SOUTHERN SURGICAL ASSOCIATION ARTICLE

Contemporary Burn Survival

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BACKGROUND: The standard of burn treatment today reflects major advances. We sought to quantitate the impact of these advances on burn survival via age-stratified mortality ratios compared with other reported mortality analyses in burns.

STUDY DESIGN: Age, percent of the total body surface area (TBSA) burned, presence of inhalation injury, length of stay, and survival status were recorded at admission and at discharge for all new burn admissions between 1989 and 2017. The expected mortality probability was calculated using historical multiple regression techniques and compared with observed data. We developed a prediction model for our observed data.

RESULTS: Between 1989 and 2017, there were 10,384 consecutive new burn admissions, with 355 mortalities (median age, 13 years; median percent TBSA burn, 11%). We saw a significant decrease in our observed mortality data compared to historical predictions ($p < 0.0001$), and a 2% reduction per year in mortality during the 3 decades. The prediction model of mortality for the data is as follows: $\Pr(\text{dying}) = e^x/(1 + e^x)$ where $x = -6.44 - 0.12\ \text{age} + 0.0042\ \text{age}^2 - 0.0000283\ \text{age}^3 + 0.0499\ \text{TBSA} + 1.21\ \text{Inhalation Injury} + 0.015\ \text{third degree TBSA}$.

CONCLUSIONS: The reduction in mortality over time may be attributed to successful changes in standard of care protocols in the burn center that improved the outlook for burned individuals, including protocols for management of inhalation injury, nutrition, resuscitation, and early excision and grafting. (J Am Coll Surg 2018;■:1−11. © 2018 Published by Elsevier Inc. on behalf of the American College of Surgeons.)

Mortality from burns is determined by age, sex, burn size, and the presence or absence of inhalation injury. Severe burn injuries also produce a profound hypermetabolic stress response, which is characterized by excessive glucose production, protein catabolism, and an influx of oxidants.[1-3] The stress response to burn causes a severe loss of lean body mass and muscle wasting.[4,5] Infection that occurs during the hospital course, immunologic compromise,[6] and growth delays in both muscle and bone[7] contribute to morbidity, mortality, and prolonged recovery.

The association between percent total body surface area (TBSA) burned and survival was first noted in 1902.[8] Beginning in 1949, age-stratified probit modeling was used to evaluate changes in the standard of burn care, although other methods have been occasionally used.[9] Probit analysis converts a sigmoid dose-response curve into linear form and allows the evaluation of burn size in terms of mortality and other binary outcomes data.[10-12] Bull, Squire, and Fisher[13-15] are credited with the first application of probit analysis for the quantitative assessment of advancements in burn care, and 3 analyses were separately published spanning the years 1942 to 1970. They selected the age categories of 0 to 14, 15 to 44, 45 to 64, and ≥65 years; for each, they reported the percent TBSA burned that resulted in 50%

Disclosure Information: Nothing to disclose.

Disclosures outside the scope of this work: Dr Herndon receives royalties from Elsevier.

Support: This work was supported by NIDILRR (90DP0043-02-01 [DNH]), NIH (P50GM060338, R01GM056687, T32GM008256 [DNH]; R01HD049471 [OES]; and R01GM112936 [CCF]), Shriners Hospitals for Children (84080, 80100, 71008, and 71000 [DNH]), the Department of Surgery at UTMB (2014-667 [LES]), and the Remembering the 15 Research Education Endowment Fund. This study was also conducted with the support of UTMB's Institute for Translational Sciences, supported in part by a Clinical and Translational Science Award (UL1TR000071) from the National Center for Advancing Translational Sciences (NIH).

Disclaimer: None of the funding sources had any role in the design of the study, in the writing of the manuscript, or in the collection, analysis, and/or interpretation of the data.

Presented at the Southern Surgical Association 129th Annual Meeting, Hot Springs, VA, December 2017.

Received December 19, 2017; Accepted December 19, 2017.

