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Rising mortality in patients with combined burn and trauma☆

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ABSTRACT

Combined trauma in the burn patient has been previously shown to have higher mortality. With improved critical care and multidisciplinary approach, we hypothesized the risk of mortality in combined burn and trauma has decreased. A retrospective analysis of trauma, burn and combined burn-trauma patients in the National Trauma Data Bank was performed comparing years 2007–2015 to years 1994–2002. The impact of burn injuries on mortality in patients with minor trauma has decreased (OR 2.45, CI 2.26–2.66, $p < 0.001$ compared to OR 4.04, CI 4.51–4.66, $p < 0.001$) in years 2007–2015 while the impact of burn injuries on mortality in patients with severe trauma has increased (OR 1.37, CI 1.29–1.47, $p < 0.001$ compared to OR 1.26, CI 1.05–1.51, $p < 0.001$). When controlling for known risk factors of mortality in burn and trauma, the contribution of the severity of trauma on mortality in combined burn-trauma patients with total body surface area $\geq$20% is negligible. In contrast, an increase in percentage of total body surface area burned is associated with a step-wise increase in mortality for all combined burn-trauma patients. However, the largest impact is seen in patients with minor trauma. This population represents a unique overlap of patients where future collaborative research can help identify best practices and improve outcomes.

1. Introduction

Trauma is the leading cause of death in adults younger than 46 years old [1]. The addition of burn injuries to a trauma patient has been said to cause a "two-hit" phenomena of injury which may have a synergistic effect resulting in higher morbidity [2]. Using the National Trauma Data Bank (NTDB), Hawkins et al. found 43% of all burn admissions suffered combined trauma [3]. With nearly one million burn injuries occurring each year and 45,000 undergoing hospitalization, there is a significant population affected by combined burn-trauma [4].

The successful management of the combined burn-trauma patient begins with early resuscitation, selective intubation, sepsis prevention, timely surgical intervention and early post-operative rehabilitation with psychosocial support. Since the successful management of the burn patient is complex, optimal treatment is delivered best by the integration and expertise of multiple healthcare providers focusing on individual components in the care of the patient [5]. The

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importance of the multi-disciplinary approach becomes more apparent in burn patients with concurrent trauma as this patient group has been reported to have higher mortality [6]. In a prior NTDB study, patients with combined trauma and minor burns had nearly a five-fold increased risk of mortality compared to those with minor burn injuries alone [3]. However, the most recent year of the NTDB analyzed was fifteen years ago (1994–2002). With improved critical care and integration of the multidisciplinary approach, we hypothesized the risk of mortality in combined burn and trauma has decreased nationally.

2. Methods

We performed a retrospective analysis of the NTDB between January 2007 and December 2015 [7]. Similar to the Hawkins et al. (1994–2002) study, our inclusion criteria included all patients within the NTDB [3]. They were categorized into three mutually exclusive groups: trauma only (T), burn only (B) and combined burn and trauma (BT). Patients were selected based on burn and trauma related diagnoses using International Classification of Diseases (ICD) version 9 diagnosis codes (burn ICD-9 codes 940–949; trauma ICD-9 codes: 800–939 and 950–999).

Patient demographic information was collected including age, treatment at a burn center (≥5 dedicated burn-beds), pre-hospital comorbidities and the presence of hypotension (systolic blood pressure <90 mmHg) on admission. Pre-hospital comorbidities included congestive heart failure (CHF), smoking, end-stage renal disease (ESRD), cerebrovascular accident (CVA), diabetes, hypertension and chronic obstructive pulmonary disease (COPD). The injury profile included the injury severity score (ISS), total body surface area (TBSA) of burns, associated injuries and mechanism of injury. The outcomes evaluated included total hospital length of stay (LOS), Intensive Care Unit (ICU) LOS, ventilator days and mortality. In-hospital complications evaluated included severe sepsis, pneumonia, catheter related blood stream infection (CRBSI), unplanned ICU admission, unplanned intubation, compartment syndrome, myocardial infarction (MI), urinary tract infection (UTI), superficial infection, deep vein thrombosis (DVT), pulmonary embolism (PE), acute respiratory distress syndrome (ARDS) and acute kidney injury (AKI). All missing data points were not imputed but treated as missing data.

