

## OBJECTIVE ESTIMATES OF THE PROBABILITY OF DEATH FROM BURN INJURIES

COLLEEN M. RYAN, M.D., DAVID A. SCHOENFELD, PH.D., WILLIAM P. THORPE, PH.D., ROBERT L. SHERIDAN, M.D., EDWIN H. CASSEM, M.D., AND RONALD G. TOMPKINS, M.D., Sc.D.

## ABSTRACT

**Background** Over the past 20 years, there has been remarkable improvement in the chances of survival of patients treated in burn centers. A simple, accurate system for objectively estimating the probability of death would be useful in counseling patients and making medical decisions.

**Methods** We conducted a retrospective review of all 1665 patients with acute burn injuries admitted from 1990 to 1994 to Massachusetts General Hospital and the Shriners Burns Institute in Boston. Using logistic-regression analysis, we developed probability estimates for the prediction of mortality based on a minimal set of well-defined variables. The resulting mortality formula was used to determine whether changes in mortality have occurred since 1984, and it was tested prospectively on all 530 patients with acute burn injuries admitted in 1995 or 1996.

**Results** Of the 1665 patients (mean [ $\pm$ SD] age,  $21\pm 20$  years; mean burn size,  $14\pm 20$  percent of body-surface area), 1598 (96 percent) lived to discharge. The mean length of stay was  $21\pm 29$  days. Three risk factors for death were identified: age greater than 60 years, more than 40 percent of body-surface area burned, and inhalation injury. The mortality formula we developed predicts 0.3 percent, 3 percent, 33 percent, or approximately 90 percent mortality, depending on whether zero, one, two, or three risk factors are present. The results of the prospective test of the formula were similar. A large increase in the proportion of patients who chose not to be resuscitated complicated comparisons of mortality over time.

**Conclusions** The probability of death after burns is low and can be predicted soon after injury on the basis of simple, objective clinical criteria. (N Engl J Med 1998;338:362-6.)

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**A**CCURATE, objective estimates of the probability of death from burn injuries would, as envisioned by Knaus et al.,<sup>1</sup> provide clinicians with an explicit basis for clinical decisions, help them understand the relative contributions of specific prognostic criteria, and reduce reliance on clinical intuition. These estimates would also be useful to patients and to others making medical and financial decisions about their care. The most widely used formulas for the prediction of mortality from burns are based on a minimal set of easily obtained variables. A classic example<sup>2</sup> calculated the percent likelihood of mortality as the patient's

age in years plus the percentage of the body-surface area that was burned. This formula, which was useful for triage and early assessment of outcome because it was easily remembered and applied, has become obsolete because of the remarkable improvement in survival rates in major burn centers in the past 20 years.<sup>3</sup> In contrast, more recent formulas have limited clinical use because they are difficult to remember or apply or they require more sophisticated clinical variables.<sup>3-6</sup>

In this study we examined data on mortality and length of stay among patients with burns who were treated in two centers from 1990 to 1996. We then developed estimates of the probability of death and length of stay based on information available on admission. The goal was to develop simple, objective probability estimates, thereby reducing reliance on subjective estimates of outcome.

## METHODS

We retrospectively reviewed the records of all 1665 patients with acute burn injuries admitted to the Shriners Burns Institute, Boston, and Massachusetts General Hospital from 1990 to 1994. Information collected included age, sex, admission and discharge dates, length of stay, extent of burn (sum of the extent of second- and third-degree burns), type of burn, presence or absence of inhalation injury, need for escharotomy, and mortality. Burn types were classified as flame, scald, contact, chemical, electrical, and other (e.g., radiation). Inhalation injury was considered present if the fire had occurred in a closed space, if bronchoscopy on admission found soot below the level of the vocal cords, or if the blood carboxyhemoglobin concentration was elevated on admission. We included all patients in the study who died before discharge, including those who died within 72 hours after admission (defined as early death), those for whom there were do-not-resuscitate orders, those who died while in a persistent vegetative state, and those who died of causes other than burns. Permission for record review was obtained from the Subcommittee for Human Studies at Massachusetts General Hospital.

