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The impact of non-thermal injuries in combined burn trauma: A retrospective analysis over the past 35 years☆

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Abstract *Introduction:* Combined burn trauma is rather uncommon and frequently difficult to manage. Historically combined burn trauma contributed to high mortality rates in severely injured patients. The purpose of this study was to determine the incidence, mechanisms and impact of non-thermal injuries in patients with severe burns.
Methods: The charts of 2536 patients admitted to the Burn Center of the University Hospital Zurich between 1977 and 2013 were reviewed and retrospectively analyzed. Patients with additional injuries were identified and analyzed statistically.
Results: Over 35 years from 1977 to 2013 a total of 100 burn patients (3.9%) with additional trauma were identified. Motor vehicle crash was the most common mechanism of injury (44%) from 1977 to 1995, compared to electrical injury (33%) from 1996 to 2013. Skeletal trauma including spinal and pelvic injury was the most common form (71%). Additional thoracic or abdominal trauma represented the highest risk factor for in-hospital mortality (adjusted RR

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2.2, 95% CI 0.6–7.6). However, after 1995 the presence of any form of additional injury did not have a significant impact on in-hospital mortality (unadjusted RR 0.97, 95% CI 0.5–1.7, p = 0.914).

Conclusions: Concomitant trauma did not reveal a significant impact on in-hospital mortality in our burn center recently. Retrospectively, trauma mechanisms shifted from motor vehicle crashes to electrical injuries in our population. Safety measures for motor vehicles and adequate emergency room algorithms seem to have contributed to a reduction of severity of injury and mortality.

Introduction

The association of burn trauma with additional major non-thermal injury is rather uncommon. The prevalence of combined burn trauma has been reported ranging from 0.4 to 5.8%.[1] Additional injuries in burn patients result from motor vehicle or plane crashes, electrical injuries with falls, explosions, assaults or attempted suicide, and domestic accidents, including fires with structural collapse or falls during escape from house burns.[1-4] These accidents occur in occupational and non-occupational settings. Fractures are the most common form of non-thermal injury, occurring in 45–64%, followed by soft tissue injuries in 36–52%, traumatic brain injury in 17–26% and thoracic or abdominal injuries in 4–24%.[2,3,5]

In terms of assessment, resuscitation, timing and technique of injury treatment, the combined burn trauma patient presents major challenges. In accordance with the Advanced Trauma Life Support (ATLS) standards[6] and the Principles of Damage Control Resuscitation[7] the initial management of a trauma patient consists in stabilization and resuscitation with airway maintenance, ventilation support if necessary to ensure adequate oxygenation, and hemorrhage control. For the burn patient, hypothermia management and resuscitation are most important.

Although there is paucity of data available regarding combined burn trauma, mortality in this group of patients has been reported being increased as compared to trauma-only and burn-only patients, respectively.[1,4]

The purpose of this retrospective study was to determine the incidence, mechanisms and impact of different forms of non-thermal injuries in patients with burn injuries and associated trauma at our institution by analyzing the data collected over the past 35 years.

Patients and methods

This study summarized the data of patients admitted to the Burn Center of the University Hospital Zurich between January 1977 and December 2013. Before 1998 the data were obtained from paper archives. Records from the subsequent 15 years were extracted from the computed clinic information system of the University Hospital Zurich. A total of 2536 patients were eligible for evaluation and had complete datasets available for data review and analysis. Epidemiological data were collected and transferred to a databank. Patients were subdivided into two groups according to the time period in which they were hospitalized (group 1: from 1977 to 1995, group 2: from 1996 to 2013). In 1995, the Burn Center faculty retired and treatment concepts changed. Faculty retired again in 2013.

