) sickness	31	6.0	144	4.8
Reduced hearing	17	3.3	97	3.2
Symptoms of decompression illness	25	4.8	240	7.9
Non specified	105	20.5	391	12.9
Total number of reported problems	516		3031	

Both the cited references deal with experienced divers of two categories. In diving training mild ear squeeze is so common that it is looked upon as part of the normal picture.

Among the British sub aqua club accident reports from 2003 published in internet it was possible to find 3 ruptured ear drums and 2 sinus problems, which is 10 % of the total of 52 reports which is not different from the mean of 16 % barotraumas of ear, sinuses and lungs seen in the voluntary reports to the Swedish Sports Diving Federation 1997 to 2002. Most likely this is only a fraction of all ENT related problems, but ENT-problems are usually minor, and thus not reported, since the diver abort the dive because of pain before any damage is caused. Even more severe ENT-problems are most likely under reported since there is no real incentive for reporting. There are good reasons to believe that divers are treated at hospitals without reporting this since the accident happened during a recreational activity or during education when the diver is a student and not employed.

Divers Alert Network, DAN do not mention ENT-trauma in their statistics and ENT-problems are not noted as a possible causing factor behind fatalities in their 2002 statistics.

In a quantitative risk assessment of scuba diving 1997, the HSE analysed a total of 286 fatalities reported by BSAC and DAN (5). In a list of 36 possible factors behind fatalities ENT-problems are not mentioned which tells us that ENT problems as a factor behind fatalities is either uncommon or overlooked. In contrast Antonelli and co-workers (6) showed that almost all inner ears from 11 consecutive male scuba diving fatalities, in a geographical region, had serious pathologic findings on autopsies. It was, however, not possible to determine if the pathology found was the cause of the fatality or a result of the emergency ascent often involved in the accident.

Consequences of problems in the ENT system during diving

The outer ear canal

Blockage

Blockage of the outer ear canal during descent will cause the ear drum to bulge outwards when the middle ear is pressure equilibrated. The diver can not feel the direction and interpret the pain in the ear as an insufficiently pressure equilibrated middle ear and force even more air into the middle ear, which might rupture the ear drum. The blockage could be caused by a tight hood preventing the entrance of water or air from filling the outer ear canal on descent. In inexperienced divers diving without hood the blockage can be caused by a hydroscopic swelling of accumulated cerumen that becomes a “cerumen obturata”. Frequent diving without hood keeps the outer ear canal free from cerumen and this might cause other type of problems (see below)

Thanks to the liquid filled systems in the inner ear connected to the CSF the inner ear is protected from damage in this situation.

Infection

In most cases the otitis of the outer ear is mild and causes only itching and could be difficult to differentiate from an eczema caused by water and loss of cerumen. In most recreational diving and commercial surface oriented diving infections and eczemas of the ear canal do not cause serious problems since there is a chance for the skin to dry out between the dives.

Among saturation divers in the Norwegian sector, however, 44,5 % of all medical problems are related to otitis of the ear canal (7). An infection of the outer ear canal can be very dramatic because of the severe pain that makes it impossible for the diver to wear the helmet. Diving operations have been aborted due to several divers being struck by infections of their ear canals (8).

The Eustachean tube and middle ear

The first to happen when diving with blocked Eustachian tubes is a reduction of hearing, which most likely will pass unnoticed because of the dramatic change in hearing when shifting from an air to a water environment. The feeling of fullness and later the pain will be followed by a rupture of a vein resulting in pressure equilibration by blood that fills the middle ear, which makes the pain go away, or the rupture of the ear drum. The rupture is painful, but afterwards the diver most often report very little until a possible infection has developed.

If the Eustachian tube is closed, and wrong equilibration technique is used, the round window may rupture. (See below Inner ear.) The inner ear and CSF liquid pressures adjusts, through the vascular system, to the ambient pressure. An additional elevation of the inner ear pressure, transmitted via blood from a forcefully elevated intra thoracic pressure during a Valsalva (to clear the ears) may give such liquid pressures in the inner ears that the round window may burst into the relatively low pressure in the middle ear. To avoid this, ear clearing should not involve a Valsalva manoeuvre, but be preformed as a Frenzel manoeuvre, in which the pharyngeal muscles contribute, not only to the pressure build up in the pharynx, but also promote opening of the Eustachian tubes. The closed glottis prevents the gas from going down into the lungs.

