PHYSICAL REHABILITATION OF PEDIATRIC BURNS

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SUMMARY. Significant improvements have been made in the acute treatment of pediatric burn injuries over the past 3 decades which have significantly decreased mortality. Each year, more burned children are necessitating serious medical attention during their convalescence. For children with serious consequences resulting from burns that can persist from childhood through adolescence into adulthood, the value of long-term rehabilitation cannot be over stated. Burn injury management should not focus only on the immediate treatment. Long-term functional outcome and the required rehabilitation that burn victims must go through should be given equal if not more attention. The present is a review of the available modalities utilized for the physical rehabilitation of convalescent pediatric burns in order to overcome the catabolic state, improve muscle power and fitness, reduce disfiguring scars and prevent contractures.

Keywords: pediatric burn, pediatric burn rehabilitation, post-burn hypermetabolism, burn scar, burn procedural pain

Introduction

Childhood is a very important period for development of social, motor and cognitive functioning.[1] Unfortunately, burns are relatively common especially within the pediatric age group worldwide.[2] Burn injuries may be severely stressful experiences with serious consequences that can persist from childhood through adolescence into adulthood.[1,3]

Significant improvements have been made for the management of the acute phase of pediatric burn injuries over the past 3 decades, such as early fluid resuscitation, early burn wound excision and closure, antibiotics, and enteral feeding, which have decreased mortality significantly.[1,2,4,5] Thus more children are entering convalescence following their injury, albeit with devastating permanent disfigurement and disability that have a major impact on their developmental, functional, and aesthetic status.[1-6]

A severe burn, in addition to disfiguring scarring and debilitating contractures, results in a hypermetabolic and catabolic state characterized by increases in resting energy expenditure (REE), tachycardia, insulin resistance, negative muscle protein balance, decrease in bone mass, and growth delay.[4] Children with burns of more than 30-40% of their total body surface area demonstrate a negative lean body mass (LBM) balance for at least 9 months after trauma[4,7] and a continuous hypermetabolic state for up to 2-3 years post burn injury.[4,8,9] During acute admission, the rise in REE may be up to 180% of normal values, declining to 150% by the time of full wound healing at 2 months, and steadily declining to 115% of predicted values at 12 months.[7,10] Impaired glucose metabolism persists throughout the first 6 months after injury. Derangement of circulating hormones, including cortisol and insulin, together with elevated pro-inflammatory cytokines, may persist for up to 36 months.[10,11] The hypermetabolic state during convalescence is a major contributor to long-term morbidity resulting in a significant delay in recovery and reintegration back into society.[4,12,13]

At present, attention in burn care and research is shifting from acute care and reducing mortality towards life quality and optimization of patients' outcomes in both the short- and long-term post burn.[1,14] Central to all treatment efforts is an emphasis on restoration of function. Physical rehabilitation is fundamental.[15-17] Burn rehabilitation is dependent on age, depth and extent of the burns, degree of wound healing, presence of infection, and psychosocial status of the child and family.[18] It requires the participation of the child as well as the caregiver[16] and begins when wound healing is complete.[19] It may take months to years and requires long-term efforts and follow-up as the child grows to get back into the functioning arena.[18,20] Rehabil-

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itation focuses on scar prevention, hypertrophic scar suppression, management of heterotopic ossification, leukoderma, and pruritis, as well as restoration of the patient's functional capacity, such as full range of motion, muscle strength, and independent mobility and activities of daily living. It also includes complex reconstruction procedures and measures to reintegrate the patient into the home and community.[6,19]

Pediatric burn patients with a developing personality and body image require different considerations to adult patients because of different cognitive, social, physiological, and anatomic factors.[21] To guide the pediatric patient through the treatment of a disfiguring burn injury and to ensure that every aspect of the child's physical, psychological and social needs is met during hospitalization and following his discharge, a multidisciplinary team approach is required involving physicians, nurses, psychologists, physical therapists, occupational therapists, and social workers.[6,17,18] This is best achieved when burned children are managed at dedicated, well-equipped burn facilities.[3,6,17,18]

Thus burn injury management should not focus only on the immediate treatment. Long-term outcome and the required rehabilitation that burn victims must go through should be given equal if not more attention.[6,17] The present is a review of the available modalities utilized for the physical rehabilitation of convalescent pediatric burns.

