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Development of the Burn Frailty Index: A prognostication index for elderly patients sustaining burn injuries

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ABSTRACT

Background: Frailty has demonstrated enhanced prognostic ability for elderly patient morbidity. The aim was to create a burn-specific frailty index for elderly patients and compare it to commonly used scoring systems in burn management.
Methods: From 2013 to 2017, we prospectively surveyed a randomized cohort of patients ≥65-years-old previously admitted to our burn unit. Prognostic comparisons with 6 commonly used indices and multivariate risk analyses were performed.
Results: Of 100 included patients, n = 32 were classified as frail. The mean patient age was 73.0 ± 6.8-years with a median follow up of 20.9 months. There were 13 moralities in total, 12 occurred in the frail group including 5 in-house mortalities. Patients classified as frail had significantly more complications ($p < 0.001$), non-home discharges ($p < 0.001$), ICU admissions, and longer hospital and ICU lengths of stay ($p < 0.001$), decreased 1 and 3-year survival ($p = 0.001$). The BFI was identified as an independent predictor of mortality ($p = 0.001$) and course-altering diagnoses including sepsis/septic shock, ARDS/ALI, and AKI.
Conclusions: The Burn Frailty Index accurately predicts morbidity and mortality in elderly frail patients suffering burn injuries.

Background

It is estimated that 424,000 patients are treated annually in the United States for burn injuries.[1] The incidence of fatal fire and inhalation injuries in elderly patients ≥65-years of age is increasing and currently estimated at 32.0%.[2] By the year 2050, an estimated 21.0% of the United States population will surpass the age of 65-years, increasing their risk of sustaining fatal burn injuries.[3] Many burn-severity scoring systems have been devised to assist clinicians with morbidity and mortality prognostication. Despite an advancing understanding of burn injuries and pathophysiology, the cornerstones for predictive scoring models continues to be age, total body surface area percent burned (TBSA), and inhalation injury.[4–6] However, elderly patients pose a unique challenge and may have attenuated or exaggerated risk of mortality not accounted for by age and TBSA alone.

The lethal dose (LD50) for the elderly is 10–25% TBSA, which is 10–20% lower than for children and adults <65-years of age.[7–9] With a lower LD50, other factors must influence morbidity in this population. The correlation between comorbidity accumulation with advancing age and increasingly poor outcomes of the elderly patient and has been previously defined as frailty.[9,10] Frailty, more so than age, has been shown to predict morbidity and mortality in various elderly patient populations and has been validated in trauma, surgical, and critical care literature.[11–18]

To date, no such frailty index has been created which specifically addresses the complex and extensive physiologic derangements for elderly frail patients who sustain burn injuries. This is a 3-part study: 1) We sought to create a burn specific frailty index, called

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the Burn Frailty Index (BFI), from the previously validated Emergency General Surgery Frailty Index (EGSFI) and; 2) Compare the predictive abilities of the BFI with several well-known severity and comorbidity indices commonly used in burn prognostication.

Methods

After IRB approval was obtained, we prospectively surveyed a randomized cohort of patients ≥65-years-old previously admitted to our American Burn Association Certified Burn Unit backed by an ACS-verified Level-1 trauma center from February 10, 2011 to June 8, 2017. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines were used in preparation of this manuscript. Our aims were 1) To create the BFI from the previously validated EGSFI and; 2) Compare the predictive abilities of the BFI with several well-known severity and comorbidity-based outcomes indices commonly used in burn prognostication.[4–6,18–21]

Study inclusion criteria included patients ≥65-years-old and a burn of any etiology. Exclusion criteria included patients age <65-year-old, inhalation injuries caused by mechanisms unrelated to a burn, patients with non-burn indications requiring burn unit admission, and patients with poly-trauma associated with their burn injury. Patients were included regardless of TBSA, degree or depth of burns, or the presence or absence of inhalation injury.

Our primary outcome measure was all-cause mortality. Secondary outcomes included minor and major complications, hospital and burn intensive care unit (BICU) length of stay, course-altering diagnoses, BICU therapy durations, and discharges to non-home settings. Course altering diagnoses included sepsis/septic shock, adult and acute respiratory distress syndrome (ARDS), acute lung injury (ALI), acute renal failure/acute kidney injury (AKI/ARF), and inhalation injury. Sepsis and septic shock were classified using the Third International Consensus Definitions for Sepsis and Septic Shock (Sepsis-3) recommendations.[19] ARDS and ALI were classified using the ARDS definition Task Force Berlin definitions.[22] AKI/ARF was defined using the Kidney Disease: Improving global outcomes (KDIGO) classifications.[23] Inhalation injuries were diagnosed clinically with bronchoscopy only. Non-home discharge locations included sub-acute rehab, skilled nursing, and long-term acute care facilities. We used the Clavien-Dindo system for classifying complications.[24,25] Classes I or II complications were grouped as minor complications and classes III, IV, and V complications were grouped as major complications. Except for inhalation injuries, course altering diagnoses are included in major complications.

