

Chapter 2

The Mangled Extremity in Children

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Abstract A mangled extremity is an extremity that has sustained severe traumatic injury to at least three of the systems of a limb (soft tissue, bone, nerves, and vasculature). Management of mangled extremities in children poses a difficult challenge to the treating surgeon, as decisions must be made quickly to ensure the best possible outcome for the patient. The most difficult decision is whether limb salvage should be attempted or amputation should be performed. This chapter reviews the presentation, evaluation, treatment, and outcomes of mangled extremities in children.

Keywords Mangled extremity • Mangled limb • Traumatic amputation • Acquired limb deficiency • Limb salvage • Lawnmower injury • Farm machinery injury

Introduction

A mangled extremity is defined as severe traumatic injury to at least 3 out of 4 systems of a limb (soft tissue, bone, nerves, and vasculature) [1]. It is often referred to as a traumatic amputation or acquired limb deficiency because the overwhelming majority

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of these injuries present as an amputated or near-amputated limb. Although significant strides in emergency care and reconstructive techniques have been made, the mangled limb is typically associated with an extremely poor prognosis. Almost every treatment option usually results in some decline in functionality.

In North America, injuries to children are a pressing public health concern, as more than 70% of catastrophic injuries resulting in significant morbidity to children are preventable [2]. The primary mechanism of injury is power lawn mower injuries, causing 42% of all amputations in children less than 10 years of age [3]. In many cases, the child is riding on the lawn mower with a parent or grandparent and subsequently falls off the resulting in severe injury. Alternatively, the child may be playing in the yard and the parent or grandparent reverses the power lawn mower without realizing the child is there. In both cases, the resulting injury is devastating to the child physically and psychologically and to the family psychologically and financially.

Farm machinery, motor vehicle accidents, and railroad injuries are other causes of mangled extremities in children [2, 4] (Fig. 2.1). Explosions from fireworks can cause amputations of digits or the entire hand, In areas ravaged by war, children can sustain more severe mangled extremities resulting from land-mine explosions or gunshot wounds [5, 6].

Demographics

Demographical information for children sustaining severe trauma to the extremities is limited, however, it is well established that ride-on lawn mowers and farm machinery are a significant cause of morbidity in children [7, 8]. Additionally, multiple studies have shown a twofold to threefold higher incidence of injuries in males [3, 4].

Time of year also has been shown to be significant with lawn mower and motor vehicle accidents primarily taking place in the summer months (i.e., June and July, respectively), and farm machinery trauma occurring in early fall (i.e., September).

Emergency Room Considerations

Presentation

The child with a mangled extremity will often present with trauma to multiple parts of the body including the head, neck, chest, or abdomen. Although severe trauma to the limb can be distracting, the surgeon should refrain from giving the mangled extremity attention until life-threatening injuries are cared for and stabilization of the patient has been achieved.

In many cases, the child will present with complete or near complete traumatic amputation of the affected limb. In other cases, the child may have sustained an



Fig. 2.1 Thirteen year old female who had her foot run over by a train. (a) Appearance of the dorsum of the foot. Note the skeletonized toes distally. (b) Plantar surface. Note the large laceration in addition to the degloving injury. (c) Lateral radiograph. Note the intact bony structure with the obvious soft tissue degloving. This patient had her toe phalanges disarticulated, which permitted coverage of the remainder of the foot with the available skin. (Courtesy of Joshua Abzug, MD)

open fracture in conjunction with severe peripheral nerve damage and/or arterial rupture. Proper evaluation and treatment of life-threatening injuries is critical to the favorable outcome of pediatric patients.

Evaluation and Preparation for Surgery

It is mandatory that advanced trauma life support (ATLS) protocols are followed starting with the ABCs (airway, breathing, circulation). Once the ABCs are completed, the remainder of the primary and secondary surveys should be performed. During the secondary survey, the mangled extremity should be assessed by first obtaining hemostasis. Usually direct pressure is sufficient to stop bleeding; however, occasionally it is necessary to utilize a tourniquet. As a last resort one can clamp or clip a vessel to obtain hemostasis; however, these measures decrease the ease and success of vasculature repair.