Descriptive statistics were performed for all variables. Similar to Hawkins et al., the reference group for T patients and B patients included patients with BT [3]. A Student's *t*-test was used to compare continuous variables and chi-square was used to compare categorical variables for bivariate analysis. Categorical data was reported as percentages, and continuous data was reported as medians with interquartile range or means with standard deviation. The primary outcome was mortality. Variables were chosen to simulate the multivariable logistic regression model used by Hawkins et al. and included age, gender, TBSA and ISS. Confounding variables were controlled for using a hierarchical multivariable logistic regression model. The impact of TBSA burned on mortality for BT patients was calculated using a reference group of T patients stratified by ISS. Similarly, the impact of ISS on mortality for BT patients was calculated using a reference group of B patients stratified by TBSA. While the abbreviated injury scale (AIS) and ISS have gone through considerable changes over the two study periods, the NTDB provides a standardized score to allow for comparisons such as the one attempted in this study [8]. The NTDB arrives at the ISS by converting ICD-9 codes to AIS using the ICD-90 Mapping program, and then calculating ISS with the resulting AIS severity scores [9]. Risk of mortality was reported with an odds ratio (OR) and 95% confidence intervals (CI).

In addition to comparing our data to the Hawkins study, we also included an analysis of mortality in patients with combined BT to determine the contribution that %TBSA burned and ISS adds to risk of mortality, respectively. An additional multivariable model was created and included previously identified risk factors for mortality in burn and/or trauma including age ≥60, hypotension on admission, smoke inhalation, COPD and in-hospital development of ARDS, AKI, CVA, MI and pneumonia [10–17]. We separated patients based on ISS range (1–15 minor, 16–25 moderate, ≥26 severe) to determine the impact of %TBSA burned on risk of mortality within each group. Next, we separated patients based on % TBSA burned (1–19% minor, 20–49% intermediate, 50–69% moderate and ≥70% severe) to determine the impact of ISS on risk of mortality within each group. The ranges chosen for TBSA in this study are pre-defined by the NTDB. All p-values were two-sided, with a statistical significance level of <0.05. All statistical analyses were performed with IBM SPSS Statistics for Windows, Version 24. (Armonk, NY: IBM Corp).

3. Results

3.1. *Patient demographics*

There were 6,539,211 T patients, 152,686 B patients and 33,813 BT patients. The incidence of patients with BT in the NTDB decreased slightly from 0.61% in 2007 to 0.45% in 2015 ($p < 0.05$) (Fig. 1). Compared to BT patients, T patients were older (mean age, 43.5 vs. 37.4 years, $p < 0.001$), less likely to be hypotensive on admission (3.1% vs. 4.7%, $p < 0.001$) or treated at a burn center (17.6% vs. 35.9%, $p < 0.001$) and more likely to be involved in a fall (41.0% vs. 8.2%, $p < 0.001$). Compared to BT patients, B patients were younger (mean age, 31.1 vs. 37.4 years, $p < 0.001$), less likely to be hypotensive on admission (2.3% vs 4.7%, $p < 0.001$) or involved in a fall (1.1% vs. 8.2%, $p < 0.001$) and more likely to be treated at a burn center (43.9% vs. 35.9%, $p < 0.001$). BT patients had a higher median ISS compared to T patients (9 vs. 6, $p < 0.001$) or B patients (9 vs. 1, $p < 0.001$) (Table 1).

