Divers

146

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Contents

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1 Core Messages

- Diving is an activity that can cause serious and long-lasting problems to the skin.
- Allergic reactions to diving equipment are mainly due to rubber chemicals.
- Cnidarian stings are the most frequently encountered injuries in the aquatic environment.
- Dousing vinegar is the most important first aid measure after contact with cnidarians.
- Bacterial infections from the aquatic environment need specific antibiotics.
- The healing time for wounds inflicted in the water can take 2–3 months.

2 Introduction

More than 70% of our planet is covered with water. With the growing population it is an understandable phenomenon that the water world is more explored than ever before. Not only in a professional way, but also due to the increase in modern mobility with low fare rates, people tend to travel to more exotic places for leisure aquatic activities or to practice aquatic sports such as snorkeling and scuba diving.

We are not well adapted to breathing underwater. Therefore, we need special adaptations to go below the water surface and stay there for reasonable time. Being there can cause specific problems to the skin.

Protection from the environment is essential, not only from the point of view of the thermal problems but also concerning the creatures living in the water. The insulating suits for the various water temperatures are mainly made of rubber or rubber-related materials (Boehncke et al. 1997; Angelini and Bonamonte 2002).

Marine creatures have the most potent venom known to humans; some are life threatening. For this reason it is important to recognize the cutaneous and systemic symptoms in order to make a correct diagnosis and give adequate treatment. Aquatic dermatology is not taught in residency training programs. The first major book was published in 1978: Atlas of Aquatic Dermatology (Fisher 1978). In 1987, an issue of clinics in Dermatology was dedicated to aquatic dermatology (Mandojana 1987). Venomous and poisonous marine animals (Williamson et al. 1996) provided a medical and biological handbook for this field of interest.

Mandojana was the first to attempt to get a systemic approach in the field of aquatic dermatology. They are ordered to the type of mechanism involved (Mandojana 1996).

1. Irritation (Contact dermatitis)
   (a) Direct chemical (allergic and toxic); Jellyfish, chlorinated water, sponges, algae, sea cucumbers, sea moss, fish, etc.
   (b) Diving gear: Irritant, allergic, and toxic
2. Infection
   (a) Primary: Cercarial dermatitis or "swimmer's itch" (Schistosome species)
   (b) Secondary: Bacteria (*Pseudomonas* species), mycobacterioses (*Mycobacterium marinum*), bacilli (*Erysipelothrix* species), *Vibrio* species, algae (*Prototheca* species), and other miscellaneous infections
3. Wounds
   (a) Active: Stings (hydroids, Portuguese man-of-war, shells (cones)), puncture, and suction (cephalopods (Octopi)), wounds (annelids (leeches)), abrasion (elasmobranches: manta ray skin), etc.
   (b) Passive: Abrasions and cuts (corals), punctures (fish spines, spiny creatures (echinodermis)), spiculous creatures (sponges), bristly creatures (worms), etc.
4. Hypersensitivity reactions: Aquagenic urticaria, aquagenic pruritus of the elderly, aquagenic pruritus, and "bath itch" (polycythemia rubra vera)
5. Aquatic sports–related lesions: "Swimmer's ear," water-ski cord strangulation of extremities, etc.
6. Dermatitis by ingestion: Scombroid fish (tuna, etc.) and ciguatera (usually by large tropical fishes)
7. Bites
   (a) Serious: Destructive (sharks, moray eels, etc.) and venomous (sea snakes, etc.)
   (b) Others: Fishes, worms, sea lice, and miscellaneous
8. Barotrauma: Mask and diving suit squeeze
9. Electric shock: Freshwater electric eels, etc.

3 Equipment

In older days, most of the other snorkeling and diving items, such as masks, fins, and mouthpieces, from the regulators were made of rubber. Nowadays most of these items are made of silicone which has less sensitizing capacity.