The updated Charleston comorbidity index (CCI), Revised Baux Score (RB), Belgian Outcomes in Burn Injury (BOBI), Sepsis-related Organ Failure Assessment tool (SOFA), and the Acute Physiology and Chronic Health Evaluation II (APACHE II) were calculated using their published instructions.[4–6,19–21] The worst physiological variables within the first 24-h of admission to the BICU were used to calculate the APACHE-II and SOFA scores.[20]

Statistical analysis

Data analysis was performed using SPSS version 24 (IBM Corp). Comparisons between 2 groups were made utilizing chi-square or Fisher's exact test. Continuous data was analyzed using 2-sample t-tests or Mann-Whitney tests for medians where appropriate. Area under the receiver operating curve (ROC) and the c-statistics were used to identify and validate specific outcomes and compare predictive capacities of the BFI and other indices.

A logistic regression model was used to determine the BFI's suitability in predicting all-cause mortality against the other indices. The Hosmer–Lemeshow goodness-of-fit test was used to determine accuracy of the logistic regression model. The log-rank test was used to compare prognostic scores in Kaplan-Meier survival analyses. A power analysis was performed at $B = 0.80$ and significance level of $\alpha = 0.05$, based on the previous validation of the EGSFI.[18] Analysis required 73 total patients (25 frail and 50 not frail) to determine a significant difference in mortality, complications, and non-home discharges at $p \leq 0.05$. All statistical tests were two-sided with significance determined at a p-value $\leq$ 0.05. All confidence intervals were obtained at the 95th percentile (CI).

Development and calculation of the BFI

Questionnaire items for the EGSFI and associated point values have been previously published.[11,18,26] Univariable comparison of the EGSFI's original 15 questions against our elderly burn population with an outcome of mortality demonstrated that the following EGSFI questions were not significantly different for patients experiencing mortality versus survivors: 1) History of hypertension (0.0% vs 24.0%, $p = 0.064$; 2) need help toileting (0.0 ± 0.0 vs 0.02 ± 0.15, $p = 0.158$); 3) Feel less useful (0.12 ± 0.30 vs 0.07 ± 0.23, $p = 0.610$); and 4) Feel effort to do everything (0.0 ± 0.0 vs 0.08 ± 0.24, $p = 0.231$). The following factors were found in significantly increased frequency in elderly burn patients suffering a mortality in our cohort: 1) History of type-II diabetes mellitus (DM) (72.7% vs 39.3%, $p = 0.026$); 2) Elevated mean TBSA (13.7 ± 14.5 vs 6.4 ± 6.0, $p = 0.001$); 3) Glasgow-coma score (GCS) (12.0 ± 5.0 vs 14.0 ± 3.0, $p = 0.003$); and 4) Elevated mean creatine on admission (CR) (1.82 ± 1.05 vs 1.09 ± 0.90, $p = 0.008$). The new question items including history of diabetes and GCS <14 were given a 1 or 0 (yes or no) scoring scheme, replacing the history of hypertension and need help toileting questions (Fig. 1). The scoring mechanisms for TBSA and CR are outlined:

ROC analysis of TBSA and CR yielded a c-statistic of 0.800 (CI 0.458–0.999) and 0.767 (CI 0.592–0.943) for an outcome of all-cause mortality, respectively. The mean TBSA coinciding with EGSFI frailty was 9.34 and a range of 5–10% was the smallest range to reach significance ($p = 0.048$) in predicting mortality and was given a point value of 0.25. The remaining range of TBSA% (10%–37%) was split into quartiles. Significance of the c-statistic above the 3rd quartile (range 20–24.9% TBSA) plateaued at $p = 0.003$. Values from 5 to 10% TBSA were assigned a value of 0.25 while the quartiles were assigned point values of 1.0, 1.5, 1.75, and 2.0 as TBSA increased with increasing quartile. An identical method was used to create the scoring scheme for CR. A CR range of 0.3–0.9 mg/dL was the lowest to reach significance ($p = 0.025$) and 2.0 the greatest ($p = 0.045$) to retain significance on ROC analysis. Values < 1.0 mg/dL received a point score of 0 and > 2.0 mg/dL received a point score of 2. The upper 2 quartiles (range 1.5–1.99 mg/dL) and lower 2 quartiles (range 1.0–1.49 mg/dL) were assigned point values of 1.0 and 1.5 respectively.

Calculation of the score involves adding together each questionnaire item's point value and dividing by 15 (Fig. 1). The maximum possible score for the new index is 1.13. To determine our frailty cutoff value, we calculated the new score for all 100 patients in our cohort and performed an area under the ROC analysis with an outcome of all-cause mortality. The c-statistic of the new BFI was 0.911 (CI 0.842–0.980; $p < 0.001$). The frailty cut-point score for maximum sensitivity and specificity was ≥0.30 where sensitivity is 0.923 (CI 0.621–0.996) and specificity is 0.770 (CI 0.665–0.851).

