INFANT BURNS IN FINLAND 1990–2010
– SPECIAL EMPHASIS ON CLINICAL
CHARACTERISTICS AND OUTCOMES

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To be publicly discussed with the permission of the Medical Faculty of the University of Helsinki, in the Niilo Hallman Auditorium of the Children’s Hospital (Stenbäckinkatu 11), on October 30th, 2015, at 12 noon.
It always seems impossible until it is done.

*Nelson Mandela*

To my family
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ABSTRACT

Background: In recent decades, the total number of burn injuries has decreased globally, while the number of childhood burns has been increasing. Infant burn victims younger than 1 year are a specific group because they are highly dependent on parents or caregivers.

Aim of the study: The aim of this study was to clarify the causes of burns, the etiological factors, and the treatment given to infant burn victims treated at the Children's Hospital in Helsinki between 2005 and 2009. The purpose of this study was to determine the incidence and trends of inpatient and outpatient treatments for burn-injured infants born in Finland between 1990 and 2010. The aim was also to identify etiological and risk factors for infant burns, and to examine the long-term health-related quality of life (HRQoL) of children having had a burn injury 5 to 9 years earlier, as infants.

Patients and methods: All burn victims younger than 1 year born 1990–2010 were identified from the National Institute of Health and Welfare (THL) and the Statistics Finland registers. The sample comprised 1842 patients. The analysis consisted of the incidence of burn injury, trends of treatment, and risk factors for burns.

Between 2005 and 2009, 692 burn victims, of whom 126 were aged less than 1 year, were treated in the Children's Hospital, Helsinki, Finland. Hospital electronic databases were searched to clarify gender, age at injury time, total body surface area (TBSA) percent, site of the accident, etiology, mechanism, length of the hospital stay, the treatment given, and possible complications. Patients treated as inpatients and outpatients were analyzed separately. In spring 2014, 5 to 9 years after the infant burn injury, the HRQoL of the 126 burn-injured children was evaluated with a validated, standardized 17D questionnaire.

Results: Between 1990 and 2011, 1842 infant burn victims (61% boys) were treated at Finnish hospitals. One third of the burns were recorded on Mondays or Tuesdays and during the winter months. During the study period, the annual overall incidence per 1000 persons rose from 0.77 to 2.04, and the incidence of outpatient-treated burns increased from 1.11 to 1.67. Operative treatment was given to 302 children, 89% of whom had more than one operation-related code recorded. Based on the analysis, the risk factors for infant burn injuries are male gender, being firstborn, the mother's young age, and low socioeconomic status.

During the 5-year study period, 126 infants injured with burns were treated in the Children's Hospital; 20 were treated as inpatients and 106 as outpatients. Girls outnumbered boys in the inpatient-treated group, and 45% of those treated as inpatients were younger than 6 months. The final mean TBSA was 8.5% (from 0.5 to 40%), and 6 patients received surgical treatment. Of the burns, 75% occurred at home, and most, 85%, were scalds caused by hot liquids spilled from a cup.

In the outpatient group, 52% were boys, and the overall majority, 57%, were aged 9 to 12 months. The final mean TBSA burned was 1.4% (range from 0.5 to 7%), and the median number of outpatient admissions was 4 (from 1 to 13). Of these patients, 80% of the burns occurred at home, and the caregiver eyewitnessed the accident in 66% of the cases. Scalds represented 61% of the burns, and 44% were on the hands.
The HRQoL of 126 patients treated for burns as infants was queried 5 to 9 years after the burn injury, and 35% of the patients responded. The respondents and non-respondents proved to be similar in terms of age, injury severity, and treatment given. The respondents appeared not to suffer from long-term consequences of the burn injury, and their HRQoL (0.968) was comparable to that of control children (0.936).

**Conclusions:** The number of infant burns increased in Finland during the study period. Two thirds of infant burns were scalds caused by hot liquids, and most of these were preventable. Firstborn boys aged 9 to 12 months of young mothers with low socioeconomic status are at greater risk for burns in the beginning of the week during the winter. The long-term HRQoL of burn-injured children was comparable to that of the controls, and they appeared not to suffer from any long-term consequences of the burn injury.
TIIVISTELMÄ

Taustaa: Viimeisten vuosikymmenen aikana palovammatapaturmien määrä on maailmassa yleisesti vähentynyt, mutta lapsuusikäisten palovamman tapaturmien määrä on lisääntynyt. Pienet, alle vuoden ikäiset lasten lapsuusikäiset palovammatapaturmien lisääntyminen kosketaan huoltajista.

Tutkimuksen tavoite: Tutkimuksessa pyrittiin selvittämään sairaalassa palovammatapaturman vuoksi hoidettujen alle vuoden ikäisten lasten palovammojen erityispiirteitä, ilmaantuvuutta (insidenssi) ja riskitekijöitä. Lisäksi haluttiin selvittää palovammojen aiheutumisohjelmaa ja annettu hoito ja hoidon tulokset sekä palovammatapaturman vaikutusta lasten terveyteen liittyvään elämänlaatuun.


Vuosina 2005–2009 Helsingissä Lasten ja nuorten sairaalassa hoidettiin 126 alle vuoden ikäistä lasta palovammatapaturman vuoksi. Sairaalassa osastolla hoidetuista 20 laspalasten enemmistö (60%) oli tyttöjä ja lähes puolet vauvoista (45%) oli alle 6 kuukauden ikäisiä. Palovammen laajuus oli keskimäärin 8.5% (0.5-40%). Suurin osa palovammoista (85%) aiheutui kuuman nesteen läikkyessä kupista ja 75% palovammoista sattui kotona. Polikliiniisesti Lasten ja nuorten sairaalassa hoidettiin 106 lasta, joista 52% oli poikia ja 57% 9-12 kuukauden ikäisiä. Palovamma-alue oli keskimäärin pieni (1.4% TBSA) ja polikliiniisten käyntien määrä vaihteli yhdessä kolmengoitoista. Kotitapaturmia oli 80% palovammoista ja kayaksi kolmasosa vammoista sattui huoltajan tai vanhemman läsnä ollessa. Käsien alueella oli 44% palovammoista ja 61% palovammoista oli kuuman nesteen aiheuttamia.
Alle vuoden iässä hoidetuilla 126 lapselta mitattiin 17D kyselytutkimuksella terveyteen liittyvää elämänlaatua 5-9 vuoden kuluttua palovammatapaturmasta. Terveiden ikävakioitujen verrokkien tiedot oli kerätty aiemmin Helsingin seudun kouluista. Vastanneiden 44 potilaan ja kaikkien 126 aiemmin hoidetun potilaan palovammat ja niiden aiheuttajat sekä annettu hoito todettiin samankaltaisiksi ja kyselyyn vastanneiden lasten terveyteen liittyvää elämänlaatu osoittautui hyväksi.

LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following publications, and they will be referred to in the text by their Roman numerals.


This thesis also contains unpublished data.

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LIST OF ABBREVIATIONS

BOQ  Burn Outcome Questionnaire
CA   catecholamine
CEA  cultured epithelial autograft
CI   confidence interval
CT   computer tomography
FFA  free fatty acids
FGF  fibroblast growth factor
HRQoL health-related quality of life
ICD  the international statistical classification of diseases and related health problems
ICU  intensive care unit
LDI  laser Doppler imaging
LSDI laser speckle contrast imaging
MBR  The Finnish Medical Birth Register
MRI  magnetic resonance imaging
NHDR The National Hospital Discharge Register
NBR  The National Burn Repository
NICU neonatal intensive care unit
PDL  pulsed dye laser
PedQL Pediatric Quality of Life Inventory
PGT  pressure garment therapy
PIC  personal identification code
POSAS Patient and Observer Assessment Scale
PTSD posttraumatic stress disorder
QoL  quality of life
RR   risk ratio
TBSA total body surface area
TG   triglyceride
TGF  transforming growth factor
THL  The National Institute of Health and Welfare
TSS  toxic shock syndrome
TSST-1 toxic shock syndrome toxin-1
VSS  Vancouver Scar Scale
1 INTRODUCTION

Infants younger than 1 year of age are at risk for injuries in general and burn injuries specifically due to their curiosity and poor awareness and understanding of dangerous situations (Drago 2005, Carlsson et al. 2006, Spinks et al. 2008, Duke et al. 2011, Stockton, Harvey & Kimble 2014). They are totally dependent on their parents and caregivers, and represent a specific and vulnerable age cohort. Newborns are physically uncoordinated, and their capability of causing burn injuries is very limited. During the first months, children explore their environment with their hands, developing more skilled movements over time, and later, after the age of 6 months, mobility develops rapidly until the child learns to walk and run. The height of a 1-year-old child is around 75 cm, which enables them to reach objects from the table, thus increasing the risk of scald burn injuries (Thompson 2001, Murphy et al. 2004).

The staff treating burn-injured infants at the Children's Hospital in Helsinki, Finland, conducted a clinical observation of the increasing number of infant burns. This study was planned to discover if the phenomenon was real and nationwide. Data focusing particularly on infant burns were also scarce, and the aim was to clarify the patterns of infant burns.

Burn injury is a devastating event for the individual and the entire family, and it may cause long-term consequences. In adults, the health-related quality of life (HRQoL) after a burn injury has been evaluated, but results focusing on childhood HRQoL after an infant burn injury are lacking (Koljonen et al. 2013b, Koljonen et al. 2013a). We wanted to investigate the impact of infant burn injury on HRQoL in later childhood. Burn-injured young age groups, infants and toddlers, have higher mortality rates than older children or adults (Morrow et al. 1996, Spinks et al. 2008). The study was also conducted to evaluate changing trends in the treatment of infant burns.
2 REVIEW OF THE LITERATURE

2.1 Skin

The skin is the largest organ in the body and has an important role of acting as a barrier and a protector between the body and the environment. It is one of the most regenerative organs, and continuous renewal and alteration in response to inner and outer stimuli is typical. The skin acts as a sensory receptor and is biochemically active when synthesizing vitamin D. The skin maintains the fluid and electrolyte balance, protects against harmful, damaging environmental insults, and regulates temperature. The skin protects the body against the entrance of undesirable substances such as microorganisms or toxins by acting as an outer protective sheath. In humans, the skin’s visual appeal, smell, and sensation have an important role in social and sexual communication (McGrath, Uitto 2010).

For an average newborn, the surface of the skin ranges from 0.2 to 0.3 m², and from 1.5 to 2.0 m² in adults. The two layers of the skin are the epidermis and dermis. The thickness of the epidermis varies from 0.05 mm on the eyelids to over 1 mm on the soles. The dermis is usually approximately 10 times thicker than the associated epidermis. In infants, the skin is remarkably thinner than in adults, which must be considered when treating young burn-injured patients. Males have thicker skin than females, and the skin thickens until the age of 30 to 40, later becoming thinner in elderly people (Chung, Sanford & Herndon 2006).

2.2 Anatomy of the skin

![Anatomy of the skin (picture by Katri Seppä)](image)

The epidermis is composed of epithelial cells, specifically keratinocytes. Other epithelial cell types include melanocytes, Langerhans cells, and Merkel cells. Melanocytes produce pigment to protect the skin from ultraviolet radiation. Langerhans cells originate from bone marrow and have a key role in the adaptive immune response of the skin. Merkel cells function as...
mechanoreceptors; they have synaptic contacts with somatosensory afferents. The basal layer of keratinocytes is called the stratum germinativum, and it contains young, mitotically active cells generating epidermal cell layers that migrate outwardly. During the outward migration, cells mature and become a layer called the stratum spinosum, where mitosis no longer exists, but protein synthesis is prominent. The stratum granulosum is the next layer outwards, where cells specialize in producing keratin. The next step of migration is the stratum lucidum in thick skin areas; cells lose their nuclei and flatten (McGrath, Uitto 2010). Cells evolve into a dead superficial layer called the stratum corneum, which consists of dead flat keratinocytes that have lost their nuclei and cytoplasmic organelles. The epidermal maturation process from the basal layer to desquamation takes approximately 2 to 4 weeks (Williams 2002, Chung, Sanford & Herndon 2006).

Skin appendages, hair follicles, sebaceous glands, and sweat glands are lined with epidermal cells extending from the epidermis downward and are located mostly in the dermis. Epithelium pockets arising from the superficial epidermis surround the hair follicles. Arrector pili is the smooth muscle bundle adhering from the epidermal layer at an angle to the follicle wall, and above its insertion, the sebaceous gland opens to the pilary canal. The eccrine sweat gland similarly derives from the epidermis and opens superficially (McGrath, Uitto 2010).

The dermis is a relatively thick layer comprised of fibrous connective tissue. The main cell type is a fibroblast-synthesizing extracellular matrix of collagen and elastin. It is responsible for the generation of connective tissue and allows the skin to recover when injured. The basement membrane is a layer between the epidermis and the dermis composed of mucopolysaccharides and fibronectin. The basal epidermal layer is attached to the basement membrane with hemidesmosomes, and the basement membrane is attached to the dermis with elastic microfibrils. The dermis is divided into the thin superficial papillary dermis and the reticular dermis; a plexus of nerves and blood vessels separates them. The reticular dermis and fatty layer contain the skin appendages, hence burns involving deep layers of skin are painless and insensate to touch (McGrath, Uitto 2010). Skin provides a barrier which minimizes the energy reaching deeper tissues, and most of the thermal energy stays in this layer.

### 2.3 Historical aspects of burn injury

Since man began to use fire for cooking and heating, burn injuries have been a threat. The cave drawings of the Neanderthal illustrate the treatment of burn injuries over 3500 years ago (Thomsen 1977). From about 1500 BC, written papyri reveal that ancient Egyptians used topic salves or ointments to treat burn wounds and the Chinese and Japanese used extracts and tinctures made from tea leaves in 600–500 BC. Hippocrates (466–377 BC) recommended the following for burn injuries: “having melted old swine’s seam and mixed it with resin and bitumen, and having spread it on a piece of cloth and warmed it at the fire, apply a bandage” (Arzt 1970). Aristotle (322 BC) asserted that draining blisters would release the heat and fluid, and enhance the progress of healing. Ancient Romans used a topical mixture of honey and bran, or cork and ashes, a method of exposing the wound to the air instead of covering it with grease, or local treatment with vinegar or wine (Arzt 1970). Over time, animal products, herbs and plants, and oily substances have been recognized as useful in local wound treatment. Early local treatment options were early versions of updated treatments such as gauze dressings and exposure. The fever and heat often present after a burn injury were relieved by bloodletting for centuries. Lead
Review of the Literature

was used because of its cooling effects, and around 800–900 AD Arabians used dressings dipped in cold or iced water or rose water to treat burns (Thomsen 1988). The treatment and knowledge of burns was based on antique and historical principles for almost 20 centuries (Van Hee, Lowis 2006).

Wilhelm Fabry, Latinized as Fabricius Hildanus (1560–1634), was regarded as the “Father of German Surgery” and published the first book exclusively written on the treatment of burns. His text was entitled “Burns” (1641), and it was devoted to the definition, causes, classification, treatment, and prognosis of burns (Kirkpatrick et al. 1995). Fabricius stated that burns cause not only immediate damage to the skin, but also have effects on the whole body system. He recommended regular changes of dressings several times a day to draw out the fire. For third-degree burns, Fabritius introduced early escharotomies and dressing changes and the prevention of contractures by manipulating joints during the application of ointment, and he constructed an apparatus for splinting extremities. He also developed methods of pain relief (Robotti 1990).

In the 18th century, the correlation between burns and symptoms of inflammation became better understood, and many publications and theses were devoted to burns during the 18th and 19th centuries. John Hunter (1728–1793) was a well-known army surgeon with experience in the management of traumatic injuries. He questioned whether gun wounds should be enlarged and if gunpowder was actually poisonous. He also taught that burn injuries and scalds are best treated with exposure and dryness. Hunter’s advice was that the acute burned area should be heated to reduce the inflammation and pain. He also acknowledged cooling to reduce inflammation but thought that removing the source of cold from the wound causes the pain to recur. Most of Hunter’s theories contradicted the knowledge of his predecessors (Hussain, Choukairi 2013).

In the 19th century, experimental surgical treatment became very popular. The American James Bigelow (1786–1879) and the Frenchman Baron Guillaume Dupuytren (1777–1835) published texts about burn classification and treatment. Dupuytren assumed that the internal symptoms of burns were a sympathetic reaction to an essential trauma, leading often to death in patients with large burns. He also concentrated on operative treatment for contractile scars (Androutsos, Karamanou & Kostakis 2011). The development of antibacterial solutions took place in the same period; in 1851, Joseph Lister introduced the antibacterial actions of carbolic acid, and this compound was soon used for burn-injured patients (Lister 1867).

The Italian Giuseppe Baronio (1759–1811) performed the first skin transplantation on lambs and published his work in 1804. In 1823 in Marburg, the first successful skin transplantation with a free skin autograft from the thigh to the nose was described, but complete failures were also recorded. The Swiss surgeon Jacques Louis Reuerdin (1842–1928) in 1871 presented his experimental work on partial-thickness skin grafting, the “split thickness graft,” performing autotransplantation (tissue from the same individual), allotransplantation (tissue from another individual), and xenotransplantation (tissue from the individual of a different species) (Van Hee, Lowis 2006). The 1939 development of dermatomes, first a drum type and later electric, made the cutting of split thickness grafts easier compared to the free-hand technique with a scalpel (Artz 1970). In the 1960s, Yugoslavian surgeon Zora Janzekovic developed and published a method of early excision and immediate skin grafting, which is still the gold standard (Janzekovic 1970).

In Finland, over the past centuries, the lack of formally educated doctors with university training was evident. Finnish folklore medicine flourished, and folk healers with traditional healing practices cared for the sick and injured. Folk healers can be divided into those acting on empirical knowledge and those acting according to various magical methods, with spells or behavioral rules (Paal 2008). Due to the northern climate in Finland, the range of plant species
is more limited than in Southern Europe, limiting the use of healing herbs. In Finnish folklore, popular plants for healing have been clovers, plantain, and marsh teas, and the ingredients of medical ointments have included tar, pitch oil, tree oil, spirits, and turnip seeds. Sauna has always had an important place in healing and was called the poor man’s pharmacy, as poultices were used in the sauna. The old Finnish saying goes as follows: “if spirits, tar, and sauna don’t help, then the disease is fatal.”

2.4 Burn injury

Burn injury causes coagulation necrosis in the skin layers; cell death is caused by both traumatic and ischemic necrosis. The temperature and concentration of the causative agent and the duration of exposure determine the depth of the burn injury. The temperature of the burn site and the thickness of the skin also impact the severity of the burn (Moritz 1947). Thermal heat or energy is transferred easily to the body by conduction, radiation, or convection. Typically, conduction injuries are scalds and contact burns. Common sources for radiation burns are sunlight or tanning beds and flash injuries from explosions. Acids, alkalis, or other organic materials cause chemical burns from exposure by contact, inhalation, ingestion, or injection. Electrical injuries occur by contact with lightning, high voltage power cords, incorrectly installed electric apparatus, or wall plugs. Falling on a treadmill or traffic accidents cause friction or abrasion injuries, which are treated similarly to burn injuries. Smoke contains many toxins, which are a leading cause of morbidity and mortality in burn patients, and therefore inhalation injury should always be considered in facial burn patients (Cinat, Smith 2006).

