David N. Herndon

TOTAL BURN CARE

Fourth Edition

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Total Burn Care

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Total Burn Care

FOURTH EDITION

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Preface
to the fourth Edition of Total Burn Care

The last 25 years burn care has improved to the extent that persons with burns covering 90% of their total body surface area can frequently survive. In the five years since the publication of the third edition of this book basic and clinical sciences have continued to provide information further elucidating the complexities of burn injuries and opportunities for improvement in care. In this edition advances in the treatment of burn shock, inhalation injury, sepsis, hypermetabolism, the operative excision of burn wounds, scar reconstruction and rehabilitation are completely reexamined. Burn care demands attention to every organ system as well as to the patient's psychological and social status. The scope of burn treatment extends beyond the preservation of life and function; and the ultimate goal is the return of burn survivors as full participants back into their communities.

The fourth edition has been extensively updated with massive additions and new data, new references; almost all chapters have been totally rewritten and updated. There are many new chapters and sections in this edition along with demonstrative color illustrations throughout the book.

Totally new to this edition is a web based support section for many of the chapters that include powerpoint presentations and helpful videos. Power points should allow visual representations of the topics covered in chapters for group discussions and individual burn units. Video clips should allow better understanding of complex procedures and concepts.

New material has been added to this edition reflecting the varied physiologic, psychological and emotional care of acutely burned patients evolving through recovery, rehabilitation, and reintegration back into society and daily life activities.

The scope of burn treatment extends beyond the preservation of life and function and the ultimate goal is the return of burn survivors, as full participants, back into their communities.

I would like to express my deep appreciation to the many respected colleagues and friends who have volunteered tirelessly of their time to produce the various chapters in this book and especially to the Shrines Hospitals for Children staff.

Sincere appreciation goes to Shari Taylor for her excellent secretarial assistance, to Ms. Sharon Nash for her editorial skills. Finally I would like to thank my wife Rose for her invaluable personal support.

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2012

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A brief history of acute burn care management

Ludwik K. Branski, David N. Herndon, Robert E. Barrow

The recognition of burns and their treatment is evident in cave paintings which are over 3500 years old. Documentation in the Egyptian Smith papyrus of 1500 BC advocated the use of a salve of resin and honey for treating burns.[1] In 600 BC, the Chinese used tinctures and extracts from tea leaves. Nearly 200 years later, Hippocrates described the use of rendered pig fat and resin impregnated in bulky dressings which was alternated with warm vinegar soaks augmented with tanning solutions made from oak bark. Celsus, in the first century AD, mentioned the use of wine and myrrh as a lotion for burns, most probably for their bacteriostatic properties.[1] Vinegar and exposure of the open wound to air was used by Galen, who lived from 130 to 210 AD, as a means of treating burns, while the Arabian physician Rhases recommended cold water for alleviating the pain associated with burns. Ambroise Paré (1510–1590 AD), who effectively treated burns with onions, was probably the first to describe a procedure for early burn wound excision. In 1607 Guilhelmus Fabricius Hildanus, a German surgeon, published *De Combustionibus*, in which he discussed the pathophysiology of burns and made unique contributions to the treatment of contractures. In 1797, Edward Kentish published an essay describing pressure dressings as a means to relieve burn pain and blisters. Around this same time, Marjolin identified squamous cell carcinomas that developed in chronic open burn wounds. In the early 19th century, Guillaume Dupuytren (Figure 1.1) reviewed the care of 50 burn patients treated with occlusive dressings and developed a classification of burn depth that remains in use today.[2] He was, perhaps, the first to recognize gastric and duodenal ulceration as a complication of severe burns, a problem that was discussed in more detail by Curling of London in 1842.[3] In 1843 the first hospital for the treatment of large burns used a cottage on the grounds of the Edinburgh Royal Infirmary.

Truman G. Blocker Jr (Figure 1.2) may have been the first to demonstrate the value of the multidisciplinary team approach to disaster burns when, on 16 April 1947, two freighters loaded with ammonium nitrate fertilizer exploded at a dock in Texas City, killing 560 people and injuring more than 3000. At that time, Blocker mobilized the University of Texas Medical Branch in Galveston, Texas, to treat the arriving truckloads of casualties. This 'Texas City Disaster' is still known as the deadliest industrial accident in American history. Over the next 9 years, Truman and Virginia Blocker followed more than 800 of these burn patients and published a number of papers and government reports on their findings.[4–6] The Blockers became renowned for their work in advancing burn care, with both receiving the Harvey Allen Distinguished Service Award from the American Burn Association. Truman Blocker Jr was also recognized for his pioneering research in treating burns 'by cleansing, exposing the burn wounds to air, and feeding them as much as they could tolerate'.[7] In 1962, his dedication to treating burned children convinced the Shriners of North America to build their first Burn Institute for Children in Galveston, Texas.[7]

Between 1942 and 1952, shock, sepsis, and multiorgan failure caused a 50% mortality rate in children with burns covering 50% of their total body surface area.[8] Recently, burn care in children has improved survival such that a burn covering more than 95% total body surface area (TBSA) can be survived in over 50% of cases.[9] In the 1970s Andrew M. Munster (Figure 1.3) became interested in measuring quality of life, when excisional surgery and other improvements led to a dramatic decrease in mortality. First published in 1982, his Burn Specific Health Scale became the foundation for most modern studies in burns outcome.[10] The scale has since been updated and extended to children.[11]

Further improvements in burn care presented in this brief historical review include excision and coverage of the burn wound, control of infection, fluid resuscitation, nutritional support, treatment of major inhalation injuries, and support of the hypermetabolic response.

