CHAPTER 32
Musculoskeletal Trauma

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Introduction

Musculoskeletal trauma principally includes fractures of the bones of the extremities; however, ligamentous injuries, joint injuries, and soft tissue trauma involving muscle may also be placed in this category. This represents one of the major burdens of injury in children. In developed countries, many extremity fractures are of little consequence and are often regarded as a "badge of courage"; the child is immobilised in a plaster or fiberglass cast for a few weeks and then returns to normal activity. In the third world, however, extremity fractures and other musculoskeletal trauma can result in permanent disability and even life-threatening injuries. Perhaps the most serious complication of fracture management in Africa is "bonesetter's limbs" or "bonesetter's gangrene", which, if it does not kill the patient, can destroy all of the soft tissue of the affected limb, leaving only contractures or exposed bones.[1]

Demographics

Data from a large paediatric trauma centre in the United States indicate that fractures are the reason for more than half of all children's admissions to the hospital for injuries. The most common injury mechanism is a fall, and the most common fracture from this mechanism is a supracondylar humerus fracture. The most common bone fracture seen in victims of both motor vehicle crashes and child abuse is of the femur. The most common bone fracture in children up to age 10 years is to the humerus, and the most common bone fracture from age 11 to 15 years is to the tibia/fibula.

Data from other studies indicate that the most common paediatric long bone fracture occurs at the forearm, followed by the femur, and then the tibia. Approximately half of all tibia fractures occur in the distal third of the bone, and 70% of tibia fractures occur as isolated injuries.[2] Combined tibia/fibula fractures are most often the result of high energy trauma such as motor vehicle crashes.[2]

The incidence of paediatric musculoskeletal trauma in most African countries is unknown; however, fractures are quite common in childhood. Fractures were the second most common injury (after burns) among 798 injured children treated at Royal Victoria Hospital (RVH) in Banjul, The Gambia.[3] Motor vehicle crashes accounted for 50% of the fractures in one study.[4] Penetrating trauma can cause musculoskeletal trauma as well.

Aetiology/Pathophysiology

Most musculoskeletal trauma is caused by falls, motor vehicle crashes, and pedestrian/vehicle injuries. Child abuse is an extremely important cause of these injuries in infants and young children. One US study demonstrated that 67% of lower extremity injuries in patients younger than 18 months of age admitted to a trauma centre were due to child abuse.[5] There is virtually no literature, however, on child-abuse–associated musculoskeletal trauma in Africa. One of the rare studies of child abuse in Africa demonstrated that, of 916 paediatric autopsies for "unnatural deaths", 24 (2.6%) were attributed to child abuse.[6] By contrast, 30–50% of the paediatric fatalities at some paediatric trauma centres in the United States are due to abuse-related injuries.

Clinical Presentation

History

The history for most musculoskeletal injuries is obvious. Most children with tibia fractures, for example, will present with a history of a traumatic event. In addition, these children typically have pain, inability to bear weight, and swelling or deformity.[2]

However, injured patients younger than 3 years of age must be evaluated carefully, as 90% of child abuse cases occur in this age group.[5] These children are nonverbal, so the history must be provided by parents or caregivers. A history that changes over time or is told differently by different adults raises suspicion of an abusive injury. Likewise, a history that is not consistent with the child's developmental ability should also raise concerns. Although child-abuse–related fractures are seen daily in major paediatric trauma centres across the United States, this mechanism of injury in children is scarcely reported in the African literature.[6,7]

Physical Examination

Tenderness, pain, and swelling of an extremity or bony prominence are the hallmarks of musculoskeletal trauma. The majority of long bone fractures will have significant pain, tenderness at the fracture site, pain with passive motion, and inability to bear weight. Bruising is often not seen acutely but may develop later.

One major pitfall when examining a child for possible musculoskeletal trauma is the failure to recognise an open fracture. With some fracture mechanisms, a long bone fragment may transiently protrude through a break in the skin, only to retract when the extremity is returned to normal position. Therefore, any break in the skin in close proximity to the fracture site should be considered an open fracture.

Open fractures are categorised into three types:

- Type I: Wounds are smaller than 1 cm with minimal soft tissue damage or contamination.
- Type II: Wounds are greater than 1 cm but without extensive soft tissue damage.
- Type III: Extensive soft tissue injury can be subcategorised as having adequate soft tissue for coverage, inadequate coverage, or vascular injury requiring repair.

