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Burn Center Volume Makes a Difference for Burned Children

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Abstract

The relationship between center volume and patient outcomes has been analyzed for multiple conditions, including burns, with variable results. To date, studies on burn volume and outcomes have primarily addressed adults. Burned children require age specific equipment and competencies in addition to burn wound care. Hence, volume may make a difference for this special population. We used the National Burn Repository (NBR) release from 2000–2009 to evaluate the influence of pediatric burn volume on outcomes using mixed effect logistic regression modeling. Of the 210,683 records in the NBR over that time span, 33,115 records for children ≤18 years of age met criteria for analysis. Of the 33,115 records, 26,280 had burn sizes smaller than 10%; only 32 of these children died. Volume of children treated varied greatly among facilities. Age, total body surface area (TBSA) burn, inhalation injury, and burn center volume influenced mortality (p<0.05) An increase in the median yearly admissions of 100 decreased the odds of mortality by approximately 40%. High volume centers (admitting >200 pediatric patients/year) had the lowest mortality when adjusting for age and injury characteristics (p<0.05). The lower mortality of children a high volume centers could reflect greater experience, resource, and specialized expertise in treating pediatric patients.

Introduction

Unintentional injury is the leading cause of morbidity and mortality in U.S. children, and burns are the third leading cause of unintentional injury deaths in children aged 0–9 years. (1) Between 2001 and 2011 a total of 1,501,737 children sustained burn injuries and 5842 died. (2) To date the evaluation of pediatric burn outcomes has been center-specific and focused on factors influencing length of stay and mortality in individual centers. (3–7) Multiple surgical studies in such varied fields as orthopedics, cardiothoracic surgery, and transplant have suggested that hospital volume may make a difference in patient outcomes. (8–11). The studies in burns, which have used either adult data or data consisting of

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combined pediatric/adult data, had somewhat different results. (12–14) These studies described varying effects of center volume on outcome, and the highest volume centers in some cases had worse outcomes than medium-high or low volume centers. None of these studies assessed pediatric burn outcomes.

Children have unique needs on multiple levels. Children, unlike adults, are developing physically, physiologically, and psychologically; hence, specialized knowledge, treatment modalities, and equipment are required to address their needs. For example, a 2 year old will require smaller central lines for venous access, have greater body surface area per unit volume (and hence, greater resuscitative needs), immature lung development, and limited ability to understand treatment or respond to stress. A burn center that treats primarily adults will likely have the wound care supplies necessary to care for children, but may be lacking in pediatric-specific support. These age-specific capabilities and competencies may be accentuated by volume of pediatric patients admitted. For centers with a large pediatric burn volume, investing in age-specific resources is more likely to be cost-effective than in smaller centers, which take care of a limited number of patients.

Given that the number of pediatric burn patients treated varies substantially among facilities (some treating hundreds of children/year while others admit a few a year) and that the management of pediatric burn patients requires additional competencies for all members of the burn care team, we hypothesized that the volume/outcome relationship in pediatric burns would differ from that of adults. We utilized the American Burn Association (ABA) National Burn Repository (NBR) the largest collection of burn data in the U.S., to evaluate the relationship between burn center pediatric volume and mortality.

Methods

This project was approved by the University of California Davis Human Subjects Review Board. The ABA NBR contains outcomes, patient, and injury characteristics for patients admitted to burn centers for treatment of burns and related medical conditions. We obtained the ABA's 2009 release of the NBR containing of 286,293 admission records. To focus on recent burn care and outcomes, we restricted our analysis to admissions in 2000 or later (210,683). We eliminated records missing information on survival to discharge (12,226), age (5,441), burn size (42,545), or inhalation injury (12,861). In addition, we removed 3,218 records identified as probable duplicates, 6,529 records with unreliable information, 23,084 records associated with readmissions, 1,038 records of patients transferred to another primary care facility, and 3,690 records of patients with non-burn injuries. (15) The 6,529 records with unreliable information consisted of burns greater than 100%, 1,358 records from a single facility at which the reported age of all patients was 0, and 5,162 records from two facilities at which no patient deaths were reported over multiple years despite third degree burns of 100%. This validation left 100,051 records of initial hospital visits (admissions and outpatient visits) with the minimum information for necessary analysis (i.e., patient age, a burn or inhalation injury, and hospital discharge status).

