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Pediatric Burns

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Introduction

This chapter is intended to give an overview of the rehabilitation of a child following burn injury. Acute management, including definitive procedures, is discussed. Pediatric burn rehabilitation is described including complications and common treatment techniques. Throughout the chapter the multidisciplinary team approach is emphasised as the best model of care and essential for optimal psychosocial, functional and cosmetic outcome following burn injury.

History

Health professionals have been treating children with burns for millennia. However, pediatrics as a separate specialty only came about in the early part of the 20th century, and burn units only started to appear at the time of the Second World War. Medical advances over the past three decades have resulted in declining mortality and shorter periods of hospitalization for children with burns when treated in a specialist burns unit (Janzekovic 1970, Herndon and Blakeney 2007). From this time, it was also realised that morbidity was reduced if occupational therapists, physical therapists, dieticians, psychologists and social workers became an integral part of burns care, thus the advent of the first true multidisciplinary burns team. As a natural progression from these improved medical outcomes, attention now is being directed to optimizing functional outcome for these children post-burn injury (Klein et al. 2007a, Tyack and Ziviani 2003). Functional outcome considers the combined effects of physical, behavioural and social skills on the child's ability to complete tasks that are meaningful, practical, sustainable over time and relate to a child's life outside the clinical environment (Tyack 2003).

Epidemiology of burns in children

It is estimated that over half a million children are hospitalized with burn injuries per year in the world, with the majority occurring in low to middle income countries in Asia and Africa (Burd and Yuen 2005). Low socio-economic status of the family and low educational level of the mother are the main demographic factors associated with a high risk of burn injury (Ahuja and Bhattacharya 2004, Van Niekerk et al. 2004). Other factors associated are: high population density, high levels of household crowding, absence of water supply and psychological stress within the family. Children who were not the biological son or daughter of the head of the household are also at increased risk for burns (Delgado et al. 2002). Non-accidental burn injury (i.e., abuse) is present in a higher

proportion of families with a single parent, a younger mother, a low income or an unemployed parent (Brown et al. 1997). Many children with non-accidental burns have a higher incidence of previous notifications for suspected abuse or neglect to child protection agencies (Andronicus et al. 1998).

World wide burns in the under-five age group account for a quarter to a half of all burn injuries attending burn centres (Laloe 2002, Ansari-Lari and Askarian 2003, Komolafe et al. 2003). The majority of burns to young children occur as accidents in the home environment (Van Niekerk et al. 2004, Laloe 2002, Ansari-Lari and Askarian 2003, Bangdiwala and Anzola-Perez 1990, Hemeda et al. 2003) (Fig. 1). Most regions however report scalds as causing the majority of burns to young children (Van Niekerk et al. 2004, Ansari-Lari and Askarian 2003, Belba and Belba 2004, Tarim et al. 2005, Al-Shehri 2004, Dewar et al. 2004). While these scalds are mainly from hot water, many other liquids being heated cause burns (Fig. 2). Contact burns from household appliances such as oven doors, hot irons and wood stoves are also common (Simons et al. 2002, Street et al. 2002). Electrical burns occur in young children exposed to electrical cords, plugs, outlets, and poorly maintained electrical devices (Hemeda et al. 2003, Lui et al. 2003, Ramakrishnan et al. 2005). (Fig. 3). Flammable liquid burns are common from cooking accidents in developing countries and in adolescent boys experimenting with petrol and other accelerants (Henderson et al. 2003). Males aged from 2.5 to 18 years are more likely to hospitalized with a burn injury that has resulted from their own behaviors, possibly due to increased exposure to activities that produce injuries and a pattern of more risk taking and rougher play than females (Piazza-Waggoner et al. 2005).

The developmental progress of a child between the ages of 0 to 15, at both a neurocognitive and physical level, influences the type of burn injury most frequently sustained, as well as the child's ability to remove him/herself from a dangerous situation (Robert et al. 2007). Parents can inadvertently contribute to the mismatch between their child's developmental skills and the demands of tasks by allowing or asking a child to perform an activity for which s/he is not developmentally capable (Rivara 1995). Up to 50% of children requiring admission to a burns centre are reported to have pre-morbid developmental delay, sensorimotor difficulties, impoverished home environment (Gorga et al. 1999), behaviour or psychological problems (Tyack and Ziviani 2003). The incidence of attention deficit hyperactivity disorder has been estimated as high as 20% (Mangus et al. 2004). More than 20% of carers report difficulties with aggression and anxiety, as well as conduct problems in children and adolescents (on which normative data was available) (Piazza-Waggoner et al. 2005). The presence of parental factors such as physical illness, substance abuse, psychiatric illness, behavioural problems, and inadequate social support is often causally related to the burn injury and influences the child's recovery (Blakeney et al. 2007).

A multidisciplinary service approach

The overall care of a child with burns is dependent on the depth and extent of the injury, the age of the child, the degree of wound healing, presence of infection, and the psychosocial status of the child and family. Therefore, a multidisciplinary team is required to ensure that every aspect of the child's physical, psychological and social

needs is met during hospitalisation and following discharge. Complex social issues often impact the delivery of a child's care and therefore require skilled personnel to manage adjustment to hospitalisation (Phillips and Rumsey 2008). Even the smallest percentage area burn if deep requires long term follow up as the child continues to grow and develop. Early intervention is the key to ensuring that children receive optimal care during their hospitalisation.

From initial presentation, the multidisciplinary team (including doctors, nurses, acute pain service, dietitians, occupational and physical therapists, social workers, mental health staff (e.g, psychiatrists), music therapists, play/diversional therapists and teachers) becomes involved in assessing and planning the care for the child. Each team member plays a vital role in determining the needs of the child and will consult separately with the patient and family upon admission. Often, the clinical nurse consultant for burns co-ordinates the referral process to the multidisciplinary team. Dressings and operative procedures are planned in consultation with all the team and the family. Team meetings are vital in ensuring communication is optimal between team members, and complex issues are discussed with the aim of care planning towards solutions and goals for the patient and family.