Groups were compared epidemiologically with respect to gender, age, mechanism of injury, total body surface area (TBSA), the presence of third degree burns, abbreviated burns severity index (ABSI) score variables[8], inhalation injury, different forms of non-thermal injuries (e.g. skeletal injury including spine and pelvis, soft tissue injury, traumatic brain injury, and thoracic or abdominal trauma), hospital length of stay, intensive care unit (ICU) length of stay and mortality. The institutional review board and local ethics committee approved the study (BASEC-Nr. 2016-00172).

Statistical analysis

In a first step of the analysis, distribution of variables was expressed using means and standard deviation (SD) for normally distributed data, and medians and interquartile ranges (IQR) for non-normally distributed data. Data were tested for normality with the Kolmogorov–Smirnov test and quantile-quantile plots of dependent variables were performed.

The incidence of different forms and mechanisms of non-thermal injuries in burned patients was expressed as frequency (%). The primary endpoint (any type of additional injury) between the two groups was compared using simple logistic regression (without adjustment for confounders), and in the main analysis, a multivariable logistic regression model with the different types of additional injuries as the dependent, and group allocation as the independent variables. Potential confounder for which adjustment was made in the regression models was only the ABSI score. These analyses were repeated for the secondary endpoint such as in-hospital mortality. For the continuous outcomes *length of hospital stay* and *length of ICU stay*, simple and multivariable models were also applied, but linear regression analysis was used.

For all results, point estimates, 95% confidence intervals (CI) and p-values ($\leq$0.05 considered significant) were reported. The statistical analyses were performed using the statistical program STATA (version 14, Stata Corp., College Station, Texas).

Table 1 Patients' characteristics.

	1977-1995 With additional traumatic injury *N* = 18	No additional traumatic injury *N* = 1408	1996-2013 With additional traumatic injury *N* = 82	No additional traumatic injury *N* = 1028
Age (years)	29.5 (19-41)	35 (24-50)	40 (25-53)	44 (30-58)
Sex (male/female)	10 (55.6%) / 8 (44.4%)	891 (63.3%) / 517 (36.7%)	63 (76.8%) / 19 (23.2%)	733 (71.3%) / 295 (28.7%)
TBSA (%)	26.5 (13-39)	21.5 (10-40)	19 (8-42)	17.5 (9-33)
ABSI score	8 (6-10)	6 (5-8)	6 (5-8)	6 (5-8)

Results reported as median (25th-75th percentile).

Results

Between 1977 and 2013, 2536 acute burn patients were admitted to the burn center. 100 of these patients (3.9%) sustained associated trauma (18 (1.3%) in group 1 from 1977 to 1995 and 82 (7.4%) in group 2 from 1996 to 2013). The median age in the first group was 29.5 years (IQR 19-41 years) compared to 40 years (IQR 25-53 years) in the second group. Male patients were more common than females (10 (55.6%) versus 8 (44.4%) in group 1; 63 (76.8%) versus 19 (23.2%) in group 2). Median burn size was 26.5% in group 1 (IQR 13-39%) versus 19% in group 2 (IQR 8-42%), with full-thickness burns in 14 patients (77.8%) in group 1 and 56 patients (68.3%) in group 2. The median ABSI score was 8 in group 1 (IQR 6-10), compared to 6 in group 2 (IQR 5-8). The differences in patients' characteristics for both groups and the epidemiological data of all burns without associated trauma in the same time periods are outlined in Table 1.

Mechanisms of injury in the combined burn trauma patient are summarized in Table 2. While motor vehicle crashes (44%) were predominant in group 1, electrical injuries (33%) prevailed in group 2. Combined injuries resulting from explosions remained constantly high with 17% in group 1 and 18% in group 2. Comparing the two groups, the decrease of motor vehicle crashes was statistically significant (adjusted RR 0.2, 95% CI 0.1 - 0.7, p = 0.008), as was the increase of electrical injuries (adjusted RR 4.9, 95% CI 0.99 - 24.6, p = 0.05).

Plane crashes, lightning strikes, assaults or suicide attempts were singular rare events. However, they were adding up to 22% of the combined burn injuries in group 1 and 23% in group 2. The chronological differences in the two subgroups are shown in Figure 2.

