

**INNER EAR BAROTRAUMA -
A REPORT OF 31 CASES**

OI Molvaer
Norwegian Underwater Technology Center (NUTEC)

The occurrence of inner ear barotrauma with or without peri lymphatic fistula, and with transient or permanent injury to the cochlea and/or the vestibular apparatus has been discussed in this journal previously.^{1,2,3} In addition to the 25 cases published by this author,² 31 more cases have been collected since 1980.

Case reports

1. A 32 year old male professional diver with previous normal hearing needed 12 minutes to descend to 30 msw due to bilateral equalization problems that were most pronounced on the right side. At the bottom he felt slightly dizzy and he got the impression that the volume was turned down in the right ear phone. After ten minutes at the bottom he started a slow ascent and stopped both at 6 msw and 3 msw. Immediately after getting onboard the boat he experienced vertigo and was unable to walk straight. As soon as he got his band mask off he realized that the hearing in his right ear was markedly reduced.

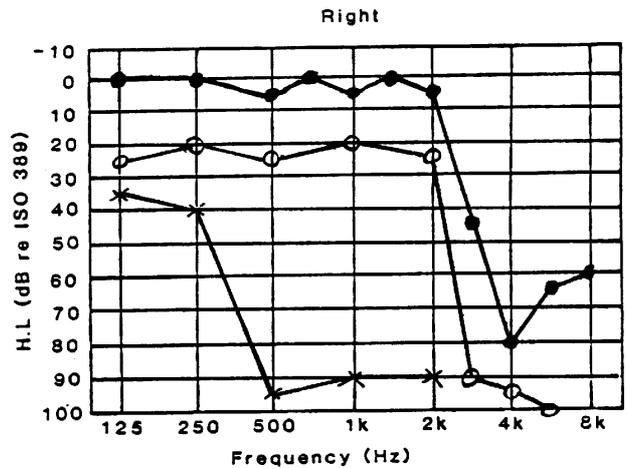
He saw a physician who found slight barotraumatic changes in both tympanic membranes and the diver got decongestant nose drops (oximetazolini chloride) and an oral decongestant (phenylpropanolamini chloride). His hearing was not examined in spite of having a plugged sensation in his right ear. The next morning he did not hear his alarm clock because his left ear lay on the pillow. He saw a diving physician who had an audiogram taken (Figure 1) and administered hyperbaric oxygen (HBO) (USN table 5). During the treatment he felt subjectively better but after the treatment his hearing was still reduced and he had ringing in the right ear. A bithermal caloric vestibular test with electronystagmography (ENG) was normal. He received another HBO session and was put to bed. Later his hearing deteriorated dramatically so he was admitted to hospital for surgery four days after the incident, but no labyrinthine fistula could be found. Nevertheless, his hearing gradually improved, but he has a marked, permanent high tone sensori-neural loss and constant ringing in the ear. He had no alternative education and ran into severe economic trouble. After a successful test dive in a dry chamber he was allowed to return to his profession three months after the incident with some limitations added to his licence.

2. A 19 year old male Navy scuba student experienced pressure equalization difficulties to his middle ears due to a common cold in the 10 msw lock of the submarine escape training tower. While performing a forceful Valsalva manoeuvre he felt pain in his right ear and became dizzy. Afterwards both tympanic membranes showed signs of barotrauma, his audiogram was normal, but the ENG disclosed a right canal paresis during bithermal caloric testing of the vestibular system.

3. A 23 year old male commercial diver had trouble clearing his left ear in an open sea dive and experienced spinning vertigo and ringing in the ear. The ringing continued for six months, and he acquired a permanent,

FIGURE 1

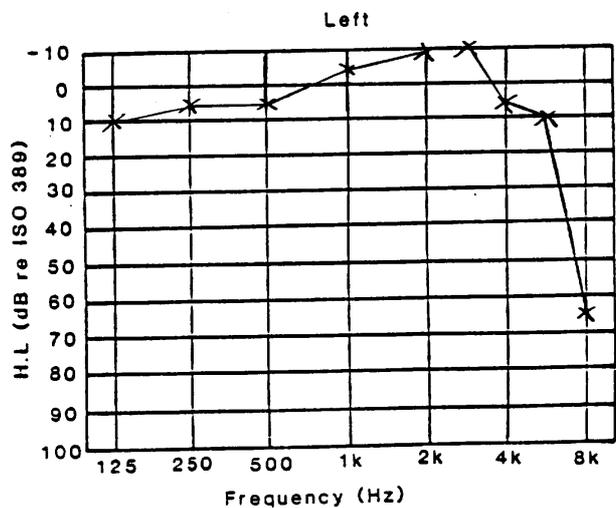
In case one, screening at 20 dB level prior to the dive was normal.



0—0: The day after the incident
X—X: Day three after the incident
•—•: Two and a half months after the incident

FIGURE 2

The hearing in Case Three - seven years after the incident.



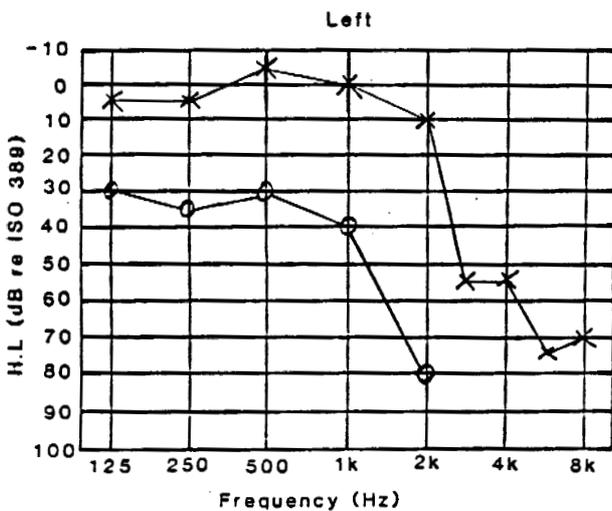
sensori-neural high tone loss (Figure 2).

4. A 26 year old female sport scuba diver had, as always, problems with the pressure equalization to her middle ears during an open dive to 20 msw for 15 minutes. During descent she felt pain in her ears, most on the left side, and performed forceful Valsalva manoeuvres. Back onboard the boat she felt unsteady and had to take a broad stance to keep her balance. Her left ear felt plugged with reduced hearing and she had continuous ringing in the same ear. The next day she saw a physician who referred her to an ENT out-patient clinic where marked barotraumatic changes were found in both ears and an

audiogram demonstrated a pronounced sensori-neural hearing loss for all test frequencies in the left ear. Above 2 kHz no hearing was detectable (Figure 3). The speech reception threshold (SRT) corresponded to the pure tone audiogram. Two days later a bithermal caloric vestibular test with ENG demonstrated a left anal paresis. She abstained from further diving, and when last seen five months later she was not dizzy, had no plugged sensation in the ear, the tinnitus (ringing) was reduced and a pure tone audiogram demonstrated markedly improved hearing.

FIGURE 3

The hearing in case 4.

