Trauma in the marine environment requiring surgery after diving

David Smart

Key words
Injury. accidents, infectious diseases, anaesthesia, safety, decompression sickness, pulmonary barotrauma, case reports

Abstract

(Smart D. Trauma in the marine environment requiring surgery after diving. *Diving and Hyperbaric Medicine*. 2007; 37: 82-4.)
The author reports a personal injury when after two dives he fell from the dive boat, sustaining a deep laceration to the arm. This required surgical repair under general anaesthesia approximately six hours later while the diver was still offgassing nitrogen. The report reviews the use of antibiotics for marine wounds, and the choice of anaesthesia for a diver when residual inert gas is present. Wounds sustained in the marine environment should be cleaned, irrigated, debrided and foreign material removed. Prophylactic antibiotics are recommended if injuries penetrate the dermis, and when the patient has immune compromise or other medical co-morbidities. A theoretical risk of nitrous oxide precipitating decompression illness is supported by basic scientific literature, and should be avoided after diving. The incidence of pneumothorax from parascalene block is low in modern anaesthesia.

A previously healthy 45-year-old male undertook two dives on the third day of a multi-dive week at the 2006 SPUMS conference at Pacific Harbour in Fiji. A total of 20.5 hours had lapsed since completion of the previous day's diving. The boat was anchored on a site in Beqa lagoon, 20 km off Fiji's main island, Viti Levu. The entry time of the first dive was 0845 hours and it was undertaken to 26 metres' sea water (msw) as a multi-level dive for a total time in the water of 53 minutes. The dive finished in 10 msw and ascent was commenced at 48 minutes with 3 minutes spent at 5 msw before surfacing at 0938 hours. A second dive was commenced, after a surface interval of 84 minutes, at 1102 hours. The maximum depth of this dive was 15.7 msw with a multi-level profile; ascent was commenced from 8 metres at 1152 hours. Five minutes were spent at 5 msw, before surfacing at 1158 hours (in-water time 56 minutes).

Soon after completing the second dive, the diver whilst returning from the bow of the dive boat slipped from the port-side gunwale, lacerating the inner aspect of his upper left arm. He fell into the sea and swam to the rear of the boat to seek assistance from other divers. The laceration exposed biceps and brachialis muscles and created a distally based flap that was 10 cm across the base. It had been exposed to tropical sea water. Fortunately, there was no significant blood vessel or nerve trauma. A first-aid dressing was applied and he was evacuated to Suva Private Hospital for surgical assessment, arriving around 1345 hours. The injured diver declined a generous offer of surgical repair under local anaesthesia at the conference venue, despite the eminent qualifications of conference delegates.

Pethidine, tetanus vaccination and ceftriaxone were administered. Initial surgical assessment indicated that the wound was likely to need debridement and delayed primary closure because of the risk of tropical marine infection. At this point, the diver contacted Divers Alert Network South East Asia-Pacific (DAN SEAP) to seek assistance with return travel to Australia. Within 90 minutes DAN SEAP had authorised a return flight by commercial aircraft to Melbourne, if required.

Surgical debridement under general anaesthesia was undertaken at 1730 hours. The diver received fentanyl, midazolam and propofol anaesthesia, spontaneously breathing via a laryngeal mask. Fortunately, the wound was judged to be suitable for primary closure (Figure 1). Metronidazole was administered intravenously during the procedure and post-operatively, and further ceftriaxone the next morning. At 2045 hours, the diver was contacted by DAN SEAP, and the flight was cancelled as primary closure had been successful. After review by the surgeon, the diver was discharged on the following day, and commenced oral ciprofloxacin 750 mg b.d. The diver then returned to the

Figure 1
Laceration of left arm following suture

conference and travelled home with the conference group as planned. The wound has since healed uneventfully. Costs were all fully covered by the diver's travel insurance.

Discussion

This case illustrates two issues worthy of consideration for the treatment of a diver sustaining trauma in the marine environment.

