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Burn intensive care treatment over the last 30 years: Improved survival and shift in case-mix

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ABSTRACT

Purpose: Mortality in burn intensive care unit (ICU) has been decreasing and treatment appears to be changing. The aims of this study: (1) examine outcome in burn patients, (2) examine changes in ICU indication and (3) explore the influence of a changing case-mix.

Methods: Retrospective study in patients admitted to ICU (1987–2016). Four groups were specified: major burns (≥15% TBSA), inhalation injury with small injury (<15% TBSA, inhalation injury), watchful waiting (<15% TBSA, without inhalation injury), tender loving care (patients withheld from treatment). Logistic regression was performed to evaluate the relation between case-mix and outcome.

Results: Overall mortality decreased to 7%. Mortality of major burns decreased by 15%. The major burn group decreased by 36%. The inhalation injury and watchful waiting group increased by 9% and 21%. The percentage of ventilated patients increased by 14% in the major burn group. 40% of patients were ventilated in the watchful waiting group.

Conclusions: After correction for case-mix, survival improved, mainly in the major burn group. Case-mix shifted towards inhalation injury and watchful waiting. Growth of the watchful waiting group is not necessarily harmful. However, the increase of mechanical ventilation could be. We suggest raising awareness for risks and consequences of mechanical ventilation.

Abbreviations: %TBSA, percentage of total body surface area; ABA, American Burn Association; ATLS, advanced trauma life support; BICU, burn intensive care unit; EMSB, European Management of Severe Burns; ICU, intensive care unit; ISBI, International Society of Burn Injuries; LOS, length of stay; LOS ICU, length of stay intensive care unit; RBAUX, revised BAUX-score; SDD, selective digestive decontamination; TBSA, total body surface area; TLC, tender loving care.

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1. Introduction

The mortality of burn victims, including patients admitted to the intensive care unit (ICU), has been steadily declining throughout the world over the last decades [1–3]. The American National Burn Repository of 2015 reported an overall mortality rate of 3.2% [4]. Dokter et al. found a similar overall mortality rate in the Netherlands [5]. The reported mortality of burn patients admitted to an intensive care unit differs between geographical regions. The mortality ranged from 10.9% in Australia and New Zealand [6] to 58.2% in Brazil [7].

The most common cause of death in the first 48 h after burn injury is hypovolemic shock. After this period, respiratory complications are the most common causes of death in burn victims [3,5]. Research and knowledge about intensive care and burn care is expanding and provides new insights in the best treatment strategy for burn patients [8–10].

Mackie et al. showed a substantial increase in the number of burn patients receiving mechanical ventilation at admission on the intensive care unit (from 38% to 76%). Furthermore, an increase from 9% to 57% (1987–1996 vs. 1997–2006) was found in patients with a suspicion of inhalation injury [11]. These developments seems to be related to aggressive airway management policies of the Advanced Trauma Life Support (ATLS) and the guidelines of the European Management of Severe Burns (EMSB), American Burn Association (ABA) and the International Society of Burn Injuries (ISBI) [11–14]. The threshold for intubation is low, wherein the maintenance of vital organ function plays an important role. This development can have negative consequences as mechanical ventilation is associated with morbidity and mortality [8].

The results of Mackie et al. and the emphasis on aggressive airway management suggest a shift towards a new intensive care indication aimed at prevention or observation instead of the classical indications of resuscitation or inhalation injury.

The aims of this study are to (1) examine whether the outcome of patients admitted to the burn intensive care unit improved over the last decades, (2) examine whether the indication for admittance to a burn intensive care unit is shifting and to (3) explore whether changes in outcome are influenced by changes in case-mix.

2. Methods

2.1. Design

A retrospectively study was performed with data extracted from a database prospectively collected by burn care professionals. The Institutional Review Board of Maasstad Hospital, Rotterdam, approved the study (L2018030). The primary outcome measure was mortality. Secondary outcomes included hospital and ICU length of stay.

2.2. Population

All patients admitted to the burn care unit at the Maasstad Hospital from January 1987 to December 2016 were eligible for inclusion. Inclusion criteria were: ≥18 years and an indication for intensive care treatment. Indications for intensive care treatment were: ≥15% percentage of total body surface affected by burn injury (%TBSA) leading to resuscitation or the need for support of vital functions (i.e. mechanical ventilation or circulatory support). Exclusion criteria were: admittance for reconstructive surgery, re-admission, delayed intensive care treatment (>24 h) and intensive care admittance for non-burn related injury.

