Not All Patients Meet the 1 Day per Percent Burn Rule: A Simple Method for Predicting Hospital Length of Stay in Patients with Burn Injury

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Abstract

Introduction: Hospital length of stay (LOS) is utilized to estimate resource utilization and quality of care.

In burns the LOS estimation is 1 day per percent total body surface area burn (1 day/%TBSA). Our purpose was to evaluate the 1 day/%TBSA burn rule and develop simple accurate formulas to predict LOS.

Methods: The American Burn Association National Burn Repository (NBR) from 2000-13 was utilized to collate data on patients >18 years. We divided 106,543 records in half, utilizing one set to develop a model (training set) and the other to test the model (test set). We calculated the difference between observed and predicted LOS for all patients, and then examined the effect of inhalation injury and age using a linear regression model containing TBSA, age, inhalation injury and all two-way interactions. We compared predictive performance of the linear regression model to the 1 day/%TBSA rule. Finally, we developed and validated three simple formulas to more accurately predict LOS than the 1 day /% TBSA rule.

Results: LOS was significantly associated with patient age, TBSA, inhalation injury, and all two-way interactions. For patients <40 years without inhalation injury the main effect of TBSA was 0.71. For each decade increase in age, LOS increased by 0.74 days/TBSA burn; inhalation injury added 1.70 days. LOS was highly variable among patients with similar burn size, age and inhalation injury due to concomitant trauma, complications, and comorbidities. We developed 3 formulas to estimate patient LOS: 1. inhalation injury present, regardless of age 2. no inhalation injury and ≥ 40 years old 3. no inhalation injury and <40 years old.

Conclusions: Traditional LOS estimates of 1 day/%TBSA burn rule is biased, underestimating LOS, particularly for patients >40 years with inhalation injury. The following formulas applied at admission

can accurately estimate hospital LOS, improve prediction over 1 day/%TBSA, and provide results comparable to complicated models:

- I. Patients with inhalation injury: $LOS = \left(\frac{age}{10}\right) + (1.5 * TBSA)$
- II. Patients without inhalation injury <40 years of age, LOS=1 day/%TBSA
- III. Patients without inhalation injury ≥40 years, LOS=((age/10)-2)+TBSA

Key Words: burn injury, hospital length of stay, outcomes

Introduction:

Hospital length of stay (LOS) impacts patients, families, providers, and hospitals. Patients view LOS as a “goal” to attain; families use LOS to plan; providers use LOS for resource utilization estimates; and payors use LOS as a quality of care indicator. Accurate LOS estimation becomes an imperative, particularly in resource intensive illnesses such as burn injury. In 2000, burn injury cost \$7.5 billion, with medical costs of over \$1.3 billion and productivity loss of \$6.2 billion, which equates to \$10.4 billion/year in 2010 dollars. (1, 2)

A commonly used method for estimating burn LOS is 1 day of hospitalization per percent burn (%TBSA). This rule originated in a round table discussion in 1986, with no data or analyses presented to support the assertion. (3) Large database analyses based on the “average” burn patient have supported this estimate; however, these estimates are subject to bias from the large number of patients with small burns. (4-6)

We previously investigated LOS for burn patients using a competing risk model. (7) Our model enabled us to predict the probability of discharge or death over time as a function burn size, patient age, and presence of inhalation injury. Although this analysis revealed interesting dynamics of the differential and changing effects of burn size and age over time and the temporal relationship between the competing risks of death and discharge, the competing risk model cannot predict actual LOS for any given patient. Rather it yields the cumulative probability that a patient with particular characteristics will be discharged (or die) by a certain time. The purpose of this study was to use the American Burn Association National Burn Repository (NBR) to develop and assess a predictive model for LOS, evaluate the 1 day/%TBSA rule, and develop a simple formula that better estimates LOS than the 1 day/%TBSA rule.