Early excision

In the early 1940s, it was recognized that one of the most effective therapies for reducing mortality from a major thermal injury was the removal of burn eschar and immediate wound closure.[12] This approach had previously not been practical in large burns owing to the associated high rate of infection and blood loss. Between 1954 and 1959, Douglas Jackson and colleagues, at the Birmingham Accident Hospital, advanced this technique in a series of pilot and controlled trials, starting with immediate fascial excision and grafting of small burn areas, and eventually covering up to 65% of the TBSA with autograft and homograft skin.[13] In this breakthrough publication, Jackson concluded that 'with adequate safeguards, excision and grafting of 20% to 30% body surface area can be carried out on the day of injury without increased risk to the patient'. This technique, however, was far from being accepted by the majority of burn surgeons, and delayed serial excision remained the prevalent approach to large burns. It was Zora Janzekovic (Figure 1.4),

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Figure 1.1 Guillaume Dupuytren.

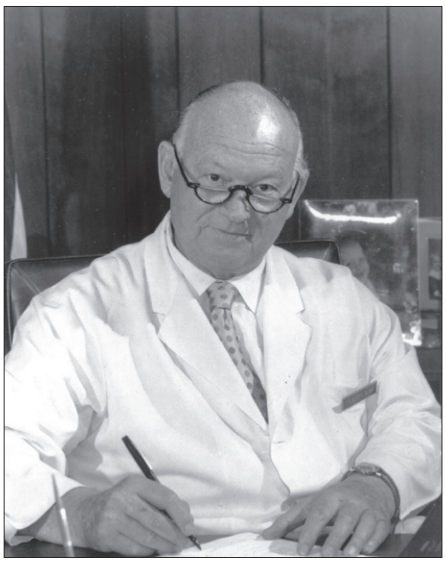

Figure 1.2 Truman G. Blocker Jr.

Figure 1.3 Andrew M. Munster.

Figure 1.4 Zora Janzekovic.

working alone in Yugoslavia in the 1960s, who developed the concept of removing deep second-degree burns by tangential excision with a simple uncalibrated knife. She treated 2615 patients with deep second-degree burns by tangential excision of eschar between the third and fifth days after burn, and covered the excised wound with skin autograft.[14] Using this technique, burned patients were able to return to work within 2 weeks or so from the time of injury. For her achievements, in 1974 she received the American Burn Association (ABA) Everett Idris Evans Memorial Medal, and in 2011 the ABA lifetime achievement award.

In the early 1970s, William Monafo (Figure 1.5) was one of the first Americans to advocate the use of tangential excision and grafting of larger burns.[15] John Burke (Figure 1.6), while at Massachusetts General Hospital in Boston, reported an unprecedented survival in children with burns over 80% of the TBSA.[16] His use of a combination of tangential excision for the smaller burns (Janzekovic's technique) and excision to the level of fascia for the larger burns resulted in a decrease in both hospital time and mortality. Lauren Engrav et al.,[17] in a randomized prospective study, compared tangential excision to non-operative treatment of burns. This study showed that, compared to non-operative treatment, early excision and grafting of deep second-degree burns reduced hospitalization time and hypertrophic scarring. In 1988, Ron G. Tompkins et al.,[18] in a statistical review of the Boston Shriners Hospital patient population from 1968 to 1986, reported a dramatic decrease in mortality in severely burned children which he attributed mainly to the advent of early excision and grafting of massive burns in use since the 1970s. In a randomized prospective trial of 85 patients with

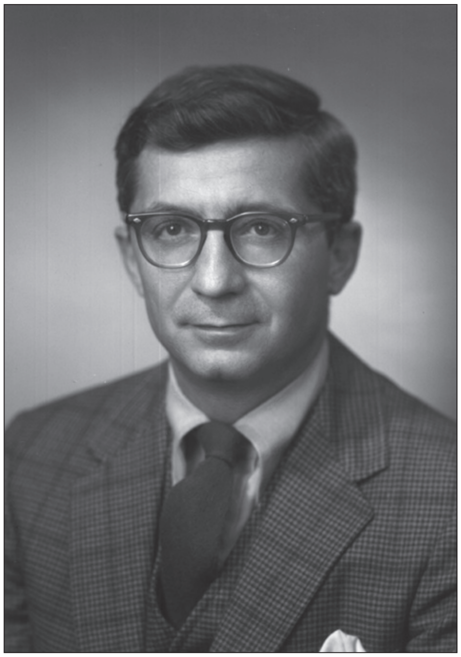

Figure 1.5 William Monafo.

