Management of Traumatic Wounds and a Novel Approach to Delivering Wound Care in Children

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Significance: The costs and morbidity of pediatric traumatic wounds are not well known. The literature lacks a comprehensive review of the volume, management, and outcomes of children sustaining soft tissue injury. We briefly review the existing literature for traumatic wounds such as open fractures and burns. Such injuries require dedicated wound care and we propose a novel approach for more efficient and more effective delivery of dedicated pediatric wound care.

Recent Advances: New pediatric literature is emerging regarding the long-term effects of wound care pain in traumatic injuries—especially burns. A variety of wound dressings and alternative management techniques exist and are geared toward reducing wound care pain. Our institution utilizes a unique model to provide adequate sedation and pain control through a dedicated pediatric wound care unit. We believe that this model reduces the cost of wound care by decreasing emergency department and operating room visits as well as hospital length of stay.

Critical Issues: First, medical costs related to pediatric traumatic wound care are not insignificant. The need for adequate pain control and sedation in children with complex wounds is traditionally managed with operating room intervention. Afterward, added costs can be from a hospital stay for ongoing acute wound management. Second, morbidities of complex traumatic wounds are shown to be related to the acute wound care received.

Future Directions: Further guidelines are needed to determine the most effective and efficient care of complex traumatic soft tissue injuries in the pediatric population.

SCOPE AND SIGNIFICANCE

ACCORDING TO THE National Trauma Data Bank, 127,234 children were admitted to a hospital for trauma in 2012.¹ Trauma is well known to be the leading cause of morbidity and mortality in children. The number of soft tissue wounds in this population, though, is not well defined. Wounds result from blunt, penetrating, and thermal mechanisms and can pose management challenges. These management challenges include initial management of a complex wound; pain and

sedation control for wound evaluation and care; ongoing delivery of wound care; and the psychological morbidity associated with traumatic wounds.

TRANSLATIONAL RELEVANCE

The heightened awareness of medical cost and impact of hospitalization on the family of the injured child will drive the evolution of wound care to a more effective and efficient strategy.² With this strategy in mind, we have instituted a unique

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Abbreviations and Acronyms

DSM = Diagnostic and Statistical Manual

ICD = International Classification of Diseases

PAWS = Pediatric Acute Wound Service

PTSD = post-traumatic stress disorder

model at our institution for the delivery of pediatric wound care that is utilized in traumatic wounds.

CLINICAL RELEVANCE

Before introducing this wound care model, we review in greater detail the types and current management of traumatic wounds with a focus on more complex injuries. We discuss the development of our novel approach to caring for these traumatic wounds. This model reduces the cost associated with the number of emergency department and operating room visits as well as the hospital length of stay for our pediatric patients. Lastly, this model addresses the risk factors associated with the morbidity of complex traumatic wounds in children.

BACKGROUND

Pediatric burns and blunt or penetrating open traumatic wounds frequently require hospitalization for management. The Burn Foundation's Pediatric Burn Fact Sheet approximates 250,000 children from age 0 to 17 who seek medical attention for burn care every year. Six percent of these children require hospitalization.³ Unlike thermal injuries, epidemiologic data regarding penetrating or blunt traumatic wounds are less well described due to two factors. First, the majority of pediatric trauma care occurs at non-designated trauma centers and non-pediatric hospitals without mandatory trauma registry reporting requirements. In addition, current databases do not specifically report detailed traumatic wounds other than burns and firearm injuries.^{1,4} As such, limited reports exist in the literature regarding traumatic soft tissue wounds in children. Guice *et al.* attempted to answer questions regarding traumatic wounds by utilizing the 2003 Kids' Inpatient Database sample to document types and volumes of specific traumatic injuries. Using discharge ICD9-CM E-codes, the authors documented a 9.05% incidence in open wounds identified in 146,358 discharge records over a 1-year period. The greatest percentage of open wounds involved the head and neck (3.46%) followed by lower extremity, upper extremity, and torso (2.31%, 1.87%, and 1.39%, respectively).⁵

The data regarding soft tissue injuries resulting from penetrating mechanisms is even less defined in children. Each year, an estimated 10,000 children seek medical attention in emergency departments as victims of firearm injuries.⁴ Keller and coworkers described 244 children who sustained a fire arm wound during a 3 year study period at our

pediatric level-one trauma center.⁶ With these limited reports for traumatic wound volume, the scope of caring for a pediatric traumatic wound remains unclear. The literature is even less regarding the cost and morbidity associated with caring for traumatic wounds in children.

