Acute Management of Pediatric Hand Burns

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The choice between conservative treatment and aggressive early excision of hand burns has been widely debated. With the introduction of topical antimicrobial agents, early tangential excision of the burn wound by Janžeković,8 and early aggressive therapy combined with the improved use of splints, the gnarled, functionless hand as a sequella of burn injury has become a rarity. Subsequent studies by Edstrom6 and others,10 however, have shown no significant difference in function between hand burns treated with early excision and those healing spontaneously. The burned hand in the child, in our experience, results from a different pattern of injury and responds differently to therapeutic intervention compared with the adult hand. For these reasons, we have developed a conservative approach to most injuries.

A retrospective review of 226 consecutive burn admissions to The Hospital for Sick Children over a 3-year period (1986 to 1988) was performed. A total of 58 patients sustained burns below the elbow. One chart was unavailable for review and 1 patient succumbed to the burn injury. The remaining 56 patients with 64 burned extremities were reviewed.

The etiology of the burn wound in our population was scald (37 per cent), flame (27 per cent), contact (25 per cent) and others, including electrical (11 per cent). The more common flame burn injury in adults tends to produce a deeper injury compared with the typical childhood scald. This favorable pattern in children allows us to treat the wound conservatively with twice daily dressings, closed dressings, and active rehabilitation therapy.

In this review we present a detailed description of our approach to wound care and briefly outline the nutritional and psychosocial aspects of pediatric burns. In addition, we discuss the

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surgical approach used in our unit and the rehabilitation of hand burns. Lastly, the result of this integrated approach is presented.

WOUND CARE

Burn injuries by their very nature interfere with the protective function of the skin, rendering the burn wound susceptible to dessication and infection. The primary goal of wound care must be to prevent infection and its sequela of conversion of the wound, damage to deeper structures, or worst of all, systemic dissemination. In addition, meticulous wound care facilitates the preservation of function and allows for appropriate therapy and positioning, which is particularly important in the hand. The description of wound care that follows, although pertaining to all anatomic regions, concentrates on the child's hand.

Open-Wound Phase

The open-wound phase refers to the period from burn insult to final closure of the wound. The child is bathed in a hydrotherapy tub, with normal saline solution, twice a day. Wounds are washed carefully to remove all loose exudate and debris. Nonviable tissue is removed from the wounds using forceps and scissors with each treatment (mechanical debridement). Unbroken blisters are left intact, if feasible, to provide a moist, sterile environment for wound healing.

Specific burn dressings for the hand are designed through collaboration between the nurse and the therapist. Individualized range-of-motion exercise programs are formulated by the therapist and are implemented at dressing changes by either the therapist or the nurse.

Dressings are changed under sterile technique with liberal application or topical silver sulfadiazine to the burn (Fig. 1). The functional hand position is maintained by placing large web spacers (5 x 2 cm pieces of gauze) between each digit (Fig. 2) and a soft roll of gauze in the palm (Fig. 3), thereby achieving maximum digital abduction and thumb opposition. The transverse arch is also maintained with this positioning routine. The roll in the palm is unnecessary if a splint is used for positioning, but web spacers remain essential (Fig. 4).

Closed-Wound Phase

The closed-wound phase begins with either spontaneous epithelialization or skin grafting. Skin grafting is often necessary for wound closure with a full thickness or deep partial thickness burn injury. After the grafting procedure, dressings are secured with a partial cast or splint, which immobilizes the hand and wrist to avoid shearing of the grafts. Hands are elevated either on pillows or with a suspension dressing. Dressings are removed by soaking in the hydrotherapy tub 7 to 10 days after grafting. Grafts that have taken well will appear pinkish and will have adhered smoothly to the base. Crusting may occur on or around the grafts and will lift off with further soaking and lubrication. Small vesicles that may appear can be pierced with a sterile needle and expressed. Initially, ointment-impregnated dressing and an antibacterial ointment are used in conjunction with a light gauze dressing. Once the grafts are secure and can be left exposed without the threat of injury (usually 3 to 5 days) or the wound has healed spontaneously, a moisturizing cream is applied several times a day to combat dryness.