Often, for reasons of managed care or distance, the child with burns is referred to their local service providers for regular follow-up upon discharge, with less frequent reviews by the specialist burns unit. Therapists working outside of a specialist burns centre are encouraged to liaise closely with their colleagues within the specialist units for advice and support in burn patient therapy management (Simons et al. 2003). It is common for ROM and strength to be lost during the first few months after discharge, particularly with inadequate outpatient rehabilitation (e.g., inexperienced therapist). The burns unit team should assess the quality of outpatient rehabilitation during routine outpatient visits to the burns unit, and arrange for readmission for focussed rehabilitation effort if substantial loss of range of movement (ROM) or strength is occurring.

Assessment of burn severity

In a hospital setting, the initial assessment of burn severity (history taking and clinical examination) will be completed by a medical officer. Such information from the child and their parents can give valuable information as to the nature and severity of the burn, and bring to light the possibility of other injuries that will impact upon rehabilitation needs. The history can also assist in determining surgery requirements. For example, flame burns usually result in a deeper burn injury than scalds. Flame burns sustained in an enclosed space or explosion from a gas or petrol fire are frequently associated with smoke inhalation, which in turn begets a higher mortality rate (Pham et al. 2007). It should be ascertained whether adequate first-aid was carried out at the scene or subsequently, as it is probably still beneficial up to three hours post burn (ANZBA 2007). Children with neurological disability such as spina bifida or diabetes may have reduced sensation predisposing to the burn. These same children are also at highest risk of a latex allergy. Previous psychiatric illness in children with burns is much less common than is seen in the adult burns population, but when present should be documented.

Following clinical examination, the child with burns may require intubation, oxygen and/or fluid resuscitation.

Intubation

Young children have a relative narrow airway and short neck with soft tissues that are readily distorted by edema (Hettiaratchy and Papini 2004). Hot gases can cause a burn to the airway above the vocal cords and may swell up over time to be worst between 12 and 36 hours, compromising the airway. A compromised airway requires prompt intubation.

Signs suggestive of significant airway injury are:

- Singed nasal hairs
- Productive cough
- Croup-like breathing
- Respiratory difficulty
- Rib retraction
- Flaring of alar nasae

Oxygen

Oxygen should be given to all cases of moderate to severe burns in children. Deep dermal or full thickness circumferential burns to the chest will compromise respiration and may necessitate escharotomies (surgical incisions through firm eschar only, not subcutaneous tissue). If the child has been involved in a blast injury, lung contusions can have occurred and ventilation and gas exchange may be compromised. Blast injuries can also cause penetrating chest trauma with a resulting pneumothorax (often under tension) (Hettiaratchy and Papini 2004).

Smoke inhalation can cause acute respiratory distress syndrome with multi-organ failure and will increase dramatically the morbidity and mortality of a burn. Changes in the voice or cry and burns or soot in the nose, mouth or pharynx should be looked for. Other features suggestive of a smoke inhalation include: a productive cough, croup like breathing, respiratory difficulty with rib retraction or flaring of the alar nasae. The products of combustion, though cooled by the time they reach the lungs, act as direct irritants to the lungs, leading to bronchiospasm, inflammation and increase in secretions. The ciliary action of respiratory epithelium is impaired, and if the inflammatory exudate is not cleared then atelectasis and pneumonia result. The situation is particularly severe in children with pre-existing asthma (Hettiaratchy and Papini 2004).

Systemic toxicity follows absorption of the products of combustion producing systemic acid/base disturbances (carbon dioxide, ammonia and hydrochloric acid), while hydrofluoric acid may produce hypocalcaemia. Carbon monoxide poisoning classically gives a cherry red appearance to the skin.

Fluid resuscitation

Burns in small children greater than 10% Total Body Surface Area (TBSA) and older children greater than 15% should be treated with intravenous resuscitation. Fluid

resuscitation increases edema in the extravascular space that can limit joint motion (Latenser and Kowal-Vern 2002, Spires et al. 2007). Edema develops within 8 to 12 hours after burn injury and peaks at approximately 36 hours. Failure to reduce edema in the first 48 to 72 hours can result in a fixed deformity, such as intrinsic minus or claw deformity of the hand (Richard and Staley 1994, Sheridan 2005). Edema management is especially important with hand burns due to its dependent position (Esselman et al. 2006).

Classification of burn injury

The severity of a burn injury is determined according to the surface area affected and depth of the burn. The body surface area affected is reported as a percentage (%TBSA) which ranges from <1% - 100%. The extent of surface area for pediatric burns is most accurately estimated using a chart based on the Lund and Browder (Lund and Browder 1994) diagram that compensates for changes in body proportions commensurate with growth (Lee and Herndon 2007). For calculation of burn size in small areas, a commonly used rule is that the child's palm, including the fingers, is 1% of body surface area (Nagel and Schunk 1997, Jose et al. 2004). The depth of the burn wound relates to the layers of skin that have been affected. Skin is considered to have two layers: the epidermis and dermis (Sheridan and Thompkins 2007). The dermal layer is further classified as papillary dermis (upper layer) and reticular dermis (lower layer). Traditionally burns were classified as 1st, 2nd or 3rd degree depending whether the burn was superficial, partial thickness or full thickness. The term 4th degree was used to describe burns which involved underlying tissues such as muscle and fascia. However, since 2001, the main classification system used throughout the world is superficial, superficial partial, deep partial, or full thickness (Shakespeare 2001).

