Update on Marine Medicine

David Boulware MD, MPH, DTM&H
Assistant Professor
Infectious Disease & International Medicine
Department of Medicine
University of Minnesota
Salt Water exposure

• 20% of the U.S. population reports saltwater recreation annually.
  – 48 million swim in salt water
  – 14 million snorkel
  – 4 million scuba dive

• 500,000 jellyfish stings occur annually in U.S.

1999-2002 National Survey on Recreation and the Environment, USDA Forest Service and the University of Tennessee, Knoxville, Tennessee.
Influence of Seasonal Climate
Water in Thailand remains 27-30°C year round
14 February 2009

Water in Thailand remains 27-30°C year round
14 August 2009

Water in Thailand remains 27-30°C year round
Time of Water borne Illness in U.S.

FIGURE 4. Number of recreational water-associated outbreaks (n = 78), by predominant illness* and month — United States, 2005–2006

- Leptospirosis
- Mixed
- Neuro
- ARI
- Skin
- AGI

No. of cases

Month

Jan  Feb  Mar  Apr  May  Jun  Jul  Aug  Sep  Oct  Nov  Dec

0  5  10  15  20  25
Surface Temperatures 2007
Vibrio Infections in U.S.

FIGURE 7. Number of illnesses associated with Vibrio isolation and recreational water (n = 189), by species and month — United States, 2005–2006

- Other species* (n = 29)
- V. parahaemolyticus (n = 33)
- V. alginolyticus (n = 60)
- V. vulnificus (n = 67)

No. of cases

Month

Jan  Feb  Mar  Apr  May  Jun  Jul  Aug  Sep  Oct  Nov  Dec
Vibrio parahaemolyticus Infections vs. Water Temperature

Vancouver, British Columbia 2001-2006 Data

Water 0°C (8-16 0°C)

Hazardous Marine Life

Contact Toxins

Injected Toxins

Predators
Contact Toxins

Sponge

Sea Urchin

Jellyfish

Coral
Contact Toxins

Sponge

**Symptoms**: Redness and edema, arthralgia

Can be rather severe = sponge dermatitis

**Treatment**:

- Rinse and dry
- Lift skeletal spikes with adhesive tape
- Apply topical steroid and benadryl
- Systemic doses of prednisone for more severe reactions (similar to contact dermatitis, e.g. poison ivy)
- Tetanus prophylaxis
Contact Toxins

Sea Urchins (Echinoderms)
- multiple small slender spikes that may be:
  - venom filled, can puncture skin, and
  - break off

Symptoms: immediate pain
  May leave dark pigment area in dermis
  Pigment remaining longer than 48 hours
  likely represent retained foreign body

Treatment: remove spines and cleanse wound
  soak in hot water
  consider topical antibiotics and tetanus
Anemone
Severity of Nematocyst Envenomation

Anemone

Coral

Jellyfish
Nematocysts

Chemoreceptors
Mechanoreceptors

Stages of nematocyst discharge (Biology of the Invertebrates, Jan A.Pechenik p79)
Contact Toxins

**Anemone**

- sting with nematocysts

**Symptoms**: Red rash, localized swelling

**Treatment**:
- Remove tentacles
- Rinse thoroughly with sea water
- Apply ice for pain
- Topical hydrocortisone PRN
- Benadryl PRN
Contact Toxins

Coral

- Possess nematocysts
- Injury via skin lacerations and abrasions which easily become infected

Symptoms:
- Pain, erythema, weeping
- Burning, itching

Treatment
- Routine wound care
- Remove embedded coral by:
  - Rinsing or scrub brush
- Tetanus prophylaxis and topical antibiotics
Coral Dermatitis

- Chronic eruption
- Combination of:
  - Coral fragment foreign bodies
  - Chemical irritant from nematocysts
  - Inflammatory response of wound itself
- Thickened, red, weepy and painful,
- May develop bullous lesions initially
- Can take weeks to heal
- May leave hyperpigmentation
Coral Dermatitis

• Prevention:
  – Don’t touch coral

• Treatment
  – Rinsing, scrub brush debridement
  – Topical steroids (after foreign-bodies removed)
  – Watch for secondary infection