Stepwise logistic-regression analysis was performed with forward selection for evaluation of risk factors for death. Age, sex, presence or absence of inhalation injury, need for escharotomy, year of admission, and type and extent of burn were used as mortality and length-of-stay covariates. Age and burn size were coded by a method that allowed the data to dictate how many age and burn-size classifications were necessary.<sup>7</sup> Regression analysis was used for length of stay of survivors. The resulting models were

From the Shriners Burns Institute and the Sumner Redstone Burn Center (C.M.R., W.P.T., R.L.S., R.G.T.); the Massachusetts General Hospital Biostatistics Center (D.A.S.); and the Surgery (C.M.R., W.P.T., R.L.S., R.G.T.), Medicine (D.A.S.), and Psychiatry (E.H.C.) Services, Massachusetts General Hospital and Harvard Medical School — all in Boston. Address reprint requests to Dr. Tompkins at Trauma and Burn Services, Massachusetts General Hospital, Bigelow 1302, Boston, MA 02114.

**TABLE 1. MORTALITY AMONG PATIENTS ACCORDING TO AGE, BURN SIZE, AND PRESENCE OR ABSENCE OF INHALATION INJURY.**

PERCENTAGE OF BODY-SURFACE AREA BURNED	AGE (YR)									
	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100
	percent mortality (number of patients at risk)									
No inhalation injury										
0-20	0 (642)	0 (160)	1 (162)	1 (139)	1 (87)	0 (36)	0 (32)	0 (18)	8 (13)	100 (2)
21-40	0 (46)	0 (11)	0 (17)	0 (7)	0 (6)	0 (2)	0 (6)	0 (2)	100 (1)	—
41-60	0 (8)	0 (7)	0 (4)	—	0 (3)	0 (1)	—	0 (1)	—	—
61-80	33 (3)	0 (1)	0 (1)	—	—	0 (1)	—	—	—	—
81-100	0 (1)	—	—	—	0 (1)	—	—	—	—	—
Inhalation injury										
0-20	0 (17)	0 (10)	0 (11)	0 (13)	33 (3)	50 (2)	67 (3)	0 (4)	0 (2)	100 (1)
21-40	0 (12)	25 (4)	0 (11)	15 (13)	0 (13)	0 (3)	17 (6)	63 (8)	43 (7)	—
41-60	14 (14)	0 (7)	50 (4)	20 (5)	50 (6)	50 (2)	100 (3)	80 (5)	100 (2)	100 (1)
61-80	33 (3)	20 (5)	—	0 (3)	75 (4)	—	100 (1)	100 (2)	100 (1)	—
81-100	38 (8)	38 (8)	0 (1)	0 (2)	0 (3)	33 (3)	80 (5)	100 (2)	100 (1)	—

simplified to use as few variables as possible on the basis of statistical judgment justified by the data to predict risk. The mortality model was tested prospectively by application to data for patients admitted in 1995 or 1996.

Changes in mortality rates over the past decade were assessed by entering the data for 1990 to 1994 into a formula developed for estimates of the probability of death from burns based on 1984 data.<sup>3</sup>

Values are reported as means ±SD. Comparisons were made by Student's t-test. Confidence intervals were calculated for estimated probabilities from the logistic model.

**RESULTS**

Of the 1665 patients (910 children and 755 adults), 1143 (69 percent) were male and 522 (31 percent) were female, with a mean age of 21±20 years (range, 1 month to 99 years). The mean burn size was 14±20 percent of body-surface area. Two hundred forty-four patients (15 percent) had inhalation injury, and 131 (8 percent) required escharotomy. Treatment consisted of initial fluid resuscitation, early excision and grafting of burn wounds, topical antimicrobial therapy, and critical care support by a multidisciplinary team.<sup>8</sup>

The mean length of the hospital stay was 21±29 days. Of the 1665 patients, 1598 (96 percent) lived to discharge. Sixty-seven patients died (4 percent); 22 of these (33 percent) had multiple-organ-system failure, and 13 (19 percent) had early deaths. Twenty-two of the 67 patients (33 percent) had do-not-resuscitate orders, 5 (7 percent) died with a diagnosis of persistent vegetative state, and 5 (7 percent) died of non-burn-related causes. To our knowledge, only 2 of the 1598 patients who lived to discharge (0.1 percent) died within three months after discharge, both of underlying disease processes unrelated to the burn injury. These patients were considered survivors for the purposes of this study.

**A Model for Estimating the Probability of Death**

Sex, admission and discharge dates, type of burn, and need for escharotomy were not significantly associated with mortality. The identified risk factors for death were an age greater than 60 years, a burn covering more than 40 percent of body-surface area, and inhalation injury. Table 1 shows the distribution of patients according to these risk factors and actual mortality.