3.2. *Hospital outcomes*

Compared to BT patients, T patients had a shorter mean LOS (5.1 vs. 10.9 days, $p < 0.001$) and lower rates of ARDS (0.9% vs. 3.3%, $p < 0.001$), pneumonia (2.0% vs. 6.1%, $p < 0.001$) and mortality (3.9% vs. 8.5%, $p < 0.001$). B patients also had a shorter mean LOS (5.5 vs. 10.9 days, $p < 0.001$) and lower rates of ARDS (0.6% vs. 3.3%, $p < 0.001$), pneumonia (6.1% vs. 1.6%, $p < 0.001$) and mortality (2.4% vs 8.5%, $p < 0.001$). More B patients were involved in an accident with a hot substance compared to BT patients (45.5% vs. 5.1%, $p < 0.001$) (Table 2).

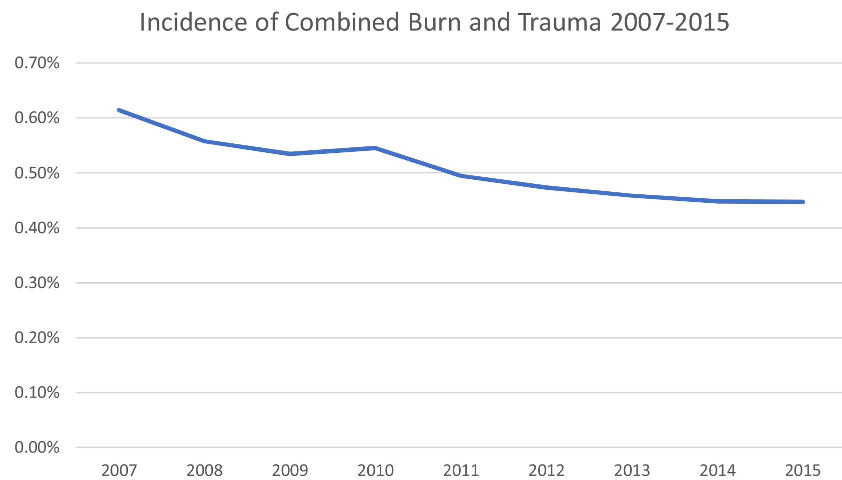

Fig. 1 – Incidence of combined burn and trauma in the National Trauma Data Bank 2007–2015.

Table 1 – Demographics of trauma-only, burn-only and combined burn and trauma.

Characteristic	Trauma only (n=6,539,211)	Burn only (n=152,686)	Combined burn & trauma (n=33,813)
Age, year, mean (SD)	43.5 (24)	31.1 (23)	37.4 (20)
Male, n (%)	4,075,231 (62.5%)	104,315 (68.8%)	24,594 (73.2%)
ISS, median (IQR)	6.0 (7)	1.0 (3)	9.0 (15)
Hypotensive on admission, n (%)	204,085 (3.1%)	3510 (2.3%)	1601 (4.7%)
Comorbidities, n (%)			
Congestive heart failure	183,798 (2.8%)	2225 (1.5%)	530 (1.6%)
Smoker	696,541 (10.7%)	22,210 (14.5%)	4940 (14.6%)
End-stage renal disease	44,315 (0.7%)	448 (0.3%)	97 (0.3%)
Cerebrovascular accident	122,959 (1.9%)	1284 (0.8%)	330 (1.0%)
Diabetes	595,620 (9.1%)	9430 (6.2%)	2207 (6.5%)
Hypertension	1,522,293 (23.3%)	20,361 (13.3%)	5237 (15.5%)
COPD	392,496 (6.0%)	10501 (6.9%)	2166 (6.4%)
Mechanism, n (%)			
Motor vehicle accident	1,482,735 (22.7%)	1045 (0.7%)	6347 (18.8%)
Fall	2,682,565 (41.0%)	1723 (1.1%)	2761 (8.2%)
Other blunt	1,461,637 (22.4%)	1645 (1.1%)	6161 (18.2%)
Penetrating	233610 (3.6%)	35 (<0.1%)	409 (1.2%)
Hot substance, accident	–	69,445 (45.5%)	3714 (5.1%)
Hot substance, self-injury	–	1446 (0.9%)	317 (0.9%)^{NS}
Hot substance, assault	–	1473 (1.0%)	625 (1.8%)
Burn-center, n (%)	1,148,446 (17.6%)	67045 (43.9%)	12,155 (35.9%)

ISS=injury severity score, SD=standard deviation, IQR=interquartile range, NS=not statistically significant, COPD=chronic obstructive pulmonary disease.