2.3. Data collection

The database contains extensive data including the nature of the trauma, details about the burns (i.e. %TBSA burned, BAUX-score, revised BAUX-score (RBAUX), inhalation injury) and intensive care treatment (i.e. ventilator days, length of stay (LOS), antibiotics use). The treating burn care professionals clinically diagnosed inhalation injury. To examine trends over time, a 30-year period was divided in three decades: 1987–1996, 1997–2006 and 2007–2016. Furthermore, four treatment groups were defined based on the type of ICU indication: (1) major burn trauma group, (2) inhalation Injury with small burn trauma group, (3) watchful waiting group, (4) tender loving care group.

2.4. Treatment groups

(1) Major burn group: all patients in the major burn group had a TBSA burned ≥15% with or without inhalation injury. Patients were resuscitated using the Parkland formula. The administered volume was adjusted based on diuresis with a target of 0,5 ml/kg/h. Hypertonic sodium bicarbonate solution was used for resuscitation (Sodium 202 mmol/ml, Chloride 145 mmol/ml, Bicarbonate 57 mmol/ml, ethylenediaminetetraacetic acid 50 mg/ml). After 12 h an albumin infusion was started [9].
(2) Inhalation injury with small burn trauma group: all patients in this group had inhalation injury with or without small burn trauma (<15% TBSA burned). Due to smaller burns, these patients were not resuscitated using the Parkland formula.
(3) Watchful waiting group: patients in this group had small burns (<15% TBSA burned) and were not diagnosed with inhalation injury. Indications included the suspicion of (but not proven) inhalation injury and the risk of swelling of the face and neck and thereby threatening the airway.
(4) Tender loving care (TLC) group: these patients were refrained from active treatment and received palliative treatment at admittance at the burn intensive care unit due to an expected poor outcome. The decision for tender loving care was weighed for each individual case by an experienced team of burn care professionals based on age, %TBSA burned, location of the burn injury and medical history of the patient. All patients died of irreversible shock as resuscitation was withheld.

Since 1994, in all groups (except group 4) selective digestive decontamination (SDD) was started in patients with ≥20% TBSA burned or in patients expected to need respiratory support for >48 h [15]. All patients in group 1–3 received standardized intensive care treatment in case of organ failure (i.e. mechanical ventilation, renal replacement therapy, etc.) All burns were initially treated with cerium silver sulphadiazine or silver sulphadiazine. Wound dressings were changed daily [16].

2.5. *Statistical analysis*

Baseline characteristics were described in counts and percentages (dichotomous/categorical variables), means and standard deviations (normally distributed continuous variables) or median and 25th–75th percentile (non-normally distributed continuous variables). Differences between time periods or treatment groups were compared using a Pearson Chi-Square test (categorical variables) or ANOVA (other variables). A forward stepwise logistic regression analysis was performed to evaluate the relationship between study period, gender, burn characteristics and survival. All data were analyzed using IBM SPSS statistical analysis package version 23.

3. Results

Fig. 1 shows the enrolment flow chart. A total of 1141 patients were admitted to the burn ICU. Of these, 1033 patients were included for active treatment while 108 patients received tender loving care.

3.1. *Major burn group*

Patient characteristics are reported in Table 1 and Appendix 1. The major burn group is the largest group of patients admitted. The mortality decreased significantly from 24% in the first decade to 9% in the last ($p < 0.05$, corrected for changes in burn characteristics: %TBSA, age, full-thickness burn, sepsis, inhalation injury and case-mix). This group has the highest mortality compared to the other active treatment groups. Despite a decrease in mortality, the hospital LOS and the ICU LOS remained stable over the decades. The number of patients with full thickness burns and sepsis decreased. However, the revised BAUX-score increased from 75% in the first decade to 78% in the last decade. This is due to an increase in mean age and a higher number of patients with inhalation injury. Furthermore, more patients had circulatory comorbidity in the last decade when compared to the first. The interval from burn trauma to surgery decreased by 5 days–8 days in the last decade and had no significant effect on the decrease in mortality. The percentage of patients on mechanical ventilation increased from 44% in the first decade to 58% in the last. While this increased, the days on mechanical ventilation decreased significantly. In the last decade, patients in the major burn group had more severe burns compared to the inhalation injury group and watchful waiting group indicated by a higher %TBSA, BAUX-score and percentage of full thickness burns. This resulted in significantly more days on the ventilator and a longer ICU and hospital stay. However, the revised-BAUX score was similar to the group with inhalation injury with small burns.