Methods:

This study was approved by the UC Davis Human Subjects Review Board. The NBR contains outcomes, patient and injury characteristics for patients admitted to burn centers. We obtained the American Burn Association's 2009 NBR release containing 286,293 admission records. To focus on recent burn care, we restricted our analysis to admissions in 2000-9 (210,683). We dropped records missing information on survival (12,226), age (5,441), burn size (42,545), inhalation injury (12,861), or LOS (4,471). (19) We also removed 6,530 records with unreliable information (e.g., TBSA>100), 23,084 readmissions, 1,038 patients transferred to another primary care facility, 3,690 patients with non-burn injuries, 3,218 records identified as probable duplicates, 1,038 patients transferred to another facility, and 115 records for which ventilator days and/or intensive care unit (ICU) days exceeded hospital LOS. We further limited the data set to adults 18 years and older (63,547) and to patients discharged alive (59,722).

We subsequently obtained the ABA's 2010-2013 NBR release containing 182,398 records. Similar to the 2009 data pull, we dropped patients transferred to another facility (1,495), readmissions (40,555), non-burn injuries (9,268) and patients potentially also represented in the 2000-9 data pull (discharge, admission or injury year prior to 2010) (49,977). We dropped records missing information on survival (889), age (1,058), burn size (6,203), LOS (94), or inhalation injury status (2,060). Finally 100 records for which ICU days and/or ventilator days exceeded hospital LOS were dropped. Retaining records of adults 18 years and older who were discharged alive left 46,821 records. Combining with the 2009 data pull, 106,543 records of initial admissions of adult patients were used in the analysis. Patients came from 92 different facilities.

Statistical Analysis

To develop and evaluate predictive models for LOS, we split the data into two approximately equally-sized sets by randomly dividing records from each facility in half using a computer program over the separated data sets in the order present in the original NBR dataset. One half, designated as the training set (n= 53,250), was used to evaluate the effect of predictors on LOS and develop a predictive model. Model performance then was assessed by applying it to the test set (other half of the data). (n = 53,293).

We used linear regression to model LOS as a function of %TBSA, age in years, and presence of inhalation injury and all two-way interactions between these factors. For the TBSA*Age interaction, the product of TBSA and Age was divided by 1,000 for inclusion in the regression model. A generalized estimating equation approach was used to estimate the effect of predictors on LOS and robust standard errors used to account for clustering of patients by facility. P-values less than 0.05 were considered significant. Proc Genmod in SAS version 9.3 was used to fit the generalized estimating equation models.

Results

LOS was significantly associated with patient age, TBSA and the interaction between age and TBSA; two way-interactions of inhalation injury with age and TBSA were significant (Supplemental Digital Content – Table 1). The parameter estimate for the main effect of TBSA was 0.71 for younger adults without inhalation injury (LOS increases <1 day/%TBSA). For every decade increase in age, LOS increased by 0.74 days/%TBSA; inhalation injury added 1.70 days. The effects of TBSA, age and inhalation injury are not simply additive on two-way interaction analysis; all had positive interactions. Thus, LOS increases more for a given change in TBSA or age when the patient also has inhalation injury. For example, for a patient with inhalation injury, LOS increases by 1.06 (0.709+0.350) days per 1% burn size increase and by 0.121 (0.074+0.047) days for every 1 year increase in age. The interaction between TBSA and age

indicates that LOS increases more with a 1% increase in TBSA for older patients than for younger patients.

We applied the linear regression model developed with the training set to the test set. We compared the regression performances and the 1 day/%TBSA rule graphically and quantitatively by calculating the mean and standard deviation of the difference between observed and predicted LOS. The 1 day/%TBSA rule was biased, underestimating LOS, particularly for patients with inhalation injury (Table 1). The standard deviations of the differences between observed and predicted LOS were slightly larger for the 1 day/%TBSA rule than for the regression model. In contrast to the 1 day/%TBSA rule, the regression model was unbiased. These findings highlight the importance of accounting for age and inhalation injury in predicting burn LOS.

