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Research Article

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Burns in the elderly: a nationwide study on management and clinical outcomes

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Abstract

Background: In modern-day burn care, advanced age remains an important predictor for mortality among burn victims. In this study, we compared the complete treatment trajectory (including pre-hospital and surgical treatment) and the outcomes between an elderly burn population and a younger adult burn population.

Methods: In this nationwide study, data from the Dutch Burn Repository were used. This is a uniform national registration for Dutch specialized burn care. All adult patients that were admitted to one of the three Dutch burn centres from the period 2009 to 2015 were included in the analysis. Burn patients were considered as elderly when ≥65 years of age, and were then further subdivided into three age categories: 65–74, 75–85 and 85+ years. Younger adults in the age category 18–64 years were used as the reference group. Surgical management was studied comprehensively and included timing of surgery, the number of procedures and details on the surgical technique, especially the technique used for debridement and the grafting technique that was applied. For the comparison of clinical outcome, the following parameters were included: mortality, wound infections, length of stay/TBSA (total body surface area) burned, discharge disposition and secondary reconstructions.

Results: During the study period, 3155 adult patients were included (elderly, $n = 505$). Burn severity, reflected by the median TBSA, varied between 3.2–4.0% and was comparable, but aetiology and pre-hospital care were different between elderly and the younger adult reference group. Surgical treatment was initiated significantly faster in elderly burn patients ($p < 0.001$). Less selective techniques for surgical debridement were used in the elderly burns patients (hydrosurgery, 42.0% vs 23.5–22.6%), and on the other hand more avulsion (5.3% vs 7.3–17.6%) and primary wound closure (6.7% vs 24.5%). The most frequently used grafting technique was meshed skin grafts

(79.2–88.6%); this was not related to age. Mortality increased rapidly with a higher age and showed a high peak in the 85+ category (23.8%). Furthermore, considerable differences were found in hospital discharge disposition between the elderly and the reference group.
Conclusions: In conclusion, elderly burn patients who require specialized burn care are vulnerable and medically challenging. Differences in aetiology, comorbidity, physiology and the management prior to admission possibly affect the initial surgical management and result in significantly worse outcomes in elderly. Elderly patients need optimal, timely and specialized burn care to enhance survival after burn injuries.

Key words: Burns, Nationwide study, Elderly, Surgical management, Clinical outcomes

Background

The elderly burn population constitutes a vulnerable and often challenging group for specialized burn care. Despite major advances in burn care, age is still among the most significant predictors of mortality after burns [1]. Although several studies demonstrate a significant reduction in mortality in the elderly in recent decades [2, 3], other studies emphasize that elderly patients still lag behind on mortality and other relevant outcomes in comparison to younger burn patients [1, 4, 5].

The WHO predicts that, worldwide, the population aged 60 or older will increase from 12% to 22% in the period between 2015 and 2050 and that countries will be faced with major challenges to ensure their health and social systems [6]. These estimations are similar for high-income countries [1, 7]. As a consequence of this global aging, the proportion of elderly in specialized burn care is expected to increase accordingly. On top of this demographic shift, in the Netherlands the community-dwelling elderly population is growing relatively fast due to prolonged independent living as a result of government policy. These community-dwelling elderly are particularly prone to burn injuries due to impaired vision, age-related deterioration in judgement and coordination, lower mobility and slower response to danger [1, 8]; this makes daily activities, such as cooking and bathing, more hazardous for elderly [9].

In recent years, burn care research has focused increasingly on the elderly burn population, with studies regarding epidemiology and prevention [7], aetiology [10] and outcome measures, such as mortality [1, 11], discharge disposition and functional outcomes [1, 12–15]. These studies contributed to the body of knowledge of the elderly burn population and created awareness of this future issue and the pitfalls that might be encountered when caring for this population. However, only a few studies have focused on treatment and, more specifically, surgical strategy and techniques applied in the treatment of the elderly.