The Burn Frailty Index - Questions and Scoring						
1) Cancer history	No (0)			Yes (1)		
2) Diabetes	No (0)			Yes (1)		
3) Need help with grooming	No (0)			Yes (1)		
4) Neeg help with managing money	No (0)			Yes (1)		
5) Need help doing household work	No (0)			Yes (1)		
6) Feel sexually active	No (0)			Yes (1)		
7) Coronary artery disease	Medication (0.25)	PCI (0.50)		CABG (0.75)		MI (1)
8) Dementia	None (0)	Mild (0.25)		Moderate (0.5)		Severe (1)
9) Need help walking	None (0)	Cane (0.25)		Walker (0.75)		Wheelchair (1)
10) Feel sad	Rarely (0)		Sometimes (0.5)		Most of time (1)	
11) Feel lonely	Rarely (0)		Sometimes (0.5)		Most of time (1)	
12) GCS on admission	≥14 (0)			<14 (1)		
13) Albumin level on admission	≥3 mg/dL (0)			<3 mg/dL (1)		
14) Creatinine level on admission	< 1.0 mg/dL (0)	1.0 - 1.49 mg/dL (1)		1.5 - 1.99 mg/dL (1.5)		≥2.0 mg/dL (2)
15) TBSA on admission	< 5.0% (0)	5.0% - 9.9% (0.25)	10% - 14.9% (1.00)	15% - 19.9% (1.50)	20% - 24.9% (1.75)	≥25% (2)

Fig. 1. The Burn Frailty Index scoring scheme. Divide sum of questions by 15. Maximum point value is 1.13 with scores ≥0.30 = frail. On a continuous scale, 0 = not frail and 1.13 = extremely frailty.

Results

Of 100 patients, n = 32 were classified as frail using the BFI. Baseline characteristics, demographics, and patient injury stratification can be found in Table 1. There were no differences in age, sex, gender, or body mass index (BMI) between groups.The majority of patients were 73-year-old Caucasian males (52.0%) with hypertension and an average BMI of 24.5 ± 6.1 kg/cm^2. DM and cerebrovascular accidents were significantly more prevalent in frail patients. The most common burn mechanism was flame burns and an a mean TBSA of 7.5 ± 8.2. There were no significant differences in burn mechanism, burn depth, or body region involvement between groups.

Operative, critical care, and disposition

Data detailing the patients course in the burn intensive care unit (BICU) are found in Table 2. The median number of operating room (OR) visits was 1 (range 1–6 days) visit per patient. However, the frail group required significantly more OR visits on average compared to the not frail group (1.3 ± 1.6 vs 0.6 ± 0.8; p = 0.013) who were primarily managed with non-surgical debridement. Frail

Table 1
Baseline characteristics, comorbidities and injury stratification.

Variable	Not Frail (n = 68)		BFI Frail (n = 32)		p-value
Age, mean (SD)	73.5	(±6.8)	74	(±6.9)	0.725
Sex, female (%)	39	(57.4%)	18	(56.3%)	0.917
BMI, mean (SD)	24.7	(±6.0)	24.5	(±6.6)	0.433
Comorbidities, n (%)					
Hypertension	51	(75.0%)	29	(90.6%)	0.068
Smoking	33	(48.5%)	15	(46.9%)	0.877
Alcohol consumption	12	(17.6%)	2	(6.3%)	0.125
Diabetes mellitus type II	19	(27.9%)	21	(65.6%)	0.000[a]
Cerebrovascular accident	4	(5.9%)	10	(31.3%)	0.001
Coronary artery disease	25	(36.8%)	18	(56.3%)	0.066
Chronic obstructive pulmonary disease	17	(25.0%)	12	(37.5%)	0.199
Cancer history	12	(17.6%)	5	(15.6%)	0.063
GCS <15, n (%)	14.4	(±2.5)	12.8	(±4.5)	0.008[a]
Arrive intubated, n (%)	3	(4.4%)	5	(15.6%)	0.063
Physical signs of inhalation injury[b], n (%)	9	(13.2%)	11	(34.4%)	0.014[a]
Carboxyhemoglobin, percentage, mean (SD)	0.7	(±1.3)	3.0	(±6.4)	0.006[a]
Burn Mechanism, n (%)					
Flame	41	(60.3%)	17	(53.1%)	0.498
Grease	4	(5.9%)	1	(3.1%)	0.555
Water scald	17	(25.0%)	6	(18.8%)	0.488
Inhalation injury only	1	(1.5%)	4	(12.5%)	0.018[a]
Other[c]	5	(7.4%)	4	(12.5%)	0.401
TBSA%, mean (SD)	5.3	(±4.0)	12.0	(±12.1)	<0.001[a]
Superficial partial	2	(±2.8)	3	(±4.5)	0.829
Deep partial	2	(±3.7)	5	(±9.9)	0.898
Full Thickness	1	(±2.2)	3	(±9.1)	0.378
Body regional involvement, n (%)					
Dorsal gluteal burn	7	(10.3%)	3	(9.4%)	0.886
Torso involvement	19	(27.9%)	10	(31.3%)	0.734
Head/Neck involvement	24	(35.3%)	15	(46.9%)	0.268

[a] Indicates significance < 0.05.
[b] Includes carbonaceous sputum, singed perioral hair, perioral edema and desquamation, and stridor.
[c] Other mechanisms include chemical, contact, electric and radiant burns.