Table 2 Mechanisms of injury in combined burn trauma.

	1977-1995 *N* = 18	1996-2013 *N* = 82
Motor vehicle crashes	8 (44%)	11 (13%)
Domestic accidents	1 (6%)	11 (13%)
Electrical injuries	2 (11%)	27 (33%)
Explosions	3 (17%)	15 (18%)
Others	4 (22%)	18 (23%)

The associated non-thermal injuries are outlined in Table 3. Skeletal injuries were most common in both groups and occurred in 16 patients (88.9%) in group 1 and 55 patients (67.1%) in group 2. The risk for additional skeletal injuries significantly decreased over time (adjusted RR 0.2, 95% CI 0.04-0.9, p = 0.034). Soft tissue injury occurred in 7 patients (38.9%) in group 1 and 40 patients (48.8%) in group 2. Traumatic brain injury was found in 7 patients (38.9%) in group 1 and 23 patients (28.0%) in group 2; combined thoracic and abdominal trauma in 7 patients (38.9%) in group 1 and 12 patients (14.6%) in group 2. While no patient with inhalation injury was found in group 1, 11 cases (13.4%) with inhalation injury were found in group 2. The chronological differences in the two subgroups are shown in Figure 1.

Median length of hospital stay was 23.5 days (IQR 14-60 days) in group 1 and 27.5 days (IQR 12-53 days) in group 2. Median length of ICU stay was 16 days (IQR 13-32 days) in group 1 and 16.5 days (IQR 6-39 days) in group 2. There was no statistically significant difference between the two groups regarding the length of hospital or ICU stay (adjusted differences RR 9.0, 95% CI −5.8-23.8, p = 0.232, and RR 4.6, 95% CI −7.7-16.9, p = 0.456, respectively).

In-hospital mortality among all burn patients admitted from 1977 to 2013 was 17% (426 of 2536 patients). In the same period, in-hospital mortality in patients with any form of additional injury was 22% (22/100). Comparing in-hospital mortality in those patients with additional injuries (22%) to those without any additional injury (17%) was statistically not significant (unadjusted RR 1.4, 95% CI 0.9-2.3, p = 0.158, Table 4a). However, from 1977 till 1995 there was a statistically significant association of in-hospital mortality following burn injury with additional trauma: in-hospital mortality without additional traumatic injury 15% (211/1408) versus in-hospital mortality with additional traumatic injury 39% (7/18), unadjusted RR 3.6, 95% CI 1.4-9.4, p = 0.009 (Table 4b). From 1996 to 2013, 19% (193/1028) of burn patients without additional traumatic injury died, compared to 18% (15/82) in the group with additional traumatic injury (unadjusted RR 0.97, 95% CI 0.5-1.7, p = 0.914, Table 4c).

In our patient population, we showed that all different forms of non-thermal injuries were not associated with a

Table 3 Additional injuries: multivariable logistic & linear regression analysis.

	1977-1995 *N* = 18	1996-2013 *N* = 82	Unadjusted RR (95% CI, p-value)	Adjusted RR (95% CI, p-value)
Skeletal injury incl. spine and pelvis (%)	16 (88.9%)	55 (67.1%)	0.3 (0.1-1.2, p = 0.082)	0.2 (0.04-0.9, p = 0.034)
Soft tissue injury (%)	7 (38.9%)	40 (48.8%)	1.5 (0.5-4.2, p = 0.448)	1.3 (0.4-4.1, p = 0.689)
Traumatic brain injury (%)	7 (38.9%)	23 (28.0%)	0.6 (0.2-1.8, p = 0.366)	0.5 (0.2-1.8, p = 0.299)
Combined thoracic and abdominal injuries (%)	7 (38.9%)	12 (14.6%)	0.3 (0.1-0.8, p = 0.023)	0.4 (0.1-1.3, p = 0.131)
Inhalation injury (%)	0%	11 (13.4%)	p = 0.101	-
In-hospital mortality (%)	7 (38.9%)	15 (18.3%)	0.4 (0.1-1.1, p = 0.063)	0.5 (0.1-1.7, p = 0.255)
	1977-1995 *N* = 18	**1996-2013 *N* = 82**	**Unadjusted differences (95% CI, p-value)**	**Adjusted differences (95% CI, p-value)**
Length of hospital stay (days)	23.5 (14-60)	27.5 (12-53)	0.3 (−14.6-15.3, p = 0.965)	9.0 (−5.8-23.8, p = 0.232)
Length of ICU stay (days)	16 (13-32)	16.5 (6-39)	−2.3 (−14.8-10.2, p = 0.718)	4.6 (−7.7-16.9, p = 0.456)

