Research Article
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The Impact of Area-Limited Skin Burns in the Severity of the Burn Disease and Outcome of Inhalation Injury

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INTRODUCTION Inhalation injury (InI) makes burn disease more severe. However, it remains unexplored what is the minimum area of the burn that can significantly aggravate of the course of InI.
The objective was to compare the incidence of acute respiratory failure (ARF), pneumonia, and mortality between patients with InI and InI with superficial skin burns up to 3% total body surface area (TBSA).

MATERIAL AND METHODS 125 patients with InI and I–II degree skin burns up to 3% TBSA were allocated into 4 groups: InI without skin burns, InI with burns up to 1% TBSA, up to 2%, and up to 3% TBSA.

RESULTS In the group with InI and skin burns up to 2%, the number of ARF, pneumonia cases, and deaths did not statistically significantly differ from the InI group, however in group of InI and burns of more than 2% TBSA, there were more of those complications.

CONCLUSION Skin burns of I–II degree over 2% TBSA increase the incidence of acute respiratory failure, pneumonia, and death in patients with InI.

Keywords: inhalation injury, skin burns, acute respiratory failure, pneumonia, fatal outcome, mortality, death

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ABI, airway burn injury
ARDS, acute respiratory distress syndrome
ARF, acute respiratory failure
BS, bronchoscopy
CCI, Charlson Comorbidity Index
FET, Fisher's exact test
InI, inhalation injury
InI+B, inhalation injury and skin burns
MLV, mechanical lung ventilation
TBSA, total body surface area

INTRODUCTION

Inhalation injury (InI) develops as a result of smoke inhalation from a fire in an enclosed space. The thermal agent usually affects only the upper respiratory tract. At the same time, toxic smoke compounds cause local damage to the parenchyma of the tracheobronchial tree and lungs and have a systemic effect on the body [1, 2, 3]. In response to damage to the parenchyma, neurogenic inflammation develops [4]. Trauma and neurogenic inflammation can cause acute respiratory distress syndrome (ARDS) [2, 5] and obstructive syndrome [6], leading to the development of acute respiratory failure (ARF).

The most common complication and cause of death in patients with skin burns and InI is nosocomial pneumonia [7, 8, 9, 10]. Factors contributing to its development include: erosive and ulcerative lesions of the mucous membrane, ARDS, a large area of skin burns [10, 11].

It is known that InI in patients with extensive skin burns worsens their course and outcome [1, 10, 12, 13]. However, it remains unknown what percentage of burn worsens the course and outcome of InI, which is important for patients with minimal superficial skin burns, in which the leading clinical manifestations are associated with damage to the tracheobronchial tree and lungs.

The aim of the study was to compare the incidence of ARF, pneumonia, and deaths in patients with isolated InI and InI combined with skin burns of I - II degree of up to 3% TBSA

MATERIAL AND METHODS

The medical records of 125 patients admitted to the Burn Center of the N.V. Sklifosovsky Research Institute for Emergency Medicine in 2018-2020 were retrospectively reviewed.

Criteria for inclusion in the study were the age over 18 years, hospital admission within the first 24 hours after injury, presence of InI without skin burns, as well as InI combined with superficial burns (I - II degree according to ICD-10) of up to 3% TBSA.

Of 125 patients, 61 (49%) were men and 64 (51%) were women. The age of the patients ranged from 18 to 92 years, the area of burns was from 0 to 3% TBSA, the Charlson Comorbidity Index was from 0 to 8.

In order to confirm InI, all patients underwent diagnostic bronchoscopy (BS) upon admission. Based on the results of the BS, the degree of airway burn injury (ABI) according to the native classification developed at the N.V. Sklifosovsky Research Institute for Emergency Medicine: the 1 degree corresponds to a catarrhal injury of the tracheobronchial tree, the 2 implies erosive form, the 3 is ulcerative one, and the 4 means necrotic form [14]. In this study, none of the patients was diagnosed with the fourth degree of ABI.

Pneumonia was diagnosed on the basis of clinical data and X-ray examination of the chest organs in the posterior-anterior view.

The Charlson Comorbidity Index (CCI) was used to assess comorbidity according to the method developed by M. Charlson with patient age taken into account [15].

All patients were divided into the following 4 groups with regard to the burn area: those with isolated InI (InI group), with InI and skin burns of I - II degree of 0.1-1.0% TBSA (group InI+B 1), 1.1-2.0% TBSA (group InI+B 2), and 2.1-3.0% TBSA (group InI+B 3).

