THE SQUEEZE, THE EAR AND PREVENTION

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As it is only a short time since water sports have become popular, and then only on a part-time basis, the human ear is not now, nor will it ever be, suited for prolonged immersion in water. There are various ear disorders peculiar to scuba diving and they occur in each of the three parts of the ear: the outer, the middle and the inner ear. "Squeeze" is a term used by divers, being their name for barotrauma, derived from the pressure squeezing the affected part and the "Reverse Squeeze" by pressure of expanding gas.

Outer Ear Squeeze or "Reverse Ear"

Outer ear squeeze (Figure 1) is a similar condition to the squeeze of the middle ear, results in damage to the skin of the outer ear canal and requires pressure changes of 20-50 feet. The outer opening of the ear canal becomes obstructed by the pliable rubber hood, and as the air pressure in the outer ear canal does not equalise with water pressure, a negative pressure develops in relation to the surrounding pressure and to the middle ear which has been pressurised by auto-inflation. This negative pressure, when sufficiently great, results in rupture of blood vessels, haemorrhages under the skin, blood blisters and rupture of these. To prevent it, it is reasonable to cut a small hole in the hood over the ear to let in water and this does improve underwater hearing and some people claim, an improvement in their ability to clear their ears. The diagnosis is made from the history - ear pain not relieved by inflating the middle ear and bleeding from the ear. Examination shows a tattered ear canal and after cleaning no hearing loss. The early treatment is as for a ruptured ear drum - keep dry, antibiotic powder, and then cleaning in ten days to inspect for residual damage.

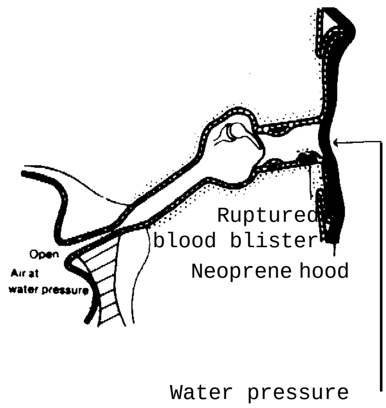

Fig. 1. "Reverse Ear" or outer Ear Squeeze. The Eustachian tbe is open but the ear canal is blocked, producing low pressure in this canal.

Middle Ear Disorders

An abscess in the middle ear is not very common, being caused by infection in the nose as a result of excessive nasal congestion due to the irritation in the nose of sea water, the entry of which is prevented by the face mask. The infection then spreads up the Eustachian tube to the middle ear. It is commoner in social surface swimmers because they allow water into the nose, but it is rare in trained swimmers because of their breathing technique.

The eardrum ruptures due to poor middle ear pressure equalisation on descent, 9 cases (Figure 2),when the rupture is inward or on ascent, 4 cases(Figure 3),due to congestion of the Eustachian tube preventing air escape from the middle ear when the drum ruptures outwards. Prevention is dependent on a healthy nose and the ability to clear the ears. In only two cases did vertigo occur as a result of the cold water gaining entrance to the middle ear.

Aural barotrauma or pressure damage to the ear of a lesser extent involving earache or pain and bleeding into the eardrum especially on the handle of the malleus where it can frequently be seen in scuba divers, illustrate the common occurrence of ear troubles all due to defective function of the Eustachian tube. The Eustachian dysfunction also plays a major part in the inner ear disorders.

Inner Ear Disorders

In the distinction between vertigo and dizziness, both of which are symptoms and not disease entities, vertigo denotes a hallucinatory state of movement, not restricted to the sensation of rotation but also when objects within the visual fields are moving rapidly from side to side or up and down.

Alternobaric vertigo which occurs when ascending is due to the expansion of the air in the middle ear (Figure 3) as the surrounding or ambient pressure decreases. Normally the Eustachian tube opens passively allowing out the excess air on ascent, but when the tube is congested there has to be a greater differential pressure to force open the semi-blocked tube. As this pressure rises the eardrum rarely ruptures, but in those cases whose eardrums remain intact, vertigo can occur.

Because some cases develop a vertical movement of the eyes up and down, such that objects seem to move up and down and it is probable that the footplate of the stapes, which is normally only 2 mm from the utricle of the balancing apparatus, stimulates this directly. It has been shown that stimulation of part of the balancing apparatus causes movement of the eyes up and down and so the diver sees objects moving up and down, the "shimmer effect". In those cases in which a rotary vertigo occurs, this is due to greater stimulation affecting other parts of the of the balancing apparatus causing a horizontal movement of the eyes resulting in a feeling of rotation or spinning. The directional response in these cases of vertigo is important in deciding whether or not the Round Window membrane is ruptured.