NUTRITION

Nutrition is an important factor in promoting wound healing and preventing infection. The
Figure 1. Topical silver sulfadiazine is liberally applied to the cleansed, debrided hand.

Figure 2. Large web spacers are carefully placed between all the digits to enhance abduction.

Figure 3. A soft roll of gauze is placed in the palm and the hand is molded into the position of function around it.
child with burns has increased caloric and protein requirements. In addition, nutritional support must meet the child’s normal growth and developmental needs. It is rare, particularly in the younger age groups, for a burned child to consume enough calories and protein to meet these combined requirements. The hospitalized child may refuse to eat because of separation from family and surroundings, general malaise, the restrictions of dressings, or differences in cultural background. The child may refuse to eat as his only means to exercise control over the situation.

The need for supplemental nasogastric feeds is not determined by the size of the burned area. If the child is unable to consume 50 per cent of his baseline plus burn caloric and protein requirements by mouth, nasogastric tube feeding is initiated. Feeds are started early, reaching the child’s optimum nutritional requirements within the first 48 hours after the burn occurred.

The nutritional status of the child should be assessed and followed closely using daily weights and calorie counts. The nurse should work closely with the dietician to accomplish these goals.

**PSYCHOSOCIAL ASPECTS**

Any burn injury to a child places added emotional stress on the family unit. Certainly, burn injuries to a child’s hand raise many parental concerns such as fear of loss of function and altered appearance. Parents often feel guilty regarding the cause of their child’s injuries. It is therefore very important for a social worker to be actively involved from admission to discharge and beyond, and to keep parents well informed of their child’s care and progress. This contact helps to decrease any unwarranted fears and anxiety.

**PAIN MANAGEMENT**

The most important objective of pain management is that the child be comfortable and tolerate painful procedures with a sense of control. The child must also be able to enjoy the remainder of the day pain free to play, eat, and rest comfortably. Good communication is required to document the specifics that help each child with pain control. Consistency of care helps the child to feel more secure and less anxious.

Narcotic analgesics are given before tub procedures, although some older children may prefer medication immediately after dressing changes. Other methods of pain control include the use of distraction such as play, music, toys, television, and the use of imagery and relaxation techniques. School-age children and adolescents like to participate in their own care as much as possible in ways such as helping to remove cream. However, time limits and contracts must be made between the child and caregiver.

**SURGICAL CONSIDERATIONS**

**Indications**

Deciding whether or not to graft burns to the hand of a child can be extremely difficult. This
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Decision is related, in part, to the epidemiology of childhood burns. Many are scald injuries, which are of indeterminate depth. The other important difference in childhood burns is that the hand will withstand immobilization through longer periods of time without significant residual stiffness, allowing the clinician the opportunity to defer the decision about grafting.

Immediate surgery in burns of the hands in children is limited to escharotomy. Escharotomies should be considered in any patient with circumferential burns to the fingers, hand, or forearm. Assessment of the vascular supply to the tips of fingers can be made both clinically, by using capillary refill and turgor, and also by using various forms of instrumentation, such as Doppler flowmeters, to assess digital artery flow. Escharotomy should be undertaken in any hand in which there is a serious concern about the circulation to the digits.

Scald burns of the hand can often be left to allow full demarcation of full thickness and partial thickness areas. In small children it is possible to maintain a satisfactory range of motion while still applying occlusive burn dressings. Fastidious nursing care is the key to provide safety in deferring treatment in hand burns. Two to 3 weeks of spontaneous healing are allowed before making a final decision about grafting.

Flame burns commonly require skin grafting. In these cases, the areas of full thickness loss may be apparent at initial assessment. Escharotomies will have been performed and early surgery can be undertaken with excision of the burn scar in a tangential fashion and grafting.