The most common associated injuries in BT patients, in order, were TBI (19.2%), upper extremity fracture (15.6%) and lung injury (12.6%).

3.3. *Mortality in BT: 1994–2002 compared to 2007–2015*

Using the same logistic regression model as Hawkins et al. in their 1994–2002 NTDB study, we calculated the risk of mortality in BT patients compared to T patients stratified by ISS in years 2007–2015. Compared to T patients, those with BT had higher risk for mortality in all ISS groups with the highest increased risk in those with minor trauma (ISS 1–15) (OR 2.45, CI 2.26–2.66, $p<0.001$). The impact of BT on mortality in patients with minor trauma (ISS 1–15) decreased from OR 4.04 in 1994–2002 to OR 2.45 in 2007–2015. The impact of BT on patients with severe trauma (ISS > 26) increased from OR 1.26 in 1994–2002 to OR 1.37 in 2007–2015 (Table 3).

Similarly, BT patients were compared to B patients stratified by TBSA and compared to the 1994–2002 NTDB study using the same logistic regression model. Compared to B patients, those with BT had higher risk for mortality in all TBSA groups with the highest increased risk in patients with minor burns (TBSA 1–19%) (OR 5.35, CI 4.73–6.05, $p<0.001$). The impact of BT on mortality in patients with minor burns (TBSA 1–19)

Table 2 – Analysis of clinical outcomes in trauma-only, burn-only and combined burn and trauma.

Outcome	Trauma only (n=6,539,211)	Burn only (n=152,686)	Combined burn & trauma (n=33,813)
LOS, days, mean (SD)	5.1 (8)	5.5 (10)	10.9 (19)
ICU, days, mean (SD)	5.1 (7)	8.1 (14)	12.3 (20)
Ventilator, days, mean (SD)	6.0 (9)	7.6 (13)	10.3 (17)
Complications, n (%)			
Acute kidney injury	42,316 (0.6%)	1025 (0.7%)	854 (2.5%)
ARDS	58,431 (0.9%)	937 (0.6%)	1102 (3.3%)
Deep vein thrombosis	46,174 (0.7%)	415 (0.3%)	488 (1.4%)
Pulmonary embolism	19,396 (0.3%)	124 (0.1%)	181 (0.5%)
Superficial infection	9375 (0.1%)	305 (0.2%)	224 (0.7%)
Urinary tract infection	54,490 (0.8%)	1005 (0.7%)	492 (1.5%)
Myocardial infarction	14,265 (0.2%)	220 (0.1%)	96 (0.3%)
Compartment syndrome	13,116 (0.2%)	171 (0.1%)	338 (1.0%)
Unplanned intubation	30,421 (0.5%)	447 (0.3%)	274 (0.8%)
Unplanned ICU admission	20,470 (0.3%)	177 (0.1%)	102 (0.3%)
CRBSI	3298 (0.1%)	128 (0.1%)	103 (0.3%)
Pneumonia	128,941 (2.0%)	2449 (1.6%)	2077 (6.1%)
Severe sepsis	11,479 (0.2%)	398 (0.3%)	282 (0.8%)
Mortality, n (%)	240,115 (3.9%)	3232 (2.4%)	2682 (8.5%)

LOS=length of stay, ICU=intensive care unit, ARDS=acute respiratory distress syndrome, CRBSI=catheter related blood stream infection, SD=standard deviation

Table 3 – Adjusted[a] odds ratio for risk of mortality in combined trauma-burn versus trauma only.

