



# Cool Running Water First Aid Decreases Skin Grafting Requirements in Pediatric Burns: A Cohort Study of Two Thousand Four Hundred Ninety-five Children

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**Study objective:** First-aid guidelines recommend the administration of cool running water in the early management of thermal injury. Our objective is to analyze the associations between first aid and skin-grafting requirements in children with burns.

**Methods:** This cohort study used a prospectively collected registry of patients managed at a tertiary children's hospital. Multivariate logistic regression models were used to evaluate the relationship between first aid and the requirement for skin grafting. Secondary outcomes included time to re-epithelialization, wound depth, hospital admission and length of stay, and operating room interventions. Adequate first aid was defined as 20 minutes of cool running water within 3 hours of injury.

**Results:** In our cohort of 2,495 children, 2,259 (90.6%) received first aid involving running water, but only 1,780 (71.3%) were given the adequate duration. A total of 236 children (9.5%) required grafting. The odds of grafting were decreased in the adequate first aid group (odds ratio [OR] 0.6; 95% confidence interval [CI] 0.4 to 0.8). The provision of adequate running water was further associated with reductions in full-thickness depth (OR 0.4; 95% CI 0.2 to 0.6), hospital admission (OR 0.7; 95% CI 0.3 to 0.9), and operating room interventions (OR 0.7; 95% CI 0.5 to 0.9), but not hospital length of stay (hazard ratio=0.9; 95% CI 0.7 to 1.2;  $P=.48$ ).

**Conclusion:** Burn severity and clinical outcomes improved with the administration of cool running water. Adequate first aid must be prioritized by out-of-hospital and emergency medical services in the preliminary management of pediatric burns. [Ann Emerg Med. 2020;75:75-85.]

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## INTRODUCTION

### Background

Current first-aid guidelines in the United States,<sup>1</sup> United Kingdom,<sup>2</sup> and Australia<sup>3</sup> call for the irrigation of acute burns with cool running water. In contrast with that for alternative treatments such as ice,<sup>4</sup> aloe vera,<sup>5</sup> and toothpaste,<sup>6</sup> a solid body of evidence has developed around the favorable effects of water first aid. Early research reported possible associations with decreased mortality,<sup>7</sup> infection, clinical appointments, pain,<sup>8</sup> and scarring.<sup>9</sup> More recently, a series of animal model studies observed the greatest improvements in re-epithelialization, depth, and cosmetic outcomes with the application of cool running water for 20 minutes immediately postburn, although benefits were still noted after a delay of up to 3 hours.<sup>4,10-12</sup>

Despite this research, there is still debate surrounding the optimal duration of first aid, with recommendations ranging from a full 20 minutes in Australia,<sup>3</sup> the United Kingdom,<sup>2</sup> and Europe<sup>13</sup> to only approximately 5 minutes in the United States.<sup>1</sup>

Relatively little research has explored the effect of cool running water on clinical outcomes in human populations, and the few existing studies lack consistency in their findings and definitions of appropriate first aid.<sup>14-17</sup> By far the most comprehensive human evidence to date was provided by a pair of recent Australian studies involving large adult cohorts.<sup>18,19</sup> Both identified several clinical benefits associated with the provision of cool running water first aid, including decreased surgical requirements, time to re-epithelialization, burn depth, ICU admission, and length

**Editor's Capsule Summary***What is already known on this topic*

Many guidelines recommend irrigation with cool running water for 20 minutes' duration after a burn.

*What question this study addressed*

Is there an association between 20 minutes of cool running water within 3 hours of injury and skin-grafting requirements in children with burns?

*What this study adds to our knowledge*

In this cohort study, the odds of skin grafting were decreased among children who had 20 minutes of cold running water (odds ratio 0.6; 95% confidence interval 0.4 to 0.8).

*How this is relevant to clinical practice*

Although this study establishes only association, in the absence of better-evidence first-aid guidelines, physicians should promote 20 minutes of cool-water irrigation for burns in children.

of stay in the hospital. Together, they were the first studies to convincingly demonstrate cool running water's effectiveness as a first-aid intervention for adult burns.

**Importance**

Although children are at particularly high risk of burn injuries,<sup>20</sup> there is a paucity of literature addressing the relationship between burn first aid and clinical outcomes in pediatric populations. Because of differences in volume, surface area,<sup>21</sup> and skin thickness,<sup>22,23</sup> it is unknown whether benefits in adults apply to children.

**Goals of This Investigation**

The purpose of this study was to determine the relationship between cool running water first aid and burn wound healing in a large pediatric cohort. We tested the hypothesis that adequate first aid, 20 minutes of cool running water, would be associated with a decrease in the odds of grafting. We further examined its relationship with secondary outcomes, including time to re-epithelialization, burn depth, hospital admission, hospital length of stay, and general operating room requirements.

**MATERIALS AND METHODS****Study Design and Setting**

This study was designed with a prospectively collected database that documents every pediatric burn patient (0 to

16 years) attending the only dedicated children's burn center in the Australian state of Queensland. The database contains information on all inpatients and outpatients treated at the center, capturing the entirety of their journey of care until discharge from the service or referral to scar management. Data from July 2013 to June 2016 were extracted and analyzed.

In line with recommendations by the European Burns Association,<sup>13</sup> British Burn Association,<sup>2</sup> and Australian and New Zealand Burn Association,<sup>3</sup> first aid was characterized as adequate if it involved greater than or equal to 20 minutes of cool running water delivered either cumulatively or continuously within 3 hours of injury. Any other form of first aid, including cool running water of less than 20 minutes' duration or the use of alternatives (eg, still water, ice, aloe vera), was classified as inadequate. Friction, electrical, and chemical burns were excluded, along with cases in which the type or duration of first aid was unknown.

