Current Expectations for Survival in Pediatric Burns

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Background: Conventional wisdom and published reports suggest that children, particularly those younger than 48 months, have higher mortality rates after burns than young adults. However, coincident with refinements in resuscitation, operative techniques, and critical care, survival rates for children with burns seem to have improved. To document this change and to define current expectations, a review of deaths during two 7-year intervals separated by a decade was done.

Design: We examined the clinical course of children who died after admission for care of acute thermal burns during two 7-year intervals: calendar years 1974 to 1980 inclusive (group 1) and 1991 to 1997 inclusive (group 2). Dying children were stratified by total body surface area (TBSA) burned: small (0%-39%), midsize (40%-59%), and large (60%-100%) TBSA burns. Children who arrived with anoxic brain injury or in a moribund state with refractory shock were excluded from analysis (4 children in group 1 and 5 in group 2); 2 of these children in group 2 died and became solid organ donors.

Setting: Regional pediatric burn center.

Patients: Six hundred seventy-eight children in group 1 and 1150 children in group 2.

Main Outcome Measure: Survival.

Results: In children with 0% to 39% TBSA burns, mortality was 0.6% in group 1 and 0% in group 2 (Fisher exact test, \(P = .04\); \(\chi^2\) test, \(P = .02\)). In children with 40% to 59% TBSA burns, mortality was 7.7% in group 1 and 0% in group 2 (Fisher exact test, \(P = .07\); \(\chi^2\) test, \(P = .047\)). In children with 60% to 100% TBSA burns, mortality was 33.3% in group 1 and 14.3% in group 2 (Fisher exact test, \(P = .04\); \(\chi^2\) test, \(P = .02\)). Although 59% of the children in group 2 were younger than 48 months, including 55% of those with 40% to 59% TBSA burns and 41% of those with 60% to 100% TBSA burns, there were no deaths in this age group.

Conclusion: Survival rates after burns have improved significantly for children. At present, most children, even young children and children with large burns, should survive.


Although improved survival rates for adults who sustain a burn injury have been suggested by recent institutional reviews, survival rates have not been demonstrated in children. A 1991 review of 1443 adult and pediatric patients with burns cared for over 10 years demonstrated that children younger than 48 months with burns on more than 30% of their body surface had a higher mortality rate than older children with similar injuries (46.9% vs 12.5%, \(P < .01\)). These authors concluded, “These data indicate that children aged 48 months and younger do not tolerate large thermal injuries as well as adults.” A 1996 review of 449 pediatric patients cared for over a 6-year period reinforced this finding, demonstrating that children younger than 4 years with burns on more than 30% of their body surface had a higher mortality rate than older children with similar injuries (46.9% vs 12.5%, \(P < .01\)). These authors concluded, “Large burn size was the strongest predictor of mortality, followed by (in order) age younger than 4 years and the presence of inhalation injury. Infants and young children have the highest risk of death from burn injury. Burns on less than 30% total body surface area (TBSA) without an inhalation injury (such as small scald injuries) are occasionally lethal in infants and small children, despite modern therapy.”
METHODS

We examined the difference in mortality in children admitted to the Boston Shriners Burns Hospital (Boston, Mass) for care of acute thermal burns during two 7-year intervals: calendar years 1974 to 1980 inclusive (group 1) and 1991 to 1997 inclusive (group 2). The Boston Shriners Burns Hospital is a 30-bed facility, certified as a burn center by the American College of Surgeons (Chicago, Ill) and American Burn Association (Chicago), that provides comprehensive free care to children with burn injuries of all sizes and severity. During the decade between the 2 intervals, major advances were made in many aspects of burn care, including resuscitation, intensive care, mechanical ventilation, monitoring, antimicrobials, vascular access, nutritional support, wound excision, pain control, skin and blood banking, and techniques of reconstruction and rehabilitation. Early excision and effective immediate closure of deep burns prevents the otherwise inevitable occurrence of wound sepsis and systemic infection and inflammation.

Permission was granted by the human studies committee for this review. Medical records of all patients who died were reviewed for demographics, inhalation injury, length of stay, time to initial excision and closure operation, and cause of death. By record review, an effort was made to determine if gross total wound closure (either permanent or temporary) had been achieved by the time of death. This was coded as yes or no and was deemed to have been achieved if, on review of the record, at least 75% of the wound appeared to have been closed by the time the child died. The hospital does have a computerized registry, but the records of earlier patients had not been entered. All reviews were done using paper records. Dying children were stratified by TBSA burned: small (0%-39%), midsize (40%-59%), and large (60%-100%) TBSA burns. Children who lived less than 24 hours after the injury (ie, those who generally arrived in a moribund state at the time of death), only 16 (69%) of the 23 appeared from record review to have at least 75% wound closure at the time of death. In group 1, 23 (77%) of 30 underwent at least 1 operation with 75% wound closure vs 4 of 4 children who died were reviewed in detail. Children who lived less than 24 hours after admission or had support withdrawn secondary to brain death associated with their injury were excluded from further analysis (Table 1).