Population	1994–2002			2007–2015		
	OR	CI	p Value	OR	CI	p Value
ISS 1–15	4.04	3.51–4.66	<0.001	2.45	2.26–2.66	<0.001
ISS 16–25	2.10	1.70–2.50	<0.001	1.53	1.39–1.67	<0.001
ISS ≥26	1.26	1.05–1.51	<0.001	1.37	1.29–1.47	<0.001

ISS=injury severity score.
[a] Controlled for age ≥60 and male gender.

increased from OR 5.00 in 1994–2002 to OR 5.35 in 2007–2015. Similarly, the impact of BT on mortality in patients with severe burns (TBSA ≥ 70%) increased from OR 1.45 in 1994–2002 to OR 1.92 in 2007–2015 (Table 4).

Table 4 – Adjusted[a] odds ratio for risk of mortality in combined trauma-burn versus burn only.

Population[b]	1994–2002			2007–2015		
	OR	CI	p Value	OR	CI	p Value
TBSA 1–19%	5.00	3.54–7.06	<0.001	5.35	4.73–6.05	<0.001
TBSA 20–49%	6.99	4.36–11.20	<0.001	2.89	2.48–3.38	<0.001
TBSA 50–69%	2.00	1.50–2.50	<0.001	1.54	1.19–2.00	<0.001
TBSA ≥70%	1.45	1.15–1.82	<0.001	1.92	1.45–2.54	<0.001

TBSA=total body surface area.
[a] Controlled for age ≥60 and male gender.
[b] Hawkins et al. used following ranges (TBSA 1–25%, 26–50%, 51–75%, 76–100%).

3.4. *Mortality controlled for known risk factors in BT patients*

Using a multivariable logistic regression model controlling for known risk factors, an analysis for risk of mortality in combined burn and trauma was performed. When analyzing BT patients grouped by ISS and stratified by TBSA within each group, most ISS groups demonstrated a stepwise progression of increased rates and risk of mortality based on higher TBSA. The moderate ISS group (16–25) with TBSA 1–19% was the only exception ($p=0.80$) (Table 5). When analyzing BT patients grouped by TBSA and stratified by ISS within each group, ISS was only associated with risk of mortality in the TBSA 1–19% group. In this group, those with minor trauma (ISS 1–15) had lower risk of mortality (OR 0.36, CI 0.22–0.57, $p<0.001$) while those with severe trauma (ISS ≥ 26) had higher risk of mortality (OR 2.81, CI 1.71–4.64, $p<0.001$). In BT patients with TBSA ≥ 20%, ISS was not an independent risk factor for mortality ($p>0.05$) (Table 6). In a sub-analysis, treatment at a burn center was independently associated with risk of mortality in BT patients (OR 1.61, CI 1.33–2.14, $p<0.001$).

4. Discussion

Our study provides a contemporary analysis of mortality in patients with BT. The incidence of BT decreased slightly from 2007 to 2015 but remains low at 0.45% in the most recent year analyzed. Compared to a previous NTDB study using data from 1994 to 2002, we demonstrate that the impact of BT on risk for mortality in patients with minor trauma (ISS 1–15) has decreased in years 2007–2015 while the impact of BT on risk for mortality in patients with severe trauma (ISS ≥ 26) has increased. The impact of BT on mortality in patients with minor (TBSA 1–19%) and severe (TBSA ≥ 70%) burns has also increased during the same time period. However, when

Table 5 – Adjusted[a] odds ratio for mortality in combined burn trauma stratified by injury severity score.