Materials and methods

Using the keywords "rehabilitation pediatric burns", "pediatric burn", "burn rehabilitation", "pediatric burn scar", "hypertrophic scar", "burn procedural pain" and "burn scar management" an electronic database search of PubMed, Medline, Scopus, CINAHL, and EMBASE was conducted. The search was limited to papers published in English within the last 15 years. Key references cited by some of the retrieved studies were also consulted for their relevance.

Metabolic modulation

Post-burn hypermetabolic response is characterized by increased protein breakdown coupled with inadequate protein synthesis. This leads to decrease in LBM and subsequently to muscle weakness. The catabolic effects nevertheless are not limited to muscle, as bone mineral content (BMC) and fat mass are decreased as well.[9]

Generally, vigorous nutritional support during acute hospitalization as well as after hospital discharge has not been effective to promote anabolism of burn patients.[22,23] Various treatment options have been investigated. A number of anabolic hormones have been used with varying beneficial effects including insulin, growth hormone, insulin-like growth factor-I (IGF-I), oxandrolone, and testosterone.[4,22,24] Of these, insulin appears to be most effective in increasing net protein synthesis during the acute burn phase.[22] It has been demonstrated that control of hyperglycemia in the intensive care unit or burn unit with intensive insulin treatment is associated with improved outcomes.[22] Moreover, in pediatric burn patients, insulin significantly lowers serum concentration of several pro-inflammatory cytokines and up-regulates anti-inflammatory cytokines.[22]

Administration of oxandrolone 0.1 mg/kg/day, an anabolic synthetic androgenic steroid, significantly increases LBM and net balance of muscle protein and improves the long-term recovery of severely burned children. When administered to severely burned children during the acute hospitalization phase, muscle anabolism improves significantly. Oxandrolone administration for about one year after a burn injury significantly attenuates muscle catabolism, decreases REE, rate pressure product RPP, and increases IGF-1 secretion, LBM and muscle strength. Oxandrolone-treated children exhibit improved height percentile and BMC. The maximal effect of oxandrolone is observed in children aged 7-18 years and its therapeutic benefits persist for up to 5 years post burn.[9,25-27] However, for severely burned children, oxandrolone, given over a shorter time period, combined with a 12-week exercise program results in significantly greater beneficial effects than oxandrolone alone or exercise alone.[9,24] An oxandrolone dosage of 0.1 mg/kg twice daily for up to 12 months has been proven to be relatively safe. However, patients need to be monitored closely for possible adverse effects such as hepatotoxicity, hirsutism/testicular atrophy, or behavioral changes.[24,27] Endogenous catecholamines are prime mediators of the hypermetabolic response following major trauma. They cause tachycardia and increase myocardial contractility, myocardial oxygen consumption, and local myocardial hypoxia. Catecholamine concentrations in plasma rise immediately as much as tenfold and remain elevated for 2 years after burn injury.[22,28] Elevated levels have been associated with cardiotoxicity.[28] Beta-adrenergic blockade of severely thermally injured subjects with propranolol (a nonselective beta-antagonist) can blunt the hypermetabolic catecholamine effect and attenuates very effectively catecholamine-induced muscle catabolism and lipolysis. It decreases oxygen demand and REE, obligatory thermogenesis, cardiac work, heart rate, and cardiac oxygen demand. It also modifies any catecholamine-mediated defect in lymphocyte activation, and improves immune response with decreased infectious complications. The use of beta-blocking agents may also decrease the inflammatory response by decreasing levels of IL-6, MCP-1, and other cytokines.[22,28,29] In children with >30% TBSA burns, propranolol administration for 12 months is safe. It decreases REE by 20% during the first 6 months after injury[28,29] and

decreases hepatic fat accumulation and triacylglycerol storage.[22] A propranolol dosage of 4mg/kg/day is extremely well tolerated in the pediatric age group with few episodes of bradycardia, hypoglycemia, or other major adverse effects. With this therapy a 15% decrease in heart rate occurs within 4 weeks, although tachycardia of 120-140% of the predicted normal rate persists for 1-3 months before decreasing to 110% at 6 months post injury.[28]