RR = risk ratio; CI = confidence interval;
ICU = intensive care unit; results were adjusted for possible confounders such as the ABSI score. Results reported as median (25th-75th percentile).

Table 4a Association of in-hospital mortality with additional traumatic injury during the period 1977-2013.

	No additional traumatic injury *N* = 2436	With additional traumatic injury *N* = 100	Unadjusted RR (95% CI, p-value)
In-hospital mortality (%)	404 (17%)	22 (22%)	1.4 (0.9-2.3, p = 0.158)

RR = risk ratio;
CI = confidence interval.

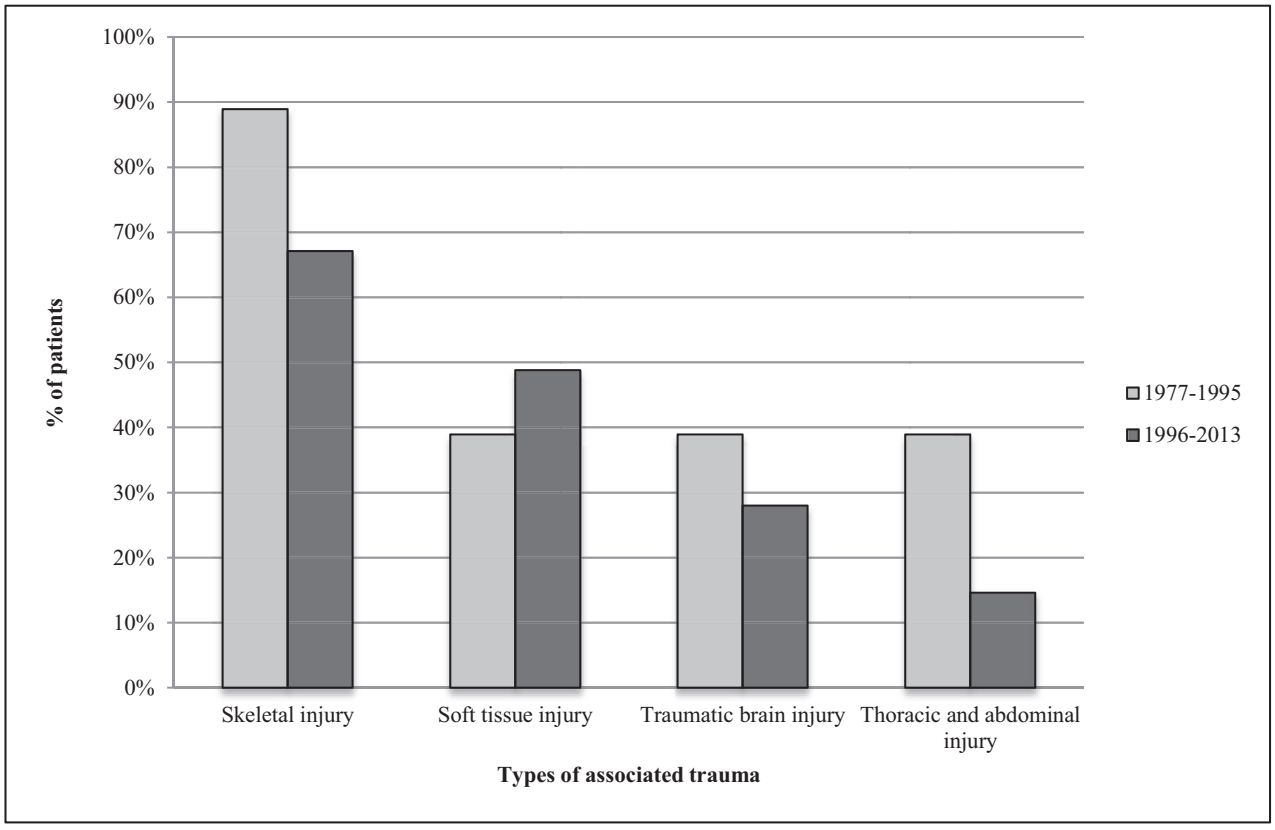

Figure 1 Types of associated trauma in the combined burn trauma patient.