Figure 1.7 J. Wesley Alexander.

Figure 1.6 John Burke.

third-degree burns covering 30% or more of their TBSA, Herndon et al.[19] reported a decrease in mortality in those treated with early excision of the entire wound compared to conservative treatment. Other studies have reported that prompt excision of the burn eschar improves long-term outcome and cosmesis, thereby reducing the amount of reconstructive procedures required.

Skin grafting

Progress in skin grafting techniques has paralleled the developments in wound excision. In 1869, J. P. Reverdin, a Swiss medical student, successfully reproduced skin grafts.[20] In the 1870s, George David Pollock popularized the method in England.[21] The method gained widespread attention throughout Europe, but as the results were extremely variable it quickly fell into disrepute. J.S. Davis resurrected this technique in 1914 and reported the use of 'small deep skin grafts', which were later known as pinch grafts.[22] Split-thickness skin grafts became more popular during the 1930s, due, in part, to improved and reliable instrumentation. The 'Humby knife', developed in 1936, was the first reliable dermatome, but its use was cumbersome. E.C. Padgett developed an adjustable dermatome which had cosmetic advantages and allowed the procurement of a consistent split-thickness skin graft.[23,24] Padgett also developed a system for categorizing skin grafts into four types based on thickness.[25] In1964 J.C. Tanner Jr and colleagues revolutionized wound grafting with the development of the meshed skin graft;[26] however, for prompt excision and immediate wound closure to be practical in burns covering more than 50% of the TBSA, alternative materials and approaches to wound closure were necessary. To meet these demands, a system of cryopreservation and long-term storage of human skin for periods extending up to several months was developed.[27] Although controversy surrounds the degree of viability of the cells within the preserved skin, this method has allowed greater flexibility in the clinical use of autologous skin and allogenic skin harvested from cadavers. J. Wesley Alexander (Figure 1.7) developed a simple method for widely expanding autograft skin and then covering it with cadaver skin.[28] This so called 'sandwich technique' has been the mainstay of treatment of massively burned individuals.

In 1981, John Burke and Ioannis Yannas developed an artificial skin which consists of a silastic epidermis and a porous collagen–chondroitin dermis, and is marketed today as Integra. Burke was also the first to use this artificial skin on very large burns which covered over 80% of the TBSA.[29]

David Heimbach led one of the early multicenter randomized clinical trials using Integra.[30] Its use in the coverage of extensive burns has remained limited, partly due to the persistently high cost of the material and the need for a two-stage approach. Integra has since become popular for smaller immediate burn coverage and burn reconstruction. In 1989, J.F. Hansbrough and S.T. Boyce first reported the use of cultured autologous keratinocytes and fibroblasts on top of a collagen membrane (composite skin graft, CSS).[31] A larger trial by Boyce[32] revealed that the use of CSS in extensive burns reduces the requirement for harvesting of donor skin compared to conventional skin autografts, and that the quality of grafted skin did not differ between CSS and skin autograft after 1 year. The search for an engineered skin substitute to replace all of the functions of intact human skin is ongoing; composite cultured skin analogs, perhaps combined with mesenchymal stem cells, may offer the best opportunity for better outcomes.[33,34]

Topical control of infection

An important major advancement in burn care that has reduced mortality is infection control. One of the first topical antimicrobials, sodium hypochlorite (NaClO), discovered in the 18th century, was widely used as a disinfectant throughout the 19th century, but its use was frequently associated with irritation and topical reactions.[35] In 1915, Henry D. Dakin standardized hypochlorite solutions and described the concentration of 0.5% NaClO as most effective.[36] His discovery came at a time when scores of severely wounded soldiers were dying of wound infections on the battlefields of World War I. With the help of a Rockefeller Institute grant, Dakin teamed up with the then already famous French surgeon and Noble Prize winner Alexis Carrel to create a system of mechanical cleansing, surgical debridement, and topical application of hypochlorite solution, which was meticulously protocolized and used successfully in wounds and burns.[37] Subsequently, concentrations of sodium hypochlorite were investigated for antibacterial activity and tissue toxicity in vitro and in vivo, and it was found that a concentration of 0.025% NaClO was most efficacious as it had sufficient bactericidal properties but fewer detrimental effects on wound healing.[38]

Mafenide acetate (Sulfamylon), a drug used by the Germans for treatment of open wounds in World War II, was adapted for treating burns at the Institute of Surgical Research in San Antonio, Texas, by microbiologist Robert Lindberg and surgeon John Moncrief.[39] This antibiotic would penetrate third-degree eschar and was extremely effective against a wide spectrum of pathogens. Simultaneously, in New York, Charles Fox developed silver sulfadiazine cream (Silvadene), which was almost as efficacious as mafenide acetate.[40] Although mafenide acetate penetrates the burn eschar quickly, it is a carbonic anhydrase inhibitor which can cause systemic acidosis and compensatory hyperventilation and may lead to pulmonary edema. Because of its success in controlling infection in burns combined with minimal side effects, silver sulfadiazine has become the mainstay of topical antimicrobial therapy.