To further assess prediction rule performance, we plotted predicted versus observed LOS (Figure 1). For patients with inhalation injury (Figure 1A), all methods underestimate LOS for patients with prolonged hospitalization (divergence of the two lines with increasing observed LOS). Notably, the 1 day/%TBSA rule underestimates LOS when patients have inhalation injury; the regression model overestimates slightly for short LOS but does not underestimate long LOS as severely as the 1 day/%TBSA rule. The two methods show similar dynamics for patients without inhalation injury (Figure 1B).

Finally, we compared the models by plotting the difference between observed and predicted LOS versus age by inhalation injury status (Figure 2). For patients with inhalation injury, the regression model is largely unbiased while the 1 day/%TBSA rule shows a consistent underestimation bias (Figure 2A). In the absence of inhalation injury, the regression model remains unbiased over the entire age range but the 1 day/%TBSA rule underestimates LOS for patients >40 years with the degree of bias increasing with age (Figure 2B).

Development of Refined LOS Rule

The preceding analyses showed that age and inhalation injury are important contributors to hospital LOS. Although the regression model better predicted LOS than the 1 day/%TBSA rule, this model cannot readily be applied at bedside. We sought to develop a predictive rule that was comparably easy to remember and calculate as the 1 day/%TBSA rule but better accounted for age and inhalation injury.

We developed separate guidelines for patients with and without inhalation injury. To determine how to incorporate age, we used the training set to estimate the relationships between LOS and TBSA along the continuum of ages by fitting linear regressions to data subsetted with a moving window of 5 years. This analysis was conducted separately for patients with and without inhalation injury. We then plotted the intercepts and slope coefficients from the regressions versus age and fit smoothing splines to identify major trends (Figure 3).

These plots showed that the intercepts for the regressions of LOS versus TBSA increased approximately linearly with age both for patients with (Figure 3A) and without inhalation injury (Figure 3C). For patients with inhalation injury, the slopes of the regressions between LOS and TBSA ranged from about 1.25 to 1.5 (Figure 3B). For patients without inhalation injury, the slopes for patients younger than about 40 years old were about 0.9 days/1% TBSA but increased to more than 1 day/1% TBSA for older patients (Figure 3D).

The staying-power of the 1 day/%TBSA guideline for estimating LOS is its ease of use and simplicity. For any refined rule to be successful, it must also be easy to remember and apply. Meeting these objectives necessarily requires simplifications. Based on the relationships between LOS and inhalation injury, age and TBSA we suggest the following rules for approximating LOS for burn patients based on burn size, age and inhalation injury.

I. For all patients with inhalation injury, we suggest

$$LOS = \left(\frac{age}{10}\right) + (1.5 * TBSA)$$

i.e., estimate LOS as 1 day per each decade of age plus one and half times the burn size in percent. The 1.5 days/%TBSA is somewhat higher than observed for patients with inhalation injury (Figure 3B) but is easier to remember and calculate than other options such as 1.3.

II. For patients without inhalation injury

a. For <40 years of age, we suggest using 1 day/%TBSA

For patients less than 40 and without inhalation injury, the slope coefficients were between about 0.85 and 0.95 days/%TBSA. While 1 day/%TBSA is slightly higher it is easier to use and allows for some adjustment for age which is not otherwise included in this rule (Figure 3D).

b. For patients ≥40 years, we suggest

$$LOS = \left(\left(\frac{age}{10}\right) - 2\right) + TBSA$$

We selected 40 years as the break point based on Figure 2 in which the smoothing spline deviated from 1 day/%TBSA starting at about 40 years old. We subtract 2 days for the age adjustment because the intercept from fitting a linear regression to the intercepts versus age in Figure 3C was -1.7.

We applied our new guideline to the test set and compared its performance to the regression model and the 1 day/%TBSA rule. Our new guideline performed similarly to the regression model in that it was unbiased with comparable standard deviations. (Illustration of LOS calculation in Supplemental Digital Content – Table 2).

