Ruptured tympanic membrane from underwater impact with an Atlantic salmon, *Salmo salar*

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Abstract

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An unusual case of tympanic membrane rupture in a diver due to impact from an Atlantic Salmon, *salmo salar* is described. The diver was treated conservatively and the injury fully healed by eight weeks after which the diver successfully returned to diving. The author contends that the appearances of such traumatic perforations differ from barotrauma in divers secondary to ear clearing problems on descent.

Introduction

Ear barotrauma is a common injury in compressed gas divers and snorkellers. Middle ear barotrauma (MEBt) is a subset of ear barotrauma and is the most common medical disorder experienced by divers, constituting 46% of diving ear, nose and throat disorders.^{1,2} It results from inability to auto-inflate the middle ear to match the outside pressure as it rises when the diver descends. The tympanic membrane (TM) is stretched beyond physiological limits sustaining injury. The MEBt injury presents as a spectrum from symptoms of blockage (but no signs), through progressively increasing inflammation in the middle ear and of the TM, which frequently is accompanied by an effusion.¹

The most extreme form of MEBt is a perforation of the TM. Exact figures are unknown, but perforated TM is quite rare in divers compared with other grades of MEBt, probably because they experience intolerable pain and abort their dive before perforation occurs. In addition, effusion and middle ear mucosal swelling may dampen the degree of force on the TM, protecting it from the extreme deviation that produces perforation. If a perforation does occur in this setting, it may be subtle and difficult to diagnose. Divers exposed to a rapid descent (for example, accidental over-weighting) or a sudden external pressure force (for example, a blast injury) may also present with TM perforation. Three cases have been reported anecdotally from swim fin blows to the side of the head, despite water-polo cap ear protection, during underwater hockey competition (Davis FM, personal communication, 2017). It is believed this is the first reported case of TM rupture due to direct impact from the Atlantic salmon, *Salmo salar* (presented with the patient's permission).

Case report

A 34-year-old male occupational diver was undertaking his usual duties as a diver on an Atlantic salmon farm in Tasmania, Australia. He was wearing an 8 mm wetsuit with full neoprene hood, breathing from surface supply breathing apparatus with communications. He had completed a number of dives within the salmon pens as part of his routine work. He had no ear clearing problems or symptoms during his dives. He was submerged at a depth of 17 metres at the base of the fish enclosure when he noticed that the salmon were unusually active and swimming rapidly around him. A fish of approximately 5 kg in mass collided with the right side of his head over his right ear, causing him immediate pain, tinnitus and a brief feeling of vertigo. He communicated the event to his supervisor then commenced a slow ascent.

On arrival at the support vessel, his vertigo had improved, but he had persistent pain, tinnitus and impaired hearing in the right ear. He was initially assessed by his local GP, who referred him to the Royal Hobart Hospital hyperbaric facility. Otoscopic examination demonstrated a normal left tympanic membrane (TM), with normal auto-inflation. The right TM demonstrated a small (< 25%) perforation in the lower *pars tensa* (Figure 1). The otoscope fogged when a Valsalva manoeuvre was attempted, and tympanometry persistently recorded 'open' without producing a pressure curve. Audiometry demonstrated minor loss (10 dB) in high frequencies compared to his last fitness-to-dive assessment.

The diver was treated conservatively with analgesia and advised not to dive for eight weeks and to keep the ear dry. During this period, he undertook surface-based activities for his employer. Eight weeks later, he was asymptomatic with

Figure 1

Right tympanic membrane showing perforation in the *pars tensa*

Figure 2

Healed right tympanic membrane at eight weeks post injury

normal looking TMs bilaterally (Figure 2). Autoinflation, tympanometry and audiometry were normal. He has successfully returned to diving without problems.

Discussion

Traumatic TM rupture can cause severe pain, bleeding, tinnitus and hearing loss for the injured individual.¹⁻³ Other than diving, TM perforation can result from multiple aetiologies. These can include direct penetrating trauma from foreign objects, percussion injury (slaps, water ski accidents), sudden negative pressure, basal skull fracture, barotrauma or iatrogenic injury.^{3,4} Larger perforations appear to result from higher energy injuries or direct penetrating trauma. The following factors affect prognosis for healing: large perforations are less likely to heal spontaneously; final healing and hearing results are good regardless of treatment employed; spontaneous healing provides a better result than surgical intervention and infection adversely affects healing.⁴ “*Masterly inactivity should be religiously followed and unnecessary surgical intervention should be discouraged*” when assessing treatment options.³ Between 80% and 90% of perforations heal spontaneously inside three months.⁴⁻⁶ Use of gel-foam patches to treat larger tears has been reported to improve healing in a randomised controlled trial.⁶

In my experience of more than twenty cases of perforated TMs from diving, the localised pattern of perforation from *Salmo salar* differs from TM injury sustained by divers when they cannot clear their middle ear, resulting in MEBt. Divers with ear-clearing problems tend to have more widespread injection of the TM associated with the perforation. The perforation is usually less obvious (often a small slit), or may be hidden by haemorrhage, and requires confirmation

by tympanometry. I postulate that this latter injury is due to slower onset of the barotrauma, which may follow multiple (unsuccessful) attempts at clearing the ears. I have been unable to locate any reported cases of tympanic membrane rupture due to direct impact from the Atlantic Salmon, *Salmo salar*, or other fish.