![Figure 2: Jackson's three zones of burn (illustration by Elina Laitakari)](image)
2.4.1 The three zones of burn injury

Burn injury progressively destructs cell layers, denaturizes cellular proteins, and disrupts homeostasis. Three zones of burn injury are recognized in the skin: coagulation, stasis, and hyperemia (Jackson 1953). The coagulation zone contains the area of eschar, where the cells are totally destroyed. Tissue perfusion is remarkably diminished in the zone of stasis surrounding the zone of coagulation. Local release of inflammatory agents causes platelet thrombus, neutrophil adherence, fibrin deposition, and vasoconstriction leading to cell necrosis. The impaired blood flow postburn continues up to 48 hours, and the aim of burn resuscitation is to prevent irreversible damage and, additionally, to increase tissue perfusion. In the peripherally located zone of hyperemia, vasodilatation induces an increased perfusion allowing minimally damaged tissue to recover, unless there are factors complicating the recovery, such as infection, sepsis, or prolonged hypoperfusion. The zones of burn injury are three dimensional, and the enlarging of the central coagulation zone will lead to greater tissue loss. The increased permeability of peripheral vessels and microvascularity, which allows plasma proteins to leak into the interstitium, causes burn wound edema (Zawacki 1974, Chung, Sanford & Herndon 2006).

2.4.2 Burn pathophysiology

A burn injury larger than 20% of the total body surface area (TBSA) leads to systemic effects. These are caused by a burn injury–induced release of inflammatory agents, toxins, and changes in perfusion. Different systemic effects are related to burn injury: peroxidation of hepatocytes, myocardial depression, hypermetabolism, renal tubule damage, decreased blood flow to gut, pulmonary hypertension and edema, and fat and skeletal muscle catabolism. The incidence of at least two organ system failures in children treated in intensive care units for large burns is 19 to 27%. Inhalation injury and large and full-thickness burns are risk factors for systemic organ failure (Wilkinson et al. 1986, Kraft et al. 2014). The incidence of multiple organ dysfunction in patients having a burned TBSA greater than 20% is 40–60%. Increased mortality rates (22–100%) are related to the risk of major infections and sepsis, liver and renal failure have the worst outcome, and more than three organ-system failures are fatal (Butler, Sheridan 2012).

2.5 Burn wound depth

2.5.1 Classification

Classically, burn wounds have been classified into four degrees depending on the wound depth (first-, second-, third-, and fourth-degree burns) (Artz 1970). Lately, the description has changed to indicate the injured anatomical structures of the skin. Burn wounds are classified as superficial, partial-thickness, full-thickness, and subdermal burns (Cinat, Smith 2006, Sjöberg 2012). In first-degree or superficial burns, typically caused by sun radiation, the superficial epidermis is damaged. The affected area is painful, with vasodilatation and erythema, but heals within 2 to 3 days. Second-degree or partial-thickness burns penetrate the epidermis to the dermis and are divided into two subgroups, superficial or deep, depending on the depth of the injured dermis. In superficial partial-thickness burns, the epidermis and superficial parts of the dermis are damaged. Burned lesions are painful due to nerve endings reaching the dermis, blister formation and edema are present, the surface is moist, and capillary refill is visible after compression. The migration of epithelial cells from skin appendages induces healing usually within 2 weeks, often
leaving pigmentation changes in the skin (Zeitlin, Somppi & Järnberg 1993, Sjöberg 2012). Deep partial-thickness burns damage most of the dermis, including the nerve ends, causing painless areas, and the healing capacity without surgical treatment is very limited (Heimbach et al. 1992, Heimbach, Mann & Engrav 2002).

2.5.2 Estimation of the burn depth

Estimation of the depth of the burn is a key decision that influences the treatment chosen for any thermal injury. Traditionally, the principal method has been serial clinical evaluation of the burned area. It is a subjective assessment based on a visual, tactile inspection of the wound, and even experienced surgeons may make inaccurate estimations in around 25% of cases (Heimbach et al. 1992, Lindahl, Tesselaar & Sjöberg 2013). Burns in young children are mostly scalds, and typically the depth of the burn varies in the burned area. Accuracy in the estimation of the burn depth leads to appropriate wound management, thus preventing unnecessary surgery.

2.5.3 Estimation tools

A variety of methods and techniques provide an estimation tool of burn depth, including digital imaging, biopsy, transcutaneous microscopy, differential reflectance photometry, perfusion fluorometry, radioisotope studies, thermography, and ultrasound (Holland, Martin & Cass 2002, Atiyeh, Gunn & Hayek 2005). Each method has its disadvantages, and the costs of equipment and the lack of appropriate data have impeded their wide acceptance.

2.5.4 Laser Doppler imaging

Recently, biomedical laser instruments have been developed to measure blood flow in tissues, of which laser Doppler imaging (LDI) produces a color-coded image of the skin blood perfusion. A low-intensity red laser light beam penetrates the dermis, and both moving red blood cells and the static tissue reflect the beam. The LDI instrument assigns perfusion units to quantify the movement of red blood cells flowing through the vessels, and perfusion units are translated into different colors (Mill et al. 2009). Earlier, LDI has been confirmed to be an accurate and reliable tool for diagnosing pediatric superficial, deep partial, and full-thickness burns, mainly scalds, when performed 36–72 hours postburn, having an accuracy of over 90% compared to one of 60–80% with clinical methods (Pape, Skouras & Byrne 2001, Holland, Martin & Cass 2002, La Hei, Holland & Martin 2006, Mill et al. 2009). Examination with LDI takes several minutes and is noninvasive and noncontact, although young children may need to be sedated. Moderate degrees of movement, infection, the type of first aid given, or the type of dressing have proven to have no impact on its accuracy (Nguyen et al. 2010).

2.5.5 Videomicroscopy

Videomicroscopy is based on the visualization of the dermal capillary structures, and the estimation of the burn depth is based on capillary destruction and hemoglobin deposition in deep partial-thickness injuries and their complete destruction in full-thickness injuries. The results of videomicroscopy were compared to both the clinical and LDI findings, and they were found capable of accurately and objectively assessing burn depth (McGill et al. 2007).
2.5.6 Laser speckle contrast imaging

Laser speckle contrast imaging (LSDI) is a noninvasive camera-based system where the skin area is illuminated by a coherent laser light, which is randomly backscattered from the optically robust red blood cells and creates an interference pattern or speckle pattern on the camera sensor based on the red blood cells' movement. LSDI is comparable to LDI when performed during the first week postburn, but the equipment is cheaper, and the imaging time duration is only a few seconds (Lindahl, Tesselaar & Sjöberg 2013).

2.5.7 Current modalities

More than 50 studies concerning LDI assessment of burn depth have been written in recent decades describing its advantages, and despite numerous alternative modalities, LDI remains the most favored, especially in the United Kingdom (Khatib et al. 2014). However, LDI equipment is expensive, and topographically uneven areas of the body remain a challenge to scan. Tattoos, peripheral vascular disease, and anemia may skew the results of LDI, and more research is required (Khatib et al. 2014, Jost, Osland 2014). LDI has been used successfully in young children (less than age 2), but data focusing specifically infant burn victims are scarce (Mill et al. 2009, Nguyen et al. 2010). Children's thinner skin, often smaller TBSA% burned, and good healing response in addition to the absence of comorbidities may facilitate an earlier diagnosis with LDI (Nguyen et al. 2010).

Despite the wide range of modalities available for assessing burn depth, a survey from United States burn centers showed that the most preferred modality currently for burn depth assessment is clinical examination in 60% of cases, followed by LDI and biopsy (Jost, Osland 2014). The most interesting and promising modalities for daily use were clinical examination, LDI, and noncontact/high-frequency ultrasound. The limitations on the wide use of new modalities were costs, availability, and the lack of support from up-to-date evidence. Further studies and research are needed before the new modalities are taken into widespread daily use.

2.6 Epidemiology

2.6.1 Traumas and burns worldwide

Worldwide, around 11 million burns occur annually, representing the fourth common cause of injuries and the cause of 300 000 deaths. Fire-related burns result in disability-adjusted life years, and over 90% of burn-related deaths occur in low and middle income countries lacking prevention programs and having inefficient acute care systems (Peck 2011, Burd, Yuen 2005). In high income countries, racial and ethnic minority, low socioeconomic status, age, and gender are risk factors for burn injuries, with males and very young and elderly people having a higher risk for burns. Males represent 50% higher rates for burns in all age groups, and the elderly population of more than 65 years accounts for 29% of domestic fire victims in the United States. In recent decades, the overall incidence of burns and burn mortality has decreased. Simultaneously, in low income countries, mortality for childhood burns is still double that of high income countries (Peck 2011). Young children of less than 2 years have the highest overall rate of injury, and burns remain the fifth highest cause of death in infants (Agran et al. 2001, Pickett et al. 2003, Van Niekerk, Rode & Laflamme 2004a, Bowman et al. 2011).
2.6.2 The National Burn Repository

The National Burn Repository (NBR) collects data on inpatient-treated burns from 91 burn centers in the United States, 4 in Canada, and recently 2 in Sweden. It is the best source of information regarding the demographics of inpatient-treated thermal injuries. It contains data on burn etiology, the patient's age, gender, and the survival of burns. According to the NBR's annual report in 2013, children of less than 5 years represented 20% of all burned patients, and 12% of burn victims were older than 60 years. Two thirds of all burned patients were men, mortality for all burns was recorded as 3.4%, and 73% of patients had burns on less than 10% of TBSA with a mortality of 0.6%. Most of the burns (72%) occurred at home, and the length of hospital stay correlated well with the TBSA burned, approximately 1 day per percent of TBSA burned (American Burn Association 2013). The incidence of emergency department visits in the United States for burns is highest in the age groups of less than 10 and 20–30 years, from 3.3 to 3.5 per 1000 persons (Fagenholz et al. 2007).

2.6.3 Factors influencing survival

The prediction of survival and the outcomes of treatment is important when planning burn treatment. Factors influencing overall survival are improvements in care, better drugs, the development of grafting methods and wound care materials, advanced life support systems, and sensitive monitoring systems. The lack of pre-existing co-morbidities predicts better outcomes, especially in children. Factors worsening the outcomes of burns are age (younger than 2 or older than 65), burn size, inhalation injury, and need of mechanical ventilation for longer than 4 days. The most common complications related to burns in all age groups are pneumonia, cellulitis, urinary tract infections, respiratory failure, wound infections, and sepsis (American Burn Association 2013, Kraft et al. 2012a). A burned TBSA of larger than 60% is a crucial threshold concerning postburn morbidity and mortality, and the presence of inhalation injury worsens the outcome (Kraft et al. 2012a). The risk of infections, sepsis, multiorgan failure, and insulin resistance increases with cumulative TBSA. Children with a burned TBSA of more than 60% have mortality rates of 14%, burns with a TBSA of more than 80% are related to 33% mortality, and burns with 90 to 100% TBSA have 55% mortality (Wolf et al. 1997, Sheridan et al. 2000b, Kraft et al. 2012a).

2.6.4 Incidence of burns

In Finland, the annual incidence (per 100 000 persons) of inpatient-treated trauma in children aged less than 18 increased 5% between 1997 and 2006 (from 486 in 1997 to 510 in 2006, p < 0.0001). Simultaneously, the incidence of burns in children younger than 18 decreased 23% (from 29.1 in 1997 to 22.5 in 2006) (Suominen et al. 2011b). Earlier, from the 1960s, 1970s and 1980s, Zeitlin et al. reported that 80% of childhood burn injuries occurred in patients younger than 4 years. The majority, over 80% of burns, were scalds caused by hot liquids (Zeitlin, Somppi & Järnberg 1993). The incidence of pediatric burns (younger than 16) requiring treatment in intensive care units (ICU) in Finland was 0.1 per 100 000 persons from 1994 to 2004. All patients had scalds, and the median TBSA was 26%. The median age was 5, one third of the patients were aged less than 2 years, and none of them died (Papp et al. 2008). In Finland, the incidence of fire-related inpatient treated burns has been 5.6 per 100 000, 6% of them being fatal (Haikonen et al. 2013). Recently, Dokter et al. from the Netherlands reported that in recent decades, the overall
incidence of burn injuries has increased 42% (from 2.72 to 4.66 per 100 000 persons), and the incidence rates were the highest in children aged 0 to 4 years, doubling during the study period from 10.26 to 22.96 per 100 000 (Dokter et al. 2014). Overall mortality in Dutch burn centers was 4.1%, and during the study period the median TBSA of burns decreased from 8% to 4%. Data focusing particularly on the incidence of infant burns in Finland has not been previously published.

2.6.5 Young boys and toddlers at risk of burns


Children aged 1 to 3 years are called toddlers (“to toddle” means walk unsteadily). A peak at the toddler age group of 1 to 2 years of age exists; they represent one third of all pediatric burn victims. Toddlers’ burns are typically partial-thickness, and their risk for burns is up to 10-fold higher than that of school-aged children (Van Niekerk, Rode & Laflamme 2004b, Drago 2005, Schricke et al. 2013, Shah et al. 2013, Kemp et al. 2014, Zhou et al. 2014). Young children and infants have higher mortality rates than do older children; death rates from 0 to 10% have been recorded (Morrow et al. 1996, Kai-Yang et al. 2008, Spinks et al. 2008, Arslan et al. 2013).

Scalds and contact burns are the most common types of pediatric burn injury. Around 60% of burn injuries in children younger than 5 years are scalds, and 20% are contact burns. In older age groups, school-aged children, and adolescents, flames and fire are causes of burn injury in half of the cases (American Burn Association 2013).

2.7 Burn wound treatment

2.7.1 First aid

First aid is treatment given outside the hospital, before the initial treatment by the personnel of an ambulance service or in emergency units. In the 1880s, German surgeon Friedrich von Esmarch (1823-1908) first described “first aid” while teaching soldiers in battlefields how to bandage and splint to help their wounded companions (Cuttle et al. 2009). Throughout history, many different, and sometimes harmful and peculiar, techniques have been used to treat burns. Some of those treatments are still in prehospital and household use, especially in developing countries or in rural areas with low education. The topical treatment of burns outside the hospital has included hot or cold water, ice, urine, plant oils, ointments made from plant roots or leaves, mud, burned snail shells, eggs, honey, and mixtures of urine with mud and cow dung (Cuttle et al. 2009).

During the 18th century a debate arose over whether burns should be treated with hot or cold water to enhance healing (Hussain, Choukairi 2013). By using a porcine skin model with deep dermal burn wounds, the optimal duration and timing for running cold water from a tap has been shown to be 20 minutes immediately after a burn, but even 10 minutes of running cold water or even cooling after a 1 hour delay will improve the results in re-epithelialization (Cuttle et al. 2010).
2.7.2 Burn depth and treatment

The treatment of the burn wound is based on the depth of the wound and the size of the burned area. Factors affecting the depth of the burn wound are contact temperature, duration of contact, and thickness of the skin. In chemical burns, the alteration of pH and the disruption of the cell membranes from the direct toxic effects are factors influencing the depth and severity of the burn (Cinat, Smith 2006). Correct estimation of the burned area and its depth is the cornerstone of burn treatment (Miller et al. 1991, Nagel, Schunk 1997, Chan et al. 2012, Parvizi et al. 2014). Scalds in particular are often a mixture of superficial and deep dermal burns, which may lead to difficulties in classification and determination of the proper treatment. Commonly, the clinical assessment of the burn depth changes during the first week postburn, which should be taken into account to avoid unnecessary surgery in superficial burns and to help plan surgical treatment for deep burn wounds (Monafo, Bessey 2002, Kagan et al. 2013).

2.7.3 Superficial and partial-thickness burns and topical wound care

Epidermal, superficial burns are typically sunburns healing over 2 or 3 days. Partial-thickness burns will develop blisters in a couple of hours after the injury. Broken blisters should be debrided; palmar blisters on the hand compromising circulation or restricting range of motion should be sterile revised by unroofing the devitalized epidermis. Intact blisters may be left or aspirated and wrapped in dry dressings (Swain et al. 1987, Hudspith, Rayatt 2004, Palmieri 2009, Jamshidi, Sato 2013). Partial-thickness burn wounds usually heal in 2 or 3 weeks without surgical treatment with local wound care, and no major scarring or hypertrophy is evident, although pigmentation changes may occur (Zeitlin et al. 1998).