Carl Moyer and William Monafo initially used 0.5% silver nitrate soaks as a potent topical antibacterial agent for burns, a treatment that was described in their landmark publication[41] and remains the treatment of choice in many burn centers today. With the introduction of efficacious silver-containing topical antimicrobials, burn wound sepsis rapidly decreased. Early excision and coverage further reduced the morbidity and mortality from burn wound sepsis. Nystatin in combination with silver sulfadiazine has been used to control *Candida* at Shriners Burns Hospital for Children in Galveston, Texas.[42] Mafenide acetate, however, remains useful in treating invasive wound infections.[43]

Nutritional support

P.A. Shaffer and W. Coleman advocated high caloric feeding for burn patients as early as 1909,[44] and D.W. Wilmore supported supranormal feeding with a caloric intake as high as 8000 kcal/day.[45] P. William Curreri (Figure 1.8) retrospectively looked at a number of burned patients to quantify the amount of calories required to maintain body weight over a period of time. In a study of nine adults with 40% TBSA burns, he found that maintenance feeding at 25 kcal/kg plus an additional 40 kcal/% TBSA burned per day would maintain their body weight during acute hospitalization.[46] A.B. Sutherland proposed that children should receive 60 kcal/kg body weight plus 35 kcal/% TBSA burned per day to maintain their body weight.[47] D.N. Herndon et al. subsequently showed that supplemental parenteral nutrition increased both immune deficiency and mortality, and recommended continuous enteral feeding, when tolerated, as a standard treatment for burns.[48]

The composition of nutritional sources for burned patients has been debated in the past. In 1959, F.D. Moore advocated that the negative nitrogen balance and weight loss in burns and trauma should be met with an adequate intake of nitrogen and calories.[49] This was supported by many

Figure 1.8 P. William Curreri.

others, including T. Blocker Jr,[50] C. Artz, [51] and later by Sutherland.[47]

Fluid resuscitation

The foundation of current fluid and electrolyte management began with the studies of Frank P. Underhill, who, as Professor of Pharmacology and Toxicology at Yale, studied 20 individuals burned in a 1921 fire at the Rialto Theatre.[52] Underhill found that the composition of blister fluid was similar to that of plasma and could be replicated by a salt solution containing protein. He suggested that burn patient mortality was due to loss of fluid and not, as previously thought, from toxins. In 1944, C.C. Lund and N.C. Browder estimated burn surface areas and developed diagrams by which physicians could easily draw the burned areas and derive a quantifiable percent describing the surface area burned.[53] This led to fluid replacement strategies based on surface area burned. G.A. Knaysi et al. proposed a simple 'rule of nines' for evaluating the percentage of body surface area burned.[54] In the late 1940s, O. Cope and F.D. Moore (Figure 1.9 and Figure 1.10) were able to quantify the amount of fluid required per area burned for adequate resuscitation from the amount needed in young adults who were trapped inside the burning Coconut Grove Nightclub in Boston in 1942. They postulated that the space between cells was a major recipient of plasma loss, causing swelling in both injured and uninjured tissues in proportion to the burn size.[55] Moore concluded that additional fluid, over that collected from the bed sheets and measured as evaporative water loss, was needed in the first 8 hours after burn to replace 'third space' losses. He then developed a formula for replacement of fluid based on the percent of the body surface area burned.[56] M.G. Kyle and A.B. Wallace showed that the heads of children were relatively larger and the legs relatively shorter than in adults, and modified the fluid replacement formulas for use in children.[57] I.E. Evans and his colleagues made recommendations relating fluid requirements to body weight and surface area burned.[58] From their recommendations, intravenous infusion of normal saline plus colloid (1.0 mL/kg/% burn) along with 2000 mL dextrose 5% solution to cover insensible water losses was administered over the first 24 hours after burn. One year later, E. Reiss presented the Brooke formula, which modified the Evans formula by substituting lactated Ringer's for normal saline and reducing the amount of colloid given.[59] Charles R. Baxter (Figure 1.11) and G. Tom Shires (Figure 1.12) developed a formula without colloid, which is now referred to as the Parkland formula.[60] This is perhaps the most widely used formula today and recommends 4 mL of lactated Ringer's solution/kg/% TBSA burned

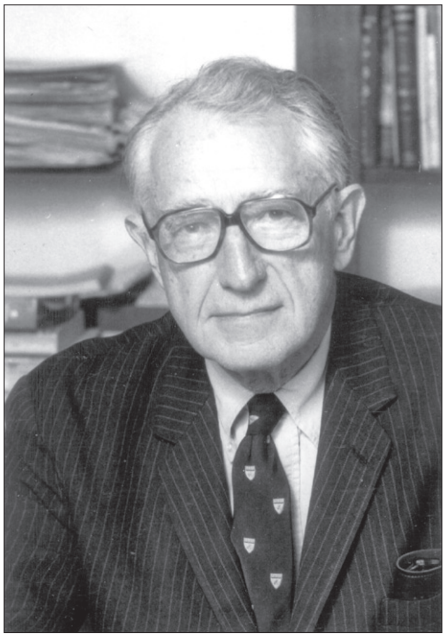

Figure 1.10 Francis D. Moore.

