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Eye trauma is a common chief complaint among emergency department (ED) pediatric patients. Although many eye injuries can be prevented by appropriate supervision of children's activities and the appropriate use of protective eye wear, eye injuries remain an important cause of visual loss. Specific attention to the physical examination is mandatory in the evaluation of pediatric eye trauma, and although challenging should include visual acuity, pupillary reactions, external examination, ocular motility, visual field testing, slit-lamp examination, fluorescein staining, intraocular pressure, and funduscopic examination. Certain "tricks of the trade" are presented here to aid the clinician in obtaining this critical information.

Following complete evaluation, many patients with eye injuries can be managed as outpatients with appropriate medical management and ophthalmologic follow-up. Certain eye injuries warrant ophthalmologic consultation, including hyphema, penetrating globe injury, suspected or known open globe injury, retrobulbar hematoma, or any eye injury resulting in significant visual loss. The authors present a complete review of the evaluation and management of the patient with a potential eye injury.

— *The Editor*

Keeping an "Eye" on the Patient: Pediatric Eye Trauma

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Introduction

Eye trauma is a common chief complaint among ED patients. It is estimated that 2.4 million eye injuries occur annually in the United States, accounting for 0.2% of ED visits; approximately one-third of eye injuries occur in pediatrics.[1,2] The majority of injuries occur in the home, followed by public places, such as schools or athletic facilities.[3] The most common injuries include corneal abrasion, blunt trauma, and corneal foreign body.[4,5] Ocular trauma is one of the most significant causes of visual loss in pediatric patients. Many eye injuries can be pre-

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vented by appropriate supervision of children's activities and the appropriate use of protective eye wear during sports.

Eye injuries often are isolated injuries and may be managed as outpatients; Approximately 2-3% of patients require inpatient hospital admission.[6] It is important to note, however, that eye injuries also may be associated with major trauma, particularly in patients with facial fractures, facial contusions, or basilar skull fractures; patients require a comprehensive evaluation to exclude concomitant injuries.[7,8]

Examination of the Injured Eye in the Pediatric Patient

Examining the injured eye of a pediatric patient may pose a significant challenge. Most patients older than age 3 can be successfully examined using interactive distracting techniques and parental assistance; rarely, a papoose board or sedation may be required to complete an adequate examination. Topical anesthesia may give the patient comfort during the eye examination. After collecting a comprehensive history, the physical examination of the eye should include these elements: visual acuity, pupillary reactions, external examination, ocular motility, visual field testing, slit-lamp examination, fluorescein staining, intraocular pressure, and funduscopic examination.[9] However, certain areas of a thorough eye examination are age specific, other areas are independent of age, and most depend on patient cooperation. Remember to perform the more uncomfortable portions of the examination last.

Visual acuity is the vital sign of the eye, and is absolutely essential in the evaluation of eye trauma. An adhesive eye patch should be used for the assessment of vision in children. Inadvertent peeking around a parent's hand or wand occluder can lead to a false determination of vision in the traumatized eye. Visual acuity should never be excluded and the only time that it should be postponed is when a patient presents with a chemical exposure to the eye requiring immediate irrigation. Visual acuity in the neonate, infant, and toddlers is performed by assessing pupillary reaction to light. A light source should be used 1-3 feet away; the ability to track and fixate on light determines adequate visual acuity. Steady fixation is considered roughly equivalent to 20/40, unsteady fixation is equivalent to 20/100, and inability to fixate is equivalent to 20/400. By the age of 2-3 years, normal development places visual acuity at 20/20; therefore, a child should be able to participate in formal acuity testing by this age.

Formal visual acuity testing is performed using a Snellen chart, Allen figures (pictures), or rotating "E" chart at 20 feet. Testing should always be done with correction (if possible) or with a pin hole device if the patient is myopic. A pre-made pinhole device will correct most refractive errors to at least 20/30. If a pinhole device is not available, a quick alternative can be made using an 18-gauge needle and an index card, or a metal eye shield with multiple small holes also can be used. If a refractive error exists beyond 20/30, it should not be attributed to simple refractive error. When patients are unable to read the first line (20/200), shorten the distance to 10 feet and ask them to read the top line (10/200). Continued inability to read any letters will necessitate the physician counting his or her fingers for the patient and recording the distance at which the patient reports visualizing them (e.g., able to count 3 fingers at 3 feet). If the patient is unable to count fingers, then attempt to see if he or she can visualize gross hand motion or are able to detect light perception.[10,11]

Pupil examination should include size, shape, symmetry, and reaction to light. A unilateral dilated pupil raises concern for compression of the third nerve, which may be a sign of uncal herniation, especially when it is associated with traumatic head injuries. If this finding is present, the physician should perform a more detailed assessment, as there are other causes of unequal pupils, such as anisocoria or direct pupillary injury.

Tear drop pupils should alert the emergency physician that ocular perforation has occurred. After a penetrating injury to the eye, the pupillary margin and portions of the iris are drawn into the penetrating wound, causing a tear drop appearance with the apex pointing to the injury. During the pupillary exam, if a penetrating injury to the eye is suspected, avoid applying any pressure to the eye.

Examination of the eye should include evaluation for an afferent pupillary defect. A swinging flashlight test will deter-

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mine if there is a relative afferent pupillary defect, also known as a Marcus Gunn pupil. A relative afferent pupillary defect can be seen in traumatic optic neuropathy. Shining a light on the uninvolved eye results in constriction of both the ipsilateral pupil (direct response) and contralateral pupil (consensual response). When the light is swung to the pupil with a damaged optic nerve or chiasm, it is as if the intensity of the light has diminished (reduced input along a damaged afferent system) and the pupil dilates. If the patient has suffered bilateral symmetric traumatic optic neuropathy, there will be no afferent pupillary defect (APD). Damage to the efferent system of the pupil, either cholinergic as in a third nerve palsy or sympathetic as in Horner's syndrome, results in unequal pupil size or anisocoria.[12]

External examination of the eye includes observing for proptosis (suggestive of retrobulbar hematoma) and enophthalmos (suggestive of ocular rupture or blow-out fracture). The eyelids should be examined for lacerations, contusions, and punctures. The inner aspects of the eyelids should be examined, looking for foreign bodies and subconjunctival hemorrhage. The cornea, sclera, and conjunctiva should be examined by gross inspection as well as by slit lamp examination. The anterior chamber should be examined after the patient has been upright for several minutes to allow visualization of a hyphema, if present. Evaluate the conjunctiva to detect lacerations, foreign bodies, or underlying scleral perforations.

Ocular motility should be assessed and documented. If a patient is unable to move the eye in a certain direction, concerns for entrapment of a muscle from an orbital blow-out fracture, direct muscle injury, or central nervous problem should be considered. If the complaint is diplopia after trauma, evaluation should assess whether the diplopia is monocular (typically lens related) or binocular (entrapment, muscle injury, or CNS injury).

Visual field testing can be brief and simply involve the four major quadrants of vision; formal visual field testing can be done at a later time. Visual field testing is important to perform, especially if the history suggests the possibility of retinal detachment or vitreous hemorrhage (e.g., new floaters or flashes of light after eye trauma). Performing visual field testing is quick and easy. The patient should cover one eye and the physician should get at eye level and hold his fingers halfway between himself and the patient. The patient should be asked to look at the physician's nose while he or she slowly brings fingers from the outside in, making sure the patient does not look away from the physician's nose and toward the fingers. Binocular visual field loss is typically neurological in nature.

Slit lamp examination in older children is performed using the same technique as that used for adults. Younger children may feel more comfortable sitting on a parent's lap for the examination. Some tricks to making younger children more cooperative for the examination is to coax them into seeing something fun in the slit lamp (e.g., favorite cartoon character). Have parents place their chin in the device first to reassure the child, and tell the child that they will see a "pretty blue light." When examining infants, ask parents to sit and support the child's bottom with one hand while resting the other hand on the back of the infant's head. If the child is not cooperative, a Wood's lamp may be used as an alternative to diagnosing corneal defects; however, Wood's lamp examination does not allow the detail of inspection afforded by slit lamp examination. Some direct ophthalmoscopes have a cobalt blue light that can facilitate detection of a corneal abrasion.

Intraocular pressure (IOP) evaluation is useful in the setting of non-open globe trauma. IOP testing is contraindicated in suspected globe perforation, corneal abrasion, and foreign bodies. IOP evaluation is useful in patients with simple hyphemas in whom you do not suspect ocular rupture. IOP can be measured with a portable tonometer, or using slit lamp applanation tonometry. Normal IOP is 21 mmHg or less. Errors in tonometry can easily be made by placing too much pressure on the eye or the patient blinking or crying, all of which may artificially elevate IOP.

Finally, to view the posterior portions of the eye and retina, funduscopic examination is indicated. To assist in good visualization of the optic nerve and retina, have lights in the room turned off and turn the intensity of the ophthalmoscope to its lowest setting and smallest aperture. While examining infants, making creative noises and clicking sounds will enhance your success. Toddlers may be afraid of the ophthalmoscope, but allowing them to see it up close and possibly hold it may take away some of their anxiety. Another trick with toddlers is to ask them to look for their favorite cartoon character in the light as you are performing your examination. Ideally, funduscopic examination is best performed after dilation. Pupils should not be dilated if serial neurologic exams are to be performed or if acute angle closure glaucoma is suspected.

Corneal Abrasions

Corneal abrasions are one of the most common eye injuries and may occur from a variety of mechanisms, including, among others: projectiles, foreign bodies, direct trauma, fingernails, contact lenses, and bee stings.[13,14] Symptoms of corneal abrasion may include pain, tearing, blepharospasm, photophobia, or foreign body sensation.

Examination should include evaluation of the location, depth, and surface area of the abrasion, using fluorescein staining and slit lamp examination. Lid eversion should be performed to rule out retained foreign body. Current treatment includes pain control, topical antibiotics, topical analgesics, and cycloplegic agents. Eye patching has no demonstrated benefit and is no longer recommended for corneal abrasions.[15-18] Patching impairs depth perception and was shown in children to result in difficulty with ambulation.[18]

A topical antibiotic is indicated to prevent bacterial infection, although antibiotics do not have proven benefit in improved outcomes. Appropriate choices may include a topical quinolone, such as ciprofloxacin or ofloxacin drops, erythromycin ointment, polymyxin/trimethoprim drops, or numerous others.

Topical analgesics such as dicolfenac (Voltaren) and ketorolac (Acular) have shown a beneficial effect in reducing pain in corneal abrasions. A meta-analysis review of five randomized controlled studies showed a reduction of pain on a visual analog scale.[19] Patients using topical nonsteroidal antiinflammatory drugs (NSAIDs) had greater relief of pain and used fewer oral analgesics and narcotics; however, an increase in initial transient stinging was commonly noted as an adverse effect.[19,20]

The use of a cycloplegic agent, such as homatropine or atropine, will relieve pain resulting from ciliary spasm. Home use of topical anesthetics should be avoided, due to negative effects on healing and increased risk of recurrent injury. Tetanus toxoid is routinely recommended for patients without an updated immunization status;[21] however, a search of the literature from two separate sources did not identify any cases of clinical tetanus developing from a simple corneal abrasion.[22]

Most corneal abrasions heal well within 24 hours. Rarely, complications may occur; these include: delayed healing, scarring, infection, visual loss, or missed retained foreign body. Close follow-up is essential to ensure appropriate healing and relief of symptoms. In particular, injuries that result from vegetable or botanical matter or contact lens injury make the patient at higher risk for *Pseudomonas* infection and require close follow-up.

Corneal Foreign Bodies

A great variety of intraocular foreign bodies have been described, including metal fragments, wood, plastic, and others. Once it is determined that the injury to the eye is caused by a simple foreign body with resultant corneal abrasion, removal of the foreign body should be performed under slit lamp visualization. This should allow consistent and stable removal of the offending irritant.[23]

Corneal foreign bodies often can be safely removed in the ED. In an effort to remove an irritant from the pediatric eye, an attempt at removal with a moistened cotton tipped swab may be attempted first. If this effort is unsuccessful, the use of a needle is indicated to remove the foreign body. It is important to reassure the patient and parents that the needle does not go into the eye, but merely rests on the surface. In younger children, procedural sedation may be necessary to facilitate the removal of the foreign body. Attach a standard 5/8 inch 25-gauge needle to a 3 mL syringe for stability. Some prefer to bend the needle shaft 30 degrees to facilitate the approach to the eye. The foreign body can then be gently lifted off of the surface of the cornea. Once the foreign body is dislodged, use a moist cotton swab to remove it from the surface of the eye if necessary. If a rust ring remains following removal of a metallic foreign body, this also may be removed in the ED with either the needle or a burr. It also is acceptable to schedule ophthalmology follow-up for removal within 24-48 hours.[24] If the child is unable to cooperate, ophthalmology consultation is indicated.

Following foreign body removal, reexamine the eye to make sure no signs of ocular penetration are present. Pay particular attention for any leak of fluid that appears to be a green stream after application of fluorescein dye (Seidel's sign). After the foreign body is removed and ocular perforation is excluded, then treat the injury as a typical corneal abrasion.

Penetrating Ocular Injuries

Common causes of penetrating ocular injuries include glass, BB's, metallic fragments, toys, sticks, and wood/plastic particles that have become projectiles.[23,25] Bony fracture fragments also may cause intraocular foreign bodies or injury.[26] Most injuries could have been avoided if proper safety equipment, mainly safety glasses, were worn.[27] Factors associated with worse prognosis include objects with higher mass or objects with a blade shape, as opposed to disc, cylinder, or sphere shapes.[28] Clinical factors predictive of poor outcome include visual acuity worse than 20/200, pupillary abnormalities, and hyphema.