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https://doi.org/10.1016/j.jamcollsurg.2017.12.045
ISSN 1072-7515/18

Table 1. Historical Comparison of Percent Total Body Surface Area Burn Resulting in 50% Mortality (Lethal $Area_{50}$)

		0–14 y		15–44 y		45–64 y		≥65 y	
Year	**First author (country)**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
1949	Bull (UK)	342	51	311	43	95	23	46	9
1954	Bull (UK)	1,366	49	967	46	330	27	144	10
1956	Schwartz (US)	—	—	480	65	—	—	—	—
1957	Barnes (US)	217	39	221	65	219	39	128	26
1964	Pruitt (US)	238	49	806	56	56*	29*	—	—
1971	Bull (UK)	962	64	565	56	246	40	149	17
1980	Curerri (US)	232	63	413	63	178	38	114	23
1987	Herndon (US)	875	95	612	76	132	46	52	19

*≥50 years.

mortality (LA_{50}).[13-15] Barnes[16] reported data from Massachusetts General Hospital in 1957. Schwartz and colleagues,[17] and later Pruitt and associates,[18] reported similar numbers for the Brooke Army Medical Center; additional reports of burn LA_{50} have used the 4 age categories established by Bull, Squire, and Fisher (Table 1). In 1980, Curerri and coworkers[19] predicted age-adjusted mortality in 937 burned patients (79% survival, median age of 29 years, median burn size of 18% TBSA) using a logistic regression formula to describe the standard of care at the time. Predicted mortality based on TBSA burn and age was used as the primary metric of progress in burn care in their model. There was an apparent decrease in mortality beginning in 1987, particularly in younger individuals, which may have been attributed to the implementation of standardized protocols. To further explore mortality, we analyzed data from 1989 and onward.

The specific objectives of our study were to determine a regression model of mortality in all pediatric and adult burned patients who were admitted to Shriners Hospitals for Children—Galveston (SHC) or the Blocker Burn Unit (BBU) in Galveston, from 1989 to 2017. All patients were treated according to standardized protocols of care at 1 burn center, including protocols for inhalation injury, nutrition, resuscitation strategies, and early excision and grafting. This retrospective chart and database review was approved by the University of Texas Medical Branch Institutional Review Board (Protocol No. 14-036 and 17-0036). The datasets analyzed during this study are available from the corresponding author on reasonable request.

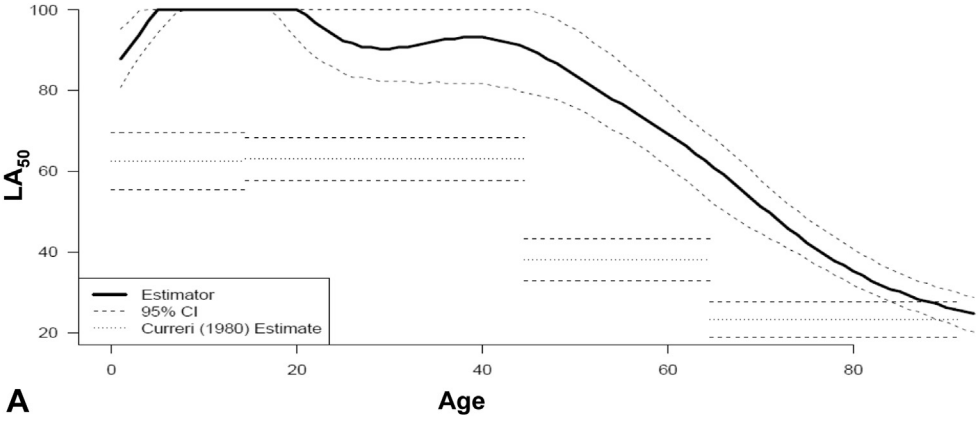

Figure 1. (A) The LA_{50} (% total body surface area resulting in 50% mortality) function of the nonlinear prediction model (solid line) with 95% CI (dashed lines) compared with Curerri and colleagues'[19] model (dotted lines). (B-D) shows a comparison of (B) Curreri,[19] (C) Shirani,[20] and (D) revised Baux[21] prediction of probability of mortality (small dotted line at 45 degrees) vs observed rate of mortality (solid line) along with standard errors, overall and divided by age groups. (Ba) The Curreri predicted and true survival rates overall and among different age groups: (Bb) 0 to 14 years, (Bc) 15 to 44 years, (Bd) 45 to 64 years, (Be) >65 years, from 1989 to 2017. Similar comparisons are illustrated with (Ca-e) Shirani and (Da-e) the revised Baux analysis. In both historical cases, the predicted fit falls below the line of agreement, indicating that these models predicted a greater number of mortalities than we observed in our dataset.