Management of Orthopaedic Injuries in Multiply Injured Child

Abstract

Multiply injured child is a unique challenge to the medical communities worldwide. It is a leading cause of preventable mortality and morbidity in children. Common skeletal injuries include closed or open fractures of tibia and femur and pelvic injuries. Initial management focuses on saving life and then saving limb as per pediatric advanced life support and advanced trauma life support. Orthopedic management of open fracture includes splinting the limb, administration of prophylactic antibiotic, and surgical debridement of the wound when safe. However, gross contamination, compartment syndrome, and vascular injuries demand urgent attention.

Keywords: *Multiply injured child, multi trauma in children, pediatric trauma*
MeSH terms: *Pediatrics, multiple trauma, open fractures, compartment syndrome*

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Introduction

Trauma remains a leading cause of potentially preventable mortality and morbidity in children in low-income and middle-income countries,[1-4] and financial burden is disproportionately high in countries with limited resources. In India, road traffic accidents and falls from height account for most pediatric multitrauma.[5,6] Financial and psychological burden of an injured child on a family is significant[7] and often underestimated. Children frequently sustain head, abdominal, and chest injuries when involved in major trauma, which can be life threatening. On the other hand, skeletal trauma is rarely life threatening but can be a source of significant morbidity.[8,9] Extremity trauma is seen in 76% of multiply injured children,[10] hence orthopedic surgeons are often involved extensively in looking after them. Furthermore, the presence of skeletal trauma influences the outcome adversely in multiply injured children. Central musculoskeletal injuries (spine, clavicle/scapula, and pelvis) increase intensive care and hospital stay.[11,12] Overall, children have excellent recovery potential, even from serious head injury, so a positive outlook and aggressive management of skeletal injuries are recommended. Several recent studies seem to support better outcomes if multiply injured children are cared for in a pediatric trauma center (PTC)[13-15] but access to PTC remains limited even in developed countries.[16-18] Knudson and McGrath[19] outlined the essential elements in caring for polytrauma children outside of PTCs. Ideally, a trauma unit treating children should have surgeons who are experts in trauma care in general and understand the special physiological needs of children.[20] Pediatric general surgeon and neurosurgeon are essential to manage these children appropriately, as abdominal and head injuries are a common cause of mortality. This review focuses on the pattern of injuries in pediatric multitrauma, initial resuscitation, and current controversies and agreements in the management of various orthopedic injuries.

Initial Assessment

Initial assessment should follow principles of pediatric advanced life support and advanced trauma life support because the processes of acute care determine the outcome, irrespective of the type of trauma center. Children differ from adults in many ways and children are not simply small adults. Children have a large surface area for the body mass so are more prone to hypothermia compared to adults. Children have a very good physiological reserve and maintain blood pressure very well until at least 25% blood volume is lost; hence pulse rate is a good measure. Large head circumference, in relation to a relatively small chest, flexes the cervical spine if the child is transported on an adult type

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transport. Hence, a mattress under the chest (to elevate the chest) or a cut out for the occiput is recommended to avoid flexion of cervical spine, which could displace an unstable cervical spine injury.[21] Long bone fractures also differ in skeletally immature patients. Thick periosteum makes closed reduction easy as part of it remains intact in many fractures. Similarly, it helps fracture healing. It also limits the displacement of fractures, so degree of displacement of a fracture is not always proportionate to the energy transmitted to the limb. Growth plates are unique to children and injury to the ends of long bones adds another dimension of partial or complete growth arrest, not only requiring reconstructive surgery but also result in long term morbidity. Furthermore, crush injury to growth plate from high energy trauma might not be obvious immediately, so parents should be alerted appropriately.