3.2. *Inhalation injury with small burns group*

The proportion of patients treated in this group increased from 13% in the first decade to 29% in the last. The %TBSA decreased while other burn characteristics remained stable (i.e. revised BAUX-score and ABSI score). Not all patients were mechanically ventilated in the last decade (89%) versus 100% of patients in the first decade. The number of days on ventilator decreased from 7 to 5 days during three decades. The mortality showed a non-significant downward trend. The percentage of facial burns is higher compared to the major burn group but similar to the watchful waiting group.

3.3. *Watchful waiting group*

The watchful waiting group consisted of 5 patients in the first decade and increased to 85 patients in the last decade. The %TBSA and the number of days on mechanical ventilation decreased significantly. The watchful waiting group had a high number of facial burns similar to the inhalation with small burns group. However, none of the patients in the watchful waiting group had clinically diagnosed inhalation injury. The etiology of burns in the watchful waiting group was different compared to other groups. The most common etiologies in the major burn group were flame and scalding. In the watchful waiting group, flame related burn trauma was most common. However, the watchful waiting group also contained a substantial percentage of chemical and contact burns. The mortality in the watchful waiting group was 1% in the last decade and thus substantially lower than the mortality in the major burn group. When comparing the watchful waiting group with both other groups, the revised BAUX-score and ABSI-score were lower in the last decade. The burn size was

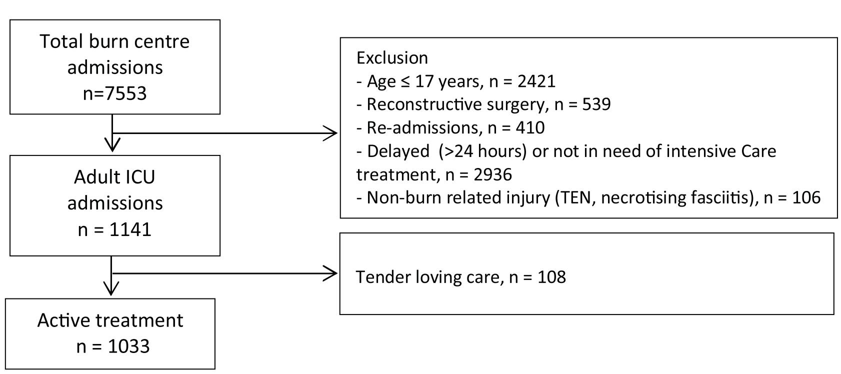

Fig. 1 – Flow chart enrolment patients, January 1987–December 2016.

Table 1 – Characteristics of patients and treatment of all patients admitted to the burn intensive care unit.

	1987–1996 n=279	1997–2006 n=368	2007–2016 n=386
Age (mean ± SD)*	41 ± 17	45 ± 18	45 ± 17
Male (%)	68	71	73
Etiology (%)**			
Flame	93	84	85
Oil	1	2	1
Scalding	6	10	8
Other	0	4	7
%TBSA (mean ± SD)∫	27 ± 16	21 ± 16	17 ± 16
Full thickness burn (%TBSA) (median (25th–75th percentile))*	13 (5–30)	8 (2–18)	3 (0-12)
Inhalation injury (%)	40	44	49
BAUX-score (mean ± SD)°	68 ± 21	66 ± 23	62 ± 22
Revised BAUX-score (mean ± SD)+	75 ± 23	74 ± 25	70 ± 24
ABSI (mean ± SD)∫	8 ± 2	7 ± 2	6 ± 2
Escharotomy (%)**	28	19	15
Surgery (%)**	70	60	52
Interval to surgery (median (25th–75th percentile))°	12 (7–17)	12 (6–19)	9 (5–26)
Mechanical ventilation (%)°	52	55	64
Ventilator days (median (25th–75th percentile))°	12 (5–30)	12 (6–19)	9 (5–16)

