Review articles

Venomous marine animals

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Abstract

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Marine animals cause human deaths and severe morbidity in many countries having tropical or sub-tropical waters. With travel to remote areas becoming more commonplace, general practitioners, and diving and tropical medicine specialists must routinely advise others of potential marine envenomation problems. Simple first aid and medical treatments are suggested. Although not all current recommended first-aid treatments have been proven, most have a sound basis and appear effective. The known world distribution of the main groups of venomous marine vertebrates is discussed and suggestions made for the awareness and prevention of such marine envenomation.

Introduction

Venomous marine animals are present worldwide but are mainly confined to the Indo-Pacific Region (Table 1). Their envenomation usually injects a large amount of venom into one area, with a consequent relatively slow absorption. This needs different first-aid principles to jellyfish envenomation, where extensive amounts of tentacle contact usually results in a significant amount of venom injected over a larger area with consequent rapid onset of symptoms.

The first-aid treatment of all marine envenomation can be divided into two main treatment groups (Figure 1).

1 Prevention of further envenomation
   - Pressure-immobilisation bandaging[1] – bites, etc
   - Vinegar – for box jellyfish stings only, e.g., *Chironex*, Irukandji (*Carukia barnesi*)[2,3]

2 Treatment of pain
   - Heat (hot water) for penetrating spiny fish injuries (fish barbs, etc)[4]
   - Cold packs or ice for jellyfish stings (any species)[5]

In addition, resuscitation in the field followed by advanced life support may be required as clinically indicated.

First-aid treatment of marine envenomation pain

HEAT TREATMENT: PENETRATING SPINE INJURIES

Heat is the best first-aid treatment to date for all penetrating spine injuries.[4] The envenomed limb should immediately be placed in hot water; about 43 ºC is the most that the majority of people can stand without causing scalding. It is essential the rescuer tests it first, as the victim may be in such pain that they cannot properly distinguish the apparent water temperature, and many severe scalds have been caused by not doing so.[4] In Europe, there have been so many victims scalded from this treatment, especially when treating Weever fish injuries, that their policy has changed to cold packs for penetrating injuries (personal communication, Dietrich Mebbs, Clinical Toxicology Course, Adelaide, 2003).

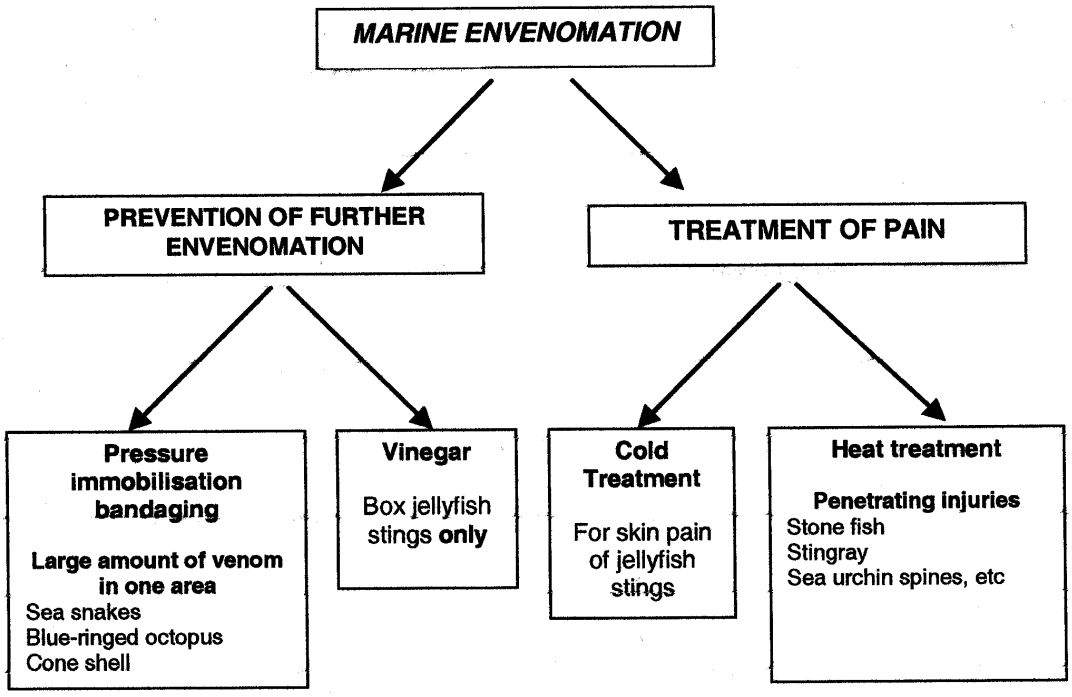
It has been postulated that the hot water denatures the venom; but a temperature of about 60 ºC is needed to achieve this in the species concerned. It is a little difficult and unwise to place a victim's appendage into water at around 60 ºC!