Superficial burns

Involve only epidermis. Although painful, healing usually occurs within one week without any residual scarring (Bessy 2007).

Superficial partial thickness burns

Involve only papillary dermis and epidermis. Burns of this depth are expected to heal in 1 to 2 weeks and should not result in visible changes to the skin beyond 6 months (Bessy 2007).

Deep dermal partial thickness burns

Involve epidermis and dermis to reticular dermis. It is usually expected that burns of this depth would take longer than 3 weeks to heal and skin grafting is recommended to promote early wound closure and to reduce the degree of residual scarring (Bessy 2007).

Full thickness burns

Evident involvement of the whole thickness of the skin and possibly subcutaneous tissue. Skin grafting is essential since there is little potential for spontaneous healing (Greenhalgh 2007).

Essentially, if a burn heals spontaneously (i.e., without the need for skin grafting) with complete skin coverage of the affected area within two weeks, it will do so without a hypertrophic (red, raised, rigid) scar or functional impairment, but can result in long-term pigment changes. If healing takes more than three weeks, hypertrophic scarring inevitably results and can lead to functional impairment (Greenhalgh 2007). As a general rule, the depth of the burn is usually underestimated at initial presentation (Sheridan 2002) and is rarely of uniform thickness (Johnson 1994).

Burn wound assessment

A visual examination by an experienced burn surgeon remains the most widely used method of classification (Sheridan 2002). However, many burn centres are equipped with a Laser Doppler scanner that can determine the depth of injury up to five days of the burn (Fig. 4). It works by scanning the skin with a low power laser penetrating 1mm into the skin to determine blood flow. These instruments have been extensively studied in children, and when used by trained personnel and are very accurate in predicting which children require skin grafting (Holland et al. 2002, La Hei et al. 2006). Analgesia and sedation are often required to keep the child still for the scan which can take up to several minutes to complete. Eye protection for the child is mandatory.

Pain management

A skilled pediatric pain service is invaluable to any burn centre. The service should provide a 24-hour on-call service, and a twice daily pain rounds. Pain scoring and ongoing assessment should be recorded hourly on observation charts by nursing staff using appropriate tools. For very young children the FLACC (Faces, Legs, Activity, Cry and Consolability) pain assessment tool is appropriate (Manwaorren and Hynan 2003). For verbalising four to eight year olds a good tools is the FPS-R (Revised Faces Pain Scale) (Hicks et al. 2001). Finally for children older than eight, the self reporting VAS (Visual Analogue Scale) is very useful (De Jong et al. 2005). Pain scoring is then utilised to identify and communicate ongoing pain issues if modifications to medications are required.

Patient Controlled Analgesia (PCA) pumps are utilised with a background infusion of morphine for children who are developmentally capable (generally above 7 years of age) (Gaukroger et al. 1991). As the patient progresses and pain is well controlled, oral medications such as slow release morphine are instituted, with a view to ceasing intravenous medications as soon as possible. Fast acting oral opioid medication is useful for breakthrough pain (such as oxycodone), when intravenous morphine is ceased and slow release has started. If breakthrough medications are needed, the slow release morphine can then be titrated up until breakthrough medications are not necessary.

Procedural pain is treated on an individual basis in consultation with the pain service. General anaesthetic is considered for patients in early stages of admission. When the child has progressed past skin grafting and donor sites are fully healed, conscious sedation is considered. Anaesthetic personnel are booked to attend for often the first 1-2 baths after general anaesthetic has ceased. Oral conscious sedation is often given via nasogastric tube, with anaesthetic staff present during bath if any further medication or

airway management is required (Humphries et al. 1997, Sharar et al. 2002, Day et al. 2006). The burns therapist must ensure that the child has had adequate pain relief prior to therapy sessions. Timing exercises and splinting reviews with dressing changes and wound cleansing, or theatre trips, will minimize the need for additional medications while increasing the efficacy of the treatment with reduced patient discomfort (Sheridan 2005) (Fig. 5).

Age appropriate strategies for distraction during procedures to reduce pain and anxiety have been effective. These include traditional distracters such as music therapy (Presner et al. 2001), play therapy and movies (Landolt et al. 2002), but also newer systems such as augmented reality and virtual reality (Das et al. 2005, Mott et al. 2008) (Fig. 6).

Pruritis is always problematic to the burned child in the recovery phase. Itch control is difficult, but can often be managed in the short term by oral medications such as antihistamines. Long term oral medications are often considered for neuropathic pain and itch control, but due to the excess cost and excessive reports of side effects this is carefully considered on an individual patient basis (Matheson et al. 2001, Vitale et al. 1991, Gordon 1988, Bell et al. 1988).

The ideal wound dressing

The ideal burn dressing has the following attributes: broad spectrum antimicrobial activity requiring infrequent changing with minimal discomfort, and promotion of re-epithelialisation while being cost effective. Antimicrobial activity in the dressing has been shown to decrease wound-related infections and morbidity when used appropriately. It does this by controlling microbial colonisation, thus preventing development of invasive infections such as toxic shock syndrome (Palmieri and Greenhalgh 2002, Young and Thornton 2007). Toxic shock syndrome classically affects young children with small partial thickness burns that would be expected to fully re-epithelialise (Frame et al. 1985). Some centres use dressings without antimicrobial properties (e.g., paraffin gauze), advocating that all antimicrobial dressings delay wound healing, and they accept a higher rate of burn wound infection (Edwards-Jones et al. 2000). Other centres attempt to decrease this increased infection rate by taking children to theatre for surgical debridement to remove debris and burn eschar prior to application of a non-antimicrobial dressing under aseptic conditions. This dressing will then remain intact until the wound is healed or grafted. Infrequent dressing changes are desirable to decrease what is a distressing procedure, especially in children. Increasing the rate of re-epithelialisation is important because if a burn re-epithelialises within 2 to 3 weeks it will generally do so without scarring. After this time, it will inevitably scar.