All patients with musculoskeletal injuries require a thorough neurovascular examination. It is critical to identify vascular injury early, so that limb loss can be prevented. The "5 P's" mnemonic is used to look for signs of vascular insufficiency in an injured limb:

1. *Pain* is the most sensitive sign. Note that this refers to pain in the distal extremity (i.e., hand or foot), not at the fracture site.
2. *Paraethesias* is numbness as well as loss of proprioception (position sense).
3. *Pallor* is pale appearance of the hands or feet.
4. *Poikolothermia* is cold to the touch.
5. *Pulselessness* is a late sign. Permanent muscle damage has probably already occurred by the time pulses are lost.

The fractures most commonly associated with vascular injuries are supracondylar fracture of the humerus (brachial artery injury), posterior knee dislocation (popliteal artery injury), and distal femur fracture (distal femoral artery injury).

In most cases, fracture reduction is all that is required to relieve compression of the artery and restore circulation. If many hours have elapsed between injury and fracture reduction, however, fasciotomy may be required to restore adequate blood flow to the extremity. If the combination of fracture reduction and fasciotomy does not restore perfusion to the extremity (as evidenced by return of pulse, capillary refill, and sensation), it is likely that an arterial thrombosis is present. The choice at this point becomes vascular reconstruction or amputation if gangrene begins to set in and threatens life. Reconstruction can require an arteriogram, exploration of the arterial injury, a vein patch, or even a reverse autologous vein graft, which is not likely to be available in rural areas except in major teaching hospitals.

Even in the absence of the suspicion of a fracture, it is important to examine all soft tissue wounds for evidence of penetration into the muscle, dirt contamination, and the presence of other foreign bodies. Deep contaminated wounds are setups for serious infections. It is difficult to get children to cooperate with infiltration with local anaesthetics for exploration of wounds; therefore, the use of general anaesthetics is advocated for full exploration of deep wounds in most cases.

Investigations

Plain film radiography remains the standard diagnostic modality for most fractures. At least two images that are at right angles to each other should be obtained. In addition, plain films should also include the joint above and below (proximal and distal to) the fracture site. Not all fractures are immediately apparent on initial radiographs. Images should be repeated 1 to 2 weeks after injury if pain persists.

Plain film imaging, using lower energy "soft tissue" settings, can be useful for identifying imbedded foreign bodies or undisplaced subtle fractures (such as the fat pad sign seen in intraarticular fractures of the elbow). The presence of gas bubbles in the soft tissues on plain film imaging is an ominous sign of a potentially life-threatening anaerobic soft tissue infection. Plain film radiography is also useful for detecting dislocations in children.

Management

Stabilising the Patient at Presentation

A head-to-toe general examination of the fully undressed child should be carried out on presentation. First, the patient is assessed for associated injuries, particularly in injuries from high-energy mechanisms such as motor vehicle crashes. Thereafter, when other life-threatening injuries have been excluded, an examination of the injured limb is done. After the examination of the injured extremity is complete, including a thorough neurovascular examination, a splint is applied. Splinting the injured extremity reduces pain and discomfort, minimises further soft tissue trauma, preserves neurovascular function, prevents swelling of the soft tissue, and makes future repairs easier.

If bone is protruding through an open wound in the skin (an open fracture), thorough pulsatile irrigation with isotonic saline and coverage with sterile dressing soaked with the saline should be done. No attempt should be made to return the bone to the depths of the wound until debridement and cleansing have been achieved in an orthopaedic unit. Splints can be made out of virtually any rigid material; even folded magazines bound with loose mesh gauze can be used to splint a forearm fracture. Sling and swath is used for fractures of the humerus or the shoulder girdle. Femur fractures typically can be bound to the other thigh with a splint or traction may be used. All open fractures must be covered with parenteral third-generation cephalosporins and tetanus prophylaxis, and the patient should receive pain medication.

For seriously injured children, it is important to remember that no matter how severe the injured extremity, the patient's life has priority over the limb. In the initial hours after a child suffers a mangled extremity, the two most likely causes of death are hypovolaemia (from haemorrhage) and hypothermia. The standard Advanced Trauma Life Support (ATLS®) resuscitation protocol of the American College of Surgeons is designed to address these issues. Patients with complex open fractures or fractures requiring internal or external fixation will likely require transfer to an orthopaedic unit. Proper attention to these injuries will improve their outcome.

