

The Effect of Burn Center Volume on Mortality in a Pediatric Population: An Analysis of the National Burn Repository

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The effect of burn center volume on mortality has been demonstrated in adults. The authors sought to evaluate whether such a relationship existed in burned children. The National Burn Repository, a voluntary registry sponsored by the American Burn Association, was queried for all data points on patients aged 18 years or less and treated from 2002 to 2011. Facilities were divided into quartiles based on average annual burn volume. Demographics and clinical characteristics were compared across groups, and univariate and multivariate logistic regressions were performed to evaluate relationships between facility volume, patient characteristics, and mortality. The authors analyzed 38,234 patients admitted to 88 unique facilities. Children under age 4 years or with larger burns were more likely to be managed at high-volume and very high-volume centers (57.12 and 53.41%, respectively). Overall mortality was low (0.85%). Comparing mortality across quartiles demonstrated improved unadjusted mortality rates at the low- and high-volume centers compared with the medium-volume and very high-volume centers although univariate logistic regression did not find a significant relationship. However, multivariate analysis identified burn center volume as a significant predictor of decreased mortality after controlling for patient characteristics including age, mechanism of injury, burn size, and presence of inhalation injury. Mortality among pediatric burn patients is low and was primarily related to patient and injury characteristics, such as burn size, inhalation injury, and burn cause. Average annual admission rate had a significant but small effect on mortality when injury characteristics were considered. (*J Burn Care Res* 2016;37:32–37)

The American Burn Association (ABA) estimates that severe burns are responsible for 40,000 annual admissions, of which approximately 30% are children.^{1,2} Pediatric burn patients differ from adults in both the pattern of injuries, with a significantly larger

proportion sustaining scalds and/or intentional injuries, and the approach to resuscitation.^{2,3}

Physicians, patient advocacy groups, policy-makers, and insurance providers alike are placing increased emphasis on quality improvement initiatives in all disciplines of medicine. These initiatives aim to reduce the mortality and morbidity while increasing the patient satisfaction and cost effectiveness of care. Leading burn surgeons have long recognized the need for establishing and maintaining a high standard of care for the specialized needs of burn patients to optimize outcomes.⁴ The ABA incorporated these standards into the criteria used for the Burn Center Verification process. Although these guidelines were recently revised, the language pertaining specifically to verification as a pediatric burn center remains somewhat vague. Currently, verified pediatric centers are required to have a child life specialist available and be able to “demonstrate facilities, protocols, and personnel specific

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to the care of critically injured pediatric patients.”⁵ The result is a wide variation in the types of centers that care for children, from adult centers to general children’s hospitals, to one of only six verified pediatric burn centers in North America.⁶ Several studies have demonstrated that burn center volume does have an effect on mortality.^{7–9} We therefore sought to evaluate whether patient volume impacted mortality in a pediatric burn population.

METHODS

The National Burn Repository (NBR) is a voluntary registry sponsored by the ABA, which is updated annually.² This computerized database contains information on patient age, sex, race, cause of injury, percent, and degree of %TBSA burned, presence of inhalational injury, and pre-existing medical conditions. Verified burn centers are required to contribute to the NBR, but many other nonverified facilities contribute data as well; the NBR does not contain information regarding center verification status and identifies contributing centers only by a unique code. For the purposes of this study, NBR version 8.0 was queried for all data points, yielding data on patients treated from 2002 to 2011. We restricted our analysis to initial visits for all unique patients aged 0 to 18 years, yielding a total of 38,234 records. Patient age, mechanism of injury, %TBSA burned, presence of inhalational injury, and outcomes including mortality were collected. Data within this set were internally validated by removing duplicated entries identified using unique patient codes, removing patients identified as readmissions, and cross-referencing categories with free text submitted by the treating facility as part of the database to complete missing values and standardize classification of burn mechanism where possible. Institutional review board approval was not required since the analysis was done on deidentified data.

We calculated the facility average annual burn volume by summing the number of burn patients at each facility and dividing by the number of years for which the facility submitted data to the NBR. Centers were then separated into quartiles (low, medium, high, and very high) based on calculated

average annual patient volume. All analyses were completed using R (R Development Core Team, Vienna, Austria). Descriptive analyses comparing demographics, clinical characteristics, and outcomes across the quartiles were completed using χ^2 test, χ^2 test for trend, Fisher’s exact test, and analysis of variance tests where appropriate. Backward and forward stepwise logistic regression was performed to evaluate the relationships between facility volume, patient characteristics, and mortality using the rms package in R.¹⁰ We selected variables to include in the final model based on the significance of each predictor ($P < .05$) and compared model iterations based on Akaike’s Information Criteria and the r^2 values as evidence of the model’s ability to predict mortality.