Once hemostasis has been obtained, the difficult decision regarding limb salvage versus amputation must be considered. The mangled extremity severity score (MESS) is a simple grading scale used to assist surgeons with this difficult decision-making process and has been validated in studies examining outcomes in adults with severe lower extremity injuries [9, 10]. It assigns scores to various clinical findings associated with the mangled limb. If the skeletal or soft tissue injury is low energy (stab, fracture, civilian gunshot wound) 1 point is assigned, if it is medium energy (open or multiple fractures), 2 points are given, if it is high energy (shotgun or military gunshot, crush injury), 3 points are given, and if it is very high energy (high energy plus gross contamination), 4 points are given. If the limb has a reduced or absent pulse but normal perfusion, 1 point is given, if there is a limb that is pulseless with diminished capillary refill, 2 points are given, and if there is a limb that is cool, paralyzed, insensate, or numb, 3 points are given. If the patient's systolic blood pressure is always greater than 90 mmHG then 0 points are given, if the systolic blood pressure is transiently less than 90 mmHG then 1 point is given, and if the systolic blood pressure is persistently less than 90 mmHG then 2 points are given. No points are added if the patient is less than 30 years of age, 1 point if the patient is between 30 and 50 years old, and 2 points are added if the patient is over 50 years of age [9]. If the sum of the scores is greater than or equal to 7, amputation is indicated. If the score is less than 7, successful limb salvage may be indicated. Studies have suggested that the MESS may be useful in the pediatric population [11]; however, no study has validated such usage. Therefore, while the MESS may be used as a guideline for treating the afflicted child, much of the evaluation may depend on the experience and judgment of the surgeon.

One may argue that an attempt to salvage every mangled extremity should be made, and a revision amputation can be undertaken if there are complications with the salvaged limb. However, the treating surgeon should be careful not to follow this logic.

A failed salvaged limb requiring secondary amputation has potentially devastating consequences for the patient, not only physically in terms of multiple hospitalizations and procedures but also psychosocially in terms of bearing the brunt of the psychological consequence of severe injury twice [1]. On the other hand, children possess a superior healing potential compared to that of adults, which may encourage the surgeon to pursue limb salvage more aggressively than in adults (Fig. 2.2). Thus, thorough evaluation must be undertaken and all attempts to identify injured limbs that would benefit most from early amputation should be made.



Fig. 2.2 (a) Fourteen year old boy who fell while jumping onto a freight train. AP radiograph shows fracture-dislocations of the right midfoot in association of an ankle fracture-dislocation, which was reduced in the ER. He had near-amputation of the 5th ray and severe loss of lateral soft tissue. AP (b) and lateral (c) radiographs of the foot after 10 procedures. He underwent triple arthrodesis in his final procedure to realign the hindfoot. He is now independently weight-bearing with an orthotic (Courtesy of Joshua Abzug, MD)

Early in the evaluation process, the orthopedic surgeon should work with other surgical specialists such as plastic surgeons, hand surgeons, and vascular surgeons to assess the damage of the limb and its recovery potential. Although there are few definitive useful guidelines for immediate amputation, some signs may indicate that amputation is best performed early. Considerations include the fracture pattern, the extent of vascular injury, and the integrity of perfusion to the extremity as well as the presence of nerve injury [1, 12].

The mechanism of injury should also be considered when deciding whether to pursue limb salvage or amputation. Extensive crush injuries may indicate amputation, while clean, sharp lacerations may have more potential for replantation. Injuries from lawn mowers or farm machinery may be associated with extensive contamination that complicates the attempt at limb salvage, and therefore amputation may be the best option.

Additionally, the time elapsed since injury should also play a role in the decision process. Muscle undergoes irreversible ischemic damage after losing perfusion for more than 6 h when warm and 12 h when cold. Other soft tissue structures, such as nerves, undergo irreversible damage after losing blood supply for 12–24 h.

Ischemic necrosis can have substantial implications in the reconstruction effort. In the field, amputated parts should be wrapped in gauze, placed in a sealed plastic bag and then placed on ice to minimize effects of ischemic damage. The parts should never be placed directly on the ice. In the emergency room, parts of the limb that have lost partial or complete perfusion should be wrapped in gauze, placing a plastic bag with ice around them to cool the ischemic parts of the extremity [13]. Care should be taken to lower the temperature of the limb, but not freeze any tissues as that may cause more damage.

