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[3] but it is possible that the cause of these ruptures in divers is different from the usual land-based ruptures. Molvær[4] 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[3] 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.

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FACTORS AFFECTING REBREATHER PERFORMANCE

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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.[1] 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 essentially independent of depth, but as gas density increases the work of breathing it can increase in relevance.

Scrubbers and scrubbing CO_2

Although the function of the scrubber canister is straightforward, the chemistry is slightly complex. The absorption of carbon dioxide by an alkaline metal hydroxide takes place in several steps; the alkaline metals may be one or more of sodium, calcium and lithium. Water vapour is necessary to start the reaction and ultimately the water is returned. Carbon dioxide ends up being converted to carbonates of the alkaline metals, such as sodium carbonate.

Considerable engineering goes into the design of a scrubber canister. It has to be an engineering trade off of several factors, including resistance, channelling, protection against water entry and cold effects. Gas flow through the canister should impose minimal resistance, but if the path is too short and the gas goes through too quickly (short dwell time) then it may not have long enough time to react. If the material settles and leaves areas with lower resistance the gas will go preferentially through the paths of least resistance and will exhausts the absorbent near the easy paths but miss the rest of it, known as channelling. Baffles, packing springs and other tricks are used to maintain an even packing density (hence resistance) and reduce channelling. Another trade off is that of particle size. Larger particles cause less resistance, but the surface area for exchange is less than with smaller particles; the smaller particles have higher resistance. Ways of dealing with this include constructing the particles to have more surface area and to pick the best combination of path length and cross-section for the granule size.

There is a wide variety of scrubber designs and a choice of several scrubber materials. Scrubber design can be a lifetime engineering speciality. [1,2] The material in Volume 2 of the US Navy Diving Manual on the Mk 15/16 system is invaluable to anyone contemplating designing or using a rebreather.[3]

The effect of cold on CO_2 absorbents

A major problem is the function of the scrubber when the diver is in cold water. Soda lime loses much of its appetite for CO_2 when cold. This can reduce the duration to a fraction of its endurance when warm. Countermeasures to cold degradation of scrubber performance include insulation of the scrubber and hoses, active warming with hot water or electrical or chemical heat and the use of lithium hydroxide (which works better than soda lime when cold but is much more caustic). For reasons not fully understood a scrubber does not work as well at greater depths.

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Results

A multi-disciplinary approach has resulted whereby 17 case which initial approach could not be explained were resolved with credible scientific explanation.

Conclusions

In fatal diving accidents it has to be recognised that it is not only the medical experts, but a team of technicians, engineers and scientists who are able to reach a logical and, perhaps more importantly, a legally defensible position.

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Key Words

Accidents, deaths, investigations.