INFECTION RISK AND ANTIBIOTIC MANAGEMENT

The marine environment carries a number of *Vibrio* species (*alginolyticus*, *damsela*, *fluvalis*, *holliisae*, *parahaemolyticus* and *vulnificus*), *Alteromonas* species (*espejiana*, *haloplaktis* and *macleodii*), *Pseudomonas marina*, *Mycobacterium marinum*, *Erysipelothrix rhusiopathiae* and *Delaya venustus*. Bacterial counts and species vary, depending on proximity to human habitation.[1] Faecal bacteria may contaminate sea water where untreated sewage is discharged into the sea, creating a higher risk of wound infection.[2]

There is a paucity of literature on the question of prophylactic antibiotics for marine wounds. A structured literature search using the headings *marine wound, marine trauma*, *antibiotic prophylaxis* or *treatment* identified 11 papers over 20 years; nine were case histories or small case series and two were reviews. A broadened search to include specific marine organisms identified a further 29 case reports (32 subjects, 18 of whom sustained marine wounds). Reports were biased towards wounds that were contaminated, and therefore complicated, resulting in the affected individual seeking hospital treatment. No prospective series of marine wounds were identified.

It is not possible to assess the incidence of contamination from marine injuries. It is likely that the majority of marine wounds are uncomplicated. Despite the focus in the literature on marine organisms, data from a larger series of contaminated wounds acquired in the tropics demonstrated that marine organisms were causative in less than 40% of cases.[1] The most common organisms were *Staphylococcus aureus*, pyogenic *Streptococcus* and enteric bacilli (Table 1). The largest series, reported in 1993, involved 93 soft-tissue infections caused by marine *Vibrio* species; 76 had definite sea water contact with wounds.[3] Nearly 60% of affected individuals had underlying conditions that compromised their immunity, for example: liver disease, diabetes, steroid use, and cancer. Factors affecting risk of infection included the degree of contamination of the marine environment, the depth of wound and tissue planes crossed, presence of foreign material, host defences and delay since injury. A recent review recommended "*trauma occurring in brackish or salt water should be treated with doxycycline or ceftazidime, or a fluoroquinolone*",[2] and also indicated the need for appropriate wound management.

An additional hazard of marine wounds is the potential for marine animal venoms (e.g., from stingrays) to cause delayed tissue necrosis. Isbister recommended that prophylactic antibiotics are typically not necessary for venomous marine fish spines unless there has been a residual foreign body or the patient is immunosuppressed.[4]

The level of evidence for recommended treatment of marine wounds is level 4 (case data) or level 5 (expert opinion/ consensus guidelines). The following general principles apply:

- All wounds should be cleaned, irrigated and foreign material removed.
- If a marine spine such as a stingray barb has penetrated skin, retained foreign material should be excluded by imaging (ultrasound or plain X-ray).
- Surgical exploration or excision should be undertaken, particularly when an underlying deep structure might be penetrated.
- Debridement of dead or devitalised tissue should occur, including the possibility of excising the wound track if the spine or barb was likely to have venom surrounding it.
- For minor wounds not penetrating the dermis, wound care only is required and antibiotics are not considered necessary.
- For injuries penetrating the dermis or when the patient is immune compromised, antibiotic prophylaxis is recommended. Single antibiotic therapy is recommended using doxycycline, co-trimoxazole, the fluoroquinolones or third-generation cephalosporins. When samples are taken from marine wounds for microbiological evaluation, the laboratory should be informed so they can perform specific cultures for marine organisms that may require varying salt concentrations and incubation temperatures for growth.[1–3]

Table 1
Sea-water contaminated injuries requiring hospital treatment in Northern Queensland during 1990–1991 (N = 41)[1]

Mechanism	**Number**
Coral cuts	25
Fish spines	2
Fish hooks	6
Boating mishap	3
Other injuries	5
Infections indentified	**Number**
Streptococcus pyogenes	19
Staphylococcus aureus	20
Enteric Bacilli	17
Marine Vibrios	12
Aeromonads	4

MANAGEMENT OF ANAESTHESIA SOON AFTER DIVING

This issue caused the author (patient) some concern. Despite offers of debridement/repair by SPUMS colleagues at the conference venue, the flap was quite large and would have involved high doses of local anaesthetic for infiltration anaesthesia. This may have been the only option if a properly constituted operating theatre with sterile equipment was not available.