The skin’s protective function and mild antiseptic barrier are lost when a burn injury occurs, resulting in impaired immunological defense. Burn wounds and excised or granulating wounds cause extensive fluid and heat loss. The main principles of topical wound care and burn dressings are to protect and enhance wound healing, prevent infections and metabolic heat and fluid loss, minimize pain and cosmetic impairment, and preserve function. Superficial burn wounds left without dressings are painful, and deeper burns become very sensitive during the re-innervation of the injured nerves. Burn wounds heal best in a moist, but not wet, environment that promotes good conditions for healing and protects the wound. Other aspects include offering pain relief, occluding and absorbing wound exudates, and maintaining motion by splinting joints (Monafo, Bessey 2002). A large range of dressings and wound management agents are available, the most common of which in current use are listed in Table 1. All of these can be used successfully in the hands of skilled burn care personnel (Monafo, Bessey 2002, Warner, Coffee & Yowler 2014, Wasiak et al. 2013).
### Table 1: Topical agents, dressings, and membranes for burn care (modified after Warner et al. 2014. Trade names as they are on the Finnish market in March 2015)

<table>
<thead>
<tr>
<th>Agent</th>
<th>Description</th>
<th>Action</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Silver sulfadiazine</strong></td>
<td>Water soluble cream compound containing silver nitrate and sodium sulfadiazine</td>
<td>Binds to bacterial cell membranes and interferes with DNA synthesis, wide spectrum antimicrobial action against Gram- and Gram+ organisms</td>
<td>Painless, penetrates eschar poorly, may delay healing, forms “pseudo-eschar,” transient leukopenia possible</td>
</tr>
<tr>
<td>Mafedine acetate</td>
<td>Water-soluble nonstaining cream</td>
<td>Bacteriostatic against many Gram- and Gram+ organisms, Pseudomonas</td>
<td>Penetrates thick eschar, painful on application, may delay healing and cause metabolic acidosis</td>
</tr>
<tr>
<td>Bacitracin</td>
<td>Antibacterial cream</td>
<td>Narrow antimicrobial coverage</td>
<td>May cause urticaria, does not penetrate eschar, can be used on face</td>
</tr>
<tr>
<td>Mupirocin</td>
<td>Antibacterial cream</td>
<td>Bacteriostatic at low and bactericidal at high concentrations</td>
<td>Good Gram+ antimicrobial coverage, can be used on face</td>
</tr>
<tr>
<td>Collagenase</td>
<td>Enzymatic debriding ointment</td>
<td>Collagen digestion in necrotic tissue</td>
<td>Contributes to the formation of granulation tissue, no use with silver dressings</td>
</tr>
<tr>
<td><strong>Dressings and membranes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impregnated nonadherent gauze</td>
<td>Semiocclusive with 3% Bismuth Tribromophenate or Paraffin</td>
<td>Nonadherent, maintains a moist environment</td>
<td>Deodorizing, no antimicrobial activity</td>
</tr>
<tr>
<td>Silicone</td>
<td>Polyamide net coated with soft silicone</td>
<td>Nonabsorptive, nonadherent silicone net</td>
<td>Transparent, allows exudation drainage to secondary dressings, painless, non-antimicrobial</td>
</tr>
<tr>
<td>Hydrocolloids</td>
<td>Hydrocolloid, moisture-retentive wound dressing</td>
<td>Forms a hydrophilic gel facilitating autolytic debridement</td>
<td>Less pain, keeps environment moist</td>
</tr>
<tr>
<td>Biobrane</td>
<td>Silicone membrane bonded to a nylon mesh to which peptides from a porcine dermal collagen source have been bonded to the nylon membrane</td>
<td>Adheres to the wound until epithelization</td>
<td>Increases speed of healing, tolerates wetting, application at time of injury, less pain</td>
</tr>
<tr>
<td>Suprathel</td>
<td>Temporary, synthetic thin elastic membrane, lactocaptoomer, main substitute polyactic acid</td>
<td>Elastic, adheres to the wound until epithelization, pH low</td>
<td>One-time application after debridement, painless, permeable, completely resorbable</td>
</tr>
<tr>
<td><strong>Silver-impregnated dressings</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AquacelAg</td>
<td>Hydrofiber with silver</td>
<td>Antimicrobial, absorptive</td>
<td>High exuding wounds, nonadherent, effective up to 7 days</td>
</tr>
<tr>
<td>MepilexAg</td>
<td>Silicone foam dressing, silver</td>
<td>Antimicrobial, absorptive</td>
<td>Nonadherent, antimicrobial, effective up to 7 days</td>
</tr>
<tr>
<td>Acticoat</td>
<td>Rayon/polyester sheet bonded polyethylene mesh coated with nanocrystalline film of pure silver</td>
<td>Low concentrations of silver released when moistened, nonabsorptive</td>
<td>Broad antimicrobial spectrum, painless, decreases dressing changes</td>
</tr>
</tbody>
</table>
Two methods of burn wound treatment in superficial or partial-thickness burn wounds are in general use: an open method with topical antimicrobial agents and regular dressing changes, and a closed method with synthetic biologic occlusive dressings such as Biobrane® or Suprathel® without topical antimicrobial agents (Warner, Coffee & Yowler 2014). A number of dressings are available, some of which may have certain advantages over others related to their antimicrobial agents, the length of time of wound healing, the number of dressing changes needed, and reduced pain experience. However, strong evidence is missing, the quality of most studies is poor, and trial samples are small (Wasiak et al. 2013). In most studies, the dressing method used had no impact on healing time, but the use of silver-impregnated dressings is mostly related to less pain and a reduced number of dressing changes (Atiyeh et al. 2007, Genuino et al. 2014, Ostlie et al. 2012, Wasiak et al. 2013, Yarboro 2013).

In the last 50 years, silver sulfadiazine (Flamazine®, Silvadene®) has been the gold standard in the treatment of partial-thickness burns (Moyer et al. 1965, Klasen 2000, Atiyeh et al. 2007). The use of topical silver sulfadiazine is prohibited in pregnant or lactating women, newborns, and patients with sulpha allergy. According to recent findings, silver is in vitro toxic to both keratinocytes and fibroblasts, fibroblasts appearing to be even more sensitive to it (Poon, Burd 2004). This may cause delayed healing and increased scarring, and lead us to prefer slow dose silver releasing dressings instead of silver sulfadiazine. Most of the new silver-containing wound dressings are expensive, which may restrict their use.

In patients with partial-thickness burn wounds, keratinocyte-fibrin sealant sprays, fibrin sealants containing growth factors and cell suspensions, and amniotic membranes containing stem cells have also been used, but they are expensive, and further investigations in prospective clinical trials are needed (Jeschke, Herndon 2014).

### 2.8 Surgical treatment of burns

Full-thickness burns occur when all layers of the dermis and underlying adipose tissue are damaged, and in deep full-thickness burns, the underlying structures, fascia, muscle, ligaments, and tendon are also involved. In full-thickness burns, burn eschar develops, and the treatment usually includes excision and grafting, but closure in stages, amputation, tissue transfer, or microvascular procedures are sometimes inevitable (Kagan et al. 2013).

The goals for the surgical treatment of burn wounds are optimal and rapid healing, minimizing infective complications and scar contracture formation, while maximizing the best functional, social, and cosmetic outcomes (Kagan et al. 2013). Since the 1970s, early excision and skin grafting has been the gold standard (Jazekovic 1970, Lindell-Iwan 1980, Herndon et al. 1989). Full-thickness and deep partial-thickness burns should be treated with early excision and grafting. In both adult and child burn patients, these shorten the length of the hospital stay and reduce sepsis development and mortality in non-inhalation injury patients (Xiao-Wu et al. 2002, Atiyeh, Gunn & Hayek 2005, Ong, Samuel & Song 2006, Sheridan, Chang 2014). In patients with large, over 20% TBSA burns, serial operative procedures may be performed during the first several days of the injury to completely excise the full-thickness burned areas and cover them with skin grafts or temporary coverage (Atiyeh, Gunn & Hayek 2005, Sheridan, Chang 2014). The initial decision concerning surgical treatment is based on the burned area and its depth, possible smoke inhalation injury, and co-existing medical conditions (Atiyeh, Gunn & Hayek 2005, Kagan et al. 2013). Injury severity scoring systems are essential for triage and estimation of
the treatment outcome of the victims. Such an injury severity scoring system for burn patients has considerable practical value, being statistically derived from injury-related predictors and outcome measures (Baker, O’neill 1976, Atiyeh, Gunn & Hayek 2005).

2.8.1 **Edema and decompression**

In the acute phase of burn resuscitation, intravenous fluid therapy and tissue edema increase the interstitial pressure of underlying tissues. Due to edema and increased initial pressure in tissues, both venous outflow and arterial inflow decrease, leading to symptoms of compartment syndrome, dysfunction, ischemia, and necrosis. Circumferential eschar may constrict either circulation in the extremities or respiration in the chest. In the abdominal and chest area, impaired blood flow to the liver, kidneys, and gut may inflict rapid hepatic and renal failure, intestinal ischemia, and restriction of diaphragmatic excursion causing ventilation problems, especially in patients with inhalation injury (Sheridan et al. 1994, Sheridan, Chang 2014). An important part of early burn care is decompression, relieving the eschar compression on the underlying tissues. An escharotomy involves surgical incisions across burn eschar (necrotic skin) performed during the first 24 hours after a burn to relieve the pressure on the underlying tissues. Escharotomy incisions, which are illustrated in Figure 3, are made to both sides of the torso and to the affected body part; a horizontal incision in the chest area is also needed to help ventilation. Patients with high-voltage electrical injury, very deep burns, or crush injuries require subfascial excision (Kagan et al. 2013, Sheridan, Chang 2014). Eschar is removed in the operation room to the level of viable underlying tissue after stabilization of the patient.

![Escharotomy lines](image)

*Figure 3: Escharotomy lines (illustration by Elina Laitakari)*
2.8.2 Debridement and excision of the burn wound

Debridement is “cleaning” of the wound and is usually performed on superficial burn wounds when skin grafting is expected to be unnecessary. Surgical mechanical or sharp removal is done of all loose, devitalized, necrotic, and contaminated tissue, including possible foreign bodies and debris. Debridement of the wound reduces the risk of infection and cleans the wound surfaces, creating optimal circumstances for wound healing (Kagan et al. 2013).

Accurate estimation of the burn wound depth and area is the cornerstone of surgical treatment, as the area needing procedures and the depth of the excision (tangential or full-thickness) must be determined. Traditionally, excisions are performed tangentially with a dermatome or Goulian-Wecke knife by shaving off thin layers of eschar until viable healthy tissue is visible. White dermis and bright yellow fat tissue are signs of vitality; excisions should be deep enough to remove all necrotic tissue and bacterially contaminated areas in order to save the viable dermis and minimize hematoma formation. The location of donor sites, the thickness of the skin to be harvested, and preparation for wound coverage when the graft need exceeds the amount of donor sites should be carefully planned preoperatively (Kagan et al. 2013).

2.8.3 Blood loss and surgical treatment

Blood loss during early excision procedures may be extensive and is estimated at 100 to 200 ml/TBSA% excised, depending on the timing postburn. The availability of blood products, red blood cells, and clotting factors is crucial; therefore techniques minimizing blood loss should be considered (Sheridan, Chang 2014, Cartotto et al. 2000, Beausang et al. 1999). Free capillary bleeding serves as the best indicator for wound bed viability, although techniques to reduce intraoperative blood loss may make the estimation of viability more challenging. Techniques minimizing blood loss are maintenance of normal body temperature, preoperative tourniquet application in the proximal parts of extremities, and topical application of thrombin and/or vasoconstrictive solutions. The subcutaneous infiltration of saline solution with vasoconstrictives and local anesthetics into both the burn wound and split skin graft donor sites, and coagulating electrocautery use on fascial excisions and hemostasis reduce blood loss during surgery (Sheridan, Chang 2014, Cartotto et al. 2000, Shah, Dunn & Davenport 1999). The subdermal infiltration of vasoconstrictive solutions causes minimal acute cardiovascular effects (Atiyeh, Gunn & Hayek 2005, Shah, Dunn & Davenport 1999).

Recently, hydrosurgery has been increasingly used to debride superficial or partial-thickness burn wounds, but it also has been used in full-thickness burns as an alternative for conventional excision. The Versajet® (Smith and Nephew, Melbourne, Victoria, Australia) hydrosurgery system produces a high-pressure jet of sterile saline, which is tangentially directed to the burn wound surface, while it simultaneously suctions debris (D’Cruz, Martin & Holland 2013). Hydrosurgery has been proposed to be more effective in dermal preservation, and it is also suitable for pediatric burn wounds; no differences concerning postoperative healing time or contracture rates have been reported when compared to traditional procedures (Cubison, Pape & Jeffery 2006, D’Cruz, Martin & Holland 2013).

Fascial and subfascial excisions are performed on massive deep burns or high-voltage electric burns and on crush or blast injuries, including soft tissue trauma. Negative pressure devices may be needed to prepare the wounds for definitive closure, and local or distal flaps may be needed (Sheridan, Chang 2014).
2.8.4 Skin grafting

An excellent result usually follows when well-excised wounds are covered with autografts from uninjured skin. Skin grafts need to be modified or expanded by meshing the grafts (common mesh ratios 1:1, 1.5:1, 2:1, 3:1, 4:1), and the larger the ratio of the mesh, the more area of excised wound can be covered. With a larger mesh ratio, hypertrophic scarring may later be more evident, and secondary coverage may be needed (Kagan et al. 2013). Preoperative planning includes the decision on the location of donor sites and the thickness of the skin to be harvested. Thinner grafts are more adherent and vascularized, and the donor site is sooner ready for re-harvesting; thicker grafts contract less, but donor site scarring may occur. Back and scalp have the thickest skin, and the best cosmetic result and color match in facial burns is achieved with the scalp as the donor site (Greenhalgh et al. 2013). It is essential that the graft consistently adapts to the wound surface and that fat is not left exposed and desiccate between the expanded interstices (Sheridan, Chang 2014).

The scalp is potentially a large donor site in infants and toddlers, comprising about 9 to 10% of the total body surface compared to about 4% in adults. It is therefore an important source of skin grafts in infants and toddlers, often offering excellent healing and invisible scars with good cosmetic results (Wyrzykowski, Chrzanowska & Czauderna 2014).

An important role for the postoperative management of burn surgery is the securing and stabilizing of skin grafts by sutures, staples, glue, tapes, and postoperative dressings with the placement of splints to secure and support joint areas. Negative pressure dressings can be used in minor grafted burns in children or adults with intact skin surrounding the burn wound, and they may be advantageous in highly active children for keeping the dressing and the graft properly placed and absorbing exudates (Koehler et al. 2014). The donor sites are usually covered with hydrocolloid or occlusive membranes to reduce pain and maintain proper circumstances for wound healing.

2.8.5 Skin substitutes

Multiple staged surgical procedures are performed when burns are large and covering all excised areas with autografts is impossible during the same operation. Excised areas are temporarily covered with dressings, skin substitutes, or skin replacements. Skin substitute is a biomaterial, engineered tissue or a combination of cells (keratinocytes) and materials that can be used as a substitute for skin when autografting is impossible. Skin replacement is tissue that completely replaces lost skin with healthy skin (Kagan et al. 2013).

Human cadaver allograft skin may be used as a temporary biologic dressing when skin donor sites are limited or as a secondary coverage over large meshed autografts. Xenografts (donor species include frog, lizard, rabbit, dog, and pig) have been used for hundreds of years, but rejection will develop over time. Rarely, isografts (from an identical twin) may be used for final closure of the wound. Biobrane® is a temporary wound cover consisting of flexible nylon fabric with a silicone membrane coated with porcine dermal collagen (Kagan et al. 2013). A number of permanent wound-coverage products are available, AlloDerm® (acellular human dermal allograft) is totally devoid of epidermis and needs to be covered with a split thickness skin graft; it replaces a portion of the missing dermis. Integra® is a two-layer skin regeneration system; the outer layer is a thin silicone film, and the inner layer is constructed of a complex matrix of cross-linked fibers with bovine collagen and shark chondroitin. After the template inner layer...
becomes vascularized, the silicone outer layer is removed, and the inner layer is covered with a thin epidermal autograft (Atiyeh, Gunn & Hayek 2005, Nyame, Chiang & Orgill 2014).

Since 1975, cell therapy, or “test tube skin,” has been developed to replace severe damaged tissues with cultured cells, for example, with autologous cultured keratinocytes (Rheinwald, Green 1975, Atiyeh, Gunn & Hayek 2005). Cultured epithelial autografts (CEA) are not suitable in deep burns when dermis is destroyed, but they can be used in partial-thickness burns on properly prepared wounds. CEAs are the common standard in clinically applied engineered skin substitutes, but unsuitable as a permanent skin substitute in burn patients (Atiyeh, Gunn & Hayek 2005). Allogenic cultured epidermis has been used in the treatment of ulcers and deep partial-thickness burns, but long-term trials are lacking.

2.9 Development and the development of movement during infancy

During infancy, the overall development mainly comprises changes in body size and motoric skills, and the development of thinking, language, and problem solving. As brains mature through synapse proliferation, personal features are expressed, and the social understanding of relationships develops. A child’s first 3 years are characterized by rapid growth, and at this time the body proportions change. Newborns are physically uncoordinated, but learn to sit up by the age of 6 months and to stand and walk around their first birthday. The development of eye-hand coordination makes infants capable of reaching and picking up small objects. At this age, children have a poor understanding of potentially hazardous situations; therefore monitoring the safety of their environment is essential (Thompson 2001). The height of a 1-year-old is around 75 cm, which enables them to reach objects from a table, thus increasing the risk of scald burn injuries.

According to Bernstein (1996), movements are units of actions resulting from central nervous system commands or are reflexive, and pleasurable feelings from their outcomes make them more likely to be repeated. The repetition of movement leads to learning (Bernstein 1996). Children begin to reach for moving objects before the age of 3 months, but their movement patterns are shaky and uncontrolled. These movement patterns change during the following weeks and months as the dynamic postural control of the arm develops. At around 30–36 weeks of age, the development of arm and hand movements offers improved curve and speed control, and some improvement in reaching skills follows by the end of the first year (Thelen, Corbetta & Spencer 1996).
### Table 2: Literature review on recent articles concerning all types of burn injuries, focusing on infants younger than 1 year

<table>
<thead>
<tr>
<th>Author, year, country</th>
<th>Patients &lt; 1 year (inpatient)</th>
<th>Boys/girls</th>
<th>Etiology (%)</th>
<th>%TBSA range</th>
<th>Mortality</th>
<th>Major reason for burns</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arslan E et al., 1999, Turkey</td>
<td>39 (39)</td>
<td>26/13</td>
<td>hot water scalds (74), hot milk scalds (8), flame (15), electrical (3)</td>
<td>5–91</td>
<td>&gt;25 %TBSA 58.3% &gt;30 %TBSA 85.7%</td>
<td>Parents’ negligence</td>
</tr>
<tr>
<td>Warrington S et al., 2001, UK</td>
<td>172 (15)</td>
<td>NA</td>
<td>scalds (48), contact burns (40), sun (5.8), flame (2.9), cigarette (1.2), not known (0.6)</td>
<td>NA</td>
<td>none</td>
<td>The role of development is important in determining the risk as, before the age of 6 months, the infant’s acquisition of motor skills makes them unlikely to encounter a hot object.</td>
</tr>
<tr>
<td>Sun B et al., 2004, China</td>
<td>4¹</td>
<td>3/1</td>
<td>scalds from over-heated bath water (100)</td>
<td>1–60</td>
<td>none</td>
<td>Cases were caused by overheated water in the neonatal unit because of the carelessness of the nursing staff.</td>
</tr>
<tr>
<td>Nguyen D et al., 2008, UK</td>
<td>104 (66)</td>
<td>59/45</td>
<td>scalds (65), contact burns (30), chemical, flame, friction, and radiation (5)</td>
<td>&lt;0.5–38</td>
<td>none</td>
<td>Most of the scalds were caused by hot water being used to prepare a feed or to warm the baby bottle. In some cases, both the baby and the hot solution were being held at the same time.</td>
</tr>
<tr>
<td>Burlinson C et al., 2009, Australia</td>
<td>28² (10)</td>
<td>NA</td>
<td>scalds (43), contact burns (39), sunburns (11), TPN burns in premature infants in the NICU (7)</td>
<td>&lt;0.5–30</td>
<td>none</td>
<td>The reason for scalds was preparing milk bottles by warming them in hot water; contact burns on hands resulted from hot objects left carelessly within the reach of a baby.</td>
</tr>
<tr>
<td>Cox S et al., 2011, South Africa</td>
<td>86³ (86)</td>
<td>NA</td>
<td>scalds (52), flame (44), kerosene (1), primitive heating (1), warming bottles (1)</td>
<td>1–55</td>
<td>8</td>
<td>Careless handling of candles or cigarettes; for scalds, spillage of hot water. The injuries were due to problems in poor socioeconomic living conditions and the lack of understanding of water temperatures required when bathing a baby.</td>
</tr>
<tr>
<td>Ugburo A et al., 2013, South-Western Nigeria</td>
<td>21⁴ (21)</td>
<td>NA</td>
<td>thermal (90.5), chemical (9.5)</td>
<td>26±5.53</td>
<td>43.5%</td>
<td>Domestic incidents from flames, associated with prolonged morbidity and high mortality</td>
</tr>
<tr>
<td>Saaiq M et al., 2013, Pakistan</td>
<td>11⁵ (11)</td>
<td>8/3</td>
<td>Contact burns (36.3), scalds (27.2), flames (36.4)</td>
<td>3–55</td>
<td>27.2%</td>
<td>Contact burns from room heaters, scalds, flame burns caused by leaked natural gas or candles. The face was most frequently affected.</td>
</tr>
</tbody>
</table>

NA = information not available
¹ Neonates aged between 1 to 16 days, ² all aged less than 6 months, ³ all under 4 months of age,
⁴ neonates aged 16±2 days, ⁵ neonates aged 1 to 28 days.
2.10 Special features of pediatric burns

2.10.1 Infants and toddlers

Little specific data is available on infant burns. The literature review of recent studies focusing specifically on burn-injured children aged less than 1 year is in Table 2.