RESULTS

A total of 38,234 patients were admitted to 88 facilities. Patient age had a unimodal distribution, with 51.0% of children less than age 4 years (interquartile range, 1.3–11 years). Only 325 deaths were reported in this population, yielding an overall mortality rate of 0.85%. The most common reported cause of death was multisystem organ failure ($n = 41$) although the cause of death was omitted or unknown for more than half of the entries. Scalds remain the most common cause of injury, representing more than 43% of the database entries, followed by flame (23%) and contact (14%) burns.

Only 3.8% of patients had a burn size greater than 30% TBSA; mortality in this group was significantly higher than patients with a burn size less than 30% (12.7 vs 0.3%, $P < .001$). Presence of inhalation injury was reported in 1072 patients (2.8%), was typically associated with flame burns (69.7% of all inhalations), and was also predictive of mortality (12.1 vs 0.5%, $P < .001$). Age less than 4 years was associated with a lower rate of mortality among children with small (0–29.9% TBSA) burn size and a higher rate among children with medium size (30–59.5% TBSA) injuries (Table 1).

Facilities were grouped into quartiles (low, medium, high, and very high) based on annual

Table 1. Mortality rate stratified by age and burn size

Burn Size	0–4 Yr		>4 Yr		P
	n	Mortality Rate, %	n	Mortality Rate, %	
Small (0–29.9% TBSA)	18,929	0.25	16,424	0.47	.0006
Medium (30–59.9% TBSA)	426	9.60	716	4.32	.0006
Large (>60% TBSA)	117	29.06	295	27.36	.82

Table 2. Patient characteristics by burn center volume

	Quartile				P
	Low	Medium	High	Very High	
n	738	3748	8857	24,891	
Average annual admissions (range)	1–15.5	17.8–35.7	35.8–87.3	90.3–386.7	
Age (mean ± SD)	12.52 ± 6.34	7.67 ± 6.44	5.67 ± 5.53	5.93 ± 5.59	<.001
Age category (%)					<.001
0–4 yr	19.1	44.53	57.12	53.41	
>4 yr	80.89	55.47	42.88	46.59	
Sex (% male)	71.41	65.82	62.79	63.11	<.001
Mechanism (%)					<.001
Scald	27.73	46.38	56.26	47.11	
Flame	53.41	33.11	21.93	26.15	
Contact	9.19	9.32	14.59	17.38	
Grease	3.49	5.74	2.5	3.05	
Chemical	1.74	1.38	1.11	1.14	
Other	4.44	4.06	3.6	5.17	
Inhalational injury (%)	4.81	3.96	3.16	3.08	.008
ICU stay (%)	49.05	31.37	44.09	20.83	<.001
Ventilated (%)	13.51	8.09	5.59	8.61	<.001
Burn size (%TBSA) (%)					<.001
0–9.9	73.05	75.52	78.31	78.46	
10–19.9	14.09	17.42	16.32	12.93	
20–29.9	5.47	3.97	3.16	3.6	
30–39.9	3.28	1.28	0.99	1.82	
40–49.9	2.33	0.78	0.51	1.04	
50–59.9	0.82	0.33	0.2	0.75	
60–69.9	0.41	0.22	0.2	0.56	
70–79.9	0.27	0.14	0.13	0.34	
80–89.9	0	0.19	0.09	0.27	
90–100	0.27	0.14	0.09	0.23	
Disposition (%)					<.001
Home	91.1	92.49	86.93	94.66	
Transfer	3.71	1.74	9.02	1.29	
Rehabilitation/skilled nursing facility	3.86	1.98	1.5	1.64	
Discharged to alternate caregiver	0.45	2.65	2.04	1.39	
Mortality (%)	0.678	1.04	0.49	0.95	.0004

ICU, intensive care unit.

average number of admissions. Table 2 compares basic demographic data as well as cause and size of burn, presence of inhalation injury, and mortality between the quartiles. Significant differences were found between groups in nearly all patient characteristics examined, including patient age, sex, %TBSA burned, and inhalation injury ($P < .001$). Low- and medium-volume centers cared predominantly for patients aged 4 years and older (80.89 and 55.47%, respectively), while a slight majority of children were less than 4 years old at the high and very high centers (57.12 and 53.41%, respectively). A greater proportion of flame burns were seen at low-volume centers. Children at low- and

medium-volume centers were significantly more likely to be transferred (3.71 and 9.02%) to another hospital or service on discharge than children at medium-volume and very high-volume centers (1.74 and 1.29%, respectively, $P < .001$). Mortality was low overall, but significantly lower rates were seen at centers in the low- and high-volume centers on this univariate analysis.