Hot-water treatment is very effective, but as soon as the water cools the pain will return. Consequently, it needs topping up regularly, testing each time this is done.[4] The author has known it used for up to four hours until someone arrived back for further treatment; and it still remained

Table 1
Geographical locations of human fatalities from marine animal envenomation

Blue-ringed octopus	Australia, Singapore
Cone shell	Australia, Fiji, India (Banda), New Caledonia, Japan (Okinawa), Vanuatu
Sea snake	Burma, Malaysia, India (Madras), Indonesia (Java), Japan (Okinawa), Oman, Vietnam
Stingray	California, Colombia, Fiji, New Zealand, Surinam, Texas
Stonefish	?Australia (Thursday Island), East Africa, Japan, Seychelles

Figure 1
First-aid treatment of marine-envenomation pain



effective. A source of hot water on a deserted island is usually obtainable from the engine on the boat that transported people there.

After reaching medical aid, the envenomated area must be assessed and, if warranted, surgically explored under good anaesthetic cover; a nerve block or general anaesthetic, not just local anaesthetic.[6] Often the author also treats victims routinely with antibiotics to cover marine organisms (see below). Finally tetanus prophylaxis must be up to date. The tetanus protocol has recently changed, with the usual course up until the age of 15 years, then just a single booster at 40 for life cover. Obviously, many clinical factors must be considered if further tetanus injections may be needed for any particular wound at any time.

The most common causes of penetrating spine injuries are described below.

Stonefish

There are two main types of stonefish – the estuarine and reef species. They are brown to sandstone in colour, blending perfectly with their surroundings and so are very difficult to see (Figure 2). The usual means of envenomation is when the unsuspecting victim steps on them, often whilst walking on rocks. The stonefish (*Synanceja sp.*) has 13 dorsal spines, which are defensive and not used for capture of food. Paired venom glands are attached to each spine, and when the spine is pushed down (e.g., pressure applied by a human foot) it penetrates the skin and acts like an injector, forcing venom into the wound.

ENVENOMATION

The envenomation is quite characteristic (Figure 3). The puncture mark often has a local bluish tinge around it and the severe local pain (usually on the foot) extends, causing severe limb pain and paraesthesiae. The victim is usually distraught with pain and in apparent shock, with low blood pressure, pale skin, nausea and dizziness.[7]

TREATMENT

The severe local pain usually responds to hot-water treatment as described above and/or local nerve block. Parenteral analgesia may be necessary and Commonwealth Serum Laboratories (CSL) antivenom is available and provides good pain relief given as soon as possible, but later use in intractable pain is still effective.

FATALITIES

Despite the stonefish's fearsome reputation, there have been no fatalities in Australia. One described as occurring on Thursday Island appears more like a stingray death when the actual evidence is considered.[8] World fatalities are both rare and poorly documented, and often cannot be corroborated. In the deaths mentioned in the literature occurring in East Africa, the reports that do exist are poor and first-hand accounts do not actually exist.[9] In Okinawa a fisherman supposedly picked up a stonefish and suddenly collapsed in the water: classified as a stonefish death but with a very unusual history of sudden onset. Perhaps the pain triggered a pre-existing cardiac condition?[4] Another

'unusual' death was in a diver who sat on one underwater. The injury was so painful that he made a rapid, uncontrolled ascent to the surface and died from a massive arterial gas embolism (personal communication, Williamson J, 2002).