The study was approved by the Children's Health Service District–Human Research Ethics Committee. Consent for inclusion in the database was obtained at data collection. Patient information was deidentified while undergoing statistical analysis, maintaining patient privacy and confidentiality.

**Selection of Participants**

Investigators conducted structured interviews with all families who consented to data collection at their first presentation to the participating hospital's burn outpatient department or inpatient ward. Patients were referred to the burn service by the children's hospital's own emergency department (ED), a local hospital ED, a general practitioner, or another source (eg, a pediatrician). Information collected during the structured interviews included demographics and injury-related details such as mechanism of injury and first aid. All interventions performed in the first 3 hours postinjury were documented, encompassing treatment provided at the scene of the injury, in the care of paramedics, in the ED or other referral center, or all 3. Total first aid was divided into 6 categories: no first aid; an alternative to cool running water; or durations of cool running water lasting less than 5 minutes, 5 to 10 minutes, 11 to 19 minutes, or greater than or equal to 20 minutes.

Because previous research demonstrated that socioeconomic disadvantage was associated with a reduced likelihood of receiving first aid and poorer clinical outcomes among children with burns,<sup>24,25</sup> patient socioeconomic status was assessed to be included as a covariate in the

analytic models. It was evaluated indirectly with postcode through the Socio-Economic Indexes for Areas developed by the Australian Bureau of Statistics.<sup>26</sup> For the purposes of this research, socioeconomic status deciles were divided into 3 groups: disadvantaged (deciles 1 to 4), advantaged (deciles 5 to 8), and highly advantaged (deciles 9 and 10).

### Outcome Measures

The primary outcome of the study, skin grafting, serves as a strong indicator of burn severity, healing capacity, and patient morbidity. Grafting is undertaken only when clinicians conclude that a wound is incapable of healing spontaneously or without sufficient speed to prevent significant scarring. Secondary outcomes included time to re-epithelialization among ungrafted burns, wound depth, hospital admission and length of stay, and requirements for any operating room interventions.

Grafting procedures, operating room interventions, hospital admission, and hospital length of stay were recorded through active tracking of patients and post hoc review of their medical charts. Time to re-epithelialization was assessed by calculating the number of days between the date of injury and the completion of acute treatment in the outpatient department. Senior burns clinicians visually assessed and classified burn depth on initial review in the outpatient department or inpatient ward according to the classification system by Shakespeare.<sup>27</sup> For burns characterized by a mixture of thicknesses, researchers recorded the most severe depth. Total body surface area percentage was estimated with the Lund and Browder<sup>28</sup> method, also on initial assessment.

### Primary Data Analysis

Descriptive statistics were carried out for all key variables, with 95% confidence intervals (CIs) reported where relevant. Median and interquartile range were calculated for continuous data.  $\chi^2$  Tests were performed to examine the relationships between purely categorical variables and the provision of first aid. Where variables were continuous, Kruskal-Wallis and Mann-Whitney tests were used.

Associations between cool running water first aid and each outcome variable were evaluated by performing 3 separate comparisons, based on different categorizations of first-aid duration and type. The primary analysis involved the comparison of wounds given adequate first aid composed of greater than or equal to 20 minutes of cool running water to those managed inadequately with any other form of first aid. Further comparisons were conducted between cool running water-treated burns and

those that received either no first aid or an alternative to cool running water, and the 6 durational categories of first aid outlined previously.

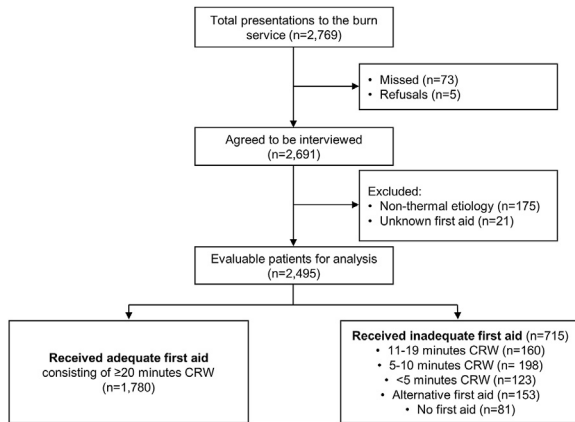
The relationship between adequate cool running water and the studied clinical outcomes was evaluated first by the risk difference and 95% CI. Additionally, associations with grafting, hospital admission, and operating room intervention were assessed by binomial logistic regression models. A multinomial logistic regression model was used to identify any associations with depth. From these logistic regressions, odds ratios (ORs) for the outcome variables, as well as 95% CI, were estimated. Hazard ratios (HRs) and 95% CI of time to re-epithelialization and hospital length of stay were determined with Cox regression models. To assess the relationship between first aid and healing in burns at greatest risk of scarring, subgroup analyses—also involving Cox regression models—were conducted to estimate HR and 95% CI of time to re-epithelialization in burns requiring greater than or equal to 10 days to re-epithelialize. This threshold was selected in light of the study by Cubison et al<sup>29</sup> of hypertrophic scar formation in children with scald injuries, which identified 10 to 14 days as the shortest period of burn wound healing associated with scarring. In accordance with the practices and recommendations of previous studies investigating first aid for burns,<sup>18,19</sup> all regression models were adjusted for age, sex, socioeconomic status, mechanism of injury, and total body surface area. Logistic regression was chosen over other methods such as propensity score matching, given its precedence of use in burns first aid literature and evidence suggesting it has less bias in cohorts with large numbers of events per confounder.<sup>30</sup>  $P < .05$  was accepted as statistically significant. All data analyses were conducted with SPSS (version 25; SPSS, Inc., Chicago, IL).

