



Summer seemed to come early this year with 90 degree temperatures in May! In Minnesota that means it is time to take advantage of the wonderful lakes. We can't emphasize enough the importance of safe practices in these settings. Programs to reduce alcohol consumption, increase the use of personal flotation devices, and improve training and supervision of children and young people is key for injury prevention. In this edition of *North Memorial Trauma Update* we will be discussing injuries associated with the use of watercraft and recreational water settings.

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Prevention and Treatment of Injuries Associated With Aquatic Recreational Activities

In this issue of *Trauma Update*, we address injuries associated with the use of watercraft and recreational water settings, in both controlled environments such as pools as well as less controlled natural settings. In pools and water parks, patients are more likely to suffer spinal cord injury due to axial loading of the spinal column from diving accidents as well as the effects of immersion such as anoxic injury and aspiration induced lung injury. In contrast to this, injuries occurring in natural settings may have these elements as well as blunt injuries associated with a greater transfer of kinetic energy to the patient, from boats or personal watercraft, elements of penetrating trauma such as propeller injuries as well as a greater potential for hypothermia. These will be discussed separately.

Injuries associated with the recreational use of bodies of water and watercraft have significant public health implications as drowning is the seventh leading cause of unintentional injury resulting in death in the U.S. for all age groups and the second leading cause of fatal injuries in children less than 14 years of age. To put this in perspective, during the 2001-2002 biennium drowning injuries resulted in 3,372 deaths per year and 4,174 patients per year being treated in emergency departments in the US. In Minnesota it is reported that there are 21 boating related fatalities per year and 40 non-boating related drownings per year.

NEAR DROWNING VS. FATAL DROWNING INJURIES

When analyzing nonfatal near drowning injuries, 52% occurred in children less than five years of age while 25% occurred in individuals 5-14 years of age and 23% in individuals > 15 years. It is estimated that 66% of near drowning episodes occur in pools with only 34% occurring in natural water. For this category of injuries, improved safety measures including more secure enclosures around pools, closer supervision of younger children and swimming instruction are the most significant preventative measures available. Fatal events are more likely to occur in individuals > 15 years of age (76%), are more likely to involve watercraft and to occur in natural water (71%). In a report of watercraft-related drownings among New York State residents, Browne and colleagues reported

continued on page 2



that 60% of episodes were associated with the watercraft capsizing or the victim falling overboard and that only 9% of drowning victims were reported to have been wearing personal flotation devices at the time of their death. In contrast to this, alcohol has been reported to be involved in up to 70% of water related fatalities. When watercraft were involved fatalities were more likely to occur with small boats (less than 19 feet in length), personal watercraft or canoes and when individuals who were inexperienced were involved. This makes programs to reduce alcohol consumption, increase the use of personal flotation devices and improve the training and supervision of young boaters' key for injury prevention.

Many of these areas of concern overlap in the case of personal watercraft. These are often operated by younger and less experienced individuals and have been associated with alcohol consumption. All of these are features which may characterize individuals who are thought to be more likely to engage in high risk activities. Injuries associated with the use of personal watercraft include thoracolumbar spine and spinal cord injuries as well as other serious injuries (closed-head injuries, hollow and solid viscus injuries, and blunt chest trauma). When comparing accidents involving personal water craft with small boats, those involving personal water craft are more likely to produce long-bone fractures and are more likely to require operative intervention, (75% for personal watercraft vs. 43% for small boats), Beierle et. al.

INITIAL ASSESSMENT AND TREATMENT

While fatal and near fatal events provide a valid means of classification and reporting they can only be applied retrospectively, when the patient's response to resuscitation is known. Because of this the concepts of attending to the patient's Airway, Breathing and Circulation (A B C) as well as preventing additional Disability remain central in the initial assessment and management of the patient. Removing of wet clothing and covering the patient,

including their head, with dry blankets will help reduce heat loss thus avoiding or minimizing hypothermia. Timely attention to these details is important as several series have found that the only victims who survived near drownings were those for whom resuscitative measures were initiated at the scene. For those whom resuscitative measures were not initiated until reaching the emergency department none survived. Additionally it is important to maintain spine precautions during the rescue and resuscitation as the patient may well have suffered a spinal



cord injury, from diving into the water or other impacts, which have rendered them incapable of rescuing themselves from the situation. An excellent review of this entire topic, including many of the nuances of this patient population, is provided in the reference by Joost et. al. in the reference section.