Early excision and grafting in the elderly has been studied before, but five retrospective studies showed inconclusive results on mortality, length of stay (LOS) and infection [2, 10, 16–18]. Significant physiological differences exist between elderly and younger adult burn patients that negatively affect burn severity, treatment and outcomes in the elderly. An illustrative example is the atrophic skin in elderly, with thinning of dermis and a decrease in epidermal appendages [19]. This initially leads to deeper burns in the elderly, that is, a higher ratio of full-thickness total body surface area (TBSA)/TBSA burned, compared to younger patients [20], but also to impaired healing of burns and donor sites. Other clinically relevant factors, such as more extensive comorbidity and associated polypharmacy [12] and less physiological reserves [21] and malnutrition [4] are all described as factors that impair recovery after burns in the elderly. Although these factors have been well studied, it is unclear how burn physicians deal with this in their decision for surgical treatment.

The primary objective of this study was to compare medical management (including pre-hospital management and surgical treatment) and clinical outcomes between an elderly burn population and a younger adult burn population.

Methods

Design and study population

In this nationwide observational study, the medical and surgical management applied in an elderly burn population and a reference younger adult burn population were compared.

Data were retrieved from the Dutch Burn Repository R3, a uniform national registration for Dutch specialized burn care. This database includes key information on all patients admitted to one of the three Dutch burn centres from 2009 onwards. Data extraction was performed in May 2016. The Ethics Committee of the Maasstad Hospital, Rotterdam, gave approval under the registration number L2016–030.

Patients

All patients aged >18 years with a burn-related admission from 2009 up to and including 2015 were eligible. Patients who only received end-of-life care upon admission were excluded in the analysis of treatment and clinical outcomes. Elderly patients were, in compliance with the definition of the WHO, defined as those ≥65 years. Because there is no consensus on an exact cut-off point in age from which elderly patients are particularly susceptible to the negative consequences of burns [5], elderly patients were subdivided into three age categories: 65–74 years, 75–85 and ≥85 years. Younger adults were defined as patients aged 18–64 years and were used as a reference group.

Standard of burn care

In the study period, no major alterations to the referral criteria and management of severe burn patients were implemented in Dutch burn care. From 1998 onwards, the Emergency Management of Severe Burns (EMSB) criteria for referral to a Dutch burn centre applied (appendix). Assessment of all acute patients was conducted according to the EMSB protocol. Adult patients with a TBSA burned >15%, unstable patients or patients with a high suspicion of inhalation injury were admitted to the burn centre intensive care unit (ICU) for resuscitation (if TBSA>15%) according to the Parkland formula and/or airway and hemodynamic observation. Wound care varied and depended on factors such as burn depth, TBSA burned, affected body region, planned re-assessments of burn depth and scheduled surgery, but mainly consisted of topical treatment with silver sulfadiazine (Flammazine®), Flammacerium® (face) or non-adherent wound dressings combined with topical antimicrobials, such as povidone iodine or Fucidin®.

Data collection

Surgical management encompassed all decisions that were made around whether or not to perform surgery (% conservative/surgical treatment), single-step versus stepwise approaches (TBSA excised per surgical procedure) and aspects of timing, including time to first surgery, which was divided into early (<7 days post-burn) and delayed (>7 days post-burn).

The applied surgical technique was divided by the technique for the excision of eschar and the type of graft that was applied. Tangential excision is defined as sharp tangential excision with the use of hand-held knives. Hydrosurgery is tangential excision with a debridement tool that produces a high-pressure jet of water across an aperture in an angled handpiece with a vacuum that removes surface debris, which is sucked into the machine. Avulsion, also called fascial excision, is the total removal of epidermis, dermis and the subcutaneous layer. Additionally, the use of allografts, for temporary wound closure and/or wound bed preparation before autologous grafting, was included. Primary closure is closure of the adjacent healthy skin without the need of a skin graft or allograft.

Clinical outcomes included: mortality, wound infection, total LOS, LOS/TBSA, re-admissions, discharge destination and secondary reconstructions. Wound infection was defined as the combination of clinical symptoms, positive wound swabs and antibiotic treatment.

TBSA was defined as the sum of all dermal and full-thickness burns within a single patient. Burn severity was estimated using the Revised Baux score [22]. Inhalation injury was diagnosed clinically and mostly confirmed by bronchoscopy.

Data analysis and statistical analysis

Socioeconomic status (SES) was assessed as an aggregate proxy based on income, education and work participation in each patient's postal code area, according to the method of the Netherlands Institute for Social Research [23]. The SES scores were graded into quintiles and the lowest quintile was considered as a low SES.