Table 2
Operative and critical care data.

Variable	Not Frail (n = 68)		BFI Frail (n = 32)		p-value
BICU admissions, n (%)	8	(11.8%)	19	(59.4%)	<0.001*
BICU days, mean (SD)	0.8	(±3.5)	19.0	(±24.0)	<0.001*
Course-altering diagnoses, n (%)					
Sepsis/Shock	0		13	(40.6%)	0.002*
ARDS/ALI	0		9	(28.1%)	0.026*
ARF/AKI	0		8	(25.0%)	0.034*
Inhalation injury	0		6	(18.8%)	0.048*
BICU therapy days, mean (SD)					
Ventilator support	0		19.8	(±23.1)	0.005*
Tracheostomy	0		14.9	(±20.6)	0.008*
Vasopressor support	0		9.6	(±13.2)	0.011*
Central venous line	0.5	(±1.4)	21.4	(±20.9)	0.002*
Arterial line	0		20.1	(±21.0)	0.001*
Antibiotic support	0.9	(±2.5)	12.3	(±12.8)	0.016*
Antifungal support	0		3.7	(±7.5)	0.269*
Total parenteral nutrition	0		2.8	(±4.4)	0.050*
Tube feeding	0		15.8	(±21.9)	0.021*
Hemodialysis/CVVT	0		8.1	(±15.9)	0.040*
Positive cultures, n (%)	0		10	(31.3%)	0.030*
Paralysis for respiratory failure, n (%)	0		10	(31.3%)	0.005*
Prostaglandin for respiratory failure, n (%)	0		7	(21.9%)	0.032*
Bronchoscopies, mean (SD)	0		2.0	(±0.0)	0.011*
Complications, n (%)					
Minor	5	(7.4%)	3	(9.4%)	0.728
Major	4	(5.9%)	18	(56.3%)	<0.001*
Disposition					
Length of stay, days, mean (SD)	12.7	(±44.2)	22.5	(±21.6)	<0.001*
Non-home discharge, n (%)	11	(16.2%)	21	(65.6%)	<0.001*
Readmission within 30 days, n (%)	0		3	(9.4%)	0.005*
In-hospital mortality, n (%)	0		5	(15.6%)	0.001*
Mortalities at 5-years, n (%)	1	(1.5%)	12	(37.5%)	<0.001*

patients required significantly more skin area to be grafted (1549.0 ± 1586.1 vs $739.4 \pm 672.0\ cm^2$; $p = 0.028$), had a higher estimated blood loss (758.9 ± 957.0 vs. 263.2 ± 208.2 mL; $p = 0.008$), and required more packed red blood cells (3.05 ± 3.71 vs 0.62 ± 1.10 units; $p = 0.001$) and fresh frozen plasma (1.27 ± 2.39 vs 0.09 ± 0.38; $p = 0.006$). There were no differences between quantities of IV fluid administration or units of platelets administered between groups.

Overall, 27 patients required BICU admission averaging 4.4 ± 12.4 days. Of these patients, 19 (70.4%) were frail. The frail group demonstrated significant need for all BICU therapies including invasive and medical respiratory interventions, compared to the not frail group.

The median length of stay for not frail and BFI frail patients was 5 days (range 1–67) and 15 days (range 1–96), respectively. Thirteen mortalities occurred. The overall rate of mortality at 1, 3, and 5 years of follow-up were 11.0%, 13.0%, and 13.0% with all mortalities occurring before 2 years. All mortalities occurring within the first year of discharge occurred within the frail group. Stratified by frailty status, mortality rates for the BFI frail group at 1 and 3 years were 34.4% (11/32) and 37.5% (12/32). Only one mortality occurred in the not frail group at 1.9 years after discharge (Fig. 2). Of the 8 mortalities occurring after discharge, all were determined to be caused by myocardial infarction or cardiac failure per family report. A breakdown of the percentages in which frailty and severity contributed to the overall score of each of the 13 mortalities is found in Fig. 3. In the BFI frail group, 8 of mortalities had a TBSA <10. Of which, 3 occurred in the hospital.

