Welcome to the Divers Alert Network Ears and Diving web-based seminar. This online lecture has been compiled by the DAN America Training Department and is based on a presentation by Dr. Frans Cronje, Executive & Medical Director - DAN Southern Africa.

This seminar will help you better understand your ears and the way they are affected by pressure. We will show you how to find the most effective way to equalize your ears and learn how important your ears are to diving – they are not just something to keep your sunglasses in place!

This seminar will not make you an expert in solving ear troubles, nor train you to diagnose injuries or infections affecting the ear. However it will make you a better informed diver leading to safer diving habits as it related to your ears and assist you in educating others about respecting and protecting their ears.

Print out this document and use it to follow along with the seminar presentation. Fill in the blanks to remember certain key information. Not all of the text from every slide is included in this document, but it does include key areas you will want to remember.
Most Common Problems

Of all the potential problems that affect divers, ear problems are not only the most common, but also most likely to keep divers out of the water.

There are two potential factors that may affect the ears during diving -- ____________ and pressure.

Pressure/Moisture

Water:

- Affects the quality of hearing and our ability to localize sound
- Exposes the external ear to the ____________
- Cold water may cause dizziness

Pressure may:
- Result in trauma
- Lead to absorption of inert gas with ________________________
- Cause dizziness in cases of extreme pressure – called __________________________

Three parts of the ear

The ear consists of three parts:

- **External ear** which you dig in with your fingernails, car keys or ear swabs and is exposed to water during diving
- **Middle ear** where sound waves are conducted and magnified 14 times through a ____________ that communicates to the outside world via the Eustachian tube;
- **Inner ear** where sound waves and ________________ is converted into electrical impulses and conducted to the brain.

We will now look at each of these sections in turn.

External Ear

External Ear Description
The External Ear begins with the visible protrusion called the pinna

- It contains a fleshy protective lump, just in front of the ear canal, called the tragus
  - This is a telltale spot for testing for _______________________________
- The external opening, or meatus, leads towards the ear drum
**Exstoses**
Divers and swimmers, especially those who spend a lot of time in cold water, sometimes develop _________________ in their external ear canals, called exstoses.

- Cold water irritates or damages the underlying bone resulting in subsequent gradual overgrowth of bone.

These lesions are not troublesome but can become a problem if they eventually impair the natural _________________ from the ear, or lead to blockage that affects hearing.

They then need to be surgically removed. Unfortunately, they have a tendency to recur.

**Ear Canal**
The skin over the external part of the ear contains hair and modified sweat glands that produce the cerumen, or earwax.

- Earwax is a natural barrier to _________________
- Continuous soaking during diving can remove the wax

Just inside the ear is an area of skin with no hairs or wax – unless wax has been forced in by inserting objects, like cotton swabs, into the ear.

This smooth skin overlies bone and is _______________. Infection or injury can be very painful.

**Swimmers Ear**
The most common problem with the external ear, and the second most common problem in divers, is otitis externa or Swimmers Ear.

Swimmers Ear occurs when the combination of the loss of protective wax, water-logging of the skin, and _________________ (such as from scratching or digging in the ear with cotton swabs) allow _________________ to invade the skin.

Again, the best solution is never to scratch the ear or poke things into it.

**Infection signs**
The easiest way to recognize an external ear infection is by the _________________ of ear pain which is often _________________ or touching the pinna or tragus. Gradually there is a discharge followed by closing over of the ear canal.
The pain, which is particularly evident when you gently tug on the ear or press on the trachus, distinguishes external otitis from ________________ where such pressure is ________________.

**Pressure Damage**

Pressure damage of the external ear can result when a diver wears earplugs, has a tight fitting hood that traps air in the external ear canal or when earwax completely blocks the canal.

**Boyle's Law**

The volume of the air space will decrease as pressure increases

- This causes the eardrum to ________________ as the diver descends and forces the earplug in deeper.

Attempts at equalizing the ear only makes matters worse.

Injury caused by the earplugs may cause ________________ in the ear canal and even on the eardrum itself.

Fortunately, the condition clears on its own, but diving may have to be delayed until everything is healed.

**Earplugs should not be worn by divers.**

**Middle ear**

**Details**

Middle ear barotrauma, or a pressure injury to the middle ear, is the ________________ problem affecting divers.

Approximately 65 percent of all divers will suffer from this malady at some stage during their dive careers.

The tympanic membrane, or eardrum, is like a sealed door to the middle ear, which contains

- the Malleus, or hammer
- the Incus, or anvil
- and the Stapes, or stirrup

These three bones form a chain that ________________ sound 14 times between the eardrum to the inner ear.
The middle ear communicates with the outside world via a _________________ tube called the Eustachian tube.