Pediatric burn rehabilitation

Acute care

Acute care is dependent on the depth and extent of the injury, the age of the child, the presence of infection, the degree of wound healing, and the psychosocial status of the child and family. Management may involve the relief of respiratory distress, prevention of burn shock, and ensuring all tissues are receiving adequate blood flow (Lee and

Herndon 2007). Management can include insertion of a nasotracheal tube or endotracheal tube to assist respiration, inserting a nasogastric tube for gastric decompression and ongoing nutritional support, and performing an escharotomy or fasciotomy on the extremities to assist vascular return and lympahatic draining (Lee and Herndon 2007). Insertion of an indwelling catheter and an intravascular catheter can also be necessary to monitor and assist tissue perfusion . Relief of pain and anxiety is also a consideration for which analgesia is provided (Meyer et al. 2007). Additional foci include the treatment of an inhalation injury, nutrition, infection, wound management and psychosocial support (Lee and Herndon 2007). Anti-deformity positioning and splinting (see later), and exercise (see later) are completed for the prevention of secondary conditions (e.g, contractures, joint stiffness). Operative treatment is usually commenced for burns estimated to be of deep partial-thickness or full-thickness depth and therefore unlikely to heal spontaneously within 10 to 14 days (Muller et al. 2007). Operative techniques include debridement of necrotic tissue to a viable vascular bed and skin grafting. Splinting and positioning regimes post-surgery are determined by wound coverage technique (e.g., autograft, cultured epithelium, biologic closure) (Sheridan and Thompkins 2007, Muller et al. 2007). Splinting should be performed in the operating theatre at the end of the procedure while the child is still under general anaesthetic. Psychosocial support in the form of procedural education is provided to the child, and their families, with consideration of their neurocognitive development (Benjamin and Herndon 2002). Such aid is usually provided following a discussion with the caregivers and/or child regarding pre-morbid functioning (occupational roles, play, leisure). Parents and other family members require support, comfort and guidance, and family involvement in patient care is to be encouraged (Blakeney et al. 2007).

Acute care of children with burns that do not require surgical intervention involves minimizing the risk of infection, assisting wound healing, preserving physical function, minimizing cosmetic deformity, and minimizing psychosocial sequelae by providing appropriate pain relief and ongoing supportive education for the child and family (Hartford and Kealey 2007).

Rehabilitation, reconstruction and reintegration

While rehabilitation efforts commence from the outset of burn care in order to achieve optimal patient functioning, it becomes more time consuming for the burns therapist once skin closure has occurred. The importance of early and active focus on long-term rehabilitation goals cannot be overly emphasized (Sheridan 2005). Rehabilitation is focused on the prevention of post-acute sequelae such as management of scarring and contractures. It is achieved using treatments such as pressure garments, splinting and positioning, exercise and ambulation and ongoing education of the child and caregiver (Serghiou et al. 2007). Return to normal daily activities such as attending school is encouraged, and supported by return to school visiting programs (Staley et al. 1999, Bishop and Gilinsky 1995) and burn camping programs (Rimmer et al. 2007). While proper care in the acute phase will minimize the need for burn reconstruction at a later date, generally a predictable set of operations are commonly required during the first post-injury years. The need for reconstructive surgery must be considered within the context of the child with burn's functional and cosmetic needs, with collaboration

between the child (if able) and the family, burns therapist, and surgeon (Sheridan 2005). The burns therapist has a vital role in the planning and timing of reconstructive surgical procedures after the acute discharge, helping to identify the need and sequencing of surgical releases and educating the child and the caregivers in regard to perioperative care (Sheridan 2005).

Complications post-burn injury

Contractures

Contractures (inability to perform full range of motion) result from factors such as limb positioning, duration of immobilization, and muscle, soft tissue and bony pathology, and place the person at risk of secondary medical and functional deficits (Schneider et al. 2006). (Fig. 7). Joints overlaid by deep partial-thickness or full-thickness burns are at high risk for developing contracture. Contractures tend to be associated with the "position of comfort" (e.g., axillary adduction contractures, elbow and knee flexion contractures, hip flexion contractures), except for hands (which present with intrinsic minus or claw deformity). Contractures are a common problem following burn injury, and have been reported in up to 42% of patients receiving burn care (Esselman et al. 2006). The shoulder, elbow and hand are most commonly affected (Schneider et al. 2006).

Scarring

Hypertrophic and, to a lesser extent, keloid-like scarring are common and caused by proliferation of dermal tissue following skin injury (Aarabi et al. 2007). Scar is considered immature if it is red, raised and/or rigid and mature when it is avascular, flat, pliable and soft. Approximately 1 to 3 months post-healing after deep partial-thickness or full-thickness burns, hypertrophic scarring typically appears and may create a wide range of cosmetic and functional problems. The inflexibility of the scar may limit motion of the joint or soft tissue (Spires et al. 2007).

Infection

Early signs of infection include increased redness, warmth, pain and swelling of the wound. Early burn wound infections tend to result from Gram-positive organisms such as *Staphylococcus* and *Streptococcus*, which are normal cutaneous flora (Palmieri and Greenhalgh 2002). Red streaking, extending from the wound in a child is indicative of a streptococcal infection and mandates intravenous antibiotics in addition to a topical antimicrobial dressing. Gram-negative wound infections tend to predominate after 7-10 days in larger, deeper burns. Gram-negative infections are heralded by increased greenish exudate from the wound, high fevers, and pain (Palmieri and Greenhalgh 2002). Many burn wounds that are colonised rather than infected by Gram-negative organisms will also have a green exudate. Burns therapy programs are generally able to be continued in the presence of infection, in close consultation with the burns consultant.