Records for children (< 18 years old) were extracted. Thirteen facilities that did not treat any children less than 10 years old were dropped from the analysis. Two facilities that only had records for 2009, a partial year in the 2009 NBR release, also were dropped. These restrictions left 33,115 records from 65 facilities.

Statistical Analysis

Mixed effect logistic regression models were used to evaluate the effect of facility size, patient age, TBSA burn and the presence of inhalation injury (Inhale) on mortality. For facility size, we calculated the median yearly admissions for each facility for the period 2000–2008 (Admits). Data from 2009 were not included in this calculation because the data did not cover an entire year. Facility was included as a random effect to account for correlation among patients treated at the same facility. Proc GLIMMIX in SAS software version 9.4 was used to fit these regressions. Models were compared based on significance ($p < 0.05$) of the predictors and AIC values. We first fit a model containing all main patient-level effects (TBSA, Age, Inhale) and all two-way interactions. Retaining only the significant predictors ($p<0.05$), we then investigated including quadratic terms for TBSA and Age. Based on this modeling we reduced the model to significant patient-level predictors and added the facility level predictor of Admits – the median yearly admissions at each facility. A quadratic term for Admits and two-way interactions of Admits with patient-level predictors were modeled. We also evaluated the models including random effects for TBSA and Age (i.e., random slopes for these predictors allowing each facility to have facility-specific slopes). Finally, we considered facility size as a categorical variable rather than as the continuous variable Admits, by classifying facilities as follows:

- X-Large = median yearly admissions of 200 or greater (n=7)
- Large = median yearly admissions of [100–200] (n=6)
- Medium = median yearly admissions of [50–100] (n=18)
- Small = median yearly admissions of [25–50] (n=16)
- Extra Small = median yearly admissions less than 25 (n=18)

The fit of the final model was assessed using Hosmer and Lemeshow’s goodness of fit tests.

Results

Facilities varied substantially in the number of pediatric patients treated (Figure 1). Within a region as defined in the NBR, the most severely injured patients were typically treated at hospitals admitting the largest number of pediatric burn patients. (Figure 2). Mortality was low, < 2%, at most facilities and tended to decrease with facility size although there was considerable variability (Figure 3). The most parsimonious best fitting model for mortality contained Admits, Age, TBSA, Inhale and the interaction between TBSA and Inhale with a facility random effect. Quadratic terms for Age, TBSA and Admits were not significant ($p > 0.05$). Interactions between Admits and the patient-level predictors (Age, TBSA, Inhale) were not significant ($p > 0.05$). Interactions between Age and TBSA and Age and Inhale also were not significant. Including a random slope for TBSA yielded a slightly higher AIC value (1477) than the intercept alone model (1476) while a random slope for Age yielded a slightly lower AIC value (1475). Because the random slopes did not demonstrably improve the AIC values, we did not retain them in the final model. The Hosmer and Lemeshow tests were not significant ($p > 0.05$) indicating adequate model fit.

Consistent with our previous investigations for children, mortality declined with increasing age and increased with TBSA and inhalation injury.(16) Interestingly, the coefficient for the TBSA* Inhale interaction was negative indicating a lower rate of increase in mortality risk per percent TBSA increase in the presence of inhalation injury. This apparent anomaly likely stems from the differential effect of inhalation injury on mortality in conjunction with burn severity. Patients with large burns have a high mortality probability regardless of the presence of inhalation injury. In contrast, patients with small burns have a high probability of survival from the burns but inhalation injury can markedly increase the risk of mortality.