• Duration
  – May last weeks to months
  • especially if retained foreign body
Contact Toxins

Fire Coral

- not a true coral
- has nematocysts and sharp calcified exterior skeleton

**Symptoms:** Immediate burning sensation

**Treatment:**
- Rinse with seawater (NOT freshwater)
- Apply vinegar or isopropyl alcohol to wound to deactivate non-discharged nematocysts
- Apply topical hydrocortisone 2-3x daily
Contact Toxins

Jellyfish

• Phylum: Cnidaria
• Powerful nematocysts in floating tentacles
• Oceans world-wide → venom of Indo-Pacific species more severe than Atlantic.
• There is a great deal of inter-species variation
In Thailand

• Box jellyfish present in Thai waters
• Multiple species

• Occasional Deaths
  • April 2008 -- 10 year old girl at Ko Lanta
  • 8-9 August 2002 -- 23yo F, 34yo M in at Koh Pha Ngan
NEMATOCYST VENOM COMPONENTS

- Bradykinin
- Hemolysin
- Serotonin
- Histamine
- Prostaglandins
- ATP
- Hyaluronidase
- Nucleosidases
- Alkaline protease
- Acid protease
- Phosphodiesterase
- Acid phosphatase
- Fibrinolysin
- Leucine aminopeptidase
- RNAase
- DNAase
- Membrane Attack Complex
Contact Toxins

Jellyfish Sting

**Symptoms:** rapid onset of pain

- Red, swollen, hot rash → usually linear and blotchy
- Can have pustule and vesicle formation
- Severe stings → may develop skin necrosis and systemic symptoms: muscle cramps, fever, chills, vomiting, resp distress and CV collapse
- Venom of Indo-Pacific jellies produce systemic toxicity.
- Type-I Anaphylaxis is rare.
- There is direct toxicity of venom
- Type-IV hypersensitivity more common in Atlantic species of Jellyfish.
Contact Toxins

Treatment: Jellyfish (Nematocyst) sting

1. Remove any visible tentacles

2. Use shaving cream and razor to remove any remaining particles (credit card)

3. Rinse repeatedly with vinegar, rubbing ETOH or Windex™ (may cause Man O’ War nematocysts to fire)

4. Apply topical hydrocortisone and benadryl for mild disease. More severe events may require systemic prednisone course.

5. In field management of shock or CPR

6. Antivenin for box jellyfish available in some locations.

7. Ongoing Thai Randomized Treatment Trial
To Pee, Or Not to Pee?
Nematocyst Envenomation

Results from the sting of phylum *Cnidaria* organisms
- Anemone
- Coral
- Jellyfish

Nematocysts are activated by both chemical and contact mechanisms

Do NOT rub affected area
Do NOT rinse with freshwater
Do NOT urinate on wound

DO “fan” affected limb immediately underwater
DO rinse copiously with SEAwater
DO urinate in a porcelain receptacle (toilet)
Jellyfish stings

• The nematocysts require stimulation by both chemical and tactile stimuli to fire
  – Evolutionary makes sense
  – Don’t want to sting self or inanimate objects

• Can you prevent the sting?

Clown Fish

- Clown Fish live within sea anemones.
  - Don’t get stung by anemone’s nematocysts
- Why?
  - Clown Fish have a mucous coating which protects them.
    - Species dependent protection
    - The mucous coating protects them in several ways:
Jellyfish Sting Inhibitor: Mechanism of Action

1. **Highly hydrophobic**
   - Decreases tentacle contact with the skin
   - Increases difficulty of envenomation.

2. **Glycosaminoglycans mimic the composition of the jellyfish’s bell.**
   - Confuses self-recognition system
   - Interferes with nematocysts firing.

3. **Competitive antagonist to nonselective chemoreceptors**
   - Receptors bind amino acids and sugar secretions from prey
   - Sensitize the nematocysts to enable firing upon contact.