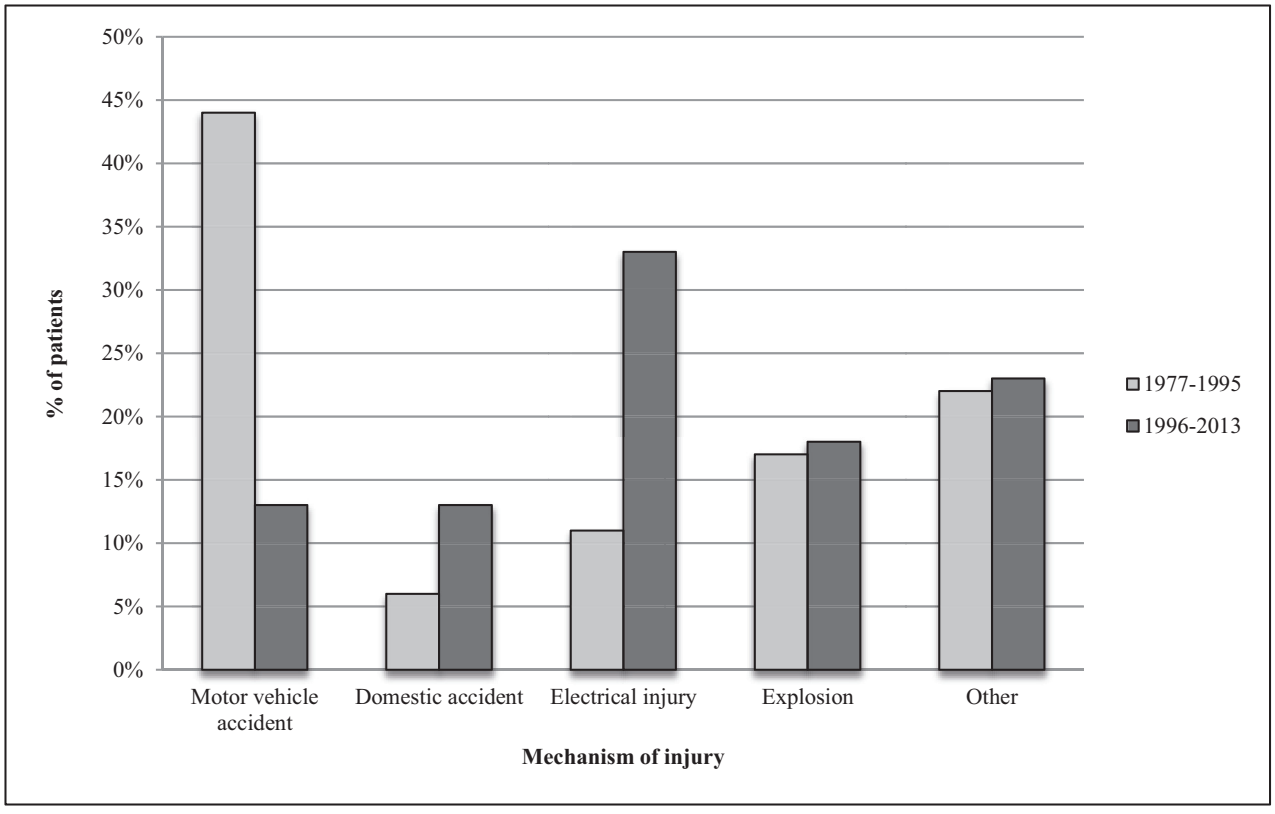

Figure 2 Mechanisms of injury in combined burn trauma.

Table 4b Association of in-hospital mortality with additional traumatic injury during the period 1977–1995.

	No additional traumatic injury *N* = 1408	With additional traumatic injury *N* = 18	Unadjusted RR (95% CI, p-value)
In-hospital mortality (%)	211 (15%)	7 (39%)	3.6 (1.4-9.4, p = 0.009)

RR = risk ratio;
CI = confidence interval.

Table 4c Association of in-hospital mortality with additional traumatic injury during the period 1996–2013.

	No additional traumatic injury *N* = 1028	With additional traumatic injury *N* = 82	Unadjusted RR (95% CI, p-value)
In-hospital mortality (%)	193 (19%)	15 (18%)	0.97 (0.5-1.7, p = 0.914)

RR = risk ratio;
CI = confidence interval.

statistically significant increased risk of in-hospital mortality: with the strongest association of additional thoracic or abdominal injury (adjusted RR 2.2, 95% CI 0.6–7.6), followed by additional soft tissue injury (adjusted RR 1.7, 95% CI 0.5–5.7), additional traumatic brain injury (adjusted RR 1.6, 95% CI 0.5–5.3), additional inhalation injury (adjusted RR 1.5, 95% CI 0.3–7.5), and additional skeletal injury (adjusted RR 1.2, 95% CI 0.4–4.1). However, none of the results were statistically significant (Table 5), therefore showing trends only.

Discussion

While in the 1970s and 1980s motor vehicle crashes seemed to be a predominant source of combined burn trauma, electrical injury prevailed post-millennial. Overall, the most common form of non-thermal injury was skeletal trauma including spinal and pelvic injuries. The association of in-hospital mortality with combined burn trauma was particularly strong before 1996, while fatalities were reduced by half and the presence of any form of additional injury did not have a significant impact on in-hospital mortality in the new millennium.