Lastly, overall assessment of the child's health and social situation should be considered when deciding between limb salvage and amputation. Co-morbidities such as cardiac conditions or diabetes may affect the child's ability to tolerate extensive surgical reconstruction. Once limb salvage or amputation has been recommended, and the parents are in agreement, the child should be immediately taken to the operating room and prepared for surgery.

Surgical Treatment

Amputation

When amputation is pursued, it is important for the surgeon to consider the growth potential of the limb as well as the usage of a prosthesis. In upper limb amputation, the surgeon should maintain the maximum amount of bone length possible while still excising the traumatized area of the limb. This will enable the limb to be utilized as a "helper hand". If the trauma is limited to the distal aspect of the limb, and carpal/metacarpal bones can be saved, the child may be able to retain the ability to pinch and pick up small objects.

In above-knee amputations, the surgeon should retain as much of the femur as possible as a short femur could be lengthened in the future. It is important to ensure that there is sufficient soft tissue coverage at the distal end of the above-knee amputation as direct weight-bearing on a prosthesis will occur here. If the child can retain a long femur, his or her surface contact with the prosthesis will increase and provide a more stable base for abductor function, minimizing abductor lurch.

In through-knee amputations (i.e., knee disarticulation), the child can retain good functionality as bony overgrowth is limited and an excellent surface for prosthetic contact and control is maintained [14]. To provide the patient with maximal hip extension power, the surgeon should attach the hamstrings to the stumps of the cruciate ligaments [15]. Because the femur of the amputated limb will grow at nearly the same rate as the normal limb, the surgeon should perform a distal femoral epiphysiodesis some years before the child reaches skeletal maturity so that the femoral stump can be fitted with a prosthesis including a knee without creating a leg length discrepancy.

With below-knee amputations, any viable part of the proximal tibia should be preserved as lengthening of the proximal tibia will aid in permitting usage of prosthesis [16]. Although this procedure may be difficult for both the surgeon and the patient, the child has the potential for significantly higher functional gains compared to knee disarticulations and above-knee amputations. Among the benefits is control of the knee joint, preservation of knee proprioception, and decreased energy expenditure during walking and standing. The prosthetic devices used for below-knee amputees are simpler, easier to fit, and more comfortable. To achieve maximal results, the surgeon should aim to have at least 6 cm below the knee joint by the time the child reaches skeletal maturity [2].

Limb Salvage

Limb salvage requires a multidisciplinary surgical approach, including contributions from orthopedic surgeons, plastic surgeons, upper extremity surgeons, and vascular surgeons. After anesthesia and administration of prophylactic antibiotics, the mangled extremity should be briefly irrigated and gross debris removed. A detailed exam evaluating injuries to nerves, vascular structures, bone, and soft tissue structures should be performed next. If vascular compromise is present, it should be addressed immediately so that extensive and thorough excision of contaminated tissue can take place without worry of prolonging ischemia time.

The most important goal in early treatment of the mangled extremity is performing a thorough debridement of wound to prevent contamination and limit the chances of subsequent infection. An open, compromised wound with high levels of contamination can result in invasive infections to the child in as little as 6 h after injury [13]. It has been shown that thorough debridement and flap coverage within the first 72 h leads to a decreased infection rate, fewer secondary amputations, and a lower non-union rate [17, 18].

Open fractures should be treated as an emergency with surgical intervention ideally occurring within 4–8 h after the injury [19, 20]. Excision of nonviable muscle and contaminated or avascular bone fragments should be undertaken during the debridement as these are niduses for infection. Jagged bone edges can be smoothed utilizing a rasp or a saw to make the bone ends more amenable to subsequent bone graft procedures that may be required in the future. Once adequate vascularity is