Table 2 condenses these data and shows that the presence of any one or two risk factors had a similar effect on mortality, allowing greater simplification of the mortality model. When the number of risk factors was used as a single covariate, no individual factor remained significant except an age of more than 90 years. Only four patients were older than 90; three of them had do-not-resuscitate orders. This model is described by equation 1:

$$\text{logit} = -5.89 + 2.58n,$$

where n is the number of risk factors and logit is the natural logarithm of the ratio of the probability of dying to the probability of living. The frequency of these three factors and the actual mortality and estimated probability of death based on this model are shown in Table 3.

With this model, mortality estimates can be easily remembered according to a simple clinical rule. When burn size of more than 40 percent of body-surface area, age greater than 60 years, and presence of inhalation injury are taken as risk factors, patient mortality is 0.3 percent with no risk factors, 3 percent with one risk factor, 33 percent with two risk factors, and approximately 90 percent with all three risk factors. This rule is applicable to all patients younger than 90.

**TABLE 2.** FREQUENCY OF EACH RISK FACTOR AND MORTALITY RATES.\*

NO. OF RISK FACTORS	AGE >60 Yr	>40% OF BODY-SURFACE AREA BURNED	INHALATION INJURY	NO. OF PATIENTS	NO. OF DEATHS	MORTALITY RATE (%)
0	—	—	—	1314	3	0.2
1	—	—	+	112	5	4
1	—	+	—	31	1	3
1	+	—	—	75	4	5
2	—	+	+	79	21	27
2	+	—	+	31	12	39
2	+	+	—	1	0	0
3	+	+	+	22	21	95

\*A minus sign indicates that the risk factor is not present, and a plus sign that the risk factor is present.

**TABLE 3.** ACTUAL AND ESTIMATED MORTALITY FROM BURNS ACCORDING TO THE NUMBER OF RISK FACTORS.

NO. OF RISK FACTORS	NO. OF PATIENTS	NO. OF DEATHS	ESTIMATED NO. OF DEATHS	ACTUAL MORTALITY	ESTIMATED MORTALITY (90% CI)*
					percent
0	1314	3	3	0.2	0.3 (0.1–0.6)
1	218	10	8	5	3 (2–5)
2	111	33	37	30	33 (26–41)
3	22	21	19	95	87 (78–93)

\*CI denotes confidence interval.

**Prospective Evaluation of Model**

A total of 530 patients with burns were admitted during 1995 and 1996. Their mean age was 25±23 years, their mean burn size was 13±16 percent of body-surface area, and 13 percent had inhalation injury. Thirty-two of the 530 patients (6 percent) died. The mortality rates were 0.7 percent, 14 percent, 39 percent, and 90 percent for patients with zero, one, two, and three risk factors, respectively, percentages similar to those predicted by equation 1.

**Assessment of Changes in Mortality from the 1980s to the 1990s**

The development of a model for estimating the probability of death from burns permits comparison of the probability estimates over time. The log of the odds of death (logit) was found previously<sup>3</sup> to be described by equation 2:

$$\text{logit} = -7.37 + 0.05(\text{age}) - 0.15(\text{year}) + 0.11(\% \text{ body-surface area}) - 6.61 \times 10^{-4}(\% \text{ body-surface area} - \text{mean } \% \text{ body-surface area})^2 + 1.04 \times 10^{-3}(\text{age} - \text{mean age})^2,$$

where age is the patient's age in years and year is the year of admission. Mortality decreased from 1974 to 1984. To test whether mortality decreased after

1984, the probability of mortality for each risk group in the period from 1990 to 1994 was estimated with equation 2 (with year set at 1984). The observed mortality was not significantly different from the expected mortality, indicating that mortality had not changed since 1984. Equations 1 and 2 functioned similarly as predictors.

In the previous study,<sup>3</sup> early deaths (14 of 1103 patients, or 1.3 percent) and 1 death in a patient with a do-not-resuscitate order were excluded, and patients in a persistent vegetative state were not considered. In 1990 to 1994, the analysis included patients with early deaths (13 of 1665 patients, or 0.8 percent) and those who died while under a do-not-resuscitate order or in a persistent vegetative state (27 patients, or 1.6 percent). If these patients are excluded, the overall difference in mortality between the decades remains similar.