Care of Cervical Spine

Pediatric cervical spine differs from adult spine because of immature skeleton, incomplete development of spinous processes, ligament laxity, relatively horizontal orientation of the facet joints, relative large head-to-body ratio, and less developed muscles. These differences cause unique patterns of injuries, and generally prognosis is better.[22] Children under 2 years of age rarely sustain bony cervical spine injury but are prone to cervical cord injury due to relative hypermobility of spine. Autopsies have shown that bony spinal column can withstand 2 inches of stretching, whereas neurovascular structures shear at a quarter of an inch stretch.[23] This results in neurological injury without radiological changes – spinal cord injury without radiological abnormality (SCIWORA). However, SCIWORA is rare and magnetic resonance imaging (MRI) scan is essential to diagnose this entity.[24,25] Between 2 and 8 years of age, injuries occur at C3 or above. Fulcrum of motion in this age group is centered at C2–C3, whereas in adults, it is at C5–C6. Thorough history of mechanism of injury should be obtained because cervical spine injury is likely in motor vehicle accidents (both occupant and pedestrian) and falls from height. Children are often unable to provide full history and signs of injury can be subtle. Hence, cervical spine should be thoroughly evaluated in case of suspicion. Plain X-ray of cervical spine is the most accepted initial modality. Cross-table lateral view alone can miss 20%–25% fractures so an anteroposterior view should always be included to look for lateral mass and transverse process fractures. Odontoid view is not helpful in children under 8 years of age, and its use remains controversial.[23,26] Images that do not show entire cervical spine should not be accepted. Several normal variations in pediatric cervical spine such as pseudosubluxation at C2–C3 and retropharyngeal swelling due to crying can mislead the clinician and pediatric radiologist's opinion should be sought. Routine use of computed tomography (CT) scan remains controversial in children due to the risk of high dose of radiation to thyroid. However, CT is recommended if plain X-rays remain inconclusive or when there is evidence of cervical spine injury on plain X-ray. MRI scan is recommended if child does not become alert or not accessible for neurological examination within 72 h.[26]

Systemic Reaction to Multitrauma in Children

Clinicians dealing with adult trauma patients are familiar with the systemic reaction to trauma, the cascade of events that lead to multiorgan failure, and the measures to minimize such a damage. Triad of death – hypothermia, acidosis, and coagulopathy – represents serious state and every effort is made to prevent it. Concept of damage control surgery was developed to prevent multiple organ failure (MOF) from the triad of death. Children react differently to MOF and generally resistant to it compared to adults with equivalent injury.[27] MOF develops early in children and resolves without the need for advanced therapies such as steroid rescue or assisted ventilation. Immune dysfunction-related infections seen in adults with MOF are not common in children. Hence, Pandya *et al*.[28] were of the opinion that if surgical fixation of a fractures is deemed necessary, it can be safely carried out during early stages of MOF. However, in cases where child is already hypothermic (<35°C) or acidaemic (pH of <7.15 units) and coagulopathic, damage control approach[29] should be adopted. After airway, breathing, and circulation are stabilized, preliminary care of traumatized limb and skeletal trauma includes covering all wounds, aligning deformed limbs, and documenting neurovascular status of the limb before and after manipulation and assessment of muscular compartments in all cases. Avoid skeletal traction at this stage and use splints, leaving sufficient room for peripheral venous access as much as possible. Once the child is adequately resuscitated and life-threatening injuries are dealt with, skeletal trauma should be treated aggressively.

A team leader should be established early and clear communication and goals should be established as soon as possible and any changes to such a plan are discussed with all concerned, documented, and communicated. Communication with all surgical and medical teams involved in caring for the child is the key to minimize delays and optimize recovery but all too often this aspect of care is lacking. Continuity of care is also paramount as these children are often transferred between intensive care and subspecialty wards. All imaging modalities should be liberally used to assess injured limbs and they should be available to all specialists at all times. This is facilitated by the digital archiving systems in most countries.