Most interesting is that mortality was significantly, negatively related to the median yearly admissions. Although the effect was small, it was statistically significant. With an increase in the median yearly admissions by 100, the odds of mortality declined about 40%. However, pediatric burn patients tend to have small burns and very high survival. Of the 33,115 records, 26,280 had burn sizes smaller than 10%; only 32 of these children died. Of the 32 patients with <10% burn who died, 25 had concomitant inhalation injury. Of the remaining 7, one was struck by lightning, one was electrocuted, and the other 5 had no comorbidities listed. Of the 5 with no comorbidities, one had cardiovascular failure, one a scald (which can result in major inflammatory response and death in the very young even with a small burn) and the final from a contact burn (likely to have other non-burn related injuries). For most pediatric burns, a 40% reduction in the odds of mortality would be negligible because the burns are small and odds of mortality already very low. For large burns however, a 40% reduction in the odds of mortality is much more significant. Figure 4 illustrates the estimated effect of facility size on the probability of mortality for a 10 year old child without inhalation injury with burns varying in size from 25 to 75%. A negligible effect is seen at 25% TBSA but for a patient with 75% TBSA the estimated mortality is reduced from about 30% at a facility with median yearly admissions of 75 to about 17% at a facility with 300 median yearly admissions. Older children in the 15–18 year old group have mortality on par with the young adult population (18–25 year old) and can be successfully treated at an experienced burn center.

In their analysis, Light et al. categorized facility size based on volume into four groups: low, medium, high and very high volume centers. (14) They found a non-linear relationship between mortality and center volume, specifically mortality was highest for low and very high volume centers. In our analysis, we used volume as a continuous predictor and a linear relationship between mortality and admissions appeared to be adequate since including a quadratic term for admits was not significant. Nevertheless, we further considered the possibility of non-linear effects by modeling facility size as a categorical variable. Consistent with our findings, this model indicated that mortality was lowest in the largest facilities (X-Large facilities), and highest in the smallest facilities (Extra Small facilities) (Table 2). Unlike Light et al.'s findings for adults, for children the largest facilities had the lowest mortality after adjusting for patient age and injury characteristics.

DISCUSSION

After controlling for differences in patient characteristics, mortality for pediatric burns differs significantly across facilities. There is some evidence indicating that pediatric burn patient mortality is lower at larger facilities than at smaller facilities. However, because the mortality of burned children is low, this effect is rather small, and there is substantial variation. Further, for small facilities, estimation of mortality is naturally poor given the small number of patients. Given these limitations and considerations, our results do suggest that pediatric burn patient facility volume influences the mortality of pediatric burn patients. Given that patients with burns >40% TBSA have a differential in mortality, particularly in the <15 year old age group, we suggest that this is a reasonable criteria at which to consider transfer to a high volume center. However, each center should critically assess its ability to care for and monitor outcomes for children with any significant burn injury.

Our results differ somewhat from the volume/outcome burn literature. Both Light and Hranjec found that burn center volume does not necessarily correlate with better outcomes. (12,14) Hranjec suggests that there is an optimal range of admissions per center per year based on local resources, and that overwhelmed centers may provide less than optimal care. Our study differs from these studies in the patient population evaluated: Light evaluated only adults and Hranjec evaluated a mixture of adults and children. The large number of adults vs. children as well as the higher mortality in adults will introduce age bias for mortality. Another reason for the differential could be that centers taking care of large numbers of pediatric burn patients have not reached their maximum capacity based on available resources and thus are able to provide optimal care.

Volume-outcome relationship studies in Pediatric Intensive Care Units (PICU) have likewise shown varied results depending on the statistical analysis used. One study of the Pediatric Critical Care Study Group documented an inverse relationship between risk-adjusted mortality and volume using linear regression, while a second study, using mixed-effects hierarchiacal techniques, demonstrated best outcomes in mid-to large-sized PICUs. (17,18) Another study of pediatric asthma treatment demonstrated improved outcomes with higher volumes. (19) Differences in these studies could be due to the broad range of diagnoses treated in a PICU (including both surgical and nonsurgical illnesses), which may diminish the effects of a specialized care team. In burn injury, the impact of specialized protocols can be optimized.

The different results for these studies suggest that the relationship between volume and outcomes is complex and involves the integration of multiple factors other than the number of admissions. Patient illness severity, disease-specific treatment requirements, need for specialized high intensity care, resource requirements, specialized staff training, transportation, and funding all may play a role. In a study of healthcare resource utilization for pediatric burn treatment, Shields reported that the most severely injured burned children are treated at higher volume centers. (20) There are a variety of reasons why centers taking care of larger numbers of pediatric burn patients may have improved outcomes. Large pediatric burn centers serve as referral centers and treat many of the most severely injured patients in a region. Larger volume centers are likely to have more experience, more specialized care providers, and greater resources available to care for critically ill pediatric patients. Conversely, referrals to large centers may be skewed towards children with more complex other medical problems or higher injury severity, which could serve to increase mortality at those centers.