Data are presented in mean ± standard deviation or median (25–75th percentile). Differences in patient, burn and treatment characteristics between the four age categories were tested with the Chi-square for categorical data, one-way analysis of variance for continuous data with a normal distribution or the non-parametric Kruskall–Wallis test for continuous data without a normal distribution. Differences in patient, burn and treatment characteristics between those who received early versus delayed surgery were tested with the Chi-square for categorical data, the *t* test for continuous data with a normal distribution or the non-parametric Mann–Whitney *U* test for continuous data without a normal distribution.

Results

Patients

During the six-year study period (2009–2015), a total of 5339 patients were admitted to one of the three Dutch burn centres. A total of 3155 adult burn patients were eligible. Upon admission, 34 (1.1%) adult burn patients only received end-of-life care because of burn severities incompatible with life. Their mean age was 61.1 years; the median Revised Baux score was 130, with a median full-thickness TBSA of 52%; and 24 (70.6%) patients suffered from comorbidity in at least one major organ system. These patients were excluded from the analysis of treatment and clinical outcomes (Figure 1). Included patients were younger (mean, 45.4 years) and had less severe burns (median Revised Baux score, 50.0; 0% full-thickness burns) and has less comorbidity (30.3%).

The annual proportion of elderly patients requiring specialized burn care increased during the period studied from 53 (14.5%) to 94 (18.9%) patients. Overall, males outnumbered females (66.4% vs 33.6%); however, in the oldest age category (85+), the ratio completely reversed and females were over-represented (30.6 vs 69.4) (Table 1). A trend was seen towards a lower SES in the oldest age category (85+) ($p = 0.08$). Comorbidity in major organ systems significantly increased ($p < 0.001$) with higher age. Accordingly, the number of organ systems affected per patient was significantly higher ($p < 0.001$) in the older age categories (Table 1).

Burn characteristics

The majority of the burns were caused by flame (57.7%) or scald (16.8%). Yet, aetiology significantly differed