Children are at higher risk for open globe injuries than adults; open globe injuries are the leading cause of monocular blindness in children world wide.[29] Associated injuries may include corneal injury, scleral laceration, retinal detachment, or numerous other injuries. Thus, whenever a penetrating injury to the eye is suspected, a complete physician examination should be conducted, and ophthalmologic consultation obtained.[30] Penetrating injuries may present immediately or up to years following the injury.[31]

Terms relevant to penetrating eye injuries include:

Laceration: a defect in the cornea or sclera caused by a sharp object;

Rupture: a disruption of the cornea or sclera caused by indirect forces or agents of blunt trauma, including low-velocity missiles such as BB's;

Penetration: any injury that traverses the partial thickness of the sclera or cornea;

Perforation: any injury that traverses the full thickness of the sclera or cornea; and

Double perforation: any injury that enters the eye and traverses the intraocular cavity and exits the sclera on the opposite side.[30]

The anatomy of the bony orbit protects the eye from most oblique and posterior injuries. Smaller missiles and sharp objects are often capable of entering the area within the orbital rim, increasing the likelihood of piercing the globe. Therefore, ocular penetration must be suspected whenever there has been a laceration, puncture, or disruption of the eyelids or orbital bone; or periorbital ecchymosis.[32]

In many cases, high-velocity projectiles that are small may penetrate the eyelid /globe and cause little pain or visual disturbance at all. The cornea may seal over the entry portal, leading to

Table 1. Management of Perforating Eye Injuries

1. Document visual acuity.
2. Protect eye with metal shield.
3. Do not touch the eye or attempt tonometry.
4. Do not instill any drops.
5. Obtain imaging of the orbits (x-ray or CT scan).
6. Administer systemic antibiotics.
7. Administer tetanus prophylaxis as indicated.
8. Administer antiemetics to prevent rise of intraocular pressure.
9. Obtain immediate ophthalmology consultation.

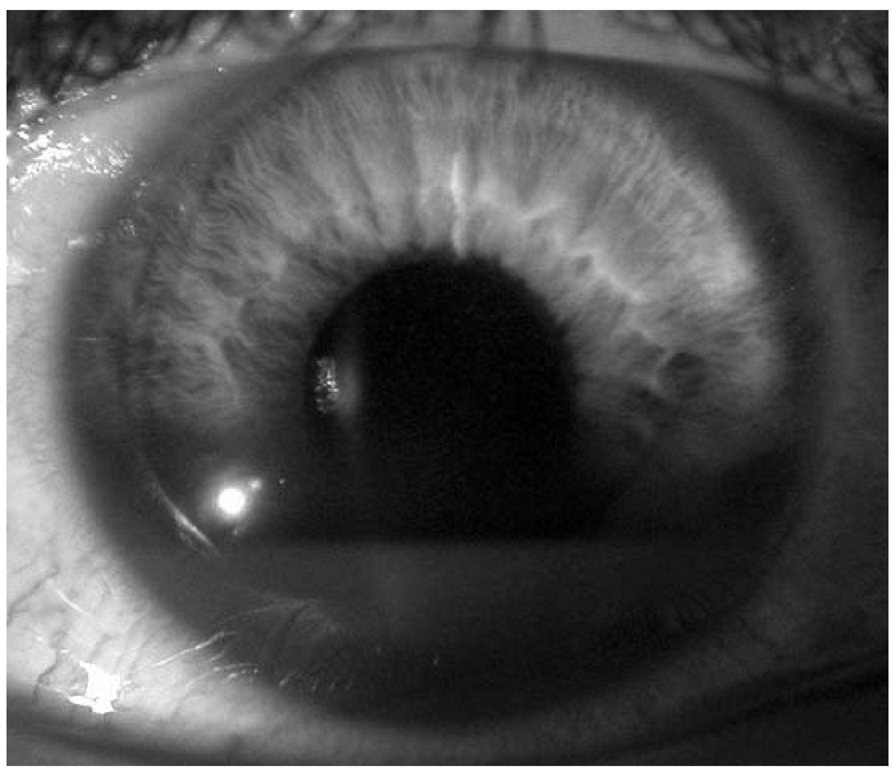
Table 2. Pitfalls in Management of Perforating Eye Trauma

1. Intraocular foreign bodies may be missed in asymptomatic patients with normal vision.
2. Negative x-ray or CT scan does not rule out the possibility of an intraocular foreign body.
3. Negative Seidel's test does not rule out full thickness corneal laceration (may simply be the result of self sealing wound).
4. All patients with suspected ocular perforation require ophthalmology consultation.

a paucity of eye findings. Intraocular foreign bodies should be considered in all penetrating eye injuries. If a penetrating globe injury is suspected, no pressure should be exerted on the eye because of risk of expelling intraocular contents. Perform a complete neurologic examination and obtain a through history of the events, keeping in mind that children may not tell the entire truth for fear of negative consequences. A detailed ocular examination should include visual acuity testing; pupillary testing; examination of the cornea, sclera and anterior chamber with slit lamp when possible; and funduscopic exam. Special attention should be made to look for signs of possible perforation, such as extensive subconjunctival hemorrhage and chemosis, collapse and hemorrhage in the anterior chamber, pupil and iris irregularities, positive Seidel's test, and traumatic cataract. Seidel's test is conducted by instilling fluorescein into the affected eye and examination under a slit lamp for a bright green stream of fluid resulting from the outflow of aqueous humor. If examination cannot be adequately performed due to emotional distress or poor cooperation, suspicion of a penetrating injury justifies an ophthalmologic consultlation for possible evaluation under anesthesia in the operating room where the nature and extent of the injury may be adequately addressed.

All penetrating eye injuries or suspected penetration warrant radiographic imaging. Be aware that x-ray may serve to reveal the size and number of metallic foreign bodies; however, it does not determine the exact three dimensional orientation of the foreign body with respect to the globe. Plain films also are not adequate for full evaluation of adjacent boney structures, sinuses, soft tissue, and the evaluation of nonmetallic objects that may be readily seen on CT scan. Randomized retrospective study of the accuracy of CT scan in evaluating open globe injuries has shown a sensitivity of 75% and specificity of 95% for picking up such injuries in the absence of clinical examination or history.[33] It is, therefore,

Figure 1. Hyphema: Blood in the Anterior Chamber of the Eye



Courtesy of Colin G. Kaide, MD, FACEP, FAAEM, The Ohio State University Department of Emergency Medicine.

Table 3. Classification of Traumatic Hyphema*

GRADE	FREQUENCY	PROGNOSIS OF 20/50 OR BETTER
Microhyphema	6-28%	75-90%
I	44-77	75-90%
II	3-20	65-70%
III	1-14	25-50%
IV	1-8	25-50%

* Adapted from: Brandt MT, Haug RH. Traumatic hyphema: a comprehensive review. *J Oral Maxillofac Surg* 2001;59:1462-70.

Table 4. Management of Hyphema

- ❑ Elevation of head to 30 degrees
- ❑ Rigid eye shield
- ❑ Topical antibiotics
- ❑ Topical corticosteroids
- ❑ Cycloplegics
- ❑ Avoid antiplatelet agents
- ❑ Treat elevated IOP (if indicated)
- ❑ Bedrest except bathroom privileges

recommended that patients with suspected intraorbital foreign bodies undergo CT scan with 1.5-3.0 mm cuts with coronal reconstruction when available.

Ultrasonography also may be helpful in the identification of intraorbital foreign bodies, although suboptimal sensitivity suggests that additional imaging should be performed if they are suspected clinically.[34] In addition, intracranial foreign bodies may be associated with perforating ocular injuries, and intracranial imaging should be considered.[35] *(See Tables 1 and 2.)*

Hyphema

Hyphema (blood in the anterior chamber) is a common condition seen after blunt ocular trauma in pediatric patients, and results from rupture of the iris or ciliary body blood vessels.[11,36] *(See Figure 1.)* Hyphema is more common among males, particularly those aged 15-18. Hyphema may occur secondary to blunt trauma, projectiles, or explosions, including specific examples of fists, balls, motor vehicle collisions, rocks, airbags, sticks, pellet guns, toys, tools, and numerous others.[37,38] Hyphema usually occurs from a tear in the anterior portion of the ciliary body. Hyphema should be observed after the patient has been sitting upright for several minutes, to allow for layering and to accentuate visualization of the hyphema. Other associated eye injuries may occur, including corneal injuries (26-40% incidence), posterior segment injuries, and rebleeding. Hyphemas are classified according to amount of hemorrhage. *(See Table 3.)*

Complications of hyphema may include corneal blood staining, visual loss, secondary glaucoma, secondary hemorrhage, and optic nerve atrophy. Factors related to poor outcome include grade of hyphema, intraocular hypertension, time for hemorrhage absorption, and associated posterior segment lesions.[39] Good visual recovery occurs in only 35% of patients with total hyphema.

Corneal blood staining occurs in 2-11% of patients with hyphema, and occurs more commonly among higher grade hyphemas. Corneal blood staining may lead to visual loss or amblyopia.

Increased intraocular pressure is common; about one-third of patients with hyphema have increased intraocular pressure.

Secondary hemorrhage is associated with increased morbidity, including corneal blood staining, secondary glaucoma, optic nerve atrophy, and visual loss. It typically occurs 2-7 days after the primary injury. It occurs more commonly in patients with poorer initial visual acuity, large hyphema (more than 33% of anterior chamber), delayed medical attention, initial elevated intraocular pressure, and use of antiplatelet medications.[40] It has been estimated that secondary hemorrhage occurs in 5-22% of patients with hyphema.[40]

Outpatient management is feasible for most patients with low-grade hyphema.[39] Although traditional management in the past included strict bed rest, sedation, and eye patching, these treatments have not demonstrated improved outcomes. Hospital admission is usually not necessary and is not associated with improved outcome, although admission may be indicated for patients with secondary hemorrhage, markedly elevated IOP, sickle cell disease, hemophilia, visual loss, child abuse or those who are noncompliant.[41] Elevation of the head to 30 degrees aids in hyphema clearance and facilitates the diagnosis of secondary hemorrhage. Patients should be told to avoid vigorous physical activity. The use of eye patching is controversial. Patching may improve comfort and reduce eye movement, although some authors argue that patching may raise the eye temperature and promote bacterial growth. Typically, topical antibiotics, cycloplegic agents, and topical corticosteroids are indicated. *(See Table 4.)* Other treatments remain controversial, and may include topical cycloplegics, systemic steroids, topical or systemic antifibrinolytics, topical beta-blockers, and carbonic anhydrase inhibitors. Surgical treatments, including paracentesis, hyphectomy, clot irrigation, or trabeculectomy, are indicated only for uncontrolled elevated IOP, corneal staining, or large hyphemas.

Thermal and Chemical Burns

Chemical burns to the eye occur as a result of direct exposure to a caustic chemical. Common sources of injury to the pediatric patient include household cleaning agents, automotive cleansers, swimming pool chlorine or other chemicals, battery acid, and other chemicals. Chemical burns are classified by tissue damage as associated with prognosis. *(See Table 5.)*

Table 5. Chemical Eye Burns Classification

GRADE	APPEARANCE	PROGNOSIS
I	Hyperemia, opacification	Complete recovery
II	Chemosis, opacification	Complete recovery
III	Severe chemosis, opacification, tissue damage	Scarring, visual loss
IV	Extensive necrosis, chemosis, opacification	Scarring, visual loss

Table 6. Management of Chemical Burns to the Eye

- ❏ Immediate and copious irrigation until pH normalizes
- ❏ Foreign body removal (if indicated)
- ❏ Debridement of devitalized tissue
- ❏ Lubricants
- ❏ Artificial tears
- ❏ Topical steroids
- ❏ Topical antibiotics
- ❏ Management of increased intraocular pressure (if indicated)

Alkali burns often are more extensive than corresponding acid burns. Alkali rapidly penetrates the cornea and leads to increased pH of the aqueous fluid, causing liquefaction necrosis with extensive loss of corneal epithelium. Widespread tissue damage may follow the rapid rise in pH.

Acid burns also may be severe; however, the coagulation necrosis initiated by acid injury limits the extent of tissue injury in many cases. Following acid exposure, protein coagulation in the corneal epithelium produces a barrier to deeper penetration of acid. Hydrofluoric acid is an exception to this mechanism and may result in extensive corneal penetration and injury.

Chemical burns should be managed with immediate and copious irrigation, which improves prognosis and outcome.[42,43] Rapid initiation of irrigation is more important than the precise irrigant solution used.[44] Irrigation may be performed with a variety of readily available solutions. Normal saline (0.9%) has a pH of 4.5-6.0 and may be associated with mild discomfort. Alternative irrigants include water (readily available, but hypotonic); lactated Ringer's solution (pH 6.2-7.5); buffered normal saline (NS), with pH adjusted to 7.4 with sodium bicarbonate; and Balanced Salt Solution Plus (BSS Plus), with a pH of 7.4.[45] The use of an intraocular irrigation lens may improve the contact of the irrigant with the cornea. Effective irrigation may require topical anesthesia and/or systemic sedatives. If the pH of the chemical-causing injury is unknown, it should be presumed to be alkali. Following alkali burns, regular pH assessment with litmus paper should be performed intermittently until the pH normalizes. Acid burns should be treated with irrigation for 15-20 minutes; alkali burns may require several hours of copious irrigation.

Thermal burns are less common, but may occur as a result of splash injuries, cigarettes/cigars, fireworks, matches, lighters, curling iron contact, and others. The eye is the most common body site injured by fireworks among pediatric patients, followed by injury to the face and hands.[46] Thermal burns may be extensive and are proportionate to the time of contact and temperature of the burn surface. Often, eye protective mechanisms spare significant eye injury, including the blink, tears, bony orbit structure, and shielding of the face by the hands and arms.

Following either chemical or thermal burns, a complete eye examination and assessment should be performed, including visual acuity, intraocular pressure, and slit lamp examination. If devitalized tissue or foreign bodies are present, debridement and removal should be performed. Following irrigation for both chemical and thermal burns, supportive measures during the healing process for both chemical and thermal burns should include ocular lubricants, artificial tears, topical corticosteroids, and topical antibiotics. *(See Table 6.)*[47-49] If intraocular pressure is elevated, appropriate therapy should be instituted. Appropriate pain management may include systemic nonsteroidal anti-inflammatory agents or opioids. Ophthalmologic consultation is indicated for most injuries. Surgical management may be indicated for significant necrotic tissue or severe injury.

Blunt Eye Trauma

Blunt injuries to the eyes range in spectrum from simple contusion to retinal detachment or globe rupture. The most common cause of blunt trauma to the eye in children are sports and recreational events, which make up more than 59% of blunt injuries to the eye.[2] Sport activities such as basketball, baseball, water sports, and racquet sports account for most injuries.[12] The extent of the damage to the eye is dependent upon the size, velocity, hardness of the object, and the amount of direct force placed on the eye. It is well established that penetrating injuries to the eye have a history of poorer prognosis than blunt injuries; however, serious blunt injuries can cause a significant intraocular disruption that may cause vision threatening injuries that will need to be recognized and referred.[6]

There are two major blunt ocular injury patterns that every emergency physician should be aware of: direct globe injury and orbital fracture. A direct blow to the globe is usually caused by smaller objects that can by-pass the bony orbital rim and strike the eye directly. Forces that directly hit the eye cause a rapid compression of the globe anterior-posteriorly, with corresponding expansion/dilation of the middle of the globe. The transmission of these forces produces extensive tearing and stretching forces that cause several types of injuries.