4. **Ca\(^{2+}\) and Mg\(^{2+}\) block transmembrane signaling**
   - Reduce the osmotic force within the nematocyst capsule
   - This is necessary to create the firing force.
Initial Lab Study

• 24 subjects, 2 sites
• Arms treated with tentacles for 30-60 sec

Lab Trial Results

• Prevention
  – 100% of *Chrysaora fuscescens* stings
  – 70% of *Chiropsalmus quadrumanus* stings

<table>
<thead>
<tr>
<th>Subject No.</th>
<th>Total contact Time (s)</th>
<th>Inhibitor</th>
<th></th>
<th></th>
<th>Placebo</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Max pain</td>
<td>Max reaction</td>
<td></td>
<td>Max pain</td>
</tr>
<tr>
<td></td>
<td>Amount of pain</td>
<td>Time (min)</td>
<td>Amount</td>
<td>Time (min)</td>
<td>Amount of pain</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>20</td>
<td>1</td>
<td>15</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>10</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>20</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>20</td>
<td>1</td>
<td>15</td>
<td>1</td>
<td>90</td>
</tr>
<tr>
<td>11</td>
<td>30</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>12</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Median

| | | | | | |
|---|---|---|---|---|
| Total contact Time (s) | Inhibitor | | | Placebo |
| | Amount of pain | Time (min) | Amount | Time (min) | Amount of pain | Time (min) | Amount | Time (min) |
| 10 | 0 | 0 | 0 | 0 | 1 | 15 | 1 | 30 |

Mean

| | | | | | |
|---|---|---|---|---|
| Total contact Time (min) | Inhibitor | | | Placebo |
| | Amount of pain | Time (min) | Amount | Time (min) | Amount of pain | Time (min) | Amount | Time (min) |
| 15 | 0.3 | 2.5 | 0.1 | 7.5 | 0.83 | 20 | 1 | 47.5 |

*Max, maximum; min, minimum.*

But does it work?
in the real world?
Field Trial

- Participants: Healthy volunteers planning to snorkel for 30 to 45 minutes.
- Outcome: incidence of jellyfish stings

- 2 sites
- 6 individuals each site
- 6 day sessions
- 82 observations
Locations

- Dry Tortugas National Park, Florida
  - April 24-30, 2004

- Sapodilla Cayes, Belize.
  - January 24-30, 2005
Intervention

• Masked 26 g samples were provided.
  – Safe Sea™ SPF15  (Nidaria Technology, Israel)
  – Coppertone® SPF15  (Schering-Plough)
• 10 min prior to swimming
  – Participants applied Safe Sea to one side of their body and
  – Coppertone® to the contralateral side as placebo control.
• The subjects and observers were blinded.
• Application was observed.
Field test to evaluate the protection of Safe Sea against Jellyfish Stings and Sea Lice.

Warning: Do not take part if you are under 18 years old, pregnant, or have suspected allergic reaction topical products, or have history of severe reaction from jellyfish sting.

Direction: With your right hand apply “Pink” lotion over the left side of the body as in the picture, and “Purple” lotion over the right side.

Stay in the shade or cool area for at least 10 Min.

Go swim or snorkel for up to 45 minutes.

15 minutes after the swim mark on the picture spots where inflammation or itch developed

Write below the sums of marked spots. Indicate if rash develops during 24 hours post exposure.

<table>
<thead>
<tr>
<th>Number of Spots</th>
<th>Rash @ 24 hours</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Activity: Snorkeling
## Results

<table>
<thead>
<tr>
<th>Participant Exposures</th>
<th>Safe Sea Stings</th>
<th>Placebo Stings</th>
<th>Hair Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>13</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>7</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>6</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>7</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>7</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>82</strong></td>
<td><strong>2</strong></td>
<td><strong>11</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Safe Sea Stings</th>
<th>Placebo Stings</th>
<th>Hair Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>8.2</td>
<td>0.2</td>
<td>1.1</td>
</tr>
<tr>
<td>$P$-value</td>
<td>$&lt; 0.011$</td>
<td>0.053</td>
<td></td>
</tr>
</tbody>
</table>

Problems

• Need dense application. 2 mg/cm$^2$

• In unpublished work, it did not work against *Chironex fleckeri* (Box Jellyfish).
Schistosoma cercariae burrow into epidermis $\approx 15$ min after exiting the water once water evaporates from skin.