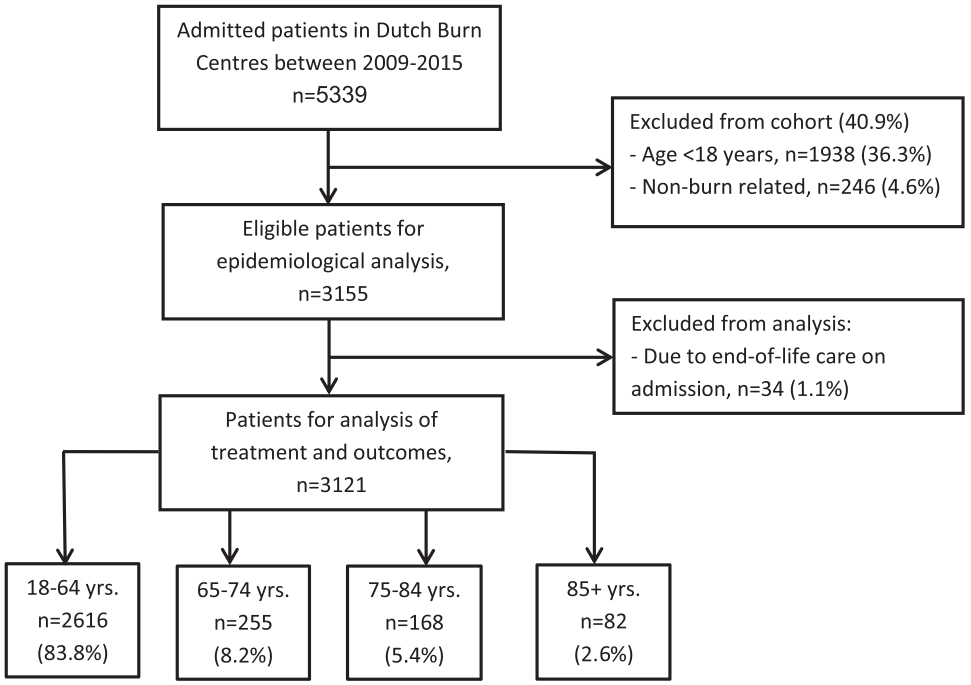

Figure 1. Flowchart patient inclusion

Table 1. Patient characteristics stratified per age category

Age categories (years)	18–64 *n* = 2616	65–74 *n* = 255	75–84 *n* = 168	85+ *n* = 82	*P* value
Sex: male, n(%)	1813 (68.9)	159 (60.7)	92 (54.4)	26 (30.6)	<0.001
Median age (25–75th percentile)*; years	40 (28–50)	69 (67–72)	79 (77–81)	88 (86–90)	
Socio-economic status (%)					
Lowest quintile	34.8	28.2	31.7	41.0	0.077
Comorbidity, n(%)					
Circulatory system	175 (6.7)	100 (39.2)	87 (51.8)	54 (69.5)	<0.001
Respiratory system	82 (3.1)	26 (10.2)	33 (19.6)	15 (18.3)	<0.001
ndocrine system	199 (7.6)	55 (21.6)	52 (31.0)	30 (36.6)	<0.001
Psychiatry	270 (10.3)	19 (7.5)	15 (8.9)	8 (9.8)	0.448
Substance abuse	155 (5.9)	17 (6.7)	5 (3.0)	0.0	0.045
Other*	274 (10.4)	91 (35.7)	86 (51.2)	53 (64.6)	<0.001
Organ systems affected, n(%)					
0	2002 (76.5)	105 (41.2)	38 (22.6)	9 (11.0)	<0.001
1	470 (18.0)	87 (34.1)	48 (28.6)	29 (35.4)	
2 or more	160 (6.1)	70 (27.5)	83 (49.4)	47 (57.3)	

*Includes digestive system, musculoskeletal, nervous system and urinary system

($p < 0.001$) by age, with an increase in contact burns (4.9 vs 9.9/11.2/21.2%) and more frequently clothes on fire with higher age (Table 2).

Burn size was similar between age categories. However, the proportion full-thickness TBSA/TBSA doubled from the youngest to the oldest age category (from 0.30 to 0.59; $p < 0.001$).

The presence of inhalation injury was generally low, approximately 1.5–2%, but this significantly increased in the two oldest age categories (5.2–6.9%; $p = 0.001$).

Pre-hospital management

The pre-hospital management of elderly burns patients was significantly different from that of the reference younger adult burn population (18–64 years). Especially adequate burn cooling deteriorated in higher age categories, in the oldest age category 40.0% of the patients did not cool at all (see Table 3). Furthermore, elderly patients were twice as likely to be referred to the burn centre by a general practitioner (10.9% vs 21.9–24.7%) and presentation at the burn centre

Table 2. Burn and accident characteristics stratified per age category

Age categories (years)	18–64 *n* = 2616	65–74 *n* = 255	75–84 *n* = 168	85+ *n* = 82	*P* value
Aetiology (%)					<0.001
Flame	58.4	57.3	51.5	50.6	
Scald	15.7	19.8	26.0	23.5	
Contact	4.9	9.9	11.2	21.2	
Hot fat	8.3	4.6	5.3	1.1	
Other	12.6	8.4	5.9	3.5	
Clothes on fire (%)*	26.7	32.8	39.6	41.2	<0.001
Body region affected ** (%)					
Head/Face/Neck	45.9	42.4	30.2	36.5	<0.001
Trunk	35.2	41.6	55.0	50.6	<0.001
Arm	45.0	44.1	44.4	51.8	0.644
Hand	46.9	47.5	32.5	34.9	0.001
Buttocks/Genitals	11.0	10.3	16.0	14.1	0.180
Legs	34.0	33.3	36.7	34.9	0.896
Feet	13.9	14.9	8.9	14.5	0.283
Inhalation injury (%)	2.0	1.5	5.2	6.9	0.001
Median %TBSA burned (25–75th percentile)	3.5 (1–8)	3.5 (1.4–8.5)	4 (1.5–8.9)	4.0 (1.0–9.0)	0.121
Ratio TBSA FT/TBSA	0.30	0.42	0.58	0.59	<0.001

*Missing data in n = 78 (2.5% of the cases)
**More than affected body region per patient is possible
TBSA total body surface area, FT full thickness

was more often delayed for more than 48 hours (11.9% vs 17.6–22.9%) (Table 3).

General in-hospital care

In-hospital care mainly differed among age categories in terms of LOS and surgical treatment for wound closure. LOS significantly increased from a median of 5 days (25–75th percentile, 1–18) in the 18–64 category to a median of 18 days (25–75th percentile, 6–28) in the oldest category (85+) (Table 4). ICU admission, ICU stay and mechanical ventilation, including ventilation days, did not significantly differ among the age categories (Table 4).