Rubber chemicals will stay a common cause of contact dermatitis. Among the numerous chemical additives in rubber products the vulcanizing and compounding agents, thiurams, carbamates, thiourea derivates, and mercapto derivates are the main contact sensitizers. During diving the release of sensitizing compounds may be facilitated by physical abrasion and the superhydration of the epidermis. To do proper patch testing it is advisable not only to take a sample of the suspected item but also to obtain information from the manufacturer (Table 1).

4 Cnidarian Envenomations

The phylum Cnidaria (formerly known as coelenterata) encompasses three major classes:

1. Scyphozoa (jellyfish)
2. Hydrozoa: (Hydroids, "fire coral," Portuguese man of war)
3. Anthozoa: (Sea anemones and hard and soft corals)

Cnidarian stings are the most frequently encountered injuries in the aquatic environment. Thus far 9000 cnidarian species have been identified. All of them share the same envenoming organ. The nematocyst consists of a sack-like structure (cnidoblast) filled with venom and a coiled thread (Fig. 1).

Table 1 Allergens for patch testing in divers

Dibutylthiourea	Wet-dry suit/mask/fins
Diethylthiourea	Wet-dry suit/fins
Diphenylthiourea	Wet-dry suit
Ethyl butylthiourea	Wet-dry suit
Mercaptobenzathiole	Wet-dry suit/mask/swim cap
Isopropylparaphenylenediamine (IPPD)	Wet-dry suit/mask/fins/straps
Para-tertiary-butylphenol-formaldehyde resin	Wet-dry suit/boots/gloves

The nematocyst can be activated by direct pressure or by changes in the direct environment. The thread penetrates the entire epidermis and the venom is directly delivered in the papillary dermis. Because of this the venom is quickly brought into the circulation. Nudibranchs and octopi that eat cnidaria use the intact nematocysts for their own protection and bring them to their skin. Tentacles broken after a storm and that float free can still sting humans. The sea bather's eruption is caused by these free floating parts (Burnett et al. 1986). The venom consists mainly of toxic or antigenic proteins and enzymes (collagenase, proteases, elastases, nucleases, hyaluronidase, and phosphatase). Others are histamine, histamine-releasers, serotonin, and kinine-like substances (Burnett 1992; Burnett and Calton 1977). The most common immediate symptom of a jellyfish sting is an acute local dermatitis: a linear, urticarial erythematous eruption that follows the pattern of the contact of the tentacles. The lesions can be necrotizing or ulcerative. A burning pain or a pruritic sensation can be felt. Depending on the species the forming of long-lasting and scarring skin lesions can occur (Figs. 2, 3, and 4).

Recurrent eruptions from jellyfish stings are frequently reported lasting from several months up to a year. The most venomous jellyfish is the *Chironex fleckeri* (southeast pacific jellyfish). It is found in the northern and western parts of Australia.

Full thickness necrosis can occur in several days after contact (Fig. 5). Other systemic reactions can lead to hemolysis, acute renal failure, and cardiac and respiratory arrest. Fatalities may occur in 10–20% of the *C. fleckeri* stings. An antivenom is available for *C. fleckeri* envenomations (Fenner and Williamson 1996). From a dermatological point it is important to treat the eruption with potent steroids (sometimes even systemic) to prevent chronic reactions and post-inflammatory hypo- or hyperpigmentation with severe scarring or atrophy. Secondary infection by aquatic bacteria is not uncommon.

Fig. 1 One day after contact with fire coral

Fig. 2 *Vibrio* spp. infection 3 weeks after injury

Fig. 3 Electron microscopy of nematocyst

5 Systemic Reactions

Some jellyfish can provoke systemic, toxic reactions. This may include headache, malaise, weakness, diaphoresis, and lacrimation. Less common are ataxia, dizziness, fainting, local cramping, muscle spasms, convulsions, paresthesias, arthralgia, chills, vomiting, diarrhea, blurred vision, throat constriction, respiratory depression, and coma. The best way is to avoid the contact with these organisms. Wearing special protective clothing can make a big difference in the contact (Fenner and Williamson 1996; Fenner et al. 1996). During the *Chironex* season in Australia

Fig. 4 Several hours after *Chironex fleckeri* contact

Fig. 5 Sponge (*Callyspongia plicifera*)

beaches are protected by special nets. The public is well informed when there are sightings.