Occupational and physical therapy

As patients survive burn injuries after a usually extensive period of bed rest and decreased activity coupled with catabolism and muscle wasting, a decrease in LBM and in physical fitness seems logical and predictable.[1,15] Physical weakness experienced with severe burns is often accompanied by decreased osteognesis, malnutrition, blunted growth, pain, and psychosocial stress.[14] Scars and contractures, which are often disfiguring and seriously debilitating both socially and physically, and which may also be associated with difficulties in speech or feeding, are further aggravating factors.[6,16] Burn scar contractures are a major source of late morbidity, particularly in children that continue to grow long after burn healing has occurred; they may restrict normal growth resulting in secondary deformities.[16,17,21]

Limiting or preventing the development of contractures by splinting and positioning is certainly the most appropriate and shortest path to achieve the best possible functional outcome, avoiding complex reconstruction and long-term rehabilitation interventions.[17] However, fitting the young pediatric burn patient with a splint that is easy to put on and, most importantly, that stays in the proper position, is an arduous and challenging task requiring therapists to use clinical judgment and creative skills.[30,31]

Occupational therapy (OT) and physiotherapy (PT), though they may be painful, are vital and critical components of multidisciplinary burn care. Early and aggressive physical therapy can help counter the decreased range of motion and mitigate the severe contractures that can develop.[3,32] Supervised resistance training and aerobic exercise programs have been shown to offer considerable benefits during outpatient rehabilitation. Resistance training for several weeks increases muscle cross-sectional area, strength, and power.[15] The current standard of care of burn patients consists of rehabilitation exercises that can be done in a hospital setting or in a patient's home[33,34] aimed at improving fatigue, muscle weakness and deconditioning, range of motion (ROM) limitations, and contractures.[3,15,35]

Care of pediatric burn patients must consider age-appropriate exercises and activities.[3] Six months post-burn injury, in children with burns of >40% TBSA, an isokinetic training program based on progressive load, performed 3 times a week for 12 weeks, has proven successful in improving muscle mass, muscle strength, and size and gait parameters. This improvement is maintained even at three months after the cessation of supervised and structured training.[33,35] A structured physical rehabilitation program, including aerobic and resistance exercises, implemented at 6 months post-burn, improves cardiopulmonary capacity, muscle mass and strength, and pulmonary function.[35,36] In severely burned children, increase in strength is due to muscular and/or neural adaptations. Training-induced muscular hypertrophy might also be at least partially related to the secretions of endogenous anabolic hormones such as growth hormone (GH) and testosterone (TES).[35,36] It is important to note, however, that although net improvements are noted after a formal training period, the absolute values in muscle strength and LBM remain below values for non-burned children.[33] Nevertheless, increase in muscle strength and ability to ambulate in a satisfactory manner augments the child's emotional and physical independence and self-confidence and results in an improvement in his/her capability to return to normal activities of daily living.[35]

In addition to the fact that the required extent and intensity of the resistance and cardiopulmonary exercises are still poorly defined,[34] genuine concerns remain despite proven benefits regarding potential exacerbation of catabolism and further elevation of REE following exercise programs in pediatric burn patients.[10] Studies have demonstrated, however, that a balanced aerobic and resistive exercise program is successful in developing LBM without further exacerbating the hypermetabolic state or leading to any exercise-induced weight loss.[10]

Management of post-burn procedural pain

The various stages of burn injury treatment are all associated with considerable pain and anxiety.[37] With most burns requiring ongoing treatment and daily highly uncomfortable physical and occupational active-assisted range-of-motion exercises, it is necessary to ensure an effective pain management plan that takes into consideration requirements of all needed procedures.[37] Procedural-induced discomfort and pain, in particular, represent one of the most challenging aspects of patient care.[38] Procedural pain, primarily in children, can have a significant impact on patient's participation in rehabilitation therapy.[32,39] In cases where there has been a negative initial experience, the child will more likely have increased anxiety and pain towards subsequent procedures.[37]

Effective management of procedural pain requires addressing the needs of individual patients and necessitates continuous reassessment of standardized protocols.[40] Administration of procedural sedation aims at reducing pain and anxiety while maintaining a level of consciousness throughout the procedure.[38] Unlike a single pharmacolog-

ic agent, combination regimens with analgesic, amnesic, and anxiolytic effects offer a more effective broader range of physical and psychological pain control.[38] However, controlling post-burn procedural pain with pharmacologic analgesia alone, mainly with opioids, may be associated with a wide spectrum of potentially prohibitive side effects, in particular decreased SaO_2 to less than 90%.[38,41,42] Moreover, standard analgesia used for pediatric patients has often failed to meet the child's needs.[38,41,44]