Surgical treatment increased from 47.5% in the youngest adults (18–64) to 63.5% in the oldest category but was highest in the age category 75–84 with 70.4%.

Surgical treatment

Time to surgery differed significantly among the age categories. The median time from injury to the first surgical procedure was lowest within the 85+ category (10.0 days; 25–75th percentile, 15.5–17.0). The median time from burn centre admission to first surgical procedure was even lower, with a median of 7.0 days (25–75th percentile, 4.0–12.0) in the oldest category (Table 5).

Both the number of surgical procedures and the percentage TBSA excised per surgical procedure were comparable among the age categories.

The applied surgical techniques for burn wound excision differed among the age categories. The majority of the burns were excised by tangential excision (66.5%), mostly with the use of hydrosurgery (40.0%), except in the oldest two age categories (75–84 and 85+). In these elderly patients, hydrosurgery was only used in 23.5% and 22.6% of the cases, respectively ($p < 0.001$). Avulsion and primary wound closure were more frequently applied ($p < 0.001$). The most frequently applied grafting technique was meshed graft in all age categories.

Early versus delayed surgery in the elderly

The majority (72.3%) of the elderly burn patients underwent their first surgical procedure after 7 days post-burn (delayed excision). Patients who received early excision before 7 days post-burn (27.7%) had a significantly higher burn severity than the delayed excision group, based on TBSA burned (12.5 vs 3.0; $p = 0.002$), TBSA full-thickness burned (6.0 vs 2.0; $p < 0.001$) and ICU admissions (50% vs 16.2%; $p = 0.002$). However, the two groups did not significantly differ in median age (77 vs 72; $p = 0.070$) and comorbidity (mean major organ systems affected, 1.4 vs 1.1; $p = 0.641$).

Clinical outcomes

Overall mortality jumped from 1.3% and 3.1% in the first two age categories (18–64 and 65–74) to 9.1% and 23.8% in the last two age categories (75–84 and 85+).

Wound healing was complicated by infection in 2.9% of the cases; however in the 65–74 category this percentage was significantly higher at 7.0%.

The burden of care, represented as the median LOS per percent of TBSA, almost tripled ($p < 0.001$) from 1.3 days per percent of TBSA (25–75th percentile, 0.5–2.8) in the younger adults (18–64) to 3.5 (25–75th percentile, 1.1–7.0) in the oldest age category.

Table 3. Prehospital care stratified per age category

Age categories (years)	18–64 *n* = 2616	65–74 *n* = 255	75–84 *n* = 168	85+ *n* = 82	*P* value
Prehospital care					
Burn cooling (%) (missing value, n = 33)					<0.001
Direct	70.6	59.2	54.4	36.5	
Delayed*	10.6	11.8	14.8	22.4	
None	17.7	28.6	29.6	40.0	
Referrer (%)					<0.001
General Practitioner	10.9	22.1	21.9	24.7	
Other hospital	62.1	59.5	54.4	51.8	
Emergency services	19.1	13.4	18.3	22.4	
Other**	7.9	5.0	5.3	1.2	
Delay in presentation Burn centre of >48 hours (%)***	11.9	22.9	21.9	17.6	<0.001
Comfort care upon admission (%)	0.7	2.3	2.4	5.9	0.019

*After 10 minutes

**Including self-referral

***Patient with day-care admission for surgery were excluded

Table 4. In-hospital treatment characteristics stratified per age category

Age categories (years)	18–64 *n* = 2598	65–74 *n* = 249	75–84 *n* = 164	85+ *n* = 77	*P* value
Median length of stay in days (25–75th percentile)	5 (1–18)	12 (2–25)	16 (4–237)	18 (6–28)	<0.001
ICU admission (%)	19.0	17.8	24.5	24.2	0.256
Mean ICU stay in days (SD)	12.2 (18.4)	11.8 (15.5)	12.5 (13.4)	7.8 (8.7)	0.552
Mechanical Ventilation (%)	71.8	55.4	67.9	66.7	0.079
Mean ventilation in days (SD)	11.2 (16.7)	11,5 (13.9)	10.8 (10.4)	4.9 (4.9)	0.389
Surgical treatment for wound closure (%)	47.5	63.7	70.4	63.5	<0.001