CENTRAL NERVOUS SYSTEM AND LUNG INJURY

The most serious complications of nonfatal submersion events include anoxic encephalopathy and acute lung injury. While there are differences in the pulmonary injuries sustained with fresh and salt water immersion, in general it is best that individuals sustaining a significant immersion event be evaluated for hypothermia, possible anoxic injury and aspiration. With respect to the latter, aggressive pulmonary care is recommended for individuals who could have aspirated water or gastric contents into the lungs as this is associated with developing pneumonitis which may progress to Acute Lung Injury or Adult Respiratory Distress Syndrome. Aggressive pulmonary cares are also indicated for individuals who are hypothermic as hypothermia is associated with increased pulmonary secretions, (see below). In both cases it is important to culture pulmonary secretions, however, unless the body of water in which the patient is found is known to harbor large inoculums of a significant pathogen, prophylactic antibiotics are not generally recommended. While the effects of anoxic brain injury can not be undone it is generally recommended that a strategy of preventing secondary injury, as in traumatic

continued on page 3

brain injury, be considered. These include maintaining an adequate cerebral perfusion pressure, oxygenation and glucose control. A detailed discussion of anoxic brain injury is beyond the scope of this presentation and readers are referred to the recent review by Dr. Robert Roach in the Volume 9 issue of North Memorial Trauma Update for a more detailed discussion.

HYPOTHERMIA

Heat loss is an almost uniform finding from more prolonged episodes of immersion as the body's means of preserving and generating heat (vasoconstriction, shivering and non-shivering thermogenesis and active movement of muscles) are not able to fully counteract the heat loss that may occur in water. Physiologic derangements are often evident at 35°C and become more severe below 32°C. Hypothermic patients have additional areas of care that must be addressed. They will typically have significant fluid requirements for resuscitation, are expected to experience bradydysrhythmias, as well as life threatening ventricular dysrhythmias, and have significant increases in respiratory secretions, making pulmonary toilet critical. Additionally, hypothermia is associated with a coagulopathy, as low body temperatures interfere with the activity of the coagulation proteins and platelet function. The coagulopathy of hypothermia may be particularly detrimental when the immersion event occurs in conjunction with significant blunt or penetrating trauma.

Given recent reports of improved neurologic outcome being associated with therapeutic hypothermia in patients who have suffered a primary cardiac arrest, the possibility of using therapeutic hypothermia to reduce neurological deficits in patients suffering from drowning has been raised. To date no randomized clinical trials have been published which confirm a benefit, however, the two human trials in adults resuscitated from a primary cardiac arrest have resulted in some authors advocating that drowning victims who remain comatose after restoration of spontaneous circulation should be considered for controlled mild hypothermia, in the range of 32°C-35°C, for 12 to 24 hours. This approach is completely experimental, and requires mechanical ventilation, sedation and paralysis to prevent shivering thermogenesis. Therapeutic hypothermia is available at our institution as well as other tertiary care facilities in the state.

PROPELLER RELATED INJURIES

Perhaps the most disfiguring of boating injuries are boat-propeller related injuries. These injuries typically

produce multiple, deep, parallel lacerations that can result in permanent scarring, loss of a significant amount of body wall, traumatic amputations and substantial blood loss. Furthermore, these may be associated with significant blunt injury to the thoracic and abdominal viscera as well as skeletal fractures which may further complicate assessment and treatment of the patient. According to U.S. Coast Guard statistics most boat-propeller-related injuries result from operator error with many being preventable. They recommend the following to avoid these injuries: Be certain that every passenger is wearing a personal flotation device; Avoid operating a boat while under the influence of alcohol or drugs; Keep the boat clear of marked swimming and diving areas; Ensure that passengers are properly seated before getting underway; Never start a boat with the engine in gear; Designate a passenger who will keep water skier(s) in sight at all times and Never allow passengers to ride on a seat back.

When encountering an individual who has suffered such an injury, attention to the A, B, Cs of resuscitation and prevention of further neurological disability are central as are minimizing the effects of increased heat loss due to loss of the abdominal wall and loss of normal chest wall mechanics on ventilation. In the case of a significant chest wall defect early definitive airway control is beneficial. When this is not possible one may consider covering the involved area with an occlusive dressing that seals on three sides, as has been described for 'sucking chest wounds'. This may improve ventilation, in the face of compromised respiratory mechanics, while preventing the possibility of a tension pneumothorax. Long-term, the treatment of these injuries may be complicated by significant loss of body wall and soft tissues which may limit options for reconstructive procedures.

VERTEBRAL AND AXIAL SKELETAL INJURIES

Another category of injuries associated with aquatic sporting and recreational activities are vertebral fractures and spinal cord injuries. These have been seen in accidents involving diving and personal water craft. In diving accidents, where injuries involving the upper extremities and skull more frequently occur, cervical and upper thoracic spine injuries are more common. Injuries associated with personal water craft crashes tend to result in more spinal injuries in the thoraco-abdominal region. These observations reinforce the importance of maintaining spine precautions during the rescue and resuscitation of patients involved in water and watercraft related injuries.

continued on page 4



WATERSKIING AND WAKEBOARDING RELATED INJURIES

Waterskiing-related injuries are classified into four categories. Injuries caused by a fall into unobstructed water (with water injection injuries to the genitourinary tract), Injuries caused by boat propeller blades, Injuries caused by collisions with obstacles or a boat and Injury by the tow rope. In a recent review of 612 waterskiing and wakeboarding injuries Hostetler and colleagues found that traumatic brain injuries were significantly more common in injuries related to wake-boarding incidents (12.5%) vs. for waterskiing incidents (2.4%) while musculoskeletal injuries were more common following waterskiing injuries (36.3%) than wakeboarding.