Missing values full thickness burns period 1 n=67, period 2 n=47.
* $p < 0.05$, Overall difference, post hoc comparison period 1 vs. other two periods.
∫ $p < 0.05$, Overall difference, post hoc comparison period 1 vs. period 2 vs. period 3.
° $p < 0.05$, Overall difference, post hoc comparison period 1 and period 2 vs. period 3.
+ $p < 0.05$, Overall difference, post hoc comparison period 1 vs. period 3.
** $p < 0.05$.

similar in the watchful waiting group compared to the inhalation with small burns group, but lower compared to the major burn group.

3.4. *Tender loving care group*

The characteristics of the TLC group are specified in Table 2. The group remained similar over time regarding burn characteristics (%TBSA, ABSI, BAUX-score), gender and age. The percentage of patients receiving TLC declined from 16% in the first decade to 6% in the last decade. Overall, 9% of all patients admitted at the burn intensive care unit received palliative treatment. The main mechanism of burn trauma in this group was flame-related injury.

3.5. *Overall comparison*

The case mix of treated patients in the intensive care unit changed significantly during the decades, as shown in Fig. 2. The proportion of the major burn group decreased from 85% to 49%. Both the proportion of the inhalation injury with small burn group and the watchful waiting group increased to 29% and 22% of all ICU admissions respectively.

Table 3 shows the overall patient characteristics of all groups combined. The mortality of the actively treated groups

Table 2 – Characteristics of patients receiving tender loving care.

Period	1987–1996	1997–2006	2007–2016
N	54	30	24
Age (mean ± SD)	69 ± 20	63 ± 26	62 ± 23
Male (%)	46	47	58
Etiology (%)			
Flame	100	100	92
Scalding	–	–	8
%TBSA (mean ± SD)	62 ± 23	62 ± 26	64 ± 26
Full thickness burn (%TBSA)	61 ± 23	58 ± 26	62 ± 26
Facial burns (%)	85	93	79
Inhalation injury (%)	80	97	79
BAUX-score (mean ± SD)	129 ± 19	125 ± 18	126 ± 20
Revised BAUX-score (mean ± SD)	143 ± 20	142 ± 18	140 ± 23
ABSI (mean ± SD)	13 ± 2	13 ± 2	13 ± 2

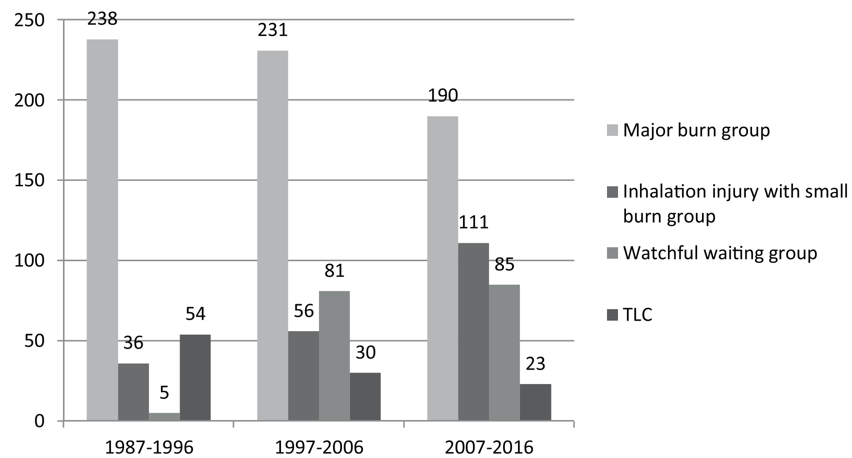

Fig. 2 – Trend in intensive care indication (data label=n).

Table 3 – Overall outcome of patients admitted to the burn intensive care unit.