Papular eruption occurring within 12 hours of exposure

Cercariae (larvae) can not penetrate beneath the epidermis, eventually die, and create inflammation.
Marine Envenomations

- **Swimmer’s Itch**
  - Caused by non-human schistosomas
- **Sea Bather’s Eruption**
  - Caused by the larvae of thimble jellyfish
  - *Lunuche unguulate* (Atlantic Ocean)
Sea Bather’s eruption

Area under a SCUBA weight belt on the flank.
Seabather’s Eruption

Caused by the larvae of thimble jellyfish
\((Lunuche\ ungulate)\)

- Larvae get trapped under swimwear
Seabather’s Eruption

- Jellyfish larvae discharge as they dry out
- Initiates a Type IV hypersensitivity reaction
  - Rash shows up 24-48 hours later
  - Afflicts up to 20% of ocean goers in Florida
  - Prior sensitization increases likelihood
  - Showering with scrubbing, changing out of swim wear decreases risk
  - Alternatively, wearing abbreviated swim wear
Hazardous Marine Life

Contact Toxins
Injected Toxins
Predators
Injected Toxins

Scorpionfish  Stingray  Cone snail
Injected Toxins

Stingray

- serrated bony spine at base of tail which injects venom
- commonly occurs when stepped on in shallow water
- toxin is heat labile and induces vasoconstriction
- **Symptoms:** Intense pain and local ischemia
  - Jagged wound
  - Salivation, sweating, vomiting
  - Cardiovascular collapse
- **Treatment:** Irrigate the wound
  - Soak in hot water (115 degrees) for 30-90 min.
  - May need local infiltration of anesthetic or nerve block
  - Be prepared to support cardiovascular status
Injected Toxins

Scorpionfish

- Lionfish and Stonefish species which sport poisonous spines
- Stonefish and scorpion fish toxins can be deadly
- Toxin is heat labile, similar to stingray
- Symptoms: Severe pain and local ischemia
  
  Progresses to vomiting, hypotension, delerium and CV collapse

- Treatment: Irrigate wound
  
  Soak in hot water for 30 to 90 min
  Analgesia – local anesthetic or n. block
  Antibiotics and tetanus prophylaxis
  Scorpionfish antivenin is available
Injected Toxins

Cone snail
- phylum mollusca
- two component toxin – causes sustained muscular contraction and inhibits excitatory nerves
- has detachable dart-like tooth which penetrates the foot

Symptoms: Puncture wound with localized ischemia
Can progress to respiratory distress and paralysis

Treatment: Immobilize the limb
Apply a pressure dressing
Analgesics and tetanus prophylaxis
Be prepared to support respiratory status
Principles

Nematocysts
- When in doubt – rinse first with salt water
- Then rinse with vinegar

Injected toxins or puncture wounds
- Soak in hot water
Hazardous Marine Life

- Contact Toxins
- Injected Toxins
- Predators
Predators
Predators

Barracuda
- Of 22 species, only the Great Barracuda has been reported to attack humans
- Attracted to shiny objects
- Attacks seem isolated to spearfisherman and provocation
- Biggest danger to humans via ciguatera
Predators

Moray Eel
- Found in shallow water and in crevices of reefs
- Attacks humans only when provoked
- Large jaws and sharp teeth that can cause significant soft tissue and even bony damage
Predators

Shark

- Species known to attack humans
  - Great White, Tiger, Bull, Oceanic White Tip and Hammerhead
- Attracted to fish blood and signs of distress
- No evidence that menstruation is a risk factor
- Injuries to fisherman handling sharks caught in nets are more common
- Wounds have high propensity for infection due to presence of seawater, sand, plant debris and shark mouth flora
Predators

Shark Attack

- 50 events occur worldwide each year (1/3 in Florida)
- 10% are fatal
- Chance is 1 in 5 million of attack

* ISAF – International Shark Attack File at Florida Museum of Natural History 2005
Predators

Sea snakes
- 32 species off N. coast of Australia / Indo-Pacific
- Air breathers, inquisitive, non aggressive
- HIGHLY toxic venom → causes paralysis and myolysis
- Bites with multiple sharp non-fang teeth
- Bite may or may not be envenomated
Predators

Sea snakes

-sx: After 30 min develop stiffness, muscle aches
    Soon blurred vision, ptosis, opthalmoplegia or limb weakness
    Followed by lethargy and resp paralysis
    May develop hemoglobinuria, no coagulopathy