A blockage of the Eustachean tube during ascent results in a higher pressure than ambient in the middle ear. If this is one sided (only on one ear) and more than 6.5 kPa above ambient this is said to cause alternobaric vertigo according to Tjernstrom (9). The mechanism is unknown. In a mixed population of mainly recreational divers 17.1% reported to have experienced alternobaric vertigo at least once during their diving career, and as many as 11.4 % reported that they had had difficulties finding their way back to the surface (10).

The alternobaric vertigo is short lasting and constitutes a limited risk in commercial diving using helmets and tethered divers. For a freely swimming diver on his/her own the loss of orientation and vertigo causing vomiting the AV is a serious risk and might very well be behind fatalities in diving.

Since inert gas is reabsorbed from any hollow structure because of the so called “oxygen window effect”, and this is enhanced during oxygen breathing, oxygen diving could cause problems with a negative relative pressure in badly ventilated hollow structures. Another effect of oxygen diving is that the hollow structures will be pressure equilibrated with oxygen during the descent. This is then easily absorbed by the blood in the mucosal lining after the dive which will cause a negative relative pressure in the structure if it not ventilated or pressure equilibrated. In aviation the phenomenon with serum filled middle ears, when wakening up the day after a day with flying with oxygen breathing, is called “oxygen splash”. The same phenomenon is not uncommon in oxygen diving as described by Shupak et al (11).

Infections
The middle ear infection could be a result of penetration of contaminated material in conjunction to a rupture of an ear drum but is most commonly a problem of the childhood with little impact on diving. Scars on the tympanic membrane as a result of previous middle ear infections rarely causes problems in diving.

The inner ear
During diving the individual is eliminated from many inputs that help to maintain orientation and the sense of what is vertical and horizontal, which leaves the inner ear more or less alone to maintain this function. A loss of function or damage does not only reduce work efficiency, but could also impose a risk for serious accidents.

Round window rupture
Initially described by Freeman and Edmonds in 1972 (12) round window rupture has shown to be about 1% of the medical cases presenting at the Royal Australian Navy Diving Medical Centre (13). The signs and symptoms when the rupture appear could be dramatic and the loss of orientation, the vertigo and the nausea can definitely jeopardize both work efficiency and safe return to the surface.

Decompression illness
Embolisation of the arteries to the inner ear as a result of a major cardiac right to left shunt has been presented as a risk of diving by two independent groups (14,15). Formation of bubbles in the peril- or endo-lymph due to super saturation is a possibility as shown mathematically by Doolette and Mitchell (16) and observed as a clinical reality especially from deep dives (17,18). These problems usually do not appear until after the dive which eliminates this illness as a safety risk during the water phase of the dive but of course must be considered as a risk of the dive itself.

Motion sickness
In shallow diving freely swimming divers or divers working on floating equipment may experience motion sickness or sea-sickness. Also divers in saturation are exposed to the risk during transfer in bells and stay in saturation systems on deck, while the heave compensator usually keep the bell stable while at the work site. The incapacitating effect of motion sickness is well known and it might also pose a safety risk during diving.
A nauseating effect of seaweed swaying back and forth may cause a similar effect to the simulator illness in flight training, which might reduce alertness and thus pose a safety risk in diving.

The nose and sinuses
The only sinus that causes problems in any serious number of occasions is the frontal sinus that has a comparable long and narrow passage. Localised pain, but not infrequently a dull indefinable headache during or after diving is the prominent symptom. After diving blood or blood coloured discharge from the nose is frequently seen. The remaining over pressure in a maxillary sinus at arrival to surface can cause tooth ache through pressure

on exposed nerves in the bottom of the sinus or double vision by pushing on the eye bulb via a flexible wall between the sinus and the orbita.
Polyps in the sinus can act as valves making gas transfer into the sinus possible, but blocking the return of gas out of the sinus on ascent.
Headache, during or after dive, should always be investigated as a possible result of badly ventilated sinuses.