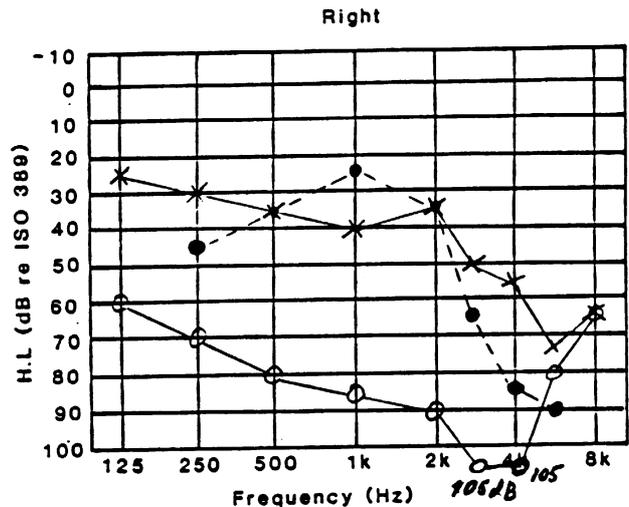


0—0: Two weeks after the dive
X--X: Two months later

5. A 16 year old male sport scuba diver performed an open sea dive in spite of having a common cold. He had equalization trouble and performed forceful Valsalva manoeuvres. He experienced ringing in his right ear, which felt plugged, and he felt dizzy. Since the cochlear symptoms continued he, two weeks later, saw a physician who gave him penicillin and referred him to an ENT out-patient clinic. The tympanic membranes were then normal, but pure tone audiometry revealed a grossly elevated hearing threshold for all tests frequencies in his right ear, and SRT demonstrated a discrimination loss of 60%. Two months later the hearing had improved markedly and there was no longer any discrimination loss. Two and a half years later he was rejected as an applicant for the Navy Academy due to the hearing impairment that by then had again increased. At 8 kHz no hearing could be detected at all (>120dB) (Figure 4).

FIGURE 4

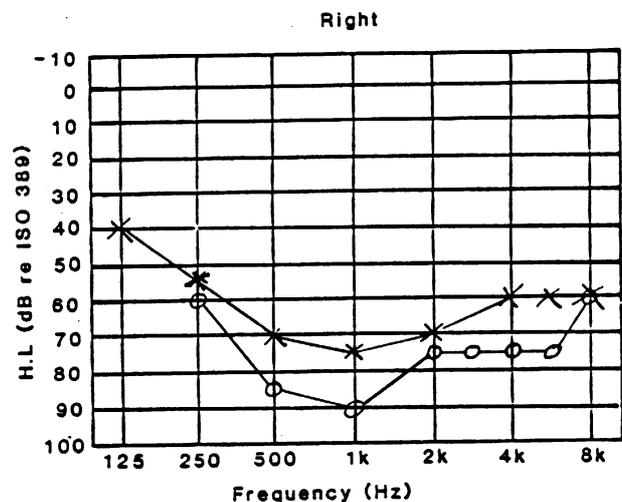
The hearing in case 5.



0—0: Two weeks after the dive
X--X: Two months later
●—●: Two and a half years later

FIGURE 5

The hearing in case 6.



0—0: Three days after the dive
X—X: One month after the dive (12 days postoperatively)

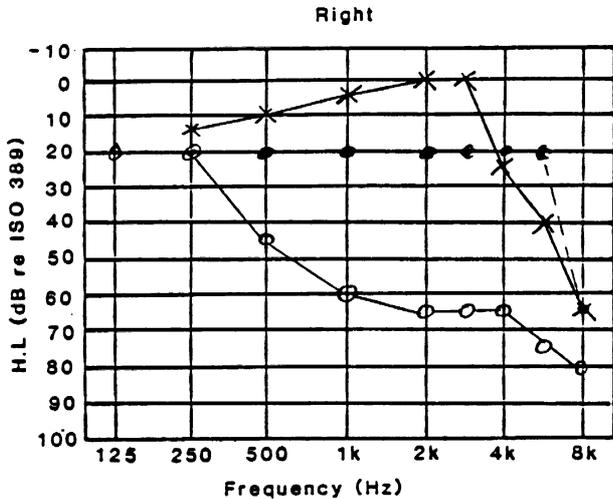
6. A female sport scuba diver performed, on her 29th birthday, an open sea dive to 19 msw. Prior to the dive she had normal hearing but afterwards she experienced pain and ringing in her right ear and was dizzy. Three days later she saw a physician who found signs of marked barotrauma in her right tympanic membrane and also a severe hearing loss in the same ear (Figure 5). She was given decongestant

7. A 26 year old male engineer experienced spinning vertigo after playing underwater rugby (breath-hold diving) for one half hour in a 4 metre deep pool. He was unable to fix his gaze which flickered back and forth, he was nauseated and his gait was unsteady. He was seen by a physician and admitted to the hospital ENT department the next morning, where he received an IV drip (500 cc of normal saline). He was discharged symptom free the next evening. He had not experienced any cochlear symptoms, and a control six weeks later showed normal hearing and vestibular function.

8. A 20 year old male Navy diver made a breath-hold dive to 18.5 metres in a submarine escape training tower. During ascent his right ear would not vent properly and upon surfacing the ear felt plugged, the hearing was reduced and he experienced tinnitus. Prior to the dive an audiometric screening at 20 dB level was normal. Three days after the dive an audiogram showed a pronounced hearing loss in the middle and high frequencies (Figure 6) and he was the next day put to bed in the Navy hospital. He had experienced no vestibular symptoms. His hearing improved gradually, and two and a half months after the dive an audiometric screening at 20 dB level was normal except for a drop to 65 dB at 8 kHz. Tinnitus decreased and he was allowed to start diving again. Besides his Navy diving he dived in a civilian scuba club. After four open sea scuba dives, two of them to 50 msw, his hearing was still stable.

FIGURE 6

The hearing in case 8.



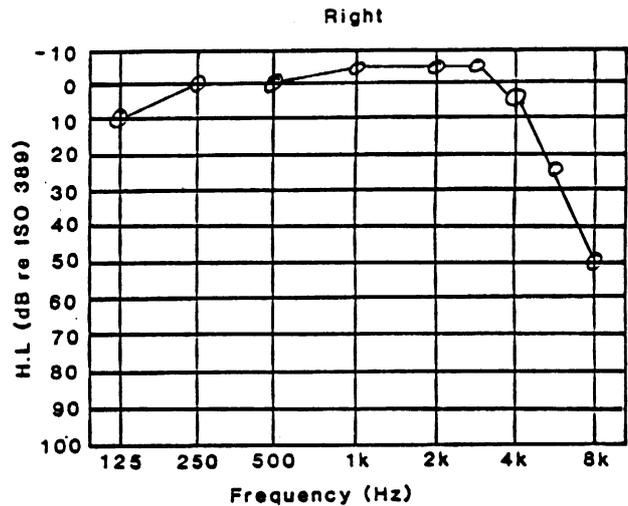
O—O: Three days post dive
 X—X: Two months post dive
 •—•: Screening at 20 dB level two and a half months post dive

9. A 22 year old male Navy diver, who usually had problems with pressure equalization to his ears in the initial phase of descent, became so eager to chase a fish during an open sea scuba dive that he ignored normal equalization procedures. During the fast descent he felt pain in his right ear, and after coming onboard the boat he had ringing in the ear, which periodically felt plugged, and he was dizzy. He did not see a physician until a week after the dive, and since the cochlear symptoms would not

completely clear he was seen by an ENT specialist six months later. Vestibular tests were then normal, but he still had intermittent tinnitus and sometimes a plugged sensation in the ear, and a pure tone audiogram showed a sensorineural high tone loss (Figure 7). Prior to the dive an audiometric screening at 20 dB-level was normal.

FIGURE 7

The hearing in case 9 six months post dive.