Contact burns can lead to significant skin loss. This often occurs on the palmar surface of the hand, which is otherwise usually spared full thickness injury owing to its thickness. Even very narrow areas of burn on the palmar surface may require grafting, particularly if they are aligned along the flexion arc of the finger. This may reduce the likelihood of contracture of the small joints of the hand, although secondary surgery is often required.

Timing of Surgery

Although many authors have demonstrated that early surgery should be undertaken in hand burns to provide early mobilization, our experience has shown that it is possible to defer surgical management of burned hands in children and still achieve full mobilization. The advantage of this approach is that it allows more accurate assessment of the burn wound. In addition, burns over the extensor surface of the fingers, which can be extremely difficult to debride given the very thin skin and subcutaneous tissue overlying the extensor peritenon, can be allowed to separate so that only minimal debridement is required.

Surgical Technique

Escharotomies can be performed in an awake patient without anesthesia. Escharotomy incisions should be carried down the midlateral and midmedial aspects of the forearm and extend from those incisions along the radial aspect of the thumb and ulnar aspect of the little finger. Any involved digits should have midlateral incisions made on both sides throughout the entire extent of the eschar and extending to the pulp of the finger. In electrical injuries, fasciotomies are usually required, and it is advantageous to shift the incision to the palmar surface and undertake a wide S-shaped incision such that the carpal tunnel can be released through the base of this wound.

Escharotomy incisions should transgress the entire thickness of the dermis exposing the underlying fat. Restoration of distal perfusion can then be monitored. Hemostasis is sometimes required but usually light pressure will stop bleeding from the escharotomy wound. Significant amounts of fluids will ooze from escharotomy sites and an appropriate burn dressing must be applied.

Debridement of hand burns remains a matter of individual preference for different surgeons. Debridement of the upper extremity can be undertaken under tourniquet control to reduce the risk of producing significant blood loss in a small child. A number of specific techniques have been described.

The full thickness eschar can be excised in tota in a' single swath using a dermitome. Although this technique is commonly used on other parts of the body in flame burns, it is uncommon to use it in hand burns, where the
risk to vital structures is great and the best possible scarring is desirable.

The technique of tangential excision involves removing, in a serial fashion, very thin layers of the eschar from the burn surface. This debridement is repeated until healthy bleeding tissue is encountered. In this way it is hoped that the maximum amount of viable dermis is maintained to provide a better base than fat for skin grafting and to allow for improved scars. Although this technique is frequently done without a tourniquet so that the bleeding pattern can be appreciated, it must be understood that significant bleeding can occur from such a procedure. Immediately upon debridement, the wounds can be covered in fine mesh gauze soaked in a solution of normal saline, thrombin, and neosynephrine. This not only keeps the wounds moist but reduces substantially the amount of bleeding from the wounds. Pressure can be applied by wrapping the extremity in a gauze or flannel bandage.

If the wound has been allowed to separate spontaneously, only a limited debridement of the granulation tissue may be required. If the tissue is sufficiently healthy, a simple wipe with a damp or dry gauze may provide adequate removal of any debris on the surface. If granulation tissue has become mature, it may be necessary to debride more rigorously with the blunt edge of Howarth elevator or the back of a scalpel blade or handle. If the granulations are hypertrophic and appear not to be an adequate bed for skin grafting, frank excision of the granulation tissue may be required with a dermatome.

Given the size and area of hand burns commonly seen in practice, the usual donor site in children is the buttock. The patient can be positioned in the decubitus position and both the extremity and buttock can be prepared and draped with ease. The hip and knee are flexed to place the buttock skin under tension for skin graft harvesting. Dressings of the surgeon’s choice can be applied to the donor site with care to provide a seal between the perineum and dressing using waterproof tape.