Stingray

The stingray is a large, flat fish with flaps that enable it to swim gracefully through the water. It has a tail with at least one barb, and occasionally up to seven. The barb(s) face backwards in the normal state and are usually covered in a friable sheath of tissue. Stingrays are usually gentle creatures, known as the 'pussycat of the sea'. However, they have a bad habit of burying themselves in the sand and just resting there. Fishermen also have some very bad habits, such as walking through shallow water not looking where they tread.

ENVENOMATION

Treading on the flap of the stingray produces a reflex action where the tail whips forwards with great force, and the barbs can easily penetrate the integument of the victim, even through rubber or leather covering (boots, etc., Figure 4).

Pain is instant and severe. Jagged lacerations can occur and heavy bleeding has resulted in several fatalities.[10] The barbs can either break off and remain embedded in tissue, or stab the tissue and be totally withdrawn. As the barb sheath penetrates the tissue its surrounding integument is torn off, leaving a trail of venom and debris. This venomous tissue causes localised myolysis and inflammation with local or extended tissue necrosis. Penetration of abdomen and chest greatly increases morbidity and mortality.

TREATMENT

The whole tract should be excised, if at all possible, and the crater packed with an alginate-based wick to allow healing by secondary intention. These dressings are useful in toxin absorption and are left in place for as long as possible. They frequently fall out at about 8 to 10 days, or are then easily removed without pain or damage to the healing wound.[11] Tetanus immunisation is advised. Follow up to exclude secondary infection may be necessary as this often causes major problems.

FATALITIES

At least 17 fatalities from stingrays have been reported worldwide, including in New Zealand, Surinam, West Atlantic, Texas, Fiji, California, and Australia.[4] Although it was reported that a fresh-water species of stingray had caused multiple fatalities in Colombia,[12] this report has recently been questioned for its accuracy. Trunk wounds are responsible for most of the fatalities, but acute exsanguination has caused at least two deaths, and another occurred from tetanus complicating a lower-leg wound.

The two Australian deaths were bizarre. The first occurred in 1936 in St Kilda in the open swimming baths. A soldier dived into the water but suddenly surfaced in severe pain and quickly died. He had a stab wound in his chest that had penetrated his heart. Despite draining the whole of the baths and finding nothing, the cause was presumed to be a stingray.[13] The other occurred about ten years ago as a boat travelled across Mourilyan Harbour near Innisfail. A large stingray leaped out of the water. Its flaps hit the first person and the barbs hit a 12-year-old boy sitting in the middle of the boat, with one barb entering his knee and another the chest. In hospital, he had only some chest discomfort and was cardiologically stable with a normal chest X-ray. The chest wound was explored using local anaesthetic and a probe and the tract suggested the barb had glanced off a rib and been withdrawn as there was no trace of any part of it. After thorough local cleansing and injection of Betadine™ down the tract, he was sent home the next morning. Five days later he suddenly dropped dead at home.[6] The venom causes muscle necrosis, and his post-mortem examination revealed that the barb had gone directly into his heart before being withdrawn and that the retained venomous tissue caused progressive myocardial necrosis. Suddenly, this caused a small hole to develop in the cardiac muscle with its consequent catastrophic effect. Death was caused by cardiac tamponade with a huge haemothorax.[6]

Bullrout

These are common fish in fresh and brackish water where they are usually unseen and easily stepped on by their unsuspecting victims, in a way similar to stonefish.

Other fish with venomous spines

Lungfish, scorpion fish, lionfish (Figure 5) and Weever fish all have penetrating barbs that may cause local pain ranging from irritating to really severe and agonising. Lionfish do have a reputation in the Philippines for causing death, but again nothing has ever been proven and published in a reputable journal. However, the problem is that in the Philippines you die, you are buried and that's it; there are no good or reliable figures on mortality or morbidity on any deaths in non-metropolitan areas.[4]

Sea urchins – echinoderms

Sea-urchin-spine penetrations are common and are not very venomous but most unpleasant. Echinoderms have hundreds of sharp spikes, looking like 'spiky balls'. They are often present on rocks close to or in shallow water. When they are accidentally stepped on, thousands of little spikes break off in the victim's foot. Though they are not venomous, they are mentioned here as they fit into the heat-treatment framework.