As expected, children with larger burns were treated at the higher-volume centers (Figure 1). As burn size increased, the proportion of children managed at low- and high-volume centers decreased ($P = .002$ and $P < .001$, respectively); similarly, as burn size increased, the proportion of children

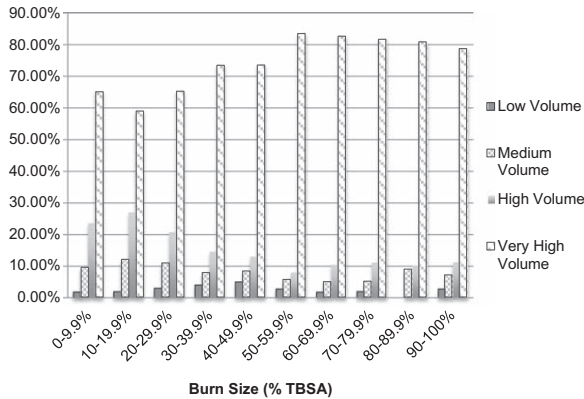


Figure 1. Proportion of children receiving care by center volume and burn size.

managed at the very high-volume centers increased ($P < .001$). We found no significant changes in the medium-volume centers. When stratified by burn size and facility volume without adjustment for other factors such as mechanism of injury or presence of inhalation injury, we found no significant differences in mortality between quartiles (Table 3). Unadjusted univariate logistic regression did not find center volume alone, either as a continuous variable or when divided into a categorical variable based on quartiles, to be a significant predictor of mortality.

Multivariate logistic regression was used to estimate the risk of death for burn center volume, adjusting for age, presence of inhalational injury, and %TBSA burned. This yielded a model with a moderate r^2 (.35) and high C -statistic (.93). We found the evidence for systematic overfitting and underestimation of mortality at higher probabilities of mortality, but correction using bootstrapping did not alter the C -statistic. Table 4 demonstrates the mortality odds as predicted by this model. Interestingly, “other” causes of injury are associated with an increased risk of mortality; unfortunately, this is difficult to interpret as this category represents a highly heterogeneous population with desquamating skin diseases and/or infections, degloving injuries, radiation injuries, and any other injury the treating center described as “other nonburn.” A subset analysis of children under the age of 4 years yielded similar results, with burn center volume again demonstrating a small but significant impact on mortality (results not published).

DISCUSSION

Before adjusting for other variables, facility average annual admission rate does have an impact on

mortality among pediatric burn patients. Patient and injury characteristics, including age, burn size, presence of inhalation injury, and cause of injury remain the most influential predictors of mortality. After adjusting for these factors, the annual admission rate has a very small but nevertheless statistically significant effect on observed mortality. The lowest unadjusted mortality rates are found at the low- and high-volume centers. The highest-volume centers are more likely to care for younger patients and patients with larger injuries, and when patient and injury characteristics are considered, the lowest mortality was found in the higher-volume centers. These findings are concordant with the bulk of the literature on pediatric burns and severe burns in general.

Conceptually, it is expected that higher mortality rates will be found among younger children with immature immune, pulmonary, cardiovascular, and neurologic systems although this issue remains somewhat controversial in the literature.¹⁰ While several single-institution retrospective studies failed to find an increased risk of death among young children, a previous NBR review demonstrated worse outcomes in children under the age of 4 years similar to what was found here.¹¹⁻¹³ While a single-institution study has the advantage of eliminating reporting errors inherent to a national database review, it also likely lacks the power to detect smaller differences, as the overall mortality rate among children with severe burns is quite low. We also found no difference in mortality in the largest burns (>60% TBSA) between the age groups, but we did find a marked difference in those with burns between 30 and 60% TBSA, with a 122% increase in mortality rate in those less than 4 years old.