The costs related to the care of specific pediatric traumatic wounds is published to a limited extent. Shields *et al.* estimated that there were 10,000 hospitalizations for pediatric burn care in 2000 and that the charges associated with these hospitalizations totaled \$200 million U.S. dollars.⁷ From the National Burn Repository 2012 Report, average hospital length of stay is slightly greater than 1 day per percent total body surface area burned.⁸ A recent publication of pediatric burn patients treated at a burn center showed that these patients required an average of 1.9 hospitalizations. The mean total cost per hospitalization was \$83,535 per patient, and the median total cost was \$16,331 per patient.⁹ Much less is known about the cost of wound care for complex blunt or penetrating open traumatic injuries.

The morbidity of traumatic wound in children varies with regard to the type of wound. Early morbidity of burns involves infection. Pneumonia, urinary tract infection, and cellulitis are the most common complications associated with pediatric burns.⁸ A known long-term morbidity of deep burns is wound scar contracture. Less well known is the morbidity associated with the psychiatric impact in children who sustain a traumatic burn. Saxe *et al.* reported that the DSM-III criteria for post-traumatic stress disorder (PTSD) were met in 30% of severely burned children who were interviewed 6 months after their injury.¹⁰ In 2012, Thomas *et al.* reported the prevalence and characteristics of personality disorders in pediatric burn patients. The authors found that a personality disorder was present in 49% of the 98 patients in the study. A factor that contributes to this morbidity may be the acute pain associated with initial burn wound care.¹¹

Other traumatic wounds seen in children include fire arm injuries, open fractures, avulsions and lacerations, and penetrating wounds. Of the soft tissue nonthermal injuries, open fractures have been the best characterized. Rennie *et al.*, in a study describing all pediatric fractures observed in a single geographic area, reported 0.7% of the 2198 total fractures as open.¹² Lower extremity fractures to the femur and tibia carry the highest incidence of associated soft tissue wounds in children (4–5%).^{13–15} Morbidity from open traumatic

wounds include pain from tissue debridement and dressing changes.

DISCUSSION

Standard management of traumatic wounds

Initial surgical evaluation and management of a traumatic wound may take place in the emergency department or operating room due to the need for pain management. Further hospital admission may be needed for ongoing intravenous pain management related to care for the wound.² For example, we know that acute burn wound assessment and management is painful. Verified children's burn centers have done studies to determine combinations of medications to provide the most optimal procedural analgesia and sedation.¹⁶ The literature is more limited characterizing the pain associated with wound exploration and dressing care for nonthermal pediatric traumatic wound. The following sections will briefly review wound care management for burns and open traumatic injuries.

Burn care. A burn wound is managed initially with debridement of the non-vitalized tissue. This enables initial determination of the burn size, depth, and degree. There are four types of burn degrees. A first-degree burn has all layers of the skin intact and viable. These first-degree burns are painful to touch but do not need any debridement or wound care intervention, because there is no devitalized tissue. The pain associated with second-degree burns is encountered with wound care consisting of initial débridements, cleansing of the wound, and dressing management. The pain associated with third-degree and fourth-degree burns is due to burn wound bed excision and grafting and subsequent wound care for the graft.¹⁷ The burn débridements, cleansing and dressing are integral to preventing infection and promoting optimal wound healing.