Especially in younger age groups, burn injury is one of the most common reasons for hospital treatment compared to other childhood accidents. Of all burn injuries, 25% occur in children aged less than 4 years, up to 90% of them being scalds (Schiestl et al. 2013). It is important to remember that children are not small-sized adults, and therefore their treatment has special features.

A child’s skin is more delicate and thinner than that of an adult, having less resistance to heat. Dermal appendages in pediatric skin are also shallower than those of adults; thus full-thickness burns may result from lower temperatures and after a shorter duration of contact (Williams 2011). Toddlers have thicker adipose tissue between the skin and tendons in the hand area, and children often have prominent inguinal skin folds, offering an optimal donor site for full-thickness skin grafts (Palmieri 2009). Typically, children have a slower withdrawal reflex than adults, and therefore deeper contact burns can occur in the palmar hand area.

Children have a different body surface area and anatomical structure compared to adults. A greater body surface area and percentage of water in relation to body weight lower children’s tolerance of hypothermia, and their accentuated metabolism sets them at risk of developing metabolic acidosis (Grisolia et al. 2005, Warden 2007, Williams 2011). Intensive cooling with running cold water may cause hypothermia in children. The younger the patients are, the more challenging are fluid resuscitation and treatment of the burn. Intravenous cannulation of a small child is often demanding and difficult, and in emergency situations, such as burn injuries, rapid access can be gained by a time-consuming intraosseal route, which has decreased the need for immediate central venous access (Haas 2004).

2.10.2 Evaluation of the TBSA burned in children

Current and exact evaluation of the TBSA burned is the cornerstone of all treatment in pediatric burn victims. Three commonly used estimation methods are the palmar surface area (Amirsheybani et al. 2001, Nagel, Schunk 1997), Wallace’s rule of nines (Knaysi, Crikelair & Cosman 1968), and the Lund and Browder (1944) chart, which was developed to take into account changes in body surface area size with age and growth. The palmar surface, including the palm and fingers area of the injured person’s hand, covers in children approximately 1% of the body surface, but in adults the palmar surface is smaller in relation to the body surface, thus making this measurement method inaccurate (Amirsheybani et al. 2001).

Inaccurate burn estimation is a common problem in hospital emergency units. Up to 80% of children with burns may have their burned area overestimated, particularly in burns larger than 10% of TBSA (Hammond, Ward 1987, Chan et al. 2012).

2.10.3 Inhalation injury

Inhalation injury is still the leading cause of death in fire-related burn injuries. Early diagnosis of bronchopulmonary injury is essential for survival, and the primary diagnosis is often clinical, based on the history of closed-space exposure, facial burns, or carbonaceous debris in the mouth or pharynx (Gauglitz, Jeschke 2012, Jeschke, Herndon 2014). Breathing complications in burned
children are related to inhalation burns, but also to deep burns in the facial and neck area that may cause soft tissue edema. A child’s anatomical relationships differ from those of adults (often short neck, narrow and soft trachea), and intubation becomes more complicated and sometimes impossible; thus a tracheotomy may be required (Warden 2007, Williams 2011). Bronchoscopy findings in inhalation injury are airway edema, inflammation, mucosal necrosis, soot and charring in the airway, tissue sloughing, and carbonaceous material in the airway. Overall survival is worse in patients having more severe bronchoscopic findings (Endorf, Gamelli 2007, Gauglitz, Jeschke 2012). In adult patients with acute lung injury, mechanical ventilation with a lower tidal volume and high-frequency ventilation have decreased mortality. These procedures also increased the number of days without ventilator use (De Campos 2000). The management of inhalation injury consists of ventilatory support, bronchoscopy lavations, pressure-controlled ventilation with permissive hypercapnia, nebulization therapy with heparin, alpha-mimetics, or polymyxin B, and antibiotic treatment prior to positive culture results of pneumonia (Gauglitz, Jeschke 2012).

2.10.4 Metabolism and energy requirements

In the first days after injury, the metabolic rates of burn-injured children can be dramatically accelerated, causing the wasting of lean body mass. Children’s nutritional needs differ from those of adults as they need energy for proper growth and neurodevelopment in addition to maintenance fluid and resting energy needs (Askegard-Giesmann, Kenney 2014). Insufficient energy and protein intake may result in wound healing impairment, organ dysfunction, a raised risk of infection, and increased mortality. Specific formulas to estimate increased energy requirements have been developed. In children, those based on body surface area are more appropriate when considering the greater body surface area related to weight (per kilogram). Factors influencing the energy requirements in burned children are TBSA, growth, age, high basal metabolic rate, and decreased endogenous energy reserves (Mayes et al. 1996, Lee et al. 2011).

In children, flame burns increase hypermetabolic inflammatory and acute phase responses to the burn injury, when compared to those of scalds (Kraft et al. 2011). Stress, inflammation, hypermetabolism, and impaired immune function are factors raising catecholamine (CA) levels after severe burns. Higher CA levels among pediatric burn victims are reported in males, large burns of over 40% TBSA, and older children, and they are associated with higher mortality (Kulp et al. 2010). Burn injury induces profound lipolysis, consisting of the breakdown (hydrolysis) of triacylglycerol into free fatty acids (FFAs) and glycerol. Inflammation and hypermetabolism induce increased acute-phase protein synthesis and elevate triglycerides (TG) and FFA. In a study by Kraft et al., pediatric patients having elevated triglycerides and undergoing increased acute-phase protein synthesis had worse clinical outcomes and organ function, whereas increased FFAs did not alter the postburn outcome (Kraft et al. 2012b). Effective strategies to minimize metabolic disturbances in severe burns include early excision and grafting, maintenance of an environmental temperature of 30 to 32°C, and preference for enteral feeding of a low fat, high carbohydrate and protein diet (Herndon, Tompkins 2004, Jeschke, Herndon 2014).

2.10.5 Hypermetabolic response

A burn injury–induced hypermetabolic response causes adverse consequences, especially protein catabolism. Supplementation with recombinant growth hormone, insulin-like growth
factor, anabolic steroids, or beta-adrenergic blockage (propranolol) have been investigated for preventing and facilitating this response (Gauglitz, Jeschke 2012). Treatment of hyperglycemia with continuous low-dose insulin infusion and of the catecholamine surge with the use of beta-blockers, and the use of the synthetic testosterone analogue oxandrolone with advanced ventilation strategies improve survival and outcomes in severely burned pediatric patients (Herndon, Tompkins 2004, Pham et al. 2005, Williams et al. 2011, Gauglitz, Jeschke 2012, Jeschke, Herndon 2014). Hypermetabolic and catabolic states after a massive burn injury may persist for up to 2 years and impair rehabilitation and reintegration. Long-term treatment with recombinant human growth hormone in children improved growth and lean body mass, whereas hypermetabolism decreased, scarring improved, but a negative impact on bone mineral contents was reported (Branski et al. 2009).

2.11 Fluid resuscitation in pediatric burns

Initial management of pediatric burn injury is based on the ABC approach (airway, breathing, circulation), the same as for any other patient with trauma or burn (Gauglitz, Jeschke 2012). Fluid resuscitation after a burn injury can be considered as much art as it is science. Clinical observations, patient monitoring, and interventions have a specific role in volume replacement; thus data guiding decision making exists (Cocks, O’Connell & Martin 1998). Fluid resuscitation in pediatric burns follows the same principles as in adults: adequate volume restoration and the correction of electrolyte disturbances, while limiting renal failure and pulmonary edema. Adults with burns covering an area of more than 15 to 20% and children with an area of more than 10% benefit from fluid resuscitation. The goal of burn resuscitation is to prevent burn shock rather than treat it (Pham et al. 2008, Gauglitz, Jeschke 2012).

2.11.1 Common formulas for fluid resuscitation

Many different formulas for calculating and estimating the fluid volume required have been introduced over time. Correct and accurate estimation of the burned area is the cornerstone of fluid resuscitation therapy (Parvizi et al. 2014, Schulman, King 2008, Chan et al. 2012). Cope and Moore (1947) quantified fluid volumes for resuscitation based on TBSA%, and in 1952 Evans introduced colloids for burn resuscitation (Diver 2008). In the 1960s, Charles Baxter introduced the Parkland formula as a tool to estimate the need for fluid resuscitation in burned patients during the first 24 hours. Later, the modified Brooke formula was developed at the U.S. Army Burn Center, representing a fluid resuscitation model using lactated Ringer solution (Pruitt Jr 2014).

Common formulas for volume resuscitation postburn are listed in Table 3. The Parkland formula has been adapted for both adult and pediatric burn patients. It takes into consideration the burned area (TBSA%) and the patient’s weight (kg); children additionally receive maintenance fluid based on their weight, and urine output measurement acts as an endpoint (Baxter 1979). The Parkland formula is still commonly in use because it is easy to calculate and the titration of fluids is based on measuring urine output. Later reports have revealed that despite the Parkland formula’s effectiveness, it can lead to underestimation of the required fluid volumes, especially in patients with large full-thickness burns or inhalation burns (Cartotto et al. 2002), or to overloading, or “fluid creep” (Atiyeh et al. 2012, Pruitt Jr 2000). The Galveston and the
Cincinnati formulas from Shriner's Hospital for Children are based on the burned area measured in square meters, and colloids are routinely utilized (Pham et al. 2008).

**Table 3:** Common formulas for volume resuscitation during the first 24 hours postburn (Warden 2007)

<table>
<thead>
<tr>
<th>Patients</th>
<th>Formula name</th>
<th>Solution</th>
<th>Volume in first 24 h</th>
<th>Rate of administration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adult</td>
<td>Parkland</td>
<td>Lactated Ringer’s</td>
<td>4 ml/kg/TBSA%</td>
<td>during 0–8 h 50%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>during 8–24 h 50%</td>
</tr>
<tr>
<td></td>
<td>Modified Brooke</td>
<td>Lactated Ringer’s</td>
<td>2 ml/kg/TBSA%</td>
<td>24 h, 24–48 h colloids</td>
</tr>
<tr>
<td>Children</td>
<td>Shriners–Cincinnati</td>
<td>Lactated Ringer’s</td>
<td>4 ml/kg/TBSA% +</td>
<td>24 h</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1500 ml/m² BSA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Shriners–Cincinnati</td>
<td>Lactated Ringer’s +</td>
<td>4 ml/kg/TBSA% +</td>
<td>0–8 h</td>
</tr>
<tr>
<td></td>
<td>young pediatric patients</td>
<td>50 meq NaHCO₃</td>
<td>1500 ml/m² BSA</td>
<td>8–16 h</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5% Albumin in</td>
<td></td>
<td>16–24 h</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lactated Ringer’s</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Shriners–Galveston</td>
<td>Lactated Ringer’s</td>
<td>5000 ml/m² BSA +</td>
<td>24 h</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2000 ml/m² BSA</td>
<td></td>
</tr>
</tbody>
</table>

In general, under fluid therapy, infants are at risk of hypoglycemia; therefore, adequate blood glucose monitoring and maintenance of glucose homeostasis is essential when treating pediatric burn patients. Hepatic glycogen stores in young children are depleted after 12 to 14 hours of fasting, leading to glycogen deficiency faster than adults (Parker, Hazelzet & Carcillo 2004, Schulman, King 2008, Pham et al. 2008). Confusion and debate still continue over whether colloids or crystals should be included in fluid resuscitation therapy, but the goal of the treatment is to maintain tissue perfusion with minimal edema (Cocks, O'Connell & Martin 1998, Warden 2007, Diver 2008). Well-recognized risks for fluid overload are abdominal compartment syndrome, compartment syndrome in extremities, and pulmonary edema.

### 2.12 Toxic shock syndrome

Toxic shock syndrome (TSS) is a severe systemic disorder characterized by shock, pyrexia, erythematous rash, and gastrointestinal and central nervous system symptoms, including lethargy or irritability. It is a toxin-mediated disease and the leading cause of death in children with rather small burns. Staphylococcus aureus or Group A Streptococcus is the main producer of toxins, and if untreated, TSS has a high mortality of up to 50% (Cole, Shakespeare 1990, Young, Thornton 2007, Schiestl et al. 2013). TSS was first reported in 1978 when seven children aged 8 to 17 suffered from symptoms of a high fever, headache, confusion, conjunctival hyperemia, a scarlatiniform rash, subcutaneous edema, vomiting, diarrhea, and oliguria. They finally underwent acute renal failure, hepatic abnormalities, disseminated intravascular coagulation, and severe prolonged shock (Todd et al. 1978). One of the patients died and one had toe gangrene, and during recovery all patients had fine desquamation of the affected skin and peeling of the palms and soles. TSS may present with a broad spectrum of symptoms and involve a wide range
of staphylococcal phage types with many different enterotoxins. In pediatric burn patients with relatively small burns, TSS was first described in 1985, and three of its seven victims died (Frame et al. 1985, Young, Thornton 2007).

The incidence of TSS is about 2.5% of burn-injured children. Criteria for TSS are pyrexia (>39°C), rash, diarrhea or vomiting, irritability, lymphopenia, and later hypotension and poor peripheral perfusion, and shock. Prodromal symptoms are typical for many common childhood illnesses, thus making the diagnosis challenging. A typical patient with TSS has had a thermal injury within 2 days, is aged less than 2 years, and has a burn of less than 10% TBSA (White, Thornton & Young 2005, Young, Thornton 2007). Management of TSS includes resuscitation and stabilization, treatment with anti-staphylococcal (and streptococcal) antibiotics, inspection and debridement of the burn wound, and provision of passive immunity against toxic shock syndrome toxin-1 (TSST-1).

Superantigens, such as TSST-1 and the streptococcal enterotoxin, are proteins that are able to activate the immune response system by bypassing the usual antigen-mediated immune response sequence. They cause a massive T-cell stimulation and a devastating immune cascade destructive to all end organs. In favorable conditions, approximately 20% of Staphylococcus aureus can produce TSST-1 (Young, Thornton 2007). The reason that children develop TSS is that the burn wound destroys the skin barrier, which leads to disturbance and impairment of the immune system. Because of their young age, children have not developed antibodies to the toxins produced by bacteria. The environmental factors involved in burn wounds also favor toxin production, and burn wounds are most often colonized by Staphylococcus aureus, which is responsible for most TSS.

TSS is a rather uncommon and rare complication of burns, but if untreated has a high mortality; therefore personnel treating burn-injured children should be prepared and trained to recognize it.

### 2.13 Child abuse

Over 50 years ago, Kempe first described a clinical condition called battered child. Battered child is a condition in young children with serious physical abuse, and those children are at risk of marked morbidity and mortality (Kempe et al. 1984). It has been estimated that 30% of repeatedly abused children die. Child abuse comprises conditions of physical abuse, supervision neglect, neglect of essential needs, or sexual abuse (Wibbenmeyer et al. 2014). Physical abuse means physical assaulting of the child; supervision neglect is often more difficult to verify, but it exposes children to potentially hazardous situations. Neglect of essential needs includes the failure to provide for children's nutritional, medical, social, educational, emotional, and safety needs. Verbal neglect or confinement is also defined as child abuse (Wibbenmeyer et al. 2014).

#### 2.13.1 Child abuse and burns

Burn injury is one of the most painful injuries a child can experience, and it has been estimated that around 10% of child maltreatment involves burning, with burn injuries being the most common cause of fatal child maltreatment (Greenbaum et al. 2004, Gilbert et al. 2009, Leetch, Woolridge 2013, Wibbenmeyer et al. 2014). The mechanisms of intentional child burn injuries are typically scalds caused by hot tap water that have clear upper immersion margins and a uniform depth with an absence of splash marks and that are localized on the lower extremities,
buttocks, or perineum, or upper extremities (Maguire et al. 2008). Intentional burn injuries typically appear as glove- or stocking-like burned areas. Contact burns comprise approximately one third of intentional burns; they often present the shape of the hot object used, such as irons, cigarettes, or hot kitchen utensils (Leetch, Woolridge 2013, Greenbaum et al. 2004).

A discrepancy between clinical findings and the trauma history is often evident. The pattern of a burn injury has an influence on the burned area; exposure time and the causing agent influence the depth, distribution, and the extent of the burn. A suspicion of child maltreatment should arise when the history of burn injury is lacking, unclear, inconsistent, or incompatible with the injury pattern or child’s age or capacity to move. Infants younger than 6 months are totally dependent on their caregivers for mobility, eating, drinking, and avoidance of potentially dangerous situations, and thus are not themselves capable of causing burn injuries. A pattern of abnormal behavior by the child, passiveness, introversion, fearfulness, or a history of blame placed on a sibling for causing the injury may also raise the question of child maltreatment. Wibbenmeyer et al. in 2014 reported that the risk factors for intentional burns are a patient’s age of less than 3 years, a large burned area, tap water burns, immersion lines, delay in seeking care, absence of a two-parent family (unconventional families), young parents, inconsistent trauma history, and injury pattern (Wibbenmeyer et al. 2014). Often poor hygiene, malnutrition, and previous multiple soft tissue injuries and bruises of various ages are visible in children with intentional burns. Children with an intentional burn injury often have a history of at least one previous visit to a physician for abusive trauma, at which the abuse has been missed. The risk for child abuse to recur has been estimated to be at least 35% (Leetch, Woolridge 2013).

The question of child abuse should be able to be raised without obstacles, because the cases reported by the health care system are probably only the tip of the iceberg. The treatment of child abuse traumas should involve meeting a multidisciplinary team consisting of the physician taking care of the injuries from the actual physical assault, the social worker, and a representative of child protective services (Wibbenmeyer et al. 2014). The child’s and parents’ psychological aspects should also be taken into consideration. Further physical examinations include a skeletal imaging survey to report existing earlier fractures, laboratory tests for possible blood coagulation problems, and screening for earlier head traumas by retinal examination, computed tomography (CT), or magnetic resonance imaging (MRI).