From 1974 to 1980 inclusive (group 1), there were 678 children admitted for treatment of acute thermal burns, and from 1991 to 1997 inclusive (group 2), 1150. The medical records of all those children who died were reviewed in detail. Children who lived less than 24 hours after admission or had support withdrawn secondary to brain death associated with their injury were excluded from further analysis (Table 1). There were 4 such children (0.6%) in group 1 and 5 (0.4%) in group 2. All 4 children in group 1 who were excluded died of refractory shock, which they had at admission; 1 of the children probably had an anoxic brain injury, although this was not established other than by clinical examination. Of the 5 children in group 2 who were excluded, 2 were diagnosed as having brain death and became solid organ donors, 2 were brain dead at admission by clinical examination with massive burns and had intensive care withdrawn, and 1 arrived moribund and in profound shock that remained refractory. All children who lived more than 24 hours and later died (30 in group 1 and 6 in group 2) were subjected to further analysis, as it was believed that they could have been saved.

Mechanisms of injury were similar in the 2 groups. In group 1, there were 16 children (53.3%) injured in structural fires, 9 children (30%) injured in outdoor accidents involving flames, 4 children (13.3%) injured by scalding, and 1 child (3.3%) injured by a high-voltage electrical current with secondary clothing ignition. In group 2, there were 3 children (50%) injured in structural fires, 1 child (16.7%) injured in an outdoor accident involving flames, and 2 children (33.3%) injured by high voltage electrical currents with secondary clothing ignition.

The presence or absence of inhalation injury was well documented in children in group 2, by clinical criteria and bronchoscopy, and was present in all children in group 2 who died. The presence or absence of inhalation injury was less well documented in the earlier interval, but was probably present in 19 (63%), of the 30 children in group 1, based on a careful review of the medical records.

In group 1, 23 (77%) of 30 underwent at least 1 operation to excise and close the wound, with the first operation being performed an average of 2.5 ± 1.8 days (range, 0-6 days) after admission. However, at the time of death, only 16 (69%) of the 23 appeared from record review to have at least 75% wound closure at the time of death. In group 2, 4 (66%) of 6 underwent at least 1 operation to excise and close the wound. One of these children underwent the excision at another institution prior to transfer. When this child is excluded, the first operation was performed an average of 0.7 ± 0.57 days (range, 0-1 days) after admission. On review of the medical records, it appeared that the wounds of each of the 4 children who underwent operations were at least 75% closed at the time of death. Despite the trend toward earlier operation (2.5 ± 1.8 vs 0.7 ± 0.6 days, P = .08) and more effective closure (16 of 23 children who underwent operation with 75% wound closure vs 4 of 4 children who...
underwent operation with 75% wound closure, \( P = .27 \).
In the second interval, these differences did not reach statistical significance.

After excluding those children with anoxic brain injury or refractory shock, overall survival in group 1 was 644 (95.5%) of 674 children and 1139 (99.5%) of 1145 children in group 2 (\( P/H_{11021} .001 \)). For further analysis, children were stratified by TBSA burned: small (0%-39%), midsize (40%-59%), and large (60%-100%) TBSA burns. Data are presented for each burn size group in Table 2.

In children with 0% to 39% TBSA burns, mortality was 0.6% in group 1 and 0% in group 2 (Fisher exact test, \( P = .04; \chi^2 \) test, \( P = .02 \)). In children with 40% to 59% TBSA burns, mortality was 7.7% in group 1 and 0% in group 2 (Fisher exact test, \( P = .06; \chi^2 \) test, \( P = .04 \)). In children with 60% to 100% TBSA burns, mortality was 33.3% in group 1 and 14.3% in group 2 (Fisher exact test, \( P = .04; \chi^2 \) test, \( P = .02 \)).

The most common cause of death in the earlier period was late sepsis with multiple organ failure (91% of deaths). This has declined in frequency, causing only 33% of the deaths in the recent interval. Among children in the large burn size group, the average length of stay was 31.8 ± 34.1 days in group 1 compared with 12.2 ± 16.7 days in group 2 (\( P = .08 \)). There were no significant differences between the groups in mean burn size or frequency of inhalation injury that could account for the mortality differences.