Dealing with the Families

Families of injured children should be supported throughout with clear communication, sympathetic but realistic approach. Medical staff often become the focus of their anger and guilt and surgeons should give them the

confidence that they all are on the child's side and aim to maximize recovery. Parents should be kept informed at every stage of management and soon after such intervention. Clinicians should be realistic while discussing prognosis with parents and avoid too optimistic or pessimistic views. Parents should also be alerted that some injuries may come to light weeks after the accident,[8] and this is particularly important in severely injured children.[30]

Orthopaedic Management

Orthopaedic management should focus on saving the limb in severe open fractures with timely management, splinting limbs during initial resuscitation, facilitating transfers to imaging suite and Intensive Care Units, and minimizing pain and early mobilization. Children are endowed with enormous capacity to recover and orthopedic management of skeletal injuries should be aggressive to optimize recovery of the limb. Cumbersome plaster casts such as hip spica or long leg casts should be avoided as much as possible in multiply injured child. Equally orthopedic traction – skin as well as skeletal traction – should be abandoned in favor of external fixators. They are quick to apply even in a basic setup and can be put together easily. They help reduce pain, give access to wounds, allow repeated examination of neurovascular status easily, and can be used as "portable" traction if the patient is moved around in the hospital. If applied appropriately, keeping in mind the likely definitive implant (nail or plate), they do not interfere with definitive treatment. One significant disadvantage of using ferromagnetic metallic fixators is that they are not MRI compatible. Nonferromagnetic, MRI compatible external fixators are available but expensive. Occasionally, if the construct is stable, and fracture is in satisfactory alignment, fixator can be continued as definitive treatment.

Open Fractures

Open fractures are common in high-velocity multitrauma patients and account for 10%.[8,9] Open fractures are universally classified according to modified Gustilo-Anderson Classification.[31,32] Other classifications have been proposed[33,34] but modified Gustilo-Anderson classification remains the most popular, although it is not specific for children. However, the principles of adequate emergent debridement, skeletal stabilization, and soft-tissue management are equally useful in this age group.[35-37]

Wound debridement should be ideally carried out by an orthopedic surgeon in conjunction with a plastic surgeon[38,39] in all open fractures. Current evidence seems to support that wound debridement is not necessary in Type I open fractures in children.[40,41] Debridement within 6 h of injury is neither supported by scientific literature[42,43] nor achievable in all cases. Current guidance is that it should be done on a routine trauma list within 24 h of injury, unless there is gross contamination, devascularization of the limb, or compartment syndrome (CS), in which case it should be carried out urgently.

Open Tibial Fractures

Open fracture of tibia is the most common injury in multiply traumatized children and receive lot of attention in the literature.[37,41,44-52] There is universal agreement on thorough wound debridement of Type II and Type III fractures as soon as possible.[45] Fracture can be stabilized using a range of devices including monolateral external fixators,[50] circular frames,[49] locking plates,[44,48,51] flexible nails,[47] and combination of fixators and implants. Fracture healing is more predictable in Type I and II fractures and closed reduction and casting seem to be as successful.[52,53] Although cast treatment is attractive in situations where resources are limited, one should weigh the pros and cons of leaving a multiply injured child in a long leg cast when other injuries make mobilization difficult, thus prolonging hospital stay. Type III fractures behave differently, depending on soft tissue and bone loss, and risk of infection and nonunion is similar to adults.

Open Femoral Fractures

Open fractures of femur are uncommon and represent high-velocity trauma. They are often associated with other injuries, particularly head trauma [Figure 1] and child should be carefully assessed for these injuries.[10,54,55] External fixation of fracture femur is increasingly used as a damage control measure, while the child is being resuscitated.[56] Debridement of open femoral fracture is like all open fractures. Thigh musculature provides adequate cover in most cases and plastic intervention is rarely needed. Definitive fixation of fracture is carried out as soon as child is stable. There are several options including continuing external fixation, changing to internal fixation with a plate, flexible nails, or intramedullary nail depending on age, location of fracture, available resources, and expertise.[55,57-59] External fixators, when used as definitive treatment, are associated with more complications than other modalities of fixation.[55,58] Hutchins *et al*.[55] have shown that open femoral fractures treated with external fixation took longer to unite than other methods. Presence of fracture-related complications increased the time to fracture union. Grade III injuries were the most difficult to manage; 50% fractures in their series developed osteomyelitis and 20% malunited. Intramedullary fixation is generally gaining popularity in appropriate age groups.