SUMMARY

Injuries associated with the use of recreational bodies of water and motorized vehicles are associated with significant injuries and patterns of injuries that may differ from injuries occurring on land. In pools and water parks patients are more likely to suffer spinal cord injury due to axial loading of the spinal column from diving accidents as well as the effects of immersion such as anoxic injury and aspiration induced lung injury. In contrast to this, injuries occurring in natural settings may have these elements as well as blunt injuries associated with a greater transfer of kinetic energy to the patient, from boats or personal watercraft, elements of penetrating trauma such as propeller injuries as well as a greater potential for hypothermia.

Those accidents involving motorized vessels, irrespective of size, may cause blunt and penetrating trauma which may present as vertebral and long bone fractures as well

as traumatic brain injury. Diving accidents are more likely to induce spinal cord injury while immersion and diving accidents may also produce brain injury (anoxic or traumatic). Irrespective of these details it is important that the patients initial care center on assessment of Airway, Breathing and Circulation while protecting the patients spine. These cares, which are routine for all forms of trauma, are often made more difficult to treat due to immersion with it's complicating factors of removing the patient from the injury setting as well as hypothermia and its metabolic effects as well as anoxic perfusion.

References:

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- *Salt water immersion 43 patients (26F:17M) aged 18-88. 79% were > 60. all but two patients had a PaO2/FiO2 < 300 ARDS was present in 17 and acute lung injury in 15 cases. Grogorakos L, Markou N, Psalida V et. al. Near-drowning: clinical course of lung injury in adults. Lung 2009;187(2):93-7*
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QUESTIONS:

1. Which of the following is not a correct statement about the initial assessment and treatment of potential drowning patients?

- Assess Airway, Breathing and Circulation as per standard ATLS principles.
- Spine precautions are less important in water related injuries.
- Measures to prevent hypothermia (remove wet clothing and measures to warm the patient) is an important component of the initial treatment of a patient suffering a near drowning injury.
- Resuscitative efforts should be initiated at the scene.

2. Which of the following statements are true about drowning and near drowning injuries?

- Poor supervision of younger children in recreational water environment.
- Alcohol consumption is a significant contributing factor to fatal drowning accidents.
- Infrequent use of personal floatation devices is an important contributing factor for fatal drowning injuries.
- Inexperienced boaters are more likely to suffer fatal drowning injuries
- All of the above.

3. Which of the following is not a correct feature of near drowning and fatal drowning injuries?

- Nonfatal near drowning injuries occur most commonly in individuals < 15 years of age.
- Most near drownings occur in natural water settings;
- Fatal drowning events are more likely to involve personal watercraft, canoes and small boats.
- It is estimated that only 9% of individuals suffering a fatal drowning injury were wearing personal flotation devices at the time of their injury.
- Improving the security of pool enclosures and closer supervision of young swimmers is expected to prevent near drowning injuries.

4. Which of the following is not a mechanism used by the body to preserve and/or generate heat?

- Vasodilation.
- Shivering thermogenesis.
- Non-shivering thermogenesis.
- Active muscle movement.

5. Which of the following statements about the treatment of patients suffering a near drowning injury is not correct?

- Anoxic brain injury is a significant cause of disability following near drowning.
- Prophylactic antibiotics should be initiated in patients suffering an aspiration injury as part of their near drowning injury.
- Pulmonary secretions should be cultured in patients suffering aspiration and near drowning.

- Patients suffering hypothermia have increased pulmonary secretions which mandates aggressive pulmonary toilet.

6. Which of the following statements is not correct?

- Hypothermia affects the heart and lungs but not the coagulation system.
- Therapeutic hypothermia is an experimental treatment for anoxic brain injury associated with near drowning
- Water injection injuries may occur from falls into unobstructed water.
- Traumatic brain injury is more common following wakeboarding accidents than waterskiing accidents.
- Musculoskeletal injuries are more common following waterskiing injuries than wakeboard injuries.

7. Which of the following statements is not correct?

- Boat-propeller related injuries may cause loss of significant soft tissue and traumatic amputations.
- Skeletal fractures are more common with propeller related and personal watercraft related injuries.
- Vertebral body and spinal cord injuries occur most commonly in the cervical and upper thoracic spine in individuals sustaining injuries from personal watercraft crashes.
- Injuries resulting from personal watercraft injuries are more likely to require operative intervention that those occurring in small boats.

North Memorial Injury Prevention Kids Don't Float

In 2008, North Memorial started the **Kids Don't Float** Life Jacket Loaner program on Lake Minnetonka. With funding from Safe Kids USA and the U.S. Coast Guard Auxiliary, we have installed three life jacket loaner boxes on Lake Minnetonka. The boxes are located on Gray's Bay, Maxwell Bay and the Spring Park/Hennepin County Water Patrol boat launch. The purpose of the box is to provide personal floatation devices (PFDs) for loan at the boat launch for anyone who doesn't have one, with the intent that they will return the PFD when they come ashore again. This summer will be the third year for this program and it has been very successful.

Answers: 1. b 2. e 3. b 4. a 5. b 6. a 7. c

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