Comparison and predictive ability of the BFI

The c-statistic of the new BFI was 0.911 (CI 0.842–0.980) which was significantly greater than the EGSFI 0.798 (CI 0.697–0.896) ($p < 0.001$). The sensitivity and specificity of the BFI predicting all-cause mortality is 0.923 (CI 0.621–0.996) and 0.771 (CI 0.608–0.807) while the sensitivity and specificity of the EGSFI were 0.846 (CI95% = 0.537–0.973) and 0.736 (CI95% = 0.628–0.822), respectively. A comparison of ROC analyses is located in Fig. 4. For comparison, the c-statistic for age predicting all-cause mortality was 0.525 (CI 0.357–0.692; $p = 0.774$).

On multivariate regression comparing the BFI to non-ICU metrics including the EGSFI CCI, ABSI, BOBI, and the RB, the BFI was an independent predictor of mortality with a Hosmer-Lemeshow test value of 0.733 (OR 2.778; CI 1.517–5.102; $p = 0.001$). Similarly, comparison of the BFI with ICU-specific metrics including the SOFA

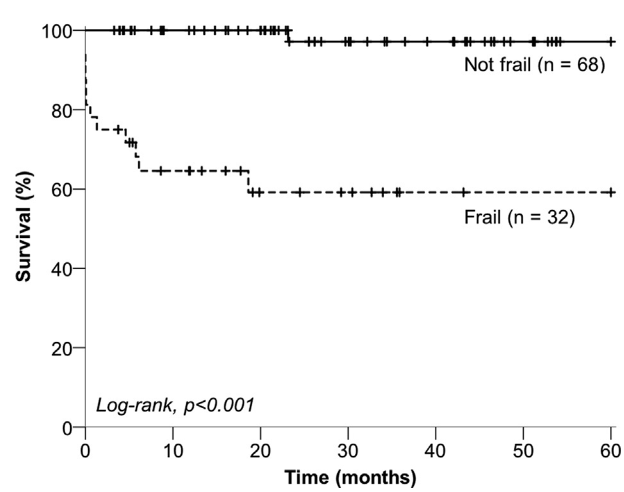


Fig. 2. Survival of patients at 60-months stratified by frailty status. Frailty determined by BFI, cut point ≥0.30. Kaplan-Meier survival analyses with significance determined by Log-rank, $p < 0.001$.

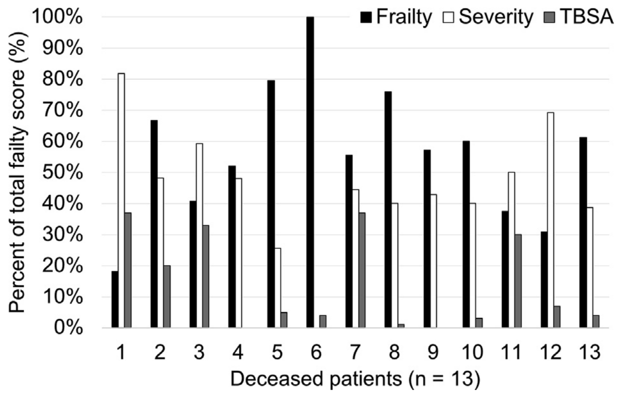


Fig. 3. Percentage breakdown of frailty (questions 1–11) and severity (questions 12–15) contributing to individual scores of deceased patients. Total body surface area (TBSA) added for reference to burn size.

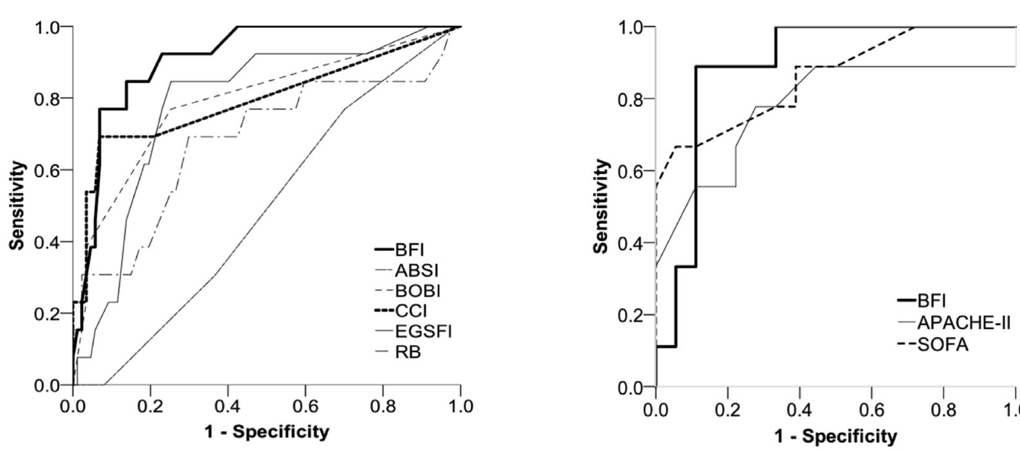
and APACHE-II scores demonstrated the BFI (OR 4.484; CI 0.870–23.256; $p = 0.073$) and SOFA (OR 1.511; CI 0.983–2.320; $p = 0.060$) as independent risk factors for mortality in patients admitted to the BICU. The Hosmer-Lemeshow test value was 0.988 but the model did not reach statistical significance. Survival outcomes (Fig. 5) stratified by scoring index and established scoring ranges for various indices is located in (Table 3). The BFI and EGSFI are primarily dichotomous outcomes and no established ranges have been observed for survival percentages. Because of this, terciles were calculated with respect to their frailty cut-points. The average and median scores for all indices analyzed are located in Table 4.