ISS 1–15	Mortality rate	OR	CI	p Value
TBSA %				
1–19	2.4%	0.82	0.67–0.99	<0.05
20–49	9.6%	2.92	2.05–4.17	<0.001
50–69	28.6%	14.36	5.23–39.40	<0.001
≥70	50.0%	69.11	11.66–409.60	<0.001
ISS 16–25	**Mortality rate**	**OR**	**CI**	**p Value**
TBSA %				
1–19	7.7%	0.80	0.61–1.05	0.80
20–49	25.0%	2.34	1.81–3.03	<0.001
50–69	38.2%	5.27	3.23–8.59	<0.001
≥70	66.2%	21.69	12.59–37.37	<0.001
ISS≥26	**Mortality rate**	**OR**	**CI**	**p Value**
TBSA %				
1–19	12.2%	0.68	0.55–0.83	<0.001
20–49	33.2%	1.25	1.01–1.55	<0.05
50–69	47.3%	2.23	1.68–2.95	<0.001
≥70	76.7%	7.82	5.69–10.73	<0.001

ISS = injury severity score, TBSA = total body surface area, OR = odds ratio, CI = confidence intervals.

[a] Controlled for age ≥60, severe grade (>3) for abbreviated injury scale for head, hypotension (systolic blood pressure ≤90 mmHg) on admission, chronic obstructive pulmonary disease, acute respiratory distress syndrome, acute kidney injury, cerebrovascular accident, myocardial infarction, pneumonia, smoke inhalation.

Table 6 – Adjusted[a] odds ratio for mortality in combined burn trauma stratified by total body surface area.

TBSA 1–19%	Mortality rate	OR	CI	p Value
ISS				
1–15	2.4%	0.36	0.22–0.57	<0.001
16–25	7.7%	0.87	0.52–1.44	0.58
≥26	23.3%	2.81	1.71–4.64	<0.001
TBSA 20–49%	**Mortality rate**	**OR**	**CI**	**p Value**
ISS				
1–15	10.8%	0.51	0.20–1.27	0.15
16–25	19.7%	1.08	0.44–2.62	0.87
≥26	33.2%	2.30	0.94–5.62	0.07
TBSA 50–69%	**Mortality rate**	**OR**	**CI**	**p Value**
ISS				
1–15	28.6%	1.21	0.23–6.31	0.82
16–25	38.2%	1.77	0.42–7.44	0.43
≥26	47.3%	2.67	0.66–10.80	0.17
TBSA≥70%	**Mortality rate**	**OR**	**CI**	**p Value**
ISS				
1–15	50.0%	0.12	0.01–1.29	0.08
16–25	66.2%	0.27	0.05–1.36	0.27
≥26	76.7%	0.47	0.10–2.22	0.34

TBSA = total body surface area, ISS = injury severity score, OR = odds ratio, CI = confidence intervals.

[a] Controlled for age ≥60, severe grade (>3) for abbreviated injury scale for head, hypotension (systolic blood pressure ≤90 mmHg) on admission, chronic obstructive pulmonary disease, acute respiratory distress syndrome, acute kidney injury, cerebrovascular accident, myocardial infarction, pneumonia, smoke inhalation.

controlling for multiple known risk factors of mortality in burn and trauma, the contribution of the severity of trauma (ISS) on risk for mortality in BT patients with TBSA ≥ 20% is negligible. In contrast, an increase in % TBSA burned is associated with a step-wise increase in mortality for all BT patients, however the largest impact seen in patients with minor injuries (ISS 1–15).