Often, determination of what type of dressing management is used takes into consideration the child's pain and anxiety level related to wound care, level of mobility, practicality of keeping the wound clean, and cost to the patient. Standard burn wound care involves prevention of infection by using topical antimicrobials (bacitracin, neomycin, polymyxin B sulfate, and silver sulfadiazine) and cleansing with soap and water. The half life of topical antimicrobials dictates daily or twice daily application.¹⁸ In our experience, extended use of silver sulfadiazine is not recommended due to difficulty in visualizing the underlying burn

wound for infection or healing unless the silver sulfadiazine is scrubbed off. We feel that such harsh cleansing of the burn wound is associated with more pain and impaired wound healing due to stripping the wound of healing epithelial cells.

Alternatives exist to daily or twice daily topical antimicrobial use for burn wounds. Newer silver impregnated dressings are antimicrobial and are touted to be associated with much less pain during removal and application. Such dressings are also made to be left on the burn wound and changed every 3 to 5 days or more often if soiled.¹⁹ The dressing is lifted off of the burn wound to enable wound assessment for healing or infection as needed and then placed back over the wound and re-secured in place with an outer dressing or adhesive. These types of dressings obviate the need for the more time-consuming and more frequent application of topical ointment over large burn wounds. In our experience, we reserve use of this type of dressing in children to whom we want to minimize daily sedation administration for daily dressing changes. Often, when the initial dressing changes are painful, we remove the patient's outer dressings to the point where they begin to experience pain and then, sedation is administered to the patient to complete the wound care. Once the burn patient is medically stable, they may be discharged from the hospital and scheduled for a return sedated or non-sedated dressing change visit in 3 to 5 days. If the patient tolerates touching of the burn wound without intravenous or inhaled analgesia and sedation at this return visit, we then transition from a silver impregnated dressing to soapy water baths of the burn wound with topical antimicrobials and clean gauze dressing.

Skin substitutes also exist for burn wounds such as Biobrane™ and Integra™. These types of dressings are applied to the burn wound after the initial debridement and cleansing. The skin substitute remains on the burn wound until the burn wound is re-epithelialized and healed. It is not meant to be removed or replaced during the healing period. Advantages include sterile coverage of the burn wound to prevent tissue fluid losses; no need for any painful dressing changes as the initial dressing remains in place until the wound re-epithelializes; and the wound remains visible underneath the skin substitute.^{20,21} However, the need for frequent re-evaluation of the burn is not eliminated, and application failures occur (5.9%). Studies of synthetic wound dressings used in children are limited by power. Cost of these dressings is still a concern, but there are studies that show less pain and trauma, decreased healing times, and

decreased hospital stays compared with conventional dressings if used on properly selected wounds.²²

Soft tissue wound care. For nonthermal traumatic soft tissue wounds, wound exploration to remove foreign bodies and assess depth of tissue injury involvement may be required. Initial debridement of devitalized tissue and washout of soiled cavities in traumatic wounds may be needed. Usually, these procedures are best tolerated by a child in the operating room under anesthesia or in the emergency department where deep sedation can be administered. Decisions about wound healing by primary, secondary, or tertiary intention are often physician dependent and take into consideration tissue availability for coverage and risk factors for wound breakdown and infection. Risk factors include duration of the open wound, grading of an associated open fracture, and degree of contamination. In a prospectively followed adult cohort, Quinn *et al.* showed that non-head and neck lacerations, contaminated lacerations, and lacerations greater than 5 cm in length were independent predictors for wound infection.²³

Wounds treated by primary intention involve immediate closure of the tissue defect. Secondary intention allows the open wound to heal by granulation and may require “wet to dry” gauze packing or placement of a drainage system to allow wound debris and bacteria to be removed during the healing process. Open wounds managed by tertiary intention are initially left open for a short time period to allow for cleansing and gentle debridement through “wet to dry” dressings before surgical closure of the defect.

Wounds with significant contamination and significant delay in access to wound care are less likely to be treated with immediate primary closure due to being at high risk for wound infection (Fig. 1). In addition, open traumatic wounds with large soft tissue defects may require delayed closure due to limited native tissue availability for coverage (Fig. 2). Traditionally, these wounds that are not amenable to primary closure are treated with daily moistened saline gauze packing of the wound cavity. The dressing removal and re-packing can be a painful, traumatic experience for the child (Fig. 3). Due to the need for frequent packing and dressing changes due to wound drainage and because of the pain associated with multiple dressing changes, alternative wound cavity dressings exist in the form of negative pressure wound dressings and vessel loop drains.