6 Treatment

Avoid further nematocyst discharge and immobilize the extremity. The inactivation of the nematocysts is best done by pouring vinegar (4–6% acetic acid) on the afflicted area for at least 30 s. Some authors promote the use of meat tenderizer although its effectiveness has never been established. Most of the venoms are thermo-labile. For that reason apply local hot water (42–45 °C). Remove the tentacles with a raiser or C-card. Check the ABC's (airway, breathing, and circulation) and treat the systemic reactions with epinephrine, corticosteroids, and antihistamines (Burnett et al. 1986; Fenner and Williamson 1996; Fenner et al. 1996).

Hydrozoa and Anthozoa can cause a milder stinging sensation with erythema and swelling and, in a later stage, papular urticaria, hemorrhage, morbilliform rash, and vesicular and pustular formation. In the case of "fire coral" (*Millepora* spp.) not only the burning sensation can occur, but also cuts from the hard lime carbonate skeleton can cause serious wounds (Auerbach 2001) (Fig. 6).

7 Dogger Bank Itch

Dogger bank itch (syn. "dead man's fingers," "sea chervil," "curly weed," "ju-ju weed") is an allergic contact dermatitis to 2-hydroxyethyl

Fig. 6 Four weeks after sponge contact

dimethylsulfoxonium, a metabolite of the marine bryozoan, *Alcyonidium diaphanum*. It is mostly seen around the North Sea. Sensitized individuals often experience an eczematous eruption between June and August (Pathmanaban et al. 2005).

8 Sponge Dermatitis

A variety of species can produce irritation when in contact with the skin. They cause this by their sharp silica spicules or by irritation like "glass wool." A number of sponges are toxic. Two syndromes can occur after sponge contact (Fig. 7):

1. Pruritic dermatitis (like plant allergic contact dermatitis). The most well-known sponge that causes this is the "fire sponge" (*Tedania ignis*) which is found in the Hawaiian and Caribbean islands. In general within a few hours the skin becomes pruritic and burns. Afterward it appears mottled and purpuric. Most reactions subside within 3–7 days. Sometimes fever, chills, malaise, dizziness, nausea, and muscle cramps occur.
2. Irritant contact dermatitis from the penetrations of the silica spicules. Severe cases can develop into an exfoliative dermatitis. There is no really effective treatment. Potent steroids provide the most benefit but they have no effect on the initial toxic reaction. Soak the affected area in vinegar (4–6% acetic acid) and use topical disinfectants (Auerbach and Halstead 2001) (Fig. 8).

9 Seaweed Dermatitis

Lyngbya majuscula is a subtropical seaweed well known for its acute toxic reaction. After storms dislodged fragments of seaweed enter bathing suits. The victim develops a stinging, burning or pruritic sensation within minutes or hours. In the swimming suit area escharotic blistering may develop. After washing with water and soap low potency steroids are helpful. The eruption usually subsides within a week (Fenner et al. 1996; Auerbach and Halstead 2001).

10 Primary Infections

10.1 Cercarial Dermatitis ("Swimmer's Itch")

This is a maculopapular cutaneous eruption caused by a *Schistosoma* species, in cercarial form derived from blood flukes that infect animals. Only a short exposure is necessary to penetrate the skin. An intense pruritic papular dermatitis of 7–10 days ensues (Mandojana 1996; Fenner et al. 1996).

10.2 Sea Bather's Eruption

It has many causative agents. Most are cnidarian nematocysts. It can occur in covered or in exposed

Fig. 7 Sea bather's eruption

Fig. 8 Thirty minutes after contact with *Physalia utriculus*

skin. After 4–24 h after exposure a mild macular dermatitis to a maculopapular or vesicular eruption can form (Fig. 9). Sometimes systemic reactions occur that are similar to the ones found after cnidarian contact. Delayed reactions are reported. Symptomatic treatment remains the best option for both conditions (Mandojana 1996; Auerbach and Halstead 2001).