Although the use of a large national data set allows for examination of volume/outcome relationships, database studies have intrinsic limitations. First, the data are submitted by a limited number of facilities and may not be representative of the overall population. Second, coding differences between facilities between facilities, particularly with respect to burn size, may impact the validity of the conclusions. Third, although this study suggests that high volume centers may have improved survival, it is not designed to identify the optimal number of pediatric burn admissions. Finally, our analysis, due to limitations in the national data set, does not capture more subtle outcome measures related to appearance (scarring, contracture formation), physical function (range of motion, developmental milestone achievement, activities of daily living), or emotional health (self-image, family life) which may be similarly related to institutional volume.

Burned children are a special population requiring high intensity age-appropriate care physically and psychologically. The number of children treated at burn centers in the United States varies markedly, and the majority of children sustain relatively small burns (<10%). Mortality in children with major burns appears to decrease in centers that treat a large volume of children with burn injuries. Further investigation into long term outcomes for children with burn injury may provide further insight into volume/outcome relationships.

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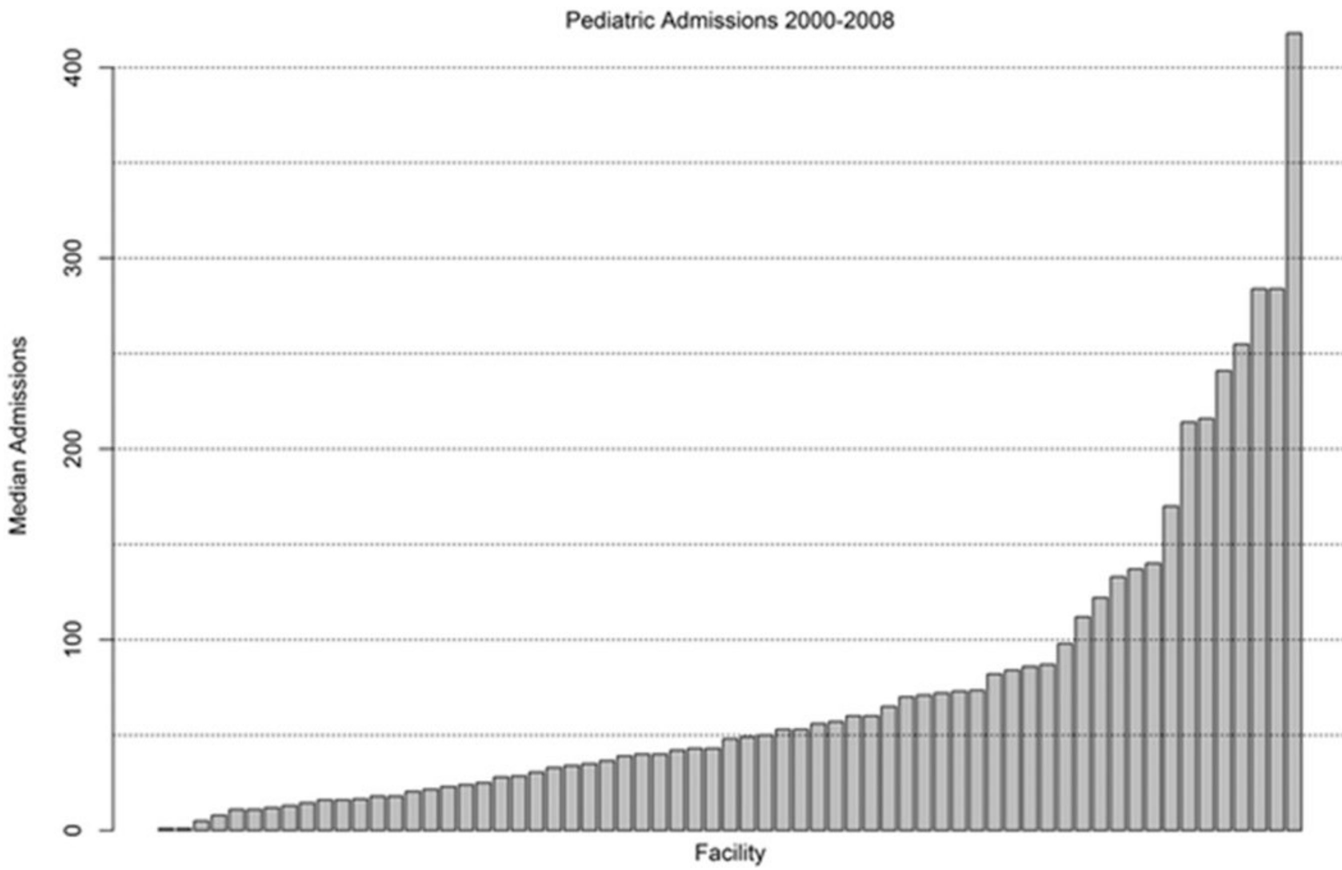