Open Forearm Bone Fractures

Open fractures of forearm are rare but generally carry good prognosis if standard principles of open fracture management are followed.[60] Open fractures of humerus are not that common as indicated by the lack of literature.

Figure 1: Child hit by speeding car. Bumper level injury (a) X-ray pelvis with both hips with proximal 2/3 thigh anteroposterior view showing bilateral femoral fractures. Child was also ejected and landed on the ground sustaining facial injuries (b) CT scan of child showing mandibular fracture and head injury. Both femoral fractures splinted in portable splints (c) X-ray both thigh with hip and knee joint anteroposterior view showing flexible intramedullary nailing performed within 48 h, after stabilization of facial injury

Degloving Injuries of Extremities

Bicycles, motorized and cycle rickshaws are a common source of multiple injuries in children in India[61-63] and crush and degloving injuries of foot and lower limbs, with or without a fracture are peculiar to these accidents. Initial management is on the lines of any open fracture. Soft-tissue management is a significant problem and plastic surgeons should be involved at a very early stage to salvage the degloved skin and cover the exposed bone.[64,65]

Compartment Syndrome

CS should be suspected in high-velocity limb trauma and careful periodic assessment of limb, and the child, is important, in order not to miss it. There are several unique features that can potentially delay the presentation and diagnosis of CS. Children tend to develop swelling and CS later than adults.[66] Conventional 5Ps (pain, pallor, paraesthesia, paralysis, and pulselessness) are not always reliable in many children. Instead one should look for 3As – increasing analgesic requirement, anxiety, and agitation.[67,68] In the very young and those who are sedated, clinical symptoms are not helpful. Repeat clinical examination by the same team and combined examination at the time of handovers is one way to make sure that the diagnosis is not missed or delayed.[66] Intracompartment pressure is not used widely in pediatric practice, not only because of lack of agreement on critical cutoff pressure[69] but also it is almost impossible to get child's cooperation for bedside measurements. Noninvasive methods such as near-infrared spectroscopy would be ideal, but it is expensive, not widely available, and not clinically fully tested. Careful titration of morphine dosage in patient/parent-controlled analgesia has also been recommended as a tool in raising the suspicion of CS in patients on narcotic analgesia.[70] Open fractures can still develop CS[71] and the presence of a wound does not automatically decompress a compartment. It should not be forgotten that CS can also develop after surgical intervention and limb should be carefully monitored in postintervention period. Open fasciotomy of all affected compartments should be urgently carried out and wounds left open. In forearm, the entire length of volar forearm, including lacertus fibrosus in the cubital fossa, is explored and decompressed. Dorsal compartment should then be assessed, and if it is felt to be tense, a dorsal compartment fasciotomy should be added. In the leg, all four compartments should be decompressed. All exposed and deep muscles are assessed for viability and any clearly dead muscle is excised. It is better to leave borderline viable muscles and revisit them at earliest opportunity because children have excellent healing potential. Although results of late fasciotomy are better in children than in adults,[66,67] it should be carried out urgently. Fasciotomies expose muscles and fracture site in some cases, thus increasing chances of infection. Fasciotomy wounds should be covered with skin grafts or secondary closure as soon as possible.