## RESULTS

### Characteristics of Study Subjects

During the study period, 2,769 patients attended the pediatric burn center. Interviews were conducted with the families of 2,691 children (Figure 1). The study excluded 175 cases with a nonthermal burn and 21 cases with unknown first-aid type, duration, or both.

Among the remaining 2,495 patients, the median age was 2 years (interquartile range [IQR] 1.0 to 6.0 years) (Table 1). Male participants composed 59.1% ( $n=1,462$ ) of the cohort. Scalds were identified as the mechanism of injury in 49.1% of cases ( $n=1,224$ ). A majority of injuries occurred in the home (85.3%;  $n=2,108$ ), and the most commonly affected body site was the upper limbs (40.3%;  $n=993$ ).



**Figure 1.** Participant flow. CRW, Cool running water.

Most patients first presented to an ED during their initial care. Local hospital EDs were responsible for 56.2% ( $n=1,402$ ) of the referrals to the burn center, and another 36.9% ( $n=921$ ) were made by the participating hospital's own ED. The remaining patients were referred from a general practice (5.0%;  $n=124$ ) or another source (eg, a pediatrician, self-referral) (1.9%;  $n=48$ ).

There was a median delay of 3.0 days (IQR 2.0 to 4.0 days) between injury and presentation to the burn center. At initial assessment by burn service clinicians, the median total body surface area was 1.0% (IQR 0.5% to 2.0%), with a range of less than 1% to 84%. Injuries with a total body surface area of 5% or greater composed 10.3% ( $n=255$ ) of the sample. Most burns were classified as superficial and partial thickness in depth (65.7%;  $n=1,604$ ).

## Main Results

Fully 96.8% of all patients (95% CI 96.1% to 97.4%;  $n=2,414$ ) had received some form of first aid within 3 hours of injury. Greater than 9 in 10 patients (90.6%; 95% CI 89.4% to 91.7%;  $n=2,259$ ) had their burns cooled with running water, but far fewer, 71.3% (95% CI 69.6% to 73.1%;  $n=1,780$ ), were given the recommended 20 minutes of cool running water. Of these patients, only 789 (44.3%; 95% CI 42% to 47%) were administered the complete duration of adequate cooling at the scene of the injury. Among the 152 children provided an alternative to cool running water, the most common treatments were still water (23.0%;  $n=35$ ), ice (21.1%;  $n=32$ ), and cold compresses (16.4%;  $n=25$ ).

Adequate first-aid provision was significantly associated with injury mechanism ( $\chi^2=109.4$ ;  $P<.001$ ). The highest proportions of adequately treated patients were those with scalds (77.7%), followed by contact burns (67.7%), flame

**Table 1.** Patient and wound demographics.

Variable	Median (IQR)	N
<b>Patient age, y</b>	2 (1-6)	2,494
<b>Total body surface area percentage affected</b>	1 (0.5-2.0)	2,485
	%	
<b>Sex</b>		
Male patient	59.1	1,462
<b>Mechanism of injury</b>		
Scald	49.1	1,224
Contact	44.7	1,116
Flame	4.8	119
Radiant heat	1.4	36
<b>Place of injury</b>		
Home	85.3	2,108
Holiday	5.8	144
Industrial/trade/farm	2.1	51
Recreation/sports	3.8	94
School or residential	1.6	39
Street	0.6	14
Other	0.8	20
<b>Body part injured</b>		
Upper limb	40.3	993
Multiple	24.5	604
Lower limb	22.3	549
Torso	9.2	228
Head	3.8	93
<b>Total body surface area percentage affected</b>		
<5	89.7	2,230
5-10	7.2	179
>10	3.1	76
<b>Wound depth</b>		
Superficial	3.2	78
Superficial partial thickness	65.7	1,604
Deep dermal partial thickness	27.1	661
Full thickness	4.1	100

Data were complete for mechanism, operating room interventions, and hospital admission. Categories in which data were missing included age ( $n=1$ ; 0.08%), total body surface area percentage affected ( $n=10$ ; 0.40%), sex ( $n=21$ ; 0.88%), place of injury ( $n=25$ ; 1.00%), body part injured ( $n=28$ ; 1.12%), and wound depth ( $n=52$ ; 2.08%).

injuries (59.7%), and radiant heat burns (8.3%). There was no association with age ( $Z=-0.911$ ;  $P=.36$ ), sex ( $\chi^2=109.4$ ;  $P=.17$ ), or total body surface area ( $Z=-0.4$ ;  $P=.72$ ).

Table 2 describes the differences in clinical outcomes and burn severity with adequate and inadequate first aid. Skin grafting was undertaken in 9.5% of cases (95% CI 8.3% to 10.6%;  $n=236$ ). The administration of adequate

**Table 2.** Differences in clinical outcomes with adequate and inadequate first aid.

Outcome	Adequate First Aid (n=1,780)			Inadequate First Aid (n= 715)			Difference	
	n*	%	SD/IQR	n	%	SD/IQR	%	95% CI
<b>Skin grafting</b>	139	7.8	(0.6)	97	13.6	(1.3)	-5.8	(-4.5 to -7.0)
<b>Full-thickness depth</b>	47	2.7	(0.4)	53	7.6	(1.0)	-4.7	(-3.7 to -6.1)
<b>Hospital admission</b>	234	13.2	(0.8)	129	18.0	(1.4)	-4.9	(-3.7 to -6.15)
<b>Operating room intervention</b>	178	10.0	(0.7)	107	15.0	(1.3)	-5.0	(-3.7 to -6.2)
<b>Time to re-epithelialization, median, days</b>								
All burns	10.0	— <sup>†</sup>	(7.0 to 14.0)	10.0	—	(7.0 to 15.0)	0.0	(0.0 to -1.0)
Burns requiring ≥10 days to re-epithelialize	13.0	—	(10.0 to 18.0)	14.0	—	(11.0 to 20.0)	-1.0	(-1.0 to -2.0)
<b>Hospital length of stay, median time, days</b>	3.0	—	(1.0 to 10.0)	3.0	—	(1.0 to 11.8)	0.0	(0.0 to -1.8)

\*Unless otherwise stated.