Non-pharmacological cognitive (distraction techniques), behavioral (conditioning/relaxation techniques) and learning techniques (preparation for procedures and education), in addition to pharmacological modalities, have been shown to play a major role in controlling procedural pain of a seriously burned child.[45] The use of purposeful playing activity in therapy of burned children, for example, can yield results that are often better than those achieved using rote exercises. When children engage in meaningful play activities, their attention is diverted away from the pain, and the experience becomes less traumatic.[18] Recently, multi-modal distraction has expanded current distraction tools and technology available and has been suggested as an effective non-pharmacological pain reducer in pediatric outpatient burns clinic particularly with painful rehabilitation therapy and wound care.[37,46] Multi-modal distraction may provide the child throughout the duration of the procedure with a feeling of control and understanding, reducing apprehension and removing the emotional/cognitive contribution to perceived pain.[37] Similar to what has already been demonstrated in adult burn patients, subjective illusion created in a child's mind based on sensory input from a virtual reality helmet and software (immersive virtual environment) successfully captivates his/her attention and substantially decreases sensory, cognitive, and affective pain and can be a useful adjunct to pharmacologic analgesia.[32,44,47] In fact, it has been conclusively demonstrated that statistically significant reduction in pain-related brain activity occurs following the use of virtual reality.[48] Moreover, the increase in fun associated with immersive virtual reality may also increase the child's cooperation and therefore would potentially result in better long-term outcomes.[32]

Alternatively, massage with or without aromatherapy may be an effective complementary therapy in pediatric burn patients. When performed 30 min before implementing a therapeutic procedure, a smooth, gentle, tactile massage technique aided by oils distracts from the negative experience and attenuates behavioral distress responses.[49,50]

Scar management

Individuals with deep burn injuries are at a high risk for hypertrophic scarring characterized by persistent inflammation and by proliferation of dermal tissue with excessive deposition of fibroblast-derived extracellular matrix proteins, especially collagen, the extent of which is dependent on patient's age, pigmentation, family history, and scar location.[6,51]

Prevention and treatment of hypertrophic scars is one of the most important issues in burn rehabilitation.[51,52] Successful management depends on early and aggressive treatment. Unfortunately, the number of studies related to prevention and/or treatment of hypertrophic scars with both agreement and consensus are limited.[53] No ideal or all-purpose method of scar control exists. A wide variety of treatments have been advocated including surgical excision and/or grafting, occlusive dressings, topical and intra-lesional corticosteroids, interferon, cryosurgery, radiation, pressure therapy, laser therapy retinoic acid, and silicone gel sheeting as well as a multitude of extracts, topical agents, and other promising, lesser known therapies directed at collagen synthesis.[51,54,55]

Traditionally, treatment of hypertrophic burn scars consists of pressure therapy that involves wearing compression garments made from elasticized fabrics.[6,56] Since it is definitely much more efficient to prevent pathologic scars than to treat them,[51] the pressure garment should be used as soon as the wound is closed.[6] Recommendations for the amount of pressure and the duration of the therapy are based merely on empirical observations but it is suggested that the efficacious compression is about 24 mm Hg to overcome capillary pressure applied 23 hours per day. With pressures above 40 mm Hg, maceration and paresthesia may occur. The mechanism of action of compression remains largely unknown; however, pressure does decrease blood flow to the scar, and the force may be sufficient enough for collagen to organize.[6,51]

There is a scarcity of sound data to show that pressure garments reduce the prevalence or magnitude of scarring despite overwhelming earlier reports. Current evidence that supports benefits of pressure garment therapy is largely anecdotal.[55] At present, a fair body of evidence may support their use, but it is not definitive scientific evidence stemming from serious research.[51] The meta-analysis recently conducted by Anzarut et al.[57] concluded that there is insufficient evidence to support the widespread use of pressure garment therapy. Despite demonstrating that pressure garment therapy improves scar height, it failed to show improvement in global scar score, pliability, vascularity or pigmentation.[58]