Heterotopic Ossification

The incidence of heterotopic ossification (HO) in the general burn population (including adults) is between 1 and 3%, making it a rare (especially in children) but functionally important complication of burn injury (Burke Evans 2007). HO results from ectopic

lamellar bone formation within the soft tissue around a joint, severely reducing range of motion and compromising limb function, most commonly in the elbow, shoulder and hip (in that order) (Esselman et al. 2006, Burke Evans 2007). Delayed wound closure over joints, prolonged immobility and forcible mobilisation of the affected joint have been identified as risk factors for its development (Klein et al. 2007b). Reducing the period of bed confinement and the duration of the post-burn hypermetabolic state is advocated as preventative measures, as well as controlled and assisted active motion, gentle terminal stretch and terminal resistance to minimize the risk of secondary injury to soft tissue (Burke Evans 2007). Improvements in functional outcome (measured as performance of activities of daily living) in children have been reported following surgical excision of HO in elbows (Gaur et al. 2003).

Neuropathies

Neurological impairment from the burn injury may be apparent at the time of admission, or become clinically evident up to 2 years post-burn injury (Warden and Warner 2007). Patients at increased risk of progressive neurological deficits include those who have sustained an electrical injury, and dysfunction may include paresis, paralysis, tremor, involuntary movement or ataxia. Peripheral neuropathies secondary to deep partial-thickness or full-thickness burns may result in sensory deficits and pain. Persistent pain that leads to permanent loss of function, despite maximum effort toward medical rehabilitation and psychological adjustment, is classified as permanent impairment (Warden and Warner 2007).

Pressure ulcer/sore

The patient with burns is at risk of pressure ulcers due to their physiological responses post-injury (e.g., hypovolemic shock resulting in blood flow being diverted away from the skin to preserve vital organ function). Additional injuries may add to the increased risk of pressure ulcers such as inhalation injury (requiring intubation and use of paralytic agents) and fluid resuscitation (resulting in edema that decreases the blood flow to the skin and adds weight to body parts) (Gordon and Marvin 2007). Poorly fabricated or applied splints can cause a pressure ulcer, with the patient at increased risk in the fluid resuscitation phase when the circumferences of their limbs are fluctuating. Time when completing dressing changes and wound care reviews, as well as when the patient is anaesthetized, can be used for careful observation of the wound as well as monitoring risk areas of pressure ulcers (Gordon and Marvin 2007).

Lymphoedema

Edema is an interstitial protein-rich substance that forms a gel-like consistency and impedes vascular clearance. The superficial lymphatic plexus resides within the dermal-epidermal junction; therefore deep partial-thickness and full-thickness burns can cause impairment to the superficial and / or deep lymphatic system. Edema arises from the lymph vascular safety system being exceeded or the lymph transport capacity being compromised (Hettrick et al. 2004). Although lymphoedema (chronic edema present >3 months) is rarely reported as a complication associated with burn injuries in children, risk factors for its development include circumferential extremity involvement and fascial excision (Hettrick et al. 2004). Should lymphoedema be present, it can be managed with

specific manual techniques, special bandaging and compression wraps and remedial exercise (Hettrick et al. 2004).

Changes in body composition

Children aged <4 years with severe burns (TBSA ≥ 40%) have significant changes in lean body mass when compared with children aged 4 to 18 years (Przkora et al. 2008). In the younger group, lean mass was lost for a minimum of 9 months post-burn injury, whereas older children were able to increase their body mass from discharge having used anabolic agents and participating in an aerobic exercise program. While anabolic agents have been used to increase lean mass in severely burned infants and toddlers, they are excluded from the benefits of an aerobic exercise program due to their age (Przkora et al. 2008, Suman et al. 2001, Przkora et al. 2007).

Therapy interventions for the child with burns

Therapy techniques following burn injury are focussed on minimising impairment to body structures, as well as encouraging healthful return to activities and participation.

Minimising impairment to body structures and functions

Splinting and positioning

- In the acute phase, anti-deformity positioning is initiated from the outset of burn care to minimize shortening of the tendons, collateral ligaments, joint capsules and to reduce extremity and facial edema (Serghiou et al. 2007) (Fig. 8). Minimizing contractures generally involves positioning which promotes extension and abduction just above the level of the heart, but specific injuries require an individualized approach (Richard and Staley 1994, Serghiou et al. 2007).

- Prophylactic splinting is rarely required, except if tendons are exposed or to prevent equinis deformity when confined to bed. In this case, the child's ankles are positioned in a neutral position and ranged twice daily.

- Splints must be "user-friendly" as poorly applied splints can cause nerve injury, loss of skin grafts, and worsening of a burn wound. An effective splint avoids pressure over bony prominences and is compatible with wound dressings and topical medications. Splints fabricated of re-mouldable materials can be modified as patient's needs change. Therapists should check splints at least twice daily, and nursing staff at least once / shift (i.e., three times per day). The use of splinting charts outlining the wearing regime and risks of the splint above the patient's bed and/or in nursing folders is an important communication tool between therapy and nursing staff.

- A positioning and splinting schedule is developed for each patient by the therapist in collaboration with the burns team. Once the acute phase is over occupational and physical therapists aim to monitor and modify exercises and splints to maintain functionality until the reconstructive phase begins. At that time, prosthetic and orthotic devices and splints focus on rehabilitating the patient with

- Factors to consider when prescribing a splint include the area of the body injured, extent and type of injury, the functional goal being addressed, and patient cooperation (Spires et al. 2007).

- Prolonged static splinting is required following skin grafting procedures, but therapy should be started within 2 to 3 weeks with the splint removed for each session. By up to 6 weeks after the surgery, night splinting alone should be sufficient and may need to be continued for 1 or 2 years (Schwarz 2007).