When the eye is struck the anterior chamber is compressed and the pupil is forced to dilate rapidly. The iris may tear, causing rupture of sphincter pupillae, which can lead to traumatic mydriasis. Force distributed directly to the peripheral iris can cause the iris to detach from its root (iridodialysis). A traumatic cataract may be seen when compressive forces damage the lens. Alternatively, the lens can be dislocated from the tearing of its insertion at the zonules. Signs of lens subluxation or dislocation include blurry vision and monocular diplopia. The eye should be carefully inspected for the presence of a hyphema. The importance of finding a hyphema on physical exam is that it is an indicator of serious ocular injury and that structures in the anterior as well as posterior segments are likely to be damaged.

As forces are distributed beyond the lens, injuries to the posterior segment are possible. The vitreous humor is attached to the retina and large stresses are able to detach the retina, leading to retinal detachment. The choroid may be stretched and torn; due to the vascular nature of this structure, choroidal rupture may occur and present as subretinal blood on funduscopic exam. Finally, commotio retinae may be seen in the setting of blunt trauma. This localized injury is identified as a whitish discoloration of the retina on funduscopic exam, which is caused by edema of the photoreceptor cells in the retina.

Significant complications may arise as a result of blunt trauma, including visual loss, disfiguration, secondary glaucoma, or traumatic optic neuropathy.[51] General treatment for blunt ocular injuries include prophylactic eye shield, pain control, and ophthalmologic consultation. Guidelines for immediate referral include: globe rupture or suspected rupture, pupil defect with dense periorbital hematoma, hyphema, significant visual loss, or subconjunctival hemorrhage (may be masking globe rupture). Blunt injuries that may require ophthalmologic consultation within 24 hours include: minor reduced visual acuity, retinal hemorrhages, eyelid lacerations, and blow-out fractures.

Orbital Wall Fractures

Orbital fractures typically are caused by blunt impact from objects larger than the orbital rim or by impacts with flat surfaces, including falls and motor vehicle collisions. Seven bones of the skull form the orbit: the maxilla, zygoma, lacrimal, ethmoid, sphenoid, palatine, and frontal bones. The term "blow-out fracture" refers to buckling of the orbital floor following intense intraorbital pressure associated with blunt trauma, which often protects the eye from more serious internal injury.[52] Entrapment of periorbital tissues, commonly including muscle, may occur as a result of phase differences of the movement of various orbital structures.[53]

The most common area to fracture is the orbital floor and medial wall due to the bone being thinner in these regions. Orbital roof fractures make up about 5% of injuries; children younger than age 7 are more prone to these injuries. The orbital roof is a very thin structure and frontal sinuses are not fully pneumatized until approximately age 7. Blunt trauma that impacts the upper portion of the orbit is dissipated by the frontal sinus. Orbital roof fractures may communicate with the brain and are more serious injuries; intracranial hemorrhage and leakage of cerebrospinal fluid may occur. Symptoms of an orbital fracture include periorbital ecchymosis, diplopia, hypoesthesia in V_2 (lower eyelid, cheek and upper lip) distribution, pain with ocular movement (especially vertical movement), and intraorbital emphysema on plain radiograph. Symptoms of nausea and vomiting may be associated with inferior rectus entrapment and a poor outcome.[54]

Diagnosis is made by radiographic imaging, with CT scan being the preferred method. Plain radiographs of the orbits have a high false-negative or non-diagnostic rate ranging from 30-50%. MRI does provide increased soft tissue detail but is not as readily available as CT scan and bone windows *are* much better with CT scan compared to MRI. Bone cortex is not well demonstrated on MRI; thus, CT scan is far superior for the detection of orbital wall fractures. Orbital CT scan exposes the patient to similar radiation as head CT scan and orbital series of plain films (0.02-0.03 Gy).[55]

Once the diagnosis is made, two management schema are available: surgical or non-surgical. Specific findings that are of particular concern include diplopia (entrapment), restriction of extraocular movements, and enophthalmos > 2 mm, or a large posterior fracture. Careful ophthalmologic examination is essential, as 26% of patients with orbital fractures have associated ocular injuries.[56] Most orbital fractures requiring surgical intervention are repaired within two weeks.[52] The initial ophthalmologic management of orbital blow-out fractures includes treatment of the area with ice for 48 hours, nasal decongestants, broad spectrum antibiotics, elevation of head of bed while sleeping, avoidance of aspirin, avoidance of nose blowing, and ophthalmologic follow up.

Retrobulbar Hemorrhage

Retrobulbar hemorrhage is a true emergency that may require urgent intervention to preserve vision. This condition is effectively a compartment syndrome within the orbit and must be managed with the same, if not more, haste as that given to any other compartment syndrome. The time until the oxygen sensitive tissues of the optic nerve are irreversibly damaged is 60 minutes.[57]

This sight-threatening injury typically arises from orbital bleeding following a non-displaced fracture of the orbital wall. As with other compartment syndromes the natural progression of the condition is increased pressure around the globe, which results in reduced retinal perfusion, compression of ciliary vessels, stretching of the optic nerve, and exophthalmos.[58] In most cases, development of retrobulbar hemorrhage occurs within a few hours of injury; however, case reports have shown that delayed retrobulbar hemorrhages can occur after the initial injury.[59] Retrobulbar hemorrhage must be treated immediately if there is evidence of visual loss. Clinical signs include pain, proptosis, loss of vision, and presence of an afferent pupillary defect. In the unconscious patient, a tense, proptotic globe and a dilated pupil may be all that is apparent in the presence of a retrobulbar hemorrhage. CT scanning of the brain and orbits will help identify orbital wall fractures and retrobulbar blood if the diagnosis is in question. The management of a retrobulbar hemorrhage is surgical and emergent ophthalmologic consultation is warranted. Emergent lateral canthotomy and cantholysis can be performed in the emergency department to definitively treat the compartment syndrome. Incising the lateral canthus and the canthal tendon allow for egress of trapped retrobulbar blood, thereby decreasing the harmful pressure on the optic nerve. Other medical treatments of potential benefit include intravenous steroids, acetazolamide, and mannitol.

Eyelid Lacerations

Eyelid lacerations are commonly seen in pediatric patients, and are often due to falls, motor vehicle collisions, dog bites, or direct impact. Evaluation should assess potential globe injury and should include visual acuity, slit lamp examination, intraocular pressure measurement, and facial nerve function. Potential bony fractures should be ruled out by examination and radiographs, if indicated.

Simple eyelid lacerations can be successfully repaired in the emergency department. Debridement of devitalized tissue may be indicated. Superficial wounds not involving the lid margins can be closed with single or two-layer closures with small absorbable suture material. Slight eversion of wound edges should reduce scar formation. The dermal layer should not be under tension. Complex wounds, including tarsal plate involvement, canaliculi involvement, lid margin involvement, or scleral involvement require ophthalmologic consultation.[60] Tetanus toxoid should be administered if indicated.

Child Abuse

Certain eye findings may be indicative of child abuse. Any injury which does not fit the characteristic pattern and severity of the described injury should heighten suspicion of possible abuse. Retinal hemorrhage occurs rarely with accidental head trauma and is commonly associated with shaken baby syndrome, particularly when seen in association with subdural hemorrhage, abnormal mental status, or seizures.[61,62] Bilateral subconjunctival hemorrhages may be seen in infants as a result of asphyxia.[63]

Conclusions

Eye trauma is a common chief complaint among emergency department pediatric patients. Many eye injuries can be prevented by appropriate supervision of children's activities and the appropriate use of protective eyewear during sports. Detailed physical examination is indicated for the evaluation of pediatric eye trauma, and should include visual acuity, pupillary reactions, external examination, ocular motility, visual field testing, slit-lamp examination, fluorescein staining, intraocular pressure, and funduscopic examination.

Most patients with eye injuries can be managed as outpatients with ophthalmologic follow-up and appropriate medical management. Certain eye injuries warrant emergent ophthalmologic consultation, including hyphema, penetrating globe injury, suspected or known open globe injury, retrobulbar hematoma, or any eye injury resulting in significant visual loss.

References

1. McCaig L, Burt CW. National Hospital Ambulatory Medical Care Survey: 2002 Emergency Department Summary. Centers for Disease Control: Advance Data from Vital and Health Statistics: no. 340. Hyattsville, Maryland: National Center for Health Statistics, 2004. http://www.cdc.gov/nchs/data/ad/ad340.pdf. Accessed on 6/18/07.
2. Brophy M, Sinclair SA, Hostetler SG, et al. Pediatric eye injury-related hospitalizations in the United States. *Pediatrics* 2006;117:e1263-1271.
3. McGwin G, Owsley C. Incidence of emergency department-treated eye injury in the United States. *Arch Ophthalmol* 2005;123:662-666.
4. Kumar NL, Black D, McClellan K. Daytime presentations to a metropolitan ophthalmic emergency department. *Clin Experiment Ophthalmol* 2005;55:586-592.
5. MacEwen CJ, Baines PS, Desai PS. Eye injuries in children: the current picture. *Br J Ophthalmol* 1999;83:933-936.
6. MacEwen CJ. Ocular injuries. *J R Coll Surg Edinb* 1999;44:317-23.
7. Garcia TA, McGetrick BA, Janik JS. Ocular injuries in children after major trauma. *J Pediatr Ophthalmol Strabismus* 2005;42:349-54.
8. Garcia TA, McGetrick BA, Janik JS. Spectrum of ocular injuries in children with major trauma. *J Trauma* 2005;59:169-174.
9. Handler JA, Ghezzi KT. General ophthalmologic examination. *Emerg Med Clin North Am* 1995;13:521-538.
10. Datner EM, Jolly T. Pediatric ophthalmology. *Emerg Med Clin North Am* 1995;13:669-679.
11. Ervin-Mulvey LD, Nelson LB, Freely DA. Pediatric eye trauma. *Pediatr Clin North Am* 1983;30:1167-1183.
12. Rodriguez JO, Lavina AM, Agarwal A. Prevention and treatment of common eye injuries in sports. *Am Fam Physician* 2003;67:1481-1488.
13. Baumeister M, uhli-Hattenbach C, Luchtenberg M. Corneal ulcer caused by a wooden foreign body in the upper eyelid 6 months after minor injury. *Ophthalmologica* 2006;220:397-399.
14. Caca I, Ari S, Ulu K, et al. Bee sting of the cornea: a case study and review of the literature. *Ann Ophthalmol* 2006;38:77-79.
15. Turner A, Rabiu M. Patching for corneal abrasion. *Cochrane Database Syst Rev* 2006;(2):CD004764.
16. Kaiser PK. A comparison of pressure patching versus no patching for corneal abrasions due to trauma or foreign body removal. Corneal

Abrasion Patching Study Group. *Ophthalmology* 1995;102:1936-1942.
17. Wilson SA, Last A. Management of corneal abrasions. *Am Fam Physician* 2004;70:123-128.
18. Michael JG, Hug D, Dowd MD. Management of corneal abrasions in children: a randomized clinical trial. *Ann Emerg Med* 2002;40:67-72.
19. Calder LA, Balusubramanian S, Fergusson D. Topical nonsteroidal anti-inflammatory drugs for corneal abrasions: meta-analysis of randomized trials. *Acad Emerg Med* 2005;12;467-473.
20. Weaver CS, Terrell KM. Evidence-based emergency medicine. Update: do ophthalmic nonsteroidal anti-inflammatory drugs reduce the pain associated with simple corneal abrasions without delaying healing? *Ann Emerg Med* 2003;41:134-140.
21. Benson WH, Snyder IS, Granus V, et al. Tetanus prophylaxis following ocular injuries. *J Emerg Med* 1993;11:677-83.
22. Mukherjee P, Sivakumar A, et al. Tetanus prophylaxis is superficial corneal abrasions. *Emerg Med J* 2003;20:62-64.
23. Gallin PF. *Pediatric Ophthalmology: A Clinical Guide*. New York: Thieme Medical. 2000.
24. Webb LA. *Manual of Eye Emergencies: Diagnosis and Treatment.* Second Ed., London: Butterworth-Heinemann. 2004
25. Gopal L, Banker AS, Deb N, et al. Management of glass intraocular foreign bodies. *Retina* 1998;18:213-20.
26. Garg SJ, Benson W, Fineman M, et al. Bone from an orbital floor fracture causing an intraocular foreign body. *Am J Ophthalmol* 2005;139:543-545.
27. Smith D, Wrenn K, Stack LB. The epidemiology and diagnosis of penetrating eye injuries. *Acad Emerg Med* 2002;9:209-213.
28. Woodcock MG, Scott RA, Huntbach J, et al. Mass and shape as factors in intraocular foreign body injuries. *Ophthalmology* 2006;113:2262-2269.
29. Narang S, Gupta V, Simalandhi P, et al. Pediatric open globe injuries. Visual outcome and risk factors for endophthalmitis. *Indian J Ophthalmol* 2004;52:29-34.
30. Lubeck D. Penetrating ocular injuries. *Emerg Med Clin North Am* 1988;6:127-146.
31. McGimpsey SJ, Rankin SJ. Presentation of intraocular foreign body 25 years after the event. *Clin Experiment Ophthalmol* 2005;33:665-666.
32. Ghazi-Nouri SM, Vote BJ, Sullivan PM. Periorbital ecchymosis as a sign of perforating injury of the globe. *Clin Experiment Ophthalmol* 2005;33:194-196.
33. Joseph DP, Pieramici DJ, Beauchamp NJ. Computed tomography in the diagnosis and prognosis of open-globe injuries. *Ophthalmology* 2000;107:1899-1906.
34. Shiver SA, Lyon M, Blaivas M. Detection of metallic ocular foreign bodies with handheld sonography in a porcine model. *J Ultrasound Med* 2005;24:1341-1346.
35. Turkcuoglu P, Aydogan S. Intracranial foreign body in a globe-perforating injury. *Can J Ophthalmol* 2006;41:504-505.
36. Brandt MT, Haug RH. Traumatic hyphema: a comprehensive review. *J Oral Maxillofac Surg* 2001;59:1462-1470.
37. Saunte JP, Saunte ME. 33 cases of airsoft pellet ocular injuries in Copenhagen, Denmark, 1998-2002. *Acta Ophthalmol Sccand* 2006;84:755-758.
38. Listman DA. Paintball injuries in children: more than meets the eye. *Pediatrics* 2004;113:e15-18.
39. Rocha KM, Martins EN, Melo LA Jr, et al. Outpatient management of traumatic hyphema in children: prospective evaluation. *J AAPOS* 2004;8:357-361.
40. Fong LP. Secondary hemorrhage in traumatic hyphema. Predictive factors for selective prophylaxis. *Ophthalmology* 1994;101:1583-1588.
41. Walton W, Von Hagen S, Grigorian R, et al. Management of traumatic hyphema. *Surv Ophthalmol* 2002;47:297-334.
42. Ikeda N, Hayasaka S, Hayasaka Y, et al. Alkali burns of the eye: effect of immediate copious irrigation with tap water on their severity. *Ophthalmologica* 2006;220:225-8.
43. Kuckelkorn R, Schrage N, Keller, G et al. Emergency treatment of chemical and thermal eye burns. *Acta Ophthalmol Scand* 2002;80:4-10.
44. Herr RD, White GL, Bernhisel K, et al. Clinical comparison of ocular irrigation fluids following chemical injury. *Am J Emerg Med* 1991; 9:228-231.
45. Saidinejad M, Burns MM. Ocular irrigant alternatives in pediatric emergency medicine. *Pediatr Emerg Care* 2005;21:23-26.
46. Witsaman RJ, Comstock RD, Smith GA. Pediatric fireworks-related injuries in the United States: 1990-2003. *Pediatrics* 2006;118:296-303.
47. Hammerton ME. Burns to the eye: an overview. *Aust Fam Physician* 1995;24:998-1003.
48. Hammerton ME. Management of ocular burns. *Aust Fam Physician* 1995;24:1006-1010.
49. Spencer T, Hall AJ, Stawell RJ. Ophthalmologic sequelae of thermal burns over ten years at the Alfred Hospital. *Ophthalmic Plast Reconstr Surgery* 2002;18:196-201.
50. Bouchard CS, Morno K, Perkins J, et al. Ocular complications of thermal injury: a 3-year retrospective. *J Trauma* 2001;50:79-82.
51. Wang BH, Robertson BC, Girotto JA, et al. Traumatic optic neuropathy: a review of 61 patients. *Plast Reconstr Surgery* 2001;107:1755-1764.
52. Brady SM, McMann MA, Mazzoli RA, et al. The diagnosis and management of orbital blowout fractures: update 2001. *Am J Emerg Med* 2001;19:147-154.
53. Fujino T, Makino K. Entrapment mechanism and ocular injury in orbital blowout fracture. *Plast Reconstr Surg* 1980;65:571-576.
54. Cohen SM, Garrett CG. Pediatric orbital floor fractures: nausea/vomiting as signs of entrapment. *Otolaryngol Head Neck Surg* 2003;129:43-47.
55. Mauriello JA, Lee HJ, Nguyen I. CT of soft tissue injury and orbital fractures. *Radiol Clin North Am* 1999;37:241-252.
56. Cook T. Ocular and periocular injuries from orbital fractures. *J Am Coll Surg* 2002;195:831-34.
57. Perry M, Dancey A, Mireskandari K, et al. Emergency care in facial trauma — a maxillofacial and ophthalmic perspective. *Injury* 2005;36:875-896.