<sup>†</sup>Dashes indicate not applicable.

cool running water first aid was associated with a decreased need for grafting; relative to all other forms of first aid, adequate cool running water yielded an OR of 0.6 (95% CI 0.4 to 0.8;  $P<.001$ ) (Figure 2).

The odds of receiving skin grafting were reduced by 44.1% (OR=0.6; 95% CI 0.4 to 0.9;  $P=.007$ ) in children provided any amount of cooling with running water (Table E1, available online at <http://www.annemergmed.com>). A dose-response relationship was noted between the odds of grafting and duration of cool running water (Figure 3). Compared with children who received no treatment, those who were administered greater than or equal to 5 minutes of cool running water or an alternative had significantly decreased odds of receiving grafting.

Among burns that did not require grafting, median time to re-epithelialization was 10 days (IQR 7 to 14 days). The likelihood of re-epithelialization was 29% greater among cool running water-treated injuries (HR=1.3; 95% CI 1.1 to 1.5;  $P=.003$ ) (Table 3) per day postburn. However, administration of cool running water was not associated with a decrease in median time to re-epithelialization. A comparison of adequately and inadequately treated burns yielded no significant difference in re-epithelialization among all wounds (HR=1.1; 95% CI 1.0 to 1.2;  $P=.06$ ). For the 1,198 burns (59.2%) requiring 10 days or longer to re-epithelialize, however, wound closure was significantly faster after the application of adequate first aid (HR=1.2; 95% CI 1.0 to 1.3;  $P=.04$ ), with a reduction in median time to re-epithelialization of 1 day, from 14 to 13 days.

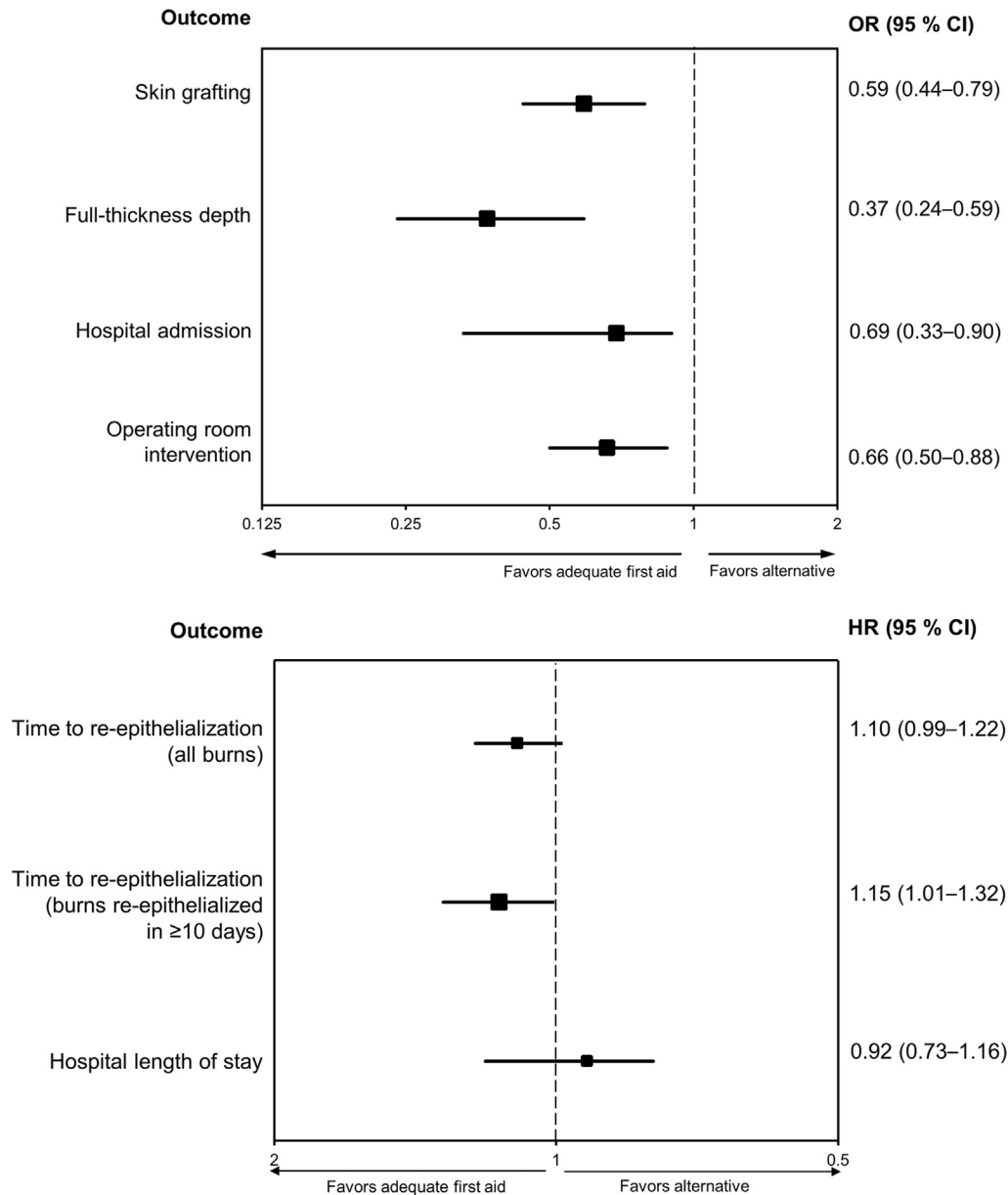
A significant inverse relationship was observed between duration of first aid and odds of full-thickness depth. Relative to burns that failed to receive any first aid, those cooled with running water for lengths of 5 minutes or greater had significantly reduced odds of classification as full thickness, with progressively greater odds reductions in