ICU intensive care unit, *SD* standard deviation

Table 5. Comparison of surgical treatment stratified per age category

Age categories (years)	18–64 *n* = 1234	65–74 *n* = 159	75–84 *n* = 115	85+ *n* = 49	*P* value
Surgical management					
Median days to first surgery from injury (25–75th percentile)	13.0 (9.0–17.0)	14.0 (9.0–19.0)	11.0 (7.0–17.0)	10 (5.5–17.0)	0.037
Median days to first surgery from admission (25–75th percentile)	10.0 5–15)	9.0 (5.0–14.0).)	7.0 4.0–11.0)	7.0 (4.0–12.0))	<0.001
Mean number of surgical procedures (SD)	1.8 (, 2.2)	1.7 (1.5)	1.7 (1.5)	1.5 (1.1)	0.827
Mean TBSA per surgery (SD)	3.1 (3.1)	2.6 (2.2)	2.7 (2.2)	3.1(2.3)	0.61
Surgical technique- excision* (%)					
Tangential	65.6	67.3	74.8	71.7	0.184
Tangential with hydrosurgery	42.0	43.0	23.5	22.6	<0.001
Avulsion	5.3	7.3	17.6	15.1	<0.001
Primary wound closure	6.7	14.5	13.4	24.5	<0.001
Surgical technique- grafting* (%)					
Meshed graft	88.6	89.1	89.1	79.2	0.216
Meek wall	6.8	6.1	11.8	5.7	0.208
Allografts	4.4	6.1	7.6	3.8	0.374
Dermal substitutes	1.8	1.8	0.8	1.8	0.886

*More than one surgical technique in the same patient is possible

SD standard deviation, *TBSA* total body surface area

The frequency of re-admissions and reconstructions did not differ significantly by age. It is of note, however, that reconstructions seem to decrease with age, with 4.7% in younger adults and young elderly (65–74), 3.0% in the 75–84 years category and none in patients in the 85+ category. Evaluation of disposition, as a measure of functional

Table 6. Comparison of clinical outcome stratified per age category

Age categories (years)	18–64 *n* = 2598	65–74 *n* = 249	75–84 *n* = 77	85+ *n* = 77	*P* value
Mortality (%)	1.3	3.1	9.1	23.8	<0.001
Wound infection (%)	2.4	7.0	1.8	5.0	<0.001
Median length of stay/% TBSA (25-75th percentile)	1.3 (0.5–2.8)	2.4 (0.9–5.5)	3.4 (1.2–6.2)	3.5 (1.1–7.0)	<0.001
Re-admission (%)	8.5	8.2	6.7	10.0	0.808
Reconstructions (%)	4.7	4.7	3.0	0.0	0.185
Discharge destination survivors (%)					
Home	85.8	77.3	53.9	41.3	<0.001
Rehabilitation	1.8	1.2	0.6	0.0	
Skilled nursing facility	1.0	8.2	21.8	22.5	
Mental institution	4.7	3.1	1.8	1.3	
Other	5.5	7.0	12.7	11.3	

TBSA total body surface area

outcome, showed a significant decrease ($p < 0.001$) in patients who were discharged to home with increasing age—instead, these elderly patients were primarily discharged to a skilled nursing facility or died (Table 6).

Discussion

This study clearly demonstrates major differences in burn severity, pre-hospital management and in-hospital specialized burn care, including surgical management and clinical outcomes, between an elderly burn population and a younger adult burn population. In all age categories burn size was comparable, but gender, aetiology and pre-hospital care were different. In the elderly, females were over-represented, scalds and contact burns were more frequent, cooling less adequate and there was more often a delayed presentation to the burn centre. Treatment in elderly patients showed a shorter time to first surgical procedure, less hydrosurgery and more avulsion and primary wound closure. Mortality jumped with increasing age, especially in the oldest patients. Furthermore, a major difference was observed in discharge disposition between younger adult and elderly patients. The data provide useful insights in the specific needs of elderly burn patients, as well as starting points to optimize care for this vulnerable burn population.