When a diver equalizes, air is driven from the back of the throat through the tube into the middle ear.

The onscreen image shows a normal tympanic membrane through an otoscope

- The quadrant on the ___________________________________, closest to the nose tends to reflect light. This is called the light reflex.

The size and shape of the light reflex can indicate if the eardrum is sucked in or bulging out. It also tends to _________________ during successful attempts at equalizing (see video). Its reflective nature makes the movement from the equalization easier to observe.

The irregularly shaped area curving into the circular tympanic membrane is the silhouette of the underlying Malleus, or hammer -- one of the bones conducting sound between the eardrum and the inner ear.

The bulge halfway up the stem of the Malleus is called the _________________.

- This is an important landmark, and is always on the same side as the nose.
- This is therefore a right eardrum.
- The light reflex is also on the same side of the of the eardrum as the lateral process.

The middle ear space is semi-closed and its lining _________________. This creates a vacuum.

- The pressure in the middle ear is usually about 20 mm Hg below ambient pressure.
- This vacuum is formed at the rate of approximately 50 mm Hg per hour.
- One atmosphere of pressure is 760 mm Hg, so this is 1/15th of an atmosphere.

The vacuum is usually broken or, in other words ________________, by yawning, swallowing or chewing.

If a diver descends more than _________________ the increased pressure collapses the Eustachian tube and it is no longer possible to equalize, _________________.

- This is just like trying to blow through a kinked straw. It can’t be done. It needs to be unkinked first.

Although the eardrum is remarkably tough, it will rupture if the pressure on the outside of the eardrum reaches the equivalent of between _________________ of sea water
pressure.

When this happens, many divers experience _________________ of the increasing pain during descent as the tension on the eardrum is relieved.

- This frequently coincides with an episode of _________________ as cold water rushes in and comes in contact with the bones surrounding the inner ear.

Once the dizziness settles, as the water warms to body temperature, many divers will believe that their equalizing problems have been solved. This is of course because the middle ear is now _________________ which is incompressible.

**Teed Scale**

**Teed Scale 0**

Refers to someone complaining of _________________ of the ear without any evidence of injury upon examination.

This condition usually improves spontaneously within 30 minutes to 24 hours. The use of decongestants under medical supervision is optional.

Usually occurs in divers _________________ with equalizing.

**Teed Scale 1**

Diver complains of blocked ears. The eardrum is slightly retracted.

Hyperemia, or engorgement of the _________________ over the stem of the Malleus, is present.

This is a self-limiting condition, often resolving within 24 to 48 hours. Use of _________________ under medical supervision is optional.

**Teed Scale 2**

This condition shows the first actual evidence of trauma. The history is similar to the milder grades.

The diver notices, and complains of, _________________.

- May persist afterwards

Small areas of pinpoint or streaky bleeding.
- Usually immediately adjacent to the stem of the Malleus
- Condition usually resolves within 48 to 72 hours
- Use of decongestants, under medical supervision, _________________

**Teed Scale 3**

his level represents even _________________ trauma with plaque-like or patchy areas of hemorrhage.

Pain is more prominent.

Use of decongestants, under medical supervision, is indicated.

Usually resolves spontaneously _________________ without complications.

**Teed Scale 4**

Recognized by pain and a sensation of fullness. Upon examination by medical personnel, _________________ can be seen behind the tympanic membrane, and bubbles can sometimes be identified.

Indicates a slow, continuous increase in pressure, or _________________ pressurization of the middle ear caused by a slow, yet persistent, descent at the threshold of pain.

The presence of blood or the history of an upper respiratory tract infection indicates the need for antibiotics and even cortisone. _________________ is also indicated – all under medical supervision.

Usually clears within 5 to 10 days.

**Teed Scale 5**

Rapid onset of pressure may result in _________________. The hole is often small and ________________.

The history of the injury is often the most useful in diagnosing perforation. Often, the diver describes _________________ of severe pain during descent followed by a noise in the ear.

The diver usually then describes an _________________ of pain followed by dizziness as cold water rushing into the middle ear, irritating the inner ear.

The dizziness usually clears within a minute

- After the dizziness clears, the diver reports no further equalizing problems
- The middle ear is now fluid-filled and no longer compressible
The diver usually experiences deafness and a ________________ on return to the surface.

Severe ear pain usually develops over several hours due to the inflammatory reaction to water in the middle ear.

Decongestants are indicated, as well as antibiotics and analgesia -- all under medical supervision.