Figure 1.9 Oliver Cope.

Figure 1.11 Charles R. Baxter.

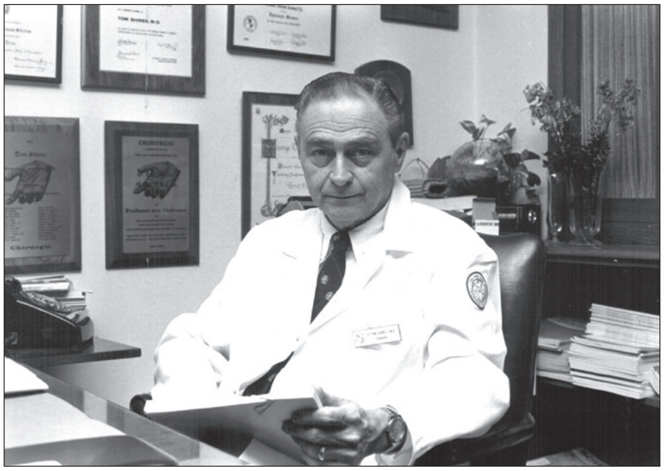

Figure 1.12 G. Tom Shires.

Figure 1.13 Basil A. Pruitt.

during the first 24 hours after burn. All these formulas advocate giving half of the fluid in the first 8 hours after burn and the other half in the subsequent 16 hours. Baxter and Shires discovered that after a cutaneous burn, not only is fluid deposited in the interstitial space but marked intracellular edema also develops. The excessive disruption of the sodium–potassium pump activity results in the inability of cells to remove excess fluid. They also showed that protein, given in the first 24 hours after injury, was not necessary, and postulated that, if used, it would leak out of the vessels and exacerbate edema. This was later substantiated in studies of burn patients with toxic inhalation injuries.[61] After a severe thermal injury fluid accumulates in the wound, and unless there is an adequate and early fluid replacement, hypovolemic shock will develop. A prolonged systemic inflammatory response to severe burns can lead to multiorgan dysfunction, sepsis, and even mortality. It has been suggested that for maximum benefit, fluid resuscitation should begin as early as 2 hours after burn.[9,62] Fluid requirements in children are greater with a concomitant inhalation injury, delayed fluid resuscitation, and larger burns.

Inhalation injury

During the 1950s and 1960s burn wound sepsis, nutrition, kidney dysfunction, wound coverage, and shock were the main foci of burn care specialists. Over the last 50 years these problems have been clinically treated with more and more success; hence a greater interest in a concomitant inhalation injury evolved. A simple classification of inhalation injury separates problems occurring in the first 24 hours after injury, which include upper airway obstruction and edema, from those that manifest after 24 hours. These include pulmonary edema and tracheobronchitis, which can progress to pneumonia, mucosal edema, and airway occlusion due to the formation of airway plugs from mucosal sloughing.[63,64] The extent of damage from the larynx to tracheobronchial tree depends upon the solubility of the toxic substance and the duration of exposure. Nearly 45% of inhalation injuries are limited to the upper passages above the vocal cords, and 50% have an injury to the major airways. Less than 5% have a direct parenchymal injury that results in early acute respiratory death.[64]

With the development of objective diagnostic methods, the incidence of an inhalation injury in burned patients can now be identified and its complications identified. Xenon-133 scanning was first used in 1972 in the diagnosis of inhalation injury.[65,66] When this radioisotope method is used in conjunction with a medical history, the identification of an inhalation injury is quite reliable. The fiberoptic bronchoscope is another diagnostic tool which, under topical anesthesia, can be used for the early diagnosis of an inhalation injury.[67] It is also capable of pulmonary lavage to remove airway plugs and deposited particulate matter.

K.Z. Shirani, Basil A. Pruitt (Figure 1.13), and A.D. Mason reported that smoke inhalation injury and pneumonia, in addition to age and burn size, greatly increased burn mortality.[68] The realization that the physician should not under-resuscitate burn patients with an inhalation injury was emphasized by P.D. Navar et al.[69] and D.N. Herndon et al.[70] A major inhalation injury requires 2 mL/kg/% TBSA burn more fluid in the first 24 hours after burn to maintain adequate urine output and organ perfusion. Multicenter studies looking at patients with adult respiratory distress have advocated respiratory support at low peak pressures to reduce the incidence of barotrauma. The high-frequency oscillating ventilator, advocated by C.J. Fitzpatrick[71] and J. Cortiella et al.,[72] has added the benefit of pressure ventilation at low tidal volumes plus rapid inspiratory minute volume, which provides a vibration to encourage inspissated sputum to travel up the airways. The use of heparin, *N*-acetylcysteine, nitric oxide inhalation, and bronchodilator aerosols have also been used with some apparent benefit, at least in pediatric populations.[73] Inhalation injury remains one of the most prominent causes of death in thermally injured patients. In children, the lethal burn area for a 10% mortality without a concomitant inhalation injury is 73% TBSA;

however, with an inhalation injury, the lethal burn size for a 10% mortality rate is 50% TBSA.[74]