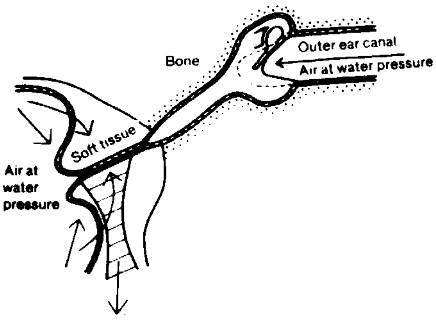

Figure 2: The Eustachian tube is locked closed, because the water pressure is greater than the muscle opening power.

Rupture of the Round Window membrane occurs through forceful and prolonged inflation of the middle ear in an attempt to overcome the relative negative middle ear pressure as a result of descent. If this inflation is delayed, greater pressure is required to overcome the pressure differential of descent.

Forceful prolonged attempts to inflate the middle ear causes high pressure inside the chest cage, preventing the blood draining down the neck from entering the chest. This causes a rise in the jugular vein and other venous pressures in the neck, then inside the head, causing decreased absorption of the cerebro-spinal fluid (CSF) which surrounds the brain and spinal cord. There is a tent-like prolongation of the subarachnoid space containing the CSF into the inferior surface of the temporal bone forming a tube of varying size, the Aqueduct of the cochlea, joining the CSF around the brain to the inner ear which is in the middle of the temporal bone. This tube's inner opening is just adjacent to the thin Round Window membrane which separates the inner ear from the middle ear.

If the CSF pressure rises high enough, there can occur a rupture forming a hole in this 3 mm Round Window membrane with loss of inner ear fluid into the middle ear and this can continue after the CSF pressure drops. Sudden deafness and variable vertigo or loss of balance develops. This membrane can be repaired by surgery and if it is carried out within 2 weeks of the incident, normal hearing results. Now that it is a recognised condition it is being diagnosed more often but many doctors and surgeons still do not bear this condition in mind when dealing with scuba divers.

It can be seen that many of the ear disorders are a direct result of malfunction of the Eustachian tube either due to faulty technique in clearing or inflating the ear, or due to a thickening or congestion of the mucous membrane lining the tube (Table 1). It is incumbent on the diver to have a healthy nose, not to lie flat as in sun bathing, and to refrain from alcoholic beverages prior to diving.

Nasal congestion is a common occurrence and undoubtedly leads to difficulty in opening the Eustachian tube. In 43 of the patients treated for ear disorders arising from scuba diving, the treatment aimed at clearing nasal congestion (Table 2) relieved their disorders.

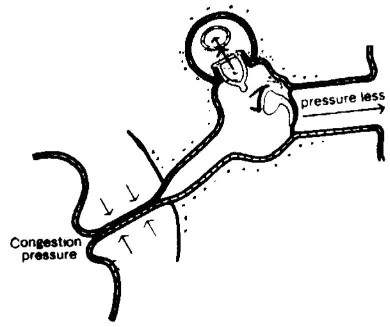

Figure 3. The "Reverse Squeeze". In ascent with the Eustachian tube blocked the expanding air pushes out the eardrum which may rupture but if not, the stapes (stirrup) bone is pushed into the middle ear where it irritates the balancing apparatus.

Table 1
Causes of Tubal Congestion

Primary nasal congestion	Alcohol
Venous congestion of posture	Sniffing

Table 2
Causes of Nasal Congestion

The common cold	Allergic rhinitis
"Sinus" trouble	Sinusitis - with pus
Deviated nasal septum	Adenoids

Valsalva's Manoeuvre

Valsalva in 1704 published the first method of getting air up the Eustachian tube, describing it as part of treatment for the discharging ear. Hold on to the nose, mouth closed and blow hard down the nose and air may go up the Eustachian tube into the middle ear. However, this procedure, if prolonged, can have some adverse effects depending on various individual characteristics.

It is said that fainting can occur, but more importantly this is the method for rupturing the Round Window membrane as already described. That it is not as dangerous as some writers described is borne out by the fact that this method is the standard procedure for thousands of scuba divers throughout the world and very few ever cause damage to their ear.

Eustachian Tube Blockage

This in turn may be due to two factors: (a) Functional, or faulty technique and (b) increased thickness or congestion of the lining of the tube.
Technique covers the fundamental details as to how the Eustachian tube opens. That Valsalva's Manoeuvre works in the majority of divers seems against the rules anyway. From the Figure 2 it is clearly seen that as the pressure is raised it will cause increased closure of the inner end of the Eustachian tube which is mostly soft tissue, projecting up to 2 cm into the throat at the back of the nose where it can be seen with a mirror.

The valvular mechanism displayed here is therefore more complex than this diagram and is illustrated with Figure 4. Valsalva's manoeuvre will occur if the first part of the Eustachian tube is opened and the air pressure will then be able to force open the second part of the tube. Unless a person inadvertently or unknowingly or inknowingly has the inner end partly open, Valsalva's manoeuvre will fail.