Edema management

- In acute phase, positioning (with extremities elevated above level of heart using splints, bedside troughs or similar devices) (Richard and Staley 1994) and splints, as well as passive ranging are used to reduce oedema. Webspacers can be placed between digits to prevent fluid collection and edema formation (Latenser and Kowal-Vern 2002).

- In the post-acute phase, residual edema contributes to joint stiffness and subsequently interferes with rehabilitation goals. Coban wrap (or similar), tubular dressings, elevation and retrograde massage can be used to decrease edema (Esselman et al. 2006).

- At most risk are areas of dependency, such as feet when standing/sitting, or back/buttock when lying. The presence of edema is assessed using tools with demonstrated reliability, such as Figure of 8 method (Maihafer et al. 2003, Pellecchia 2003), deepening of skin folds, absence of visible venous alterations and Stemmer's sign (thickened skin fold at the base of the second toe or second finger) (Hettrick et al. 2004), as well as circumferential measurements.

Respiratory management

- Respiratory management is indicated with bed rest as well as when there is evidence of injury to the organs of respiration.

- Airway clearance techniques are essential for patients with smoke inhalation, including therapeutic coughing, chest physiotherapy, early ambulation, airway suctioning, therapeutic bronchoscopy, and pharmacological agents to remove retained secretions (Mlcak and Herndon 2007, Mlcak et al. 2007).

- Pulmonary function changes following inhalation injury in children have been reported up to 10 years post-burn (Mlcak et al. 2000).

- Children with pre-existing respiratory conditions may have compromised lung function when using compression garments to head and chest, and lung function tests with garments in place and removed are recommended (Bourget et al. 2007).

Mobility and exercise

- Exercise in the acute phase of injury helps to maintain joint mobility and muscle function (Latenser and Kowal-Vern 2002). If the patient is alert and able to participate, a program of active and active-assisted exercise is appropriate. For obtunded or critically ill patients, passive ROM exercises that emphasize the end of ROM are prescribed to reduce contractures and functional loss. Ranging should be completed twice daily (Sheridan 2005).

- Resisted ROM, isometric exercises, active strengthening, mobilisation and gait training are commenced when appropriate prior to skin healing. Hydrotherapy can be utilised when the skin has sufficiently re-epithelialised with minimal open areas as it enhances the rehabilitation process (Sheridan 2005, Serghiou et al. 2007).

- In the event that full ROM is not maintained, a program of stretching is normally recommended. A sustained force to tissue will produce tissue elongation and a subsequent plastic change in length resulting in improved range of movement. Treatment intensity is determined by scar blanching (the clinical sign that the tissue's yield point is approaching) and tolerable pain (Spires et al. 2007). Gentle, prolonged stretch to healing tissue at its longest tolerable length for at least 6 to 8 hours per day is most effective (Chapman 2007). The joint needs to be moved slowly and repeatedly to its end range several times before applying a prolonged stretch that is maintained until the tissue blanches (Spires et al. 2007).

- Immediately following autografting, active and passive exercises are not performed on the limb. Depending on type of graft, condition of the graft wound, and judgement of the surgeon, no exercise of ROM is performed for approximately 3 days on mesh grafts and 5 days for sheet grafts. Heterografts (or xenografts), synthetic dressings, escharotomies and surgical debridements are not contraindications to exercise (Spires et al. 2007).

- Wrapping burned extremities with elastic bandages when the patient is sitting or ambulating contributes to a decrease in edema and is used to avoid venous pooling which can lead to graft sloughing (Spires et al. 2007).

Scar management

- Generally, people considered at risk for developing hypertrophic scarring are treated prophylactically for wounds taking more than 14 days to heal spontaneously or those requiring grafts (Chapman 2007).

- Scar management interventions typically include compression and silicone (Fig. 9), as well as steroid injections.

- Pressure garments are typically commenced as soon as the wound is able to tolerate pressure. The use of pressure in the pre-grafting or healing stages has been advocated by some authors to prepare the wound bed and assist graft

- Complications from compressive garments have been reported as wound breakdown, skeletal deformation, growth retardation and obstructive sleep apnoea (Bourget et al. 2007, Rappoport et al. 2007).

- Where it is difficult to provide pressure, such as the webspace between fingers, additional inserts of silicone or moldable materials are required to ensure an intimate fit (Spires et al. 2007). Silicone gel sheeting is ideally applied up to 24 hours per day from when epithelialization has occurred until the scar matures. Generally the recommended initial duration of the treatment is 12 hours/day, particularly when it is used in combination with pressure, on children or in warm weather or climates. Strict guidelines are necessary for cleaning and disinfection of both the product and the skin. Gel sheeting may be stabilized at the edges with tape to prevent slippage and displacement during body movement (Van den Kerckhove et al. 2001).

- Complications from silicone gel sheeting (rash, ulcer, erythma and pruritis) have been reported by some authors in over 50% of cases (Rayatt et al. 2006). While these complications are more common in children and when the gel is kept in place with pressure garments or adhesive tape, they usually resolve when the therapy is stopped temporarily or with hygiene measures (Van den Kerckhove et al. 2001).

- Steroid injections into localized early hypertrophic scarring, particularly when in highly cosmetic locations or causing severe itching, can be useful. In children they are usually performed with a general anaesthesia, as it requires a significant force to inject the steroid into dense hypertrophic scars (Sheridan 2005).

Promoting healthful return to activities and participation

Therapeutic relationship

- Best established when consistent therapist input is maintained, across both inpatient and outpatient continuum of care

- Firm but gentle approach to the treatment sessions, with adequate pain relief measures in place is vital.

- A gentle, unhurried approach to treatment sessions with conversation and encouragement may improve the patient's tolerance of treatment techniques.