Patients of groups InI+B 1, InI+B 2, and InI+B 3 did not differ statistically significantly from the InI group by age (Table 1). Patients of all groups had concomitant diseases: ischemic heart disease, cerebrovascular disease, hypertension, chronic obstructive pulmonary disease, type 2 diabetes mellitus, various types of cardiac arrhythmias, duodenal ulcer, however, they did not differ in CCI. At the same time, patients of the InI+B 1, InI+B 2, and InI+B 3 groups statistically significantly differed from each other in terms of the burn area burns ($p < 0.001$; $p<0.001$; $p<0.001$, respectively, M-W test).

Table 1

Comparative characteristics of patients in the groups by age, CCI and area of burns

Patient characteristics	Patient groups				p, K-W test
	InI (n=87)	InI+B 1 (n=20)	InI+B 2 (n=11)	InI+B 3 (n=7)	
Age, years Me (Q1; Q3)	57 (39; 72)	63 (54; 76)	61 (54; 68)	69 (47; 85)	0.337
CCI, score Me (Q1; Q3)	2 (0; 4)	2,5 (1,5; 4,5)	2 (2; 3)	4 (0; 6)	0.434
Burn area, % TBSA Me (Q1; Q3)	–	0,5 (0,2; 1,0)	2 (1,5; 2,0)	3 (3; 3)	<0.001

Notes: CCI, Charlson Comorbidity Index; InI, inhalation injury; InI+B 1, InI and I–II degree skin burns on the area of 0.1–1.0% TBSA; InI+B 2, InI and I–II degree skin burns on the area of 1.1–2.0% TBSA; InI+B 3, InI and I–II degree skin burns on the area of 2.1–3.0% TBSA; TBSA, bodysurface area

Comparison by gender between InI and InI+B 1, InI and InI+B 2, InI and InI+B 3 groups did not reveal any statistically significant differences ($p =0.628$, $p =1.000$, $p =1.000$, respectively; FET). Data are presented in Table 2.

Table 2

Characteristics of groups by gender

Gender	Patient groups			
	InI (n=87)	InI+B 1 (n=20)	InI+B 2 (n=11)	InI+B 3 (n=7)
Male	42	11	5	3
Female	45	9	6	4

Notes: InI, inhalation injury; InI+B 1, InI and I–II degree skin burns on the area of 0.1–1.0% TBSA; InI+B 2, InI and I–II degree skin burns on the area of 1.1–2.0% TBSA; InI+B 3, InI and I–II degree skin burns on the area of 2.1–3.0% TBSA; TBSA, body surface area

The InI and InI+B 1, InI and InI+B 2, InI and InI+B 3 groups did not statistically significantly differ in ABI degree:

1st degree: $p =0.555$, $p =0.448$, $p =0.339$, respectively; FET;

2nd degree: $p =0.807$, $p =0.535$, $p =1.000$, respectively; FET;

3rd degree: $p =0.764$, $p =0.123$, $p =0.183$, respectively; FET. The data are presented in Table 3.

Table 3

Characteristics of patients in the groups according to the ABI severity degree

ABI severity degree	Patient groups			
	InI (n=87)	InI+B 1 (n=20)	InI+B 2 (n=11)	InI+B 3 (n=7)
1	20	3	1	0
2	49	12	5	4
3	18	5	5	3

Notes: InI, inhalation injury; InI+B 1, InI and I–II degree skin burns on the area of 0.1–1.0% TBSA; InI+B 2, InI and I–II degree skin burns on the area of 1.1–2.0% TBSA; InI+B 3, InI and I–II degree skin burns on the area of 2.1–3.0% TBSA; TBSA, body surface area

Thus, the patients of the InI+B 1, InI+B 2, and InI+B 3 groups were comparable with the patients of the InI+B I group in terms of gender, age, CCI, and the degree of ABI and differed from them only in the area of burns.

Statistical analysis was performed using Statistica 13 software package. Descriptive statistics are presented as absolute (n) and relative values, medians (Me), lower and upper quartiles (Q1; Q3). The groups were compared using the Kruskal-Wallis (K–W test), Mann-Whitney (M-W) and Fisher's exact test (FET). The significance of differences between groups was taken at $p < 0.05$ [16].

RESULTS

To find out how the incidence of ARF, pneumonia, and deaths in patients with InI depended on the area of burns, we compared the InI+B 1, InI+B 2, and InI+B 3 groups with the InI group for these parameters.

Acute respiratory failure requiring mechanical ventilation developed in 49 (39%) patients (Table 4). The indications for the beginning of mechanical ventilation were as follows: a decrease in arterial blood saturation to 86% or lower, a decrease in the oxygenation index ⩽ 200, or pronounced manifestations of broncho-obstructive syndrome with hypercapnia of more than 50 mm Hg. Acute respiratory failure in all patients developed within the first 48 hours after injury. The duration of mechanical ventilation was 13 days or more in the survivors, 5 days or more in the dead.