The effect of young age was evaluated, given the conventional wisdom that children younger than 48 months have predictably higher mortality rates. In group 1, 13 (43%) of 30 children who died were younger than 4 years. These consisted of 3 (100%) of 3 deaths in the small burn group, 2 (40%) of 5 in the midsized burn group, and 8 (36%) of 22 in the large burn size group. From 1991 to 1997, there were no deaths in any child younger than 48 months, despite the fact that 676 (59%) of the 1145 children in group 2 were in this age group: 632 (60%) of 1053 in the 0% to 39% TBSA burn group, 27 (55%) of 49 in the 40% to 59% TBSA burn group, and 17 (41%) of 42 in the 60% to 100% TBSA burn group.

### Table 1. Injury Severity Categorized by Age

<table>
<thead>
<tr>
<th>Age, y</th>
<th>Burn Size, %</th>
<th>Inhalation Injury</th>
<th>Anoxic Brain Injury</th>
<th>Cause of Death</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>95</td>
<td>Yes</td>
<td>No</td>
<td>Refractory shock</td>
</tr>
<tr>
<td>1</td>
<td>65</td>
<td>Yes</td>
<td>No</td>
<td>Refractory shock</td>
</tr>
<tr>
<td>1.1</td>
<td>100</td>
<td>Yes</td>
<td>Probable</td>
<td>Respiratory failure</td>
</tr>
<tr>
<td>6.7</td>
<td>61</td>
<td>Yes</td>
<td>No</td>
<td>Refractory shock</td>
</tr>
</tbody>
</table>

### Table 2. Deaths Categorized by Group*

<table>
<thead>
<tr>
<th>Interval</th>
<th>Admitted</th>
<th>Died (%)</th>
<th>Burn Size, %</th>
<th>Inhalation Injury, No. (%)</th>
<th>Length of Stay Prior to Death, d</th>
<th>Cause of Death</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1 and Group 2 Deaths in the 0% to 39% TBSA Burn Group*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1974-1980</td>
<td>543</td>
<td>3 (0.6)</td>
<td>22.0 ± 7.5</td>
<td>0/3 (0)</td>
<td>5.3 ± 1.2</td>
<td>Iatrogenic vascular injury (1); sepsis/MOF (1); sepsis/respiratory failure (1)</td>
</tr>
<tr>
<td>1991-1997</td>
<td>1053</td>
<td>0 (0)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>( P )</td>
<td>NA</td>
<td>NA</td>
<td>NS†</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

| Group 1 and Group 2 Deaths in the 40% to 59% TBSA Burn Group | | | | | | |
| 1974-1980 | 65 | 5 (7.7) | 49.8 ± 5.9 | 3/5 (60) | 60.0 ± 41.1 | Sepsis/MOF (4); respiratory failure (1) |
| 1991-1997 | 49 | 0 (0) | NA | NA | NA | NA |
| \( P \) | NA | NA | NS† | NA | NA | NA |

| Group 1 and Group 2 Deaths in the 60% to 100% TBSA Burn Group | | | | | | |
| 1974-1980 | 66 | 22 (33.3) | 76.8 ± 12.4 | 16/23 (69.6) | 29.9 ± 31.1 | Sepsis/MOF (21); sepsis/TEF (1); respiratory failure (1) |
| 1991-1997 | 42 | 6 (14.3) | 83.6 ± 13.3 | 6/6 (100) | 12.9 ± 16.8 | Sepsis/MOF (2); respiratory failure (2); cardiac arrhythmia in high-voltage injury (1) |
| \( P \) | NA | .04† | NS | NS | .05 | NA |

*Admitted indicates admissions in this burn group during the specified interval; died (%), total number who died after excluded children are removed; and the percentage of admitted children who died in the specified burn size group after excluded children are removed; inhalation injury, the number of children who died who had inhalation injury; sepsis/MOF, sepsis with multiple organ failure syndrome; respiratory failure, isolated respiratory failure without apparent sepsis; NA, not applicable; NS, not significant; and sepsis/TEF, sepsis with associated tracheoesophageal fistula.
†Fisher exact test.
‡\( \chi^2 \) Test.

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Clinical experience and available data suggest that the large majority of those who survive serious burns have favorable long-term outcomes.\textsuperscript{7-10} Even those who survive massive injuries can be expected to have a satisfying quality of life, particularly if they participate in programs that offer experienced burn aftercare.\textsuperscript{11-14} Although, coincident with an increasing emphasis on fire safety and prevention, the incidence of massive burns may be declining,\textsuperscript{2,15} serious burns still occur regularly and remain very difficult clinical problems requiring care from several specialized disciplines. These needs have prompted the increasing concentration of burned children in regional centers in the past 20 years.