**Analysis of Choice of Do-Not-Resuscitate Treatment Plan**

There was a 12-fold increase in the percentage of patients with do-not-resuscitate orders between the period from 1975 to 1984<sup>3</sup> and the period from 1990 to 1994 (from 0.1 percent to 1.3 percent); all these patients died. In 1995 and 1996, this percentage increased again; 12 of 530 patients (2.3 percent) chose not to be resuscitated, 1 of whom survived. We asked whether there were characteristics that led to the decision not to resuscitate.

Equation 2 predicted that 37 patients in the period from 1990 to 1994 had an intermediate risk of death (40 to 80 percent). Among them, 11 patients (30 percent) had do-not-resuscitate orders, all of whom died, and 26 patients (70 percent) had orders to resuscitate. Among the patients for whom resuscitation was ordered, there were five deaths from multiple-organ-system failure, two early deaths, and one death from cardiac arrhythmia. There were 18 survivors (69 percent of those resuscitated).

The average age of the patients with do-not-resus-

citae orders ( $78 \pm 10$  years) and their burn size ( $43 \pm 27$  percent of body-surface area) were not significantly different from those of the resuscitated patients ( $67 \pm 15$  years and  $58 \pm 31$  percent of body-surface area). Eighty-two percent of the patients with do-not-resuscitate orders had inhalation injury, as compared with 77 percent of the resuscitated patients. Therefore, the reasons for the decision whether to resuscitate were not fully explained by the risk data presented. Notably, surviving intermediate-risk patients often had serious preexisting conditions and frequently had untoward events during hospitalization. Thus, some patients with do-not-resuscitate orders might have survived.

#### Prediction of Length of Stay

An analysis of variance was performed to determine the factors contributing to length of stay. The variables tested (age, sex, year of admission, burn size, type of burn, presence or absence of inhalation injury, and need for escharotomy) accounted for 63 percent of the variance. Many variables were significantly associated with length of stay, but burn size accounted for most of the variance. When mean length of stay was plotted against burn size, it was evident that a patient's mean length of stay could be characterized by membership in one of four groups: burn size of less than 20 percent, between 20 and 39 percent, between 40 and 89 percent, and 90 percent or more of body-surface area. The variability of length of stay within these groups is illustrated by the interquartile ranges (Table 4).

#### DISCUSSION

The mortality rate among patients with burns at our two hospitals (4 percent) is consistent with those recently reported from other centers.<sup>9,10</sup> Three risk factors for death after burns were identified: an age of more than 60 years, burn size of more than 40 percent of body-surface area, and inhalation injury. Mortality is a function of the number of risk factors present. Patients with three risk factors had very high mortality, even considering that most patients with three risk factors had do-not-resuscitate orders. Only one of seven patients (14 percent) with three risk factors who received full resuscitation efforts survived.

The mortality rate among the patients who survived one week was 2.5 percent, which was substantially lower than the overall rate of 4 percent. By the third week, the mortality rate was 1.1 percent. Multiple-organ-system failure, which occurred between the second and the eighth weeks, accounted for one third of the deaths due to burns. After the initial hospitalization for burns, life expectancy is not significantly different from that of the age-adjusted general population.<sup>11</sup>

Although there was no significant difference in

**TABLE 4.** ESTIMATES OF THE LENGTH OF THE HOSPITAL STAY ACCORDING TO INTERQUARTILE RANGES FOR BURN-SIZE GROUPS.\*

PERCENTAGE OF BODY-SURFACE AREA BURNED	LENGTH OF STAY (DAYS)	NO. OF PATIENTS
<20	6–17	1295
20–39	17–45	187
40–89	38–94	104
≥90	129–237	12

\*Sixty-seven deaths before hospital discharge were excluded from this analysis.

mortality rates between 1984 and the 1990s, the remarkably small number of deaths, the increase in the number of patients with do-not-resuscitate orders, and differences in patient-exclusion criteria between the data sets limit the sensitivity of our analysis. Given these limitations, the analysis can only suggest that no large improvements in survival have occurred. To decrease mortality further, attention must be focused on factors operating before hospitalization, including field management, early transfer, and prevention. Clearly, prevention efforts are effective<sup>12</sup> and must target older adults.

One advantage of objective estimates of the probability of death is that they help in understanding the relative influences of specific prognostic elements. Others have reported the age of the patient and the extent of the burns as contributors to the mortality rate.<sup>3–6</sup> However, few studies have emphasized the contribution of inhalation injury to mortality.<sup>9,10,13,14</sup> This study emphasizes the marked degree to which inhalation injury contributes to mortality. The depth of severe burns, as indicated by the need for escharotomy, did not contribute significantly to mortality, although it was previously implicated in mortality among patients with large burns.<sup>15</sup> Although many older women died of burns from cooking fires and most children had scald burns, sex and differences in burn type did not contribute to mortality rates once burn size, the patient's age, and the presence or absence of inhalation injury were considered.