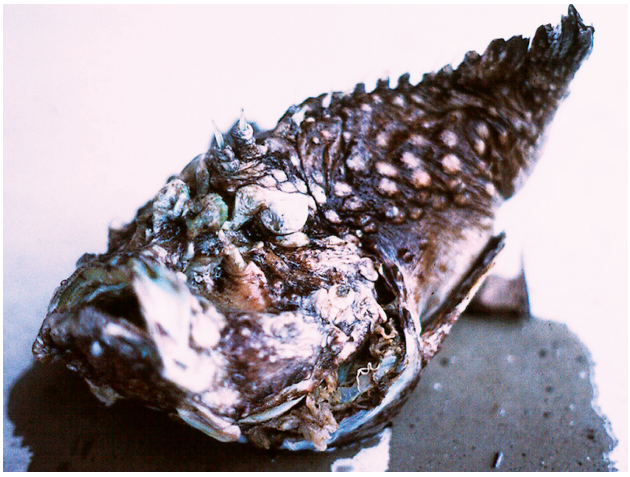


Figure 2. Stonefish

Figure 4. Stingray laceration

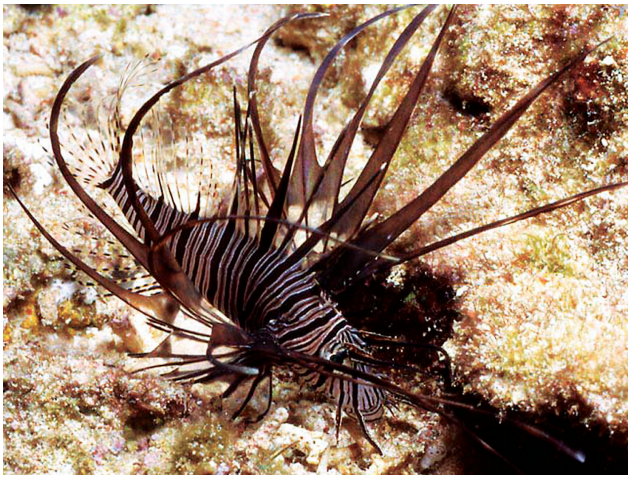


Figure 5. Lionfish

Figure 3. Stonefish injury

Figure 6. Crown of thorns starfish

Figure 7. Cone shell

Figure 8. Blue-ringed octopus

TREATMENT

There are bizarre stories of treatment (sounding more like torture), where the bottom of the foot is beaten with a stick to 'break up all the bits'. Theoretically, this should make it easier for the tissue to exude these smaller particles! Alternatively, soaking the foot in vinegar is said to help dissolve the spikes; it does not! In fact, there is no really effective, long-term treatment. Hot water relieves the pain during use and the only other treatment consists of picking out any spikes individually. This is very difficult as they break up, and this method is also painful. However, they need to just exude out individually. An X-ray should be taken to identify any deeper, broken-off fragments.

Crown of thorns starfish

Similar to the echinoderm, the crown of thorns starfish has sharp spines that can easily cause a penetrating injury (Figure 6). The spine tips are covered with a mild venom that may cause local irritation. Recurrent injury is seen in marine scientists and professional 'pest controllers' whilst injecting the animals with copper sulphate, and leads to sensitisation which may cause more severe or extensive local reactions.[4]

Pressure-immobilising bandages (PIB)

LARGE AMOUNT OF VENOM IN ONE AREA

When there is a large amount of venom in one area, Sutherland proved that, in Australian elapid snake envenomation, PIB worked very efficiently as a first-aid treatment by preventing spread of venom until medical aid could be reached.[1] The venom is not destroyed but with intravenous access, medication, colloids and antivenom, this effective, timed release of the venom means that it could be counteracted by the applied medical treatment.

It is in this context, without further medical experimentation that would be very difficult, that PIB has been recommended for envenomation by sea snake, cone shell, blue-ringed octopus and even, with great controversy, major envenomation by *Chironex fleckeri*.