Wound Care, Damage Control, and Life-Saving Operations

Care of the soft tissue trauma in association with fractures takes precedence over the definitive treatment of the fracture. The bone needs an envelope of healthy soft tissue for optimal healing. Therefore wound cleaning and debridement are essential. Damaged muscle is an excellent growth media for bacteria. Copious irrigation with normal saline solution and manual debridement is probably as important as antibiotic coverage in preventing infection. This procedure may need to be repeated more than once to achieve a clean, healing wound. In the absence of intravenous antibiotics, deep wounds involving muscle should probably be left open with twice daily dressing changes. These wounds will gradually heal by secondary intention.

Damage control orthopaedics can be defined as an operation that corrects that underlying pathophysiology (hypothermia, wound contamination, vascular obstruction) without necessarily correcting the pathology (such as a long bone fracture). The damage control philosophy emphasizes (1) prevention of hypothermia; (2) removal of all foreign material and bacterial contamination from the wound; (3) reduction of fractures and traction, if necessary, to reduce vascular compromise; (4) sterile dressings; and (5) a planned return trip to the operating room to complete the definitive repair. Damage control orthopaedics can also be considered a "life over limb" approach, meaning that saving the child's life is given priority over definitive repair of the extremity injury. In a worst-case scenario, amputation of a potential viable extremity may be contemplated. The consideration for amputation should be based on weighing the condition of the patient, the condition of the extremity, and the resources available to treat the patient.

Treatment of Musculoskeletal Trauma

Management of musculoskeletal trauma can be divided into three phases:

1. reduction of fracture;
2. immobilisation; and
3. rehabilitation.

Reduction of fractures

The goals of fracture management are (1) satisfactory bone healing (return to full weight bearing), (2) full mobility of the limb, and (3) no limb-length discrepancy. To accomplish these goals, the fracture must first be reduced.

Nonoperative treatment

The closed method (or nonoperative treatment) of fracture reduction can be done under general or local anaesthesia. Local anaesthesia can be applied to the fracture haematoma for safe and effective fracture reduction. This is particularly useful in situations where general anaesthesia is not readily available. The use of longer-acting local anaesthetics will provide pain relief for several hours after the reduction. An injection of 0.5% bupivacaine with epinephrine (1:200,000) can be administered locally at a dose of 0.5 ml/kg body weight. For patients weighing less than 10 kg, 0.25% bupivacaine with epinephrine (1:200,000) can be used at 1 ml/kg body weight. Care must be taken to avoid intravascular injection, and the injection should be performed at least 30–40 minutes before the procedure to allow maximal effect. In children with fractures of both bones of the forearm, both sites must be anaesthetised for reduction.

Ideally, fractures should be reduced under an image intensifier (C-arm). When this is not possible, fractures should be reduced by palpation only, then postreduction plain films must be obtained immediately to verify the result. It is particularly important to correct rotation when reducing fractures; otherwise, a permanent deformity will result. Some degree of fracture overlap may be acceptable and beneficial due to the overgrowth phenomenon in skeletally immature bones.

This closed method of fracture reduction is applicable to even type I open fractures, with a resultant infection rate in some series of 2.5%.[8]

Operative treatment

Many closed fractures in the adolescent age group are managed operatively in the developed countries. Open fractures are generally considered orthopaedic emergencies. Most orthopaedic surgeons agree that type II and III open fractures require urgent operative management. The goal of operative management of type II and III open fractures is to prevent infection in or around the fracture site, which can lead to osteomyelitis. Infection prevention is accomplished by: (1) administration of antibiotics, (2) copious irrigation and removal of all foreign material, (3) debridement of all devitalised tissue, and (4) coverage of all exposed bones when possible. Irrigation is generally accomplished with several litres of warmed normal saline. Battery-powered pulse irrigation devices are available in the United States. A reasonable substitute is a 60-ml syringe attached to sterile intravenous (IV) tubing with a three-way stopcock. The IV tubing is attached to a bag of warm, sterile saline off the surgical field. The stopcock is rotated to allow rapid filling, then flushing of 60-ml aliquots of saline for cleansing the wound. The saline should be ejected with force to dislodge contaminants in the wound.