2.14 Infections

2.14.1 Burn wound infections

During the acute phase of burn injury, wound infections are the most important and potentially life-threatening complications following the injury. In the past 50 years, the use of early excision and grafting has reduced the number of infections and led to better outcomes. Immediately after a thermal injury, burn wounds are sterile, but they rapidly become colonized with microorganisms. Such microorganisms are first derived from the host him- or herself and contain flora from the skin, gastrointestinal tract, and respiratory system. Within the first 48 hours, the microorganisms rapidly colonizing the wound surface are Staphylococci (gram-negative), located deep in the sweat glands and hair follicles surviving a thermal injury. Later, from 5 to 7 days postburn, gram-positive and gram-negative bacteria and yeasts colonize burn wounds. These are consequences of broad-spectrum antimicrobial therapy or microorganisms from the hospital environment (Church et al. 2006).
Effective topical antimicrobial burn wound therapy and early excision and closure of burn wounds have significantly reduced the overall rate of burn wound infections (Pruitt Jr et al. 1998). Prophylactic systemic antibiotic administration does not prevent burn wound infections, and their routine use is not recommended; systemic antibiotics should be used selectively and for only a short period of time (Church et al. 2006). Local biopsy samples or surface swabs of the burn wound and their quantitative cultures and histological examination help to target the antimicrobial therapy chosen. Invasive burn wound infections require changes in local and systemic antimicrobial therapy, and the importance of surgical debridement of the wounds should be noted (Pruitt Jr et al. 1998). Staphylococcus aureus and Pseudomonas aeruginosa are the most common causes of burn wound infections (Church et al. 2006). The antimicrobial resistance of various human bacterial and fungal wound pathogens is an emerging problem worldwide and limits the availability of effective treatment options. Burn-related deaths nowadays still occur mainly because of septic shock and organ dysfunction and failure.

2.14.2 Sepsis and pneumonia

Modern intensive care has improved the initial survival of burn shock and inhalation injury, but among ICU patients, burn victims show the highest prevalence of sepsis and mortality. Bloodstream infections and the subsequent development of sepsis occur frequently in burned ICU patients (Church et al. 2006, Rex 2012). The diagnosis of sepsis is based on clinical findings, including the onset of hypothermia or hyperthermia, hypotension, decreased urinary output, hyperglycemia, neutropenia or neutrophilia, and thrombocytopenia. Early excision therapy of burn wounds has reduced the incidence of invasive wound infection as the primary source of sepsis. Contaminated catheters and urinary tract infections may also be the cause of septicemia (Church et al. 2006).

Burn patients with inhalation injury show a high incidence of ventilator treatment–associated pneumonia causing the majority, up to 75%, of deaths related to large burns. Endotracheal aspirate samples may include multidrug-resistant pathogens. The length of ventilation and the presence of inhalation injury are factors increasing the incidence of ventilator-associated pneumonia (Rex 2012, Rogers et al. 2014).

2.15 Scarring

In recent decades, improved survival of major burns in adults and children has led to an increasing number of patients needing scar treatment and reconstructive procedures. The main goal of scar treatment is restoration of function in adherence with aesthetic principles (Cartotto et al. 2014). Deep partial-thickness and full-thickness burns almost always cause scarring, and unlike in adults, even superficial burns may cause scarring in children (Cubison, Pape & Parkhouse 2006). Children have more rapid cell turnover than do adults, leading to a higher risk of scarring. Wound healing entails inflammation, proliferation or granulation, and maturation or remodeling of the skin. Scarring is characterized by the proliferation of dermal tissue with excessive deposition of fibroblast-derived extracellular matrix proteins, persistent fibrosis, and inflammation (Slemp, Kirschner 2006, Brewin, Lister 2014). Scarring is still difficult to treat, but increased knowledge and understanding of scar formation and the pathophysiologic process of wound healing have helped to develop new treatment prospects.
2.15.1 Pathophysiology

The overabundance of collagen formation in which bundles are organized in a parallel manner is the pattern for hypertrophic scarring. In hypertrophic scars, primarily type III collagen is oriented to the epidermal surface, and keloids consist of disorganized and irregularly arranged type I and III collagens (Slemp, Kirschner 2006, Brewin, Lister 2014).

The typical appearance of scar deformity includes pigmentation disturbances, redness, excessive scar bulk and prominence, surface texture problems (meshed skin grafts), contractures, distortion of a free margin (lip or eyelid), and the contracted structure of the skin that increases the risk for repetitive breakdown (Cartotto et al. 2014). Redness is due to capillary vessel formation and chronic inflammation.

2.15.2 Risk factors for scarring

Risk factors for scarring are darker skin, female gender, burn site (neck, chest wall, and upper limbs at higher risk), multiple surgical procedures, meshed skin graft, time to healing, burn depth, age less than 30 years, and atopic skin (Lawrence et al. 2012, Cartotto et al. 2014, Kishikova et al. 2014). Hormonal levels also influence scar formation, which tends to occur more often during puberty, worsen during pregnancy, and improve in menopause (Berman et al. 2008). The prevalence of hypertrophic scarring after burn injury has been estimated to be from 32 to 72% (Lawrence et al. 2012).

2.15.3 Time and scarring

Scalds are the most common cause of children’s burns, and most of them are superficial or deep partial-thickness burns. Healing time is related to the quality of the scarring, independent of the treatment chosen. A low risk of hypertrophic scar formation exists when scalds heal before 21 days, and surgery should be reserved for those at risk of hypertrophic scarring whose healing takes more than 21 days (Cubison, Pape & Parkhouse 2006).

2.15.4 Hypertrophic scars and keloids

A typical hypertrophic scar is elevated, firm, erythematous, pruritic, and tender, and over time it often flattens, softens, becomes less erythematous, and diminishes. Keloids expand and elevate over original wound margins, are irregularly shaped, and have excessive collagen formation in the dermis during connective tissue repair. Keloids may occur 10 to 30 years after the initial injury, and dark-skinned people are at higher risk (Brewin, Lister 2014). Keloids are difficult to treat; Patel et al. stated that adolescents aged 11 to 21 years, during and after puberty, are at higher risk of keloid scar recurrence after burn injury, which may be due to their less developed immune system or decreased inflammatory response (Patel, Bailey & Yakuboff 2012). Neither steroid injections nor surgery lowered a high recurrence rate of over 80% in pediatric burn scar keloids. A number of treatments under study to resolve difficulties in keloid treatment (Patel, Bailey & Yakuboff 2012) include 5-fluorouracil, bleomycin, retinoids, and antihistamines. Currently, no ideal or all-purpose method of scar control or consensus in regard to the prevention or reduction of hypertrophic scarring caused by burn injury exist (Bloemen et al. 2009, Atiyeh, Jamon 2014).
2.15.5 Scar maturation

Maturation of the burn scar takes around one year, but it may take up to 2 years. The optimal timing for scar reconstructive procedures is usually after scar maturation, around one year from the initial injury. For the assessment of hypertrophic scarring and scar formation, several evaluation systems are available, and they monitor the maturation of the scar. The Vancouver Scar Scale (VSS) is a validated subjective scar scale including scores for vascularity, pigmentation, pliability, and height (Baryza, Baryza 1995). Another subjective and valid scale is the Patient and Observer Assessment Scale (POSAS), which also includes subjective scores for pain and pruritus (Bloemen et al. 2009, Fearmonti et al. 2011).

2.15.6 Non-operative scar management

Non-operative treatment approaches include stretching, massaging, splinting, serial casting, silicone gel and sheets, steroid injections, and pressure garments, and these may be commenced as soon as the skin is closed (Spence, Ware 2006, Atiyeh 2007, Cartotto et al. 2014). Silicone is available in gel or sheets, and it is painless and easy to use. Numerous possible mechanisms explain its efficacy, including hydration, pressure, temperature, and oxygen transmission (Spence, Ware 2006, Bloemen et al. 2009). Pressure garments to control scarring were introduced in 1835 by Rayer, but the exact mechanisms still remain unknown. It is hypothesized that pressure remodels collagen bundles, reduces collagenase, activates blood flow, decreases edema, and causes fibroblast degeneration (Spence, Ware 2006, Atiyeh 2007). Pressure garment therapy (PGT) should begin early, as soon as the skin tolerates it. The pressure recommended is 24 to 28 mmHg, and the length of the treatment is a minimum of 6 to 8 months, usually 12 to 18 months. The advantages and efficacy of PGT have been questioned. In a meta-analysis, no alteration of global scar scores was noticeable. Some improvement in scar height is reported, though the difference is small. Thus, the positive effects of PGT remain unsolved, and additional research is required (Anzarut et al. 2009).

Intralesional corticosteroids such as triamcinolone acetonide can reduce scar formation by affecting the collagen remodeling and inflammation phase and reducing myofibroblast activity, but they are unsuitable for extensive and large burn scars. A long follow-up is recommended, and adverse effects include a burning sensation, skin atrophy, depigmentation, and telangiectasia (Shelley, Dziewulska 2006, Bloemen et al. 2009). Cryotherapy, freezing with nitrous oxide and liquid nitrogen, causes cell and microvasculature damage. Partial flattening of hypertrophic scars and keloids have been reported in 50 to 85% of cases (Berman et al. 2008). The treatment requires 8 to 10 visits, usually every 3 weeks. Side effects include pain, necrosis, edema, atrophy, infections, and hyper- or hypopigmentation (Berman et al. 2008).

Experimental therapies for scar treatment include intralesional injection of bleomycin (antineoplastic agent, cytotoxic antibiotic), onion extract/heparin gel (fibroblast-inhibiting properties), enalapril (angiotensin-converting enzyme inhibitor), fibroblast growth factor-2 (FGF-2 or b-FGF), and the blocking of transforming growth factor (TGF)-b (Bloemen et al. 2009).

2.15.7 Surgical scar treatment

Burn scar contractures cause dysfunction of the joints and deformity of mobile structures, and they can be classified as diffuse or linear. Diffuse contractures are broad, extensive, and
surrounded by scarred skin. Linear contractures are narrow, often single well-defined bands surrounded by undamaged skin on one or both sides (Cartotto et al. 2014). Surgical postburn deformity and scar repair techniques include scar resection and resurfacing with direct closure, or serial excisions and covering of the defect with full-thickness skin grafts offering better color, texture, and less constriction. Surgical correction of diffuse contractions may include a transverse releasing incision with a dart or fishtail pattern at one end and the large preparation of the scarred area. Final defects may be covered with a thick skin graft, a partial-thickness graft, or with skin substitutes such as Integra®. Local or distant transfer flaps or tissue expansion is also used to achieve tension-free closure to cover the defect. Z-plasty techniques and their variants are approaches used with linear contractions (Spence, Ware 2006, Cartotto et al. 2014).

2.15.8 Laser treatment of scars

In the late 1980s, experiments began using a vascular-specified pulsed dye laser (PDL) on hypertrophic scars with port-wine stained areas. Laser-treated scars softened and became less hypertrophic and erythematous, and histopathologic examination showed improvement in dermal collagen arrangement (Alster 1997). Over the years, PDL has arisen as a successful alternative to hypertrophic scar treatment (Parrett, Donelan 2010). A wide variety of lasers are available for treating skin disorders. Before the rise of PDL, the CO₂ laser and the Nd:YAG (1064 nm) laser led to decreased collagen production, but scar recurrence rates were high, from 39 to 92% for the former and from 53 to 100% for the latter. The argon laser (488 nm) showed minimal or no improvement in scar treatment in over 90% of patients (Parrett, Donelan 2010). Over the last two decades, the 585 to 595 nm pulsed dye laser (PDL) was the most studied and preferred laser for treating hypertrophic scars and keloids (Alster 1997, Parrett, Donelan 2010). Biochemical studies suggest that 585 nm PDL treatment changes signal pathways to favor collagen degradation and fibroblast apoptosis (Wolfram et al. 2009). Donelan et al. have reported good results with the PDL. They recommend a combination of focal Z-plasty to release scar tension in facial postburn hypertrophic scars when needed, followed by PDL to soften and flatten the scar. These procedures reduce the need for scar excision surgery and offer better aesthetic results (Donelan, Parrett & Sheridan 2008).

2.15.9 Face transplantation

In recent years, from 2005 to 2013, 29 life-changing face transplantations following severe face-destroying injuries have been reported, 7 of them for facial burn injury (Fischer et al. 2014). Severe facial trauma causes problems in breathing, eating, and communicating, in addition to the burden of disfigurement leading to social isolation. The most common potentially life-threatening complications after facial allotransplantation have been opportunistic infections of viral or bacterial origin and malignancies. Facial transplant recipients are usually otherwise healthy individuals who need lifelong high-dose, multidrug immunosuppression. Most of the patients have recovered facial functions, eating, breathing, speech, facial expression, and sensation, but face transplantation still is an experimental treatment (Fischer et al. 2014, Khalifian et al. 2014).
2.16 Rehabilitation

Burn injury and its treatment draw from both the somatic and psychological resources of the injured to cope with stress, pain, shock, sepsis, and the responses of the immune system. During the healing process, potential alterations in range of motion, capacity, appearance, and psychological conditions may occur (Fauerbach et al. 2005). Physiological and psychological symptoms and findings vary widely, depending on the individual’s personal features and resilience, the seriousness of the injury, and the age at injury (Stoddard, Ryan & Schneider 2014). Physical rehabilitation is often accompanied by pain, and includes orthopedic, neurologic, and metabolic aspects. The eventual long-term goal of rehabilitation is for the patients to return to previous work, school, kindergarten, and normal activities.

Among children, family support and the characteristics of the family environment are the most important and effective resources during rehabilitation. Peer support, for example, attending burn camps, is also essential (Sheridan et al. 2000a, Landolt, Grubenmann & Meuli 2002, Sheridan et al. 2012).

2.16.1 Problems during rehabilitation

Itching and scarring are common findings postburn, and full-thickness burns cause hair loss, sensory impairment, loss of skin lubrication, and reduced heat tolerance. Sun protection is crucial, and pigmentation changes may develop in postburn areas (Warner, Coffee & Yowler 2014).

Burn-injured children may have a delay in bone growth caused by the premature fusion of long bone epiphyseal plates or the disturbance of bone metabolism (osteoporosis), and asymmetric burns may cause scoliosis or kyphosis. In adult patients, heterotopic ossification or osteophytes typically occur in the elbow area, and joint subluxations and dislocations may result from contractures. Localized or peripheral neuropathies are common in electric or large burns (Stoddard, Ryan & Schneider 2014).

Pain management after burn injury is an integral and challenging part of recovery; nonpharmacologic pain treatments should be strongly considered. Rehabilitation is typically based on multidisciplinary teamwork to achieve the best results and outcomes (Stoddard, Ryan & Schneider 2014).

2.17 Health-related quality of life after pediatric burn injury

2.17.1 Definitions

According to the constitution of the World Health Organization (WHO), health is defined as “a state of complete physical, mental, and social wellbeing, not merely the absence of disease” (WHO 1997). WHO defines Quality of Life (QoL) as individuals’ perception of their position in life in the context of their culture and living conditions and in relation to their goals, expectations, standards, and concerns. QoL is based on individuals’ own views of their wellbeing at a certain moment, and it is influenced by social relationships, working capacity, and economic view. The frequency and severity of disease can be measured, but when measuring the health-related quality of life (HRQoL), tools to estimate wellbeing in general are important. Measurement tests are usually questionnaires which intend to evaluate changes in the QoL over time and alterations in
living circumstances, taking into consideration cultural settings, language, and the participant's age. The measurement tests must be repeatable (WHO 1997).

### 2.17.2 Differences between quality of life and health-related quality of life

A universal definition of QoL and HRQoL does not exist, and in the literature, the use of QoL and HRQoL is flexible (Rosenbaum et al. 2007). QoL refers to a broader and larger concept determined by the individual's overall relation to life, such as the ability to perform the activities of daily living. The definition of QoL may vary, which makes its measurement difficult.

HRQoL focuses on health-related components, self-care, mobility, and communication, and is associated with life satisfaction (Rosenbaum et al. 2007). Sickness, injuries, and their treatment influence the individual's wellbeing and redefine them as patients. Physical, psychological, psychosocial, and economic changes related to illness have an influence on general wellbeing, and all these aspects should be considered when establishing an individual's HRQoL. HRQoL is connected to health or disease status and the impact of these on the individual's QoL, and is thought of as the subjective perception of the impact of illness or injury on daily life and tasks. Tools to collect this information must be selected carefully to understand changes in HRQoL.

### 2.17.3 Instruments

No gold standard tool exists for measuring HRQoL; hundreds of tests and questionnaires are available (Öster 2010). The 17D instrument is a standardized and validated health state descriptive system questionnaire, which has been developed in Finland for children aged 8 to 11 years, but has also been used among younger children (Apajasalo et al. 1996, Haapamäki et al. 2011, Geneid et al. 2011, Suominen et al. 2011a, Haavisto et al. 2013, Nokso-Koivisto et al. 2014). It includes 17 dimensions: mobility, vision, hearing, breathing, sleeping, eating, speech, excretion, school and hobbies, learning and memory, discomfort and symptoms, depression, distress, vitality, appearance, friends, and concentration. The respondent chooses from the 5 levels in each dimension the one best describing her/his present health status. The 17D score index ranges from 0 to 1, representing the overall HRQoL: 0 approximates being dead and 1 represents no problems in any dimension.