A structure, not much spoken about, is the soft palatine. However, if the diver can not close of the soft palatine he/she is at serious risk if the face mask is lost or just water-filled. This must be remembered when surgery is thought of or planned for snoring divers.

The mouth
Barodontalgia or toothache as a result of pressure change is observed in 2.5% of diver students. (19). Often the blame is focused on cavities and bad fillings, but Barodontalgia is seen also in teeth without caries and fillings. Old divers can witness how fillings have "exploded" in their mouth on ascent. Trapped gas behind the filling is given as explanation.
The loss of amalgam fillings is hastened by underwater electro-welding. Divers explain how they get a metal taste in the mouth when the current is on. It is not unlikely that the electrical fields cause galvanic reactions spoiling the amalgam fillings (20).

During diving with mouth piece and full face mask there is a constant load on the lower jaw. Either as a biting force to keep the mouthpiece in the mouth or a protruding force to prevent the jaw from being pushed so far back that the tongue obstructs the airways. As many as 1.9 % of instructors and dive-masters have these problems according to Ornhagen and Hagberg (3) The design of the mouthpiece with the biting surfaces at the sides rather than at the front and an anatomical seal of the full face mask, which does not require too much pull to seal, solves most of these problems.

The throat and larynx
This is probably the part of the ENT-system that causes least problem.
At high gas densities the flow restriction in the larynx may limit the ventilatory capacity, but this is not seen as a problem in deep diving.
The increased gas density at greater pressure, and the speed of sound in helium, makes communication difficult without unscramblers. A reduction of the working performance could be expected if communication is severely affected.

The threats to a diver

Many of the conditions that divers may encounter do not cause anything but a short period of diversion of attendance, which in itself may be a risk. Others can cause a

constant nuisance, which in the long run may develop irritation and affect the mind. This in itself can make divers less careful in making a good job.
Severe pain and headache will force the diver to abort the dive and vertigo and nausea may impose immediate threat to diver safety

Pain
Pain could be anything from a mild toothache to severe headache. Pain thresholds are different but eventually any diver could be forced to abort a dive because of pain. Long before that, the diver will be affected and alertness will be reduced.

Vertigo
A dizziness or instability could a diver cope with through better concentration on the job task. A rotational vertigo, however, will lead to dive abort and if the diver is tethered the life line or the umbilical will help the diver back to a safe haven. If the diver is free swimming only positive buoyancy will help the diver to a safer environment where help is to find.

Nausea
As long as the nausea does not affect the autonomous nervous system to a major degree the diver may continue the work task, but severe nausea often leads to vomiting, which in most diving equipment with full face masks poses a serious risk for aspiration and fatality. The only equipment that could be looked upon as safe during vomiting is the old hard hat with integrated dry suit.

Loss of hearing
The possibility to detect the direction to a sound source is very limited but hearing could be of importance as a warning against propellers and other potentially dangerous objects. Often the tool the diver uses creates noise, which may mask the sound from an approaching hazard. Noise from tools also makes hearing difficult inside the helmet, which could make it impossible for the diver to hear warnings and orders given from the dive control.

The noise in helmets caused by the gas flow also creates a mask to hearing and makes communication difficult. In free flow helmets the divers sometimes reduce the flow to unacceptably low values from a metabolic need perspective, in order to facilitate hearing the communication from the dive control. This could result in CO2 accumulation, headache, increased risk for oxygen convulsion, and decompression illness after decompression.

Molvaer and Albrektsen claim the accelerated presbyacusis seen in diver populations is mild and will not be a safety risk since divers often start their career with a better than normal hearing (21).

Preventive measures

Based on knowledge from accidents and reported trauma it seems possible to avoid or prevent most of the reported accidents, related to the ENT sphere, by some simple measures.

