which can arise from having loose dentures played a significant role in both the causation and management in case SC 91/6.

It is striking that, apart from the shark attack, there was a number of avoidable factors present in each of the fatal scuba diving incidents. This indicates that it should be possible to reduce even further the number of divers who die each year. So dive carefully at all times.

Acknowledgments

This report could not have been prepared without the generous help and forbearance of those charged with the management of the documentation concerning such fatalities. This is true of every State and includes the Police services in some States in reference to cases where no inquest was considered necessary. Others who have identified cases or supplied information are also thanked. It is hoped that one day there will be wider involvement in this project by members of the diving community.

PROJECT STICKYBEAK

This project is an ongoing investigation seeking to document all types and severities of diving- related accidents. Information, all of which is treated as being **CONFIDENTIAL** with regard to identifying details, is utilised in reports and case reports of fatal and non-fatal cases. Such reports can be freely used by any interested person or organisation to increase diving safety through better awareness of critical factors.

Information may be sent (in confidence) to:
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NITROUS OXIDE INDUCED DECOMPRESSION SICKNESS FOLLOWING SHOULDER CAPSULE BAROTRAUMA

Carl Edmonds

Abstract

A shoulder dislocation in a diver was complicated by her continuing the dive and developing barotrauma of ascent in the shoulder. Reduction under general anaesthesia, using nitrous oxide, was followed by clinical decompression sickness.

Case report

An experienced female diver, taking an advanced diving course in Northern Australia in June 1993, had the following dive profiles:

Day 1 3 m for 56 minutes.
Day 2 18 m for 33 minutes.
Day 3 (i) 21 m for 33 minutes, followed by a long surface interval, which left her with 4 minutes residual nitrogen time, and then
(ii) 21 m for 29 minutes .

She had logged approximately 60 dives, and was diving with two physicians when she dislocated her right shoulder. This followed a backward roll entry with heavy equipment held in her right hand. At the time she was aware of a sharp pain, but it caused little difficulty during the remainder of the 29 minute dive, with the arm splinted by the wet suit and held immobile.

She was unable to use the arm or hand throughout the dive, but the shoulder pain increased significantly during the actual ascent. She was unable to hold onto a line with that hand, and the pain caused her great discomfort and difficulty. The increasing pain forced her to slow her ascent and the shoulder was extremely painful by the time she reached the surface.

Immediate attempted reduction by the companion diver physicians failed and she was transported to hospital.

Pethidine was given for pain and metoclopramide for nausea. An X-ray confirmed the dislocation and an attempted reduction again failed.

The shoulder dislocation was successfully reduced under anaesthesia, using nitrous oxide, some two and a half hours after the dive.

The following day she was aware of lethargy, sleepiness, distortion of vision, paraesthesia and numbness of the extremities. There was a sense of disorientation and dizziness (she felt that the car in front of them was moving backwards onto their car). At that stage she was also feeling nauseated.

On examination she failed the sharpened Romberg test.

Hyperbaric oxygen therapy commenced on the second day after her anaesthetic and resulted in a prompt resolution of most of the symptoms, with a dramatic improvement in the general status. She felt well, with no more numbness or paraesthesia and regained the ability to perform the sharpened Romberg test.

She said that with recompression “I began to feel much better and afterwards appreciated how wonky I must

have been. I felt as if an unrecognised woolly feeling had been lifted. My fingers and toes were no longer tingling and my perceptions had returned to normal".

Diagnosis: (i) Dislocated shoulder, with barotrauma of ascent.
(ii) Decompression sickness, aggravated by nitrous oxide administration.

Discussion

An explanation for her symptoms, according to our current knowledge, is as follows.

Shoulder

Enclosed gas spaces in the body can produce barotrauma in diving[1].

The shoulder joint is a ball and socket arrangement partly lined by a synovial membrane. The membrane secretions permit excellent lubrication as the surfaces are apposed. There is little or no gas space, as such, between the ball and the socket. When the head of the humerus is removed from the glenoid cavity the surface tension between the two membranes must be broken and fluid or air must enter.

During dislocation and subluxation, there is probably a greater negative pressure in the joint space (relative to ambient), and therefore gas and possibly some fluid, is likely to be "sucked into" the new space, from the membrane and surrounding tissues. Tearing of the capsular membranes would also result in additional fluid accumulating in the joint.

The production of gas (>90% nitrogen) with joint traction[2,3] is well recorded in degenerative joints . When apposed joint surfaces are distracted, a partial vacuum is created and its volume must be filled. Gas, in solution in the surrounding tissues, passes into the space and occupies it as a gaseous phase. This is referred to as the "vacuum phenomenon" and is detectable by CT scan and sometimes plain X-ray. It is especially found in the intervertebral discs, where it is produced by enlarging the disc space in extension (distraction) and reduced with flexion (compression). Otherwise, the commonest joint affected is the shoulder.