Hawkins et al. were the first to provide an analysis of BT patients using the NTDB [3]. We attempted to emulate their study design to determine if risk of mortality has improved over the past fifteen years. The risk of mortality in BT patients with minor trauma has decreased. One explanation for this is that the proportion of patients with a lower ISS in the minor trauma group (ISS 1–15) was higher in our dataset compared to the previous study. Furthermore, 63.4% of patients in this group had an ISS ranging from 1 to 6. Having more BT patients with very minor traumatic injuries in our dataset may have artificially demonstrated a decrease in the risk of mortality. We are unable to compare this sub-set of data to Hawkins' study. Additionally, although age was a controlled covariate in both models, elderly patients involved in minor trauma are now receiving better care due to a number of initiatives and interventions primarily spearheaded by the American Association for Surgery of Trauma (AAST) [18–21]. The focused attention in identifying at-risk geriatric trauma patients, often with the help of geriatric consultation services, may help explain the decreased risk of mortality in BT patients involved in minor trauma [22,23]. In contrast, BT patients with severe trauma (ISS ≥ 26) have a slightly increased risk for mortality compared to previous years. This may be explained by the fact that 22.9% of patients in the severe trauma group (ISS ≥ 26) of our study had ISS ≥ 45. Again, we are unable to compare this sub-set of data to Hawkins' study. This analysis suggests that risk of mortality in most BT patients has not improved and may have worsened over the past fifteen years. This conflicts with the impressive strides we have made regarding the mortality rate for B patients over the past 40 years with a current 97% survival rate for all B patients [24–26]. BT patients may not be consistently receiving the same approach as the traditional B patient which may be resulting in worse outcomes. A prospective evaluation on BT patients to determine inconsistencies in care compared to B patients, as well as potential best practices appears warranted.

We also provided a modern analysis of mortality in all patients with BT. In almost all BT patients, an increase in % TBSA burned provided a stepwise increased risk of mortality, regardless of ISS. This is in contrast to the negligible contribution to risk of mortality that ISS had on BT patients with TBSA ≥ 20%, and conflicts with a previous report identifying ISS as an independent risk factor for mortality in all BT patients [6]. Although burn and trauma patients could be quite different, they do share some similarities that can help explain this such as the underlying pathophysiology of injury.

Burn patients have a significant systemic inflammatory response with increases in cytokines and inflammatory mediators resulting in relative immunosuppression, marked increase in risk for multi-organ failure and subsequent death [27,28]. Trauma patients also experience a significant inflammatory and cytokine storm that is often related to the degree of injury severity [29–31]. However, burn patients experience a more intense and persistent inflammatory response compared to their non-burn trauma counterparts [32]. This is supported by our data, which demonstrates that BT patients had higher rates of all in-hospital complications examined compared to T patients in addition to a higher mortality. Mace et al. demonstrated a similar trend in BT patients compared to non-burn trauma counterparts despite having a lower ISS [32]. A prospective review on BT patients to examine the association of ISS with mortality and to identify additional unique risk factors in this population is warranted.

The facility in which BT patients receive care may be related to outcomes. Regardless, more than two-thirds of B patients with significant thermal injuries are treated at a non-burn hospital in the United States with the elderly and those with comorbidities half as likely to be treated at a verified burn center [33]. Our data supports the finding that most burn patients with or without concurrent trauma are treated outside of a burn center. Interestingly, we found treatment at a burn center to be independently associated with a nearly 60% increased risk for mortality in BT patients. This is consistent with a previous report by Hranjec et al. using the National Burn Repository (NBR) to demonstrate that patients treated at higher volume centers may have higher risk for mortality likely due to overwhelmed hospital systems with limited resources [34]. Light et al. demonstrated that the relationship of volume of burn admits and mortality is not linear. Their analysis suggests that low volume centers have increased mortality while middle and high-volume centers (100–200 and 200–300 patients annually, respectively) have improved mortality which worsens again for those with very high volumes (>300 patients annually) [35]. About 25% of BT patients in our dataset were treated in facilities with >20 dedicated burn beds. In a post-hoc analysis, a higher number of burn beds did not affect mortality in BT patients treated at burn centers. Future prospective multi-center studies analyzing burn-center involvement, American Burn Association verification status, dedicated burn beds and volume must be performed to determine which factors affect outcomes in BT patients.