Immobilisation

Casts

Once closed reduction has been effected on fractures, casts could be used to immobilise it. Casts are bandages that contain chemicals that harden after water is applied. Plaster cast materials contain anhydrous calcium sulfate, which solidifies when water is added. An injured extremity must be covered with a layer of gauze or cotton padding (such as orthoban) before a cast can be applied. Additional padding should be applied to bony prominences. The cast material must be molded over bony prominences and joints. As a general rule, the joint proximal and distal to the fractured bone must be included in the cast to fully immobilise the fractured bone. However, fingertips or toes must be left exposed so that peripheral circulation can be evaluated.

The most serious complication of plaster cast application for fracture immobilisation is vascular insufficiency due to unrelieved swelling. This is the pathophysiology of bonesetter's gangrene, a serious and potentially life-threatening complication of the folk medicine practice of tightly splinting fractured extremities. The resulting vascular insufficiency leads to gangrene that is usually advanced by the time the patient seeks attention at a hospital. In one review of 35 major extremity amputations among children at a centre in Nigeria, 26 were due to trauma, and 24 of these patients had "simple, straightforward fractures" that were treated by traditional bonesetters.[9]

In the case of a cast, if unrelieved pain, sensory loss, or motor paralysis occurs, the cast must be opened immediately by splitting the cast down to the skin, allowing expansion and return of circulation. If the patient complains of localised pain, then a pressure point may be developing under the cast. The treatment of this condition is to cut a "window" into the cast, add more padding to the area, then cover the window with additional plaster.

Casts commonly used in children include the "short arm cast" for wrist fractures, which extends from just below the elbow to the metacarpo-phalangeal joints but leaves the thumb free. Forearm fractures require casting above the elbow (with the elbow at 90°). A long leg cast extends from the proximal thigh to the metatarso-phalangeal joints, and is used to treat tibia fractures. Immobilising the femur is particularly difficult because the hips must be stabilised, which requires a hip spica cast. This cast begins just below the nipples and extends to the thigh on the unaffected side and the ankle on the injured side. This is particularly useful for fractures in infants.

Traction

Traction, which is application of force along the axis of the injured bone, is used to overcome muscle spasm to reduce fractures in long bones. It is also used to immobilise long bone fractures. In other words, patients on traction do not require casts. There are two main types of traction: skin traction, where up to 5 kg of weight can be applied by attaching adhesive tapes to the skin; and skeletal traction, which requires a pin inserted transversely through a bone, taking care not to go through the growth plates to avoid premature epiphysiodesis and shortening of the bone. Traction can also be applied by gravity acting on the weight of the upper limb or a combination of traction and a cast. These are seen in distal fractures of the humerus with a hanging cast.

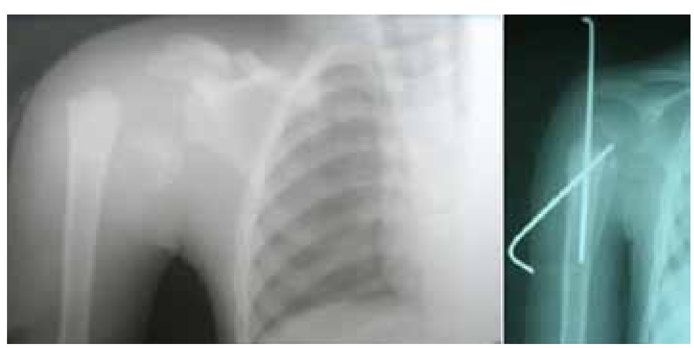
In children, skin traction can usually provide enough traction to overcome muscle tension and reduce most fractures. Russell's traction uses a weighted cord to elevate the knee and distract the lower leg, and is useful for fractures of the femoral shaft. In younger children and toddlers, Bryant's traction is used for femoral fractures: both feet and legs are suspended from the bed.

Traction is also useful to reduce an anterior shoulder dislocation, which typically occurs from a fall on an abducted arm. More than 90% of these dislocations can be reduced by having the patient lie prone on a table with the arm hanging down by the side. The dependent arm is weighted to increase the traction. Following reduction, the arm is immobilised to the body with the elbow at 90°.

Other methods

Fractures of the clavicle can be managed with a figure-of-eight splint that draws back and elevates the shoulders. This position applies traction on the distal clavicle and stabilises the fracture. These splints may occasionally cause swelling of the arms and hands.