58. Gerbino G, Ramieri G A, Nasi A. Diagnosis and treatment of retrobulbar haematomas following blunt orbital trauma: a description of eight cases. *Int J Oral Maxillofac Surg* 2005:34;127-131.
59. Ghufoor K, Sandhu G, Sutcliffe J. Delayed onset of retrobulbar haemorrhage following severe head injury: a case report and review. *Injury* 1998:29;139-141.
60. Chang EL, Rubin PA. Management of complex eyelid lacerations. *Int Ophthalmol Clin* 2002;42:187-201.
61. Pierre-Kahn V, Roche O, Dureau P, et al. Ophthalmologic findings in suspected child abuse victims with subdural hematomas. *Ophthalmology* 2003;110:1718-1723.
62. Bechtel K, Stoessel K, Leventhal JM, et al. Characteristics that distinguish accidental from abusive injury in hospitalized young children with head trauma. *Pediatrics* 2004;114:165-168.
63. Spitzer SG, Luorno J, Noel LP. Isolated subconjunctival hemorrhages in nonaccidental trauma. *J AAPOS* 2005;9:53-56.

CME Questions

61. What is the most essential aspect of the physical examination of the injured eye?
    A. intraocular pressure
    B. ocular motility
    C. pupillary response
    D. visual acuity
    E. visual field testing

62. A 5-year-old child presents with a corneal abrasion resulting from being hit in the eye with a tree branch. What type of secondary infection poses a threat to uncomplicated healing?
    A. *Aeromonas hydrophilia*
    B. *Clostridium perfringens*
    C. Methicillin-resistant *Staphylococcus aureus*
    D. *Pseudomonas aeruginosa*
    E. *Streptococcus pneumonia*

63. A 15-year-old male presents with a corneal abrasion resulting from prolonged contact lens wear. What type of secondary infection poses a threat to uncomplicated healing?
    A. *Aeromonas hydrophilia*
    B. *Clostridium perfringens*
    C. Methicillin-resistant *Staphylococcus aureus*
    D. *Pseudomonas aeruginosa*
    E. *Streptococcus pneumonia*

64. What is the preferred method of removal of corneal foreign bodies?
    A. removal with an 18-gauge needle
    B. removal with a moistened cotton-tipped swab
    C. removal with an optical burr
    D. outpatient removal within one week by ophthalmologist

65. Which of the following intraocular medications should be administered to patients with suspected perforating globe injury:
    A. antibiotics
    B. cycloplegics
    C. pilocarpine
    D. nonsteroidal anti-inflammatory drugs
    E. no ocular medications should be administered.

66. What is the priority management issue for a patient who presents with suspected alkali burn to the eye?
    A. assessment of visual acuity
    B. measurement of intraocular pressure
    C. irrigation
    D. ophthalmic antibiotic drops
    E. slit lamp examination with fluorescein

67. What acid is associated with extensive corneal injury?
    A. hydrofluoric acid
    B. hydrochloric acid
    C. sulfuric acid

CME Instructions

Physicians participate in this continuing medical education program by reading the article, using the provided references for further research, and studying the questions at the end of the article. Participants should select what they believe to be the correct answers, then refer to the list of correct answers to test their knowledge.

To clarify confusion surrounding any questions answered incorrectly, please consult the source material. After completing this activity, you must complete the evaluation form that will be provided at the end of the semester and return it in the reply envelope provided to receive a credit letter. When your evaluation is received, a credit letter will be mailed to you.

CME Objectives

The CME objectives for *Pediatric Emergency Medicine Reports* are to help physicians:

a.) Quickly recognize or increase index of suspicion for specific conditions;

b.) Describe the epidemiology, etiology, pathophysiology, historical and physical examination findings associated with the entity discussed;

c.) Correctly formulate a differential diagnosis and perform necessary diagnostic tests;

d.) Apply state-of-the-art therapeutic techniques (including the implications of pharmacologic therapy discussed) to patients with the particular medical problems discussed; and

e.) Provide patients with any necessary discharge instructions.

D. carboxyl acid
E. oxoacetyl acid

68. What clinical finding suggests the need for urgent surgical consultation for orbital blowout fracture?
A. photophobia
B. periorbital ecchymosis
C. Grade I hyphema
D. corneal abrasion
E. diplopia

69. What ED procedure should be performed for visual loss secondary to retrobulbar hemorrhage?
A. lateral canthotomy
B. measurement of intraocular pressure
C. Seidel's test
D. anterior chamber paracentesis
E. closed globe massage

70. What eye injury is commonly associated with nonaccidental child injury?
A. hyphema
B. retinal hemorrhage
C. chemical burn
D. retrobulbar hemorrhage
E. corneal abrasion

Answers: 61. D; 62. D; 63. D; 64. B; 65. E; 66. C; 67. A; 68. E; 69. A; 70. B

In Future Issues: **Child Abuse**

PEDIATRIC Emergency Medicine Reports™
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Pediatric Eye Trauma

Management of Perforating Eye Injuries

1. Document visual acuity.
2. Protect eye with metal shield.
3. Do not touch the eye or attempt tonometry.
4. Do not instill any drops.
5. Obtain imaging of the orbits (x-ray or CT scan).
6. Administer systemic antibiotics.
7. Administer tetanus prophylaxis as indicated.
8. Administer antiemetics to prevent rise of intraocular pressure.
9. Obtain immediate ophthalmology consultation.

Pitfalls in Management of Perforating Eye Trauma

1. Intraocular foreign bodies may be missed in asymptomatic patients with normal vision.
2. Negative x-ray or CT scan does not rule out the possibility of an intraocular foreign body.
3. Negative Seidel's test does not rule out full thickness corneal laceration (may simply be the result of self sealing wound).
4. All patients with suspected ocular perforation require ophthalmology consultation.

Classification of Traumatic Hyphema*

GRADE	FREQUENCY	PROGNOSIS OF 20/50 OR BETTER
Microhyphema	6-28%	75-90%
I	44-77	75-90%
II	3-20	65-70%
III	1-14	25-50%
IV	1-8	25-50%

* Adapted from: Brandt MT, Haug RH. Traumatic hyphema: a comprehensive review. *J Oral Maxillofac Surg* 2001;59:1462-70.

Management of Hyphema

- ❑ Elevation of head to 30 degrees
- ❑ Rigid eye shield
- ❑ Topical antibiotics
- ❑ Topical corticosteroids
- ❑ Cycloplegics
- ❑ Avoid antiplatelet agents
- ❑ Treat elevated IOP (if indicated)
- ❑ Bedrest except bathroom privileges

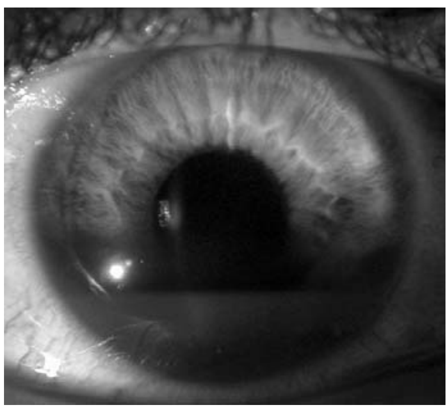
Chemical Eye Burns Classification

GRADE	APPEARANCE	PROGNOSIS
I	Hyperemia, opacification	Complete recovery
II	Chemosis, opacification	Complete recovery
III	Severe chemosis, opacification, tissue damage	Scarring, visual loss
IV	Extensive necrosis, chemosis, opacification	Scarring, visual loss

Management of Chemical Burns to the Eye

- ❑ Immediate and copious irrigation until pH normalizes
- ❑ Foreign body removal (if indicated)
- ❑ Debridement of devitalized tissue
- ❑ Lubricants
- ❑ Artificial tears
- ❑ Topical steroids
- ❑ Topical antibiotics
- ❑ Management of increased intraocular pressure (if indicated)

Hyphema: Blood in the Anterior Chamber of the Eye



Courtesy of Colin G. Kaide, MD, FACEP, FAAEM, The Ohio State University Department of Emergency Medicine.

Supplement to *Pediatric Emergency Medicine Reports*, July 2007: "Keeping an 'Eye' on the Patient: Pediatric Eye Trauma." *Authors:* Catherine A. Marco, MD, FACEP, Clinical Professor, Surgery, Medical University of Ohio, Attending Physician, St. Vincent Mercy Medical Center, Toledo, OH; and Jeffrey Salisbury, MD, St. Vincent Mercy Medical Center, Toledo, OH. *Peer reviewer:* Melanie Kazlas, MD, Acting Director, Pediatric Ophthalmology and Strabismus, Massachusetts Eye and Ear Infirmary, Harvard Medical School. *Pediatric Emergency Medicine Reports' "Rapid Access Guidelines."* **Senior Vice President and Group Publisher:** Brenda Mooney. **Editor-in-Chief:** Ann Dietrich, MD, FAAP, FACEP. **Associate Publisher:** Lee Landenberger. For customer service, call: **1-800-688-2421.**

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Trauma Reports

Vol. 8, No. 4

Supplement to *Emergency Medicine Reports* and *Pediatric Emergency Medicine Reports*

July/August 2007

Trauma is the leading cause of death in patients between the ages of 1 and 44 years and is the fifth leading cause of overall deaths in the United States. The annual cost to care for trauma is estimated at between $260 and $440 billion. Each year, more than 150,000 patients die from traumatic injuries. It is estimated that between one-third[1] and one-half[2] of these deaths occur in the out-of-hospital environment and that up to 80% of these deaths occur within the first few hours of injury.[3] This suggests that many emergency medical technicians, emergency physicians, and trauma surgeons will face the challenge of traumatic cardiopulmonary arrest following traumatic injury as a part of their clinical practice. This article reviews the incidence, cause, and factors that impact survival following traumatic cardiopulmonary arrest.

— *The Editor*

Traumatic Cardiopulmonary Arrest

Authors: **Howard A. Werman, MD, FACEP,** Professor of Clinical Emergency Medicine, The Ohio State University, Medical Director, MedFlight of Ohio; and **Robert E. Falcone, MD, FACS,** Clinical Professor of Surgery, The Ohio State University.

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Introduction

The decision to resuscitate a patient with traumatic cardiopulmonary arrest is not as simple as it may first appear. The course of action is only clear when the patient demonstrates signs of prolonged loss of vital functions (rigor mortis, dependent lividity) or an obvious unsurvivable injury (decapitation, hemicorporectomy). Many of these patients are young and in their most productive years of life; this creates an argument for aggressive management. This not only charges our decisions with an emotional element, but also implies that even limited success in the number of lives saved may reap large benefits in terms of potential economic benefit.

On the other hand, survival from traumatic cardiopulmonary arrest is unusual,[4-7] and the costs of futile resuscitation efforts can be significant. In addition, the healthcare provider must be cognizant of other concerns such as risk of exposure to blood and body fluids, consumption of valuable resources such as blood products, and risk of injury to pre-hospital providers during rapid transport.

The purpose of this article is to review the incidence and caus-

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es of traumatic cardiopulmonary arrest, identify factors that impact the outcome of these patients, and suggest a rationale approach to the management of traumatic cardiopulmonary arrest both in and out of the hospital environment.