Figure 1.
Median yearly admissions of pediatric patients at 67 facilities.

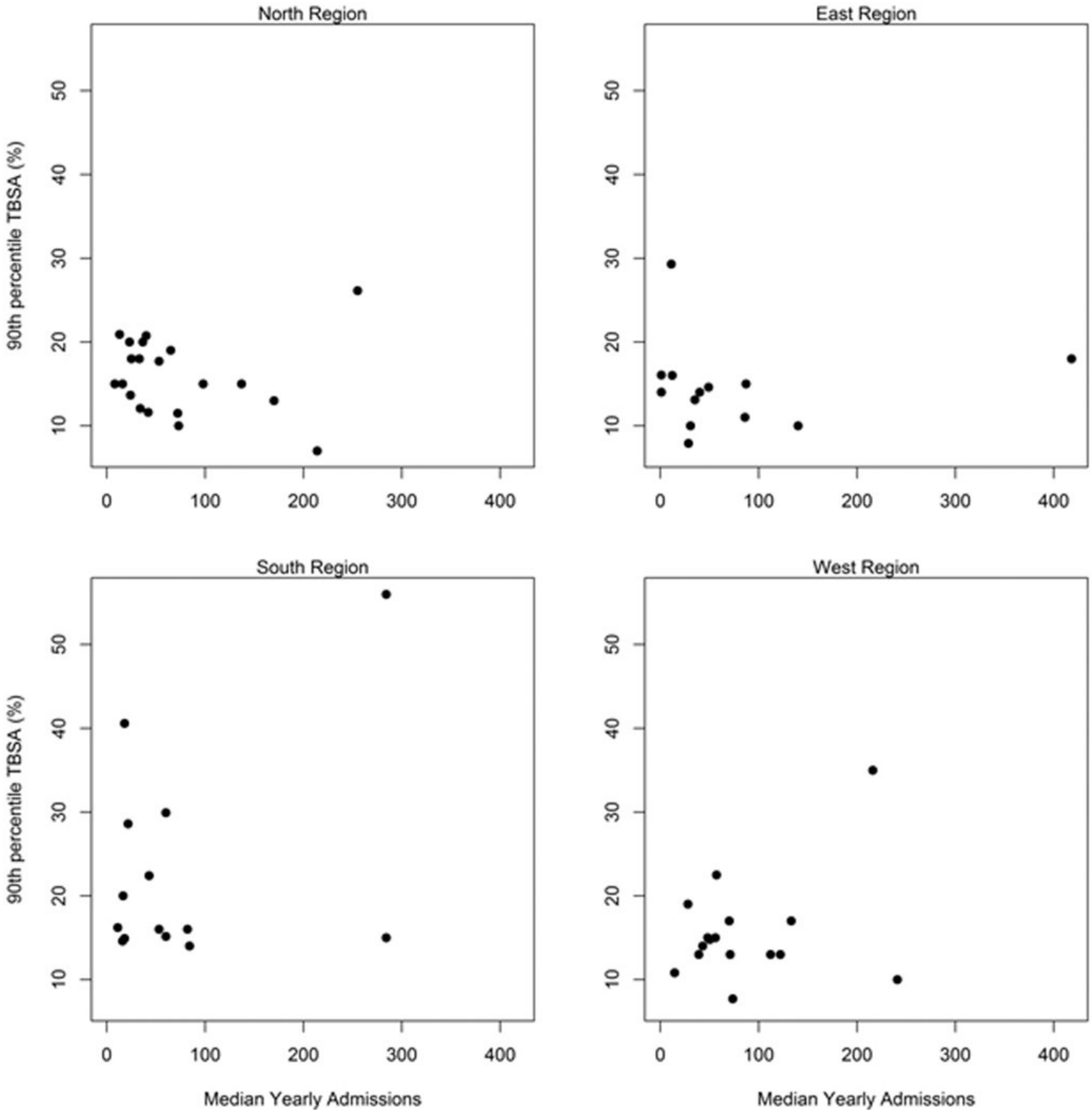

Figure 2.