After operative reduction of fractures, many hardware options are available to internally fix or immobilise the fractures, depending on the fracture configuration and proximity of fractures to the growth plates. This hardware includes smooth pins and wires, plates and screws, and external fixators (Figure 32.1). Intermedullary nails (interlocking or not) are not commonly used in children for fear of premature epiphysiodesis. Implants are available in most orthopaedic units in Africa, but tractions and casts are devices that are still handy in remote practice areas. The advantage of internal fixation is that it leads to earlier mobilisation. Any hardware used in children should be removed as soon as consolidation of the fracture sites are achieved; otherwise, growing bones could overgrow the implants and even mold onto the contours of the implants. This makes delayed removal difficult and sometimes impossible and abandoned. The development of biodegradable implants has solved these challenges.



(A) (B)

Figure 32.1: Fracture separation of proximal humeral epiphysis with shoulder dislocation (A) before treatment; (B) treated with smooth cross pin fixation.

The minimal access surgery with the aid of an image intensifier in the developed world is gradually being practiced in Nigeria and can be helpful in intraarticular fractures.

Postoperative Complications

Fortunately, nonunion of fractures is extremely rare in children. In addition, fairly significant fracture angulation will correct itself with the remodeling process that occurs during healing. Infection of an open fracture leading to osteomyelitis is a dreaded complication because it can be extremely difficult to treat, requiring long-term antibiotics and debridement of the bone to achieve control.

Prognosis and Outcomes

Fortunately, children have very resilient bones, and most fractures, including some with significant angulation, will heal without complication. Vitamin D deficiency and malnutrition can lead to delayed or poor wound healing. Lack of tetanus prophylaxis can be life-threatening following major soft tissue trauma, as the tetanus organism is common in the soil.

For open fractures, prognosis is directly affected by the availability of health care. Open fractures require treatment within 4 to 6 hours of injury. If open wounds at a fracture site are not treated by that time, the risk of infection increases markedly (Figure 32.2).

Dislocations, once promptly recognised and reduced, result in excellent outcome with a full range of movement and stable joint. Unfortunately, ignorance and cultural beliefs and (to a little extent) poverty in developing countries have led to late presentations, condemning many joints.

Prevention

Because there are very little continentwide or even countrywide paediatric trauma data, injury prevention is a difficult task in Africa. Clearly, motor vehicle usage is increasing, and motor vehicle crashes place children at high risk for major musculoskeletal injuries. Surgeons should advocate for children riding in the back seat, wearing proper restraint devices, and using car seats or booster seats where available. Children are far more likely to die when they are unrestrained and ride in the front passenger seat of the vehicle.

In urban environments, falls from heights, particularly from upper levels of multistorey buildings, are a significant cause of major injury and death. The placement of window guards, which prevent toddlers and small children from falling out of upper-storey windows, has been associated with a significant reduction in injury and death in densely populated urban neighborhoods in New York City. This pioneering work is an example of a paediatric surgeon advocating for the safety of children.[10]

In rural areas, many fractures are due to falls from economic trees. Better fruit harvesting techniques should be promoted.

Firearm trauma is also common in Africa, and more likely due to political (civil war or communal clashes) than criminal (robbery) reasons, compared to Western countries.[11,12] In a study from Nigeria, more than 40% of casualties involved noncombatants (mainly government workers and students), and the most common skeletal injury from gunfire was a femur fracture.[12] Firearm injury prevention in Africa is an enormous challenge due to political unrest and high levels of gun ownership.[11,12]

Finally, surgeons must advocate to limit or end the practise of traditional bonesetting (Figure 32.3). Complications of traditional bonesetting include nonunion or malunion (Figure 32.4) and wet gangrene, requiring amputation.[13] Nonunion or malunion typically requires open reduction and internal fixation. Death from sepsis has also occurred. Nevertheless, one recent study demonstrated that 14 of 46 patients admitted in a hospital with a known fracture opted for treatment by a bonesetter. The availability of health care facilities, the cultural environment, and the financial status of the patient were among

Figure 32.2: Orthofix in place to treat open infected fracture of the tibia.

Figure 32.3: Traditional bonesetters' splints in use.