The PedsQL™ 4.0 (Pediatric Quality of Life Inventory™ Version 4.0) is a modular instrument for measuring HRQoL in children and adolescents aged 2 to 18. It contains 23 items concerning physical, emotional, social, and school functioning. The parallel child self-report and parental proxy-report format is completed for different age groups, from toddlers to 18 years, with a 5-step response scale. Items are reverse scored and linearly transformed to a scale of 0 to 100, higher scores indicating better HRQoL (Varni, Limbers & Burwinkle 2007).
Table 4: Literature review of the health-related quality of life in pediatric burn survivors

<table>
<thead>
<tr>
<th>Author, year</th>
<th>Patients</th>
<th>Age years (% boys)</th>
<th>Instrument used</th>
<th>Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disseldorp et al. 2013</td>
<td>119</td>
<td>0.5–16 (58)</td>
<td>Pediatric Functional Independence Measure (WeeFIM)</td>
<td>Children's functional independence is affected; after 3 months it is adequate in most children.</td>
</tr>
<tr>
<td>Dodd et al. 2010</td>
<td>145</td>
<td>0–18 (NA) hands burned 57%</td>
<td>American Burn Association/Shriners Hospital for Children Burn Outcome Questionnaire (BOQ)</td>
<td>Good QoL continues to increase up to 2 years after injury; the presence of hand burns with a large TBSA is a marker of more severe illness.</td>
</tr>
<tr>
<td>Gabbe et al. 2011</td>
<td>150 pediatric trauma patients, 14 burns</td>
<td>0–16 (65)</td>
<td>The Child Health Questionnaire (CHQ), the Pediatric Quality of Life Inventory (PedsQL)</td>
<td>Seriously injured children showed ongoing disability and reduced HRQoL even 12 months after injury.</td>
</tr>
<tr>
<td>Herndon et al. 1986</td>
<td>12 large &gt;80% flame burns</td>
<td>0.8–12.4 (75)</td>
<td>The Burn Injury Questionnaire adapted from Fisher, the activity questionnaire adapted from Bar Or</td>
<td>A focus on improving the QoL after acute hospitalization is incumbent; the majority had altered perspiration, limitation of overall abilities, and problems with scarring.</td>
</tr>
<tr>
<td>Landolt et al. 2002</td>
<td>105</td>
<td>5–17 (65)</td>
<td>The Child Behavior Checklist (CBCL), the TNO-AZL Questionnaire for Children's Health-Related Quality of Life (TACQOL), the Family Relationship Index (FRI)</td>
<td>HRQoL almost normal; characteristics of the family environment are key factors in QoL follow-up; burn trauma may affect emotional functioning but have little or no impact on other areas (academic).</td>
</tr>
<tr>
<td>Maskell et al. 2013</td>
<td>66</td>
<td>8–17 (25)</td>
<td>The Paediatric Quality of Life Inventory TM 4.0 (PedsQL), the Strengths and Difficulties Questionnaire (SDQ), the Piers-Harris Self-Concept Scale</td>
<td>Lower scores on HRQoL and increased psychopathology and behavioral difficulties, no differences were found for self-concept.</td>
</tr>
<tr>
<td>Murphy et al. 2014</td>
<td>50</td>
<td>16–25 (56)</td>
<td>World Health Organization Disability Assessment Scale II (WHODAS), the Burn Specific Health Scale—Brief (BSHS-B)</td>
<td>As the TBSA burned increased, HRQoL decreased. Scores were lower with larger TBSA, males, those burned after school entry, and those transitioning into adulthood.</td>
</tr>
<tr>
<td>Niemeijer et al. 2012</td>
<td>134</td>
<td>0.5–16 (NA)</td>
<td>Pediatric Functional Independence Measure (WeeFIM)</td>
<td>The WeeFIM instrument is a feasible and reliable instrument for use in children with burns; at least 11 points of improvement state that a child has significantly improved.</td>
</tr>
<tr>
<td>Palmieri et al. 2012</td>
<td>438</td>
<td>0–5 (65) hands burned 52%</td>
<td>American Burn Association/Shriners Hospitals for Children Burn Outcome Questionnaire (BOQ)</td>
<td>Children with hand burns and 20% TBSA or greater had lower scores; the most profound impact of hand burns is in fine and gross motor function.</td>
</tr>
</tbody>
</table>
Table 4 cont.

<table>
<thead>
<tr>
<th>Author, year</th>
<th>Patients</th>
<th>Age years (% boys)</th>
<th>Instrument used</th>
<th>Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pope et al. 2007</td>
<td>36</td>
<td>11–19 (36) mean age when burned 3.75</td>
<td>The Body Esteem Scale (BES), the Satisfaction With Appearance Scale (SWAP), the Beck Depression Inventory-II (BDI-II), the Youth Quality of Life Questionnaire (YQOL)</td>
<td>Young burn survivors gave more positive evaluations of how others view their appearance and had more positive weight satisfaction and a higher HRQoL.</td>
</tr>
<tr>
<td>Rosenberg et al. 2006</td>
<td>95</td>
<td>18–28 (55) mean years since burn 14.2±5.5</td>
<td>The Quality of Life Questionnaire (QLQ)</td>
<td>QoL was impaired in young burn survivors in the domains of material wellbeing and physical wellbeing. They also had problems in interpersonal friendship relations. The control population also fared better in domains of political and vocational behavior, referring to organizational and recreational activities.</td>
</tr>
<tr>
<td>Sheridan et al. 2006a</td>
<td>80</td>
<td>large 70–98% burns 6–42 (69) mean age when burned 5.5</td>
<td>The Short Form-36 (SF-36)</td>
<td>Most children with massive burns have a HRQoL comparable with the age-matched general population. A supportive family has an enormous role in recovery.</td>
</tr>
<tr>
<td>Sheridan et al. 2012</td>
<td>399</td>
<td>4–18 (76) mean age when burned 11</td>
<td>The Family Environment Scale (FES), the American Burn Association/Shriners Hospitals for Children Burn Outcome Questionnaire (BOQ)</td>
<td>Specific family characteristics have important impacts on injury recovery in children.</td>
</tr>
<tr>
<td>Sveen et al. 2014</td>
<td>109</td>
<td>0–18 (59)</td>
<td>The American Burn Association/Shriners Hospitals for Children Burn Outcome Questionnaire (BOQ)</td>
<td>HRQoL was generally good, &gt;50% of burn victims aged 0 to 4 years had some problems with behavior, and parents reported problems with family disruption and dissatisfaction. Of patients aged 5 to 18, 51% and 58% reported lower scores in appearance and emotional health.</td>
</tr>
<tr>
<td>Van Baar et al. 2011</td>
<td>138</td>
<td>5–15 (61)</td>
<td>The American Burn Association/Shriners Hospitals for Children Burn Outcome Questionnaire (BOQ)</td>
<td>More than 50% of the burn-injured children had long-term limitations; they experienced itching and had problems with their appearance and in several psychosocial dimensions.</td>
</tr>
<tr>
<td>Weedon et al. 2011</td>
<td>70</td>
<td>2–12 (NA)</td>
<td>The Paediatric Quality of Life Inventory (PedsQL), the Household Economic and Social Status Index (HESSI)</td>
<td>The HRQoL 3 months postburn is minimally lower than the normal expected scores.</td>
</tr>
</tbody>
</table>
2.17.4 **Review of the literature on the HRQoL of burn-injured children**

The review of the most recently published articles evaluating the HRQoL of pediatric burn-injured patients in Table 4 showed large variability in the measurement tests used and the age range of the children studied. Study cohorts were often small, participating boys outnumbered girls, and the results of the HRQoL measures varied. In some surveys, young patients’ parents completed the questionnaires instead of the burn victims themselves, which may alter the results. Burn victims who had survived major massive burn injuries were recorded as having long-term limitations of overall abilities, itching, altered perspiration, and problems in appearance and in several psychosocial dimensions (Herndon et al. 1986, Sheridan et al. 2000a, Van Baar et al. 2011). Children with hand burns and larger burned areas reported lower HRQoL scores, and those with hand burn injuries had worse outcomes, including problems in fine and gross motor function skills (Dodd et al. 2010, Palmieri et al. 2012). Factors impairing HRQoL are serious injuries in trauma patients, large burns, male gender, and age; school-aged children and adolescents transitioning to adulthood have reported reduced HRQoL scores (Gabbe et al. 2011, Murphy et al. 2014).

In general, recovery from a burn injury has a good prognosis, and children’s functional independence has been adequate 3 months postinjury in most children (Disseldorp et al. 2013), or the HRQoL is only minimally lower than the normal expected scores (Weedon, Potterton 2011). In a Swedish population, HRQoL after pediatric burn injury was generally good, young burn victims had some behavioral problems and parents reported family disruption and dissatisfaction, and older (aged 5–15 years) patients reported lower scores in the dimensions of emotional health and appearance (Sveen, Sjöberg & Öster 2014). A reduction in HRQoL and increased psychopathology with behavioral difficulties have been documented, but in the same survey, no differences in self-concept were recorded (Maskell et al. 2013). Among burn-injured adolescents and young adults, QoL was impaired regarding material and physical wellbeing; problems in interpersonal friendship relations were also noticed (Rosenberg et al. 2006). The other survey recorded more positive evaluations of how others view burn victims’ appearance, more positive weight satisfaction, and higher HRQoL (Pope et al. 2007).

In recent studies, the impact of the family environment and its characteristics are key factors influencing burn recovery, rehabilitation, and HRQoL (Landolt, Grubenmann & Meuli 2002, Sheridan et al. 2012). The WeeFIM measurement instrument used in the Dutch population is a feasible and reliable instrument in children with burns, as shown by a range of Dutch users (Niemeijer et al. 2012).

Studies measuring HRQoL after a burn injury in toddlers and infants are few, although this population suffers from the highest number of childhood burn injuries. Children younger than 5 represent 20% of all burn-injured individuals, and 30% of all burn injuries occur in patients younger than 16 (American Burn Association 2013). Earlier, Finnish adult burn victims with burn injuries not requiring treatment in intensive care units have been documented as having lower scores on the HRQoL dimensions of sleeping, usual activities, discomfort and symptoms, and sexual activity (Koljonen et al. 2013b). Similarly to young burn survivors, scarring, limited physical function, and various psychological problems influence HRQoL after a burn injury in adults. Families of burn-injured children having an active recreational orientation, greater family cohesion, higher expressiveness, and fewer conflicts in the family had better scores in HRQoL (Landolt, Grubenmann & Meuli 2002, Sheridan et al. 2012). Family-related factors influence the outcome of the burn victim’s recovery and rehabilitation; in the pediatric population the impact
of parents and other family members is essential. Psychosocial support should be targeted to families as soon as dysfunctional family dynamics are detected to achieve the best outcome.

2.18 Psychological consequences and posttraumatic stress disorder after pediatric burn injury

2.18.1 The developing child

The maturing cognitive abilities of the growing child dictate the needs that should be considered when providing care to infants or toddlers. The needs of the child are related to the cognitive developmental stage and age; therefore, they may vary significantly. Children of less than 1 year of age are a specific group, being totally dependent on their parents or caregivers. The dependence of the child, especially a child younger than 6 months, encompasses mobility, eating, drinking, and the avoidance of potentially hazardous situations. Mobility develops step by step, first by creeping, crawling, sitting, and attaining an upward position, and finally by walking. Child maltreatment and possible unintentional injuries should always be taken into consideration when treating infant burn victims because their own ability to cause burns is very limited. During the first year of life, infants develop a trusting relationship with their immediate family members, and this relationship is essential to the later development of all social interaction. The need for hospital treatment at this sensitive age is a terrifying experience for both children and parents, and children are incapable of coping with it. Therefore, parental presence and involvement during hospital treatment is crucial to infants (Benjamin, Herndon 2002).

Toddlers and preschool-aged children, aged 1 to 6 years, typically exhibit imitative behavior that occasionally results in burn injury due to their immature judgment skills. This propensity can be utilized when treating burn wounds in that children can be encouraged to participate in their dressing changes and other wound care activities. During the treatment procedures, playing imitative games or interactive virtual games may reduce their pain, anxiety, and stress (Brown et al. 2012). Preschool children already have fairly good vocabulary skills and are capable of expressing their needs, though regression to toddler-like behavior postburn is often expected. School-aged children mostly experience burns from fire or scalds, often requiring surgical treatment. At this age, children can understand most basic explanations and cooperate with the procedures being performed. The gender identification of school-aged children is usually well developed, and it should be taken into consideration during treatment procedures.

Preadolescents are in some ways dependent, and they take their example for learning from the peer group. Accidents, typically involving fire and flame, cause their burn injuries. At this age, withdrawal is a typical psychological reaction to hospitalization; parents and similarly aged children provide social stimulation and support. Adolescents are maturing into adulthood roles and responsibilities, although their judgment skills are often limited because of lack of experience and their emotional reactions may be dramatized and exaggerated. Homicidal or suicidal aspects related to adolescent burn injury should be considered. Communication with adolescents should be respectful and appropriate; the feeling of being forced into procedures autocratically usually worsens their cooperation (Benjamin, Herndon 2002).

2.18.2 Posttraumatic stress disorder

Posttraumatic stress disorder (PTSD) is a relatively new diagnostic description, although the emotional effects caused by severe trauma have long been recognized (Graf, Schiestl &
Landolt 2011). In adulthood, patients who have had burns in early childhood have memories of hospitalization connected with burn treatment–induced pain (Zeitlin 1997). A burn injury is one of the most devastating of all injuries, and it may be accompanied by serious psychological effects, including PTSD. PTSD may present after exposure to a traumatic event, including a burn injury and its treatment, and it is described as a response of intense fear, horror, and helplessness. Anxiety, traumatic stress reactions, and behavioral problems may occur in the first months after the burn. Symptoms include re-experiencing the event, such as in nightmares or flashbacks, avoidance of stimuli associated with the trauma, and symptoms of increased arousal and anxiety (Sheridan et al. 2014).

2.18.3 PTSD and trauma in children

Trauma affects young children in a similar way as it affects older children and adults (Stoddard et al. 2006a). The reported prevalence rate of PTSD in children with accidental injuries ranges from 6% to 45% (Kenardy, Spence & Macleod 2006). One fourth to one third of pediatric burn victims suffer from acute and posttraumatic stress symptoms, and recent studies highlight that even children below the age of 5, constituting an important risk group for pediatric burns, may experience PTSD (De Young et al. 2012, Bakker et al. 2013, Bakker 2013).

PTSD in young children is often underdiagnosed because toddlers’ limited verbal skills conceal PTSD symptoms. Postburn PTSD is scarcely studied in very young, preschool-aged children; a review of the literature is presented in Table 5. Acute stress symptoms including re-experiencing of the event, avoidance, and arousal have been documented to exist in burn-injured patients aged 1 to 2 years (Stoddard et al. 2006a). Stoddard et al. reported that risk factors for toddlers’ acute stress symptoms were the pain experienced, a high pulse rate, larger burns, and parents’ acute stress symptoms. In young, 1 to 2-year-old children, reduced social smiling and vocalization are observational variables that may lead to a PTSD diagnosis (Stoddard et al. 2006b).

2.18.4 PTSD and families

Parents of burn victims may experience posttraumatic stress, depressive symptoms, and guilty feelings. Parental PTSD symptoms range from 12 to 52% following their child’s burn injury, and risk factors for experiencing PTSD-related psychological distress are having a daughter, witnessing the event, feeling helpless, or having past posttraumatic experiences (McGarry et al. 2013, Odar et al. 2013). Very young, preschool-aged, and moderately (TBSA of less than 10%) injured children represent the majority of pediatric burns; thus the PTSD experienced by their families has been explored only minimal. Recently, Odar et al. presented a study of 56 caregivers, showing that 29% of parents of young, preschool-aged burn victims with a TBSA of less than 10% experienced clinically significant PTSD. The extent of psychological distress was related to the child’s young age at burn, the PTSD of the child, and the source of the burn, with parents of children with contact burns experiencing more symptoms (Odar et al. 2013). Landolt et al. 2009 reported that 19% of school-aged children with burns resulting from scalds and fire requiring skin grafting suffer from PTSD symptoms several years after the burn. When assessing their HRQoL, dimensions of social functioning were impaired, and the severity of PTSD symptoms correlated with impaired HRQoL (Landolt et al. 2009).

The trauma-related anxiety and pain experienced by the child, parental posttraumatic psychological reactions, family functioning, and burn severity are factors influencing the
Review of the Literature

postburn psychological outcome (Bakker et al. 2013). Screening and assessing PTSD should be obligatory for all burn-injured children and their parents, regardless of the severity and size of the burn or parental presence at the time of the burn, to offer the best psychological support and to help families recovering from injury (Bakker 2013).

Table 5: Review of the literature on the psychological consequences and posttraumatic stress disorder (PTSD) after pediatric accidental or burn injury

<table>
<thead>
<tr>
<th>Author</th>
<th>N</th>
<th>Age (years)</th>
<th>Burn TBSA%</th>
<th>Psychological disorder</th>
</tr>
</thead>
<tbody>
<tr>
<td>De Young et al. 2012</td>
<td>130</td>
<td>1–6</td>
<td>1–27 mean 4</td>
<td>≥1 psychological disorder or PTSD in 35%, 8% not recovered by 6 months</td>
</tr>
<tr>
<td>Rimmer et al. 2014</td>
<td>197</td>
<td>8–18</td>
<td>8–95</td>
<td>Anxiety disorder 28%, panic disorder 28%, separation anxiety 44%</td>
</tr>
<tr>
<td>Thomas et al. 2012</td>
<td>98</td>
<td>18–30, age at burn &lt;16</td>
<td>&gt;30</td>
<td>≥1 personality disorders 49%</td>
</tr>
<tr>
<td>Pardo et al. 2008</td>
<td>83</td>
<td>1–17</td>
<td>1.5–47</td>
<td>Anxiety disorder, behavioral reactions</td>
</tr>
<tr>
<td>Stoddard et al. 2006b</td>
<td>72</td>
<td>1–2</td>
<td>0.5–84 mean 15</td>
<td>PTSD: pain, heart rate, reduced social smiling and vocalization</td>
</tr>
<tr>
<td>Stoddard et al. 2006a</td>
<td>52</td>
<td>1–2</td>
<td>0.5–84 mean 15</td>
<td>PTSD symptoms 29%</td>
</tr>
<tr>
<td>Sheridan et al. 2014</td>
<td>147</td>
<td>1.5–17</td>
<td>1–96</td>
<td>Opiate control of surgical pain has long-term physiologic and psychologic benefits; PTSD was reduced.</td>
</tr>
<tr>
<td>Landolt et al. 2009</td>
<td>43</td>
<td>7–16</td>
<td>1–70 mean 13</td>
<td>PTSD 4.4 years after burn in 19%</td>
</tr>
<tr>
<td>Graf et al. 2011</td>
<td>76</td>
<td>1–4</td>
<td>1–50 mean 8</td>
<td>PTSD symptoms after 15 months of the burn 13%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Author</th>
<th>N</th>
<th>Age (years)</th>
<th>Trauma</th>
<th>Psychological disorder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kenardy et al. 2006</td>
<td>135</td>
<td>7–16</td>
<td>A variety of accidents</td>
<td>PTSD symptoms 18%</td>
</tr>
<tr>
<td>Kramer et al. 2014</td>
<td>108</td>
<td>2–16</td>
<td>Road traffic and burns</td>
<td>Intervention decreased PTSD symptoms in high-risk school-aged children; no impact was seen in preschool-aged children.</td>
</tr>
</tbody>
</table>
3 AIMS OF THE STUDY

The purpose of this study was to examine the characteristics and outcomes of burn injuries of infants aged less than 1 year in Finland.

The specific aims of this study were as follows:

1) To review the causes and etiological factors of the burns and the treatment given to infant burn victims treated at the Children’s Hospital, Helsinki from 2005 to 2009. (I–II)

2) To determine the incidence of burn-injured infants born between 1990 and 2010 in Finland, and report the trends in inpatient and outpatient treatments. (III)

3) To identify etiological and risk factors for infant burns requiring hospitalization in Finland. (III)

4) To examine the long-term health-related quality of life (HRQoL) of children having had a burn injury as infants. (IV)
4 Patients and Methods

4.1 Data sources

Data from the Children’s Hospital, Helsinki University Central Hospital were gathered from the electronic hospital institutional database. Databases of the National Hospital Discharge Register, the Finnish Medical Birth Register, and the Cause of Death Register were searched using the personal identification code (PIC) as a key.