-tx: Get to an ER
    Hold site below rest of body
    Apply a pressure bandage
    Administer sea snake antivenom only if signs of envenomation
    Can use polyvalent land snake antivenin if not available or consider dialysis
Marine Infections

Acinetobacter
Actinomyces
Aeromonas
Alcaligenes
Bacillus
Bacteroides
Chromobacterium
Clostridium
Enterobacter

Erysipelothrix
Legionella
Mycobacterium
Pasteurella
Proteus
Pseudomonas
Salmonella
Staphylococcus
Streptococcus
Vibrio

*Organisms found in marine water, organisms and marine acquired wound cultures
Marine Infections

Acinetobacter
Actinomyces
Aeromonas
Alcaligenes
Alteromonas
Bacillus
Bacteroides
Chromobacterium
Clostridium
Deleya
Enterobacter

Erysipelothrix
Legionella
Mycobacterium
Pasteurella
Proteus
Pseudomonas
Salmonella
Staphylococcus
Streptococcus
Vibrio

*Organisms found in marine water, organisms and marine acquired wound cultures
Marine Infections

Erysipelothrix rhusiopathiae

- gram + rod
- found in wild and domestic animals, birds and fish
- occupational hazard for fisherman, fish handlers
- inoculation by abrasion or puncture
- pain, burning and stiffness of adjacent joints
- hard swelling with irregular violaceous color
  → spread peripherally with central clearing
- can disseminate to endocarditis
- tx: penicillin, clindamycin or cephalexin x 3 weeks
**Marine Infections**

**Mycobacterium marinum**
- atypical mycobacterium
- grows well in pools, aquaria and seawater
- wound in contact with aquarial or seawater, fish, crustacean or turtles
- 2-8 week incubation period
- suppurates and develops organized granulomas with ulceration
- diagnosis by biopsy, culture and acid fast staining
- treatment: ethambutol plus rifampin, tetracylines, quinolones or sulfa
  minimum 4 - 6 week course
Marine Infections

**Vibrio vulnificus**

- gram (-) rod
- diarrhea (enteral exposure via raw oysters)
- wound infections in immunosuppressed
  - cirrhosis, renal disease, chemotherapy patients and HIV
- inoculation by puncture from shellfish or wound contaminated by seawater
- rapid progressive cellulitis with characteristic bullous lesions
  - necrotizing vasculitis, myositis, DIC or sepsis
- diagnosis made by stool, wound or blood cultures
- tx: debridement of wounds
  - antibiotics = tetracyclines, 3rd gen cephalosporins or imipenem
Marine Infections

Vibrio parahemolyticus

- acute food poisoning scenario
- abd cramping, explosive watery diarrhea and dysentery
- also can cause wound infections
- usually self limited
<table>
<thead>
<tr>
<th>Organisms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acinetobacter</td>
</tr>
<tr>
<td>Actinomyces</td>
</tr>
<tr>
<td>Aeromonas</td>
</tr>
<tr>
<td>Alcaligenes</td>
</tr>
<tr>
<td>Alteromonas</td>
</tr>
<tr>
<td>Bacillus</td>
</tr>
<tr>
<td>Bacteroides</td>
</tr>
<tr>
<td>Chromobacterium</td>
</tr>
<tr>
<td>Clostridium</td>
</tr>
<tr>
<td>Deleya</td>
</tr>
<tr>
<td>Enterobacter</td>
</tr>
<tr>
<td>Erysipelothrix</td>
</tr>
<tr>
<td>Legionella</td>
</tr>
<tr>
<td>Mycobacterium</td>
</tr>
<tr>
<td>Pasteurella</td>
</tr>
<tr>
<td>Proteus</td>
</tr>
<tr>
<td>Pseudomonas</td>
</tr>
<tr>
<td>Salmonella</td>
</tr>
<tr>
<td><strong>Staphylococcus</strong></td>
</tr>
<tr>
<td><strong>Streptococcus</strong></td>
</tr>
<tr>
<td>Vibrio</td>
</tr>
</tbody>
</table>

*Organisms found in marine water, organisms and marine acquired wound cultures*