In most cases sheet grafts are used in hand burns because the esthetic result is substantially better. Entire units of the hand, such as the dorsum of a digit or of the hand itself, can be grafted with separate sheets. Although skin grafting of the palmar surface of the hand is not commonly required, sheet grafts are used. The grafts can be secured using staples in older children or with chromic sutures in infants and small children. The hand can then be immobilized, either internally, using K-wires placed through the metacarpal heads and along the axis of each finger, or externally, using a plaster bandage. In children the wrist is immobilized in flexion after grafting the dorsum of the hand, even though this is not the position of function. One week to 10 days of immobilization in this position does not leave significant residual stiffness in the wrist and allows for full coverage of the burn area.

It is far easier to apply a secure dressing to the grafted extremity of a young child under general anesthesia in the operating room than to struggle on the ward attempting to salvage a poorly applied dressing. Dressing materials in small sizes are required and in children under the age of 6 the partial plaster or splint is applied to an above-elbow level to secure the dressing from sliding down the forearm. Various adhesives can be used to fix the bandage to the normal skin of the extremity. A suspension dressing is required to minimize edema.

**Infection**

Infection in burn wounds may lead to delayed healing, loss of skin grafts, and systemic sepsis. Prevention is most efficacious, using the wound management principles outlined above. Routine prophylactic systemic antibiotics are not used, although some surgeons use systemic penicillin in the initial treatment of scald burns if streptococcus is prevalent in the family or community. This issue remains controversial.

Infected wounds require urgent excision and extremely close monitoring of systemic signs. Colonization of the wound, however, does not preclude grafting.

**Postoperative Care**

Skin-grafted hands should be immobilized for at least 1 week in small children. The dressing secured in the operating room is the most satisfactory dressing that can be applied and to
change this at several days requires more cooperation than the average small child can provide. By waiting 1 week after grafting, all healed areas will be manifest and any areas that have sloughed will come off with the dressing.

REHABILITATIVE MANAGEMENT

Deep thermal injuries to the hand present a specific and significant challenge to the rehabilitation team. The challenge is to manage the short lever arm available in the application of treatment modalities. In the young child this is further complicated by their lack of muscle strength to oppose the force of the contracting burn scar and by their inability to understand and cooperate in the treatment process. To overcome the identified problems and achieve an optimal outcome, a comprehensive protocol of early motion, protective positioning, and splinting is recommended.

Intrinsic factors that affect prognosis following thermal injury to the hand are the anatomic location, depth of burn, rate of healing, hereditary potential of the individual to develop scar tissue, physiologic contractile forces active in wound healing, scar maturation, and age. The young child tends to form more scar tissue. Extrinsic factors that affect prognosis are the therapeutic intervention, follow-up, and parental and patient compliance.

The goals of pediatric burn therapy are to maintain normal function, improve compromised function, and prevent the development of deformities. Intervention by physical and occupational therapy can encompass protective positioning, splinting, exercise, massage, desensitization, age-appropriate activities, and normal motor development.

Open-Wound Phase

Rehabilitative management begins in the early acute phase and continues throughout the hospitalized period. Burn area and depth are assessed and analyzed for potential problems of swelling, tendon rupture, and contracture. In the open-wound phase, the position of comfort in flexion may increase the contracture of the burn wound surface.

For superficial partial thickness burns, the hand is managed by a free active exercise program and positioning routine. The functional hand position is incorporated into the burn dressing as previously described.

The young child does not understand the need to protect vital structures that may be at risk for further damage in the open-wound phase in deep hand burns. Specific positioning and a gentle, passive exercise program is developed to minimize this risk. In deep burns that involve the dorsum of the digit, the extensor mechanism may be compromised. In the young child active exercises are limited to metacarpal-phalangeal joint flexion and extension with the interphalangeal joints maintained in full extension, abduction and adduction of the digits, and thumb opposition to the finger tips. The rationale for joint protection is not easily understood by this age group and active fisting is discouraged. A protective, passive exercise routine is designed so that each joint will be put through gentle, full passive range of motion independent of the other joints. The remaining joints of the digit being mobilized are held in a fully extended position to protect the extensor mechanism. In the older child, each joint is moved through full, active range of motion independently while the adjacent joints are stabilized in the extended posture.