- Use developmentally appropriate play to facilitate rehabilitation goals (Sheridan 2005).

Assessment of pre-morbid functioning

- Pre-morbid child factors can include developmental delay and difficulties with learning and behaviour. Seeking to restore pre-morbid function in children following burn injury is inappropriate, as developmental change and rehabilitation are occurring concurrently (Blakeney et al. 2007).

- The presence of learning difficulties or developmental delay is likely to affect the child's reaction to the burn injury, their understanding and response to treatment, and to lower the expectations of those familiar with the child (e.g., parent and teacher) in relation to their level of performance (Tyack 2001).

Ongoing education

- Begins in the acute phase, with a focus on establishing a long-term relationship to ensure compliance with therapy goals and patient's morale for recovery (Sheridan 2005).

- Social and emotional issues will impact upon how much procedural information is accepted and processed. Information may need to be repeated based upon the child and the family's presenting state. Remain conscious of child's emotional state when discussing procedures with caregivers. Generally, careful attention is taken not to discuss plans of care in front of the younger child, due to the risk of misinterpretation and increased anxiety. Specialised procedural education aimed at their developmental level is preferred (see later).

- Complex families frequently involve more than two caregivers that require separate education sessions, as well as education of extended families due to their role in the rehabilitation of the child in the long-term.

- Education and communication among all burn team members, patients and their caregivers is necessary if an effective positioning and exercise program is to be successful (Richard and Staley 1994).

- Family education and involvement with rehabilitation plans may facilitate early identification of evolving problems, thereby rectifying rehabilitation efforts (Sheridan 2005).

Procedural preparation for the child

- Age appropriate procedural preparation is facilitated in young children with cartoon books that provide a simple story about theatre, operations, skin grafting,

- For older children and adolescents a more formal education package is used, in order to engage participation in the planning of their own care. Caregivers are often encouraged to attend these sessions to support and help their child to understand and learn.

Goal setting

- Realistic therapeutic goals, as well as an appropriate plan of care, should be devised by the treatment team that includes the caregivers and child (age permitting).

- Regular meetings to discuss progress and a posted daily timetable are effective and appreciated.

- The longitudinal pattern of psychological recovery will have significant impact on the child and family's ability to participate in goal-setting activities as well as the treatment program (Blakeney et al. 2007). For example, emotional lability and cognitive and behavioural regression is typically observed during the in-hospital recuperation phase.

Discharge planning

- Appropriate functional goals prior to discharge include the ability to stand, ambulate, feed, and toilet, as well as return to school and play (as developmentally appropriate) (Sheridan 2005).

- Well-organized re-entry programs to the child's 'community' e.g., family, neighbourhood, school may facilitate the child with burns reintegration (Blakeney et al. 2007).

- Preparation of parent and child in dressing care and garment application is essential. Generally, caregivers begin to take over dressing care 1-2 weeks prior to expected discharge.

- Home modifications and assistive facilities may be required for complex patients.

- Ongoing liaison with non-specialist treating therapists is required, including visiting burns service, videoing therapy session (with patient's permission) and telephone support (Sheridan 2005).

- Telemedicine video-link follow-up consultations with the burns multidisciplinary team and local services (medical, nursing, occupational therapy, physiotherapy) are invaluable to minimise the need for long trips back to the specialist burns centre without compromising patient care (Smith et al. 2004a, Smith et al. 2004b, Johansen et al. 2004) (Fig. 10).

- Children with significant burns should be followed up to adulthood to monitor for contractures and to recognise and treat psychological problems if they arise. Transition at an appropriate time to an adult burns centre will often be required.

Ongoing psychosocial support

- Long-term emotional outcome is dependent upon the whole family's emotional care; therefore early and adequate care of the family is essential from the onset of burn care. Burns are associated with significant emotional overlay in the child and the parents or caregivers. Feelings of grief and loss are common and are normal accompaniments of burns. In addition, feelings of guilt, self reproach, fear, depression and often anger in the caregivers need to be addressed (ANZBA 2007).

- Burn camping programs appear to positively support emotional responses post-burn, including self-esteem and integration (Rimmer et al. 2007).

- Monitor for signs of acute stress and post-traumatic stress disorder symptoms (hyper-alertness, nightmares, chronic fearfulness) and refer early to appropriate services (Thomas et al. 2007).

As a natural progression from improved medical outcomes post-burn injury over the last three decades, attention now is being directed to optimizing functional outcome for children post-burn injury. Ideally, the child with burns is able to complete tasks that are meaningful, practical, sustainable over time and relate to their life outside the clinical environment (i.e., family, schoolmates and community). All members of the burn management team interact throughout the recovery period from admission to scar maturation and beyond to minimise the impact of the trauma in the long-term.

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Figure 1: Most burns in children occur in the under five age group and in the home environment.

Figure 2: Hot beverage scalds account for up to a quarter of all burns in children.

Figure 3: Electrical burns are most likely to be low voltage injuries in the home environment.

Figure 4: Laser Doppler scan showing areas of full thickness and deep dermal partial thickness burns on the chest.