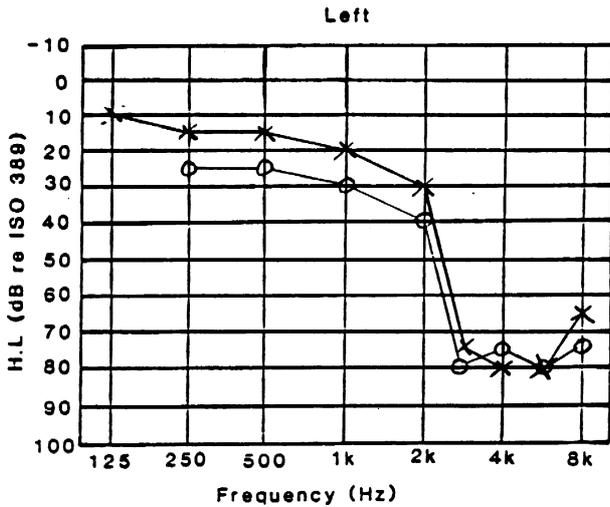


10. A 41 year old male sport scuba diver had his usual trouble with pressure equalization to his left ear when performing three repetitive open sea scuba dives. First he went to 10 metres for a couple of minutes. After five minutes at the surface he descended to 18 metres for 35 minutes. After a couple of minutes at the surface he went to eight metres for 15 minutes. When coming ashore he felt so unsteady he had to hold on to something to prevent falling, and he recognized tinnitus and reduced hearing in his left ear. He did not see a physician until 18 hours later and referral to a diving physician was delayed another day. A severe hearing loss was demonstrated (Figure 8) and he was recompressed according to USN treatment table 6, however without any appreciable effect on his symptoms.

Five days after the dive he was seen in an ENT out-patient clinic where the hearing loss was verified. He was subsequently examined by several physicians who did more extensive audiological and vestibular tests without detecting any new evidence. Three weeks after the dive he had a Stellate ganglion block and received vasodilating medication (Nicotinic acid tablets). This treatment alleviated his balance upset, but had no effect on his cochlear function. His vertigo returned, however, but brain stem evoked response audiometry (ERA) failed to reveal any central lesion. Eventually, two months after the dive, the ear was explored surgically, but no labyrinthine fistula was found. His vertigo fluctuated, but eventually disappeared. His tinnitus also fluctuated, but his hearing loss was permanent and bothered him in conversation with several people simultaneously.

FIGURE 8

The hearing in case 10

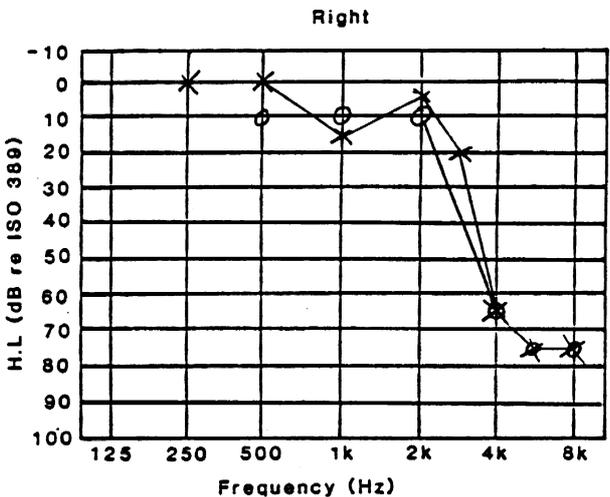


O—O: Two days post dive
X—X: One year post dive

11. A 33 year old man felt dizzy after a dive and had ringing in his right ear. An audiogram revealed a high tone loss which was increased after another dive and became permanent (Figure 9).

FIGURE 9

The hearing in case 11



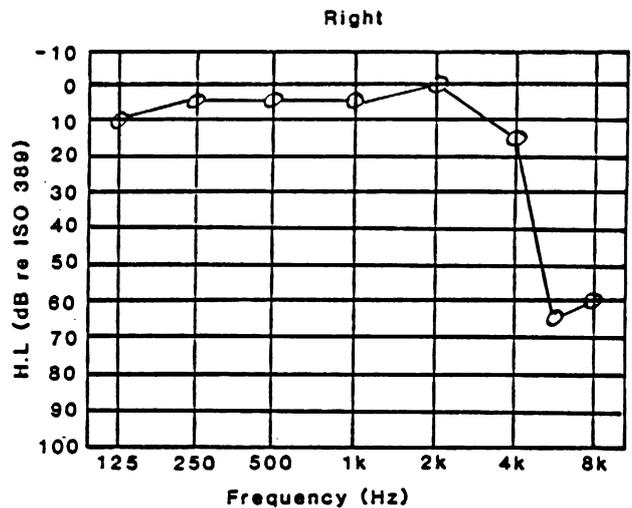
O—O: Second day post dive
X—X: Four years later

12. A 16 year old female sport diver performed an open sea scuba dive to 30 metres. She had problems with the pressure equalization to one of her middle ears due to a slight common cold. She experienced vertigo at the bottom and had problems fixing her gaze. She then ascended slowly, well within the no decompression stop limit, but was unable to climb the ladder to the boat

unaided. She experienced spinning vertigo and ringing in her right ear and was unable to walk straight or to keep her balance, and vomited 14 times. The next day she still had spinning vertigo, but was able to walk unaided. She eventually saw a physician who found one of her tympanic membranes red. In spite of admitting that he had no experience with diving casualties he did not seek advice or refer her to a specialist. Several weeks later she dived again, and again experienced vertigo. After that she stopped diving but still had constant tinnitus. Not until nearly four months after the first mentioned dive was she admitted to an ENT specialist. Her only complaint then was the tinnitus. Caloric vestibular tests were normal, but pure tone audiometry revealed a sensori-neural high tone loss in her right ear (Figure 10).

FIGURE 10

The hearing in case 12 four months post dive



13. A 19 year old male sports diver student performed an open sea scuba dive to 10 m depth. He performed a very forceful Valsalva manoeuvre during descent and experienced severe, spinning vertigo during ascent after a few minutes at depth. He also felt pain in both ears and became nauseated. When coming onshore he was unable to stand and vomited repeatedly. He was recompressed in a chamber without any effect on his symptoms, which actually became worse during decompression. He was then put to bed in an ENT department. Upon admission he was very ill with barotrauma of both middle ears (haematotympanum) and a brisk nystagmus which subsided after bed rest. Audiometry two days after the dive disclosed a sensori-neural high tone in his right ear (Figure 11). He was dismissed from hospital, subjectively well, after three days.

14. A 26 year old male (foreign) Navy diver performed an uneventful chamber dive to 50 msw on air. The day after the hearing in his left ear deteriorated seriously, and three days later he felt unsteady, he was unable to walk straight and bumped into things. He also experienced a high pitched tinnitus in his left ear. He did not see a physician until a week after the dive and was referred to an

ENT specialist who found normal tympanic membranes, but audiometry showed a pronounced sensori-neural hearing loss in his left ear (Figure 12). At 8 kHz the hearing was not measurable with the available equipment (ie. the loss exceeded 110 dB). A caloric vestibular test showed less reactivity on the left side as in a slight canal paresis. He preferred to go back to his homeland for treatment (bed rest, Rheomacrodex IV, medical treatment) and his hearing improved significantly. Decompression sickness could be a differential diagnosis in this case. One can not either completely rule out the possibility of the pure coincidence of a spontaneous hearing loss and the dive.

FIGURE 11

The hearing in case 13 two days post dive.