Interestingly, there is little data available specifically for burns and concomitant trauma. In our population injuries associated with motor vehicle crashes significantly decreased after 1995. This correlated well with the improvement of active and passive security systems in automobiles in the 1990s such as seatbelts and airbags.[9,10] Seatbelts were introduced in the 1970s, however a monetary penalty for not wearing them was only established by law in 1981 for passengers in the front seats and in 1994 for passengers in the back seats. In addition, airbag systems were routinely integrated into vehicle safety systems in the mid-1990s.[11] We would hypothesize that these improved safety measures contributed to a reduction of abdominal, thoracic and severe brain injury in our population, matching the current trauma literature.[12] The change of trauma mechanisms comes along with a reduction of trauma severity, which might account for reduction of mortality in addition.

During the first observation period of the study from 1977 to 1995 as well as from 1996 to 2013 skeletal injury was the most common form of concomitant trauma. This could be explained by the mechanisms of injury encountered. Combined burn trauma patients frequently sustain high velocity trauma such as motor vehicle crashes, falls from heights or blasts during which the body is subject to high impacts that may result in skeletal trauma. In addition, high voltage injury with associated convulsive muscular contractions and falls after flow of electricity may lead to fractures. Previous studies supported our findings of skeletal injuries being the most common form of additional trauma in combined burn trauma.[2,3,5]