10.3 Secondary Infections

Erysipelothrix rhusiopathiae is a gram-positive, facultative aerobic bacillus that can survive for months. The infection it causes is known as "fish handler's disease," "seal finger," "speck finger," or "erysipeloid of Rosenbach." It is known as an occupational hazard. A mild dermatitis occurs 1–7 days after a wound. There is an edematous halo circumscribed by a centrifugally advancing, raised, well-demarcated, and marginated erythematous ring around the central area. If untreated, the reaction will usually run its course for 1–3 weeks. Sometimes arthritis, septicemia, or endocarditis may occur. Aqueous penicillin G is given by iv.

Vibrio vulnificus is a particularly virulent marine *Vibrio* (gram-negative, free living bacterium). It is found in water temperatures between 13 °C and 20 °C. They are natural habitants. The infected area rapidly becomes erythematous, edematous, and painful, with fast spread of the cellulitis to the adjacent areas. Hemorrhagic vesicles of bullae develop at the site of primary infection. A period of

Fig. 9 Four hours after contact with *Physalia utriculus*

necrotizing vasculitis follows that turns into necrotic ulcers (Fig. 10).

Other signs include fever-like chills and sepsis. *Vibrio vulnificus* is highly fatal by septic shock. *Vibrio parahaemolyticus* can produce similar life-threatening syndromes with necrotizing myonecrosis. After a rapid diagnosis the initial treatment with the adequate antibiotic is essential. The antibiotics of first choice are trimethoprim/sulfamethoxazole or ciprofloxacin.

Aeromonas hydrophila (gram-negative) is found in freshwater. A puncture wound may become cellulitic in 8–24 h with erythema, edema, and purulent discharge. It may resemble typical streptococcal cellulitis. The same antibiotics can be used as described by the vibrio infections.

Chromobacterium violaceum is a gram-negative rod that is found in (sub)tropical freshwater rivers. The skin symptoms are secondary to bacteremia leading to diffuse pustular dermatitis, vesicles, ecchymatic maculae, macupapular rash, subcutaneous nodules, ulcers, and cellulitis. It is sensitive to trimethoprim/sulfamethoxazole (Fenner et al. 1996; Auerbach and Halstead 2001).

Diving suit dermatitis. Many authors have described diving suit dermatitis in scuba divers (Lacour et al. 1996). It is caused by *Pseudomonas aeruginosa*. (serotypes O:10 and O:6). It usually presents with diffuse, scattered, erythematous papules on the trunk and the extremities and is sometimes itchy. Treatment consists of ciprofloxacin 500 mg twice daily during 1 week. For prevention it is better to clean the suit with freshwater and take a shower directly after the dive.

Fig. 10 Three days after contact with *Physalia utriculus*

10.4 Protothecosis

The genus *Protheca* consists of achlorophyllic algae. *Prototheca wickerhamii* and *Prototheca*

zopfii are pathogenic to humans. These algae are ubiquitous and have been isolated in fresh and marine water. Percutaneous inoculation with contaminated water after trauma is the most common mechanism of infection (Walsh et al. 1998).

Patients present with non-tender pyoderma-like lesions or infiltrating papules and plaques on exposed sites. Treatment consists of antimycotic medication (itraconazole, fluconazole, or ketoconazole).

11 Venomous and Nonvenomous Fish Stings and Wounds

11.1 Sting Rays

Wounds are either lacerations or punctures. Pain is immediate. Systemic reactions may occur. Thorough irrigation is useful, but never close the wound by sutures. Antibiotic prophylaxis may be used.

11.2 Barracudas (*Sphyraena* spp.) and Moray Eels

Barracudas (*Sphyraena* spp.) and moray eels are not aggressive. Both may strike if they are disturbed. They can hold or strike and release. The wounds must be well irrigated with freshwater. Antibiotic prophylaxis can be useful (Auerbach 2001).

