

a retired commercial diver, moved to the area and opened up a diving school for the Miskito Indians, funded by the Moravian Church, and the association of lobster dive boats in Guanaja. A non-profit organization has been started by Bob Izdepski called SOS (Sub Ocean Safety) which is accepting donations of both material and money to continue working towards helping with the diving problem in La Mosquitia.

So far SOS has filmed a video concerning in-water recompression to be utilised in the diving schools, and transported the 48 inch (1.2 m) chamber to a coastal clinic in La Mosquitia. A compressor has been donated by Oceaneering, and DAN (Divers Alert Network) has donated \$2,000 US to SOS. These funds were used to rebuild a Lister engine to drive the compressor. The physician at the clinic will be instructed in diving and hyperbaric medicine by the three diving medicine specialists with SOS, Dr David Youngblood, Dr Keith VanMeter and myself.

Members of SOS have been researching the statistics of the lobster industry in Honduras. There were a total of 262 lobster boats in the Bay Islands, 70 of which dive for lobster, and the rest trap lobster. The average lobster diver makes about \$US9 a day, although many do much better. The trips last about two weeks, and they can make as much as \$US750 on a good trip.

In the last two years, the skippers have been teaching the divers about the proper size of lobsters and this year less than 5% of the take are undersized. Their project for the next season is to make sure females with eggs are not taken.

The government has imposed a four month ban on lobster fishing the last two years, and the net yield of lobster last year has been the highest in the past decade.

If a diver is paralysed, the lobster boat owner must pay him, for a year, the amount of money the diver made the day before he was injured. If the diver has not recovered, the boat owner must pay a "death settlement", which is equivalent to three years' wages.

For this reason, as well as not wanting to be responsible for another human being's death, the organization of lobster dive boat owners has written a list of standards, which they have asked the Ministry of Fishing to make as law. These standards include having clean filters on the boat's compressors; separation of the compressor's exhaust from the air intake; tank inspections every third trip; oxygen on each boat with a face mask to deliver the oxygen to an injured diver; divers to have their own depth gauge and pressure gauge (which they do not use now); every boat utilising at least four trained divers (600 of the estimated 5000 divers will have been trained by July 1996); a 3 mm (1/8 inch) or equivalent short type of wet suit.

They would also like to have every skipper take a week's "crash" course on diving, so the skippers have some idea of what the divers are doing. The skippers and the instructors at the dive school are urging the divers to stop using rum and marijuana before their dives. Tobacco and rum are used in La Mosquitia from childhood and it is taking a large effort to decrease their use of these.

Plans are being formulated for several studies on the long term effects of untreated decompression sickness from both a physical and a neuropsychological standpoint using the large population of divers from La Mosquitia as well as several other Caribbean islands where the same problems exist. A second study is planned using the many injured divers presenting on each boat. We are contemplating using on-the-site treatment of injured divers, alternating in-water oxygen recompression therapy using the Australian tables, versus emergency treatment with oxygen in a portable 2 ATA chamber which will also be on the boat. After initial emergency treatment, the divers will receive standard recompression therapy at the main chamber in the nearest clinic. Statistics will be kept to see which is the most effective treatment, on site surface oxygen, in-water oxygen recompression, or emergency 2 ATA chamber oxygen.

Similar problems are occurring in many other areas of the Caribbean, as well as many other third world areas where the lure of money outweighs the significant risk from DCI in untrained divers and uncaring boat operators. Hopefully the work of Sub Ocean Safety and other interested groups can continue to make a positive impact on these areas in the future.

*Tom Millington, MD is Medical Director, St John's Pleasant Valley Diving Medicine and Hyperbaric Oxygen Department, Camarillo, California, USA. His address is Lombard Medical Group Inc., 2230 Lynn Road, Thousand Oaks, California 91360 USA.*

## **ROUND WINDOW MEMBRANE RUPTURE IN SCUBA DIVERS**

Noel Roydhouse

### **Summary**

Since 1971 the author has examined 19 cases of round window membrane (RWM) rupture and one case of oval window rupture caused by scuba diving. They consisted of 8 cases operated on and in which flow of perilymph was seen (Group A), 2 cases operated on and an intact RWM and oval window annular ligament (OWAL) were seen

(Group B), 6 cases in whom the diagnosis was solely on clinical grounds with no operation (Group C) and a group of 4 cases treated by other surgeons but examined for a follow up or second opinion (Group D). The average follow-up period for the 4 groups are 6.9, 10.5, 11.6 and 5.5 years respectively. Three patients have been followed for over 20 years. The symptoms for each group are given. Group C symptoms were worse than the other groups which offers support for the diagnosis. The follow-up allows comparison of initial with final audiograms and the post-treatment years of further diving. The operated cases appear to have a better prognosis, however the return to diving in all groups did not result in a relapse. Two case histories and a brief comment on the causation is given.

**Key words**

Barotrauma, ENT, injury, recreational diving, treatment.