Table 4

Characteristics of groups by the number of acute respiratory failure cases, pneumonia cases, and the outcome

Parameter		Patient groups				Total (n=125)
		InI (n=87)	InI+B 1 (n=20)	InI+B 2 (n=11)	InI+B 3 (n=7)	
ABI, n	yes	28	10	6	5	49
	no	59	10	5	2	76
Pneumonia, n	yes	37	10	6	5	58
	no	50	10	5	2	67
Outcome, n	alive	70	16	9	3	98
	died	17	4	2	4	27

Notes: InI, inhalation injury; InI+B 1, InI and I–II degree skin burns on the area of 0.1–1.0% TBSA; InI+B 2, InI and I–II degree skin burns on the area of 1.1–2.0% TBSA; InI+B 3, InI and I–II degree skin burns on the area of 2.1–3.0% TBSA; TBSA, body surface area

The number of patients with ARF between the groups of InI and InI+B 1 and between the InI and InI+B 2 groups did not differ statistically significantly ($p = 0.194$; $p = 0.182$, respectively; FET). The number of patients with ARF in the InI+B 3 group was statistically significantly higher than in the InI+B group ($p = 0.049$; FET). The proportion of patients with ARF in the InI+B 1 and InI+B 2 groups was 1.6-1.7 times higher than in the InI group, and that in InI+B 3 group was 2.2 times higher than in the InI group (Figure 1).

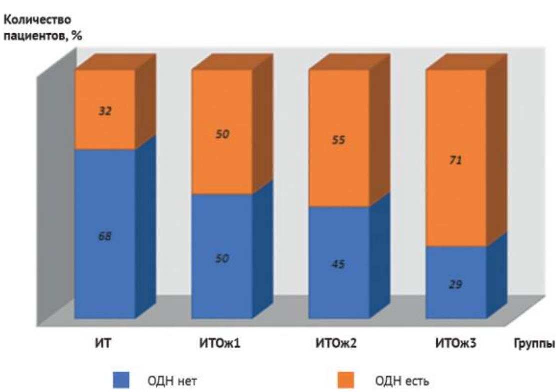

Fig. 1. Proportion of patients with acute respiratory failure and without it in the groups

Notes: InI, inhalation injury; InI+B 1, InI and I–II degree skin burns on the area of 0.1–1.0% TBSA; InI+B 2, InI and I–II degree skin burns on the area of 1.1–2.0% TBSA; InI+B 3, InI and I–II degree skin burns on the area of 2.1–3.0% TBSA; TBSA, body surface area

Pneumonia was diagnosed in 58 (46%) patients. The number of patients with pneumonia did not differ statistically significantly between the InI and InI+B 1 groups and between the InI and InI+B 2 groups (p = 0.621;

p = 0.527, respectively; FET). Despite the fact that we did not find a statistically significant difference in the number of patients with pneumonia between the InI and InI+B 3 groups (p = 0.236; FET), there were 1.7 times more patients with pneumonia in the InI+B 3 group (71%) than in the InI group (43 %) (Figure 2).

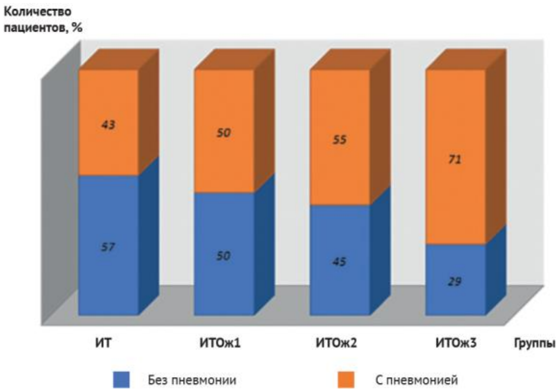

Fig. 2. Proportion of patients with pneumonia and without it in groups

Notes: InI, inhalation injury; InI+B 1, InI and I–II degree skin burns on the area of 0.1–1.0% TBSA; InI+B 2, InI and I–II degree skin burns on the area of 1.1–2.0% TBSA; InI+B 3, InI and I–II degree skin burns on the area of 2.1–3.0% TBSA; TBSA, body surface area

It should be noted that pneumonia was diagnosed in 47 (81%) patients on mechanical ventilation, which was statistically significantly more common than in patients without mechanical ventilation – (n = 11; 19%) (p < 0.001; FET).