Incidence of Trauma Arrest

The exact incidence of traumatic cardiopulmonary arrest is difficult to determine. There are an estimated 60 million people injured annually in the United States; approximately 5-10% of these patients are injured seriously. This equates to 3-6 million patients with serious injury yearly. This number can be validated by a derivation that suggests one in six of the 29.5 million patients admitted to the hospital for trauma (4.9 million hospitalizations) will have a serious injury.[8] If we assume that 80% of the 150,000 trauma deaths occur in either the out-of-hospital setting or during early resuscitation,[1-3] we can estimate that 2-4 patients out of 100 with significant trauma will suffer a traumatic cardiopulmonary arrest.

This derived estimate seems to track well with two large studies. Battistella and coworkers[9] described 604 traumatic cardiopulmonary arrests among 16,724 patients admitted to their Level I trauma center. This suggests 3.6 trauma arrests for every 100 admissions. Similarly, Stockinger and McSwain[10] found 588 traumatic cardiopulmonary arrests among 16,651 Level I trauma admissions or 3.5 trauma arrests per 100 admissions.

It is of interest that Falcone and colleagues[11] found 320 traumatic cardiopulmonary arrests among 12,518 air medical transports, or 2.6 trauma arrests per 100 transports. Presumably, many of the transported patients were not exclusively trauma patients. Margolin et al[12] found only 67 traumatic cardiopulmonary arrests among 14,905 transports. This represents a significantly lower incidence of 4.5 trauma arrests per 1000 transports and also may reflect a difference in referral patterns for air transport in their region.

Gathering more specific estimates in the scientific literature is difficult for several reasons. First, the definition of traumatic cardiopulmonary arrest varies among studies with regard to the inclusion of non-trauma diagnosis such as asphyxia, drowning, hanging, electrocution, and major burns. Many other studies include only those patients taken to trauma centers. Thus, they may underestimate the true incidence of traumatic cardiopulmonary arrest by excluding patients with early out-of-hospital death who may be pronounced in the field or transported to non-trauma hospitals. Other studies fail to identify the total number of patients admitted to the study facility or catchment area,[7,13,14] thus making any population or admission-based estimates difficult. Finally, many other authors tend to focus on segmented populations or specific mechanisms of injury,[15] which makes a true determination of incidence impossible.

Epidemiology of Trauma Arrest

It is important to understand the exact causes of early trauma deaths so that one can implement treatment protocols that address the most common causes of traumatic cardiopulmonary arrest. Baker and coworkers[16] were the first to describe the pattern of early trauma deaths. Blunt injuries caused 53% of deaths, and penetrating trauma caused an additional 40%. More than one-half of the patients (53%) died prior to arrival to the hospital, and 29% died in the first 48 hours. Sauaia et al[1] conducted a similar study in Denver. They found that 49% of deaths were due to penetrating trauma and 48% were due to blunt injury. In their study, 34% of deaths occurred before reaching the hospital and 53% died within the first 48 hours of admission. Patients with penetrating injury who reached the hospital tended to die early (first 48 hours), whereas those with blunt trauma typically suffered late deaths. Almost half (52%) of prehospital deaths were due to central nervous system (CNS) injury, and an additional 36% were due to exsanguinations or a combination of both injury patterns. In patients who died in the first 48 hours of admission, exsanguination was the major cause of death. Trunkey[2] noted that most of the out-of-hospital deaths were caused by CNS (brain and spinal cord injury) and major vascular trauma whereas early deaths were due primarily to exsanguination. These findings were recently validated in a rural setting[17] in which 42% of deaths were related to CNS injury, 20% were due to exsanguinations, and 8% were due to airway compromise.

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Correction

In the May/June 2007 issue of *Trauma Reports*, a sentence was noted incorrectly on page 3. It should have read: "Given the aging population of the United States, the incidence of hip fracture is estimated to exceed more than 500,000 cases by the year 2040."

Table 1. Leading Causes of Trauma Deaths

PREHOSPITAL	EARLY HOSPITAL
Major head injury	Hemoperitoneum
Spinal cord injury	Massive hemothorax
Traumatic aortic rupture	Retroperitoneal hemorrhage from major pelvic fractures
Major vascular injury	
Cardiac rupture	
Airway compromise	

The major prehospital and early hospital causes of death are listed in Table 1.

Factors Affecting Survival

Overall, survival from traumatic cardiopulmonary arrest is low. The survival in those studies focusing on prehospital traumatic cardiopulmonary arrest varies from 0-2.9%. *(See Table 2.)* Although much of this information is derived from studies on emergency thoracotomy, several authors have examined overall survival for those patients in which resuscitation and transport is provided. Two additional points need to be made about studies of traumatic cardiopulmonary arrest. First, there is no standardized definition or terminology that exists for this field that mirrors the the Utstein criteria used in studies involving primary cardiac arrest.[18] At a minimum, a gold standard for reporting results should be the number or percent of neurologically intact survivors. Additionally, it must be remembered that the overall survival rate for primary cardiac arrest, when measured in terms of neurologically intact survivors, is not significantly better than traumatic cardiac arrest, particularly in urban environments.[19,20]

Shimazu and coworkers[4] examined survival among 267 victims of traumatic cardiopulmonary arrest (including 217 blunt injuries and 55 penetrating injuries). There were 7 (2.6%) survivors; 4 (1.5%) were neurologically intact. Stratton et al[21] examined 1051 victims of traumatic cardiopulmonary arrest, including 497 penetrating injuries and 382 blunt trauma victims. One hundred sixteen patients were excluded for various reasons, including loss of pulse in the field. The survival rate was 0.8% for penetrating injury and 1.6% for blunt injury. Battistella and colleagues[9] found an overall survival rate of 2.6%, with nearly one-half of the survivors having neurologic sequelae. Other studies by Fulton et al[22] (2.6%) and Pasquale et al[14] (2.9%) confirm these results.

Recent studies, however, have demonstrated more promising results. Willis and coworkers[23] reported a survival rate of 4.5% among trauma arrests transported to the hospital over a four-year period. Their methodology did not include victims pronounced on-scene and also included other non-traumatic diagnoses such as electrocution. Cera and coworkers[7] noted 15 surviving patients among 195 patients (7.7%) arriving at their trauma center with CPR in progress, including 34 patients in which no resuscitation was attempted. Lockey et al[24] found a survival of 7.5% among 909 trauma arrests transported by air medical transport. This included a significant number of patients who were pronounced dead in the field. Finally, Pickens et al[13] also found an overall survival rate of 7.7% among 184 patients transported to a Level I trauma center with CPR in progress. Overall, 3590 patients with traumatic cardiopulmonary arrest were reported in these studies, with 180 (5.1%) survivors.

Several authors have evaluated more specific criteria that can be used to identify those victims of traumatic cardiopulmonary arrest, criteria that can be used to predict survival or reduce futile resuscitative efforts. These are described below.

Initial Cardiac Rhythm

At least five studies have addressed the impact of underlying cardiac rhythm on survival. Esposito and colleagues[25] were able to document an underlying rhythm in 102 of their study population. There were two survivors in this group: one with an underlying ventricular dysrhythmia and one with sinus-based PEA (pulseless electrical activity). No patient with asystole survived. Fulton et al[22] found that patients with an underlying ventricular dysrhythmia or PEA had a better outcome than those with asystole or an idioventricular rhythm. In fact, no asystolic patients survived. Interestingly, however, no patient who was defibrillated upon arrival to the trauma center survived. This contrasts with a study by Aprahamian et al[26] in which only patients who required defibrillation in the emergency department survived. In their series of 604 trauma arrests, Battistella et al[9] found no survivors among

Table 2. Survival from Traumatic Cardiopulmonary Arrest

AUTHOR	MECHANISM	NO. PATIENTS	NO. SURVIVAL	COMMENT
Shimazu et al[4]	Blunt, penetrating	267	7 (2.6%)	Only included those patients transported to hospital; only 4 neurologically intact
Stratton et al[21]	Blunt, penetrating	879	9 (1.0%)	116 patients pronounced in field excluded; 3 neurologically intact
Battistella et al[9]	Blunt, penetrating	604	16 (2.7%)	All patients included; 7 neurologically impaired
Fulton et al[22]	Blunt, penetrating	245	6 (2.4%)	Only included those patients transported to hospital
Pasqualeet al[14]	Blunt, penetrating	106	3 (2.8%)	Only included those patients transported to hospital
Willis et al[23]	Blunt, penetrating	89	4 (4.5%)	Only included those patients transported to hospital
Cera et al[7]	Blunt, penetrating	195	53 (27.2%)	Only included those patients transported to hospital
Lockey et al[24]	Blunt, penetrating	909	68 (7.5%)	Only included air transported patients
Pickens et al[13]	Blunt, penetrating	266	14 (5.3%)	Only included patients transported to hospital

212 patients who had asystole and no long-term survivors among patients with PEA and a heart rate less than 40, although 5 of 134 were admitted. All 16 survivors came from the group including those with a heart rate of more than 40 beats per minute. Stratton and colleagues[21] also found that all neurologically intact survivors had PEA with an underlying rhythm of sinus tachycardia or normal sinus rhythm. On the other hand, Cera and coworkers[7] found that PEA with an underlying sinus rhythm was predictive of better survival but 11 survivors had PEA (20.7% of survivors) and 3 survivors had ventricular dysrhythmias (5.7%). Finally, Pickens and colleagues[13] found that an underlying rate of 40 or greater showed improved survival, although 43% of survivors had a rate of less than 40. Also, none of the patients who required defibrillation in the emergency department survived. This final point may reflect that patients with multiple traumatic cardiac arrests have a uniformly poor prognosis.[23]

Duration of CPR

There is significant evidence to suggest that the duration of chest compressions may have an impact on the outcome of traumatic cardiopulmonary arrest. Mattox et al[27] reviewed 100 consecutive cases of trauma (37 blunt and 63 penetrating) in patients who received more than 3 minutes of CPR. There were no survivors in these patients. One intriguing finding was the presence of fatal air embolism in the coronary arteries on autopsy in 12 patients with lung parenchymal injury. Durham and colleagues[28] noted a statistical difference in CPR time for survivors of stab wounds, gunshot wounds, and blunt trauma. They proposed a limit of 5 minutes for patient viability following trauma cardiopulmonary arrest. Pasquale et al[14] supported these findings in 89 patients who underwent more than 5 minutes of CPR following blunt or non-thoracic penetrating trauma. There were no survivors in this population. The two survivors in the Pasquale and coworker's study[14] both had CPR of less than 5 minutes and survived neurologically intact. Fulton et al[22] found no survivors among those patients who had CPR performed for longer than ten minutes or who sustained multiple cardiac arrests. However, they concluded that CPR should not be performed for longer than 30 minutes without response. This agrees with the findings of Falcone et al;[11] in their study of air transported patients, the average time of CPR was 33 minutes. There were no survivors in their study. On the other hand, more recent work by Pickens and colleagues[13] demonstrated that 3 of their 14 survivors had CPR in progress for more than 15 minutes. This last study suggests that although shorter duration of CPR is associated with better survival, prolonged CPR does not preclude a successful outcome. Fialka and coworkers[29] showed that the average duration of closed chest CPR was 13 minutes (range, 11-15 minutes) among their surviving patients.

Advanced Life Support (ALS) Measures

The role of prehospital ALS, including airway management and intravenous access, has been hotly debated in the trauma literature. The role of specific interventions, particularly endotracheal intubation, has been considered with regard to outcome from traumatic cardiopulmonary arrest. Copass et al[30] reported on 131 patients who required CPR following traumatic injury. They found that survivors were more likely to have successful endotracheal intubation (97% versus 65%) and intravenous access (100% versus 70%). They concluded that advanced life support skills improved outcome. Durham et al[28] also supported the use of prehospital intubation demonstrating that 58% of survivors of stab wounds and 67% of gunshot wound survivors underwent field intubation. This compared to 31% and 41%, respectively, among non-survivors. There were no survivors among the 30% of patients with blunt trauma who underwent field intubation. Fulton,[22] however, found 5 survivors among 189 (2.6%) who had prehospital intubation versus 1 survivor (1.8%) among patients intubated in the resuscitation suite.

Rosemurgy and colleagues[5] reported that more than 50% of their patients had scene times in excess of 20 minutes for intubation, intravenous access, extrication, and patient packaging. They had no survivors in their study, suggesting that advanced life support measures conveyed no advantage in their patients. Stratton et al[21] reported that none of the 3 neurologically intact patients with traumatic cardiopulmonary arrest who survived (all with penetrating trauma) had field intubation, despite that 83.1% of victims with penetrating trauma were intubated. Cera et al[7] found that field intubation had no impact on survival from traumatic cardiopulmonary arrest; it was performed in 53.8% of survivors and 73.4% of non-survivors. Perron et al[31] looked at prehospital intubation in pediatric patients and found that there was a significant reduction in mortality when comparing survival in all admitted patients (29%) versus those with prehospital intubation (19%).

Thus, the role of prehospital advanced life support measures remains controversial as it relates to the treatment of traumatic cardiopulmonary arrest. It is expected that field intubation may be helpful for primary etiologies with airway compromise such as hanging or high cervical injuries but may serve to prolong scene time and duration of CPR when performed to the exclusion of other measures. Support for intubation in the pediatric population is limited. Intravenous access is less well studied as it impacts outcome from traumatic cardiopulmonary arrest.

Air Medical Transport

The use of air medical transport for traumatic cardiopulmonary arrest has been examined by several authors. Wright and colleagues[32] evaluated the use of air transport in 67 trauma patients who sustained a cardiac arrest either before or during transport. In this group, there were 86.6% blunt trauma patients. Twenty patients (29.9%) were pronounced dead on-scene. Forty-seven were transported, of which only 6 responded with a pulse. All 47 patients died. Autopsies were available in 66 cases, 61 demonstrated major head injury, cervical spine injuries, or major thoracic injury. Rosemurgy et al[5] noted that 91% of patients in their study arrived via air medical transport. As noted above, there also were no survivors in their study. This supports the futility of air medical transport in such cases.