Our main objective was to compare surgical treatment and clinical outcomes between an elderly burn population and a younger adult burn population. Surgical management was indeed significantly different in these two populations. In the first place, time to first surgery from admission and, to a lesser extent, from injury onwards was considerably shorter in the elderly. In most elderly patients, excision and grafting was performed around day 7 after admission, probably because of more rapid burn demarcation of deeper burns and partially because of a delay in admission. Compared to other studies, surgical treatment in our cohort started relatively late. This is in line with the more conservative approach as is traditionally followed in several European burn centres.

In cases of early surgery before 7 days in our cohort, this decision seemed based on burn severity and not on patient-related factors such as age and comorbidity. Consequently, we were unable to examine the effect of early versus delayed surgery on clinical outcomes as the two groups were significantly different on burn severity. This is unfortunate, since there is no consensus in the burn literature on this topic. Previously, five retrospective studies examined the effect of early excision and grafting in elderly patients but found inconsistent results on mortality and LOS [2, 10, 16–18]. Three studies demonstrated no improvement in mortality [2, 10, 16], one study indicated an improvement in mortality [17] and another study showed an increased mortality [18]. The impact of early excision on LOS was also ambiguous in one study indicating a shortened LOS [16] and another study indicating no impact on hospital stay [10]. Infection rate was only described in one study and was reduced in the early excision group [16]. Moreover, these studies were predominately out of date (1985–1998) and therefore may not apply to modern burn care. A Cochrane review on the effectiveness of early excision and grafting for burns in all ages concluded that the methodological quality of the included studies does not allow for conclusive judgements [24]. The extensiveness of excision seemed unaffected in our study by limitations related to age and secondary comorbidity as both the number of surgical procedures and the TBSA excised per procedure did not differ between elderly and younger adults. However, eschar excision was often performed with less selective excision methods in the elderly (less hydrosurgery, more primary wound closure and avulsion). Presumably, this is related to deeper burns in the elderly and less priority to the preservation of viable dermis.

Clinical outcomes were substantially poorer in elderly patients. In particular, mortality dramatically increased with age up to 23.8% in the 85+ category, considering these were all patients with an intention to treat upon admission and generally moderate burn severity with a mean SD TBSA of 7.9 ± 12. Mortality in our cohort was lower compared to

several international studies in the elderly in a similar period (>2005) [2, 20, 25], which reported a mortality of about 48%. These studies included patients with a higher mean TBSA burned (13–23%) but, on the other hand, mortality was calculated in younger age categories of 65+ [2, 20, 25] or 75+ [20] compared to the mortality in our 85+ category. Chang *et al*. also found a mortality of 23% (TBSA, 15.5%), LOS/%TBSA in this study was, in line with our results, also increased in the elderly (2.1 day/TBSA) [26].

Ideally, clinical outcome includes functional outcomes, next to mortality. Our data were limited to discharge destination, giving a gross indication of functional status after discharge. In the near future the Dutch burn centres will implement routine outcome measurement in the daily practice of burn care. This Burn Centre Outcomes Registry Netherlands aims to gain insight into patient-reported outcomes after specialized burn care [27].

Overall, the burden of inpatient care in the elderly was significantly higher compared to younger adults, as indicated by longer median LOS, more ICU admissions and more frequent surgical treatment.

With increasing age, burn severity increased in our cohort. This was characterized by a higher ratio of full-thickness TBSA/TBSA burned (which doubled from 0.30 to 0.59) and more frequent inhalation injury in the elderly. These results are comparable to the study of Albarnoz *et al*., who also observed proportions of deep TBSA/TBSA nearly twice as high in the elderly (23.3% <65 years vs 41.0% >65 years) [20].

Logically, Revised Baux scores increased significantly with age, as age is an important part of the score. Inhalation injury also contributed to higher Revised Baux scores as it was more present in the elderly. This might be related to elderly people having a slower response to danger in case of (house) fire [8]. On the other hand, the Revised Baux score does not account for the higher proportion of deeper burns in the elderly. Although the Revised Baux score adequately predicts mortality, it does not reflect the burden of care (in this case, need for surgery) in the elderly, nor does it account for comorbidity, as was suggested recently by Heng *et al* [28].