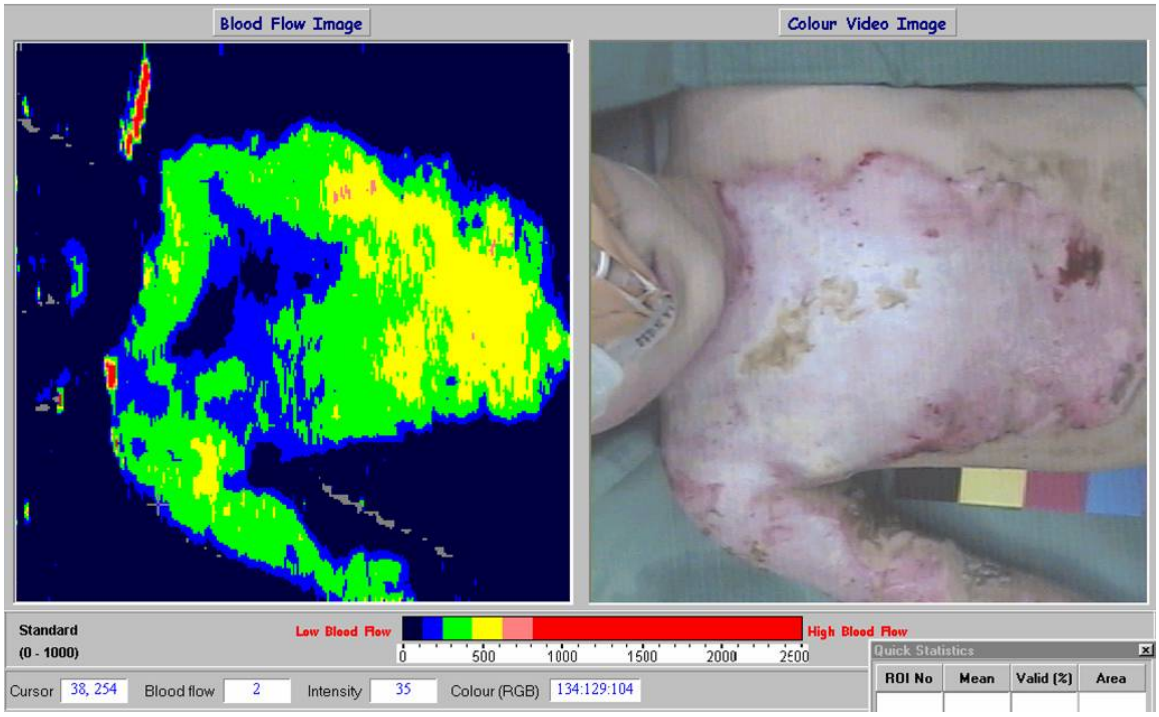

Figure 5: Timing therapy procedures with dressing changes.

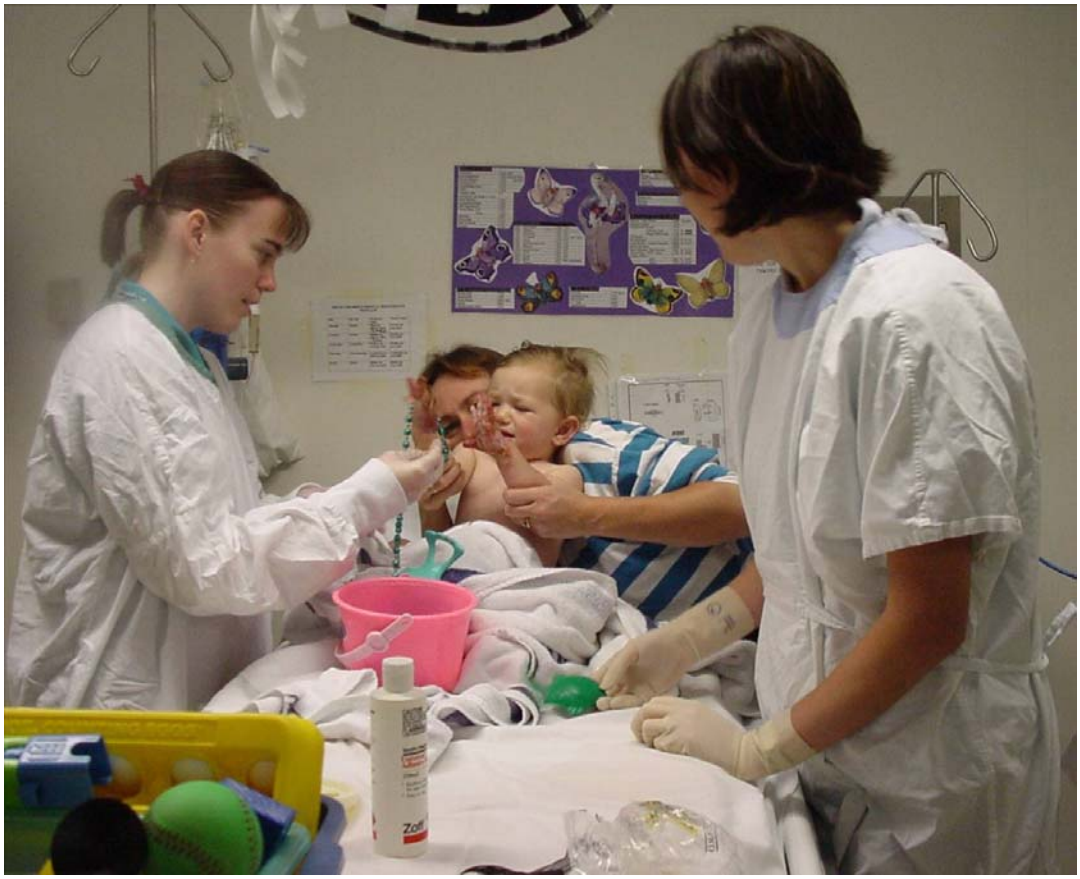

Figure 6: An augmented reality device being used to alleviate pain and anxiety during a burns dressing procedure.

Figure 7: Contractures to elbow, wrist and fingers as a result of hypertrophic scarring.

Figure 8: Anti-deformity positioning from onset of burn care.

Figure 9: Custom made pressure garments are measured and fitted when the child's skin is able to withstand pressure and edema resolved.

Figure 10: Tele-conferencing for follow-up for burns patients is effective and avoids long trips for the child and family.