Vascular Injuries

Vascular injury in supracondylar fractures of humerus is familiar to most orthopedic surgeons and general principles of reduce the deformity and reassess the circulation also apply in other displaced long bone fractures with vascular compromise. In multitrauma, vascular injury is a result of blunt trauma from bone fragment rather than laceration of artery from a bone spike.[72,73] Shah *et al*.[72] reported that 26% of pediatric vascular injuries were vasospasm and successfully treated nonoperatively. Sixty two percent of the injuries in their series were in the upper limb. Lower limb injuries were common around knee and associated

with knee dislocations and femoral fractures. They recommended arteriogram, often on table, as majority of these children were taken to theater to surgically stabilize the fracture, if "hard signs" of arterial injury such as distal ischemia or absent pulses, active hemorrhage, expanding or pulsatile hematoma, and bruit or thrill were present. Regular clinical assessment and Doppler studies are also essential in cases where arteriogram is not needed. Definitive vascular repair is preferably performed by a vascular surgeon for an excellent outcome. Generally, limb salvage rate is high in children.

Pelvic Trauma

Pelvic fractures result from high energy trauma and often associated with trauma to limbs, chest, spine, abdomen, and head.[74-76] Unlike adults, pelvic trauma is not a cause of mortality in multitrauma children. However, associated head and visceral injuries can prove fatal. Children with pelvic fractures are carefully and thoroughly assessed to rule out rectal and urogenital injuries including CT scans and appropriate contrast studies [Figure 2]. Majority of pelvic fracture are stable injuries and can be treated nonoperatively and mobilized early.[77] Unstable injuries can be stabilized using pelvic binders, C-clamp, or an external fixator. Latter is easy to apply and ideal if access to abdomen and bladder is needed.

Closed Multiple Fractures of Long Bones

Closed fractures of long bones in multitrauma children should be preferably surgically stabilized even if they are usually treated nonoperatively in other circumstances. Early stabilization reduces pain, reduces the complications of immobilization,[78] aids transfers and mobilization, and decreases inpatient stay in the absence of traumatic brain injury. Operative fixation should be ideally completed between 2nd and 3rd day provided the child is stable. It is safer to carry out definitive fixation during early stages of multiorgan failure. Long bone fractures should be aggressively treated even in severely brain-injured children as they have enormous potential to recover [Figure 3].

A great range of implants and techniques are employed in stabilizing fractures in pediatric age group. Growth

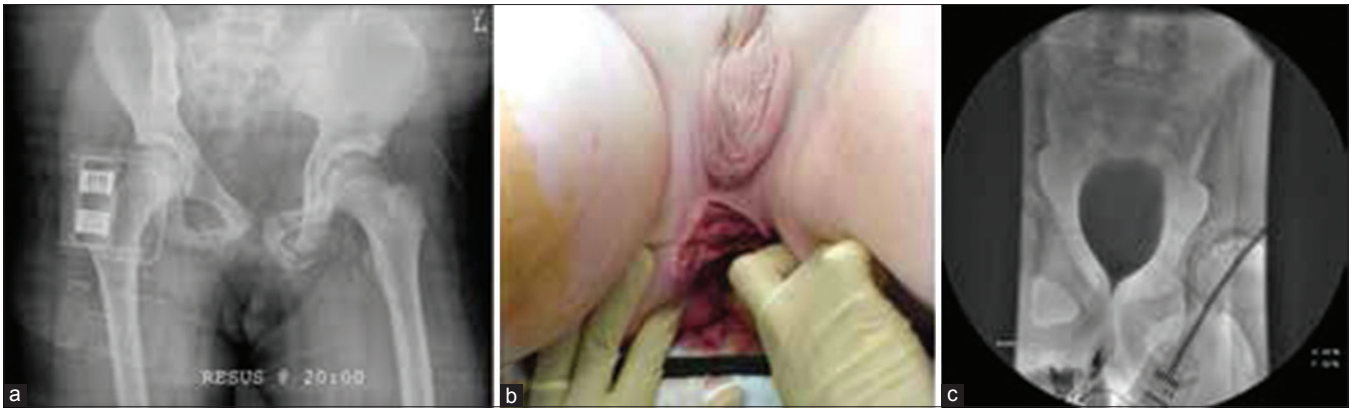

Figure 2: Child involved in a motor vehicle accident. (a and b) X-ray pelvis with both hips anteroposterior view and clinical photograph showing pelvic fracture with perineal injury (c) Cystogram performed to assess urogenital injuries