90th percentile of TBSA (%) for pediatric patients at each facility versus median yearly admissions at each facility organized by region as defined in the NBR.

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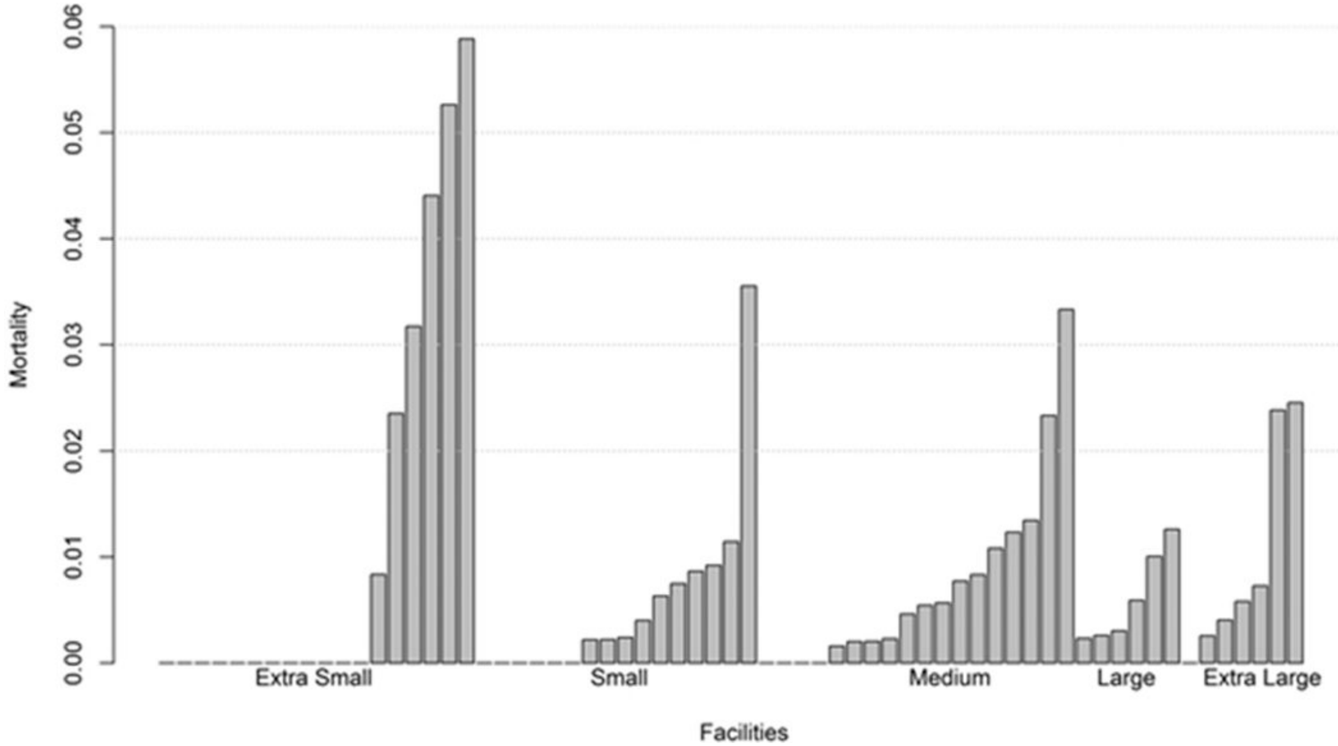

Figure 3.

Mortality at each facility analyzed organized by facility size: Extra small < 25, Small [25–50), Medium [50–100), Large [100–200), Extra Large ≥ 200 median yearly admissions.