the 5- to 10-minute (OR=0.3; 95% CI 0.1 to 1.0;  $P=.04$ ), 11- to 19-minute (OR=0.3; 95% CI 0.1 to 0.9;  $P=.03$ ), and greater than or equal to 20-minute (OR=0.2; 95% CI 0.1 to 0.4;  $P<.001$ ) groups (Table E1, available online at <http://www.annemergmed.com>). Compared with treatments of no first aid or an alternative, the provision of any cool running water was associated with an OR of 0.3 (95% CI 0.2 to 0.6;  $P<.001$ ). The odds of patients who received adequate first aid presenting with a full-thickness burn were 62.6% lower than those of children given any other form of first aid (OR=0.4; 95% CI 0.2 to 0.6;  $P<.001$ ). Figure 4 illustrates the nonlinear relationship between the probability of full-thickness depth and total body surface area, which suggests that the benefit of adequate first aid might be greatest in larger burns between 10% and 40% total body surface area. However, the trend—which was also observed in the context of skin grafting—must be viewed cautiously because this range represents only 3.7% of the cohort (n=91).

Overall, 14.5% of patients (95% CI 13.2% to 15.9%; n=363) were admitted to the hospital at some point during their management. The odds of admission decreased by 35.8% with the provision of any cool running water (OR=0.6; 95% CI 0.4 to 1.0;  $P=.03$ ) and by 31.0% with the application of adequate first aid (OR=0.7; 95% CI 0.3 to 0.9;  $P=.006$ ).

For those admitted as inpatients, median hospital length of stay was 3 days (IQR 1 to 10 days). Cox regression analyses revealed no significant associations with first aid. Length of stay did not significantly change with the provision of any cool running water (HR=0.7; 95% CI 0.5 to 1.0;  $P=.07$ ) or adequate first aid (HR=0.9; 95% CI 0.7 to 1.2;  $P=.48$ ).

Slightly more than 11% of patients (11.4%; 95% CI 10.2% to 12.7%; n=285) underwent treatment in an operating room. The list of operating room interventions



**Figure 2.** Relationships between adequate first aid and each outcome measure. Error bars show 95% CIs.

performed in this cohort included dressing changes under general anesthetic, debridements, escharotomies, full-thickness skin grafts, scar revisions, split-thickness skin grafts, and steroid injections. Any amount of cooling with running water was associated with a 42.4% reduction in the odds of intervention in an operating room (OR=0.6; 95% CI 0.4 to 0.9;  $P=.008$ ). Relative to that of children given inadequate first aid, the OR of requiring an operating room intervention for recipients of adequate cool running water was 0.7 (95% CI 0.5 to 0.9;  $P=.004$ ).

As with grafting, hospital admission and operating room requirements showed a dose-response relationship with first-aid duration. For both, the OR was significant for

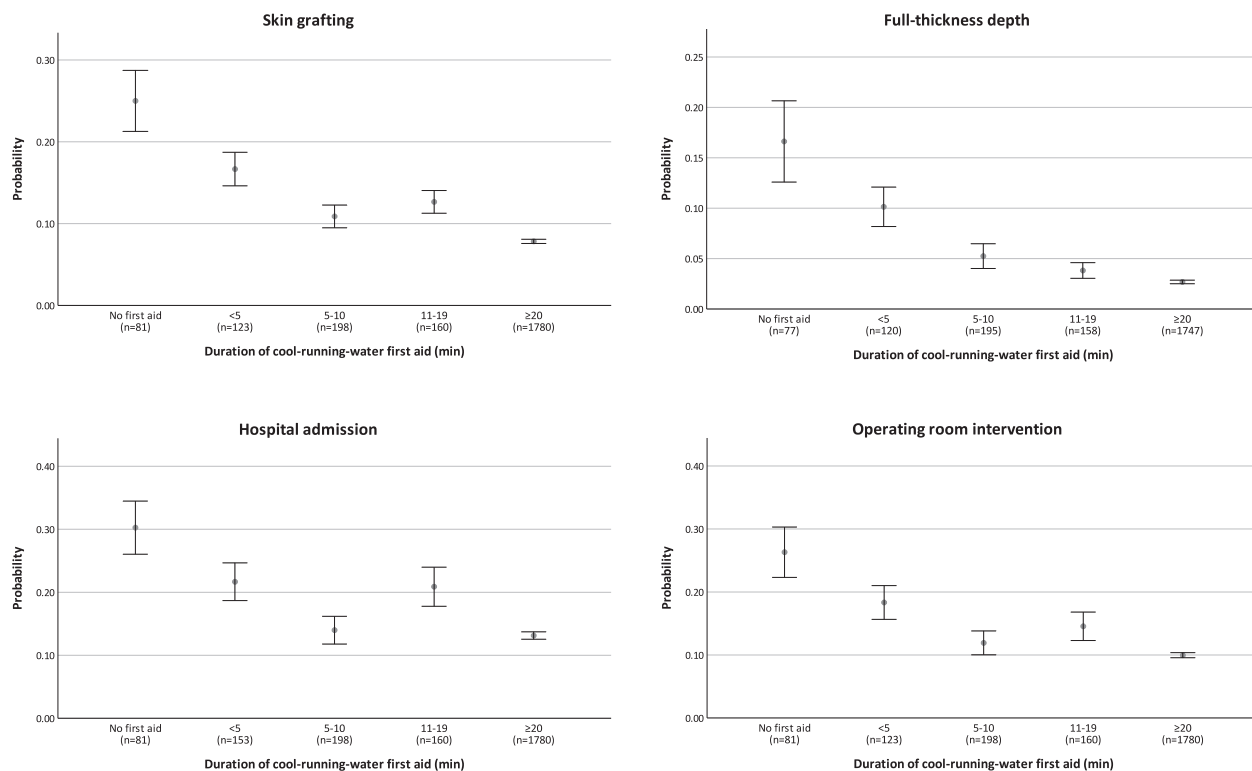
alternative treatment and all durations of cool running water greater than or equal to 5 minutes.