Hypermetabolic response to trauma

Major decreases in mortality have also resulted from a better understanding of how to support the hypermetabolic response to severe burns. This response is characterized by an increase in the metabolic rate and peripheral catabolism. The catabolic response was described by H. Sneve as exhaustion and emaciation, and he recommended a nourishing diet and exercise.[75] O. Cope et al.[76] quantified the metabolic rate in patients with moderate burns, and Francis D. Moore advocated the maintenance of cell mass by continuous feeding to prevent catabolism after trauma and injury.[77] Over the last 30 years the hypermetabolic response to burn has been shown to increase metabolism, negative nitrogen balance, glucose intolerance, and insulin resistance. In 1974, Douglas Wilmore and colleagues defined catecholamines as the primary mediator of this hypermetabolic response, and suggested that catecholamines were five- to sixfold elevated after major burns, thereby causing an increase in peripheral lipolysis and catabolism of peripheral protein.[78] In 1984, P.Q. Bessey demonstrated that the stress response required not only catecholamines but also cortisol and glucagon.[79] Wilmore et al. examined the effect of ambient temperature on the hypermetabolic response to burns and reported that burn patients desired an environmental temperature of 33°C and were striving for a core temperature of 38.5°C.[80] Warming the environment from 28° to 33°C substantially decreased the hypermetabolic response, but did not abolish it. He suggested that the wound itself served as the afferent arm of the hypermetabolic response, and its consuming greed for glucose and other nutrients was at the expense of the rest of the body.[81] Wilmore also felt that heat was produced by biochemical inefficiency, which was later defined by Robert Wolfe as futile substrate cycling.[82] Wolfe et al. also demonstrated that burned patients were glucose intolerant and insulin resistant, with an increase in glucose transport to the periphery but a decrease in glucose uptake into the cells.[83] D.W. Hart et al. further showed that the metabolic response rose with increasing burn size, reaching a plateau at a 40% TBSA burn.[84]

In the past three decades, pharmacologic modulators, such as the β-receptor antagonist propranolol, the anabolic agent human recombinant growth hormone, the synthetic anabolic testosterone analog oxandrolone, insulin, and the glucose uptake modulator metformin, have all shown some beneficial effects in reducing the hypermetabolic response in burn patients.

Summary

The evolution of burn treatments has been extremely productive over the last 50 years. The mortality of severely burned patients has decreased significantly thanks to improvements in early resuscitation, infection control, nutrition, attenuation of the hypermetabolic response, and new and improved surgical approaches. In burned children, a 98% TBSA burn now has a 50% survival rate.[74] It is hoped that the next few years will witness the development of an artificial skin which combines the concepts of J.F. Burke [29] with the tissue culture technology described by E. Bell.[85] Inhalation injury, however, remains one of the major determinants of mortality in those with severe burns. Further improvements in the treatment of inhalation injuries are expected through the development of arterial venous CO_2 removal and extracorporeal membrane oxygenation devices.[86] Perhaps even lung transplants will fit into the treatment regimen for end-stage pulmonary failure. Research continues to strive for a better understanding of the pathophysiology of burn scar contractures and hypertrophic scarring.[87] Although decreases in burn mortality can be expected, continued advances to rehabilitate patients and return them to productive life are an important step forward in burn care management.

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CHAPTER 2

Teamwork for total burn care: burn centers and multidisciplinary burn teams

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Introduction

Severe burn injuries evoke strong emotional responses in most people, including health professionals, who are confronted by the specter of pain, deformity, and potential death. Intense pain and repeated episodes of sepsis, followed either by death or by survival encumbered by pronounced disfigurement and disability, have been the expected sequelae to serious burns for most of mankind's history.[1] However, these dire consequences have been ameliorated so that, although burn injury is still intensely painful and sad, the probability of death has been significantly diminished. During the decade prior to 1951, young adults (15–43 years of age) with total body surface area (TBSA) burns of 45% or greater had a 49% mortality rate (Table 2.1).[2] Forty years later, statistics from the pediatric and adult burn units in Galveston, Texas, show that a 49% mortality rate is associated with TBSA burns of 70% or greater in this age group. Over the past decade, mortality figures have decreased even more dramatically, so that almost all infants and children can be expected to survive when resuscitated adequately and quickly.[3] Although improved survival has been the primary focus of advances in burn treatment for many decades, that goal has now been virtually accomplished. The major goal is now rehabilitation of burn survivors to maximize quality of life and reduce morbidity.