	1987–1996	1997–2006	2007–2016
N	279	368	386
Mortality (%)#	23	18	7*
Mortality including TLC (%)#	36	24	12*
Sepsis (%)	36	23	13*
Length of stay hospital+	33 (19–65)	29 (15–51)	21 (7–41)*
Length of stay ICU+	4 (2–14)	4 (2–15)	3 (2–9)
LOS/% TBSA+	1.8 (0.9–3.1)	1.9 (1.0–3.2)	1.7 (1.1–2.9)
LOS ICU/% TBSA	0.1 (0.1–0.7)	0.3 (0.1–0.9)	0.4 (0.2–1.0)
Days till death in ICU (days) (n=111)	14 (8–24)	14 (7–33)	9 (4–14)
Days till death after ICU (days) (n=40)	43 (11–83)	26 (15–42)	51 (11–67)
Complication rate (%)	22	17	15*
- Multi-organ failure (%)	8	7	3
- Pneumonia (%)	3	2	4
- Pulmonary embolism (%)	1	–	1
- ARDS (%)	2	3	1
- Renal failure	1	2	1
- Miscellaneous (%)	8	3	5

+ Median (25th–75th percentile).
* $p<0.05$ within groups between period 1 vs. period 2 vs. period 3.
# Corrected for %TBSA, age, full-thickness burn, sepsis, inhalation injury.

decreased from 23% in the first decade to 7% in the last decade. When including the TLC group, the mortality decreased from 36% in the first decade to 13% in the last decade. The complication rate decreased to 15% in the last decade. The nature of the complications remained similar, the most common being multi-organ failure and pneumonia. The hospital length of stay decreased from 33 to 21 days in this study period. The length of stay in each separate group did not change significantly. However, a downward trend is visible in the inhalation injury with small burns group and the watchful waiting group. The interval from injury to death remained stable over the three decades. Most patients died while in ICU (74%), the other 26% died while admitted on the general ward.

3.6. *Risk factors*

Table 4 states risk factors for mortality. Gender, RBAUX, % TBSA full thickness and study decade were related to mortality in both univariable and in multivariable analysis. All in all, a decreasing trend in mortality over time is observed after controlling for changes in case mix.

4. Discussion

Overall mortality in patients admitted to the burn ICU decreased over the last three decades, from 23% in 1987–1996 to 9% in 2007–2016. The case-mix changed significantly. Fewer patients were treated for major burn injury and more patients were treated for inhalation injury or were admitted for watchful waiting. The downward trend in mortality remained significant after controlling for patient and burn characteristics and changes in case-mix.

Looking at subgroups, the mortality in the major burn group decreased to 9% in 2007–2016 while the mortality in other groups did not change significantly. The mortality in the

Table 4 – Predictors of mortality.

	Univariable odds ratio (95% CI)	Multivariable odds ratio (95% CI)
Gender		
Male	1.000	1.000
Female	2.081 (1.465–2.955)	1.590 (1.001–2.526)
Revised Baux		
Per point	1.069 (1.058–1.080)	1.052 (1.038–1.065)
Per 10 points	1.949 (1.757–2.159)	1.656 (1.455–1.886)
Full thickness burns		
Per 1%	1.074 (1.061–1.087)	1.035 (1.020–1.050)
Per 5%	1.429 (1.345–1.518)	1.190 (1.106–1.279)
Period		
1987–1996	1.000	1.000
1997–2006	0.720 (0.490–1.057)	0.732 (0.423–1.265)
2007–2016	0.228 (0.140–0.373)	0.222 (0.117–0.420)

Missing value; full thickness burns (n=114). Forward stepwise LR, Nagelkerke^2 0.46.

inhalation injury with small burn group is decreasing though not statistically significant. The main improvement in overall survival seems to be achieved in the major burn group.

When comparing our results to recent literature, two recent studies also showed a downward trend in mortality of patients admitted to a burn intensive care in the Western world [2,3]. Overall mortality ranged from 10.9% to 15.9% [2,6,17]. The BEAMS study from Australia and New Zealand reported the lowest mortality (10.9%). The overall mortality rate and that of the major burn group in our study are comparable to the mortality rate in the BEAMS study. In addition, the patients' mean age (42 years vs. 41 years) and percentage of inhalation injury (39% versus 36%) are similar. However, the reported %TBSA in our study is higher compared to the BEAMS study (30% vs. 17%). The BEAMS study did not describe a TLC group which could imply that these patients were included in the mortality analysis. The authors reported a mortality rate of 10.9%. This is comparable to our finding with a mortality rate of 12% after including the TLC group.