The volar burn does not typically compromise the flexor tendons. There are no limitations in the active exercise routine. The younger child is encouraged to use the hand in water play, which is a relaxing and comfortable medium in which to achieve the full benefit of unrestricted movement. As well as performing free active exercises, a specific passive exercise routine is aimed at maintaining the palmar spread by maximizing the mobility of the first, fourth, and fifth metacarpals into extension and abduction. At the same time, the fingers and thumb are stretched gently into hyperextension.

Appropriate passive exercises are repeated twice if full range is achieved easily. If skin or joint tightness becomes apparent, however, the repetitions are increased until full range of motion is regained. The exercise program is performed twice daily after the wounds have been cleaned and just prior to dressing.

Splints are used in hand burns that are gauged to be of sufficient depth to produce
significant scars or to require grafting. In volvar burns, however, this decision may be deferred until the wounds have declared themselves, eliminating direct contact with the splint as a further cause for burn wound conversion in more superficial injuries.

When splinting the hand of the infant and toddler, one must consider that the digits are short lever arms and are therefore difficult to immobilize in the adult resting position of metacarpal-phalangeal joint flexion and interphalangeal joint extension. The child can easily escape the splint in this position by actively flexing the metacarpal-phalangeal joints, resulting in the hand becoming fisted within the splint. To solve this problem, the effective lever arm is extended to include the metacarpals, and the hand is positioned in full metacarpal-phalangeal and interphalangeal joint extension and finger abduction. The positions for the thumb and wrist are dependent on the specific burn. The splint is held in place with a conforming lid of similar material producing a bivalved orthosis. For the older child the position of the hand is similar to the approach described for the adult, with the metacarpal-phalangeal joints positioned in sixty degrees of flexion and the interphalangeal joints in ten degrees of flexion. Gauze bandage is wrapped lightly to hold the splint in position.

The material of choice for splint fabrication is a low temperature thermoplastic. The splint is worn continuously except for hydrotherapy sessions and is cleaned with a warm solution of soap and water.

Closed-Wound Phase

Rehabilitative management in the closed-wound phase must address the intrinsic factors in burn wound healing. The natural course of the burn scar is to contract, resulting in classic hand deformities. The increase in blood supply and cellular activity, which causes hypertrophic scar formation, is affected by compression of the scar. The key principles in therapy for burn scar contractures are elongation and compression.

In deep dorsal burns the contractile forces result in a deformity of metacarpal-phalangeal hyperextension, adduction and extension of the thumb, and flattening of the transverse palmar arch. If the wrist is involved it may be pulled into extension. The interphalangeal joints will be pulled into flexion as a result of the tenodesis effect and the greater strength of the long flexor tendons.

Active range of motion is encouraged through age-appropriate play with resisted activities. In the young child, the lack of muscle strength to overcome the contractile forces of the burn scar is a handicap; therefore, an aggressive exercise program is of primary importance. For the child who is unable to make a full fist actively, a program of sustained passive stretching with massage is used 4 times daily until full range is regained. The child is then encouraged to maintain this range through active play, and emphasis is placed on resisted grip activities. Strengthening of the long flexors and the intrinsic muscles of the hand is important in limiting the potential for deformity.

In the closed-wound phase, the bivalved splint used in the young child is modified to gain twenty degrees of metacarpal-phalangeal joint flexion. Dynamic flexion splinting may be required as an adjunct to the passive exercise routine. The most common approach is to use a flexion mitten that is attached to a wrist cuff (Fig. 5). Hooks glued to the fingernail are contraindicated, since traction forces applied to the nail in a child under 5 years can result in damage to the immature nail bed or avulsion of the nail plate.