Deviations from Predicted LOS

Although the regression model and our refined guideline captured the main dynamics of LOS as a function of TBSA, age and inhalation injury, there was substantial variability, highlighting the complexities of burn patient LOS. We sought to identify additional factors that influence burn LOS. Using the results of the regression model, we separated patients into three groups based on differences in observed and predicted LOS:

1. Short stay: differences between observed and predicted more extreme than the 10th quantile of differences (-9.6 days). Patients in this group had hospital stays much shorter than predicted.
2. Long stay: differences between observed and predicted more extreme than the 90th quantile of differences (9.7 days). Patients in this group had hospital stays much longer than predicted.
3. Average stay: differences between observed and predicted between the 10th and 90th quantiles (-9.6 to 9.7 days).

We then summarized potentially meaningful characteristics of these groups of patients to the extent additional information was available in the NBR.

Summaries of the patient group data suggest reasons for the high degree of variability in LOS among burn patients (Table 2). Patients with LOS longer than predicted had larger full thickness burns, higher incidence of combined burn and trauma injury, increased likelihood of comorbidities or complications during hospitalization. Patients with hospital stays shorter than predicted more commonly had inhalation injury, and somewhat larger burns with a greater percentage of partial thickness burns than patients with average or long stays.

Discussion:

LOS after burn injury is an important indicator used in many different arenas to gauge quality of care and to plan resource utilization. For example, insurance companies utilize these estimates as

screening tools for audits, hospitals use LOS estimates to develop staffing plans, and managers use it as a measure of quality. Our study confirmed that LOS is a complex entity that is influenced by many variables such that the 1 day/%TBSA rule is reasonable only for patients without inhalation injury who are <40 years old. Both inhalation injury and age markedly influence LOS after burn injury, and two simple and related formulas improved the accuracy of LOS estimation for patients >40 years with inhalation injury.

Our study differs from others predicting LOS after burn injury in that we incorporated all three major factors (age, TBSA, and inhalation injury) to develop individual formulas that more accurately reflect patient outcomes. (4-6, 13) Our formulas are simple to use, easy to remember, and can be applied at admission. Previously developed formulas necessarily underestimate LOS at higher ages and/or in the presence of inhalation injury. The newer formulas may also prove helpful in quality improvement in these groups by providing a more accurate assessment than the 1 day/%TBSA burn.

However, no formula estimating LOS can be accurate for all patients and situations, as a myriad of factors that cannot be measured, such as family influence and social issues cannot be readily incorporated in a formula. Understanding who is likely to deviate from the formula provides the clinicians with insight that they can pass on to the family. Clearly, patients with concomitant trauma, comorbidities, and complications are likely to have hospital stays longer than predicted with models that only include TBSA, age and inhalation injury. The extent to which these factors extend LOS will depend on their nature and severity. Likewise, the data originate in the U.S. and may not be applicable in other parts of the world. Finally, potential for biased data exists in any registry collection; however, the large number and consistency of the entries in the NBR minimizes this potential.

Conversely, some patients have LOS much shorter than predicted using TBSA, age and inhalation injury. We found some of the patients with very short observed LOS relative to predicted LOS to have

larger burns than other patients, but with a larger percentage of partial thickness burns. Thus, it is likely that these patients had low severity burns albeit over a large surface area which allowed them to be discharged quickly. Other factors contributing to patients with shorter LOS than predicted are less clear. Although we included inhalation injury in our models, the estimation of its effect on LOS is crude. In the NBR, inhalation injury is simply coded as present or absent without any information on severity. This lack of severity discrimination could explain why inhalation injury was more common in patients with extremely short LOS relative to predicted LOS as compared to the other groupings. Without severity information, the predicted effect of inhalation injury on LOS is “one-size-fits-all” and reflects the average difference in LOS between patients with and without inhalation injury. As a result, regardless of severity, the incremental effect is the same. Thus, LOS may be substantially overestimated for patients with minor inhalation injury.