Two other methods of anaesthesia had the potential to precipitate diving-related illness, or impact on diving in the future. Nitrous oxide (N_2O) is often still used as part of inhalation anaesthesia. A literature search using the headings *nitrous oxide*, *anaesthesia*, and *decompression sickness* identified 11 papers: one case report, one letter and nine basic science studies. Three laboratory studies showed N_2O has the potential to diffuse into pre-existing nitrogen bubbles, potentially precipitating decompression sickness (DCS).[5–7]

The case report recorded a six-day interval between the diving and onset of symptoms consistent with DCS, which appeared after anaesthesia for an elective ENT procedure. Symptom resolution occurred with recompression.[8] In the author's personal case the temporal relationship between diving and anaesthesia was much closer. According to US Navy, DCIEM, and dive computer tables, there were significant amounts of residual nitrogen creating a risk of diffusion of nitrous oxide into nitrogen micronuclei. The author's impassioned request to the anaesthetist to refrain from using N_2O was granted.

Regional anaesthesia using a parascalene brachial plexus block was also discussed. The risks to divers of this procedure stem from the potential to cause pneumothorax – a possible contra-indication to further diving. The author identified ten papers specifically examining the incidence of pneumothorax associated with this procedure; the two largest series were evaluated.[9,10] An incidence of 0.8% was reported in1,248 blocks performed without ultrasound or nerve stimulator, and no cases in a second series of 2,810 blocks using a nerve stimulator.[9,10] Neither a nerve stimulator nor an ultrasound was available for the procedure, so this method of anaesthesia was declined.

Conclusions

Cleansing, decontamination and debridement form the basis of marine wound management. Level 4/5 evidence suggests prophylactic antibiotics are required for injuries penetrating the dermis or in patients with immune compromise. Single antibiotic therapy is recommended: doxycycline, co-trimoxazole, fluoroquinolones or a third-generation cephalosporin. A theoretical risk exists of N_2O precipitating DCS and its use should be avoided after diving. The incidence of pneumothorax from parascalene block is low in modern anaesthesia.

Acknowledgements

The author acknowledges the support of conference colleagues, employees from Aquatrek, Fiji, Allways staff and Suva Private Hospital staff. It was reassuring that evacuation to an Australian health facility was an option with the support of DAN SEAP.

References

1 Ashdown L. Callanan V. Marine wound infections. In: Williamson JA, Fenner PJ, Burnett JW, Rivkin JF, editors. *Venomous and poisonous marine animals. A medical and biological handbook*. Sydney: University of New South Wales Press; 1996. p. 88-97.
2 Noonberg GE. Management of extremity trauma and related infections occurring in the aquatic environment. *J Am Acad Orthop Surg*. 2005; 13: 243-53.
3 Howard RJ, Bennett NT. Infections caused by halophilic marine *Vibrio* bacteria. *Ann Surg*. 1993; 217: 525-31.
4 Isbister GK. Venomous fish stings in northern Australia. *Am J Emerg Med*. 2001; 19: 561-5.
5 Hyldegaard O, Madsen J. Influence of heliox, oxygen and N_2O-O_2 breathing on bubbles in adipose tissue. *Undersea Biomed Res*. 1989; 16: 185-93.
6 Hyldegaard O, Moller M, Madsen J. Effect of He-O_2, O_2, N_2O-O_2 breathing on injected bubbles in spinal white matter. *Undersea Biomed Res*. 1991; 18: 361-71.
7 Butler BD, Conkin J, Luehr S. Pulmonary haemodynamics, extravascular lung water and residual gas bubbles following low dose venous gas embolism in dogs. *Aviat Space Environ Med*.1989; 60: 1178-82.
8 Acott CJ, Gorman DF. Decompression illness and nitrous oxide anaesthesia in a sport diver. *Anaesth Intens Care*.1992; 20: 249-50.
9 Thompson AM, Newman RJ, Semple JC. Brachial plexus anaesthesia for upper limb surgery: a review of eight years' experience. *J Hand Surg [Br]*. 1988; 13: 195-8.
10 Monzo Abad E, Baeza Gil C, Galindo Sanchez F, Hajro M, Gonzales Menendez A, Kim-Darov V. Parascalene brachial plexus block: experience of 10 years. *Rev Esp Anestesiol Reanim*. 2004; 51: 61-9.

Associate Professor David Smart, MB, BS, FACEM, MD, is the joint Medical Director of the Department of Diving and Hyperbaric Medicine, Royal Hobart Hospital
Hobart, Tasmania
Australia
Phone: *+61-(0)3-6222-8193*
E-mail: *<david.smart@dhhs.tas.gov.au>*

This case report was presented at the SPUMS 2007 ASM in Tutukaka, New Zealand.