Discussion

Our analysis sought to create and validate a burn-specific frailty index for elderly patients. The disparity for increased mortality in burn patients ≥65-years-old has been highly published and this is the first study to evaluate the disparity with respect to frailty.[1,2,7–9] The BFI was derived from the previously validated EGSFI score, which was an attractive choice for several reasons: It was quick and simple to calculate, it incorporated cardiac disease and mental health as factors, and included albumin as a surrogate to nutritional status. Surgical and anesthesia literature have previously demonstrated that these factors are associated with poor outcomes.[27–31] Mental health status, specifically depression, has also been associated with increasing disability in patients with critical illnesses and is exacerbated further by burn injuries.[30–33]

The original EGSFI published by Orouji et al. demonstrated a significantly predictive model for elderly patients undergoing emergent general surgical procedures (c-statistic = 0.712; CI 0.638–0.787).[11,12,18] When applied to our burn cohort, the predictive ability of the EGSFI was enhanced, likely because of the exceptional physiologic response that burn injuries inflict compared to other surgical emergencies. After alteration to create the BFI, the new model demonstrated superiority in predicting most adverse outcomes. The BFI discriminates against patients requiring advanced invasive critical care needs which are associated with diminishing outcomes, prolonged length-of-stay, and increasing hospital costs.[34–36] While we did not perform a formal cost analysis our results intuitively suggest that treatment costs are greater in patients determined to be frail by the BFI.

The BFI was created to be calculated upon patient presentation to the trauma bay with routine laboratories. ICU-specific indices (SOFA and APACHE-II) have high prognostic ability for mortality but require disease progression, multiple time dependent data points, and multiple calculations to be meaningful. These indices may be further biased in theoretical comparisons because calculations typically occur as patients are admitted to the BICU with signs of deterioration. The BFI does not require patient deterioration for calculation and appears to be a strong predictor of decompensation later on in admission (Table 2).



Variable	AUROC	p-value	CI95%
BFI	0.911	<0.001*	0.842 - 0.980
ABSI	0.489	0.902	0.339 - 0.640
BOBI	0.791	0.001*	0.643 - 0.939
CCI	0.794	0.001*	0.630 - 0.958
EGSFI	0.786	0.001*	0.659 - 0.913
RB	0.682	0.035*	0.503 - 0.861

A

Variable	AUROC	p-value	CI95%
BFI	0.889	0.001*	0.760 - 1.000
APACHE-II	0.781	0.019*	0.565 - 0.997
SOFA	0.861	0.003*	0.704 - 1.000

B

Fig. 4. A) Comparison of ROC analyses of all-cause mortality prediction by the burn frailty index (BFI), Acute Burn Severity Index (ABSI), Belgian Outcome in Burn Injury (BOBI), the updated Charleston Comorbidity Index (CCI), the Emergency General Surgery Frailty Index (EGSFI), and the revised Baux Score (RB). Includes n = 100 patients with an outcome of all-cause mortality; **B)** Comparison of ROC analyses for all-cause mortality prediction of the BFI and BICU-specific indices: Sequential Organ Failure Assessment Score (SOFA), and the Acute Physiologic Assessment and Chronic Health Evaluation. Includes n = 26 patients admitted to the BICU during the study period.