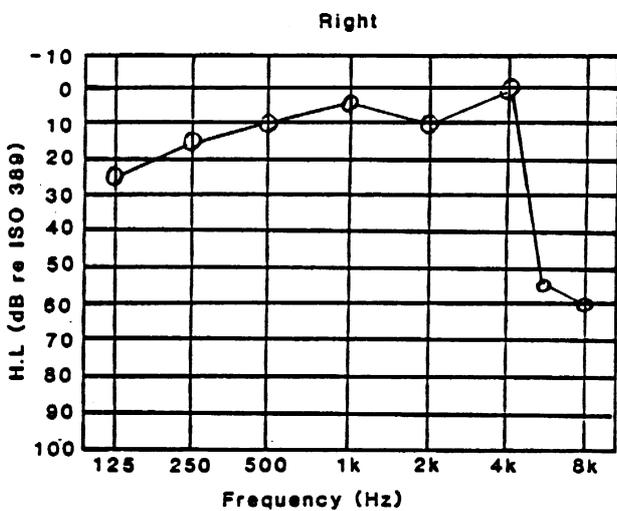
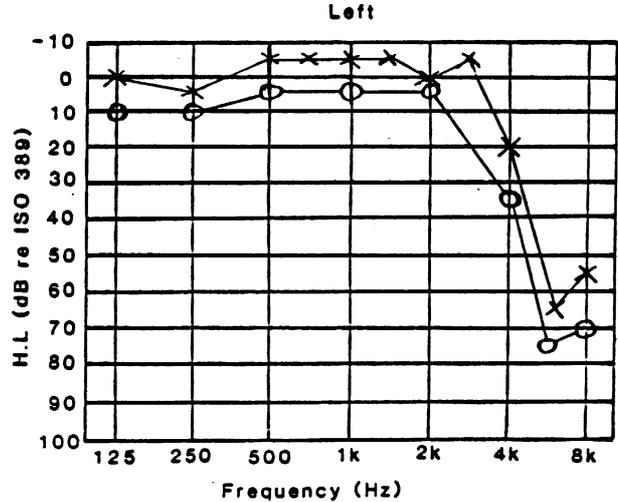


FIGURE 13

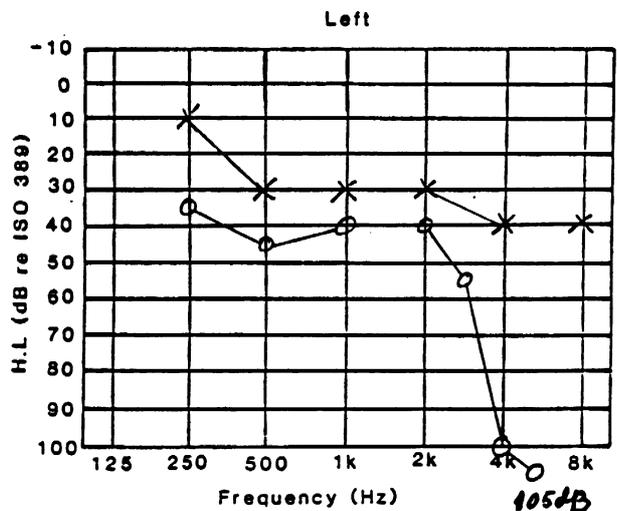
The hearing in case 15



0—0: Two days after the dive
 X—X: One month after the dive

FIGURE 12

The hearing in case 14.



0—0: One week post dive
 X—X: Six weeks post dive

15. A 23 year old male sport diving student made an open sea scuba dive to 8 metres. He had difficulties with the pressure equalization to his ears, especially the left, and performed forceful Valsalva manoeuvres. He felt pain in his left ear during descent and ringing in the ear as soon as he took off his gear after surfacing. He had no vestibular symptoms. Since the tinnitus continued, he saw an ENT specialist two days after the dive. The tympanic membranes were normal, as was a bithermal, caloric vestibular test, but pure tone audiometry revealed a sensori-neural high tone loss in his left ear (Figure 13). Prior to the dive he had, audiometrically verified, normal hearing. One month after the dive the hearing had improved slightly, but the tinnitus was unchanged.

16. A 25 year old male Air Force helicopter pilot performed escape training from a capsized helicopter simulator in the upside down position in a pool at approximately three metres depth. He was under water holding his breath for approximately 30 seconds, and was unable to equalize the pressure to his middle ears. Afterwards he felt pain in his left ear which also felt plugged. He also experienced tinnitus and slight vertigo. Aspirin alleviated the pain, but even after a week the vertigo was bothersome and the tinnitus lasted for two weeks. A couple of weeks after the incident he was seen in an ENT out-patient clinic where his tympanic membranes were found normal. A transient positioning nystagmus to the left on head rotation to the right was recognized, but hot water (44°C) stimulation gave symmetric response. Unfortunately cold water stimulation was not performed nor audiometry. After a few weeks the pilot became symptom free. I think the cause of his cochleo-vestibular symptoms was inner ear barotrauma.

17. A 19 year old male professional diver, who doubled as a sport scuba instructor, performed ten consecutive open sea dives to 10 metres, each of approximately nine minutes duration, in order to familiarize student divers

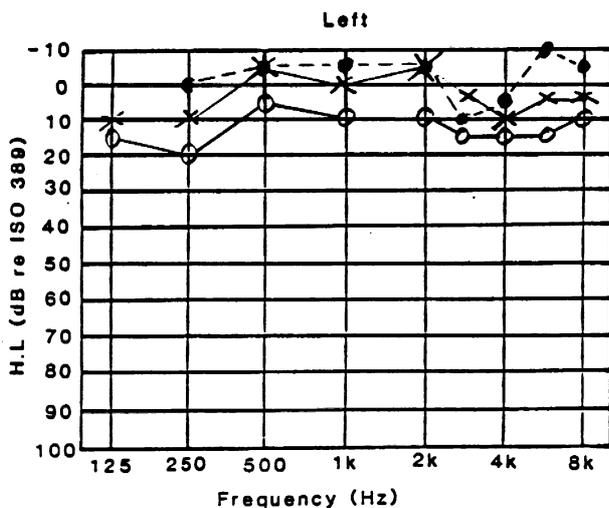
with open sea diving. The tenth ascent was rather fast, and at three metres depth he suddenly experienced a sharp pain in his left ear. He loosened the line to the student who surfaced while he himself returned to the bottom. There the pain was somewhat relieved, but he felt slightly dizzy. After a few minutes he ascended slowly without any change in the symptoms, but he had to sit down as soon as he came ashore due to vertigo.

He was also slightly nauseated. Later he felt a tender swelling behind the left ear and describes crepitation on pressing against it. The skin over the swelling was red. The ear felt plugged and subjectively his hearing was reduced on that side. The next day he saw an ENT specialist who examined him otologically and otoneurologically. There was a slight elevation of the hearing threshold as compared to a recording taken six months previously. The loss was sensori-neural. (Figure 14. Bone conduction has been omitted for clarity). Bithermal caloric vestibular tests revealed a left sided canal paresis. A chest x-ray was negative. He was reported sick for two weeks and put to bed with elevated head. The only medication was aspirin. He was not allowed to dive until after a control two months later. He then felt fit and healthy and the vestibular control test suggested an overcompensation of a peripheral injury on the left side. After a supervised pressure chamber test he was allowed to resume diving.