Falcone et al[11] reviewed 320 patients who had cardiopulmonary resuscitation following trauma. Within this group, 88.9% sustained

Table 3. Survival from Traumatic Cardiopulmonary Arrest for Pediatric Patients

AUTHOR	MECHANISM	NO. PATIENTS	NO. SURVIVAL	COMMENT
Sheikh et al[34]	Blunt	27	0 (0%)	Only included patients transported to hospital
Li et al[35]	Blunt, penetrating	957	224 (23.5%)	Included only patients taken to pediatric trauma center
Perron et al[31]	Blunt, penetrating	729	165 (22.6%)	Same database as Li et al
Suominen et al[36]	Blunt, penetrating	121	4 (3.3%)	All EMS trauma arrests
Fisher et al[37]	Blunt	65	1 (1.5%)	Only included patients transported to hospital
Calkins et al[38]	Blunt	25	2 (4%)	Only included patients transported to hospital

blunt injuries and 80% were transported directly from the scene of the injury. Only 6 of 320 (1.9%) patients survived. The average CPR time was 33 minutes. There was no advantage found for mechanism of injury, CPR time, or initial underlying rhythm. An analysis of the 6 survivors revealed that 3 were revived with bystander CPR (calling into question whether they were truly in cardiac arrest) and the 3 others had vital signs upon presenting to an outside emergency department. The recommendation was to use the initial response to resuscitation as a triage tool.

A protocol of using the response to initial resuscitation efforts to activate an air medical response was supported by Margolin and coworkers,[12] who found only 13 survivors among 67 patients who sustained traumatic cardiopulmonary arrest. Blunt trauma was the mechanism of injury in 79% of cases. Twelve of the 13 survivors had a sinus based rhythm on the transport team's arrival. Survivors also had a higher systolic blood pressure and revised trauma score on arrival of the air medical team. These authors concluded that response to initial resuscitation should dictate activation of the air medical team.

Lockey et al[24] described their 10-year experience in direct response to 909 cases of traumatic cardiopulmonary arrest. There were 68 (7.5%) survivors. Seven hundred forty (81.4%) were pronounced dead on-scene. The number of patients transported after resuscitation was 169, of which 131 were ultimately admitted to the hospital. It is unclear what percentage of these 169 patients had a response to resuscitation. These authors noted that patients with primary asphyxiating injury and penetrating trauma with cardiac tamponade had a better rate of survival.

Finally, DiBartolomeo and colleagues[33] compared outcomes between basic life support-staffed (BLS-staffed) ground EMS units and a physician-staffed helicopter in the outcomes of 129 patients who suffered traumatic cardiopulmonary arrest. The demographic distribution between the 56 patients treated by helicopter crews and 73 patients treated by ground crews were similar with regard to mechanism of injury and gender. There was a statistically but not clinically significant difference in age. There were no survivors treated by ground BLS response and 2 (3%) survivors of those treated by physician-staffed helicopter crew. Both patients were neurologically impaired. These authors suggested that larger scale studies would need to be performed to determine the efficacy of air medical response.

These studies suggest that the use of air medical transport is not futile but should be limited to patients who have a response to initial resuscitation on-scene or within the referring hospital.

Pediatric Patients

Although in general, age and gender have not been shown to be a factor in survival from traumatic cardiopulmonary arrest, it is reasonable to consider whether pediatric patients have a better outcome than adult patients. *(See Table 3.)* Sheikh and Brogan[34] reported on their 5-year experience with blunt trauma victims receiving both open and closed chest CPR. All patients were in cardiac arrest at the time of presentation. All but 4 of the patients were in asystole at the time of presentation to the trauma center, although 8 patients had PEA with a sinus rhythm when first treated by EMS. The mean CPR time was between 7 and 8 minutes. Despite that 15 patients received open thoracotomy at the time of presentation, no patient survived to discharge.

Pediatric traumatic cardiopulmonary arrest also was investigated by Li et al[35]who reported on 957 patients who underwent CPR either prior to or upon admission to pediatric trauma centers reporting to the National Pediatric Trauma Registry. Of these cases, there were 224 (23.5%) survivors. There was an almost universally dismal prognosis for patients with an asystolic rhythm on arrival (1 of 87 survived). Other factors that were associated with poor outcome included: systolic blood pressure less than 60 mmHg, comatose state, penetrating trauma, and need for CPR upon admission. Sixty-four percent of survivors had some functional disability. The data from the National Pediatric Trauma Database was further examined by Perron and colleagues,[31] who also reported survival in 25% of their study subjects. They confirmed poor outcome in patients with penetrating trauma and those children requiring additional CPR. In addition, prehospital intubation was associated with a worse outcome than that seen in those children who arrived unintubated. It should be remembered that both these results may be influenced by selection bias as out-of-hospital deaths as well as pediatric trauma arrests transported to non-trauma hospitals were not included.

Suominen et al[36] presented a more dismal picture in their 10-year review of pediatric traumatic cardiopulmonary arrest. They reviewed the outcomes of 41 pediatric patients with cardiac arrest, although 15 were secondary to smoke inhalation, strangulation or electrocution. Of the 26 remaining patients, 23 suffered a blunt injury and 3 suffered penetrating injury. Two of the 26 patients survived (7.7%), with only one who was neurologically intact. Only one of 21 patients whose initial rhythm was asystole survived. No trauma patient who arrived without vital signs survived.

Fisher and coworkers[37] described their 12-year experience with 65 victims of blunt traumatic cardiopulmonary arrest in pediatric patients. Sixty-four (99%) of these patients expired, with 61 (93.8%) dying within the first 24 hours of admission. No patient survived neurologically intact. Of the 36 patients who had an autopsy, 31 had lethal cranial and cervical injuries, 16 had lethal abdominal injuries, and 12 had lethal thoracic injuries (myocardial rupture, aortic or vena caval disruption).

Most recently, Calkins and colleagues[38] described their experience with 25 children with traumatic cardiopulmonary arrest during a 3-year period. Sixty-four percent had CPR during transport, whereas 36% had CPR started in the resuscitation area. There were 2 survivors (8%), both of whom had CPR started in the trauma suite. Twenty-one patients died from severe head or spinal cord injury. Only 2 of 23 deaths (9%) were due to exsanguinating hemorrhage. Neither survivor had associated head injury or any neurologic sequelae on discharge.

These studies suggest that children have not been as well studied as adult populations but appear to have an equally dismal prognosis.

NAEMSP/COT Recommendations. Traumatic cardiopulmonary arrest, in general, has had a very dismal prognosis; this led the National Association of EMS Physicians and the American College of Surgeons Committee on Trauma to develop a joint position paper[39] that discusses a rational and measured approach to patients who sustain a cardiac arrest after trauma. These recommendations attempt to incorporate many of the findings cited above and also have incorporated much of the literature addressing emergency thoracotomy (cited later in this text). The full recommendations can be found online at: *www.naemsp.org/pdf/guideterminate.pdf*. In short, the recommendations were offered to provide guidance to health care providers who attend to victims of traumatic cardiopulmonary arrest and define situations where such efforts may be futile, costly, and risky.

At least three studies have specifically evaluated the NAEMSP/COT recommendations. Pickens[13] compared the clinical circumstances for each of their 14 survivors and found that 13 would not have undergone resuscitation if their system had utilized these recommendations. They had two surviving blunt trauma victims who were pulseless, apneic, and without an organized rhythm on presentation. Two victims of penetrating trauma were initially in asystole. Three survivors had documented CPR times in excess of 15 minutes. Willis et al[23] noted that two of their 4 surviving patients who have qualified for termination of resuscitation efforts in the field had the NAEMSP/COT guidelines been utilized. Finally, Lockey et al[24] found that 13 (36%) of their 36 survivors would have breached the guidelines had they been strictly applied. This included 5 surviving blunt trauma victims who were pulseless, apneic, and without an organized rhythm; one patient with penetrating trauma who was apneic, pulseless and without signs of life; and 7 survivors whose cardiac arrest was witnessed and resuscitation efforts exceeded 15 minutes without response. Thus it appears that the current NAEMSP/COT recommendations are not 100% sensitive in identifying patients likely to fail resuscitation efforts.

Prehospital Care of Traumatic Cardiopulmonary Arrest

Based on the information provided above, it appears that there may be no absolute recommendations that can be made regarding the out-of-hospital disposition of patients with traumatic cardiopulmonary arrest. However, there are some treatment recommendations that can be made based on the likely causes of early trauma arrest and considering those conditions that may be potentially reversible. *(See Figure 1.)* These recommendations should be consistent with the treatment algorithms proposed in the International Trauma Life Support (ITLS), Prehospital Trauma Life Support (PHTLS), and Advanced Trauma Life Support (ATLS) courses. Continued support of the patient with traumatic cardiopulmonary arrest with chest compressions and other advanced cardiac life support is essential despite evidence that chest compressions themselves can be harmful.[25]

Airway with Cervical Spine Control and Ventilatory Assistance. Given that there are many causes of early death in which both the airway and cervical spine may be at risk, it seems reasonable to emphasize the establishment of a patent airway. Airway compromise from head injury, drug and alcohol intoxication, vomitus, and secretions, as well as direct airway injury, may lead to early death. Although airway compromise is the third leading cause of traumatic cardiopulmonary arrest behind craniocervical injury and thoracic vascular injury,[40] it must remain the first priority in approaching the patient.

Basic airway maneuvers should be emphasized first, including the jaw-thrust maneuver, neutral head positioning, and adequate suctioning of the airway. As demonstrated in the previous discussion, the role of prehospital endotracheal intubation in patients with traumatic cardiopulmonary arrest remains controversial. The discussion in these patients parallels recent concerns raised by other authors about the application of this skill in the out-of-hospital treatment of both adults[41,42] and children.[43] Prehospital intubation is probably most effective in the hands of providers who use it frequently, have continued training in this skill, and who are capable of completing this task quickly and competently.

The role of alternative airways such as the laryngeal mask airway, Combitube, pharyngeotracheal lumen airway, or newer single lumen airways (e.g., King LT) in this setting needs to be explored.

Restoration of Circulating Blood Volume. Since major thoracic vascular injury is a major cause of out-of-hospital death and thoracoabdominal hemorrhage is implicated in early in-hospital death, it is essential that intravenous access be established and fluid replacement be initiated to provide any hope of success.

With regard to vascular access, care must be taken to minimize the time on-scene in patients with traumatic cardiac arrest. The current recommendation for any trauma patient is to have two large bore intravenous catheters inserted with crystalloid solutions infusing as rapidly as possible. However, the benefit of this therapy must be weighed against the time consumed establishing vascular access.[44] Intravenous access should not delay transport to an ED, especially in an urban setting. When transport times are longer (rural settings), IV fluids become more important and a minimal delay in transport becomes less important in comparison.

Although there is significant debate about permissive hypotension particularly in the setting of penetrating trauma,[45] establishing a measurable blood pressure must remain a goal in the trauma arrest victim. At least one study has suggested that a systolic blood pressure of greater than 60 mmHg upon arrival to the hospital confers a survival advantage for victims of traumatic cardiopulmonary arrest.[28]

The current resuscitation fluid recommendation remains a crystalloid solution of either normal saline or lactated Ringer's solution. Blood substitutes may be a promising alternative in the future but recent trials have been hindered by ethical concerns.[46] The use of hypertonic saline has been explored in both military[47] and civilian[48] settings as a more efficient method of restoring circulating blood volume in the setting of early shock. However, there is not sufficient evidence to conclusively support the use of this agent in the routine management of profound blood loss or traumatic cardiopulmonary arrest.

Focusing on vascular access, intraosseous infusion remains a viable option that can be established rapidly[49] and provide for rapid infusion of virtually any resuscitation fluid at rates approaching large bore peripheral intravenous lines. Sites for insertion most commonly include the sternum and proximal femur; alternative sites, including the femur and proximal humerus, also have been used. The proximal tibia seems to be ideal since it is located away from the thorax where chest compressions are provided and the landmarks are easily identified. Lower extremity fractures may preclude the use of this site and complications such as compartment syndrome and osteomyelitis must be considered.

Other Interventions. In reviewing other potentially reversible causes of traumatic cardiac arrest, both tension pneumothorax and cardiac tamponade must be considered. The classic findings of tension pneumothorax, including distant or absent breath sounds, tympany on percussion of the involved hemithorax, neck vein distention, and tracheal deviation, may be difficult to appreciate in the out-of-hospital setting. The most reliable finding is difficult ventilation of these patients. Treatment of this condition in the out-of-hospital setting relies primarily upon needle decompression of the involved pneumothorax by insertion of a catheter into the second intercostal space. Some prehospital protocols will call for empiric needle decompression of both hemithoraces in all cases of traumatic cardiopulmonary arrest based on limitations in the physical assessment of these patients. Several case reports have noted that needle catheters were not effective in relieving a tension pneumothorax.[50,51] One prospective study addressed the effectiveness of this maneuver and concluded that needle decompression is of limited efficacy.[52] However, if accomplished quickly and effectively, there is essentially no added risk to the patient, who is already "dead" and has very little else to loose.

Several studies have noted that patients with pericardial tamponade have a favorable prognosis if identified early.[53-55] Here again, the classic signs of tamponade, including muffled heart tones and distended neck veins, may be difficult to appreciate in the prehospital setting. Decompression of cardiac tamponade using a subxyphoid approach has been taught in some prehospital texts and has been in use by EMS systems. However, data on the utility of this procedure in major cardiac injury indicate that it is not effective.[56,57] Contrary to needle decompression for suspected tension pneumothorax, a significant pericardial tamponade resulting in a cardiopulmonary arrest will almost certainly require a pericardiotomy for relief and control. In this instance, even a delay of a few moments can make the difference between life and death. If a cardiac tamponade is suspected and the patient is in an urban environment, transport should be the primary consideration.