Our findings add to the narrative of how specialized resources are utilized in patients involved with burns and concurrent trauma. Much can be learned from burn mass causality incidents which may involve more than 20 deaths at the scene [36–38]. Disaster planning involves a concerted effort between burn specialists, trauma surgeons, nurses, mid-level practitioners, respiratory therapists and pharmacists to deliver optimal care to patients involved in burn disasters [39,40]. Unfortunately, no formal evidence-based guidelines exist on how BT patients are to be triaged and diverted to specialized centers which opens the possibility of overwhelming resources best used for complex patients [41]. Although burn patients may benefit from the specialized care available at verified burn-centers, other important patient care needs must be assessed and addressed prior to transfer [42]. Clear communication between burn and trauma centers, as well as collaboration among burn and trauma surgeons within an institution, is paramount for the optimal management of BT patients.

The military has made tremendous advancements in combat casualty care that has resulted in reduced morbidity and mortality for both burn and multiple trauma patients. They have published on specific lessons learned including infrastructure and specialty care issues but have not specifically addressed the issue of the coordination between burn and trauma and how to stage the care as this is not listed as one of the 47 clinical practice guidelines which serve as the backbone of the system-wide Joint Trauma System Performance Improvement program [43]. However, much like civilian studies, the military literature suggests that the best management of BT patients depends on the concerted effort of both trauma and burn surgeons [44]. For example, BT patients treated with opioids for burns may make the clinical diagnosis of associated traumatic injuries such as a spinal injury difficult [45]. On the other hand, significant fluid resuscitation for burn injuries may prevent "permissive hypotension" in patients with an aortic injury or complicate a new bowel anastomosis [46].

Our study is limited by the fact that we use a large national database and thus reporting bias is present. Additionally, timing of intervention is not available in the NTDB. Data collection between burn and non-burn facilities may differ leading to data misrepresentation. The study design was constructed in order to limit the contribution of the TBSA to the severity of the remaining trauma as measured by ISS, and vise-versa. We partitioned groups of ISS (1–15, 16–25, and ≥26) and within each group, we stratified by TBSA (1–19%, 20–49%, 50–69% and ≥70%). This allowed us, to the best of our ability and within the limitations of the database, to determine the contribution of mortality for each TBSA within the respective ISS group. This approach does not completely limit the interaction of burn size on ISS and the possibility of confounding is still feasible. In addition, selecting the appropriate database relevant to the study population likely affects results and conclusions. The NTDB is not specifically designed to include BT patients or even B patients; as such, it may not capture the true national profile of BT patients invalidating our results. Santaniello et al. demonstrates that the incidence of BT in the NBR is significantly different than the NTDB (5.8% vs. 0.44%) [6]. Our data is also limited by the potential effect of missing data and unknown confounders. The comparison of our data with that of the prior NTDB study by Hawkins et al. is also limited by the fact that TBSA ranges reported by the NTDB changed between the two study periods. For example, the prior NTDB study used TBSA 1–25% while we used TBSA 1–19%. They also used TBSA ≥ 76% while we used TBSA ≥ 70%. This discrepancy introduced a conservative bias and likely attenuated the risk of mortality reported in our study. The current quality of data regarding BT patients is inadequate and requires changes to allow for better reporting and collection. We hope our study provides an impetus to create a national multidisciplinary coalition that will better serve this unique patient population and perhaps spearhead a national database designed for BT patients. This will likely provide for a more accurate portrayal of outcomes in BT patients and barriers of health so that improvements in care can be made.

5. Conclusion

The incidence of combined burn-trauma injuries has remained relatively unchanged. Contrary to our hypothesis, mortality has slightly increased for most combined burn-trauma patients except for those involved in minor trauma. The degree of TBSA burned contributes to mortality in all combined burn-trauma patients while injury severity only affects mortality in combined burn-trauma patients with <20% TBSA burned. This population represents a unique overlap of patients where future collaborative research is needed to better identify best practices and improve outcomes. This is particularly true in mass casualty and disaster management scenarios where trauma, burn and general surgeons must be prepared to provide high quality care to this unique subset of patients.

Declarations of interest

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