To provide a continuous wound environment that is conducive to healing and minimize frequent

Figure 1. An open contaminated traumatic wound from a bicycle brake handle. To see this illustration in color, the reader is referred to the web version of this article at www.liebertpub.com/wound

dressing changes, negative pressure wound dressings or vacuum-assisted closure devices have been utilized for pediatric indications.^{24–27} Contractor *et al.* published a comprehensive review of the literature on the use of negative pressure wound dressing for pediatric patients. This review was not limited to pediatric trauma patients. The authors summarized the types of pediatric wounds for which a vacuum-assisted closure device was used, including traumatic wounds such as open fractures, burns, and soft tissue injuries. Contractor *et al.* concluded that negative pressure wound dressings are being used as first-line therapy or as a bridge to anticipated final wound coverage. The authors further discuss that negative pressure wound dressings can have several benefits—decreased costs associated with wound care, shorter length of

Figure 2. An open fracture. To see this illustration in color, the reader is referred to the web version of this article at www.liebertpub.com/wound

Figure 3. A large traumatic wound of the back from a lawn mower. To see this illustration in color, the reader is referred to the web version of this article at www.liebertpub.com/wound

hospital stay, fewer dressing changes, and greater patient and family satisfaction.²⁶ Halvorson *et al.* also reported the use of vacuum-assisted closure device for the management of pediatric open fractures.²⁸ The authors found that the rate of infection was not different from the standard rate associated with traditional “wet to dry” gauze packing dressings changed frequently. As a secondary benefit, the authors noted that a decreased need for eventual flap coverage of an open fracture wound was accomplished with the use of the vacuum-assisted closure device.

Other advantages of a vacuum-assisted closure device include increased granulation tissue and decreased frequency of dressing change when compared with “wet to dry” gauze packing.²⁷ Typically, the vacuum sponge dressing is changed every 3 to 5 days. Less need for dressing changes translates to less pain experienced. Vacuum sponge dressing changes can be done at home as an outpatient depending on the complexity of the wound and pain tolerance of the patient. In our experience, the vacuum sponge dressing change is not universally tolerated by children at home due to the anxiety and pain associated with the procedure, especially in the early stages of wound healing. Though the vacuum sponge dressing is occlusive, the negative pressure environment allows for bacteria to drain through connected drain tubing into a collection canister. Home vacuum sponge dressings are connected via tubing to a portable, light-weight (as low as 2.5 pounds), battery charged machine with a collection canister. Disadvantages for this type of dressing include variable insurance coverage, need for it to be connected to a machine, and need for the dressing to stay occlusive.

For smaller, contaminated penetrating traumatic wound cavities that may or may not be “through and through” injuries, providers manage the wound with saline moist gauze packing that is changed daily or more frequently. We have used a Penrose or vessel loop drain as an alternative to wound packing. An example of a wound that utilized a vessel loop includes a tree branch impalement of the superficial abdominal wall. The patient had an entrance site, while an exit site was created with a 5 mm incision at the distal end of the branch (Fig. 4). The vessel loop is a thin silicone ribbon that can be passed from one open wound to another and secured in place with knots. This ribbon allows the wounds to remain “open” for outpatient soapy water bath cleansing while allowing the underlying soft tissues to granulate in around the thin ribbon. This management does not employ frequent gauze packing and replacement. The loop can be removed as an outpatient without any sedation in several days. Its success in the pediatric population is well documented in soft tissue abscess management.^{29,30}

St. Louis Children’s Hospital Paws model

Management of acute traumatic wounds can involve hospital admission and surgical intervention. This surgical intervention may take place in the operating room or emergency department to provide adequate analgesia and anesthesia. Surgical intervention examples are burn or soiled soft tissue debridement and initial application of a negative pressure wound dressing or drain placement. Less invasive subsequent inpatient management of the wound such as a burn dressing