The retrospective study protocols (I, II, IV) had the approval of the Internal Review Board of the Helsinki University Central Hospital (§25 / 8.4.2011, §60 / 8.10.2012). The National Institute of Health and Welfare and Statistics Finland approved the study protocol of the retrospective register linkage study (III) (THL/1077/5.05.00/2012, TK-53-879-12). The Ethics Committee of Helsinki University Central Hospital and the Institutional Review Board approved the protocol of the health-related quality of life study (IV), (341/13/03/03/2013, §30 / 11.2.2014).

4.2 Patients and study designs

All 692 admissions from January 1, 2005 to December 31, 2009 due to burn injury in children of less than 16 years were identified from the electronic hospital database of the Children's Hospital, Helsinki. Included were 126 patients who had been treated in the Children's Hospital for burn injury and were aged less than 1 year at the time of injury (I, II, IV). Inclusion criteria for the epidemiological study (III) were that the child was aged less than 1 year at the time of burn injury, was born between 1990 and 2010, and had been treated in the hospital in Finland between 1990 and 2011. Altogether 1923 patients were identified from the registers of the National Institute of Health and Welfare (THL) and Statistics Finland, of which 1842 were included. Excluded were 3 patients, 2 girls and 1 boy, who died at the site of the burn injury, and 78 patients who could not be tracked because of a missing or incomplete personal identification code (PIC). They had a nonvalid PIC, were born elsewhere than in Finland, or were non-residents.

4.3 Study I

The study comprised 20 infant burn victims aged less than 1 year at time of injury and treated as inpatients in the Children's Hospital during the 5-year study period. Information concerning the patient's age at time of injury, gender, site of the accident, mechanisms of the injury, site of the injury and TBSA%, length of hospital stay, possible complications, and the treatment given was gathered from the hospital's electronic patient records.

4.4 Study II

The study comprised 106 patients aged less than 1 year at the time of burn injury who were treated as outpatients in the Children's Hospital during the 5-year study period. We searched from the electronic hospital notes the patient's age at time of injury, gender, mechanism of the burn, site of injury, TBSA%, treatment given, and the number of outpatient admissions.
4.5 Study III

This was a retrospective register linkage study; the inclusion criteria were that the child was born between January 1, 1990 and December 31, 2010 and had been treated in the hospital for burn injury between January 1, 1990 and December 31, 2011. The Finnish Institute of Health and Welfare (THL) has administered the National Hospital Discharge Register (NHDR) since 1967 and the Finnish Medical Birth Register (MBR) since 1987. Since the 1960s, all citizens and permanent residents in Finland have been issued a unique personal identification code (PIC), which is assigned in the birth hospital and remains unchanged over the lifetime. Finnish register databases include the PIC, which was used when tracking patients.

Patients with burn injury–related ICD codes were tracked, and ICD-9 codes (from 1990 to 1995) were manually converted to correspond to the ICD-10 codes T20 to T32.9 used from 1996. The NHDR includes up to 7 discharge diagnoses, the first being the primary cause of the hospital stay. Data concerning age at the time of burn injury, gender, place of residence, duration and number of inpatient treatments, and from 1998, the number of outpatient treatments in public hospitals came from the NHDR, as well as injury-related data, admission date, length of hospital stay, type of visit (inpatient or outpatient), and surgical treatment given. From 1998, ICD-10 codes representing the injury site and external causes of the injury were available. All data were gathered from the NHDR using the PIC as a key.

Maternal- and birth-related factors came from the MBR. We recorded information on birth weight and gestational age, the mother’s parity, number of fetuses during pregnancy, maternal age, smoking during pregnancy, and the mother’s socioeconomic and marital status. Socioeconomic status was based on the mother’s occupation during pregnancy using a four-step scoring system.

We excluded patients who had died at the site of the burn injury or during the transport to hospital, altogether 3 patients. According to Finnish legislation, an autopsy is performed to confirm the causes for all injury-related and sudden deaths, because all those deceased from injuries receive a main cause of death and an ICD-10 code. Statistics Finland produces the Cause-of-Death Register of Finland containing data on fatal injuries.

Altogether we verified 1923 patients, of which 3 died at the injury site, and 78 could not be tracked because of a missing, incomplete, or nonvalid PIC due to being noncitizens/nonresidents or having been born elsewhere than in Finland. A total of 1824 patients met the inclusion criteria.

4.6 Study IV

This study comprised 126 patients, who had earlier suffered from burn injury before the age of 1 year and had been treated for burn injury in the Children’s Hospital, Helsinki between January 1, 2005 and December 31, 2009. In the spring of 2014, the patients received by mail an HRQoL survey and two informed-consent forms (for both the child and his or her parent/caregiver), and were asked to sign the consent forms and complete the questionnaires with the assistance of their parents, if necessary. A prepaid envelope was enclosed, and two reminders were sent in case of nonresponse. Altogether 44 (35%) patients responded.
HRQoL was measured with a standardized and validated, generic 17D questionnaire developed in Finland for children aged 8 to 11 years, but it has also been used for younger children (Geneid et al. 2011, Haapamäki et al. 2011, Haavisto et al. 2013, Nokso-Koivisto et al. 2014). The 17D is also a visual questionnaire containing drawings, although parental assistance may be needed for children still unable to read. The HRQoL scores of the study population were compared to an age-standardized peer group, constructed from previously reported data on a sample of 244 healthy school children from several schools in the Greater Helsinki area. We compared the respondent’s cohort (n=44) to all the burn-injured children whom we approached (n=126) to ensure that burn injury–related features, burn size and site, treatment given, and age were similar in both groups.

4.7  Statistical analyses

P-values of less than 0.05 were considered statistically significant. The statistical analyses in Study II were implemented in close collaboration with a professional statistician. In Study II, the statistical analysis was conducted with NCSS 2009 (NCSS. NCSS, LLC. Kaysville, UT, USA). Spearman’s rank correlation test was used to calculate the correlation between age and final TBSA%. The Mann-Whitney U-test was used when analyzing age and the location of the burn, and gender and final TBSA%. Gender and location of the burn were further studied with cross-tabulation and chi-square tests. A statistical analysis between the estimated and final TBSA% was performed with the Wilcoxon signed-rank test, and the connection between the final TBSA% and the number of outpatient visits was tested with Spearman’s correlation.

In Study III, we calculated the incidences of burn injuries and risk ratios (RR) with 95% confidence intervals (CI) for various risk factors related to burn injuries, and tests of relative proportions and chi-square tests were calculated where appropriate. In Study IV, we analyzed the data using the SPSS for Windows statistical software version 19.0 (SPSS, Inc., Chicago, IL, USA). The Pearson chi-square test or an independent samples t-test was used to analyze the significance of the differences between the groups.
5 RESULTS

A total of 692 burn-injured children younger than 16 and admitted between 2005 and 2009 were identified from electronic hospital databases and the records of the Children's Hospital, Helsinki University Central Hospital. Inclusion criteria were age less than 1 year at time of injury and treatment at hospital, resulting in altogether 126 patients, which represented 18% of all pediatric burn victims in the Children's Hospital. Of these, 20 (3% of all) were treated as inpatients and 106 (15% of all) as outpatients.

5.1 Study I – Inpatient-treated infant burn victims

The age of the 20 (16% of all < 1 year) patients requiring inpatient treatment for burn injury varied from 1 day to 336 days, averaging 191 days (6.4 months). Younger than 6 months were 9 (45%) of the patients. Girls represented 60% of the patients treated as inpatients; the gender ratio was 1:1.2. The number of burn-injured infants treated as inpatients rose during the 5-year study period; during the first 2 study years only 1 patient was admitted annually, and during the following years from 5 to 7. The final TBSA of the burn varied from 0.5 to 40%, averaging 8.5%; 6 (30%) patients had a TBSA ≥10%, and overestimation of the initial TBSA during admittance occurred in 13 (65%) of the patients. Excision and autologous split-thickness skin grafting was performed on 6 (30%) patients. The mean length of hospital stay was 9.5 days, 6 days among patients receiving conservative treatment, and 20.5 days in those receiving surgical treatment. Outpatient clinic admissions varied from 1 to 15, mean 4 times. No deaths occurred, and child abuse was not recorded. At home occurred 15 (75%) of the burns, and 17 (85%) of them were scalds, the most common causing agent being hot liquid (tea, water, or coffee) spilling from a cup. A radiator, a hot oven door, and a warming package used before taking blood samples at a hospital newborn ward caused 3 contact burns. Burns were located in multiple areas, although none of them were in the genital or perineal area.

One complication during the intensive care unit (ICU) period was recorded: a scalded patient with a TBSA of 40% had a pulmonary embolus that was suspected to have resulted from a hypotonic period during the induction of anesthesia.

5.2 Study II – Outpatient-treated infant burn victims

During the 5-year study period, 106 (84% of all < 1 year old burn-injured infants) infants were treated as outpatients. The history of the accidents was consistent with the injuries; therefore child abuse was not suspected. Information concerning the injury pattern or burned area was not available for one patient. Boys (52%) outnumbered girls, and the majority (57%) of the patients were aged 9 to 12 months. Younger than 6 months were 20% of patients, and only 6 (5.7%) patients were younger than 3 months. The final determination of TBSA of the burn ranged from 0.5 to 7%, averaging 1.4%, and most, 60%, of the patients had a TBSA from 1 to 5%. None had a TBSA greater than 10%. Statistical analysis was insignificant between genders in terms of burn location or TBSA. All patients received conservative treatment, and complications were not recorded. The number of outpatient admissions ranged from 1 to 13, the first admission was usually performed 2 days after injury, and the median was 4 admissions. Conservative treatment in outpatient visits consisted of dressing changes and checking the burned area by hospital staff.
Results
every 2 to 3 days until epithelization was complete. A statistically significant connection between
the burned area and outpatient clinic admissions was established (p<0.001). The majority (80%)
of the burns occurred at home, and in most cases (66%), a parent/caregiver was present and
eyewitnessed the accident.

Burns were located in multiple areas in 44% of the patients, and 44% of the burns were on
the hands. The mean TBSA of the 65 (61%) scalds was 1.7% and of the contact burns 0.9%. The
mean age of scalded patients was 8.3 months and of contact-burned patients 9.2 months. The
most common cause of scalds (34%) was hot liquid spilling from a cup. Other sources of scalds
were hot water from a pot or electric kettle, hot coffee from a falling coffee machine, and from
hot soup, porridge, or pizza in a dish. Contact burns occurred mostly (24%) when touching a hot
fireplace or oven door. Other causes of contact burns were hot electric radiators, hot kettles or
pots, hot irons, hot stoves, and a hot light bulb from a falling lamp.

5.3 Study IV – HRQoL after an infant burn requiring hospital
admittance

The HRQoL was queried of those 126 patients who had been treated for burn injuries at the age
of less than 1 year in the Children's Hospital, Helsinki 5 to 9 years earlier. After two reminders,
44 (35%) completed 17D questionnaires with informed consent forms were received; patients
were not otherwise contacted. The majority of respondents were boys (64%) with a mean age of
7.4 years, and the responding girls’ mean age was 6.6 years. The mean age of all respondents was
7.0 years, (range 4–9 years), and the time from trauma ranged from 4.3 to 9.5 years. The mean
TBSA of the burns ranged from 0.5 to 40%, and the mean TBSA of patients treated as inpatients
was 9.45% and for outpatients 1.75%. We compared the information concerning gender, age at
time of injury, burn type (scald or contact burn), type of hospital care (inpatient or outpatient),
site of burn, and TBSA between the respondents’ group (n=44) and all 126 treated patients to
clarify whether the groups were similar according to their injuries and treatment given. The only
statistically significant (p= 0.025) difference between these groups was that boys returned the
17D questionnaires more often; in the respondents' group the gender ratio was 1:0.6. Concerning
other dimensions, the groups were statistically similar; therefore the group of respondents could
be assessed as representing the group of all 126 burn-injured children.

The mean HRQoL score of the respondents (0.968) was statistically significantly higher (p <
0.01) than the HRQoL score of the control group (0.936). On the dimensions of hearing, sleeping,
learning, discomfort and depression, and vitality, respondents fared statistically significantly
better. A separate analysis of the HRQoL of burn-injured girls and boys showed that girls more
often expressed disturbances in the dimensions of breathing, sleeping, elimination, discomfort,
vitality, appearance, friends, and school. These differences were statistically nonsignificant. The
mean HRQoL score of the boys was 0.968, and of the girls 0.950. On the dimension of learning,
girls fared statistically significantly better (HRQoL scores 1.0 and 0.97, p < 0.05) than boys. A
comparison between the HRQoL of patients treated as outpatients and those treated as inpatients
showed that the mean HRQoL score of the patients treated as inpatients was 0.926, and 0.972 for
patients treated as outpatients. On the dimensions of breathing (0.86 and 0.97), speech (0.92 and
1.0), and friends (0.90 and 1.0), the group of patients treated as outpatients fared statistically
significantly better (p < 0.05). No statistically significant differences in the HRQoL emerged
between the groups of scalded and contact-burned children.
5.4 Study III – Incidence of infant burns in Finland

We performed a retrospective register linkage epidemiologic study to find the incidence and risk factors for infant burns in Finland between 1990 and 2011. A total of 1923 patients were identified from the registers, 1842 of whom were included in this study. Three injury-site deaths and 78 (4.1%) patients with missing or nonvalid PIC were excluded, and inpatient mortality was zero. Our study cohort comprised 725 girls and 1117 boys, gender ratio 1:1.5. The mean age of all injured infants was 267 days (8.9 months), of girls 255 days (8.5 months) and of boys 275 days (9.2 months). Background information on the patients, the mother’s pregnancy, and maternal-related details are provided in Table 6.

Table 6: Background information of the 1842 burn-injured infants treated in Finland between 1990 and 2011

<table>
<thead>
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<th>All</th>
<th>Per 1000</th>
<th>RR</th>
<th>95% CI</th>
</tr>
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<td></td>
<td></td>
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<td>Girls</td>
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<td>0.87-1.28</td>
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<td></td>
<td></td>
</tr>
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<tr>
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<td>49</td>
<td>1.35</td>
<td>0.96</td>
<td>0.73-1.26</td>
</tr>
<tr>
<td>3</td>
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<td>0.95</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Maternal age</strong></td>
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<td>5.33</td>
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<td>2.67</td>
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<td>40-44</td>
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<thead>
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<td>1.00</td>
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<td>1.00</td>
<td></td>
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<tr>
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<td>0.95</td>
<td>0.84-1.08</td>
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<td>352</td>
<td>0.86</td>
<td>0.56</td>
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</tr>
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</table>
5.4.1 Incidence

The annual overall incidence per 1000 of infant burns increased during the 20-year study period from 0.77 to 2.04 (p < 0.001). Similarly, the incidence of outpatient-treated burns increased from 1.11 to 1.67, and the incidence of inpatient-treated burns decreased from 0.77 to 0.36 (p < 0.001). In the older age groups of 6 to 9 months and 9 to 12 months, the incidence in boys was clearly higher than that of girls, 29% and 41% respectively (Figure 4).

Figure 4: Incidence per 1000 persons stratified by sex and age (days)

5.4.2 Inpatient and outpatient treatment

Outpatients comprised 1160 (63%) of the patients, and inpatients 682 (37%). One third (31.3%) of the inpatient-treated patients were in the hospital for one day, and half (48%) of the patients had a hospital stay of 2 days. The length of the hospital stay was shorter than a week for 504 (27.4%) of the patients and was 2 to 3 weeks for 25 (1.4%). The longest hospital stay was 93 days, and 11 (0.6%) patients stayed in the hospital longer than 3 weeks. Outpatient admissions were recorded from 1998 on, and the incidence of outpatient-treated patients increased during the study period from 1.11 to 1.67 per 1000.

5.4.3 Etiology

Since 1998, ICD-10 codes related to place of occurrence have been recorded, although these were only available in 618 treatment periods involving 486 patients (26% of all patients). Of these, 435 (70.4%) were recorded as accidents at home, 23 (3.7%) as other leisure-activity accidents, 9 (1.5%) as caused at a hospital or from hospital-associated external causes, 2 (0.3%) as school- or kindergarten-related accidents, and 8 (1.3%) were classified as unspecified accidents. Nine of the patients had more than one injury location code. Etiology and external causes of injury were
available in 618 (33.6%) cases, 37 of the external causes could not be tracked, and altogether 581 (31.5%) of the ICD9/10 codes were included in the data. We discovered 274 (14.9% of all) contact burns and 220 (11.9% of all) scalds. Only 16 (2.8% of all) patients had an injury related to exposure to smoke, fire, flames, or heat from a manmade origin.

Of the burn injury–related ICD-10 codes (T20–T32), 39% (714 patients) were burns and corrosions of the wrist and hand, of which 28% (519 patients) were aged 9 to 12 months, and only 20 (1.1%) younger than 6 months. Second-degree burns occurred in 452 (24.5%) infants, and 337 (18.3%) of them were aged 9 to 12 months. A total of 258 (14.0%) infants had trunk burns, 162 (8.8%) having second-degree burns and 167 (9.1%) aged 9 to 12 months.

### 5.4.4 Surgical treatment

Surgical procedures were performed 1012 times for 302 (16.4%) children, and 271 of them had more than one operative code. The total number of operative codes included was 993, and 558 (59.2% of all operation-related codes) of the codes were related to burns, such as dressing changes, debridement, excision, and skin grafting. Autologous skin grafting was performed 125 (12.6%) times, and the 527 (56.5%) oldest children, aged 9 to 12 months, had the highest prevalence of receiving surgical treatment.

### 5.4.5 Seasonal and weekday variation

We searched for the seasonal and weekday variation of the burns, and found that 30% of the burns occurred during the 3 winter months (December, January, and February), \( p < 0.001 \). The highest number of burns occurred in December: 205 (11%) of all burns. The monthly variation ranged from 125 (7%) burns in August to 179 (10%) in February. On Mondays and Tuesdays occurred 35% (642) of burns (\( p < 0.001 \)), occurred, and we recorded no increase during holiday times nor during Christmas or New Year celebrations. The highest number of burns per day was recorded on the 29\(^{th}\) of December: that total was 13 burns (mean 5.3 per day, range from 1 to 13).