The natural history of an extensive burn is grim. Those who survive burn shock succumb to wound sepsis in the days and weeks after injury.\textsuperscript{16,17} Initial attempts to modify this natural history involved fluid resuscitation, topical medications, and antibiotics. The increased need for fluids in burn patients was recognized in the 1930s and 1940s,\textsuperscript{18} and fluid resuscitation techniques were developed and continue to be refined.\textsuperscript{19,21} However, the promulgation of these resuscitation formulas sometimes allowed patients with large burns to survive burn shock, only to die from sepsis later.

Perhaps the worst possible outcome after a large burn, both in terms of cost and patient suffering, is seen in cases in which effective resuscitation and strong intensive care is combined with ineffectual wound closure. Such patients suffer protracted septic hospitalizations and often eventual death. This phenomenon was highlighted in a series of reports by Linn et al\textsuperscript{22-24} in the early 1970s. These authors described burn care in Florida at that time, comparing outcomes between those treated in general hospitals and those treated in the state's then multiple self-designated burn units. These patients presumably received good general supportive care, but wounds were not treated surgically until late in the course of the disease, as this was prior to the wide adoption of early excision and closure of burns. Hospital stays were longer in the burn units and outcomes were unsatisfying. Linn et al concluded that “burns might be identified as an illness for which current limits in management abilities limit the ultimate proportion of successful outcomes.” In 1971, mortality rates in a large regional burn unit were examined.\textsuperscript{25} This discussion focused on the emergence of gram-negative, rather than gram-positive, bacteria as the more common cause of septic death. The survival rate for TBSA burns on more than 60% of the body surface was less than 10%. The report concluded that (1) burn deaths tend to occur later in the course of treatment than they did 10 years previously (probably because of better supportive care), and (2) the species of organisms producing the complications of infection are continuously changing (probably because of the introduction of newer antibiotics). However, survival was little affected by refinements in supportive care and antibiotics.

In 1970, Janzekovic\textsuperscript{26} published a report describing the layered excision of small burn wounds with immediate autografting in which she reported decreased hospital stays and improved functional outcomes. This concept was then taken to patients with larger injuries, using autograft and allograft, and reports appeared demonstrating improved survival, truncated hospital stays, and the perception of improved functional results.\textsuperscript{27-29} This maneuver addressed the root cause of the common septic mortality, and is now widely practiced.\textsuperscript{30,31}

Predicting burn mortality has been evaluated by several authors who have used burn size and the presence or absence of inhalation injury to develop predictive equations.\textsuperscript{32-34} In a recent report from the Massachusetts General Hospital (Boston) and Boston Shriners Burn Hospital burn program,\textsuperscript{35} data from 1665 adult and pediatric patients with burn injuries admitted from 1990 to 1994 were used to develop objective probability estimates for survival. Using logistic-regression analysis, age older than 60 years, burn size more than 40% TBSA, and inhalation injury were identified as significant risk factors for mortality. The data sets for this study and for the present study were different, although there was a partial overlap between the earlier report and the second interval of the current report. Based on our recent experience, development of such accurate predictive equations does not seem possible for children in the current era, there being no mortality in those with a burn size of less than 60% TBSA.

The influence of inhalation injury on mortality has been demonstrated by several reports.\textsuperscript{2,35,36} All those who died during the recent interval had sustained inhalation injury, and more than 60% of those who died during the earlier interval had sustained inhalation injury. The combination of a burn of 60% or more with an inhalation injury clearly places a child in a higher risk category. The longer hospitalization time prior to death in the earlier compared with the later interval requires comment. These deaths were generally due to late sepsis or multiple organ failure, which in burn patients may result from open wounds. More effective wound closure, aided by the ready availability of cadaver allograft, may have contributed to a reduction of this phenomenon in the recent interval.

The influence of young age on mortality was examined, as conventional wisdom holds that younger children are at a higher risk for mortality after burn injury.\textsuperscript{3,4} However, our data seem to refute this concept, given the fact that there were no deaths in children younger than 48 months in the recent 7-year interval, despite substantial numbers of seriously burned children in this age group. The perceived improvement in survival in this age group is supported by current clinical experience\textsuperscript{27} and may be attributed to improved critical care and operative techniques for younger children.

It is impossible to attribute the improvement in survival between these intervals to any single change. Strides have been made in resuscitation, intensive care, mechanical ventilation, monitoring, antimicrobials, vascular access, nutritional support, wound excision, pain control, and skin and blood banking. All of these changes have contributed, although it seems likely that the most important change is that which directly addresses the primary problem of the burn patient: prompt identification, excision, and effective closure of deep wounds. At the present time, most children, even young children and children with large burns, should survive their injuries.
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REFERENCES