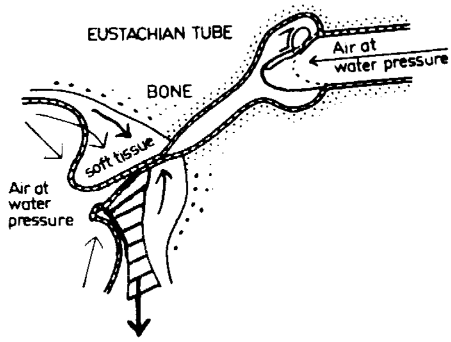

Figure 4 Before Valsalva's manoeuvre will work the inner end of the Eustachian tube must be partially opened.

How then to set this muscle going so as to clear the ears?

Frenzel Manoeuvre

This was studied by the Germans before the Second World War in their dive bomber pilots who had to inflate their ears as they descended rapidly. Herman Frenzel described in 1938 a manoeuvre to inflate the Eustachian tube without having to use the pressure effect of the lungs. With the vocal cords closed, the air in the nasopharynx is suddenly compressed by forcing the base of the tongue and the palate against the posterior wall of the nasopharynx. To perform this, one takes a light inspiration and blocks the glottis suddenly as if about to lift a heavy weight, pinch the nostrils and start to make the sound "K" which rises the base of the tongue and makes it go back against the soft palate which then forces the air into the Eustachian tube. This position is similar to the beginning of a swallow and if performed correctly one feels the pressure on the nose which is pinched, and the sensation of fullness in the ear. The mouth may be open or shut. This manoeuvre is completely independent of respiration and has no effect on the air below the glottis. There is also no effect on the return of blood causing blood pressure changes or any likelihood of Round Window rupture.

The Voluntary Tubal Opening has been described by French divers and consists of trick movements of muscles around the Eustachian tube. By obtaining a controlled contraction of the soft palate and of the upper throat muscles a force capable of overcoming the normal elasticity closing the Eustachian tube is obtained and the tube opens and a patent canal is present for equalisation of the air pressure between the back of the nose and the middle ear.

You have to be able to activate these muscles and reproduce the same feelings in the upper neck or behind the jaws as when the ears clear by other methods. To make it easier to reproduce these sensations one can look in a mirror with light from a window and view the soft palate and back of the tongue, the scuba diver is asked to try and mimic these movements himself while looking in a mirror.

In fact whether or not a person succeeds in holding the Eustachian tube open he does learn to activate the muscles which tend to open up the tube so that an increase in pressure in the nose or throat finishes off the opening and this enables clearing of the ears to be performed with less pressure from blowing. Many divers blow down the blocked nose then wriggle their jaw about until the ears clear and they are then trying out all the various muscles in that region until the correct one is activated. From what has been said if they were to find out what particular movement is the necessary one, then instead of aimlessly wriggling the jaws about they should go direct for that movement which opens the tube. The most important advice is that all divers should inflate their ears before leaving the surface to give them a higher pressure in the middle ear to reverse the effect of the squeeze and giving them time to get stabilised under the water before inflation is required again. The diver should then be continually inflating his ears every 2 or 3 feet of descent by whatever method he has found to suit himself.

As mentioned at the beginning, the human ear is not now, nor will it ever be suited for prolonged immersion under the water. However, if the proper precautions are taken to minimise the effects of the water on the ear and the nose, it should be possible to make any person's nose and ear suitable for scuba diving.

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Whales: not Haemophilia but an adaptation for deep diving

Although cetaceans appear to have prolonged blood-clotting times this does not mean that they are haemophiliacs. In some instances it has been shown that certain blood-clotting factors are absent in the blood of whales, but this does not appear to affect the clotting in normal wounds or tissue damage. However, clotting within the blood vessels may be affected. This decrease in intravascular clotting would be advantageous to deep-diving animals such as whales for two reasons. First, disseminated intravascular coagulation is a major factor in severe cases of decompression sickness in man, so the lack of such coagulation could help prevent decompression sickness in whales. Second, acidic blood in man is hypercoaguable. After a long dive, a cetacean’s blood is more acidic due to increased carbon oxide content. Lack of coagulating factors may help keep the blood more fluid. In conclusion, whales have a highly evolved circulatory system adapted to their deep-diving way of life. They are not, however, haemophiliacs.

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Parrot fever from Clams

A research team from the Smithsonian Institution and Maryland Department of Natural Resources has been looking at marine animal diseases by studying the gut contents of Chesapeake clams and oysters under the high magnification of an electron microscope. They find shellfish infested with a variety of phages and microbes, including some that resemble the chlamydia of psittacosis, the disease of parrots that also infects humans. Thus, they suggest, clams may transmit this disease to humans who eat raw clams.

Sea Technology, June 1977

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Are the days of deadliness of the shy blue-ringed octopus numbered? There is enough venom in the adult’s two tiny sacs to kill 10 people. But now Macquarie University reports that a five-member research team has discovered the chemical make-up of the main lethal toxin in the venom. It is identical to the known compound, tetrodotoxin, present in toad fish, some newts and frogs. Now what is needed is the antidote.

Sydney Morning Herald, 19 Nov 1977