Despite precise fitting techniques, pressure garments do not provide a consistent amount of pressure at the scar/garment interface.[59] Pressure garment therapy requires significant sustained patient involvement and co-operation.[60] Unfortunately, compliance with the recommended wearing schedule is difficult, especially in pediatric patients for a number reasons. Wearing pressure garments is uncomfortable and challenging; problems with movement,

appearance, fit, comfort, swelling of extremities, rashes and blistering are common.[55]

Gel sheeting, either hydrogel or silicone sheeting, can be used in conjunction with pressure garments or can be held in place by one of several elastic devices. These materials may soften the scar by maintaining hydration and decreasing tension. They seem to increase scar maturation and decrease hypertrophy.[6] Although silicone gel sheeting is widely used and assumed to be beneficial, it is worth noting that the evidence supporting its effectiveness is class 3 at best.[51] Common problems associated with gel sheeting include skin maceration, persistent pruritis, skin breakdown, skin rash, foul smell, and poor patient compliance.[51] The international panel of experts that reviewed the literature on scar management in 2002 concluded that: "Widespread burn scars should be treated with first-line therapy of silicone gel sheeting and pressure garments, although there remains limited significant evidence for the effectiveness of pressure garments". This recommendation at present remains unchanged.[61,62] Other modalities are available to be used in conjunction with pressure garments. Current theories report that minimal increases in temperature, even by 1°C, promote collagenolysis and scar maturation. Ultrasonic or microwave heating softens scars and loosens stiff joints. They also seem to reduce collagen content by increasing collagenase activity.[6]

Massage therapy, manual or mechanical such as compressed air, threadlike showers, and vacuotherapy, routinely used by therapists for the treatment of various conditions, is standard therapy in rehabilitation centers specializing in the treatment of scars and burns with reported increased pliability and decreased scar banding.[51] Massage indications depend on the burn zone as well as on the characteristics and development of the scar. Although various techniques may be applied, none have been validated. Their use is thus based on experience and does not have any scientific basis.[51] On the contrary, a study examining the use of friction massage over a 3-month period in pediatric patients with hypertrophic scars has failed to demonstrate any appreciable effects of massage therapy on the vascularity, pliability, and height of the scars, although there were reports of a decrease in pruritus in some patients.[63] Massage therapy may be counterproductive by stimulating fibroblast proliferation.[6]

Conclusion

The current paper describes rehabilitation of children after a burn injury. Rehabilitation carries particular importance because the consequences of pediatric burn injuries can persist from childhood through adolescence into adulthood. It is aimed at improving the survivors' quality of life and optimizing the clinical process and patients' outcomes in both the short- and long-term. It comprises attenuation of the catabolic hypermetabolic effects, managing debilitating scarring, and improving functional recovery. A key factor in proper management of pediatric burns remains adequate pain control. Since the experience of pain is multifactorial, both pharmacologic and non-pharmacologic therapy should be highly individualized and frequently adjusted to address the needs of each patient.[40] Although present rehabilitation modalities are not optimal, new insights are continuously gained that can trigger improvements in rehabilitation protocols for optimal functional recovery of children after severe burn injuries.

RÉSUMÉ. Des améliorations importantes ont été apportées dans le traitement aigu des brûlures pédiatriques au cours des trois dernières décennies qui ont diminué de façon significative la mortalité. Chaque année, de plus en plus d'enfants brûlés ont besoin d'une attention médicale sérieuse durant leur convalescence. Pour les enfants ayant des conséquences graves suite aux brûlures qui peuvent persister de l'enfance à l'adolescence à l'âge adulte, la valeur de la réhabilitation à long terme ne peut pas être surestimée. La gestion des blessures causées par des brûlures ne devrait pas se concentrer uniquement sur le traitement immédiat. Le résultat fonctionnel à long terme et la réhabilitation nécessaire pour les victimes de brûlures devraient recevoir autant, sinon plus d'attention. Le présent est un examen des modalités disponibles utilisés pour la réhabilitation physique suite aux brûlures pédiatriques afin de surmonter l'état catabolique, améliorer la puissance musculaire, réduire les cicatrices défigurantes et d'empêcher les contractures.

Mots-clés: brûlure pédiatrique, réhabilitation pédiatrique post-brûlure, hypermétabolisme post-brûlure, cicatrice, douleur procédurale

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