There has always been a fight, especially amongst various first-aid groups and emergency-medicine doctors, as to where the bandage should start. The most current agreed practice, discussed by the Australian Resuscitation Council recently, is that you start at the tips – distally to proximally. However, the author's strongly held view is that there is real benefit from immediate pressure bandaging over the envenomation site followed by pressure bandaging from the distal tip of the envenomated limb(s) towards the body. Finally, and most importantly, pressure immobilisation should involve the whole limb, which also must be completely immobilised; both legs tied together with firm boarding between them, or a sling applied to the arm and it tied to the victim's side.

In summary, based on Sutherland's work on Australian elapids, PIB is used in the first aid for envenomation by:
- land snakes in Australia
- sea snakes (probably)
- cone shells
- blue-ringed octopus.

Cone shells

Cone shells are brightly coloured, triangular-shaped shells with a longitudinal fold, or 'split' running the length of the shell from the blunt shell top to the point (Figure 7). A proboscis, like a small, hollow, flexible tube, can emerge from anywhere along the slit, although frequently and usually from the tip of the cone. At the base of the proboscis is an area containing a number of barbs, called radicular teeth. These barbs are bathed in a potent venom. The proboscis acts similarly to a blowpipe and these tiny barbs can be fired a reasonable distance, possibly a metre or so. This barb envenomation leaves a bolus of venom in one area; making PIB the initial first-aid treatment of choice.

Human envenomation occurs in a few main ways. It most often occurs in shell collectors. In the one Australian fatality, a shell collector picked up a 15 cm *Conus geographicus*, and placed it in his pocket. Despite feeling a small prick he thought nothing of it, but developed breathing difficulty and died on the boat trip to the mainland.[14]

ENVENOMATION

Cone shells produce a rather unusual envenomation. It causes a localised, sharp pain, sometimes very mild but sometimes extremely painful.

There is usually very little reaction at the site. Careful illumination may reveal an embedded barb, but this is very rare. Local flushing of the skin or a small macular rash may be present at the envenomation site. Macular rashes can develop over the face and ears or become generalised and may be intensely pruritic and distressing. The skin pain and pruritus may continue for weeks.[4]

Envenomation by some of the fish-eating cones, particularly *Conus geographicus* and *Conus textile* can rapidly cause numbness and local swelling, marked nausea, incoordination, muscular weakness and difficulty breathing due to progressive weakness of diaphragm and intercostal muscles. This may very rapidly proceed to respiratory paralysis and death from asphyxia without immediate airway and ventilatory support.[4,15]

An unusual presentation reported by the author involved someone just walking along the beach, touching nothing, but feeling a sudden small stab in the leg. Minutes later he had the severe pruritic rash all around his face and ears

and developed trouble breathing. Despite his oxygen saturation dropping to 85% on room air and commencing oxygen in the ambulance, he was not admitted to hospital as the rash had gone and his breathing had improved! This presentation is unproven and atypical but can surely be attributed to cone-shell envenomation after all other possibilities had been exhausted.

TREATMENT

PIB and respiratory support are required. Initial expired-air resuscitation is followed by intubation and mechanical ventilation in hospital for four to six hours until spontaneous breathing returns.[4]

FATALITIES

There have been fifteen proven deaths, all of them from the Indo-Pacific region.[15] The Australian death occurred on Hayman Island in 1936.[14] Other deaths have occurred in Fiji, and Okinawa, Japan.[4]

Sea snakes

Sea snakes are common in all oceans except for the Atlantic. They are most common in tropical and sub-tropical zones of Australia. They are similar in appearance to land snakes except they have a flattened paddle-like tail that makes swimming possible. They are air breathers having no gills, and are inquisitive but not usually aggressive. However, there was one notable attack by a sea snake at Bondi Beach that caused severe envenomation problems.[16]

Sea snakes in Australia can be divided into two main groups:

- those with large mouths that rarely bite and even more rarely envenomate, i.e., they do not inject their venom
- those with small mouths and, although their venom is some of the most potent in the world, are almost unable to take a large enough bite to envenomate. However, even a scratch from a tooth covered in venom may produce a full envenomation and death.