Such improvement in forestalling death is a direct result of the maturation of burn care science. Scientifically sound analyses of patient data have led to the development of formulas for fluid resuscitation[4–6] and nutritional support.[7,8] Clinical research has demonstrated the utility of topical antimicrobials in delaying the onset of sepsis, thereby contributing to decreased mortality in burn patients. Prospective randomized clinical trials have shown that early surgical therapy is efficacious in improving survival for many burned patients by reducing blood loss and diminishing the occurrence of sepsis.[9–14] Basic science and clinical research have helped reduce mortality by characterizing the pathophysiological changes related to inhalation injury and suggesting treatment methods that have reduced the incidence of pulmonary edema and pneumonia.[15–18] Scientific investigations of the hypermetabolic response to major burn injury have led to improved management of this life-threatening phenomenon, not only enhancing survival, but also promising an improved quality of life.[19–32]

Optimal treatment of severely burned patients requires significant healthcare resources and has led to the development of burn centers. Centralizing services to regional burn centers has made the implementation of multidisciplinary acute critical care and long-term rehabilitation possible. It has also enhanced opportunities for study and research over the past several decades.

Over the past half century the implementation of a wide range of medical discoveries and innovations has improved patient outcomes following severe burns. Key areas of advancement in recent decades include fluid resuscitation protocols; early burn wound excision and closure with grafts or skin substitutes; nutritional support regimens; topical antimicrobials and treatment of sepsis; thermally neutral ambient temperatures; and pharmacological modulation of hypermetabolic and catabolic responses. These factors have reduced morbidity and mortality from severe burns by improving wound healing, reducing inflammation and energy demands, and attenuating hypermetabolism and muscle catabolism.

Melding scientific research with clinical care has been promoted in recent burn care history, largely because of the aggregation of burn patients into single-purpose units staffed by dedicated healthcare personnel. Dedicated burn units were first established in Great Britain to facilitate nursing care. The first US burn center was established at the Medical College of Virginia in 1946. In the same year, the US Army Surgical Research Unit (later renamed the US Army Institute of Surgical Research) was established. Directors of both centers and later, the founders of the Burn Hospitals of Shriners Hospitals for Children, emphasized the importance of collaboration between clinical care and basic scientific disciplines.[1]

The organizational design of these centers engendered a self-perpetuating feedback loop of clinical and basic scientific inquiry. In this system, scientists receive first-hand information about clinical problems, and clinicians receive provocative ideas about patient responses to injury from experts in other disciplines. Advances in burn care attest to the value of a dedicated burn unit organized around a collegial group of basic scientists, clinical researchers, and clinical caregivers, all asking questions of each other, sharing

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Table 2.1 Percent total body surface area (TBSA) burn producing an expected mortality of 50% in 1952, 1993, and 2006

Age (years)	1953† (% TBSA)	1993* (% TBSA)	2006° (% TBSA)
0–14	49	98	99
15–44	46	72	88
45–65	27	51	75
65	10	25	33

†Bull, JP, Fisher, AJ. *Annals of Surgery* 1954; 139.

*Shriners Hospital for Children and University of Texas Medical Branch, Galveston, Texas.

°Pereira CT *et al. J Am Coll Surg* 2006; 202(3): 536–548 and unpublished data. PP. 1138–1140 (PC65).

observations and information, and seeking solutions to improve patient welfare.

Findings from the group at the Army Surgical Research Institute point to the necessity of involving many disciplines in the treatment of patients with major burn injuries and stress the utility of a team concept.[1] The International Society of Burn Injuries and its journal, *Burns*, as well as the American Burn Association and its publication, *Journal of Burn Care and Research*, have publicized the notion of successful multidisciplinary work by burn teams to widespread audiences.

Members of a burn team

The management of severe burn injuries benefits from concentrated integration of health services and professionals, with care being significantly enhanced by a true multidisciplinary approach. The complex nature of burn injuries necessitates a diverse range of skills for optimal care. A single specialist cannot be expected to possess all the skills, knowledge, and energy required for the comprehensive care of severely injured patients. Thus, reliance is placed on a group of specialists to provide integrated care through innovative organization and collaboration.

In addition to burn-specific providers, the burn team consists of epidemiologists, molecular biologists, microbiologists, physiologists, biochemists, pharmacists, pathologists, endocrinologists, nutritionists, and numerous other scientific and medical specialists.

At times, the burn team can be thought of as including the environmental service workers responsible for cleaning the unit, the volunteers who may assist in a variety of ways to provide comfort for patients and families, the hospital administrator, and many others who support the day-to-day operations of a burn center and significantly affect the well-being of patients and staff. However, the traditional burn team consists of a multidisciplinary group of direct-care providers. Burn surgeons, nurses, dietitians, and physical and occupational therapists form the skeletal core; most burn units also include anesthesiologists, respiratory therapists, pharmacists, and social workers. The decrease in mortality rates in recent years has heightened interest in the quality of life of burn survivors, both acutely in the hospital and long term. Consequently, more burn units have added psychologists, psychiatrists, and more recently, exercise physiologists to their burn team. In pediatric units, child life specialists and school teachers are also significant members of the team.

Patients and their families are infrequently mentioned as members of the team but are obviously important in influencing the outcome of treatment. Persons with major burn injuries contribute actively to their own recovery, and each brings individual needs and agendas into the hospital setting that may influence the way treatment is provided by the professional care team.[33] The patient's family members often become active participants. This is obvious in the case of children, but also true in the case of adults. Family members become conduits of information from the professional staff to the patient. At times, they act as spokespersons for the patient, and at other times, they become advocates for the staff in encouraging the patient to cooperate with dreaded procedures.