The numbers of ICU admissions ( $n=17$ ) and deaths ( $n=2$ ) were too low to factor into the analysis.

Table E2 (available online at <http://www.annemergmed.com>) documents the relationships between the covariates and outcome variables.

## LIMITATIONS

The results must be interpreted in light of the following limitations. First, all cool running water treatments of greater than or equal to 20 minutes were categorized into a single group. In their animal model, Bartlett et al<sup>10</sup> found



**Figure 3.** Dose-response relationships between first aid duration and each outcome measure. Error bars show 95% CIs.

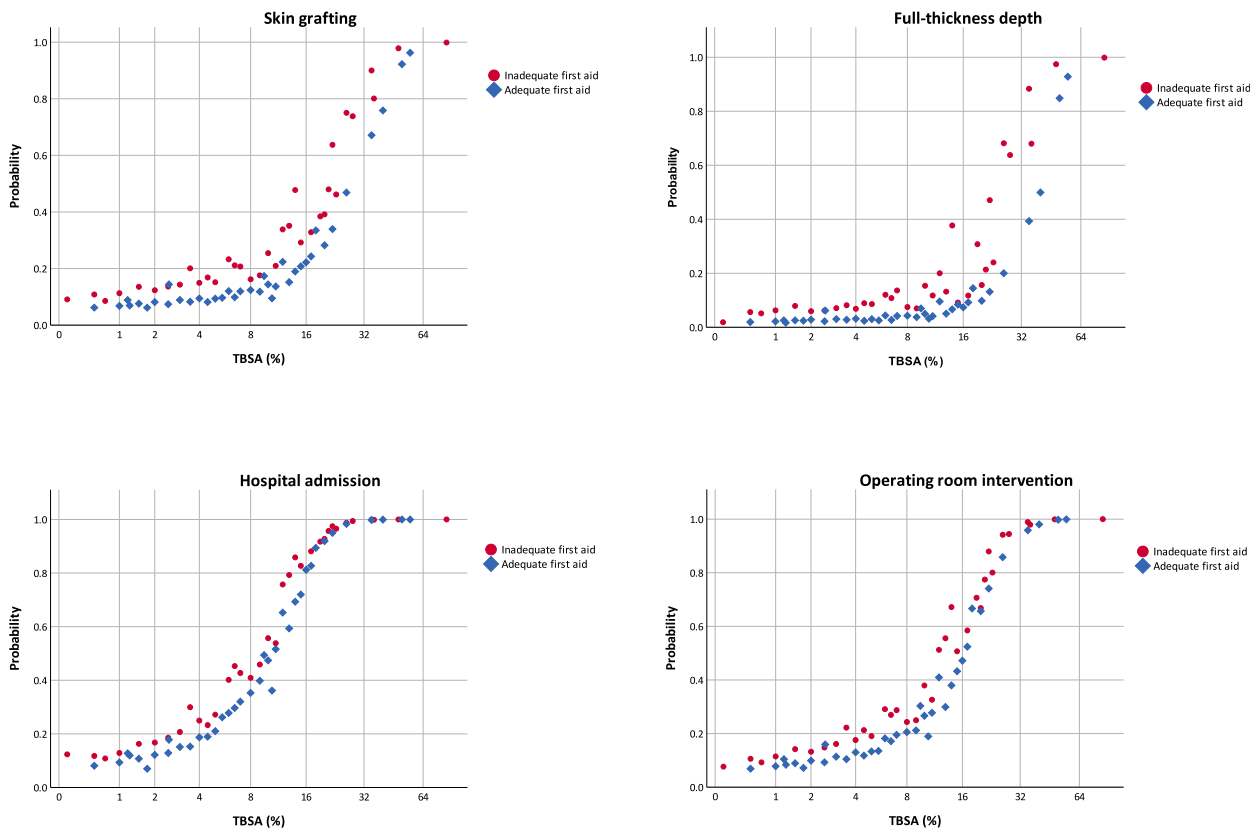
**Table 3.** Results of regression analyses evaluating the effect of first aid on burn severity and clinical outcomes.