The perforation will usually close ________________ without complications in 10 days to two weeks. In rare instances the perforation needs to be surgically corrected by a procedure called a tympanoplasty.

**Ear Equalization**

**Introduction to Equalization**

The one sure way to avoid the risk of middle ear barotrauma is to avoid diving altogether.

To minimize the risk, and continue to dive, divers must ________________ their ears to the surrounding pressure early and often. However, active ear equalizing is not a natural activity for non-divers.

In fact, many people are “scared” of their ears and describe the ________________ during equalizing as being uncomfortable.

**Overview**

There are many techniques for equalizing the middle ear to ambient pressure. The most common and useful ones are discussed here.

These various techniques give divers a number of equalizing options, as people may respond better to some techniques than to others.

**Automatic**

Swallowing and yawning are the ________________ to equalize the middle ear.

- Middle ear infections in children result from a failure of these mechanisms.

During sleep, equalizing occurs approximately every ________________ through swallowing. It occurs ________________ while awake.

Some individuals can open their Eustachian tubes voluntarily with a twitch in the throat.

- Many commercial divers master this technique
Valsalva
In 1704 Antonio Maria Valsalva described a technique to expel pus from the ear through _______________. Today, it is the technique most commonly taught to divers.

It involves _______________ and blowing the nose, blowing air up the Eustachian tube and equalizing the middle ear. It can be performed very _______________, leading to inner ear problems.

The safest recommendation to divers is never to perform an _______________ blow for more than five seconds.

Toynbee
Joseph Toynbee first described this technique of _______________ the nose and swallowing to equalize the ears.

This technique is _______________ and works well when there are problems with the Eustachian tube as it involves small pressures only. It tends to equalize _______________. It is a gentle technique divers can use to equalize before and during descent.

At the surface, the diver’s ears may feel blocked after performing this technique.

Frenzel
Herman Frenzel described this technique for the benefit of German Stuka pilots in WWII.

To perform it, move the tongue quickly _______________ against the soft palate. This creates a pressure wave and positions the muscles for easy equalization. You can make this technique more effective by _______________ the nose at the same time.

To teach this technique, have the subject say the letter “_______________” in the back of the throat while pinching the nose.

Twitching
The Twitching Technique is a good technique for people unfamiliar with equalizing. This lets them understand how equalized ears should feel and is a great teaching tool.

While pinching the nose, _______________ the head to the side. The ear facing forward generally equalizes.

Repeat the procedure in the other direction to equalize the other ear.
Troubleshooting

All divers are affected by equalizing problems from time to time, and there are several techniques that may assist them. They may also be useful in hyperbaric chambers in general.

Lowry

- May be useful to improve equalizing in general
- Pinch the nose, gently blow against the blocked nose and _______________ simultaneously

This technique is difficult to do with a regulator, but it can assist the discovery and improvement of equalizing techniques.

Head Tilt is a simple, yet effective technique to make _______________ equalization techniques more effective.

Tilt the head and neck to one side while keeping your shoulders stable. Point the “_______________” ear upwards, then equalize using any one of the conventional techniques.

Edmonds

- Jut the jaw forward while attempting to _______________ normally
- This maneuver tends to open the Eustachian tube

Inner Ear

Organs

Past the Middle Ear, the Inner Ear contains the organs of
______________________________ -- the cochlea and the vestibular apparatus.

The Middle Ear communicates with the Inner Ear through two membranes called the oval and the round windows.

The oval window contains the footplate of the stapes or the stirrup.

- The stapes _______________ sound waves from the eardrum to the inner ear
- It amplifies signals 14 times

The ______________________________ provides a method for the fluid-filled inner ear to expand with the movements of the oval window.
**Danger**

When a diver attempts to equalize forcefully, he is at risk of bursting the round and oval windows.

Straining transmits a _________________ wave through the blood to the brain.

- This pressure is transmitted to the inner ear through a thin tube called the endolymphatic duct

Combined with a vacuum in the middle ear, as is usually present in an ear that needs to be equalized, the chances of __________________________ rupture are even higher.

If an inner ear window ruptures, the diver will experience sudden deafness, dizziness and ringing in the ears. These conditions will persist after the diver reaches the surface.

**Dizziness vs. Vertigo**

Vertigo is the sensation that the room is _________________ or spinning, or that the person is moving or spinning within the environment.

The term "dizziness" is often used for milder feelings of _________________, but this word needs to be distinguished from symptoms such as balance difficulty, fainting, or general weakness.

True dizziness is a lightheadedness or a sensation that you are about to faint.

True vertigo requires the _________________ of movement.

Any dizziness or vertigo symptom needs prompt professional medical advice.