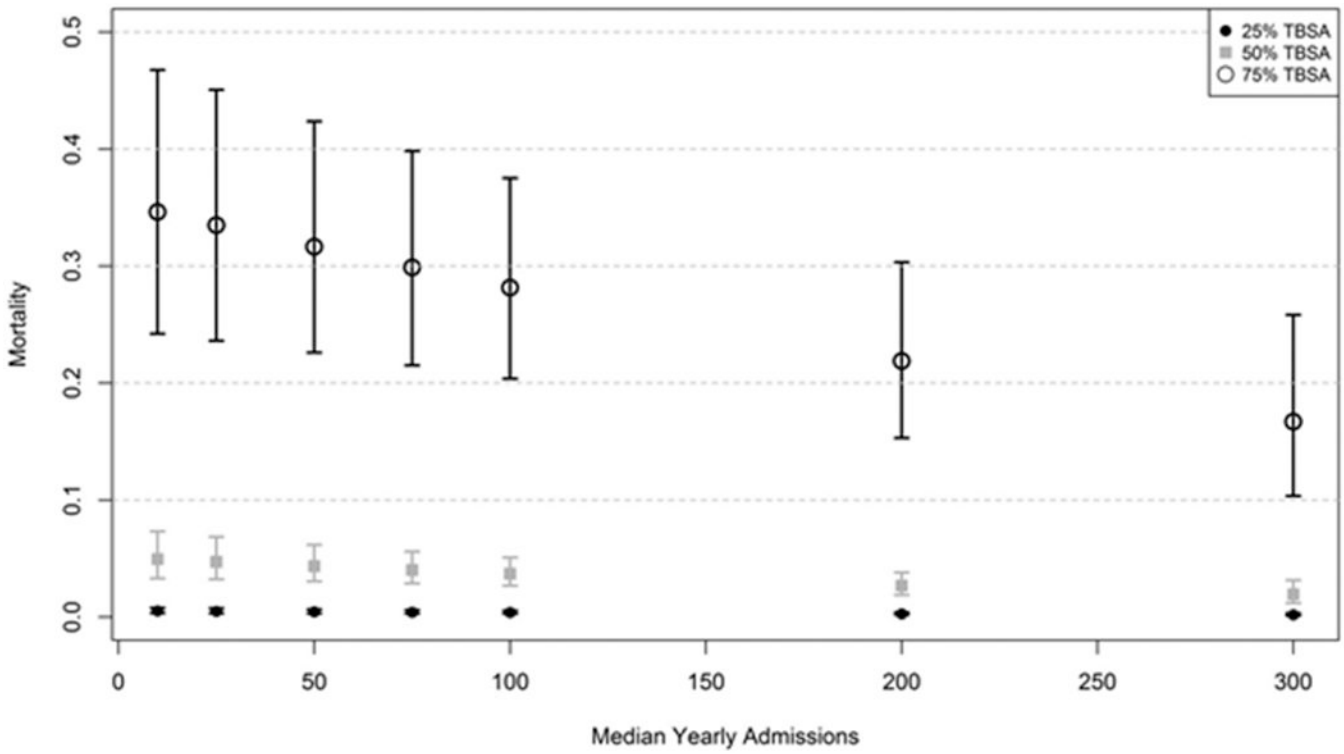

Figure 4.
Estimated mortality for a 10 year old child without inhalation injury with 25%, 50%, or 75% TBSA for varying facility sizes.

Table 1

Estimates, standard errors and p-values for fixed effect predictors in final mortality model

Predictor	Estimate	Standard Error	P-value
Intercept	−7.061	0.262	< 0.0001
Admits	−0.003	0.001	0.0045
Age	−0.0514	0.014	0.0005
TBSA	0.093	0.004	< 0.0001
Inhale	4.378	0.276	< 0.0001
TBSA*Inhale	−0.045	0.005	< 0.0001

Fixed effect predictors included age, burn size (TBSA-total body surface area), inhalation injury (Inhale) and combined burn size and inhalation injury (TBSA*Inhale).

Table 2

Coefficients for facility size groups

Facility Size	Coefficient	Standard Error
XS	0.943	0.430
S	0.640	0.385
M	0.851	0.342
L	0.885	0.410

Coefficients included extra small (XS, median yearly admission <25), small (S, median yearly admission 25–49), medium (M, median yearly admission 50=99), and large (L, median yearly admission 100–199). Extra large facilities were considered as baseline group, coefficient = 0.