Three and a half months later he performed two repetitive open sea dives to 12 metres for nine minutes and to approximately 27 metres for 20 minutes (in the "wrong" sequence: shallowest first) in spite of having a common cold. The first dive was unremarkable, but during the second descent he felt pain in his sinuses and his left ear

FIGURE 14

The hearing in case 17



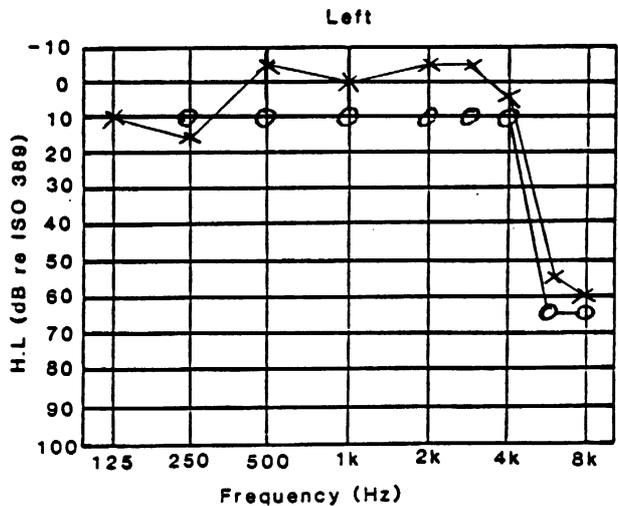
●—●: Pre dive
 ○—○: First day post dive
 X—X: One week post dive

cleared less easily than the right. On the bottom he experienced spinning vertigo, and after surfacing he felt nauseated and vomited once. The next day he vomited four times and saw a physician familiar with diving. He received decongestant nose drops and tablets plus anti-vertiginous tablets and was put to bed. Three days later he still felt slightly dizzy and vestibular testing showed a left canal paresis, slightly worse than after the first injury. He had no cochlear symptoms and an audiogram was close to the pre-dive recording. He was prohibited from diving for six weeks and advised not to dive during respiratory tract infections.

18. A 20 year old male Navy scuba diver experienced barotrauma of his left ear while wearing a full face mask in an open sea dive. In connection with the injury he felt a slight ringing in the ear. Prior to the dive his pure tone audiogram was normal, but a routine control five months later revealed a sensori-neural high tone loss in the affected ear, where he still experienced a high pitched tinnitus while in silent surroundings (Figure 15). Three years later he was accepted as a student at the Norwegian Government Diver Training School in order to get into commercial deep diving, in spite of the fact that his reported high tone hearing loss was permanent. The hearing in his right ear was normal, though.

FIGURE 15

The hearing in case 18.



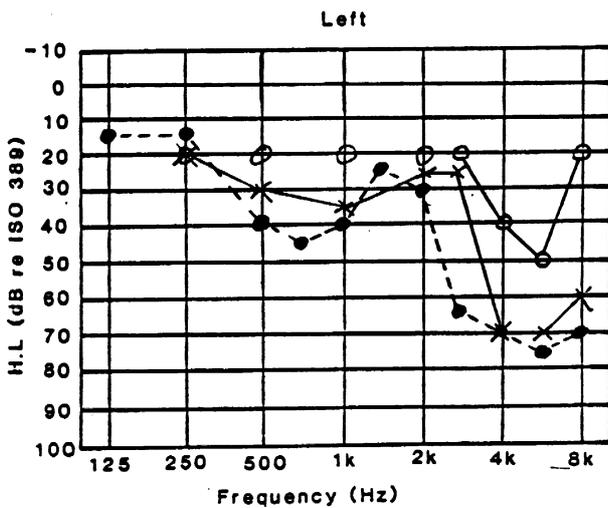
○—○: Five months after the dive
 X—X: Three years later

19. A 22 year old man attending a course in sport scuba diving as a leisure time activity during his military service performed an open sea dive to 15 metres for eight minutes. As usual he had equalization problems and performed forceful Valsalva manoeuvres. He did not experience anything peculiar until he came into the silence of his bedroom nine hours after the dive when he recognized a high pitched ringing in his left ear. The tinnitus fluctuated for some days, but eventually became constant. Nine days after the dive he finished his compulsory military service.

A medical examination in that connection revealed an elevation of the hearing threshold in his left ear as compared to the audiogram taken when he entered the military services, but even then the 20 dB level screening had revealed a, probably noise induced, high tone notch in the audiogram from his left ear. He was referred to an ENT specialist who confirmed the hearing loss as sensori-neural, but except for that found normal ears, including vestibular function as tested with bithermal stimulation and ENG. At that time bed rest was tried, but seven months later the hearing had deteriorated significantly at 3 kHz (Figure 16).

FIGURE 16

The hearing in case 19.



0—0: Pre dive screening at 20 dB level
 X—X: Nine days post dive
 I—I: Seven months later

20. A 37 year old male engineer using diving in his work for underwater inspection and non-destructive testing (NDT) performed an open sea dive to 15 metres depth in spite of having a common cold. He had equalization problems and thus had to perform equalization manoeuvres forcefully and more frequently than usual. After the dive his left ear felt plugged and the hearing in that ear was much reduced. He saw a local physician who reassured him, and when he saw an ENT specialist six months later a sensori-neural hearing loss in the left ear was confirmed (Figure 17).

21. A 29 year old male Navy physician performed a 90 metre dry chamber dive on air. He had difficulties with the pressure equalization to his ears and performed Valsalva manoeuvres repeatedly. Prior to the dive he had no cochlear symptoms and an audiometric screening at 15 dB level was normal. After the dive his left ear felt plugged with reduced hearing and tinnitus, and an audiogram demonstrated a most unusual pattern with a predominantly low tone sensori-neural loss, indicating a lesion in the apical part of the cochlea (Figure 18). He still has tinnitus and hearing loss in that ear 16 years after the incident.

FIGURE 17

The hearing in case 20 six months post dive.

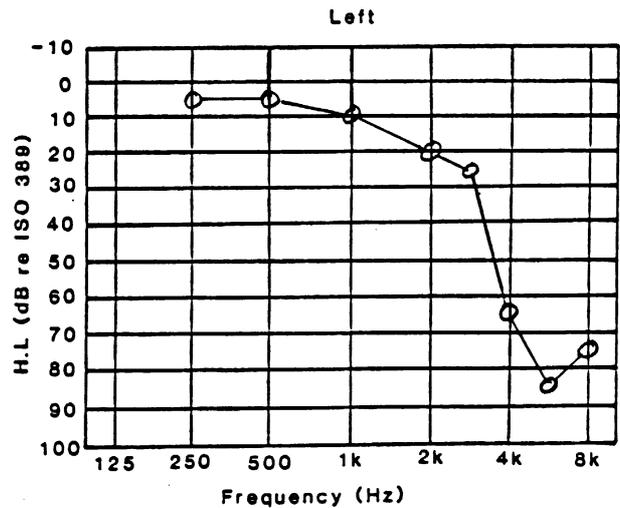
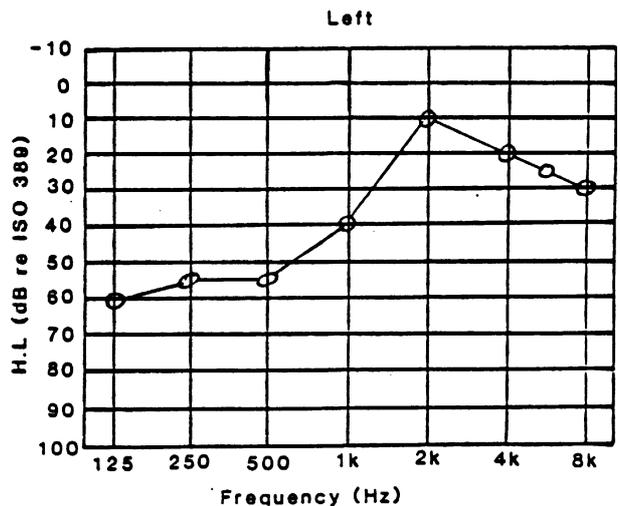


FIGURE 18

The hearing in case 21 immediately after the dive. Pre dive screening at 15 dB level was normal.