With so many diverse personalities and specialists potentially involved, purporting to know what or who constitutes a burn team may seem absurd. Nevertheless, references to 'burn team' are plentiful, and there is agreement on the specialists and care providers whose expertise is required for optimal care of patients with significant burn injuries (Figure 2.1a and 2.1b).

Burn surgeons

The ultimate responsibility and overall control for the care of a patient lies with the admitting burn surgeon. The burn surgeon is either a general surgeon or plastic surgeon with expertise in providing emergency and critical care, as well as in performing skin grafting and amputations. The burn surgeon provides leadership and guidance for the rest of the team, which may include several surgeons. This leadership is particularly important during the early phase of patient care, when moment-to-moment decisions must be made based on the surgeon's knowledge of physiologic responses to injury, current scientific evidence, and appropriate medical/surgical treatments. The surgeon must not only possess knowledge and skill in medicine, but also be able to exchange information clearly with a diverse staff of experts in other disciplines. The surgeon alone cannot provide comprehensive care, but must be wise enough to know when and how to seek counsel as well as how to give clear and firm direction to activities surrounding patient care. The senior surgeon is accorded the most authority and control of any member of the team, and thus bears the responsibility and receives accolades for the success of the team as a whole.[33]

Nurses

Nurses represent the largest single disciplinary segment of the burn team, providing continuous coordinated care to the patient. They are responsible for technical management of the 24-hour physical treatment of the patient. They control the therapeutic milieu that allows the patient to recover. They also provide emotional support to the patient and their family. Nursing staff are often the first to identify changes in a patient's condition and initiate therapeutic interventions. Because recovery from a major burn is rather slow, burn nurses must merge the qualities of sophisticated intensive

Figure 2.1a, b Experts from diverse disciplines gather together with common goals and tasks, having overlapping values to achieve their objectives.

care nursing with the challenging aspects of psychiatric nursing. Nursing case management can play an important role in burn treatment, extending the coordination of care beyond the hospitalization through the lengthy period of outpatient rehabilitation.

Anesthesiologists

An anesthesiologist who is an expert in the altered physiologic parameters of burned patients is critical to the survival of the patient, who usually undergoes multiple acute surgical procedures. Anesthesiologists on the burn team must be familiar with the phases of burn recovery and the physiologic changes to be anticipated as the burn wounds heal.[1] Anesthesiologists play a significant role in facilitating comfort for burned patients, not only in the operating room, but also during the painful ordeals of dressing changes, staple removal, and physical exercise.

Respiratory therapists

Inhalation injury, prolonged bed rest, fluid shifts, and the threat of pneumonia, concomitant with burn injury, render respiratory therapists essential to the patient's welfare. Respiratory therapists evaluate pulmonary mechanics, perform therapy to facilitate breathing, and closely monitor the status of the patient's respiratory function.

Rehabilitation therapists

Occupational and physical therapists begin planning therapeutic interventions on the patient's admission to maximize functional recovery. Burned patients require special positioning and splinting, early mobilization, strengthening exercises, endurance activities, and pressure garments to promote healing while controlling scar formation. These therapists must be very creative in designing and applying the appropriate appliances. Knowledge of the timing of application is necessary. In addition, rehabilitation therapists must become expert behavioral managers, as their necessary treatments are usually painful to the recovering patient. While the patient is angry, protesting loudly, or pleading for mercy, the rehabilitation therapist must persist with aggressive treatment to combat quickly forming and very strong scar contractures. The same therapist, however, is typically rewarded with adoration and gratitude from an enabled burn survivor.

Nutritionists

A nutritionist or dietitian monitors daily caloric intake and weight maintenance. They also recommend dietary interventions to provide optimal nutritional support to combat the hypermetabolic response to burn injury. Caloric intake as well as intake of appropriate vitamins, minerals, and trace elements must be managed to promote wound healing and facilitate recovery.

Psychosocial experts

Psychiatrists, psychologists, and social workers with expertise in human behavior and psychotherapeutic interventions provide continuous sensitivity in caring for the emotional and mental wellbeing of patients and their families. These professionals must be knowledgeable about the process of burn recovery as well as human behavior to make optimal interventions. They serve as confidants and supports for patients, families, and on occasion, other burn team members.[34] They often assist colleagues from other disciplines in developing behavioral interventions for problematic patients, allowing both colleague and patient to achieve therapeutic success.[35] During the initial hospitalization, these experts manage the patient's mental status, pain tolerance, and anxiety level to provide comfort and facilitate physical recovery. As the patient progresses toward rehabilitation, the role of the mental health team becomes more prominent in supporting optimal psychological, social, and physical rehabilitation.

Exercise physiologist

The exercise physiologist has recently been recognized as a key member of the comprehensive burn rehabilitation team. Traditionally, exercise physiologists study acute and chronic adaptations to a wide range of exercise conditions. At our