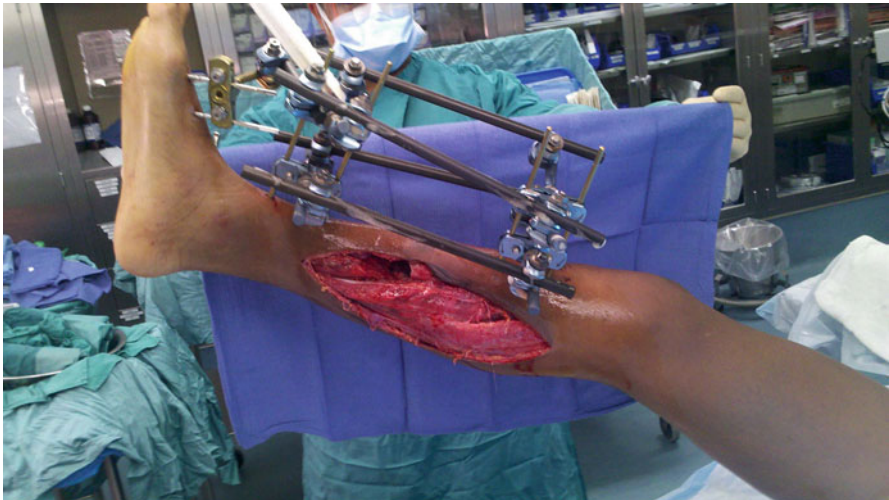


Fig. 2.3 Sixteen year old male who sustained a Type IIIB open tibia fracture. The fracture was stabilized with an external fixation system, enabling access to the skin wound created by the open fracture for later flap coverage (Courtesy of Joshua Abzug, MD)

present and the debridement has been performed, attention should be turned to stabilizing the bony elements. Typically, we utilize external fixation devices as they are readily available, easy to apply, and permit access to the soft tissue structures that may require multiple procedures in the ensuing days (Fig. 2.3). Alternative options include application of internal fixation; however, it is important to ensure that the hardware is not exposed.

Complications and Outcomes

Bony Overgrowth After Amputation

Bony overgrowth after amputation can be a significant problem, especially due to the need for children to obtain multiple prostheses as they grow. Usually, a painful bursa develops indicating friction between the bone and the prosthesis. If this is not addressed promptly, wound breakdown can occur leading to the bone protruding through the skin. Treatment is elimination of prosthetic usage followed by revision amputation [21]. Such procedures may be required every 2–3 years until skeletal maturity is reached.

One can attempt to limit bony overgrowth by having a cartilaginous surface at the end of the distal limb to help minimize overgrowth. Cases of disarticulation provide a cartilaginous surface. Alternatively, one can create a cartilaginous cap utilizing cartilage from the amputated segment or a piece of iliac crest.

Phantom Pain

Although children with congenital limb loss or very young children with acquired limb loss rarely have phantom pain, older children who undergo limb amputation may experience phantom pain [2]. Usually, this pain is not debilitating; however, severe cases do exist that may require physical therapy or medications to manage the symptoms. Intraoperatively, nerves should undergo sharp laceration with placement of the distal stump into muscle in an effort to minimize painful neuroma formation.

Psychosocial Consequences of Limb Loss

Usually, very young children do not differ much than children of congenital limb deficiencies in terms of psychosocial consequences. Their sense of loss and adjustment period is minimal. However, older children may go through a grieving process with damage to their self-esteem and self-image occurring. Encouragement and positive reinforcement is often necessary to bring children with acquired limb deficiencies back to a “normal” psychosocial state. Trained mental health providers should be involved early in the care of patients with mangled extremities.

Limb Salvage Failure

Unfortunately, limb salvage is not always successful and secondary amputation may become necessary due to lack of perfusion, infection, or chronic pain. Careful initial assessment of the limb may aid in determining if limb salvage should be attempted or primary amputation should be performed. Secondary amputation after attempted limb salvage has devastating psychosocial and financial impact on the patient and their family.

Limited studies are present discussing the advantages and disadvantages of amputation and limb salvage in children. However, a number of studies focusing on adults have provided a number of conclusions that are applicable to the pediatric population.

In a Swiss study by Hertel et al. [22], patients with severe lower extremity injuries underwent primary amputation or limb salvage. While patients with limb salvage required more surgical procedures than amputation (8 versus 3.5, respectively), they had greater functionality, less pain after complete recovery, and sustained fewer lifestyle changes compared to patients with similar injuries who underwent amputation [22]. However, Georgiadis et al. showed that amputated patients had fewer complications compared to limb salvage patients, shorter hospitalizations, less procedures, and faster recovery time [23].

These differences represent the fact that there is no right answer. Whether to attempt limb salvage or perform a primary amputation is a complex decision that occurs on a case by case basis depending on the mechanism of injury, the extent of injury, and the patient/surgeon's preferences.

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