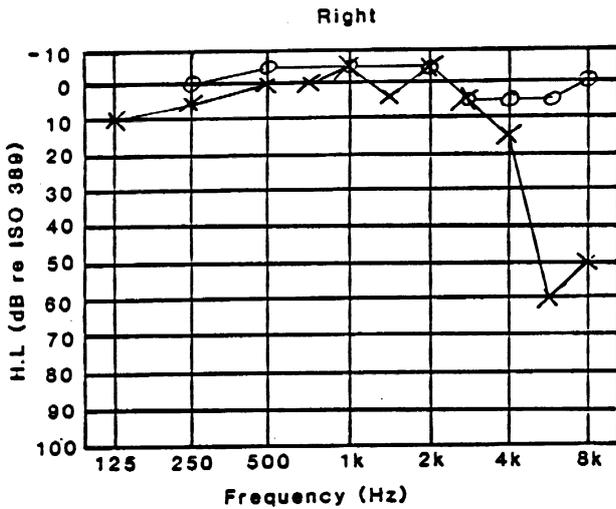


22. A 28 year old male commercial diver lost consciousness at 45 metres depth in the sea wearing a band mask and breathing nitrox. The reason for the loss of consciousness was probably oxygen poisoning. He was taken to the surface and recompressed in a chamber where he woke up at 50 metres depth without any cochlear symptoms. During the decompression his right ear would not vent properly and became painful. He also experienced tinnitus in that ear. Prior to the dive an audiogram demonstrated normal hearing, while a control six months after the dive disclosed a sensori-neural high tone loss (Figure 19). He then still had tinnitus.

During a dive several years before the described incident he had pressure equalization problems to his ears and experienced tinnitus in both ears for a month after the dive. That episode resulted in a permanent, sensori-neural high tone loss in his left ear (Figure 20).

FIGURE 19

The hearing in the right ear of case 22

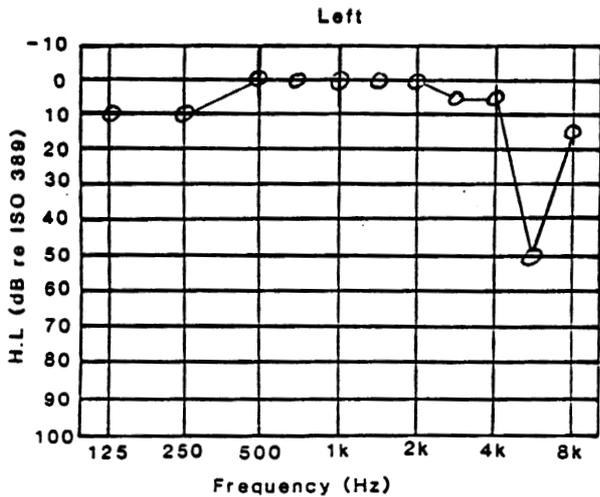


0—0: Prior to the incident
 X—X: Six months after the incident

23. A 24 year old male scuba diving student performed a breath-hold dive to 7 metres in the sea. He had pressure equalization trouble, and since he was wearing too little lead he had to use his arms to swim down and was thus unable to perform equalization manoeuvres. A painful

FIGURE 20

The hearing in the left ear of case 22 several years after a different dive.



pressure differential built up in his ears. Three hours after the dive he became dizzy. The next morning he felt fine and did a scuba dive to 12 metres. He descended slowly and managed to equalize the pressure to his ears. A couple of hours after the dive he again felt dizzy.

The next morning he again was fine and performed another scuba dive to 12 metres. He had some equalization trouble

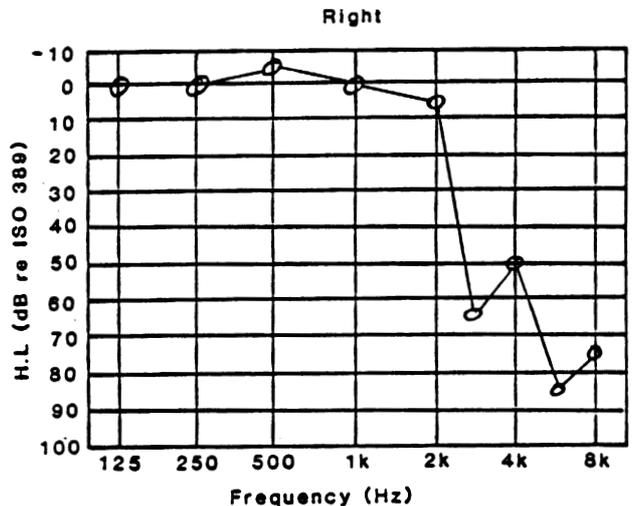
and experienced vertigo immediately after the dive of the same nautical nature as on the two previous days, but stronger. The symptoms fluctuated for the next couple of days, so he saw a physician who referred him to an ENT specialist on the third day after the last dive. Throughout he had had no cochlear symptoms. Barotraumatic changes were observed in both tympanic membranes, but a bithermal caloric test and ENG did not at that time detect any vestibular injury. Nevertheless the fluctuating symptoms continued and interfered significantly with his university studies. This was still the case two months after the dive, which is the last available information on this case. Eleven years before he had experienced vertigo and intolerance to high sound levels after head trauma. It is difficult in this case to pinpoint a possible lesion to the inner ear, but there seemed to be a definite connection between the diving and the symptoms, and the barotraumatic changes in the tympanic membranes were unmistakable and thus suggestive of inner ear injury as the cause of his symptoms.

24. A 36 year old male sport scuba diver performed approximately seven dives to a maximum of 15 metres in the sea within an hour. Before the dive he had no cochlear symptoms, but the morning after he woke up with a high pitched tinnitus in his right ear. Since that did not clear, he saw a physician a couple of days later, and the next day recompression to 50 metres in a chamber was tried without effect on his symptoms. He was seen regularly by an ENT specialist for months, but even eight years after the incident he still had constant tinnitus and sensori-neural high tone loss (Figure 21). In this case the relation to diving could be just coincidence since spontaneous hearing loss of this kind occurs now and then. A realistic differential diagnosis in this case is also decompression sickness.

25. A 27 year old male Navy diver performed approximately 20 consecutive breath-hold dives to about seven metres as an instructor in a submarine escape training tank. He did not care much about pressure equalization to his ears, and after a while he experienced a plugged

FIGURE 21

The hearing in case 24 eight years after the incident.