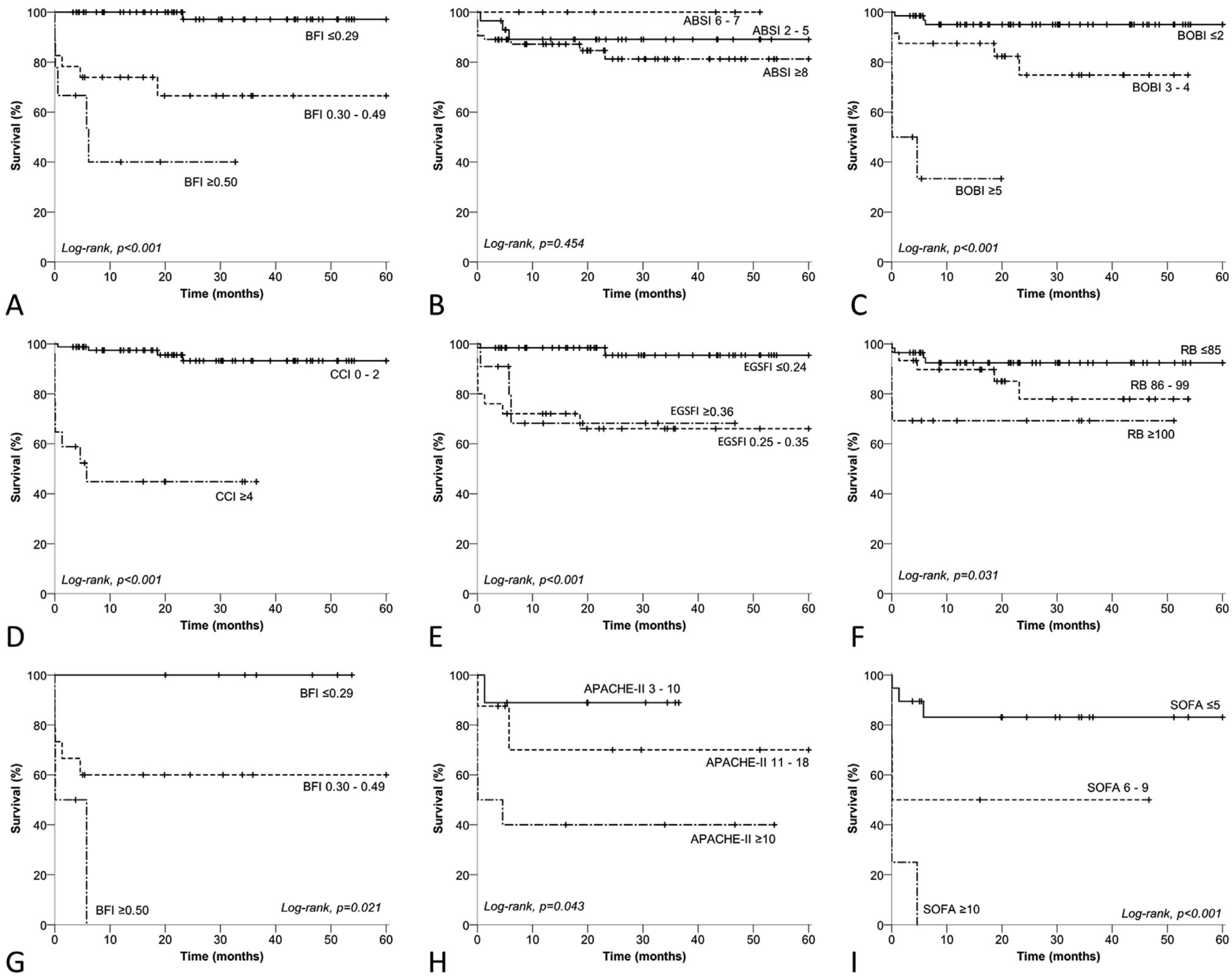


Fig. 5. Comparison of survival analyses of n = 100 patients for all-cause mortality of **A)** Burn frailty Index (BFI); **B)** Acute Burn Severity Index (ABSI); **C)** Belgian Outcome in Burn Injury (BOBI); **D)** the updated Charleston Comorbidity Index (CCI); **E)** the Emergency General Surgery Frailty Index (EGSFI); and **F)** and the revised Baux Score (RB). Comparison of survival analyses of n = 26 patients for all-cause mortality of the **G)** BFI and BICU-specific indices: **H)** Sequential Organ Failure Assessment Score (SOFA), and **I)** the Acute Physiologic Assessment and Chronic Health Evaluation.

Available burn-severity scores (RB, ABSI, and BOBI) may under-predict outcomes involving elderly patients with low TBSA burns and highly co-morbid states. (Fig. 5). This is likely secondary to their design methodology where all adult patients are included into analysis. These models had difficulty and high variability in predicting mortality in our cohort, emphasizing the unique challenge elderly burn patients present. Analysis of non-surviving patients (Fig. 3) demonstrates that even burns <5% TBSA can cause life-threatening decompensation in highly comorbid patients. Generalization of established indices to an elderly patient sustaining burn injuries may not provide adequate prognostication.

Recently, Heng et al. demonstrated that the combined

Table 3
Scoring ranges used in survival analysis.

Terciles			
Model	1	2	3
BFI	≤0.29	0.30–0.49	≥0.50
EGSFI	≤0.24	0.25–0.35	≥0.36
Mortality Range			
Model	**< 10%**	**10–29%**	**30–50**
ABSI	2–5	6–7	≥8
BOBI	0–2	3–4	≥5
CCI	0–2	3	≥4
RB	≤85	86–99	≥100
APACHE-II	3–10	11–18	≥19
SOFA	0–5	6–9	≥10

Table 4
Comparison of scoring systems between deceased and surviving patients.