Mortality is influenced by the TLC group. The decision to refrain from treatment in the TLC group is a difficult decision as there is no protocol or specific literature available. All patients in the TLC group have a revised-BAUX score of >140 indicating a poor outcome if treatment would have been started. While the characteristics of the group remained similar, the percentage of patients decreased. This decrease could indicate that more patients were treated in the major burn group. If so, this did not negatively influence the mortality rate in the major burn group. The 6% of patients receiving TLC in 2007–2016 is in line with previous studies reporting percentages ranging from 1% to 5% [5,18–20]. The decision to refrain from active treatment was mainly based on a high %TBSA and age and the localization of the burn (e.g. major full thickness burns on the head). This did not change over time. In addition, the main staff from our burn unit remained constant during the decades. However, obviously they had more experience during the last decade with regards to developments in intensive care. This could have influenced the decision to refrain from active treatment and caused a shift towards a more liberal treatment regimen.

The change in the number of TLC patients as well as the improved survival could have several reasons. The development of a level 3 intensive care unit might have had the largest impact on survival. At the start of the burn center the intensive care unit was small. In time, more dedicated and experienced staff and nurses became available. All patients now have a separate room with special air treatment and heat regulation. This decreases the occurrence of bacterial cross-contamination. During the early 2000s, knowledge of intensive care treatment developed rapidly such as lung protective ventilation and the introduction of the surviving sepsis campaign [10,21]. The introduction of SDD might have attributed to improved survival as the infection rate decreases by using SDD. This could have led to an improved outcome [15]. Finally, the shorter interval to surgery and the lower complication rate could both have had a positive effect on mortality [22]. Literature showed some indications that early excisions improves outcome compared to conservative treatment [23]. The study of Keshavarzi et al. also showed a benefit towards very early excision (48-72 h after injury) [24]. However, the 5 days reduction in the interval to surgery in the major burns group is limited. Furthermore, the influence of the shortened interval between injury and surgery is difficult to interpret, as there is little evidence for the timing of surgery between three and fourteen days. In addition, the decrease in interval had no significant effect on mortality.

The increase of the watchful waiting group to 22% of all ICU admissions is remarkable and has not been described as such in literature. The reason for admittance on the intensive care unit differs compared to the other groups. Fourteen percent of burn injuries in this group were electrical and 11% chemical. In the other groups these type of injuries are absent. Furthermore, the percentage of facial burns is high (77%) similar to the inhalation injury with small burn group. Facial burn is an indication of inhalation injury meaning that these patients are at risk for inhalation injury. Strictly speaking, there is no indication for admitting these patients on the burn intensive care unit based on burn characteristics (%TBSA <15%, no diagnosis of inhalation injury). However, complication based on the etiology and the possibility of inhalation injury are reasons for observation in the burn intensive care unit. Some patients in this group were probably admitted to the ICU following surgery or due to complications. Based on the

Revised Baux Logistic Model by Osler et al. a mortality rate of about 1% is predicted based on the RBAUX-score of 49% in the watchful waiting group [25]. This indicates that the mortality rate in the watchful waiting group is comparable to literature. The reason for the growth of the watchful waiting group is not clear. Presumably, during the first decade, there were patients with similar trauma mechanisms compared to the last decade. One of the contributing factors could be the increased awareness of specialized burn treatment and refer all to burn centers. Furthermore, nowadays a greater emphasis could be placed on observing burn patients in an intensive care environment compared to 20 years ago.

The increase in the inhalation injury with small burns group in the last decade was unexpected. The number of patients increased while the main characteristics (age, etiology and number of patients with facial burns) and survival remained similar. The reason for the increase could be similar to that of the watchful waiting group. Due to the increased awareness of specialized burn treatment patients with inhalation injury and small burns could be referred more often.