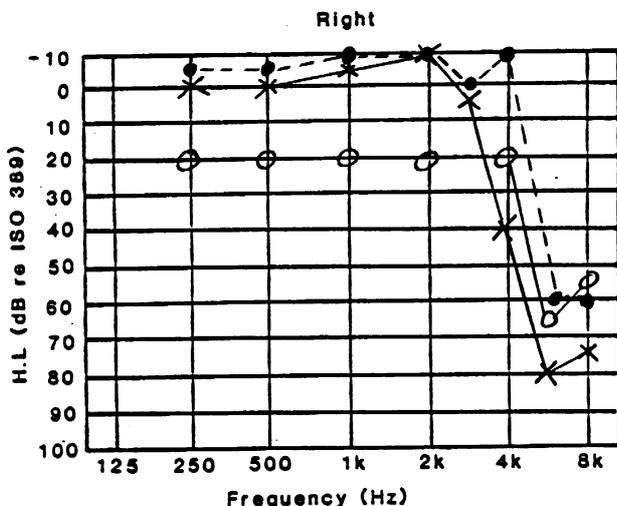
sensation, reduced hearing and tinnitus in his right ear, plus vertigo. Nevertheless he continued until the class was through, but afterwards he was unable to walk straight. One year previously he had experienced similar phenomena from his left ear after he had swum 50 metres underwater, but in that case all symptoms cleared gradually. He now expected the same course and thus postponed his visit to a physician until the next day.

He was then immediately referred to an ENT specialist who found spontaneous nystagmus of the second degree to the left, indicating the right sided canal paresis. The patient complained of pulsation and constant tinnitus in the ear, and an audiogram revealed an up to 20 dB deterioration of his high tone hearing on the right side where the hearing already was substantially reduced in the high tone range, probably due to gun-fire (Figure 22). No sign of middle ear barotrauma was found. He was put to bed and gradually improved. Five days later he had no vertigo, nor nystagmus, and the hearing had improved both subjectively and by audiometric evaluation, at 4 kHz as much as 50 dB. The high tone loss was back at pre-dive level, but caloric vestibular tests and ENG now indicated a stronger cupulo-ocular caloric response on the right than on the left side. Six months after the incident the diver was symptom free, the hearing had stabilized at pre-dive level, and bithermal caloric vestibular tests with ENG showed symmetrical and normal responses. He was then allowed to resume diving provided that he did not dive during common colds and that he was very conscientious with the pressure equalization to his ears. He was also advised not to take the surface position during submarine escape training runs.

Three weeks later he violated all the above mentioned precautions and performed 45 breathhold dives from the surface to approximately seven metres, in spite of having a common cold. Afterwards he experienced severe vertigo and nausea. He was pale and could not walk straight. He

FIGURE 22

The hearing in case 25



0—0: Pre-dive screening at 20 dB level
 X—X: One day post dive
 •—•: Six days post dive

felt a forceful pulsation in his right ear and slight, periodic tinnitus, but no subjective hearing impairment. When seen by an ENT specialist the next day his only complaint was the pulsation in his right ear. There was no significant change in hearing and no nystagmus. It was speculated that he might have a weak spot in one of the labyrinthine windows where a fistula would open when the pressure differential reached a certain level. He was reported sick for a week and taken off diving for a couple of months. A bithermal caloric vestibular test with ENG was then symmetrical and normal.

26. A 23 year old male sport scuba diver with approximately five years diving experience performed an open sea dive to 25 metres for 25 minutes. As usual he had pressure equalization trouble to his ears, mostly in the right, and performed Valsalva manoeuvres. During ascent he experienced pain in the back of his neck and head. Ten to 15 minutes after coming onboard the boat he experienced spinning vertigo and had to hold on to something to keep his balance even while sitting. The symptoms increased, he was unable to fix his gaze and vomited all the time. When he came ashore 20 minutes later he saw a local physician in general practice who referred him to the neurology department in the local hospital where electroencephalography (EEG), and skull X-ray were negative.

He was the next day transported by helicopter while breathing oxygen to the nearest Navy base where he was recompressed after a prolonged US Navy Table 6. Subjectively the treatment had no effect. Nevertheless he recovered gradually, but was unable to walk straight for one week after the dive. He had no cochlear symptoms. When seen by an ENT specialist two months later he was symptom free, but would still experience some unsteadiness in certain situations, such as when heading the ball during football games. He had not been diving since the incident. Otological and otoneurological examination was unremarkable, except for a sensori-neural high tone loss in his left ear that was present prior to the dive, which was probably caused by gunfire. He recalled having had tinnitus for a couple of days after hunting some time before. Bithermal caloric vestibular tests with ENG were normal.

27. A 45 year old male marine biologist, previously a Navy diver, now a sport scuba diver, performed approximately ten scuba dives to 5 msw for a total duration of approximately half an hour. He had to perform Valsalva manoeuvres to equalize. Immediately on coming onshore he experienced vertigo and unsteadiness and he was slightly nauseated. He also had a constant tinnitus in his right ear. When seen by an ENT specialist one and a half hours later he walked unsteadily, would grasp onto objects to secure his balance and tended to keep his neck in a fixed position. In spite of this overt symptomatology nothing objectively could be found on otological and otoneurological examination. Even a bithermal caloric vestibular test with ENG was judged to be within normal limits (even though a slight right-sided canal paresis could not be completely ruled out). The only difference in the audiogram compared to one done a year previously was a marginal 10 dB drop at 8 kHz (from ten to twenty dB). He was put to bed and the tinnitus disappeared the same evening. He kept his bed

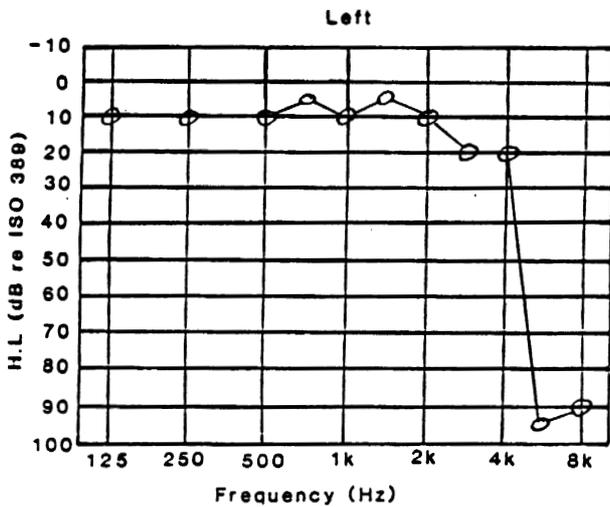
for a few days but had fluctuating tinnitus for periods and fluctuating nausea for approximately three weeks. He was symptom free when seen six weeks after the incident. A caloric test was then completely normal. He then recalled that he had been dizzy after a similar dive seven years previously and also nauseated after that type of diving four years earlier. Maybe a case with such sparse objective signs should not be classified as inner ear barotrauma, but I believe that more sensitive test methods might have proved the diagnosis.

28. A 19 year old man practised underwater rugby (breath-hold diving) in a four metre deep pool. After the game his left ear felt plugged and he had tinnitus for six months. When seen by a physician some days after the incident blood and fluid was found in the left middle ear. His audiogram was normal when reporting for military service prior to the incident, but when entering the military services after the dive a high tone loss was found in his left ear. The sensori-neural loss was confirmed four years later (Figure 23).

29. A 25 year old male scuba diver with six year's experience had for a couple of months experienced severe spinning vertigo for five to ten minutes after diving. Once it caused him to swim in a circle to the left when trying to swim ashore. Eventually, after a dive to four metres depth

FIGURE 23

The hearing in case 29 four years after the dive.



he was unable to stand up when coming ashore. He fell to the ground, was unable to fix his gaze, was very nauseated and all but vomited. He had no cochlear symptoms. The symptoms subsided in a couple of hours, but when seen by an ENT specialist two months later a bithermal caloric vestibular test with ENG revealed a centrally compensated left-sided canal injury. Except for that, an otological examination was normal, including audiometry. At that time he was symptom free. Inner ear barotrauma, possibly with a transient peri lymphatic fistula, could explain the described symptoms.