Variable	Deceased (n = 13)		Survived (n = 87)		p-value
Burn Frailty Index, mean (SD)	0.45	(±0.12)	0.20	(±0.14)	<0.001*
Burn Frailty Index, median (range)	0.45	(0.22–0.65)	0.18	(0.00–0.60)	
EGSFI, mean (SD)	0.32	(±0.12)	0.19	(±0.13)	0.002*
EGSFI, median (range)	0.32	(0.07–0.62)	0.15	(0.00–0.73)	
ABSI, mean (SD)	5.93	(±0.80)	6.16	(±0.96)	0.798
ABSI, median (range)	6.00	(5.00–7.00)	6.00	(4.00–8.00)	
BOBI, mean (SD)	3.77	(±0.44)	2.36	(±0.09)	<0.001*
BOBI, median (range)	3.00	(2.00–6.00)	2.00	(2.00–6.00)	
CCI, mean (SD)	5.13	(±1.96)	4.74	(±2.23)	<0.001*
CCI, median (range)	5.00	(2.00–9.00)	4.00	(2.00–11.00)	
Revised Baux Score, mean (SD)	92.00	(±18.18)	83.18	(±11.00)	0.012*
Revised Baux Score, median (range)	93.00	(66.00–123.00)	81.00	(67.00–112.00)	
APACHE-II, mean (SD)	19.00	(±9.57)	14.44	(±6.35)	0.027*
APACHE-II, median (range)	15.00	(7.00–34.00)	13.00	(8.00–27.00)	
SOFA, mean (SD)	6.36	(±3.98)	2.56	(±2.53)	0.004*
SOFA, median (range)	7.00	(1.00–12.00)	2.00	(0.00–7.00)	

probabilities of a severity score (RB) and co-morbidity score (CCI) were independently associated with mortality in burn patients admitted to the BICU.[37] This combination is similar to the BFI which marries disease severity and patient co-morbid status. However, the BFI is much less cumbersome to calculate, and does not require an additional calculation for interpretation. Age has been a common factor in the indices analyzed and is likely a surrogate for increasingly comorbid states. In general, it is expected that frailty increases with increasing age – as a function of comorbidity or deficit accumulation over time.[10,38] In our analysis, age was not significantly predictive of our primary outcome (c-statistic = 0.525; CI 0.357–0.692; p = 0.774).

Mortality and withdrawal of care in elderly patients sustaining burn injuries remains an important and difficult discussion. As demonstrated in our analysis, some indices do not reliably predict mortality in this cohort, especially in lower percentage burns. All of the in-hospital mortalities, as well as those which occurred within 6-months of discharge, were captured by the BFI. In our cohort, 37.5% of patients in the BFI frail group died during admission. Of these, 21.8% of frail patients died within 6 months of discharge. That contrasts with 1.5% of the not frail group which died almost 2 years after discharge. Elderly patients who are determined as frail by the BFI have increased odds of death during admission and within six months after discharge (OR = 7.411; CI 4.24–1296.54; p = 0.003). While it is not recommended that the BFI be used as the only determinant to begin withdrawal of care discussions, it does provide an objective metric with high sensitivity and specificity for mortality.

Limitations of this study include its retrospective and single institution nature. These design characteristics limit our population sample to one which is unique to our burn center but also eliminates potential variation in practices. The greatest TBSA encountered in this study was 37%. While a wider TBSA range may enhance the outcomes of the study, 37% is well above the LD50 of burns in elderly patients.[7–9] Larger burns would likely not adversely affect the trend of outcomes secondary to the scoring mechanism designed for TBSA. We were unable to fully evaluate the BFI as a continuous measure, to delineate survival ranges, due to our cohort size. Despite these shortcomings, the acuity of patients in our cohort ranges from minimal to great and enhances the generalizability of our study to small and large practices alike. A prospectively designed study with larger patient sample and large range of burn injury would be required to validate the BFI and account for regional population differences.

In conclusion: The BFI is a burn-specific frailty index which can be quickly calculated at patient presentation to the trauma bay and predicts morbidity, mortality, and need of hospital resources in elderly patients sustaining burn injuries. It accounts for the extensive burden of physiologic insult in this population. This index may help temper patient, family, and clinician expectations. Importantly, the BFI is highly predictive of mortality and can be used in guiding end-of-life and withdrawal-of-care discussions.

Conclusion

The BFI is a burn-specific frailty index which can be quickly calculated at presentation and independently predicts morbidity and mortality in frail patients sustaining burn injuries. This tool can be used for managing patient and family expectations, allocating hospital resources, coordinating disposition planning, and guiding end-of-life decisions and discussions.

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Author contributions

Study conceptualized by DM & RW. Acquisition of data performed by DM. Analysis and interpretation of data performed by DM, RW, & MD. Drafting of manuscript performed by DM, RW, MD, & PR. Critical revisions of the manuscript performed by RW, MD, PR, JH, & WI.

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