Selection and FTD assessment

Good function of the Eustachian tubes is a prerequisite for uneventful diving. There are a number of different ways to establish this. Simplest is just to ask the diver to be, to pinch the nose, close the mouth and "blow" as if blowing the nose. Under these conditions it is important to assure that the pressure reaches the epi-pharynx and the soft palatine is not closed. A simple way to achieve this is to attach a nose olive with a hard to blow balloon and ask the diver to be to inflate the balloon through the nose. This trick is used under the commercial name Otovent® when training children with aerotitis media to aerate their middle ears. (More about this under Training below.)

The outer ear canal must be free from signs of eczema and infection and should have a healthy layer of cerumen. The tympanic membrane must be intact but may contain scars from earlier trauma and middle ear infections. If any uncertainty regarding infections exists, a swab and an Uricult or Uritube culture could be made (22). Tympanometry could be helpful regarding eardrums that are difficult to inspect fully.

As usually the interview will tell a lot. Ask for problems when flying, during colds or in previous diving.

Training

Any person having air filled middle ears have a passage from the ambient atmosphere. If the tympanic membrane is intact the Eustachian tube allows air to pass and the person can pressure equilibrate. If larger amounts of air must be forced through the tubes an optimal technique is needed if the passage is narrow. The so called Frenzel technique offers this.

- A forceful elevation of the epi-pharyngeal pressure without elevation of the intra cranial pressure.
- Traction or downward pull in the para-pharyngeal muscles which tends to widen the pharyngeal opening of the Eustachean tube.

When teaching someone the Frenzel technique, feed-back to the student in the form of a video-display of the ear drum and even better the pharyngeal end of the Eustachian tube is worth a lot.
The simplest way to check is someone knows how to perform a Frenzel manoeuvre is to ask the person to pressure equilibrate his/her ears after a maximal exhalation. There is not enough air in the lungs for a Valsalva manoeuvre, but the air in the pharynx can still be compressed and you will see the bulging ear drum in your otoscope.

The advantage with the Frenzel manoeuvre in addition to the fact that it is the most effective is that it will not cause any elevation of the intra cranial pressure and hence saves the round ear from the risk of rupture with all the negative consequences that follows.

The opposite, suction of air out of the middle ear is called the Toynbee manoeuvre. Normally the clearing of over pressure in the middle ear does not require any activity and this is often called the passive clearing of the ear. If needed the Toynbee manoeuvre, swallow with a closed nose, will suck gas out of the middle ear. Since a face mask with small dead space (low compliance) will be almost the same as pinching your nose, swallowing with a face mask will suck air out of your middle ears.
The only situations when this can be needed is when you experience alternobaric vertigo during diving and when you would like to see if there is any communication to a middle ear that can not be inflates actively by the diver to be in your clinic.

Education

One of the more important parts of training of divers in diving medicine is to explain the troubles can follow after they have noticed the first signs of an effect of pressure increase or similar. The ENT region has many warning signs that must be taught to the student of diving.

- Fullness in the ear: Pressure equilibrate if no relief abort the dive
- Slight dizziness: Stop descent or ascent take a breath and focus on something
- Toothache on descent: Abort the dive
- Toothache on ascent: Try Toynbee or continue
- Headache on descent: Try Frenzel, if not better stop and wait for a while if not better abort the dive
- Difficulty to pressure equilibrate: Try descent feet first

Equipment

Respiratory equipment used in diving should have as low work of breathing and static load as possible to minimise the effects on the intra thoracic pressure, which in turn affects the central venous pressure and the swelling of the mucosal membranes in sinuses and upper air ways. A low central venous pressure makes it easier to pressure equilibrate the middle ears (23)

Face masks and helmets should have means to block the nose during pressure equilibration of the middle ears if necessary.

Hygiene and maintenance

Well maintained and serviced equipment is good not only for the ENT-system. Special care could however be called for regarding hygiene since microbes and infections cause serious threats to the ENT-system. A simple cold with swelling of the mucosal lining of

sinuses and air ways could put a stop to diving. Avoid mixing mouth pieces and face masks without cleaning and screen for Pseudomonas whenever there has been an outbreak of external otitis in a closer diver community such as a saturation diving team.

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