ENVENOMATION

Most bites are 'dry', with less than 10% of sea snakes injecting venom. The bite is relatively painless, and, if venom is injected, is followed by symptoms that include drowsiness, nausea and vomiting, weakness, visual disturbances, breathing problems and muscle pains or stiffness. Severe myolysis may cause renal impairment.[4]

TREATMENT

Antivenom is available for sea-snake envenomation from CSL. Interestingly, when CSL were actually producing this antivenom they were injecting the sea-snake venom into the same horses that had been previously used for tiger-snake antivenom production! Thus, if sea-snake antivenom is unavailable, it is possible to use tiger-snake antivenom, which works just as effectively.

FATALITIES

Fatalities have occurred regularly worldwide.[15] The greatest problem is for fishermen. When they go out fishing, sea snakes get caught up in their nets and have to be removed. This is a common time for envenomation, and figures suggest there are probably about 100 to 150 deaths per year (personal communication, Warrell D, Oxford, 2003). As only about 3% of bites are thought to be fatal this means there may be some 35–40,000 sea-snake envenomations per year.

Blue-ringed octopus (*Hapalochlaena spp.*)

The blue-ringed octopus is generally yellow to brown in colour, enabling it to blend in with its background, which is usually a rocky area, e.g., it is often found in shallow inter-tidal rock pools (Figure 8). It has eight arms growing up to 15–20 cm in diameter with the tentacles extended. When frightened or in danger, or when 'angry', e.g., being prodded by young children with sticks (!), many small, electric-blue rings appear, making it look very attractive. This often results in children picking it up to play with it, thus getting envenomed out of water. It is found all around Australia and throughout the Indo-West Pacific.[4]

ENVENOMATION

Envenomation occurs after a painless bite from a beak that is under the body of the octopus. The venom is tetrodotoxin (as in 'fugu', the Japanese fish) and is produced in the salivary glands. These are connected to the beak by small ducts.[4] The bite is commonly painless and unnoticed, and not every bite results in symptoms of envenomation. However, deaths and near deaths are well documented.[17] The venom is a salivary toxin with a complex composition, including a tetrodotoxin and hapalotoxin of great biological interest.

The first sign of serious envenomation may occur within ten minutes, with the onset of generalised progressive muscle weakness, dysphasia, dysphagia, visual disturbances and respiratory difficulties.[14] Nausea and vomiting may occur, and collapse from muscle weakness is soon seen, with unconsciousness and death in the absence of effective resuscitation. The autonomic effects of the toxin may result in fixed, dilated pupils, suggesting death. However, the victim may be conscious and aware, although unable to breathe, and may be able to recall everything that is going on during resuscitation (personal communication, Williamson J, 1985). Death occurs from respiratory paralysis, unless resuscitation is commenced.[18]

TREATMENT

PIB should be applied, and assisted ventilation will be needed for four to six hours, or possibly up to 12 hours, after which spontaneous breathing usually recurs.

FATALITIES

There are two published deaths in Australia and one in Singapore.[18,19] Note that envenomation never occurs in the water, only when the creature is irritated when taken from its natural habitat.

Marine-wound infections

Marine wounds often become contaminated by a variety of organisms different to those usually cultured from 'normal' skin wounds. Organisms include *Vibrio*, *Altermonas*, *Mycobacteria spp*. and marine varieties of *Pseudomonas*. These organisms do not respond to the usual skin antibiotics such as flucloxacillin or erythromycin. The antibiotics of choice, if culture and sensitivity are not immediately available, are doxycycline (100 mg daily) or a third-generation cephalosporin.[20] When taking a culture from a marine wound, it is essential to state this on the pathology form. Laboratories will then culture these organisms on saline-based culture plates, as marine organisms will not grow on the usual culture media.

Conclusions

Envenomation from marine animals causes human deaths and severe morbidity in both tropical Australia and many countries in the world surrounded by tropical, or sub-tropical waters. With travel becoming commonplace, doctors involved in this area must routinely advise patients and colleagues about the hazards of marine envenomation, both in Australia and overseas, whenever they are consulted or become aware of such trips.

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