**Introduction**

The popularity of scuba diving continues to increase and accordingly there is an increasing number of scuba diving accidents, injuries or adverse incidents. The more common and alarming are those cases with labyrinthine symptoms, with or without deafness. Vestibular labyrinthine symptoms include loss of balance, vertigo and dizziness. Vertigo is defined as a spinning or rotary sensation but also includes oscillopsia, a vertical or horizontal hallucinatory movement. Labyrinthine dizziness is more than just non-specific dizziness. It is more severe, associated with one or more of loss of balance, disorientation, nausea or vomiting. In a series of 1,110 divers who consulted me for their scuba diving problems, 203 fitted in to this category but did include 1 case of non-diving round window membrane (RWM) rupture (Table 1).

A subgroup of these are the 19 divers with a rupture of the RWM and one of OWAL. Goodhill<sup>1</sup> described 13 cases of round window fistula including 1 scuba diver, whilst Edmonds et al.<sup>2</sup> reported on 6 round window fistulas in naval divers. Rolland and Walsh<sup>3</sup> described 1,200 cases of repair to the round window and 20 cases of fistula of the oval window from 1989 to 1993. They included an unstated number of cases where scuba diving was a factor. Their overall failure rate was 24% but since 1990 it has been 3.1%

**Symptomatology**

The 20 cases were divided into 4 groups depending on presentation and treatment. Group A (Cases 1-8) were those seen by the author and diagnosis was confirmed at operation by viewing perilymph outflow. Case 4 had no deafness until 24 hours after the dive which increased the next day. Case 7 had no RWM at all with vertigo

**TABLE 1**

**203 CASES WITH VESTIBULAR LABYRINTHINE SYMPTOMS**

Cases with deafness	72
Cases without deafness	112
Ruptured eardrums	19
<b>Total</b>	<b>203</b>
<b>Subgroup</b>	
Ruptured window membrane	20

continuing for 3 days and a steady level 65 db loss. He was operated on after 2 days of medical treatment. Group B (Cases 9-10) were the 2 patients in whom no outflow was seen at operation. In case 9 the RWM was seen to bulge within 5 seconds of compressing the neck veins. It also had a heterogenous appearance compared with a normal membrane, suggestive of a healed rupture.

Group C (Cases 11-16) were those diagnosed as RWM rupture but for one reason or another were not operated on. It is known that some cases resolve spontaneously or heal without operation. All patients suspected of having a fistula were given medical treatment for at least 4 days before deciding on an operation. This period was shortened if there is a positive fistula sign or increasing severity of the signs and symptoms.

Table 2 (page 150) shows that Group C had generally worse symptoms than groups A and B, apart from Case 12 who denied any form of dizziness or vertigo. He had a deafness averaging 70 db across the whole frequency range except for a loss of 25 db at 500 Hz. It had been worsening progressively for 3 days. He responded immediately to bed rest, prednisone, oxpentifylline and chlorothiazide, the routine form of treatment. Oxygen therapy was also given to those admitted to hospital.

Group D were the 4 cases operated on by other surgeons but seen for a second opinion. Table 3 (page 140) shows the end results of groups A to D.

**Discussion**

Cases that were personally treated were counselled on the effect of further diving. Of the first 16 cases (Groups A, B and C) 12 had a history of difficulty in clearing their ears on descent and 2 of these were recovering from a cold and ten made a fast descent or ascent or both. Safe diving practices were stressed and only 4 gave up immediately and 2 were lost to follow-up. The reasons for giving up were: frightened off diving (2) and gave up voluntarily (2). No

**TABLE 2**  
**COMPARISON OF MAJOR SYMPTOMS OF 3 GROUPS (16 CASES) RELATED TO END OF DIVE**

	<b>Group A (Cases 1-8)</b>	<b>Group B (Cases 9-10)</b>	<b>Group C (Cases 11-16)</b>
Adverse clearing pressure	6	1	5
Onset of first symptom	-1 minute to 2 hours	5 minutes	-2 minutes to 1 minute
Modal	0 minutes	5 minutes	0 minutes
Labyrinthine symptom onset	-1 minute to 3 days	1 day	-2 minutes to 7 days
Modal	2 hours	1 day	5 min
Vertigo	4 hours	1 day	6 minutes
Off balance	4 hours	1 day	1 minutes
Longest duration	3 days	3 months	5 days
Deafness			
Onset	1 minute to 24 hours	5 minutes	1 minute to 7 days
*db loss			
modal (number of cases)	55 (4)	70 (2)	90 (3)
Tinnitus			
Onset	1 minute to 2 days	5 minutes	0 minutes to 24 hours
Severity (1 to 5, mild to severe)	1-4	1	1-4

\* Average of 3 worst frequencies of a 6 frequency audiogram

diver was forbidden to dive but they were told to telephone the author reverse charges (collect) from anywhere, if their problem recurred. There have been no recurrences.

An interesting case is not listed here because her RWM rupture occurred in a road traffic accident 3 weeks

before she went diving. She dived uneventfully but reported 3 days later with vertigo. She eventually underwent repair at consecutive operations of both RWM rupture and OWAL rupture. She later became a diving instructor and, when last contacted in 1994, had continued diving for 14 years and was off on a diving holiday to Australia.