Figure 32.4: Volksmann's ischaemic contracture of the wrist from tight traditional bonesetter's splint.

the reasons patients sought alternative care.[14] Clearly, more specialists must be trained to manage these injuries, which will eliminate the menace of traditional bonesetters in the long run.

Perhaps it is possible that African paediatric surgeons could negotiate some form of peaceful coexistence with traditional healers, so that their methods, which are highly regarded in some communities, are supplemented by modern biomedical science to prevent catastrophes; this form of relationship has been successful with traditional birth attendants in reducing maternal mortality rates in Nigeria.

Ethical Issues

In the setting of major soft tissue infections, open wounds, or complex open fractures in African children, the decision to perform an amputation can be extremely difficult. Western countries have countless approaches to these complex injuries, including hyperbaric oxygen for soft tissue infections and microvascular tissue transfer for massive open wounds. However, these are extremely expensive procedures that require prolonged hospitalisations and frequent return trips to specialists. Due to the limitations in resources and transportation in Africa, it is possible that an early amputation will result in more rapid healing of wounds, less burden on the family, and a more rapid return to a stable home life. Limb loss may have consequences, however, when the child becomes an adult with a disability. Thus, the decision to amputate an extremity will weigh heavily on a surgeon.

Evidence-Based Research

Table 32.1 presents a retrospective case series involving nonoperative management of paediatric type I open fractures of the tibia. Table 32.2 presents a retrospective case series involving bonesetter's gangrene.

Table 32.1: Evidence-based research.

Title	Nonoperative management of pediatric type I open fractures
Authors	Iobst CA, Tidwell MA, King WF
Institution	Miami Children's Hospital, Miami, Florida, USA
Reference	J Pediatr Orthop 2005; 25(4):513–517
Problem	Open tibial fractures.
Intervention	Nonoperative management of type I open fractures using antibiotics, wound cleansing, sterile dressings, and fracture immobilisation.
Comparison/ control (quality of evidence)	Retrospective case series, no controls.
Outcome/effect	There was only 1 deep infection out of 40 patients treated with the nonoperative management protocol (2.5%).
Historical significance/ comments	The techniques described in this paper could be easily adapted to the care of open fractures in children in Africa.

Table 32.2: Evidence-based research.

Title	Bone setter's gangrene
Authors	Bickler SW, Sanno-Duanda B
Institution	Department of Surgery, Royal Victoria Hospital, Banjul, The Gambia; Division of Pediatric Surgery, Department of Surgery, University of California, San Diego Medical Center, San Diego, California, USA
Reference	J Pediatr Surgery 2000; 35(10):1431–1433
Problem	Bonesetter's gangrene.
Comparison/ control (quality of evidence)	Retrospective case series, no controls.
Outcome/effect	Nine children were treated for bonesetter's gangrene during a 29- month period, accounting for 0.5% of all paediatric surgical admissions. The average age of children with bonesetter's gangrene was 8.2 years (range, 5 to 14 years). There were 6 boys and 3 girls (male to female ratio, 2:1). The left upper extremity was most commonly involved (n = 54), followed by the right upper (n = 53) and left lower (n = 51). Eight of 9 children (89%) were from rural areas in which access to health care was limited.
Historical significance/ comments	Bonesetter's gangrene is a major public health problem for children in Africa.

Key Summary Points

1. Fractures are common among children in Africa.
2. Traditional bonesetters commonly treat fractures in rural areas. This treatment may result in nonunion, ischaemic contracture, gangrene of the effected extremity, and even death. Encouraging parents to seek professional orthopaedic care for their children should be a major public health priority in Africa.
3. Nonoperative fracture reduction with immobilisation is the mainstay of fracture management for rural African children. The majority of extremity fractures will have good results with these techniques, and most children will return to full function.
4. Simple (type I) open fractures can be treated with antibiotics, local wound cleansing, sterile dressings, and fracture immobilisation.
5. Deep wounds into the muscle, even in the absence of fractures, require inspection, foreign body removal, and cleansing to prevent infection.
6. It is important to remember the "life over limb" philosophy when a child with a mangled extremity is encountered. Resuscitation is the first priority. The principles of orthopaedic damage control should be followed. It is possible that an amputation will be necessary to save the child's life.
7. There is almost no literature on child abuse in Africa. However, it is a major cause of injury and death in the United States, suggesting that these cases likely also occur in Africa.

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