Whether this newly acquired air space in the joint, following the dislocation, contributes to the sensation of pain is not known. Often air in the joint is painless. This air space would diminish with descent. However, while the subject is diving, there would be a significant nitrogen pressure gradient between the arterial supply to the tissues (including the synovial membrane) and the joint space. Nitrogen would then move into the shoulder joint, partly restoring the volume of the gas space. It is likely that the number of gas molecules in the shoulder joint capsular space would have increased during the considerable exposure to pressure.

During ascent, this gas space would then expand, producing a sensation of pressure and then pain if the capsule is distended.

After surfacing, the pressure in the shoulder joint space would reduce to approximately one atmosphere, as do all distensible gas spaces. Gas molecules would continue to move from the hyperbaric exposed "slower" tissues surrounding the joint, into this capsular space, expanding it further.

Gas in the joint spaces of aviators[4] and divers[5] exposed to decompression, have been described previously. Barotrauma has been described in bone cysts.[6] It is believed that this is the first reported case of barotrauma associated with a shoulder joint.

Decompression Sickness

Nitrous oxide (N_2O) is a fast moving gas (a diffusing capacity 35 times that of nitrogen, 0.46 compared with 0.013). Most senior anaesthetists are aware of this, and therefore know that if there are any air spaces in the body and if the subject breathes nitrous oxide, those gas spaces will expand as nitrous oxide flows into them much more rapidly than nitrogen will flow out.

The basic pathology of decompression sickness involves the development of gas bubbles in tissue and blood.

Books on diving medicine,[1] and the occasional article[7] have warned of the danger of giving N_2O, and advised therapists not to administer nitrous oxide while under pressure, or to divers after a dive, when it is thought to "precipitate decompression sickness". Some of us have even used it to aggravate subclinical decompression sickness in experimental conditions (naughty!).

When breathing N_2O, middle ear pressures rise because N_2O diffuses from the blood to the middle ear. If the Eustachian tube opens, the pressures return to normal. During middle ear surgery a rise in pressure can "pop off" the recently replaced tympanic membrane. Most anaesthetists either turn off the nitrous oxide well before the surgeon closes the tympanic membrane or use some other carrier gas.

In 1973, Professor Ralph Braur and I, at the Veterans Administration hospital near San Diego, measured middle ear pressures increasing when normal subjects breathed Heliox (80% He/20%O_2) and reducing when they breathed

oxygen, if they did not open their Eustachian tubes. We even titrated the various He/O_2 mixtures against the middle ear pressures, but the results were never published.

It is likely that nitrous oxide administered to a diver who already had sub-clinical bubble development from a considerable hyperbaric exposure, would aggravate the bubbles present.

Of interest to diving physicians, but not relevant to this case, is the analogous change of pneumothorax volume. A pneumothorax will double its size within 10 to 15 minutes if 70% nitrous oxide 30% oxygen, a common anaesthetic mixture, is breathed instead of air.

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THE WORLD AS IT IS

OUT OF COURT, OUT OF SIGHT, OUT OF MIND

Douglas Walker

There are many, often compelling, reasons why a case which has been entered into with vigour by the parties involved can end, as far as outsiders can ascertain, in a conspiracy of silence. The practice of Law frequently involves the quoting of precedents and where cases are settled out-of-court no precedents are established. It is this fact, combined with limiting the vast expense of litigation, which encourages settlements. Naturally there are losers as well as winners. Public good seems to be the loser in some out-of-court settlements as the opportunity to learn of problems and plan to avoid their repetition is lost.

This may seem an irrelevance to most divers but they would be wrong. In a hypothetical claim for damages after a diving incident which resulted in morbidity, the people sued, be they persons or organisations, will have a real interest in avoiding both publicity and cost, and hope to prove no blame should attach to their actions. Their insurer will want to minimise the expense, even if this means that the insured has to accept an implied blame which may not be deserved. The lawyers of both parties have a financial benefit from a prolonged battle, but the plaintiff can avoid the uncertainty of outcome which is always present with even the most apparently cast iron of cases.

Without going to the extremes of the claims which are rumoured to be made in America, where such cases are often taken on a no-win no-pay (contingency) basis (for a proportion of the award) it is possible to suggest some scenarios which could arise in New Zealand or Australia. Litigation could result from defective hired equipment or injury during a Resort Course Dive or a dive from a commercial dive boat. It is possible that an injured party could claim that an inadequate or incorrect course content provided less skill than the pupil required and expected. This is a veritable minefield, with present and potential risks to all levels of the diving industry.