In addition to the increase of the inhalation with small burns and the watchful waiting group, the number of patients on mechanical ventilation in the major burn group increased. This contrasts with a small decrease of days on the ventilator in the inhalation injury with small burns group. The percentage of ventilated patients in the watchful waiting group was 41% in the last decade. This is high considering a lack of an apparent reason for intubation except for facial burns. In all groups, the days on a ventilator decreased significantly. Mackie et al. reported similar findings with an increase in the number of ventilated patients and a tendency towards early termination of mechanical ventilation [11]. The latest ISBI, ABA and EMSB guidelines may play a role in the increase in mechanical ventilation and in the increase of the watchful waiting group [13,14,26]. These guidelines place emphasis on the dangers of inhalation injury and encourage aggressive airway management with rapid intubation. The EMSB guideline, for example, states: “When in doubt, intubate” [13]. Rapid intubation feels like a safe choice since there is no apparent risk. However, literature shows mechanical ventilation is correlated with substantial morbidity, mortality, prolonged intensive care and hospital admission and significant higher treatment cost [8,27–29]. The ABA guideline is the only guideline stating that unnecessary intubation leads to over-treatment [14].

Our results could contribute to knowledge about treatment of suspected inhalation injury. We suggest a more watchful waiting approach with a more conservative intubation strategy. Patients with suspected inhalation injury could be admitted to a dedicated burn ICU where they will be observed by a specialized team of burn care professionals. Furthermore, through education and protocol, the steps towards intubation could be made more transparent. For example, a flash burn of the face rarely causes inhalation injury. Therefore, intubation is rarely needed [12]. In addition, we suggest aiming for a rapid termination of mechanical ventilation. The use of bronchoscopy in all patients with a suspicion of inhalation injury might be useful [12]. A negative finding could help in the decision for early termination of mechanical ventilation. However, the decision to stop mechanical ventilation remains difficult and should be made on a case-by-case basis by a multidisciplinary team of burn care professionals.

The current study has several limitations and strengths. Firstly, this is a longitudinal cohort study over a long period. More factors could have changed during the study period than we could control for. For example, the case-mix could have been influenced by socio-economic factors (i.e. safer work environment, saver housing and increased awareness for first aid in burn trauma). As mentioned, the EMSB and ATLS guidelines changed over time which could have influenced the overall case-mix of patients admitted to the burn center. However, the influence on the case-mix of patients admitted to ICU is limited as criteria for intensive care admittance remained similar. Furthermore, this is a single center study. This could imply that our results are biased as treatment in our burn center could differ from other centers. Nevertheless, our study included a large heterogeneous sample, a well-maintained database and a long follow up. Also, the study had a long inclusion period enabling a report on trends over time with well-founded conclusions. These trends probably can to be generalized towards other burn intensive care populations. Since our database was composed retrospectively, some data were not reported. For example, cause of death was not included in the database. We could reconstruct the probable cause of death based on complication reports (multi-organ failure (47), cardiac arrest (3), ARDS (5) and brain dead (1), not-reported (100)). However, as this is speculation, we did not include them in the results. Despite this, we had sufficient data answer our research questions. We recommend replication of the study in other centers and countries in order to gain more insight in the emergence of the watchful waiting group. The diagnosis of inhalation injury is mainly based on clinical features. In most cases, starting mechanical ventilation is necessary to perform a safe bronchoscopy. The database does not include information about the decision to start mechanical ventilation.

5. Conclusion

After correction for changes in case-mix, the mortality in burn ICU patients decreased to 7% in the last decade (2007–2016). The improvement in mortality has mainly been achieved in the major burn group. However, a non-significant downward trend was also visible in the inhalation injury with small burns group. The case-mix shifted from the major burn group towards inhalation injury with small burns and the watchful waiting groups. This might partially be caused by a lower threshold for observation in the intensive care unit and a lower threshold for starting mechanical ventilation in the last decade when compared to earlier decades. While the growth of patients in the watchful waiting group is not necessarily harmful, the growth of the number of patients on mechanical ventilation could be. Mechanical ventilation can cause morbidity and mortality. We suggest raising more awareness to the risk of intubation and the negative consequences of mechanical ventilation.

Ethics approval and consent to participate

The Institutional Review Board of Maasstad Hospital, Rotterdam, approved the present study (L2018030).

Consent for publication

Not applicable.

Availability of data and material

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Not applicable.

Authors' contributions

RK was responsible for drafting the manuscript, design, statistical analysis and finalization. MB contributed to the design, statistical analysis and reviewed the manuscript. BC contributed in the initiating of the study, contributed to design and revisions. JD collected all data in the database and reviewed the manuscript. CV contributed to the design and reviewed the manuscript. All authors read and approved the final manuscript.