Overall, concomitant trauma was a significant risk factor for mortality during the early period from 1977 to 1995. This was not seen any more during the second period of the study. We can only speculate on the reasons. Probst et al.[13] reviewed 4849 polytrauma patients over a 30-year period and published comparable findings with a decline of the mortality rate from 37% between 1975–1984 to 22% from 1985 to 1994 and 18% from 1995 to 2004 in their study. Throughout our observation time pre-hospital care became more advanced with improved fluid resuscitation and shorter rescue times. In addition, in-hospital diagnostic procedures such as Focused Assessment with Sonography for Trauma (FAST) to detect abdominal hemorrhage, CT scans to detect head injuries, and until 2009 early whole-body CT scans were used more frequently, allowing for rapid diagnosis of potentially life-threatening conditions.[14,15] Furthermore, trauma teams implemented ATLS standards in the emergency room since 1998, when the concept was inaugurated in Switzerland. Since 2009, additional measures for improved patient safety in trauma management have been made, including early administration of tranexamic acid, restrictive fluid resuscitation with crystalloid solutions, permissive hypotension and damage control surgery.[16] Those advances in the management of the polytrauma patient in

Table 5 Association of in-hospital mortality with any additional injury.

	No additional skeletal injury *N* = 29	**Additional skeletal injury *N* = 71**	**Unadjusted RR (95% CI, p-value)**	**Adjusted RR (95% CI, p-value)**
In-hospital mortality (%)	6 (20.7%)	16 (22.5%)	1.1 (0.4-3.2, p = 0.840)	1.2 (0.4-4.1, p = 0.731)
	No additional traumatic brain injury *N* = 70	**Additional traumatic brain injury *N* = 30**	**Unadjusted RR (95% CI, p-value)**	**Adjusted RR (95% CI, p-value)**
In-hospital mortality (%)	15 (21.4%)	7 (23.3%)	1.1 (0.4-3.1, p = 0.833)	1.6 (0.5-5.3, p = 0.421)
	No additional thoracic-abdominal injury *N* = 81	**Additional thoracic-abdominal injury *N* = 19**	**Unadjusted RR (95% CI, p-value)**	**Adjusted RR (95% CI, p-value)**
In-hospital mortality (%)	14 (17.3%)	8 (42.1%)	3.5 (1.2-10.2, p = 0.023)	2.2 (0.6-7.6, p = 0.220)
	No additional soft tissue injury *N* = 53	**Additional soft tissue injury *N* = 47**	**Unadjusted RR (95% CI, p-value)**	**Adjusted RR (95% CI, p-value)**
In-hospital mortality (%)	12 (22.6%)	10 (21.3%)	0.9 (0.4-2.4, p = 0.869)	1.7 (0.5-5.7, p = 0.375)
	No additional inhalation injury *N* = 89	**Additional inhalation injury *N* = 11**	**Unadjusted RR (95% CI, p-value)**	**Adjusted RR (95% CI, p-value)**
In-hospital mortality (%)	17 (19.1%)	5 (45.5%)	3.5 (0.96-12.9, p = 0.057)	1.5 (0.3-7.5, p = 0.640)

RR = risk ratio;
CI = confidence interval;
results were adjusted for possible confounders such as the ABSI score.

the pre-hospital and emergency room setting contributed to the reduction of mortality.[17,18] As we have not been able to identify large outcome studies, we interpret our results in combined burn trauma in a similar direction. In fact, we believe that in addition to a change of trauma mechanisms we are observing improvement in the quality of trauma care. In our more recent cohort patients exhibited associated injuries more frequently and were older. This could simply mean that in the 1970s and 1980s patients in these categories would have deceased on site or during transportation. Nowadays, reduction of pre-hospital rescue time and emergency response quality contribute to stabilization of patients and improved survival.