Prior studies of adult burn populations demonstrate a similar nonlinear relationship between patient volume and outcomes, with the lowest adjusted mortality rate seen at the medium-volume centers.^{7,8,14} Both Light et al⁸ and Hranjec et al⁷ postulate that the slightly worse outcomes seen at the highest-volume centers could be related to the higher volumes “overwhelming” the system although the retrospective nature of these studies precludes additional investigation of this theory. We demonstrate here that the effect is likely a referral bias in that the most severely injured are cared for in the higher-volume centers, which have more experience and/or resources available for the management of pediatric patients. Indeed, transfer rates are higher at the low- and high-volume centers. In addition, the larger proportions of younger children or children with injuries classified as

Table 3. Mortality stratified by burn center volume and burn size

Burn Size (%TBSA)	Annual Burn Center Admission Volume (Quartile)				P
	Low, %	Medium, %	High, %	Very High, %	
0–9.9	0.00	0.52	0.18	0.38	.37
10–19.9	0.00	0.16	0.28	0.29	.50
20–29.9	0.00	2.10	0.73	1.04	.79
30–39.9	8.33	0.00	5.81	4.61	.91
40–49.9	0.00	14.29	9.09	5.62	.57
50–59.9	0.00	33.33	0.00	10.61	.60
60–69.9	0.00	37.50	23.53	14.81	.31
70–79.9	50.00	20.00	27.27	13.58	.13
80–89.9	—	42.86	37.50	43.75	.86
90–100	100.00	60.00	62.50	50.00	.18

“other” treated at the highest-volume centers may also partially explain the slightly worse mortality rates seen.

Palmieri et al⁹ recently published their analysis of a pediatric subset from an older version of the NBR. In that study, the authors eliminated centers that did not treat a child under the age of 10 years and then divided the remaining centers into five groups based on predefined median yearly admission rate, resulting in only seven centers being included in the extra-large-volume and six centers in the large-volume groups. The authors did find a linear improvement in mortality as volume increased. The use of quartiles instead of estimated division into groups in our study likely accounts in part for the lack of a clear linear relationship of volume to mortality.

For the purpose of this study, we assumed that average admission rate would act as a surrogate marker for the institutional expertise accrued in the course of caring for a large number of young patients. Although we did not find a linear improvement in mortality with increasing burn center volume, mortality is not the only marker of quality burn care. Facilities with significant pediatric experience have access to physiatrists, psychiatrists, social workers, and case managers with significant pediatric experience. These resources may lead to improvements in other outcome measures, such as complication rates, quality of life, functional recovery, and overall patient/family satisfaction. We believe that future studies evaluating the impact of institutional expertise in caring for pediatric patients on these outcomes are warranted. Such studies will provide additional insights into the value of pediatric-specific resources and may guide future quality initiatives. This may be demonstrated by the lower rates of discharge to

skilled nursing or rehabilitation facilities at higher-volume centers.

The conclusions of this study are limited by the fact that the data contained within the NBR vary widely in terms of the quality and consistency of reporting by contributing centers. Taylor et al¹⁵ addressed this issue to the best of their ability in their recent validation of the NBR, but missing data across important data fields remain an issue. Taylor et al also identified a number of patients who were readmitted for additional care but submitted to the NBR under a new identification code. Although we attempted to remove all duplicate patients, it is still likely that our population nonetheless contains some of these. In addition, systematic differences in the reporting of covariate factors used in the multivariate analysis (eg, a center’s routine omission of data or underestimation or overestimation of burn injury size) could alter the apparent effect of facility volume.

Table 4. Multivariate predictors of mortality

	β Coefficient	OR (95% CI)
Intercept	-13.84	OR (95% CI)
Burn center annual admission volume quartile	0.23	1.26 (1.03–1.50)
Age	-0.015	0.99 (0.97–1.01)
Burn size	4.66	105.69 (66.91–167.00)
Inhalational injury	1.8	6.08 (4.39–8.41)
Mechanism (reference = scald)		
Flame	0.52	1.68 (1.04–2.71)
Contact	-2.2	0.11 (0.02–8.1)
Grease	0.78	2.17 (0.76–6.21)
Chemical	-6.14	0 (0–1.5 × 10 ¹⁴)
Other	1.76	5.82 (3.77–8.98)

CI, confidence interval; OR, odds ratio.

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