Figure 4. A traumatic wound from a tree branch impalement. To see this illustration in color, the reader is referred to the web version of this article at www.liebertpub.com/wound

change is known to have associated pain and anxiety. The stress of inpatient treatment, specifically a burn dressing change, has been compared with “inescapable shock” or “learned helplessness” for pediatric burn patients.³¹

The Pediatric Acute Wound Service (PAWS) has been developed at our institution, and it allows for inpatient and outpatient surgical management of various soft tissue conditions. We find it to be an ideal unit where traumatic wounds, which otherwise would be historically managed in the operating room or inpatient hospital setting, can be evaluated and managed. PAWS exists as a separate unit in our hospital where outpatients arrive and where inpatients are transported for wound care. It incorporates procedural sedation and pain control with wound care expertise in a setting that does not necessitate return trips to the operating room or mandate inpatient stay for procedural pain control. One patient population where we have had the most success in utilizing PAWS is our burn patients (Fig. 5). Admitted burn patients who do not require intensive care unit monitoring or burn wound excision are candidates for undergoing their initial and subsequent burn débridements and dressing changes in PAWS until the patient is able to tolerate dressing changes with oral pain medication.

Our community pediatricians utilize PAWS as an outpatient center. When these care providers see a child for a burn, they are able to refer the patient to PAWS and avoid an emergency department visit. Pediatric surgical services, such as orthopedics, plastic surgery, and general surgery, utilize PAWS for inpatient and outpatient trau-

matic wound care. For example, while initial placement of a vacuum device is placed in the operating room by these services, follow-up device exchanges take place in PAWS as an outpatient until the patient is able to tolerate device exchanges at home or the device is discontinued.

We have previously described the decrease in resource utilization for pediatric burn patients.³² Within St. Louis Children’s Hospital, hospital costs for labor, equipment, and supplies alone for a 30 minute procedure differ depending on where the procedure takes place: \$150 (PAWS), \$550 (Emergency Department), and \$943 (Operating Room) (unpublished data). Ebach *et al.* reported not only a decrease in operating room visits but also a decreased length of stay for burn patients with the development of PAWS when compared with historical data.³³ Length of stay decreased from 9.5 to 6.2 days. We translate this outcome into decreased medical costs for hospital stay due to fewer days in the hospital. In a later study from our institution, Foglia *et al.* found a 50% reduction in hospital charges for pediatric burn care in the setting of this model that enabled outpatient burn care which was equivalent to inpatient burn care. Again, the authors demonstrated a decrease in hospital length of stay, from 10.4 to 5.8 days ($p < 0.05$). An additional finding by the authors was that infection rates did not increase with the earlier transition to outpatient burn care. Infection rates actually decreased from 5.3% to 3% in burn patients treated in PAWS ($p < 0.05$).³⁴

Turmelle *et al.* outlined the sedation training program developed at our institution that enables pediatricians, instead of pediatric anesthesi-

Figure 5. A skin graft burn dressing change. To see this illustration in color, the reader is referred to the web version of this article at www.liebertpub.com/wound

Figure 6. A Pediatric Acute Wound Service room at St. Louis Children’s Hospital. To see this illustration in color, the reader is referred to the web version of this article at www.liebertpub.com/wound

ologists, the ability to provide procedural sedation and pain management.³⁵ PAWS sedation consists of inhaled nitrous oxide or intravenous sedation medications. Bucher *et al.* describes the members of the PAWS team, which includes a pediatric surgery nurse practitioner staffing the unit 5 days a week and an available pediatric surgeon.³² Wound care and surgical supplies are housed within the PAWS unit in addition to having a whirlpool tub (Fig. 6). PAWS avoids the costs associated with the operating room, pediatric anesthesiologist, and surgeon provider. PAWS allows for the care of a trauma patient to take place away from their hospital patient room in an effort to decrease fear, pain, and anxiety with wound care. Instead, the child can then view their hospital room as a place to eat, sleep, and be with their family.