The probability estimate developed for the length of stay is based on burn size. Much of the variance was not accounted for by the data collected and is probably due to social factors. Estimates of length of stay are important for financial reasons, and accurate early estimates facilitate better financial planning by the payer. With \$2 billion spent yearly in the United States on burn care, information on costs is important. For example, an estimated \$30 million per year is billed for the care of older women with cooking-

related ignition of their clothing.<sup>16</sup> Knowledge of the huge costs of specific injuries in terms of dollars as well as lives could help identify potential sources of funding for directed prevention programs.

The objective estimate of the probability of death from burn injury enables clinicians to predict mortality with greater precision. The best measure of the predictive power of the equation is the number of patients whose estimated risk of death would change appreciably from the overall risk of 4 percent, since this risk is assigned to all, regardless of risk factors. Our simple equation identified a substantial majority (1314 of 1665 patients, or 79 percent) for whom the risk of death was very low (0.2 percent) and assigned a high risk of death (87 percent) to 22 of 1665 patients (1.3 percent).

Certain other considerations must be emphasized with respect to the application of estimates of the probability of death to individual patients, particularly when one is deciding whether resuscitation should proceed. Each estimate is a major component of, but cannot substitute wholly for, clinical decisions. Our estimates were developed on the basis of a large number of patients who underwent a particular treatment regimen, including early burn excision and grafting, topical antimicrobial therapy, and critical care support.<sup>8</sup> For some patients, the situation may not be adequately described by the data — for example, a young person with a burn on 100 percent of the body-surface area, but without inhalation injury. It would be unwise to conclude that the probability of mortality for that patient was 3 percent. Furthermore, there may be clinical variables not tested as covariates that are important for prognosis. New therapies could make current estimates obsolete.

Finally, the outcome must not be viewed solely as death or survival, without consideration of the patient's quality of life. When resuscitation decisions are considered, communication between doctors and patients or their surrogates is critical for the achievement of acceptable outcomes. These considerations

should be free from age-based discrimination, monetary pressures, and determinations of the quality of life by outsiders. Objective estimates of the probability of death provide clinicians with valuable information for use in making these decisions.

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## CORRECTION

**Estimates of the Probability of Death from Burn Injuries**

*To the Editor:* The article by Ryan et al. (Feb. 5 issue)<sup>1</sup> concerning estimates of the probability of death from burn injuries raises three issues. Assessing the probability of death is useful when mortality is a relevant end point. This is not the case in patients with burns covering 20 percent of body-surface area or less and no associated problems, such as inhalation injury. In this study, such patients constituted 77.5 percent of the total population of 1665 patients, and the mortality rate in this subgroup was 0.46 percent. Including these very-low-risk patients adds no useful information. The model should be restricted to patients with a greater risk of this end point, which could change the weight given to the variables. Furthermore, there were only 22 patients with a high probability of death (87 percent), with a lower boundary of the 95 percent confidence interval of 78 percent. This can be interpreted as equivalent to a probability of error of 22 percent if one assumes that these patients will die. We think that this number is too small to allow reliable estimates of mortality.

A model that gives individual estimates within a continuous range should be preferred to one that gives only four risk strata (0.3 percent, 3 percent, 33 percent, and 87 percent). Indeed, all tests used to assess the severity of illness in patients in the intensive care unit (the Acute Physiologic and Chronic Health Evaluation III and the Simplified Acute Physiologic Score II) provide probabilities within a continuous range. This allows one to evaluate models by calculating their discriminant power (the area under the receiver-operating-characteristic curve) and their calibration (goodness-of-fit test).<sup>2</sup> Because these data are lacking in the study by Ryan et al., their model cannot be compared with other models proposed for use in patients with burn injuries, such as the one described by Smith et al.,<sup>3</sup> which relies on the same variables and provides individual estimates of the probability of death within a continuous range.

Jean Edouard Rohan, M.D.

Cristina Esteban, M.D.

Philippe Loirat, M.D.