The strength of this study is its use of a large national data set to develop formulas that can be applied to the vast majority of burn patients. However, the study has several limitations. First, the study is limited by potential inaccuracies in the NBR. In an effort to minimize inaccuracies, we utilized our previous work, which evaluated the data for reliability and removed any questionable data points. (14) Also, the national data set is more reflective of practice in general and is thus more generalizable than studies limited to a single center. Another intrinsic limitation of the study is that burn LOS is likely influenced by factors not included in our study, such as social, familial, and education factors. However, these data are not readily available (or accurately depicted) in any data set. In an effort to keep the formula simple, we limited ourselves to easily obtained and regularly recorded factors that would be understood by patients, families, administrators, payors, and clinicians.

Conclusions

In conclusion, burn LOS is used as a surrogate for evaluating quality of care, informing families, advising administrators, and standard for research. We have developed a simple set of three rules that improve upon previous estimates which are simple to remember and use:

For patients with inhalation injury for all ages:

$$LOS = \left(\frac{age}{10}\right) + 1.5 * TBSA$$

For patients without inhalation injury <40 years of age

$$LOS = 1 \text{ day}/1\% \text{ TBSA}$$

For patients ≥ 40 years without inhalation injury:

$$LOS = \left(\left(\frac{age}{10}\right) - 2\right) + TBSA$$

However, it should be remembered that any predictive formulas are estimates, not absolutes. Factors such as comorbidities, trauma, and complications can and influence LOS and outcomes.

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Figure Legends

Figure 1. Predicted versus observed LOS for patients in a test set of the NBR using a linear regression model, the 1 day/%TBSA rule and a revised rule incorporating age and inhalation injury for patients A) with inhalation injury and B) without inhalation injury. The dashed, straight line shows one-to-one agreement; the solid line shows a smoothing spline fit to the data to reveal prominent trends.

Figure 2. Difference between observed LOS for patients in a test set of the NBR using the linear regression, the 1 day/%TBSA rule and a revised rule incorporating age and inhalation injury for patients A) with inhalation injury and B) without inhalation injury. The dashed line indicates no difference and the solid line is a smoothing spline fit to the data.

Figure 3. Estimated intercepts and slopes for the relationships between LOS and TBSA for patients with inhalation injury (A and B) and without inhalation injury (C and D) as a function of ages. Linear regressions were fit to data subsetting by age using a moving window of 5 years. Thick solid line shows a smoothing spline fit to the coefficients versus age. Dashed lines in A) and C) show linear regressions fit to the intercepts versus age.

Table 1. Comparison of New Guideline and 1 Day/1%TBSA Rule

	Regression Model	1 day/1% TBSA	New Guideline
All Records	0.0 ± 13.8	2.7 ± 14.3	0 ± 13.9
No Inhalation Injury	0.0 ± 12.5	1.8 ± 12.7	0 ± 12.5
With Inhalation Injury	0.4 ± 22.1	10.4 ± 23.0	-0.1 ± 22.2

Mean ± SD of the difference in length of stay (observed – predicted) for three predictive models of LOS developed with a training set and applied to an independent test set. Negative values indicate that predicted values overestimate LOS while positive values indicate underestimation.

Table 2. Characteristics of Patients with Short, Long and Average LOS

Variable	Short (n = 5,329)	Average (n = 42,634)	Long (n = 5,330)
Age	46.7 ± 16.6	42.0 ± 16.5	46.8 ± 17.8
Inhalation	22.9%	7.6%	18.5%
TBSA	20.3 ± 13.5	5.5 ± 6.6	13.1 ± 15.8
Full Thickness Burn	4.5 ± 10.2	1.6 ± 4.3	8.2 ± 13.6
Partial Thickness Burn	16.5 ± 11.0	4.4 ± 5.2	6.2 ± 9.4
Trauma ^a	6.3%	5.1%	16.0%
Comorbidities % of Reported % Missing	31.8 58.7	29.0 60.4	41.9 67.8
Complications % of Reported % Missing	24.9 47.9	17.7 44.1	40.0 59.9
^a Due to inconsistencies in reporting of trauma among the facilities we limited our summary of trauma to facilities and years in which at least one patient was reported to have suffered a traumatic injury. This requirement reduced the number of records for estimating the percentage of burn patients with concomitant trauma to 46,291.			