Outcome	Crude OR/HR	Adjusted OR/HR (95% CI)
<b>Skin grafting</b>		
Inadequate first aid	1 (Reference)	
Adequate first aid	0.54	0.59 (0.44–0.79)
<b>Full-thickness depth</b>		
Inadequate first aid	1 (Reference)	
Adequate first aid	0.32	0.37 (0.24–0.59)
<b>Hospital admission</b>		
Inadequate first aid	1 (Reference)	
Adequate first aid	0.69	0.69 (0.33–0.90)
<b>Operating room intervention</b>		
Inadequate first aid	1 (Reference)	
Adequate first aid	0.63	0.66 (0.50–0.88)
<b>Time to re-epithelialization</b>		
Inadequate first aid	1 (Reference)	
Adequate first aid	1.07	1.10 (0.99–1.22)
<b>Hospital length of stay</b>		
Inadequate first aid	1 (Reference)	
Adequate first aid	1.14	0.92 (0.73–1.16)

Results were controlled for age, sex, mechanism, socioeconomic status, and total body surface area percentage affected.

that 30 minutes of cool running water yielded fewer benefits than treatments of 20 minutes. Furthermore, Wood et al<sup>18</sup> showed that first aid of greater than or equal to 40 minutes' duration might actually be detrimental, possibly as a result of vasoconstriction and hypothermia. There are few documented cases in the literature of hypothermia resulting from cool water treatment,<sup>31</sup> but for some patients, particularly young children with larger burns, application of cool running water for long durations carries an obvious risk of thermoregulatory issues. A broad range of total body surface areas was included in this study, although, consistent with the known epidemiology of pediatric burns, the majority of the participants presented with wounds that were less than 5% total body surface area. The results therefore apply primarily to small- to medium-sized burns. Still, there was evidence of a clinical benefit with adequate first aid in a substantial proportion of the larger (>5% total body surface area) injuries that comprised greater than one tenth of the cohort. The findings should not, however, be assumed to generalize to chemical, electrical, or friction burns because nonthermal mechanisms were excluded from the analysis.

As a single-center study, this research has limited external validity, and continued investigation is needed to confirm its findings. Unlike past multicenter research,



**Figure 4.** Associations between total body surface area and first aid for skin grafting, full-thickness depth, hospital admission, and operating room intervention. Points represent mean probability for each given total body surface area value, as determined by logistic regression models adjusting for age, sex, socioeconomic status, and mechanism of injury.

however, this study did not have to estimate the duration of a patient's first aid; instead, detailed information about first-aid type and length was obtained directly from participants and caregivers through structured interviews. These interviews carry an inherent risk of recall bias, especially in relation to elapsed time variables, which often tend to be overestimated in retrospective reporting. Systematic overestimation of treatment exposure might obscure the relationship between cool running water duration and clinical outcomes and underestimate the intervention's true effect. One possibly ameliorating factor was the timing of the interviews, which were conducted a median of only 3 days after the injury. Additionally, an informal validation study of 100 randomly selected cases from the cohort revealed substantial agreement between the interview data and contemporaneous ambulance reports, referral letters, and ED notes (Appendix E1, available online at <http://www.annemergmed.com>).

Another limitation was the relatively low hospital admission rate, which might have biased the length-of-stay analyses and contributed to their inconclusive findings; it is possible that the sample of 363 inpatients was insufficient in size for a difference in length of stay to become apparent.

The analyses might have been further confounded by concomitant injuries, infections, or social issues that may have delayed discharge.

Finally, the noninterventional nature of the study precludes any definitive attribution of causality to first aid's associations with improved outcomes. Its findings, nevertheless, are consistent with data from past human-subjects research.<sup>18,19</sup>

## DISCUSSION

This cohort study of 2,495 children with thermal burns found that most of the clinical benefits of first aid previously reported in animal models<sup>4,10-12</sup> and adult populations<sup>18,19</sup> were also present in the studied pediatric sample. The odds of skin grafting were reduced by more than 40% in children provided adequate first aid involving greater than or equal to 20 minutes of cooling with running water.

Among patients who did not require grafting, the speed of re-epithelialization was faster with the administration of *any* cool running water. Adequate cooling, relative to all other forms of first aid, did not show a relationship with faster re-epithelialization universally. However, among burns in which the healing process was more protracted, spanning a period of 10 days or longer (ie, the wounds at



greatest risk of scarring), it was associated with significantly improved re-epithelialization speeds. Although small, the decrease in median time to healing of 1 day with adequate first aid is far from inconsequential because recent research demonstrated that the odds of hypertrophic scarring increase by a factor of 1.138 with each additional day taken to achieve re-epithelialization.<sup>32</sup>

By every metric besides hospital length of stay, burns that were cooled with running water fared significantly better than those that received no first aid or an alternative to cool running water. For emergency clinicians, these results highlight the significance of, at a minimum, initiating cooling in pediatric burn patients because any duration of cool running water appears to be better than none. Even in scenarios in which the size or distress of a child precludes extended periods of cooling, concerted efforts should be made to ensure the delivery of at least some water first aid before any further care is commenced. When possible, however, clinicians should aim for longer durations because the data suggest that the extent of first aid's therapeutic benefit is contingent on the length of time it is provided. The dose-response relationships between cool running water duration and several outcome variables clearly illustrate this point, none more so than its inverse correlation with burn depth. Across all but 2 measures (length of stay and time to re-epithelialization), the provision of greater than or equal to 20 minutes of cool running water was associated overall with superior outcomes relative to both inadequate first aid as a whole and other lengths of cool running water individually. In the first-aid and burn communities, the optimal duration of cool running water therapy remains a persistent point of disagreement. The Australian Burn Association,<sup>3</sup> British Burn Association,<sup>2</sup> and European Burns Association<sup>13</sup> all recommend 20 minutes of cool running water, whereas the American Burn Association<sup>1</sup> advocates greater than or equal to 5 minutes and the British Red Cross<sup>33</sup> and St. John Ambulance (UK)<sup>34</sup> both prescribe greater than or equal to 10 minutes.<sup>35</sup> Following similar findings from adult research, this study lends further support to the recommendation of a full 20 minutes.