The data on traumatic wound care pain and its adverse affects on children are limited to pediatric burns. The pediatric patient with a burn is evaluated and found to need hospital admission. Initial burn debridement is needed. Since this debridement is painful, the patient is separated from the parent and taken to the operating room for adequate anesthesia and analgesia. Postoperatively, the patient is in their hospital room with their family. A medical provider comes in to perform a daily burn dressing change. The patient's fear and anxiety level increases as the provider approaches the dressing and begins taking the outer dressings off. The removal of the final layers of dressing over the burn wound and cleansing of the acute wound is painful for the patient. The application of topical antibiotic and the dressing coverage is also painful to touch. The family witnesses their child in fear, anxiety, and pain. The child, at the same time, is able to see their parent stand by as the medical provider continues to perform the painful wound care. In other scenarios, it is not uncommon for the parent to ask to step out or to take up the offer to leave the room during a painful and anxiety filled dressing change.

A study by Stoddard *et al.* indicated that 25% to 33% of burn injured children go on to develop PTSD.³¹ Saxe *et al.* showed that one pathway to PTSD was mediated by separation anxiety and this was, in turn, influenced by the acute pain response.¹⁰ Stoddard *et al.* found that parents' acute stress of having a child in pain influenced the child's own acute stress symptoms.³⁶ Other studies have described problems with sleep, conduct, elimination, learning, and attention in pediatric burn patients. The adverse effects of the pain and anxiety associated with early burn wound care are not only psychological. Stoddard *et al.* discussed

that the physiological impact of pain through hormone-mediated catabolic stress response involves diminished immune function and impaired wound healing in burn patients.³¹

Within the PAWS model, pediatric patients with their burn dressing intact come to the treatment room with their parents and are sedated in the parents' presence. Once sedated, the burn dressing is removed and then, any needed burn debridement takes place. A new dressing is applied. The child does not remember that the parent has left or that the dressing care occurred. The child recovers from the sedation and wakes up witnessing a new burn dressing already in place. During the sedated dressing care, the opportunity exists for teaching the family about the wound and the care for the wound in an optimal environment that hopes to minimize the family's stress of witnessing their child in fear and pain. This is an ideal time for therapy services to also perform passive range of motion exercises on the sedated child with their wound dressings off if needed. Thus, this PAWS model avoids a child witnessing a parent separation. The model allows for analgesia beyond oral pain medication to allow for more optimal pain control and, thus, avoid the impaired wound healing and decrease in immune function that stems from the physiological impact of pain. PAWS offers adequate sedation to the burn patient, minimizing both patient and parent anxiety while prohibiting patient recollection of the dressing removal, burn wound debridement, and dressing re-application. Other advantages of PAWS include having a core staff of wound certified specialists that are up to date on the technical management and dressing supplies for burns and open soiled soft tissue defects.

SUMMARY

In summary, the management of traumatic wounds such as burns and open soft tissue defects involves costs associated with operating room charges, hospital stay, and adequate procedural sedation and pain control. The pain and anxiety associated with traumatic wound care are not insignificant and show a propensity toward decreased immune function, impaired wound healing, PTSD, personality disorders, and other pediatric behavioral problems. The PAWS model decreases hospital costs related to traumatic wound care by not utilizing operating room or emergency unit visits, by decreasing hospital length of stay through earlier transition to outpatient wound care that is equivalent to inpatient wound care. This continuity of procedural sedation

and pain control avoids the adverse effects of pain and anxiety associated with traumatic wound care. Though the actual wound itself may not be better off, we feel that the wound care is more cost efficient and more effective in addressing the risk factors for impaired wound healing and psychological and behavioral morbidity through the use of PAWS.

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TAKE-HOME POINTS

- Pediatric complex traumatic wounds are common, but optimal management is not well elucidated in the literature.
- Alternatives to typical traumatic wound dressings exist and may be more cost effective and associated with less pain and less frequent application in children.
- Pain experienced by patients during dressing changes as well as the parents' experiences are risk factors for PTSD and impaired wound healing.
- Complex traumatic wounds in children may be cared for initially and on an ongoing inpatient or outpatient basis through a specialized model unit that utilizes pediatricians for adequate sedation and pain management.
- A specialized sedation and pain control unit model can decrease costs and hospital length of stay for the management of pediatric traumatic wounds.