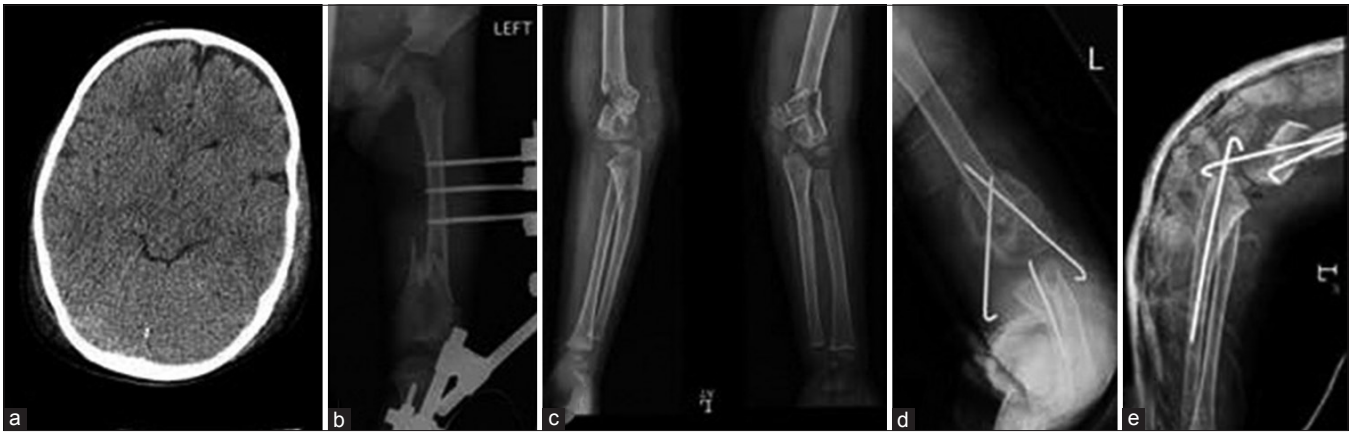

Figure 3: A toddler was in major car crash. There were two adult fatalities. Child was found several yards from the crash site, still strapped in the child's car seat. Child was in coma on arrival (a) Computed tomography scan confirms severe head injury (b and c) X-rays of left thigh and elbow with forearm showing additional injuries open IIIB left femoral fracture, closed fractures of left elbow. Child recovered completely from head injury and required multiple reconstructive procedures due to complete growth arrest of left distal femur (d and e) X-ray arm with elbow and forearm anteroposterior and lateral views showing implant in situ in olecranon and supracondylar fracture humerus

plates should be respected while planning fixation. Intramedullary implants, mainly flexible nails, are gaining in popularity for humerus, forearm bones, femur, and tibia. They have the advantage of minimally invasive technique, minimal blood loss, and ease and rapidity of application. Limitations include metaphyseal fractures, some communited, segmental shaft fractures, and body weight consideration. Disadvantages include irritation from the ends of the nails at the entry point and need for removal and re-fracture if removed early. In adolescent age group, reamed intramedullary nail is safer if piriform fossa entry is avoided and afford superior stability. Plating is a good option for communited fractures that are not suitable for flexible nails and for metaphyseal fractures. External fixators for definitive fracture management are not ideal because fracture healing can be slow and pin-tract infection increases with time. Fixators are also associated with malalignment more often than other methods. K-wires or cannulated screws are useful for intraarticular, physeal injuries and distal radial fractures.

Conclusions

Pediatric multitrauma is increasing worldwide and poses a unique challenge for medical community. Skeletal trauma is very common and orthopedic surgeons are often involved in caring for these children. Financial and psychological burden of an injured child is enormous and good multidisciplinary care is essential to reduce this.

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Conflicts of interest

There are no conflicts of interest.

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