Dizziness related to inner ear rupture is not transient -- it doesn't _________________.

This is how to distinguish an inner ear rupture from dizziness brought on by cold water entering the middle ear through a perforated ear drum.

**Dizziness**

Dizziness during descent is commonly associated with alternobaric vertigo.

- When the ears equalize at different rates the brain interprets the difference in pressure as a spinning sensation

This is very common during eardrum rupture.

- Can also occur when very cold water comes in contact with the eardrum
Dizziness on ascent may be caused by _________________ and inner ear decompression sickness

Some divers have dizziness following mild dives with no problems equalizing

**Other Causes**
Dizziness upon reaching the bottom is uncommon.

- Depends on the type of diving, diving apparatus, and gas mixtures the diver breathes.

In recreational diving on open circuit scuba, causes include:

- _________________
- Carbon dioxide retention
- Motion sickness
- _________________
- Medication and alcohol
- Middle ear barotrauma and alternobaric vertigo

**HPNS**
For commercial or technical divers, other causes must be considered including:

- Gas switch problems
- Decompression sickness
- High pressure nervous syndrome or HPNS when diving to depths greater than 400 feet of sea water/120 meters of sea water
- Must also consider the possibility of gas contamination and low oxygen levels

**Sinuses**
The other air spaces most commonly affected by increasing pressure are the sinus cavities.

- The sinuses are a part of the nasal passages.
- There are _________________ of sinus cavities.
- Under normal conditions they equalize without difficulty
- Sinus _________________ or a head cold increases the chances of injury

**Squeezes**
The Frontal Sinus has a thin, tortuous canal connecting it to the upper part of the nose.
- It is the most ________________ to blockage and pain.
- Usually felt over the eyebrow.

The cheekbone or maxillary sinus is the second most common sinus affected by diving.

- Pain is present in the ________________ or cheek

The ethmoid sinuses lie between the eyes.

- Where pain is felt

The sphenoid sinus lies behind the eyes.

- Pain is felt at the ________________

Divers should abort any dive and seek medical advice when they feel pain in any of the sinuses.

**Guidelines**

What follows are a series of guidelines to help divers keep their ears in good health so they won't be faced with the possibility of not being able to dive.

1. Ear pain and problems are common in diving.
   - With care and the avoidance of further injury, they recover very well
   - Rarely a reason to give up diving altogether

2. Pain usually comes from the external or middle ear.
   - Pain associated with chewing or moving the outer ear is likely to be an outer ear infection
   - Pain associated with a difficulty equalizing is likely related to the middle ear

3. Direct visualization of the tympanic membrane with an otoscope is a crucial aspect of determining fitness to dive. This should only be attempted by a medical professional.

4. Decongestants, such as Sudafed, are not routinely recommended for divers.
   - In selected divers, with minor difficulties in equalizing, decongestants may reduce the risk of damage to the ear and are therefore not unreasonable to use.
   - However, as with all medication, there is the risk of side effects, and no medication should be tried for the first time underwater.
   - Decongestants should never be used in an attempt to dive with a head cold or when the diver is otherwise unable to clear.
   - Decongestants should only be prescribed by a medical professional and used for no more than five days continuously.
5. Earplugs create an airspace between the earplug and the eardrum and are contraindicated with diving.

6. Deafness or blockage are important findings and suggest damage to the ear.
   - If difficulty was experienced with equalizing during a dive, the cause is likely to be related to middle ear barotrauma, although it is possibly inner ear barotrauma.
   - If the diver performed forceful attempts at equalizing, inner ear rupture is a possibility or if the diver performed a dive deeper than 80 feet (24 meters) or on mixed gas, the possibility of inner ear decompression sickness must be considered.
   - Vertigo, or twitching of the eyeballs called nystagmus, is very important and is always a serious finding.

7. Dizziness should never be ignored.
   - Dizziness that persists at the surface has several possible causes
     - Rare and serious -- Inner ear barotrauma and inner ear decompression sickness
     - Common and less serious -- alternobaric vertigo
     - Avoid factors that complicate equalizing attempts

8. Equalize early and often.
   - Attempts should occur at least once for every foot of descent or once per breath cycle during descent

9. Blow your nose prior to diving.
   - Removes excess mucus that may make equalizing more difficult.

10. Pay close attention to your ears during descent.
    - If the ears are not clearing, or if there is increasing discomfort, ascend a couple of feet and try different equalizing techniques.

11. Never hold your breath during ascent – do not try to equalize.
    - Air drains spontaneously from the middle ear during ascent. Valsalva forces air trying to escape, back into the ear – making matters worse.

12. Practice equalizing.