Before investigations that defined the parameters of optimal cool running water therapy in an animal model,<sup>4,10-12</sup> studies analyzing the effectiveness of cool running water in human beings postburn were variable in their descriptions of appropriate first aid and its clinical benefits. A 2002 New Zealand prospective study of 121 children and adults, which classified adequate first aid as greater than or equal to 10 minutes of cool running or still water, reported an association with reduced skin-grafting requirements.<sup>14</sup> In a 2005 mixed-age retrospective study from Taiwan, an improvement in hospital length of stay, but not surgery, was noted with greater than or equal to 30 minutes of room-temperature

water.<sup>15</sup> Whether this included running water, still water, or both was not specified. The first of only 2 known pediatric studies in the literature is a 2002 Vietnamese case series, which identified a relationship between decreased odds of grafting and "immediate cooling," although the authors provided no further elaboration of the type or duration of the cooling.<sup>16</sup> The second pediatric study, a 2009 retrospective audit of an Australian burn center, was the earliest to designate adequate first aid as greater than or equal to 20 minutes of cool running water.<sup>17</sup> It failed to assess a relationship with hospital length of stay or depth, and found no improvements in grafting, clinical visits, scar management, or time to re-epithelialization when all burns were analyzed together, but did reveal an association with faster re-epithelialization in contact burns, as well as decreased clinical visits in flame injuries. Compounding their inconsistent findings and variable definitions of first aid, many of these studies were constrained by limitations in sample size,<sup>14,16,17</sup> covariate adjustment, or both.<sup>14,15</sup>

It was not until very recently that strong evidence began to emerge of cool running water first aid's influence on burn severity and healing in human beings. In 2016, Wood et al<sup>18</sup> performed a cohort study of 2,897 adult inpatients in a binational Australian and New Zealand burns registry. They determined that burns cooled with any duration of cool running water showed a decreased need for wound repair surgery and ICU admission, in addition to a reduction in hospital length of stay. A 2018 single-center analysis of 4,918 Australian adult burn outpatients by Harish et al<sup>19</sup> found that the provision of 20 minutes of cool running water was associated with decreased depth, faster re-epithelialization, and reduced surgical requirements. The present study builds on and expands past findings by assessing these outcome variables in children, whose care may differ from that of adults by virtue of their greater body surface area to weight ratios<sup>22</sup> and thinner skin.<sup>23</sup> Through the inclusion of both inpatients and outpatients, the full spectrum of pediatric burns care was explored, including outcomes, such as hospital admission, not previously or only incompletely studied.<sup>18</sup> The only finding reported by previous studies<sup>14,15,18</sup> that was not corroborated by this research, in which sufficient data were available, was a relationship between cool running water provision and hospital length of stay,<sup>18</sup> although this may be attributable to the relatively small size of the inpatient sample.

The exact mechanisms by which cool running water might improve outcomes remain unclear, but its effects are known to extend beyond the mere dissipation of heat. Some authors suspect that cooling may decrease burn wound progression<sup>34</sup> by altering cellular behavior,<sup>36</sup> with past research demonstrating associations with decreased release

of lactate and histamine, stabilization of thromboxane and prostaglandin levels, and inhibition of kallikrein activity.<sup>37</sup>

The proportion of children provided adequate cool running water in this study, 71.3%, marks a substantial improvement from the 12.1% documented at a pediatric hospital covering the same population from 4 years earlier.<sup>17</sup> Nevertheless, less than half of the adequately treated cohort received the full 20 minutes of cooling at the scene of the injury. Although cool running water is believed to be most effective immediately postburn,<sup>12</sup> the improved outcomes observed in the adequate first-aid group as a whole strongly suggest that, consistent with current guidelines, cool running water continues to be of benefit up to 3 hours after injury. Out-of-hospital and emergency services should therefore prioritize first aid in the management of all patients who present within this timeframe.

In summary, this study showed significant improvements with cool running water first aid in injury severity and clinical outcomes among children postburn. The provision of adequate first aid consisting of greater than or equal to 20 minutes of cool running water within 3 hours of injury was associated with reduced skin grafting, as well as faster re-epithelialization among burns in which wound closure was more protracted, and decreased odds of full-thickness depth, hospital admission, and operating room interventions.

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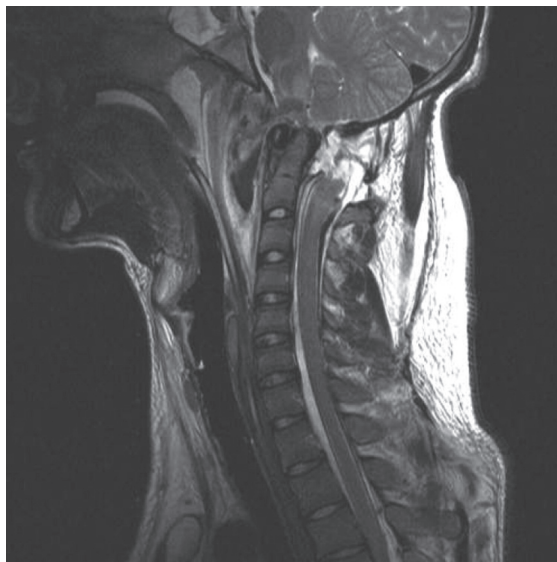
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