The number of deaths in all groups was 27 (22%). There were no statistically significant differences in the number of deaths between the InI and InI+B 1 and InI and InI+B 2 groups (p = 1.000; p = 1.000, respectively; FET). Meanwhile, in the InI+B 3 group, the number of deaths was statistically significantly higher than in the InI group (p = 0.042; FET). The data is presented in Figure 3.

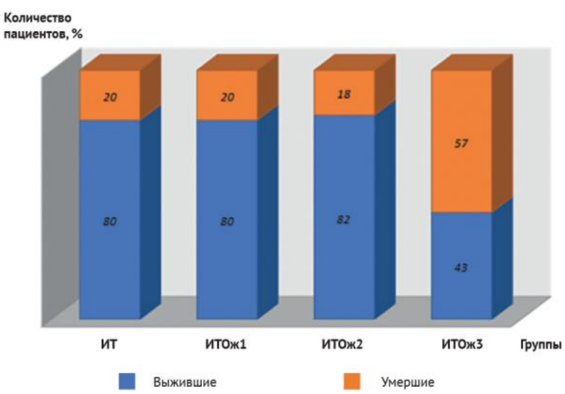

Fig. 3. Outcomes in the groups

Notes: InI, inhalation injury; InI+B 1, InI and I–II degree skin burns on the area of 0.1–1.0% TBSA; InI+B 2, InI and I–II degree skin burns on the area of 1.1–2.0% TBSA; InI+B 3, InI and I–II degree skin burns on the area of 2.1–3.0% TBSA; TBSA, body surface area

There were 27 (55%) deaths of 49 patients with ARF, which was statistically significantly more than survivors (n = 22; 45%) (p < 0.001; FET).

Of 58 patients with pneumonia, 27 (47%) died and 31 (53%) survived; no patient died among those without pneumonia. The incidence of pneumonia in the deceased was statistically significantly higher than in the survivors (p < 0.001; FET).

DISCUSSION

Earlier P.A. Brygin found that ARF, which requires mechanical ventilation, developed in 29% of patients with isolated InI [17]. In this study, ARF developed in 28% of patients with isolated InI, which confirms the previously published data. The proportion of patients with ARF was 1.6-1.7 times greater in the groups of patients with skin burns up to 2% TBSA than in the group of those with isolated InI, but no statistical differences were found. The proportion of patients with ARF in the group of patients with InI and skin burns is from 2.1%

to 3% TBSA was 2.2 times more than in the group with isolated InI, the difference was statistically significant. ARF developed in 71% of patients with skin burns on of 2.1-3% TBSA, which corresponds to the incidence of the ARF development reported in study by D. P. Mackie et al., in which ARF developed in 76% of patients with InI and skin burns over 30% TBSA [18].

According to the literature, pneumonia develops in 38-65% of patients with skin burns and InI [19, 20]. In our study, pneumonia was diagnosed in 43-71% of cases (depending on the group of patients). And, despite no statistically significant difference, the number of pneumonia cases was 1.7 times higher among patients with InI and skin burns of over 2% TBSA than in the group of patients with isolated InI.

Mortality in isolated InI makes no more than 11%, and in combination with skin burns it increases significantly and, according to different authors, reaches 30-90% [1, 21, 12, 13]. In our study, mortality in isolated InI was slightly higher and made up to 20%. In the group of patients with skin burns of over 2% TBSA, it was 2.9 times higher and amounted to 57%, which is consistent with the literature data. In the study published in 1990, the authors concluded that the presence of skin burns of 1% to 15% TBSA increase mortality among the patients with InI over 60 years old [22]. Based on our results, we can conclude that the number of deaths increases in patients older than 60 years and skin burns of over 2% TBSA. In patients with combination of InI and skin burns of up to 2% TBSA, mortality is comparable to that of patients with isolated InI.

In our study, the number of ARF, pneumonia cases, and deaths among the patients with InI and superficial skin burns of up to 2% TBSA did not differ from those among the patients with isolated InI. Meanwhile, in associated superficial burns of over 2% TBSA, the number of ARF, pneumonia cases, and deaths increased compared to those in isolated InI only.

CONCLUSIONS

1. The incidence of ARF development, pneumonia, and death rate increases in patients with InI and I-II degree skin burns of over 2% TBSA compared to those in patients with isolated InI.
2. The incidence of ARF development, pneumonia, and death rate in patients with InI and I-II degree skin burns of up to 2% TBSA does not differ from the incidence in patients with isolated InI.
3. Patients with I-II degree skin burns of up to 2% TBSA may be included in the same group as the patients with isolated InI to study ARF, pneumonia, and deaths.

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