Volar burns of the hand in the younger age group are typically contact burns. The thumb lies in a plane perpendicular to the palm so the radial aspect of the thumb is often involved. Scar contracture can result in a typical deformity of finger flexion, radial deviation of the thumb, and decreased palmar spread with adduction and opposition of the first, fourth, and fifth metacarpals. If the burned area extends onto the volar surface of the forearm, the resultant deformity will be wrist flexion.

In the closed-wound phase of deep volar burns, the most significant passive stretches are finger extension with abduction and palmar spread to flatten the transverse arch with thumb and little finger abduction and extension (Fig. 6). Activities to promote total active extension are encouraged, for example, pushing a large ball against resistance and crawling.

After the wound is closed, the splint is
of gauze is applied directly to the area being compressed and is held in place by the splint.11 This splint and insert routine provides compression and maintenance of lubrication of the scar in the elongated position. The combination of rigid orthoses and silastic insert (Fig. 8) is worn at all times for the first month following wound closure and removed only for skin care, cleaning of the splint and insert, and a specific exercise routine. The insert is boiled in a mixture of one part vinegar and two parts water once a week. The splint and insert routine is discontinued during waking hours after the first month and the child is fitted with a custom-made compression glove. Age-appropriate activities are encouraged when the child is wear-
Massage with the cream of choice is an important adjunct to provide lubrication, aid in stretching the scar, and desensitize by providing tactile stimulation. Deep finger-tip massage along the line of potential contracture with a tailored stretching and exercise program is performed four times daily. Other desensitization techniques include rubbing the healed burn area with different textures and finding objects hidden in different immersion substances (such as foam chips, rice, and macaroni). This combination of glove, splint, and insert routine is continued with the massage and exercise program until scar maturation is complete.

Dynamic extension splinting can be used in conjunction with the compression glove for the preschool-age and older child. However, it is difficult to obtain the optimum leverage in the infant and toddler group, and patient compliance is poor.

A knowledge of normal development is critical when treating children. Because of the restraining nature of bandages, splints and scar contracture, it is necessary to facilitate normal developmental movement patterns in the active treatment program. For example, a 7-month-old child should be encouraged to weight-bear in the four-point crawl position to facilitate proximal control of the shoulder girdle musculature and to encourage development of the palmar arches in the hand.
RESULTS

In 64 burned extremities treated in 56 patients, the majority of the wounds healed spontaneously (72 per cent). Most patients were healed within 3 weeks (89 per cent), including those patients being grafted by the third week. The percentage of patients in each group requiring grafting was 38 per cent for flame burns, 28 per cent in contact burns, and 14 per cent in scalds. These statistics support our impression that less severe injury occurs in the scald burn.

Children are more resilient in their response to prolonged immobilization. Bivalve splints, with inserts for younger patients and static splints for older children, were used in 18 per cent of patients once the burn wound was closed. The patients receiving these devices were those requiring grafts or those with deeper spontaneously healing wounds who were believed to be at risk for contracture. Children form hypertrophic scars more readily. To counteract this, some form of compression garment was used in 46 per cent of our patients, specifically those with deeper burns or those demonstrating this tendency in the early follow-up period.

Of the 56 patients reviewed, 12 were lost to long-term follow-up (21 per cent). Of the remaining patients, 91 per cent were judged to have normal function (Figs. 9 and 10). Of the 4 that did not, 1 lost all of the digits on the involved hand because of the severity of the
burn, 1 had normal motion but decreased grip strength, and 2 required secondary reconstructive procedures.

SUMMARY

The pattern of injury seen in pediatric hand burns differs from adults because scald burns are most common. Many of these are difficult to assess at initial presentation. In addition, children develop less stiffness in response to immobilization. For these reasons, we have developed a conservative, expectant approach for treating most pediatric hand burns.

Meticulous wound care, positioning, splinting, and exercise are required to safely accomplish the goals of rapid healing with minimal loss of function. These regimens are adapted specifically to suit the age of the child and are applied by the burn team. Normal hand function can be obtained in the majority of cases.

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