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Letters to the Editor

Proliferative retinopathy during hyperbaric oxygen treatment

A 43-year-old male with type 2 diabetes mellitus, treated with insulin for 28 years and with an HbA1c of 7.9% six months prior, suffered from bilateral plantar ulcers refractory to specialised wound care. He underwent a planned 40 sessions of hyperbaric oxygen treatment (HBOT) at 243 kPa for 90 minutes. Consent was given for this report.

The patient's ophthalmic history included bilateral proliferative diabetic retinopathy (PDR) identified on routine diabetic eye screening three years previously. This was treated with pan-retinal photocoagulation (PRP). Three months before starting HBOT, he underwent phacoemulsification and intra-ocular lens insertion of his left eye, having had the same procedure done to his right eye a year prior, without complication. He was reviewed again one week prior to his first HBOT and fundoscopy confirmed non-proliferative diabetic retinopathy (NPDR) without evidence of PDR.

The patient had a routine follow up by the ophthalmologist following his fifth HBOT when fundoscopic examination revealed pre-retinal haemorrhage, a form of PDR, in his left eye. This was treated with PRP at the time. His visual acuity, 6/9 bilaterally, had not changed, nor did he describe any changes in his visual field despite these findings.

He was seen three weeks later (following 12 further HBOT) when fundoscopy showed worsening proliferative changes, this time in both eyes. Bevacizumab was injected at the time and fill-in PRP performed the following week. His visual acuity remained unchanged in both eyes. At this point, HBOT was withheld to allow the proliferative phase of the patients' retinopathy to remit.

The potentially adverse effects of hyperbaric oxygen to the retinal vasculature of diabetic patients was postulated in 1994 following a similar experience, albeit without a baseline fundoscopic examination.¹ In particular, the concern was of accelerating the proliferative process of retinopathy with subsequent irreversible loss of vision. Thereafter, routine screening and treatment of all diabetic patients for PDR was adopted at our facility. Until now, there have been no further cases of NPDR evolving into PDR at three-month review following HBOT. Indeed, a brief literature search using the terms "retinopathy", "complications", "adverse effects", "vitreous", "hemorrhage", "haemorrhage", "hyperbaric" and "oxygen" has not found any other cases described.

In a double blind, randomised trial (meeting abstract only) of 15 diabetic patients with both NPDR and PDR, patients in neither the HBOT (243 kPa for 90 min) nor the control arm had evidence of neovascularisation nor worsening of their proliferative retinopathy at three-month follow up.²

The significance of PDR following cataract surgery has also been considered. A review article consistently found that NPDR progression occurred in up to a third of such patients. Despite this, there were no cases of NPDR progressing to PDR at 12-month follow up.³

Whether this patient's sudden progression to PDR was related to HBOT, recent cataract surgery or another unknown factor is unclear. However, the temporal relationship to 17 HBOT is difficult to explain and appears more rapid than available data regarding vascular regrowth in wound healing would suggest.

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Advertising policy for Diving and Hyperbaric Medicine

This letter is intended to serve as a policy document in relation to advertising in the journal *Diving and Hyperbaric Medicine* (DHM). The remarks and suggestions below have the support of both the EUBS and SPUMS, henceforth referred to as *the publishers*.

The publishers support the concept of advertising in DHM and value highly the contribution that any advertisers would make to the maintenance of a high-quality scientific journal. Nevertheless, it is considered that there are potential advertisers who would not be acceptable to the members of both our societies. These include those designed to market unhealthy or inefficacious products. The categories that are considered to fall under the description of 'unacceptable' are outlined below and to advertise such products and services is regarded as contrary to the scientific integrity of the Journal.

The publishers also note there is a belief in both societies that, while the appearance of an advertisement in DHM does not specifically demonstrate endorsement of the service or product by the Journal or the Societies, such an

endorsement may be assumed by many readers. There is a distinction in this regard between advertising in a non-scientific publication and a scientific journal.

The publishers recognise the final decision to reject or accept an individual advertiser lies ultimately with the Editor and the Editorial Board. These guidelines are designed to assist in decision making on this subject.

The publishers suggest the following categories of services and products would not be acceptable:

- harmful or illegal products (such as: alcohol, tobacco, recreational drugs or any such product that is classified as illegal or harmful in Australia/New Zealand or the European Community);
- products and/or services in the field of hyperbaric and diving medicine that can be classified as 'non-justified use' by the criteria set forth respectively by SPUMS and EUBS/ECHM in their official publications;
- products or services that compromise diving safety;
- various 'alternative' forms of oxygen administration (e.g., topical HBO, mild hyperbaric therapy);
- marketing the use of 'non-approved' indications (category D, E, F in the ECHM list of indications; anything not on the SPUMS list);
- marketing in support of a product or service without a medically justifiable intent. This includes any

drug or physical intervention designed to increase performance or which can potentially place patients at an unacceptable risk (such as doping products);

- products and/or services where there is no relationship to diving, diving and hyperbaric medicine, emergency, intensive care or related fields of medicine and where the same 'non-justified use' criteria apply as above;
- any product and/or service where there is a material conflict of interest with the Editor or any member of the Editorial Board. Consideration may be given to accepting an advertisement if there is a declaration of such a conflict and the Board member concerned is not involved in any decisions concerning placement, fees charged or accompanying articles.

The Editor of DHM may refer any requests for advertising to the Journal Governance Committee for advice and clarification as required.

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On behalf of the publishers EUBS and SPUMS

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Policy; Medical society; Diving industry; Hyperbaric medicine; Letters (to the Editor)

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