Acknowledgement

Not applicable.

Appendix 1. Characteristics of patients and treatment of all patients admitted to the burn intensive care unit

Group	Major burn group			Inhalation injury with small burns			Watchful waiting		
Period	1987–1996	1997–2006	2007–2016	1987–1996	1997–2006	2007–2016	1987–1996	1997–2006	2007–2016
N	238	231	190	36	56	111	5	81	85
Age (mean ± SD)	39 ± 16[*]	44 ± 19	43 ± 16	52 ± 19	45 ± 17	50 ± 18	38 ± 15	47 ± 19	43 ± 19
Male (%)	69	71	72	61	68	71	60	72	79
Etiology (%) Flame	92	84	84	97	98	99	100	72	67
Oil	1	3	2	–	–	–	–	4	2
Scalding	7	12	13	3	–	–	–	10	5
Electricity	–	–	1	–	–	–	–	6	13
Chemic	–	–	–	–	–	–	–	4	11
Contact	–	1	–	–	2	1	–	4	2
%TBSA (mean ± SD)	31 ± 15	29 ± 15	28 ± 15[○○]	7 ± 4	8 ± 4	5 ± 4[*]	9 ± 3	8 ± 4	6 ± 4[*]
Comorbidity respiratory (%)	6	4	3	6	4	9	–	5	4
Comorbidity circulatory (%)	5	10	12[*]	8	2	15	–	11	12
Full thickness burn (%TBSA)[+]	25 (11–40)	20 (9–30)	19 (10–30)[*,○○]	3 (2–8)[*]	5 (2–10)	5 (3–9)	6 (1–10)	6 (2–13)	4 (2–10)
Facial burns (%)	23	30	33	69	79	70	80	64	77
Inhalation injury (%)	32	45	41	100	100	100	–	–	–
BAUX-score (mean ± SD)	70 ± 21	73 ± 22	71 ± 21[○○]	59 ± 19	53 ± 18	55 ± 18	47 ± 16	55 ± 20	49 ± 19
Revised BAUX-score (mean ± SD)	75 ± 24[*]	81 ± 25	78 ± 24	76 ± 19	70 ± 18	72 ± 18	47 ± 16	55 ± 20	49 ± 19[○]
ABSI (mean ± SD)	7 ± 2	8 ± 2	8 ± 2	6 ± 1	6 ± 2	6 ± 1	5 ± 1	5 ± 2	5 ± 2[○]
Escharotomy (%)	33	28	27	–	4	4	20	4	4
Surgery (%)	71	67	73	56	48	31	80	51	33
Interval to surgery (days)[+]	13 (8–20)	10 (5–21)	8 (4–14)[○○]	15 (8–18)	11 (7–23)	11 (6–17)	9 (6–20)	17 (7–22)	8 (5–14)
Mechanical ventilation (%)	44	56	58[*]	100	96	89	80	22	41
Ventilator days[+]	28 (13–50)	21 (9–45)	15 (6–23)[*,○○]	7 (4–15)	11 (6–27)	5 (3–11)[*]	8 (3–40)	6 (2–30)	3 (2–5)[*]
Sepsis (%)	39	31	23[*]	14	13	5	40	5	1
Mortality (%)[#]	24	24	9[*]	19	7	6	–	7	1[**]
Length of stay hospital[#]	38 (21–73)	36 (19–65)	36 (22–61)[○○]	23 (11–34)	24 (10–42)	9 (5–24)	31 (18–47)	23 (7–38)	12 (5–21)
Length of stay ICU[#]	3 (2–14)	6 (2–21)	5 (2–19)[○○]	6 (4–13)	5 (3–13)	4 (2–6)	4 (3–30)	2 (2–3)	2 (2–3)

[+] Median (25th–75th percentile).
[*] $p < 0.05$ within groups between period 1 vs. period 2 vs. period 3.
[○] $p < 0.05$ comparing 2007–2016 major burn group vs. inhalation injury with small burns vs. watchful waiting.
[○○] Comparing 2007–2016 group vs. other two groups.
[**] Comparing 2007–2016 watchful waiting vs. major burn group.
[#] Corrected for %TBSA, age, full-thickness burn, sepsis, inhalation injury, interval to surgery.

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