Rapid Transport. There is no doubt that the duration of cardiac arrest has an impact both on patient mortality and long-term disability of survivors. In addition, the limited success of emergency thoracotomy depends on the timely delivery of a potentially salvageable patient. Each prehospital system should develop specific policies regarding the treatment and transport of patients with traumatic cardiopulmonary arrest based on their level of training, availability of providers with advanced skills such as air medical transport, proximity to the nearest emergency department, and proximity to the nearest trauma center. In urban environments, rapid transport with minimal intervention to the area trauma center is the most efficacious strategy. In more suburban environments, transport to the nearest hospital for stabilization and secondary transport to a trauma center may be the preferred strategy. Air medical support can be instrumental in accomplishing such secondary transfers.[12] The more challenging situations arise in rural locations where there is limited access to a trauma center, where transport times to the nearest hospital can be prolonged and where the provider may be capable of basic life sup-

Figure 1. Prehospital Treatment Guidelines for Traumatic Cardiopulmonary Arrest

ENVIRONMENT	TREATMENT GUIDELINES
Urban	Basic airway and spine protection measures Definitive airway and intravenous access enroute Consider needle decompression of chest Rapid transport — trauma center preferred
Suburban	Basic airway and spine protection measures Consider definitive airway and intravenous access Fluid resuscitation Needle decompression of chest Consider pericardiocentesis (if allowed by protocol) Rapid transport — nearest hospital
Rural	Consider air medical transport for ALS skills Definitive airway and intravenous access at scene Fluid resuscitation Needle decompression of chest Consider pericardiocentesis (if allowed by protocol) Rapid transport to nearest hospital or consider air medical transport for any response

Figure 2. Treatable Conditions Leading to Traumatic Cardiopulmonary Arrest

CONDITION	TREATMENT
Airway obstruction/compromise	Establish airway
Hypoventilation (spinal cord injury, ruptured diaphragm)	Ventilate
Open pneumothorax	Seal/ventilate
Tension pneumothorax	Decompress
Massive hemothorax (major vascular or cardiac injury)	Resuscitate/control*
Cardiac tamponade	Decompress/repair
Hemoperitoneum (solid organ or vascular injury)	Resuscitate/control
Retroperitoneal hemorrhage	Resuscitate/control
Non-torso exsanguination	Resuscitate/control

* Control of hemorrhage should parallel resuscitation, and will most often require surgical intervention in the unstable patient.

port only. Options in such conditions include use of air medical support to provide advanced procedures; airway stabilization with CPR and advanced life support intercept; and field pronouncement after a period of airway intervention and cardiac compressions. The specific option chosen should be addressed in regional trauma triage protocols.

Hospital Care of Traumatic Cardiopulmonary Arrest

Care of the patient with traumatic cardiopulmonary arrest should be based on the tenets of ATLS, with a focus on the identification and treatment of immediately correctable causes of cardiac arrest. *(See Figure 2.)* Treatment priorities would include establishment of a definitive airway, provision of adequate ventilation, and insertion of chest tubes in patients with tension pneumothorax, massive hemothorax, bronchial or esophageal disruption, or diaphragmatic tear. The patient's volume status should be addressed with the administration of crystalloid solution through large bore peripheral intravenous catheters. Larger infusion catheters may be utilized and early autologous and allogeneic blood transfusion also can be considered. Either a FAST exam or diagnostic peritoneal lavage should be performed to diagnose massive hemoperitoneum. The focused abdominal sonography in trauma or FAST examination has the advantage of providing information about possible pericardial tamponade and cardiac injury. Immediate radiographs of the pelvis should be obtained to detect massive retroperitoneal hemorrhage.

However, the major decision that must be made in cases of traumatic cardiopulmonary arrest is whether to perform an emergency thoracotomy. This procedure was originally described in 1897 by Rehn[58] and was rediscovered for management of traumatic cardiac arrest in the 1960s.[59,60] The procedure is performed using a left anterior lateral approach after the patient's chest has been rapidly prepped. In about 20% of cases,[61] the incision will require an extension across the right chest to control hemorrhage. The major steps involved once the chest has been opened include: 1) direct control of any cardiac or vascular injuries; 2) identification and relief of pericardial tamponade via pericardiotomy; 3) maintenance of major organ perfusion via cross-clamping of the thoracic aorta; 4) maintenance of forward blood flow by open cardiac compression; and 5) cross-clamping the pulmonary hilum to control of air embolism. None of these sub-procedures are easy. They all require training and practice. A discussion of the technique of ED thoracotomy and the credentialing of the provider are beyond the scope of this paper. Both, however, should be discussed and decided in advance.

Outcomes studies on emergency thoracotomy have been hampered by the same problems that have beset studies of prehospital cardiopulmonary arrest. They include a lack of uniform definitions and endpoints, as well as selection bias for patients taken to trauma centers. More specifically, emergency thoracotomy has been studied in a variety of disparate situations, including not only those procedures performed on the patient arriving without a pulse, but also those who lose a pulse either in the emergency department or operating suite, those who remain persistently hypotensive despite adequate resuscitation, and even those who undergo thoracotomy for ongoing thoracic hemorrhage.

The most comprehensive review on this subject was conducted by Rhee and colleagues[62] in 2000. These authors considered only studies in which both penetrating and blunt trauma were included. Their analysis focused on true emergent thoracotomies defined as those performed in the emergency department or trauma resuscitation area. The authors examined the factors that contributed to a successful discharge from the hospital and normal neurologic outcome. Twenty-four studies from 1974 through 1998 were included in their meta-analysis. The overall survival rate was 7.4% for the 4620 thoracotomies reported in this study. The survival range was from 1.8% to 27.5% depending on patient selection. Nine of the 24 studies had survival rates in excess of 10% of eligible patients. These authors demonstrated survival rates of 1.4% for blunt trauma victims, 4.3% for gunshot wounds, and 16.8% for stab wounds. Isolated cardiac injury had a survival rate of 19.4%, whereas patients with multiple injury sites had a survival of 0.7%.

The data also were examined for patients who lost signs of life, defined as cardiac electrical activity (organized cardiac rhythm), respiratory effort, or pupillary response. Patients who lost signs of life in the field had a survival of 1.2% compared to 8.9% for those who arrested during transport or 11.5% who demonstrated signs of life on arrival and subsequently arrested during resuscitation.

Although neurologic outcome was not routinely reported, survivors were neurologically normal 92.7% of the time when reported. Based on Rhee and coworkers'[62] analysis, the following recommendations for emergency thoracotomy were made: 1) it should be performed for victims of penetrating trauma with signs of life in the field not responding to fluid resuscitation or those who lose vital signs during resuscitation; 2) it should be performed for patients with penetrating injury with any sign of life in the field who is in traumatic cardiopulmonary arrest on arrival;

3) it should be performed for patients with blunt trauma who lose signs of life in the resuscitation area or immediately prior to arrival (not further defined); and 4) no emergency thoracotomy be attempted on patients who arrive without signs of life who did not have signs of life in the field. The authors did acknowledge, however, that there is no uniform predictor of mortality.

Fialka et al[29] supported the recommendation regarding performance of an emergency thoracotomy in blunt trauma victims who lose signs of life immediately before arrival. They reported 4 survivors out of 38 blunt trauma patients who had CPR for between 11 and 15 minutes prior to thoracotomy. Only one of these survivors had signs of life on arrival to the resuscitation area. Coats et al[48] confirmed that only penetrating victims with signs of life at the scene are amenable to emergency thoracotomy. There were no survivors among their patients with penetrating injury who did not demonstrate any signs of life on-scene.

More recently, Powell et al[63] shed further light on these recommendations. They reported on 26 survivors among 959 patients who underwent emergency thoracotomy. Only 4 survivors sustained blunt trauma and the maximum duration of prehospital CPR was 5 minutes. No survivor of penetrating trauma had prehospital CPR of more than 15 minutes. These authors reported 5 survivors with an initial rhythm of asystole which had been thought to be a uniformly poor prognostic indicator. Each of these patients had pericardial tamponade. Kennedy and Sharif[64] reviewed their personal experience in performing over 100 emergency thoracotomies. They reported that only 7 survived to discharge. All were victims of penetrating injury and no survivors were in traumatic cardiopulmonary arrest upon arrival of paramedics. This author has also advocated against the use of abdominal cross-clamping in performing an emergency thoracotomy and withholding the procedure for those in cardiac arrest for more than 20 minutes. Finally, Sheppard et al[65] advocated for one additional indication for emergency thoracotomy: traumatic cardiopulmonary arrest from non-torso injury. In their series of 959 patients undergoing emergency thoracotomy, 27 had non-truncal trauma. Three of 27 (11%) survived.

Pediatric patients who undergo emergency thoracotomy have demonstrated mixed results. Beaver et al[66] had no survivors among 15 children with blunt trauma patients and 2 with penetrating trauma who underwent emergency thoracotomy. Powell and colleagues,[67] however, demonstrated 4 survivors (36%) among 11 children with penetrating injury and cardiac arrest as well as one survivor (12.5%) among the 8 blunt injury victims.

These results suggest that ideally emergency thoracotomy should be performed within 5 minutes of losing vital signs for victims of blunt trauma and 15-20 minutes for victims of penetrating trauma. Special consideration should be given to victims of non-torso trauma. Emergency thoracotomy should not be undertaken for trauma victims who had no signs of life in the field and have not responded to resuscitative efforts both in the field or following initial assessment in the resuscitation area. *(See Figure 3.)*

One special consideration that must be discussed is the care of the pregnant female who has sustained a traumatic cardiopulmonary arrest. In this setting, a rapid decision must be made with regard to performing a perimortem cesarean section. The decision should be based on gestational age and fetal viability ex-utero, and the duration of cardiopulmonary arrest. Katz and coworkers[68] first introduced the term "perimortem cesarean section" and suggested that there was a 4-minute limit to fetal viability. This short interval was determined based on the limited cardiac output produced during CPR in pregnancy due to caval compression by the uterus. Since that time, there have been multiple case reports of viable infants being delivered in the perimortem period.[69,70] A recent series from Katz et al[71] described 38 cases of perimortem cesarean section in the literature from 1986-2004. The leading cause of death was maternal trauma. The authors suggest that the period of viability extends far beyond the 4 minute limit. In fact, 7 of 38 cases described had the procedure performed after 15 minutes of CPR and the infant was neurologically intact in 4 cases. This suggests that although the decision to perform an emergent perimortem cesarean section must be made rapidly, the previous limit of 4 minutes to perform the procedure appears to be arbitrary.

Figure 3. Recommendations for Performing an Emergency Thoracotomy

1. **Blunt Trauma:** Emergency thoracotomy should be performed within 5 minutes of vital sign loss.
2. **Penetrating Trauma:** Emergency thoracotomy should be performed within 15 to 20 minutes of vital sign loss.
3. **Non-torso Trauma:** Special consideration should be given to performing an emergency thoracotomy in victims with cardiac arrest.
4. **No Signs of Life in the Field:** Emergency thoracotomy should not be undertaken for trauma victims who have not responded to resuscitative efforts either in the field or following initial assessment in the resuscitation area.

Conclusion

Almost 80% of trauma deaths occur in the first few hours following injury. Therefore, it is likely that many prehospital, emergency department, and general surgery practitioners will encounter patients with traumatic cardiac arrest in their practices. Although neurologically intact survival is rare, survival from traumatic cardiopulmonary arrest is not unknown. Studies have shown that the resources dedicated to the care of these patients and the costs incurred may be offset by the return in productivity achieved by these rare survivors.

Prehospital providers must be aware of their treatment options and limitations in caring for victims of traumatic cardiopulmonary arrest. The closer in proximity one is to a trauma center, the less intervention there is to be performed on-scene. Rural providers are hindered by longer transport times and limited advanced skills. Air medical teams should be considered a potential resource in this environment.

In the hospital, initial efforts should be focused on establishing a definitive airway and intravenous access and on identification of immediately treatable conditions. Successful resuscitation must be coupled with hemorrhage control. A rapid decision must be made regarding the benefit of emergency thoracotomy. Blunt trauma patients with more than 5 minutes of CPR and penetrating trauma victims with more than 15 minutes of CPR are unlikely to survive. The pregnant trauma patient with a viable fetus should be considered for a perimortem C-section.

Although victims of traumatic cardiopulmonary arrest with penetrating trauma, signs of life on arrival to the resuscitation area, and an underlying non-perfusing sinus rhythm have a better outcome, there are no absolute predictors of survival.