*Hôpital Foch*

92151 Suresnes, France

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*To the Editor:* Ryan et al. did not discuss an important finding in their study: the 12-fold increase in the percentage of patients with do-not-resuscitate orders between the period from 1975 to 1984 and the period from 1990 to 1994. Could the authors discuss the reasons for this large increase and address the question of futility in the burn unit? The data appear to suggest that if a person is over the age of 41 years, has a burn size in excess of 61 percent of body-surface area, and has sustained an inhalation injury, then in all probability that person will die during hospitalization. What moral obligation is there to continue to treat if this prognostication is accurate?

Thomas G. Hooyman, Ph.D.

*Catholic Health Initiatives*

Denver, CO 80202

The authors reply:

*To the Editor:* The system for objectively estimating the probability of death from burn injuries is designed to help health care providers furnish initial information on mortality to patients and families, assist medical personnel with triage at injury scenes, and help researchers plan inclusion criteria for clinical trials in which mortality is a relevant end point. For these purposes, the method should be easy to use and applicable to all patients with burn injuries who require hospital treatment. Our goal was to develop a method based on a limited set of clinically apparent risk factors that could easily be determined. This method is not meant to replace severity scores that use continuous variables, such as the Acute Physiologic and Chronic Health Evaluation III index, or burn formulas<sup>1,2</sup> that were developed for other purposes and have been found to be impractical in these settings.

Our study identified a population (patients over 60 years of age with a burn size of more than 40 percent of body-surface area and inhalation injury) with a high risk of death (87 percent), as noted by Dr. Hooyman. There were only a small number of patients in this group, resulting in the lower boundary of the 95 percent confidence interval (78 percent) noted by Dr. Rohan and colleagues. We think that this level of precision is adequate for the above-mentioned purposes, especially given the complex nature of decisions about whether to provide resuscitation in situations in which the risk of death is high.

The increased incidence of patients with burn injuries who had do-not-resuscitate orders between the period from 1975 to 1984 and the period from 1990 to 1994 coincides with the growing emphasis on patient autonomy. Documentation of advance directives became mandatory for Medicare reimbursement in 1991.

Medical futility remains undefined. Patients and surrogates can refuse life-prolonging treatment regardless of the prognosis. Only when doctors judge that treatment is futile and oppose requests for treatment does the issue of futility become relevant. A doctor's refusal to accede

to requests for treatment on the basis of the presence of the three risk factors from our formula, against the family's wishes, represents an overvaluation of the certitude provided by the formula.

Table 1 of our article contained some errors. We have provided a corrected version, and we apologize for any confusion that may have resulted from the errors.

**Table 1.** Mortality among Patients According to Age, Burn Size, and Presence or Absence of Inhalation Injury.

**TABLE 1. MORTALITY AMONG PATIENTS ACCORDING TO AGE, BURN SIZE, AND PRESENCE OR ABSENCE OF INHALATION INJURY.**

PERCENTAGE OF BODY-SURFACE AREA BURNED	Age (yr)									
	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100
percent mortality (number of patients at risk)										
No inhalation injury										
0-20	0 (643)	0 (159)	1 (162)	1 (139)	1 (87)	0 (36)	0 (33)	0 (18)	8 (13)	100 (2)
21-40	0 (46)	0 (11)	0 (17)	0 (7)	0 (6)	0 (2)	0 (5)	0 (2)	100 (1)	—
41-60	0 (9)	0 (6)	0 (4)	—	0 (3)	0 (1)	—	0 (1)	—	—
61-80	33 (3)	0 (1)	0 (1)	—	—	0 (1)	—	—	—	—
81-100	0 (1)	—	—	—	0 (1)	—	—	—	—	—
Inhalation injury										
0-20	0 (19)	0 (8)	0 (11)	0 (13)	33 (3)	50 (2)	67 (3)	0 (4)	0 (2)	100 (1)
21-40	0 (12)	25 (4)	0 (11)	15 (13)	0 (13)	0 (3)	17 (6)	63 (8)	43 (7)	—
41-60	14 (14)	0 (7)	50 (4)	20 (5)	50 (6)	50 (2)	100 (3)	30 (5)	100 (2)	100 (1)
61-80	33 (3)	20 (5)	—	25 (4)	67 (3)	—	100 (1)	100 (2)	100 (1)	—
81-100	38 (8)	38 (8)	0 (1)	0 (2)	0 (3)	25 (4)	100 (5)	100 (1)	100 (1)	—

Colleen M. Ryan, M.D.  
 David A. Schoenfeld, Ph.D.  
 Edwin H. Cassem, M.D.  
 Ronald G. Tompkins, M.D.  
*Harvard Medical School*  
*Boston, MA 02114*

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