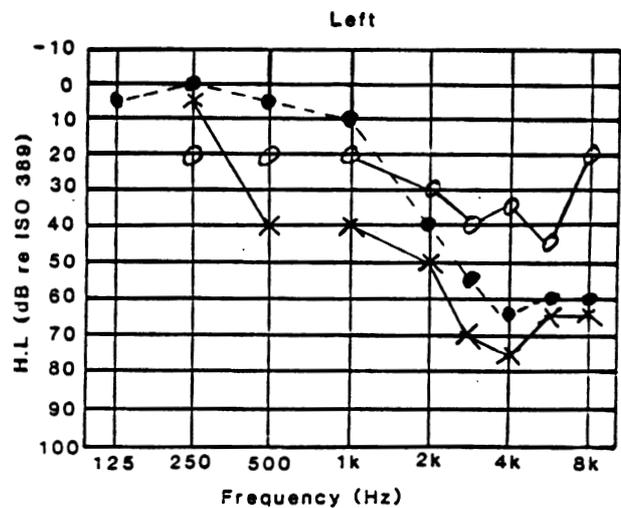
30. A 29 year old male sport scuba diver with nine years experience participated in breathhold underwater rugby and descended repeatedly to five metres depth without caring about pressure equalization to his ears. In the middle of the game his left ear suddenly felt plugged

and he experienced a continuous, high pitched tinnitus. There was no vertigo. He had experienced middle ear barotrauma on the same side twice before and thought this was the same thing. But his hearing deteriorated substantially in the course of the following two days. Then the condition started to improve and he did not see a physician until a week after the incident and was immediately referred to an ENT specialist who found his hearing significantly reduced compared to pre-dive audiograms (Figure 24). He was admitted in hospital and put to bed in the ENT department where his hearing continued to improve, so he was released after a week. Three weeks after the incident the improvement seemed to have halted, and more than four months after the incident the hearing threshold was still significantly higher than prior to the incident. Even a year later he had constant tinnitus and some problems with holding a conversation in background noise. Nevertheless he wanted to take up diving again. His marked pre-dive hearing loss was probably caused by noise exposure in mechanical industry where he had worked without using ear protectors.

31. A 30 year old male sport scuba diver performed an open sea dive to 26 metres for 26 minutes. The dive was unremarkable and he had no pressure equalization trouble to his ears. Four hours after the dive his right ear felt plugged, and the next day an ENT specialist found a

FIGURE 24

The hearing in case 30.



0—0: Pre incident screening at 20 dB level
 X—X: One week post dive
 •—•: Four months after the dive

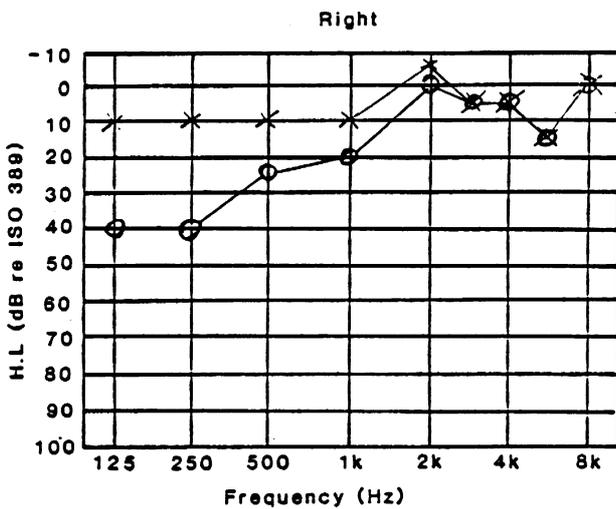
sensori-neural low tone loss in that ear (Figure 25). The day thereafter he also experienced tinnitus in his right ear and the next day (3rd day after the dive) he received hyperbaric oxygen therapy (HBO) (USN Table 6) which had no subjective effect, while the audiogram showed some improvement. The next day he got more HBO (USN Table 5) which traded his tinnitus for slight vertigo, but again the audiogram indicated improved hearing. The day after his ear felt plugged again after a lot of shouting as a coach for a volleyball team, and the tinnitus was back. Two days later the hearing had normalized subjectively

and audiometrically and he had no more tinnitus or vertigo.

This man was diving a lot so one may argue that the described symptoms occurred in time relation to a dive only by chance and that there was no causative relation, especially since he had no equalization trouble. Thus it could have been an early manifestation of Meniere's

FIGURE 25

The hearing in case 31.



0—0: First day post dive
X—X: One week post dive

disease (hydrops labyrinthi), completely unrelated to the dive, or precipitated by it. Decompression sickness (DCS) is unlikely, but cannot completely be ruled out. On the other hand, diving can cause considerable pressure differentials in the ears before a diver cares about equalizing, especially if he is distracted or busy with other tasks. So even if it may be speculative I think that also this case can be classified as inner ear barotrauma.

DISCUSSION

Even though information about dive depth is missing in five of the cases, we can conclude that this injury most often occurs at shallow depth, not surprisingly since that is where most of the diving is taking place, and also where the relative pressure/volume differences are greatest. As might be expected, the majority of the cases (45.2%) were sport scuba divers, who also perform the majority of the diving in shallow waters. Commercial divers comprised 16.1% of the total and Navy scuba divers 6.5%. The rest were divided between breath-hold and chamber diving, and in one case the information was missing. In 61% of the cases the incident happened during air scuba diving, but data were missing in two cases. The sex difference, 90.3% male and 9.7% female cases, probably more reflects the composition of the diving community rather than anything

about sex difference in susceptibility.

The delay before the diver sought medical advice varied from hours to "indefinitely", which means that the diver did not seek advice but was found by chance during routine examinations months after the incident. More than 70% reported problems with pressure equalization to the ears and close to 20% admitted to have dived in spite of a common cold when the incident occurred. Close to 26% reported to have performed forceful Valsalva manoeuvres (but data were missing in approximately 13%).

No consistent way of therapy can be traced in this material. More than 35% received no therapy at all, and data are missing in three cases. In the rest, several types of treatment were tried; bed rest, medication, IV fluid, HBO, Stellate ganglion block and ear surgery.

The lay off time before diving again varies considerably and information is missing in several cases, but in only four cases is positive information available that they stopped diving permanently. Approximately 65% experienced permanent cochlear injury, leading in one case to rejection by the Naval Academy. In a commercial diver the incident caused severe economic problems. Ten of the cases were only cochlear (two right, seven left and one bilateral), five only vestibular (one on each side and three probably bilateral) and 16 both cochlear and vestibular (ten right, six left). Thus 13 were only right-sided 14 only left-sided and four bilateral. Only three of the ears were explored surgically (two right, one left) and in only one of them was a fistula found, in the right oval window.

SUMMARY

Barotrauma of the inner ear in 31 cases (35 ears) is reported. Inner ear barotrauma is no rarity, but is under-reported. It most often occurs in shallow water. Permanent cochlear injury is common, which can seriously affect a person's choice of profession and cause social and economic problems. Of those who resumed diving some had recurrences while others were stable throughout the observation period.

REFERENCES

1. Mannerheim JE. A case of inner ear barotrauma. *SPUMS J.* 1979; 9(4): 11.
2. Molvaer OI. Acute hearing loss following diving into and in water. *SPUMS J.* 1980; 10(2): 3-12.
3. Donoghue P and Knight J. The causation of perilymph fistulae in divers. *SPUMS J.* 1980; 10(2): 13-14.