Besides the atrophic skin in the elderly [19], burns might also be deeper in the elderly because of differences in the prehospital phase. Recently, Wood *et al*. emphasized the beneficial effect of cooling on burn severity [29]. In our cohort, adequate burn cooling rapidly declined with age. The elderly often did not cool their burns at all (28.6–40.0%) and, if performed, it was more often delayed by more than 10 minutes. In line with previous studies, presentation to the burn centre was more frequently delayed by more than 48 hours [7], which might lead to inadequate or delayed specialized care in this already frail population. Again, educational campaigns to improve burn knowledge and home fire safety, as proposed by the studies of Tan *et al*. and Lehna *et al*., might be an effective intervention strategy [30, 31]. In addition, physicians outside specialized burn care should take this delayed presentation into account in their treatment decisions in order to reduce further delay to definitive treatments, including surgery.

Next to treatment and outcome, some population differences were noticed. The higher proportion of elderly female burn patients might be explained by the higher life expectancy of women compared to men and herewith changes in population composition at higher ages.

This study has some strengths and limitations. As previously mentioned, we were not able to compare early versus delayed excision and grafting because of significant differences in burn severity in the two groups. In addition, we only examined a limited number of clinical outcomes. Other limitations were the limited period of follow-up on reconstructions in patients admitted in 2014–2015 and the fact that the Dutch Burn Repository R3 database does not account for only temporary changes in discharge destinations. Thus, the number of patients that were permanently discharged to a skilled nursing facility might be overestimated. In addition, the focus of our study was to compare treatment outcome between age categories. Our database did not provide sufficient information to assess whether patients are referred or treated according to the standard model of care; more detailed data collection is necessary for such an analysis. This includes data on frailty of patients and medication use, both highly relevant predictors of outcome in elderly patients. Future research on outcome in elderly burn patients should address these topics.

Strengths of this study are its nationwide cohort, including all three Dutch burn centres, the large cohort of elderly patients and the completeness of the data, which enabled us to map the entire burn care process. Above all, we believe it is important to share data on treatment and outcome to enable burn centres worldwide to compare and evaluate their medical practise.

In our view, opportunities for improvement in burn outcome in the elderly can be realized at several levels. First, prevention and education should be targeted to the community-dwelling elderly, particular to those in neighbourhoods of low economic status [30, 31]. Education should focus on burn cooling and adequate and timely presentation to healthcare services to prevent unnecessary delay in specialized burn care, despite the unclear effect of geriatric consultation teams on outcome in trauma patients [32, 33]. In specialized burn care, we would recommend the use of geriatric consultations in the inpatient phase, to encounter preventable complications [34, 35] as was suggested in American College of Surgeons Trauma Quality Improvement Program Guidelines for Geriatric Trauma Management. Finally, future studies should aim to explore the possible beneficial effect of early surgery on mortality and other hospital-related complications, such as pneumonia, delirium and pressure sores. Early surgery is already extensively examined in the field of traumatic hip surgery in the elderly and showed distinctly better outcomes [36, 37]. This fast-track principle might be particularly beneficial for elderly

burn patients with moderate burns and limited need for resuscitation to facilitate early mobilization and reduce LOS.

Effectiveness and cost-effectiveness of optimized burn care in the elderly still need to be assessed. Such studies will help to improve health care and outcomes, with the optimal use of limited resources in health care.

Conclusions

Elderly patients constitute a vulnerable, growing and medically challenging group for specialized burn care. Aetiology, comorbidity, physiological differences and pre-hospital care all affect the surgical management in the elderly and result in poorer clinical outcomes. Opportunities for outcome improvement are in finding the right timing of surgery and optimizing the pre-hospital phase.

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Abbreviations

WHO: World Health Organization; LOS: length of stay; TBSA: total body surface area; EMSB: Emergency Management of Severe Burns; ICU: intensive care unit; SES: socioeconomic status

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Conflicts of interest

None declared.

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Appendix 1.

1998 onwards: Emergency Management of Severe Burns Criteria for referral to a Dutch Burn Centre

- Burns greater than 10% total body surface area (TBSA) in adults.
- Burns greater than 5% TBSA in children.
- Burns of special areas – face, hands, feet, perineum, genitalia and major joints.
- Full-thickness burns greater than 5% TBSA.
- Electrical burns.
- Chemical burns.
- Burns with associated inhalation injury.
- Circumferential burns of the limbs or chest.
- Burns at the extremes of age – children and the elderly.
- Burn in patients with pre-existing medical disorders which could complicate management and prolong recovery or effect mortality.
- Any burn patient with associated trauma.