REFERENCES

1. Committee on Trauma, American College of Surgeons, National Trauma Data Bank. Chicago, IL, 2013.
2. Vercruysse GA, Ingram WL, and Feliciano DV: Overutilization of regional burn centers for pediatric patients—a healthcare system problem that should be corrected. *Am J Surg* 2011; **202**: 802.
3. Pediatric Burn Fact Sheet. The Burn Foundation. www.burnfoundation.org/programs/resource.cfm?c=1&a=12 (accessed February 21, 2013).
4. National Emergency Department Sample; HCUP Databases. *Healthcare Cost and Utilization Project (HCUP)*. Rockville, MD: Agency for Healthcare Research and Quality, 2008.
5. Guice KS, Cassidy LD, and Oldham KT: Traumatic injury and children: a national assessment. *J Trauma* 2007; **63** (6 Suppl): S68.
6. Mazotas IG, Hamilton NA, McCubbins MA, and Keller MS: The long-term outcome of retained foreign bodies in pediatric gunshot wounds. *J Trauma Nurs* 2012; **19**: 240.
7. Shields BJ, Comstock RD, Fernandez SA, Xiang H, and Smith GA: Healthcare resource utilization and epidemiology of pediatric burn-associated hospitalizations, United States, 2000. *J Burn Care Res* 2007; **28**: 811.
8. National Burn Repository 2012 Annual Report. American Burn Association. www.ameriburn.org/NBR.php (accessed March 18, 2013).
9. Carey K, Kazis LE, Lee AF, Liang MH, Li NC, Hinson MI, Lydon MK, Bauk H, Shapiro GD, and Tompkins RG: Multi-Center Benchmarking Study Working Group. Measuring the cost of care for children with acute burn injury. *J Trauma Acute Care Surg* 2012; **73** (3 Suppl 2): S229.
10. Saxe GN, Stoddard F, Hall E, Chawla N, Lopez C, Sheridan R, King D, King L, and Yehuda R: Pathways to PTSD, Part I: children with burns. *Am J Psychiatry* 2005; **162**: 1299.
11. Thomas CR, Russell W, Robert RS, Holzer CE, Blakeney P, and Meyer WJ: Personality disorders in young adult survivors of pediatric burn injury. *J Pers Disorder* 2012; **26**: 255.
12. Rennie L, Court-Brown CM, Mok JY, and Beattie TF: The epidemiology of fractures in children. *Injury* 2007; **38**: 913.
13. Irwin A, Gibson P, and Ashcroft P: Open fractures of the tibia in children. *Injury* 1995; **26**: 21.
14. Hutchins CM, Sponseller PD, Sturm P, and Mosquero R: Open femur fractures in children: treatment, complications, and results. *J Pediatr Orthop* 2000; **20**: 183.
15. Loder RT, O'Donnell PW, and Feinberg JR: Epidemiology and mechanisms of femur fractures in children. *J Pediatr Orthop* 2006; **26**: 561.
16. Stoddard FJ, Jr., White GW, Kazis LE, Murphy JM, Sorrentino EA, Hinson M, Kim Stubbs T, Chan G, Sheridan RL, Palmieri T, Kagan R, Herndon D, and Tompkins RG: Patterns of medication administration from 2001 to 2009 in the treatment of children with acute burn injuries: a multicenter study. *J Burn Care Res* 2011; **32**: 519.
17. Coimbra C, Choiniere M, and Hemmerling TM: Patient-controlled sedation using propofol for