11.3 Echinoderm (Sea Urchins, Star Fish) Injuries

Echinoderms are benthic invertebrates with a radical, symmetric collomate body. There are three classes (Echinoidea, Holothuroidea, Asteroidea). There are hundreds of species of the sea urchin. In some species the spines, that are mostly located on the upper surface, are tipped with poisonous glands. Envenomation can also be caused by the seizing organs (pedicellariae) on the lower surface. People step on sea urchins or brush against them. This causes several puncture wounds which can be extremely painful. The broken spines remain embedded or leave the skin unbroken. A "tattooing" pattern is frequently seen. Most of the fragments are absorbed after a while or eliminated through the epidermis. If the spines enter near a joint, destruction and synovitis can occur. In the skin the development of foreign body granulomas is a regular finding after these injuries (Fenner et al. 1996; Auerbach and Halstead 2001).

If there is any doubt as to the diagnosis, an X-ray of the joint is useful. The spines are radiopaque. The therapy is symptomatic. Several therapies are advised by local people but their use has never been proven in studies. The *Acanthaster planci* (crown of thorns) is the most venomous tropical starfish (Asteroidea). They produce an acute painful puncture wound or a chronic swollen lesion with lymphadenopathy. Their spines are as hard as wood. Frequently these injuries are complicated by infection. Wounds need to be doused with vinegar or isopropyl alcohol and afterward placed in non-scalding hot water (42–45 °C) (Fenner et al. 1996; Auerbach 2001).

Bristle worms (Phylum: Annelida; Class: Polychaeta) have rows of thin, chitinous bristles that grow from the lateral parts of their bodies. When a worm is disturbed the bristles become erect. They penetrate the skin like polyester spines. Some of these are venomous. A pruritic, erythematous, papular, and edematous eruption can develop with a burning sensation. Necrosis and paresthesias are rare. The wounds are self-limited but secondary infection is not rare. Remove the bigger bristles with a forceps and the smaller ones with adhesive tape. After this, use vinegar (4–6% acetic acid). For persistent inflammatory reactions topical steroids may be useful (Mandojana 1996; Auerbach 2001).

Diver's hand. In saturation diving divers work for 1–3 h during a period of 14 days. Because of the length of their stay decompressing time takes 4–7 days depending on the operating depth. These divers frequently experience an extensive peeling of the upper layers of the skin. Usually it starts at the fingers and progresses proximally. It is self-

limiting in a few weeks. Medium-potency steroid provides syptomatic relief (Ahlen et al. 1998).

Aquagenic pruritus. In 1970, it was first introduced by Shelly. Steinman created a set of criteria for the diagnosis in 1985 (Steinman and Greaves 1985). There are no visible signs on the skin. In the case of a contact dermatitis some kind of rash is there.

Aquagenic urticaria. It occurs upon contact with water. Source or temperature is of no concern. Many cases have been described in the literature (Hide et al. 2000). Antihistamines are a good treatment, UVB being an alternative (Parker et al. 1992).

12 Skin Problems as a Direct Consequence of Diving Itself

12.1 Decompression Sickness

During the dive nitrogen starts to build up in the body tissues depending on the depth and the duration of the dive. When the ascent is to prompt or the dive was too long or too deep decompression sickness can occur after surfacing. On the skin a mottling erythema can occur with pallor. Decompression chamber therapy is indicated and 100% oxygen must be administrated as the first aid measure.

12.2 Squeeze

During the descent the ambient pressure increases. During this period of the dive it is very important to equalize all air-filled spaces, also the space in between the mask and the face. It can be easily done by blowing out the breathing air through the nose. When this is forgotten a hematoma can occur. If the eyes are without visible abnormalities no further treatment is necessary.

Aquatic dermatology, as stated in the introduction, is a growing field and it is not possible to highlight all the aquatic dermatoses. Hence, a brief overview of the most frequently encountered aquatic dermatoses has been presented.

13 Summary

As divers are operating in a non-forgiving environment, special equipment is necessary to perform underwater. This may lead to specific problems for the skin. The aquatic organisms in fresh and marine water have their own biological aspects which can cause serious dermatological conditions.

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