### 5.4.6 Risk factors for hospital-admitted burns in infants

Factors influencing the risk for infant burn injury were gender, parity, and the mother’s socioeconomic status and age (Table 7). We verified that boys were at higher risk (RR of 1.47, 95% CI 1.34-1.62) and that firstborn children were at higher risk than later siblings (RR 1.26, 95% CI 1.00-1.58). The mother’s young age significantly raised the risk for infant burns: among teen-age mothers the RR was 5.33 (95% CI 3.70-7.68), and the RR for mothers aged 20 to 24 was 2.67 (95% CI 1.98-3.58). The RR decreased further in older age groups, to 1.75 (95% CI 1.31-2.33) in 25–29, and 1.48 (95% CI 1.11-1.98) in 30–34-year-old mothers, but was still significantly high. The mother’s low socioeconomic status raised the risk for infant burn injury (RR 1.77, 95% CI 1.50-2.09), but birth weight, gestation of pregnancy, number of fetuses, the mother’s marital status, or smoking during pregnancy were not influencing factors.
Table 7: Risk factors influencing the risk for infant burn injury

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Risk ratio</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male gender</td>
<td>1.47</td>
<td>1.34-1.62</td>
</tr>
<tr>
<td>Parity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Firstborn</td>
<td>1.26</td>
<td>1.00-1.58</td>
</tr>
<tr>
<td>Socioeconomic status</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blue collar</td>
<td>1.77</td>
<td>1.50-2.09</td>
</tr>
<tr>
<td>Mother’s age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 20</td>
<td>5.33</td>
<td>3.70-7.68</td>
</tr>
<tr>
<td>20–24</td>
<td>2.67</td>
<td>1.98-3.58</td>
</tr>
</tbody>
</table>

5.4.7 Geographic incidence

During the study period 1990–2011, Finland was divided into 21 hospital districts, and we searched for information concerning incidence rates in different hospital districts. The incidence of burn injuries in children younger than 1 year per 1000 was highest, 2.13, on the southwest coast of Finland (Satakunta), 1.88 in the Åland islands, 1.87 in western parts of Finland (Vaasa), and 1.77 in Eastern Savo. The lowest incidences were recorded in North Karelia 0.91 and Lapland 0.98 (The National Institute of Health and Welfare).

5.4.8 Burns in Finland between 2010 and 2013

We performed an analysis of the number of burn-injured patients treated in the hospital in Finland between January 1, 2010 and December 31, 2013. The analysis showed that during this 4-year period, the total number of burn-injured patients decreased 7.4% from 1577 in 2010 to 1460 in 2013, and children aged less than 16 years represented 21.6% of all burn-injured patients. In children younger than 1 year, the incidence per 1000 persons was 3.2, among children aged 1 to 2 years 8.4, and 2 to 3 years 2.2. The incidence of burn injuries among 1- to 2-year-old boys (10.4) was more than six-fold higher than was the incidence for all men in all age groups (1.6). Incidences in different age groups and gender from 2010 to 2013 are illustrated in Figure 5 (The National Institute of Health and Welfare).

Figure 5: Incidences per 1000 persons in different age groups and gender 2010–2013
6 DISCUSSION

In recent decades, the total number of burn injuries has been decreasing (American Burn Association 2013, Agran et al. 2001, Peck 2011). However, the number of burns in toddlers and infants has been increasing, and young boys aged less than 4 years are at a particularly high risk for burn injury (Dokter et al. 2014, Pickett et al. 2003). Literature focusing on burn injuries and their mechanisms, treatment, and outcomes is incomplete on children less than 1 year of age. The separate investigation of infants younger than 1 year clarifies specific patterns of burn injury in this vulnerable age cohort. Information focusing on the burn injury patterns of infants representing different developmental stages provides more detailed information for prevention (Tse et al. 2006).

This study highlights specific characteristics of infant burns. Information on mechanisms, cause, burn size and site, the treatment given, and the changing trends of incidence was sought. The long-term HRQoL in childhood after an infant burn injury has not earlier been described in the Finnish population, and here we wanted to answer the question of whether possible long-term consequences of infant burn injuries exist.

Children younger than 1 year comprise a specific childhood group, as children aged less than 6 months are highly dependent on their parents and caregivers for mobility, eating, and drinking, and for avoidance of potentially dangerous situations. Mobility develops step by step, from crawling, creeping, and sitting, to achieving an upright position and finally walking when approaching the age of 1 year. The developmental stage of the child establishes the ability to inflict injuries on themselves; thus proper parental vigilance and a safe domestic environment have a significant impact on infant injury prevention.

6.1 Causes of infant burns

Pediatric burns are typically scalds and contact burns, scalds representing more than two thirds of young children’s burns. In older age groups, fire, flames, and electrical burns are the main causes of injury. Scalds classically occur when hot liquid (water, tea, or coffee) spills from a cup held by someone also holding the child (Drago 2005, Carlsson et al. 2006, D’Souza, Nelson & McKenzie 2009). Touching hot food on a plate is another typical pattern for infant burn injury, as shown in Study II. Caregivers may be holding the child while eating or drinking, thus placing the child within reach of a container. Most burns occur at home and in the kitchen, and current hectic lifestyles may pressure caregivers to multitask, placing children in danger if being held when the caregiver is cooking or preparing food. The majority of infant contact burns occur when touching hot glass or the metal doors of fireplaces or ovens, and the northern climate in Finland, heating, and the time spent in the house during the wintertime places young children at risk for burns. Increased knowledge of typical burn injury patterns in infants would help to prevent these injuries.

In Study III, only one third of ICD codes related to the external causes of the burn injury in the study cohort were available, and of those, 47% were contact burns and 38% scalds. The largest percentage, 39%, of the burns were located in the wrist and hand area, according well with the recorded injury pattern. Earlier, Studies I and II stated that the majority, 61%, of infant burns are scalds and that 38% were contact burns occurring at home, which is in line with previous findings (Drago 2005, Dissanaike et al. 2009, American Burn Association 2013, Arslan et al.
Discussions

2013, Dokter et al. 2014, Kemp et al. 2014). In Study I, we had a small cohort of infants treated as inpatients, the majority being girls, with a gender ratio of 1: 1.2. A similar phenomenon was perceived in Study III: in age groups younger than 6 months, the number of girls was from 7 to 10% higher than that of boys. Older age groups showed a clear male dominance (Van Niekerk, Rode & Lafamme 2004b, Drago 2005, Schricke et al. 2013, Kemp et al. 2014, Zhou et al. 2014). An explanation for the phenomenon of girls outnumbering boys as very young infants is unclear; we have speculated that baby girls may have been held more often in the arms while performing household work, but in Study I this phenomenon may be coincidental due to the small study cohort.

6.2 TBSA burned and children

The mean TBSA burned of infants treated as inpatients was 8.5%, and overestimation of the initial TBSA occurred in 65% of patients during admission in Study I. Most infant burns are minor and are treated conservatively on an outpatient basis. Accurate estimation of the burned area and its depth is a cornerstone of the treatment of all burns, since it influences fluid resuscitation and the need for surgical treatment. Scalds are often a mixture of variable depths of superficial or deep dermal burns; thus, recognizing the area of a full-thickness burn requiring surgical procedures is essential. Children have a greater body surface area and percentage of water in relation to their body weight, different anatomical relations compared to adults, more delicate and thinner skin, and an accentuated metabolism, which all make the treatment of the burn injury challenging and require expertise and knowledge from a multidisciplinary team (Mayes et al. 1996, Lee et al. 2011, Williams 2011). Infant burns are typically located in multiple areas, though burns on the wrist and hand are the most common. Burns in the hand area may lead to impairment of developing fine-motoric skills due to scarring and the operations performed to release scar contractions (Palmieri 2009).

6.3 Incidence of burns

The annual incidence of infant burns in Finland has significantly increased in recent decades. Simultaneously, the incidence of outpatient-treated infant burn injuries has also increased, while that of inpatient-treated burns has decreased. The current trend is to treat burn-injured infants as outpatients when the injury itself or a suspicion of child abuse does not require treatment as an inpatient.

Between 2010 and 2013, the number and incidence of all burns in Finland decreased, and the incidence per 1000 fell to 1.1. Children younger than 16 years represent more than one fifth (21.6%) of all those injured by burns, and the incidence of young children’s burns is alarmingly high, being almost seven-fold higher in children younger than 2 years than in children aged 3 to 16. The highest incidence emerges in children aged 1 to 2 years, 8.4.

6.4 Risk factors

Risk factors for infant burn injuries are age 9 to 12 months, being a boy or a firstborn child, having a young mother with low socioeconomic status coupled with the likelihood of having a low education, wintertime, and the beginning of the week. The mother’s marital status or an
unconventional family situation did not, in this study, influence the risk of being burned, nor did the mother's smoking. Earlier studies have shown that ethnicity has an impact on burn injuries; differences in burn etiology and TBSA in ethnic minority groups may be explained by different cooking practices (Tan, Prowse & Falder 2012, Teo, Van As & Cooper 2012).

### 6.5 HRQoL

Quality of life is a subjective concept, comprising the individual's own personal experience of his or her culture and living circumstances, and it is related to the individual's goals, expectations, standards, and concerns (WHO 1997). In contrast, for HRQoL, the experience of health or its disappearance expressed as a disease or disability influences the QoL experienced. The measurement of HRQoL targets the experienced feeling of wellbeing or lack of wellbeing. Measurement tools are mainly questionnaires developed to evaluate changes in the QoL over time and due to altered living circumstances and health conditions. Such questionnaires must take into consideration cultural settings, language, the participant's age and capability of understanding the questions and the concepts, and the skills needed to complete the forms; therefore the same tests are not appropriate to use worldwide.

We used the 17D questionnaire to investigate the HRQoL of burn-injured under-1-year-old children 5 to 9 years after treatment in a hospital in Finland. The choice of questionnaire was reasonable, because this measurement tool has been validated and generalized, was developed in Finland, and may be completed properly during a structured interview (Apajasalo et al. 1996). The 17D is modified to the age of the respondent, using pictures to help the child understand the questions and their context and to offer extra information. A control population has been gathered earlier from voluntary peer-aged elementary school children around the Greater Helsinki area.

The 17D showed that children who had been treated for burn injuries 5 to 9 years earlier, as infants, had mean HRQoL scores that were even better in some dimensions than those of the control population. Despite the greater number of responding boys, according to the statistical analyses, the differences between the respondents and all patients proved to be insignificant. Study IV demonstrated that the HRQoL 5 to 9 years after an infant burn is expected to be good when compared to that of peer-aged healthy controls. Recently, Murphy et al. reported that greater burns requiring surgical treatment worsen the experienced HRQoL, and patients treated as outpatients fare better than those treated as inpatients (Murphy et al. 2014).

Recent studies indicate that family has an important influence in the burn recovery of children and that the impact of the family environment and its characteristics are a key factor influencing HRQoL and the success of rehabilitation (Landolt, Grubenmann & Meuli 2002, Sheridan et al. 2012). Hence, parents or caregivers and other members of the family should be entitled to participate and be involved in the treatment and operations performed, and appropriate support and help for the whole family should be available and offered.

### 6.6 Prevention and treatment of burn injury

Throughout history, fire-related disasters have caused not only loss of property, but also have killed and caused disability. In 1942, in Boston, the Cocoanut Grove nightclub fire was one of the greatest public disasters in American history, causing hundreds of burns and 491 deaths.
It has greatly influenced the development of burn prevention, safety regulations, public safety legislation, and burn treatment (Liao, Rossignol 2000).

Creating effective prevention programs requires information concerning burns based on epidemiological studies and statistics on burns (Ytterstad, Smith & Coggan 1998). Information on the incidence and cause of burns, medical care, and costs is crucial. Determining the incidence of burn injuries in specific age groups is important for the identification of high-risk groups for specific types of burns and for effective and targeted prevention strategies. The best care for burn injuries is definitely prevention. Prevention is either active or passive. Active strategies include influencing behavior through education or by suggesting lifestyle changes, or initiating environmental changes through product design. Passive prevention strategies include legislation and regulation. The most effective prevention programs include both active and passive methods (Peden et al. 2008, Atiyeh, Costagliola & Hayek 2009). Prevention should also take into account geographical and socioeconomic differences based on variances in burn epidemiology.

Burns and accidents occur, but almost all infant burn injuries could be prevented; children aged less than 6 months have limited mobility and capability to cause burns to themselves. Over time, their developing skills of grasping objects and their increased mobility places children at risk for injuries in general and for burn injuries in particular. Increasing parents’ and caregivers’ general knowledge of typical patterns of infant burns and their sources could encourage them to pay closer attention to safety concerns in the home. Preventative work, education, product design, and legislation need to be strengthened to prevent infant burns and decrease their number. Special attention should be given to the counseling and encouragement of young mothers in primary health care centers and kindergartens.

Simple acts can prevent infant burns: first of all, the baby should not be held while one is eating and drinking, or handling or carrying hot items. Access to the hot doors of fireplaces and ovens should be restricted. Irons, hair straighteners, and other hot items must be stored properly, and when in use, their cables should not be allowed to hang free. Electric wall plugs can be covered and protected. Keeping young children under strict watch while they learn to move and explore their environment using their hands is crucial.

Burn injury affects all aspects of life, including the entire family of the burn-injured child. Improvements in outcomes and survival highlight the importance of the long-term HRQoL after a burn injury. The treatment of pediatric burns is challenging because of specific features of children or infants that differ from those of adult burn victims, for instance, their anatomical structures, metabolism, body surface, and psychological and psychosocial aspects.

In Finland, both plastic surgeons and pediatric surgeons treat burn-injured children; however, the best outcome could be accomplished when combining the knowledge and skills of both specialists. Cooperation should be easy, and consultation and guidance in both directions should be easily accessible. Pediatric surgeons’ expertise in the treatment of intentional injuries and child abuse is valuable. A multidisciplinary team treating burn-injured children and the entire family should be available in all pediatric surgery units. The best outcomes of the treatment of pediatric burns and of rehabilitation are the most achievable when children are treated in burn centers specializing in pediatric burns by a multidisciplinary and dedicated team.
6.7 Limitations of the study

Limitations of this study include the small number of patients in studies I (n=20) and II (n=106), even though all patients treated at the Children's Hospital, Helsinki, who met the inclusion criteria were included. Studies I and II were retrospective, and one author reviewed the electronic hospital medical records in detail. The descriptions reviewed and analyzed from the records were written by other, often younger and less experienced colleagues working in an emergency unit, and this may also be considered a limitation. The size of the burned area was estimated mainly by descriptions in patient records, and measurements in centimeters or photographs were only sometimes available. The data in hospital medical charts is recorded for purposes other than research; thus, obtaining the correct information to answer research questions may be challenging. According to earlier studies, most burn injuries are minor, heal well, and may be treated by local practitioners in health care centers or at home with or without bandages; these patients are thus missing from the study (Warrington, Wright 2001).

Previous studies have stated that ethnic background has an impact on TBSA% and the length of hospital stay in pediatric burns, but owing to Finnish data-protection legislation, information concerning the ethnicity of the burn victims and their families was not available in this study (Rimmer et al. 2008, Dissanaike, Rahimi 2009, Kramer, Rivara & Klein 2010, Tan, Prowse & Falder 2012, American Burn Association 2013). When analyzing the HRQoL after a burn injury in study IV, related factors, such as family-related matters, socioeconomic status, education, living conditions, and the parent's response to trauma, were not recorded. The respondents' cohort in Study IV was relatively small (n=44, 35% of all approached), but burn injury-related features, burn size and site, treatment given, and age at time of injury were shown to be equal in all the children (n=126) approached. The good HRQoL 5 to 9 years postburn may have reduced the willingness to respond.

Study III was a register-based study, and its limitations naturally concern the validity of the NHDR and Statistics Finland registers. The accuracy of NHDR records has been shown to be more than 95%, and they cover acute injuries of the Finnish population with an accuracy of nearly 100% (Keskimäki, Aro 1991, Sund 2012). Poor or absent recording of subsidiary diagnoses, secondary operations, and other missing or incorrectly recorded events are the most obvious weaknesses. The recording of injury site codes and outpatient admissions began in 1998, but two thirds of these codes were missing in our study cohort. TBSA% was also inadequately recorded or was missing.

Infants treated for burns in a hospital as outpatients or inpatients were included in Study III. In Finland, large burns are referred to burn centers, but local practitioners treat minor burns in primary health care centers. During the study period of 1990 to 2011, the Finnish health care system's emergency care units were developed and reorganized. Emergency care is available in units providing levels of both primary health care and tertiary health care. The triage system of emergency units may refer patients with burns, especially infants and toddlers, to tertiary level care. A larger number of pediatric patients with burns may have been treated and recorded as patients treated in a hospital. This may explain the highly increased incidence of young children's burns.
Discussion

6.8 Future prospects

This study focused on burn-injured infants aged less than 1 year at time of injury. The incidence of burns in 1 to 2-year-old toddlers has considerably increased in Finland in recent years, and further study on the patterns of burns in this age group would provide more tools to develop preventive procedures. The developmental stage of 1 to 2-year-olds concerning mobility is completely different from that of a newborn or 6-month-old infant; moreover, they are developing mental skills and beginning to understand hazardous situations, which help them to avoid accidents.

Even though a prevention program suitable for all childhood age groups seems impossible to construct, the causes for burns in different age groups are distinctive (scalds, contact burns, flames, electrical). Prevention programs proven to be effective are often combined with programs involving legislation, standards, and product modifications. Education and counseling on their own might be ineffective in reducing the incidence of burns (Peden et al. 2008).

Efforts to reduce the increasing number of infant burns are necessary and must be encouraged. General knowledge of the patterns of infant burns should be provided to parents and personnel working in primary child health centers and kindergartens. Public media and journals targeted to the staff of maternity clinics and child health centers should publish articles on these issues. Campaigns on keeping the home environment safe by providing good advice would be helpful.

To achieve the best long-term outcomes and ensure that a sufficient number of patients are treated, the management of children’s large burns should be centralized in specialized pediatric burn centers with pediatric and neonate ICUs and a multidisciplinary staff (Sheridan et al. 2000b, Kraft et al. 2012a).
7 CONCLUSIONS

On the basis of this study, the following conclusions can be drawn:

1) During the 5-year study period, 126 burn-injured infants were identified with a TBSA from 0.5 to 40%, nearly half of these, 48%, with upper extremity burns. Undergoing inpatient treatment were 20 (16%) infants, of whom 30% received surgical treatment. Of the 106 conservatively treated outpatients, most, 57%, were aged 9 to 12 months. Two thirds of burns were scalds caused by hot liquid spilling from a cup; contact burns came from the hot doors of fireplaces or ovens. Most burns occurred at home, and child abuse was not recorded.

2) From 1990 to 2011, the annual overall incidence per 1000 for all burns in children younger than 1 year increased from 0.77 to 2.04. Similarly, the incidence for outpatient burns rose from 1.11 to 1.67, but the incidence of inpatient-treated burns fell from 0.77 to 0.36.

3) Firstborn 9- to 12-month-old boys of young mothers of low socioeconomic status are at higher risk for burn injuries on Mondays and Tuesdays in the winter. Birth weight, gestation of pregnancy, number of fetuses, the mother’s smoking, and marital status had no influence on burn injuries in infants.

4) The long-term health-related quality of life (HRQoL) 5 to 9 years after burn injury in children having had a burn before the age of 1 year is good compared to that of the peer-aged control population. The etiology of the burn injury did not affect the perceived HRQoL.
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Elena
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