- dressing changes in burn patients: a dose-finding study. *Anesth Analg* 2003; **97**: 839.
18. Chung DH and Herndon DN: Burns. In: *Ashcraft's Pediatric Surgery*, 5th ed, edited by Holcomb GW and Murphy JP. Philadelphia, PA: Saunders, 2010, p. 154.
 19. Silverstein P, Heimbach D, Meites H, Latenser B, Mozingo D, Mullins F, Garner W, Turkowski J, Shupp J, Glat P, and Purdue G: An open, parallel, randomized, comparative, multicenter study to evaluate the cost-effectiveness, performance, tolerance, and safety of a silver-containing soft silicone foam dressing (intervention) vs silver sulfadiazine cream. *J Burn Care Res* 2011; **32**: 617.
 20. Leshner AP, Curry RH, Evans J, Smith VA, Fitzgerald MT, Cina RA, Streck CJ, and Hebra AV: Effectiveness of biobrane for treatment of partial-thickness burns in children. *J Pediatr Surg* 2011; **46**: 1759.
 21. Pham C, Greenwood J, Cleland H, Woodruff P, and Maddern G: Bioengineered skin substitutes for the management of burns: a systematic review. *Burns* 2007; **33**: 946.
 22. Mandal A: Paediatric partial-thickness scald burns—is Biobrane the best treatment available? *Int Wound J* 2007; **4**: 15.
 23. Quinn JV, Polevoi SK, and Kohn MA: Traumatic lacerations: what are the risks for infection and has the 'golden period' of laceration care disappeared? *Emerg Med J* 2013; **0**: 1.
 24. Mooney JF, Argenta LC, Marks MW, Morykwas MJ, and Defranzo AJ: Treatment of soft tissue defects in pediatric patients using the V.A.C. system. *Clin Orthop Relat Res* 2000; **376**: 26.
 25. Caniano DA, Ruth B, and Teich S: Wound management with vacuum-assisted closure: experience in 51 pediatric patients. *J Pediatr Surg* 2005; **40**: 128.
 26. Contractor D, Amling J, Brandoli C, and Tosi LL: Negative pressure wound therapy with reticulated open cell foam in children: an overview. *J Orthop Trauma* 2008; **22 (10 Suppl)**: S167.
 27. Chariker ME, Gerstle TL, and Morrison CS: An algorithmic approach to the use of gauze-based negative-pressure wound therapy as a bridge to closure in pediatric extremity trauma. *Plast Reconstr Surg* 2009; **123**: 1510.
 28. Halvorson J, Jinnah R, Kulp B, and Frino J: Use of vacuum-assisted closure in pediatric open fractures with a focus on the rate of infection. *Orthopedics* 2011; **34**: e256.
 29. Ladd AP, Levy MS, and Quilty J: Minimally invasive technique in treatment of complex, subcutaneous abscesses in children. *J Pediatr Surg* 2010; **45**: 1562.
 30. Tsoraides SS, Pearl RH, Stanfill AB, Wallace LJ, and Vegunta RK: Incision and loop drainage: a minimally invasive technique for subcutaneous abscess management in children. *J Pediatr Surg* 2010; **45**: 606.
 31. Stoddard FJ, Sheridan RL, Saxe GN, King BS, King BH, Chedekel DS, Schnitzer JJ, and Martyn JA: Treatment of pain in acutely burned children. *J Burn Care Rehabil* 2002; **23**: 135.
 32. Bucher BT, Seigel J, Rosenblum E, Nessler C, Keswani S, Foglia RP, Dillon PA, Warner BW, and Keller MS: A pediatric acute wound service: a novel approach in wound management. *J Pediatr Surg* 2010; **45**: 167.
 33. Ebach DR, Foglia RP, Jones MB, Langer JC, Skinner MA, Moushey R, and Meadows L: Experience with procedural sedation in a pediatric burn center. *J Pediatr Surg* 1999; **34**: 955.
 34. Foglia RP, Moushey R, Meadows L, Seigel J, and Smith M: Evolving treatment in a decade of pediatric burn care. *J Pediatr Surg* 2004; **39**: 957.
 35. Turmelle M, Moscoso LM, Hamlin KP, Daud YN, and Carlson DW: Development of a pediatric hospitalist sedation service: training and implementation. *J Hosp Med* 2012; **7**: 335.
 36. Stoddard FJ, Saxe G, Ronfeldt H, Drake JE, Burns J, Edgren C, and Sheridan R: Acute stress symptoms in young children with burns. *J Am Acad Child Adolesc Psychiatry* 2006; **45**: 87.