References

1. Sauaia A, Moore FA, Moore EE. Epidemiology of trauma deaths: a reassessment. *J Trauma* 1995;38:185-93.
2. Trunkey DD, Blaisdell FW. Epidemiology of trauma. *Sci Am* 1988;4:1.
3. Dykes EH, Spence LJ, Young JG, et al. Preventable pediatric trauma deaths in a metropolitan region. *J Pediat Surg* 1989;24:107-111.
4. Shimazu S, Shatney CH. Outcomes of trauma patients with no vital signs on hospital admission. *J Trauma* 1983;23:213-216.
5. Rosemurgy AS, Norris PA, Olson SM, et al. Prehospital traumatic cardiac arrest: The cost of futility. *J Trauma* 1993;35:468-474.
6. Martin SK, Shatney CH, Sherck JP, et al. Blunt trauma patients with prehospital pulseless electrical activity (PEA): poor ending assured. *J Trauma* 2002;53:876-881.
7. Cera SM, Mostafa G, Sing R, et al. Physiologic predictors of survival in post-traumatic arrest. *Am Surg* 2003;69:140-144.
8. Owens P, Elixhauser A. Hospital admissions that began in the emergency department, 2003. Healthcare Cost and Utilization Project (Statistical Brief #1). Agency for Healthcare Research and Quality. February 2006.
9. Battistella FD, Nugent W, Owings JT, et al. Field triage of the pulseless trauma patient. *Arch Surg* 1999;134:742-5.
10. Stockinger ZT, McSwain NE Jr. Additional evidence in support of withholding or terminating cardiopulmonary resuscitation for trauma patients in the field. *J Am Coll Surg* 2004;198:227-231.
11. Falcone RE, Herron H, Johnson R, et al. Air medical transport for the trauma patient requiring cardiopulmonary resuscitation: A 10-year experience. *Air Med J* 1995;14:197-203.
12. Margolin DA, Johann DJ, Fallon WF, et al. Response after out-of-hospital cardiac arrest in the trauma patient should determine aeromedical transport to a trauma center. *J Trauma* 1996;41:721-725.
13. Pickens JJ, Copass MK, Bulger EM. Trauma patients receiving CPR: predictors of survival. *J Trauma* 2005;58:951-958.
14. Pasquale MD, Rhodes M, Cipolle MD, et al. Defining “dead on arrival”: impact on a level I trauma center. *J Trauma* 1996;41:726-730.
15. Martin SK, Shatney CH, Scherk JP, et al. Blunt trauma patients with prehospital pulseless electrical activity (PEA): poor ending assured. *J Trauma* 2002;53:876-881.
16. Baker CC, Oppenheimer L, Stephens B, et al. Epidemiology of trauma deaths *Am J Surg* 1980;140:144-150.
17. Esposito TJ, Sanddal ND, Hansen JD, et al. Analysis of preventable trauma deaths and inappropriate trauma care in a rural state. *J Trauma* 1995;39:955-962.
18. Cummins RO, Chamberlain D, Hazinski MF, et al. Recommended guidelines for reviewing, reporting, and conducting research on in-hospital resuscitation: the in-hospital “Utstein-style”. *Resuscitation* 1997;34:151-183.
19. Dunne RB, Compton S, Zalenski RJ, et al. Outcomes from out-of-hospital cardiac arrest in Detroit. *Resuscitation* 2007;72:59-65.
20. Lombardi G, Gallagher J, Gennis P. Outcome of out-of-hospital cardiac arrest in New York City. The Pre-Hospital Arrest Survival Evaluation (PHASE) Study. *JAMA* 1994;271:678-683.
21. Stratton SJ, Brickett K, Crammer T. Prehospital pulseless, unconscious penetrating trauma victims: field assessments associated with survival. *J Trauma* 1998;45:96-100.
22. Fulton RL, Voigt WJ, Hilakos AS. Confusion surround the treatment of traumatic cardiac arrest. *J Am Coll Surg* 1995;181:209-214.
23. Willis CD, Cameron PA, Bernard SA, et al. Cardiopulmonary resuscitation after traumatic cardiac arrest is not always futile. *Injury* 2006;37:448-454.
24. Lockey D, Crewdson K, Davies G. Traumatic cardiac arrest: who are the survivors? *Ann Emerg Med* 2006;48:240-244.
25. Esposito TJ, Jurkovich GJ, Rice CL, et al. Reappraisal of emergency room thoracotomy in a changing environment. *J Trauma* 1991;31:881-887.
26. Aprahamian C, Darin JC, Thompson BM, et al. Traumatic cardiac arrest: scope of paramedic services. *Ann Emerg Med* 1985;14:583-586.
27. Mattox KL, Feliciano DV. Role of external cardiac compression in truncal trauma. *J Trauma* 1982;22:934-936.
28. Durham LA III, Richardson RJ, Wall MJ Jr, et al. Emergency center thoracotomy: impact of prehospital resuscitation. *J Trauma* 1992;32:775-779.
29. Fialka C, Sebok C, Pemetzhofer P, et al. Open-chest cardiopulmonary resuscitation after cardiac arrest in cases of blunt chest or abdominal trauma: a consecutive series. *J Trauma* 2004;57:809-814.
30. Copass MK, Oreskovich MR, Bladergroen MR, et al. Prehospital cardiopulmonary resuscitation of the critically inured patient. *Am J Surgery* 1984;148:20-26.
31. Perron AD, Sing RF, Branas CC, et al. Predicting survival in pediatric trauma patients receiving cardiopulmonary resuscitation in the prehospital setting. *Prehosp Emerg Care* 2001;5:6-9.
32. Wright SW, Dronen SC, Combs TJ, et al. Aeromedical transport of patients with posttraumatic cardiac arrest. *Ann Emerg Med* 1989;18:721-726.
33. DiBartolomeo S, Sanson G, Nardi G, et al. HEMS vs. ground-BLS care in traumatic cardiac arrest. *Prehosp Emerg Care* 2005;9:79-84.
34. Sheikh A, Brogan T. Outcome and cost of open- and closed-chest cardiopulmonary resuscitation in pediatric cardiac arrests. *Pediatr* 1994;93:392-398.
35. Li G, Tang N, DiScala C, et al. Cardiopulmonary resuscitation in pediatric trauma patients: survival and functional outcome. *J Trauma* 1999;47:1-7.
36. Suominen P, Rasanen J, Kivioja A. Efficacy of cardiopulmonary resuscitation in pulseless pediatric trauma patients. *Resuscitation* 1998;36:9-13.
37. Fisher B, Worthen M. Cardiac arrest induced by blunt trauma. *Pediat Emerg Care* 1999;15:274-276.

38. Calkins CM, Bensard DD, Partrick DA, et al. A critical analysis for children sustaining cardiac arrest after blunt trauma. *J Pediatr Surg* 2002;37:180-184.
39. Hopson LR, Hirsh E, Delgado J, et al. Guidelines for withholding or termination of resuscitation in prehospital traumatic cardiopulmonary arrest: joint position statement of the national association of EMS physicians and the American College of Surgeons committee on trauma. *J Am Coll Surg* 2003;196:102-112.
40. Baker CC, Oppenheimer L, Stephens B, et al. Epidemiology of trauma deaths. *Am J Surg* 1980;140:145.
41. Davis DP, Hoyt DB, Ochs M, et al. The effect of paramedic rapid sequence intubation on outcome in patients with severe traumatic brain injury. *J Trauma* 2003;54:444-453.
42. Wang HE, Peitzman AB, Cassidy LD, et al. Out-of-hospital endotracheal intubation and outcome after traumatic brain injury. *Ann Emerg Med* 2004;44:439-450.
43. Gausche M, Lewis RJ, Stratton SJ, et al. Effect of out-of-hospital pediatric endotracheal intubation on survival and neurological outcome: a controlled clinical trial. *JAMA* 2000;283:783-790.
44. Sampalis JS, Tamim H, Denis R, et al. Ineffectiveness of on-site intravenous lines: is prehospital time the culprit? *J Trauma* 1997;43:608-615.
45. Bickell WH, Wall MJ Jr, Pepe PE, et al. Immediate versus delayed fluid resuscitation for hypotensive patients with penetrating torso injuries. *N Engl J Med* 1994;331:1105-1109.
46. McKenna M. Polyheme and the ethics of informed consent. *Ann Emerg Med* 2006;48:563-566.
47. Dubick MA, Adkins JL. Small-volume fluid resuscitation for the far-forward combat environment: current concepts. *J Trauma* 2003;54(5 suppl):S43-S45.
48. Hoyt DB. Fluid resuscitation: the target from an analysis of trauma systems and patient survival. *J Trauma* 2003;54(5 suppl):S31-35.
49. Calkins MD, Fitzgerald G, Bentley TB, et al. Intraosseous infusion devices: a comparison for potential use in special operations. *J Trauma* 2000;48:1068-1074.
50. Mines D, Abbuhl S. Needle thoracostomy fails to detect a fatal tension pneumothorax. *Ann Emerg Med* 1993;22:833-836.
51. Patel GT. Needle thoracocentesis in tension pneumothorax: insufficient cannula length and potential failure. *Injury* 1996;27:758.
52. Cullinane DC, Morris JA, Bass JG, et al. Needle thoracostomy may not be indicated in the trauma patient. *Injury* 2001;32:749-752.
53. Coats TJ, Keogh S, Clark H, et al. Prehospital resuscitative thoracotomy for cardiac arrest after penetrating trauma: rationale and case series. *J Trauma* 2001;50:670-673.
54. Grove CA, Lemmon GA, McCarthy M. Emergency thoracotomy: appropriate use in the resuscitation of trauma patients. *Am Surg* 2002;68:313-317.
55. Lorenz HP, Steinmetz B, Leiberman J, et al. Emergency thoracotomy: survival correlates with physiologic status. *J Trauma* 1992;32:780-785.
56. Benyan AK, al A'Ragy HH. The pattern of penetrating trauma in Basrah Province: personal experience with seventy-two cases in a hospital without cardiopulmonary by-pass facility. *Int Surg* 1992;77:111-113.
57. McFarlane M, Branday JM. Penetrating injuries of the heart. *West Indian Med J* 1990;39:74-79.
58. Rehn L. Uber penetrirende herzwunden und hernaht. *Arch Klin Chir* 1897;55:315-329.
59. Beall AC, Oschner JL, Morris CG, et al. Penetrating wounds of the heart. *J Trauma* 1961;1:195-207.
60. Beall AC, Crosthait RW, Crewford ES, et al. Gunshot wounds of the chest: a please for individualization. *J Trauma* 1964;4:382-389.
61. Karmy-Jones R, Nathens A, Jurkovich GJ, et al. Urgent and emergent thoracotomy for penetrating chest trauma. *J Trauma* 2004;56:664-448.
62. Rhee PM, Acosta J, Bridgeman A, et al. Survival after emergency department thoracotomy: review of published data from the past 25 years. *J Am Coll Surg* 2000;190:288-298.
63. Powell DW, Moore EE, Cothren CC, et al. Is emergency department resuscitative thoracotomy futile care for the critically injured patient requiring prehospital cardiopulmonary resuscitation? *J Am Coll Surg* 2004;199:211-215.
64. Kennedy F, Sharif S. Emergency room thoracotomy: a single surgeon's thirteen-year experience. *Am Surg* 2000;66:56-60.
65. Sheppard FR, Cothren CC, Moore EE, et al. Emergency department resuscitative thoracotomy for nontorso injuries. *Surgery* 2006;139:574-576.
66. Beaver BL, Colombani PM, Buck JR, et al. Efficacy of emergency room thoracotomy in pediatric trauma. *J Pediatr Surg* 1987;22:19-23.
67. Powell RW, Gill EA, Jurkovich GJ, et al. Resuscitative thoracotomy in children and adolescents. *Am Surg* 1988;54:188-191.
68. Katz VL, Dotters DJ, Droegemueller W. Perimortem cesarean delivery. *Obstet Gynecol* 1986;68:571-576.

CNE/CME Objectives

Upon completing this program, the participants will be able to:

a.) discuss conditions that should increase suspicion for traumatic injuries;
b.) describe the various modalities used to identify different traumatic conditions;
c.) cite methods of quickly stabilizing and managing patients; and
d.) identify possible complications that may occur with traumatic injuries.

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Physicians and nurses participate in this continuing medical education/continuing education program by reading the article, using the provided references for further research, and studying the questions at the end of the article. Participants should select what they believe to be the correct answers, then refer to the list of correct answers to test their knowledge. To clarify confusion surrounding any questions answered incorrectly, please consult the source material. **After completing this activity, you <u>must</u> complete the evaluation form provided and return it in the reply envelope provided in order to receive a letter of credit.** When your evaluation is received, a letter of credit will be mailed to you.

69. Awwad JT, Azar GB, Aouad JT, et al. Postmortem cesarean section following maternal blast injury: case report. *J Trauma* 1994;36:260-261.
70. Lanoix R, Akkapeddi V, Goldfeder B. Perimortem cesarean section: case reports and recommendations. *Acad Emerg Med* 1995;2:1063-1067.
71. Katz V, Balderstron K, DeFreest M. Perimortem cesarean delivery: Were our assumptions correct? *Am J Obstet Gyn* 2006;192:1916-1921.

CME/CNE Questions

1. Major causes of prehospital trauma deaths include:
   A. major head injury.
   B. Spinal cord injury.
   C. traumatic aortic rupture.
   D. All of the above

2. A patient with which of the following initial cardiac rhythms is least likely to survive?
   A. PEA
   B. Ventricular fibrillation
   C. Asystole
   D. Sinus tachycardia

3. Shorter duration of CPR is associated with better survival, but prolonged CPR does not preclude a successful outcome.
   A. True
   B. False

4. Which of the following is true regarding ALS measures for prehospital traumatic cardiopulmonary arrest?
   A. Survivors were more likely to have successful endotracheal intubation and intravenous access.
   B. Long scene times led to better outcomes.
   C. All pediatric patients in traumatic cardiopulmonary arrest should be intubated.
   D. The value of field intubation is clear.

5. Studies suggest that the use of air medical transport is not futile, but should be limited to patients who have a response to initial resuscitation on-scene or within the referral hospital.
   A. True
   B. False

6. Pediatric traumatic cardiopulmonary arrest has been well studied and is associated with a better outcome than that found with adults.
   A. True
   B. False

7. The current resuscitation fluid of choice is:
   A. blood substitutes.
   B. crystalloid solution.
   C. hypertonic saline.
   D. colloids.

8. Which of the following is a recommended treatment guideline in a rural setting?
   A. Consider air medical transport for ALS skills
   B. Definitive airway and intravenous access at the scene
   C. Fluid resuscitation
   D. All of the above

9. Which of the following is a recommendation for performing emergency thoracotomy?
   A. Emergency thoracotomy should be performed within 45 minutes of vital sign loss for blunt trauma patients.
   B. Emergency thoracotomy should be performed within 15-20 minutes of vital sign loss for penetrating trauma patients.
   C. Emergency thoracotomy should be performed on patients who do not respond to resuscitative efforts in the field.
   D. Emergency thoracotomy should be performed on patients who do not respond to resuscitative efforts in the initial assessment in the ED.

10. Which of the following is true regarding the care of the pregnant trauma patient in cardiopulmonary arrest?
   A. Perimortem C-sections should never be performed.
   B. The decision to perform a perimortem C-section should consider gestational age and fetal viability.
   C. The leading cause of fetal death is direct fetal trauma.
   D. A perimortem C-section should never be considered after 4 minutes.

Answers: 1. D; 2. C; 3. A; 4. A; 5. A; 6. B; 7. B; 8. D; 9. B; 10. B

In Future Issues:

Pitfalls in Trauma Management

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2. describe the various modalities used to identify different traumatic conditions
3. cite methods of quickly stabilizing and managing patients
4. identify possible complications that may occur with traumatic injuries

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This issue includes an evaluation form to complete and return in an envelope we have provided. Please make sure you sign the attestation verifying that you have completed the activity as designed. Once we have received your completed evaluation form we will mail you a letter of credit. This activity is valid 24 months from the date of publication. The target audience for this activity is emergency medicine physicians and nurses, trauma surgeons and nurses.

Those participants who earn nursing contact hours through this activity will note that the number of contact hours is decreasing to 9 annually. This change is due to the mandatory implementation of a 60-minute contact hour as dictated by the American Nurses Credentialing Center. Previously, a 50-minute contact hour was used. AHC Media LLC is accredited as a provider of continuing nursing education by the American Nurses Credentialing Center's Commission on Accreditation.

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Sincerely,

Brenda 2. Mooney

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Dear *Pediatric Emergency Medicine Reports* Subscriber:

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1. Quickly recognize or increase index of suspicion for specific conditions;
2. Describe the epidemiology, etiology, pathophysiology, historical and physical examination findings associatd with the entity discussed;
3. Correctly formulate a differential diagnosis and perform necessary diagnostic tests;
4. Apply state-of-the-art therapeutic techniques (including the implications of pharmacologic therapy discussed) to patients with the particular medical problems discussed;
5. Provide patients with any necessary discharge instructions.

Each issue of your newsletter contains questions relating to the information provided in that issue. After reading the issue, answer the questions at the end of the issue to the best of your ability. You can then compare your answers with the correct answers provided in an answer key in the newsletter. If any of your answers were incorrect, please refer back to the source material to clarify any misunderstanding.

This activity is valid 36 months from the date of publication. The target audience for this activity is emergency medicine physicians.

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Sincerely,

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