**TABLE 3**  
**END RESULTS GROUPS A TO D**

	<b>Group A (Cases 1-8)</b>	<b>Group B (Cases 9-10)</b>	<b>Group C (Cases 11-16)</b>	<b>Group D (Cases 17-20)</b>
Years of follow up	0 to 21	1 and 20	2 to 23	0 to 16
Average	6 to 7	10.5	11.6	5.5
National Acoustic Laboratory (NAL), Australia: percentage hearing handicap				
Pre-treatment average	11.55	13.25	11.85	
Last follow up average	1.40	13.75	1.78	
Known years of diving since diagnosis	1, 1, 13, 2, 14	1, 20	3, 6, 16, 18, 23	1, 5, 16
No further diving or no follow-up	3	0	1	1

## Case Histories

### CASE 2

He was diving on holiday and came up with a feeling of pressure in his right ear. He did have some difficulty in clearing his ear. On surfacing he noted a ringing in his ears and some deafness. The deafness went away after 2 weeks but came back 2 days later and remained. The tinnitus increased and stayed stable with his deafness. Dizziness had been noted after the dive with nausea and loss of balance which lasted for 36 hours. He was a fisherman and for the month after his dive he had been carrying 50 kg baskets of fish daily.

At examination he had a positive fistula sign and said that objects "rocked from side to side." RWM repair was carried out 6 weeks after the dive. No improvement in hearing was obtained. He was back diving within a year and 13 years later his hearing had not deteriorated further.

### CASE 7

This was complicated by cerebral decompression illness after a dive, on February 15th, 1995, to 39 m. When his memory returned he was in a country hospital from which he was discharged on February 17th. He was then aware of a loss of balance and right deafness. He developed vertigo with the spinning sensation to the right, when he sat up or moved quickly. He had a minor positive fistula sign (a little light headed) and flat 65 db audiogram loss. At operation there was no RWM. It was repaired with perichondrium. His audiogram four months later was normal apart from 30 db loss at 4, 6 and 8 KHz.

He wanted to go back diving and has been lost to follow up.

## Conclusion

The message is that after a careful and probably radical repair operation of a RWM rupture the diver can return to diving. There is one proviso and that is that knowledgeable and detailed information is provided in a counselling session to the diver, preferably by a scuba diving ear surgeon. Forceful inflation of the ears should not continue for more than 5 seconds at a time and all safe diving practices should be adhered to. The series of 20 cases is small compared to Rolland and Walsh<sup>3</sup> but it is possible that the cause of these ruptures in divers is different from the usual land-based ruptures. Molv ar<sup>4</sup> hypothesises that the inner ear damage is caused by expansion on ascent of an air bubble which gains access to the inner ear through the ruptured window membrane. This seems unlikely as any rise in inner ear pressure could be vented out through the fistula. Rolland<sup>3</sup> considers that the majority of land based ruptures occur in a weakened membrane. If this is so, after a repair there is no remaining pre-existing cause.

## References

- 1 Goodhill, V. Sudden deafness and round window rupture. *Laryngoscope* 1971; 81: 1462-1474
- 2 Edmonds C, Freeman P and Tonkin J. Fistula of the round windows in diving. *Trans Amer Acad of Ophth Otol* 1974; 78: 444-452
- 3 Rolland JAB and Walsh P. Fistulas of the round and oval windows *Aust J Oto-laryngol* 1994; 1 (5):463-469
- 4 Molv ar OI. *Effects of diving on the human cochleo-vestibular system*. Norwegian Underwater Technology Centre Report No. 29-88. Bergen: NUTEC, 1988: 24

*Noel Roydhouse, ChM, FRCS, FRACS, is an Ear, Nose and Throat surgeon. His address is St Michael's Clinic, 118 Remuera Road, Auckland 5, New Zealand. Telephone + 64-(09)-524-6065, fax + 64-(09)-520-3057 and + 64-(09)-524-8307.*

## FACTORS AFFECTING REBREATHER PERFORMANCE

R W (Bill) Hamilton

### Key Words

Equipment, rebreathing.

### Breathing resistance

Work of breathing is important in rebreathers; as depth, and hence gas density, increase it can provide limitation to some systems. Tubing and hose diameters, corners, etc. become very important in rebreathers designed for deep use.

The location of the counterlung relative to the diver's lungs has a big impact on the effort of breathing. If the counterlung is above the diver's lungs the differential pressure (static lung loading) is negative and the diver has to make an extra effort to inspire. On the other hand if the breathing bag is below the diver's lungs there is a positive pressure delivered to the lungs; this requires an expiratory effort and can tend to force gas out around the seal of a full-face mask. An effective compromise is an over-the-shoulder style, or better yet a counterlung more or less wrapped round the chest. Some units use a bellows type bag with a counterweight to balance the differential pressure.<sup>1</sup> This reduces the negative pressure when the diver is prone and adds a negative pressure component when supine: it has little effect when the diver is upright or on her side, where little help is needed. Static lung loading is