Predicting the mortality of a combined burn trauma patient represents major challenges because of increased complexity with multiple factors involved. The ABSI scoring system has been widely used to estimate the outcome of burn victims since its introduction in 1982.[8] Recently, Forster et al.[19] demonstrated that it still might allow for prediction of burn patient mortality despite significant advances in burn care and changes in patient demographics over the last decades. According to our findings mortality of burn patients with or without additional trauma was similar recently. We may therefore conclude that additional trauma other than inhalation injury is not a significant factor to calculate mortality nowadays.

More recently, several studies evaluated potential modifications of the ABSI scoring system. Preexisting cardiovascular, pulmonary, renal or endocrinological comorbidities were identified to have significant impact on patient

outcomes.[20,21] In addition, the lethal triad defined by the presence of hypothermia, acidosis and coagulopathy was demonstrated to be a significant predictor of mortality also in burns.[22]

Another score frequently used to assess trauma severity is the Injury Severity Score (ISS).[23] However, there is limited research available validating this score for burns. Santaniello et al.[1] reported that the ISS was an independent predictor of mortality in combined burn trauma. On the contrary, Cassidy et al.[24] stated that the ISS was a poor predictor of death in severe burns and that variables such as age and TBSA should be considered additionally to obtain more accurate prediction of potential mortality in burns patients with associated trauma. As the ISS was not routinely used for scoring in burns at our institution, this study cannot further contribute to the body of knowledge in this regard.

As recommended by the European Burns Association[25] severe burn injuries should be treated in a specialized burn center, especially if they are associated with additional trauma. They may exhibit a different spectrum with higher TBSA and more specific burn related morbidity than trauma patients with concomitant minor burns. We would suggest differentiating between burn injury with concomitant trauma and trauma with concomitant burn injury according to the severity of the predominant injury. In detail, we believe that a major burn injury with 60% TBSA and a concomitant distal radius fracture should be treated differently than a polytrauma including blunt abdominal trauma, hemothorax, multiple fractures and 5% friction burns.

Regarding the timing and sequence of treatment, polytrauma, brain injury, perforating trauma, hemorrhage and open fractures should be treated prior to the burn injury. Burned skin is considered sterile, however after a couple of days these wounds become colonized and therefore fracture management, for example, is becoming much more complicated.[3,26]

Concomitant trauma is associated with special circumstances of the accident. All patients in our population with concomitant trauma and burns fell into the following categories: vehicle crash (e.g. car, plane, train), electrical injury, blasts, assault and suicide attempt. One category of patients that may sustain brain injury is the unconscious patient. These patients need a prioritized trauma workup according to Advanced Burn Life Support (ABLS)[27] or Emergency Management of Severe Burns (EMSB)[28] guidelines, while for the others burns specific algorithms may apply.

Although the results are based on a limited number of patients, this study comparing the outcomes of combined burn trauma, was to authors' knowledge, the largest of its kind, which has been conducted in a single European burn center. Although it was a retrospective study, confounding may be controlled by applying statistical methods such as the regression model. Given the small sample size of the earlier group from 1975 to 1984 some of the results were however statistically not significant, therefore showing trends only. Drawing conclusions from those trends is limited. The long observation period of 35 years was also associated with some limitations. First of all, treatment principles have changed, which makes it difficult to compare treatment outcomes over such a long period of time, thus generating a historical bias. Second, patient documentation was much less rigorous 35 years ago, probably leading to a selection bias.

Conclusions

The mortality among burn patients with associated trauma has been significantly reduced over the last 35 years in our cohort. Besides general advances in integrated burn care such as improved surgical wound management and the use of synthetic and bioengineered skin substitutes, optimized emergency room management and safety measures in transportation have led to reduction of severe concomitant trauma and in-hospital mortality.

To this day, the combined injury burn patient is treated as a trauma patient first. This study demonstrates, however, that concomitant trauma is basically rare and does only occur under special circumstances, e.g. motor vehicle crashes, high voltage injury, explosions, falls, assault and suicide. Adequate management of concomitant trauma in burn patients reveals a mortality risk that is not increased in comparison to patients without concomitant trauma.

Conflict of interest

None.

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