**Research Article**

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# Revision of the Frank Index for Predicting Death in Thermal Injury

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**SUMMARY** The index used in Russia to predict mortality in patients with burns, the Frank index, needs to be revised because it has a low prognostic value.

**TARGET** Modify the Frank index to increase its predictive value for mortality.

**MATERIAL AND METHODS** A retrospective study included 307 patients with skin burns. We added the age of the patient to the Frank index (FI) formula and changed the score for inhalation trauma (inhalation injury). We compared the discriminatory power and predictive value of FI and the Revised Frank Index (RFI) using statistical analysis methods.

**RESULTS** Adding the absolute number of years of the patient and 30 points for inhalation injury to the FI formula improved the discriminatory power and predictive value of RFI, which is calculated by the formula $\sum = S_{\text{surface burns}}$ (% b.s. ) + 3*$S_{\text{surface burns}}$(% b.s. ) + age (full years) + 30 (points for inhalation injury).

**CONCLUSION** The predictive power of the revised Frank index is higher than the Frank index currently used. The threshold value of the revised Frank index, dividing the forecast into favorable and unfavorable, is score 130.

**Key words:** mortality prediction index, Frank index, burns

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CI – confidence interval
b.s. – body surface
NPV – negative predictive value
PPV – positive predictive value
FET – two-tailed Fisher exact test
FI – Frank index
RFI – revised Frank index
U-test – Mann-Whitney test

## INTRODUCTION

Mortality prognosis indices in case of a disease or injury make it possible to assess the probability of a fatal outcome in patients depending on a set of prognostic factors [1, 2].

In 1960, G. Frank suggested the concept of a "prognostic index" for patients with burns, which is expressed as a single number and is associated with mortality [3]. The variables considered in this index were the area of the burn and its depth.

In subsequent years, numerous other indices for predicting death in burn victims were developed and improved [2]. Currently, different countries use the Baux [4], PBI [5], ABSI [6], BOBI [7], Ryan [8] indices and the revised Baux (RBS) [9] and ABSI [10] indices. All of them implement a scoring of predictors, the sum of which determines the prognosis of a fatal outcome. The main predictors of death in patients with burn injury include age, burn area, and inhalation injury (II) [2]. Some authors point to the female gender as a predictor of an unfavorable outcome of a burn injury [6].

In Russia Frank index (FI) has been widely used, calculated by multiplying the percentage of burns of different depths by the appropriate coefficient and then adding them up. In the case of burns of the first degree, the coefficient was 0.5, in burns of II/1 degree it was 1, in cases of degree II/2 it was 2, in cases of degree III it was 3, and in cases of degree IV it was 4 [3]. The threshold value separating the prognosis into favorable and unfavorable was determined by Frank for 3 age ranges: 15–44 — more than 171, 45–64 — more than 101, and over 65 — more than 61 points [3].

Subsequently, domestic authors made changes to the FI formula, for which we have not found scientific justification. Thus, in the 1986 burn treatment manual, FI was simplified and presented as the sum of the area of superficial burns and the area of deep burns, multiplied by 3 [11]. Since that time, the age of patients has ceased to be mentioned at all. In the 2000 burn treatment guidelines, 30 points were added to the FI for grades I and II burns and 45 points were added for grades III and IV diagnosed by endoscopic examination [12]. The prognosis was expected to be favorable if FI was up to 65–75, doubtful if FI was more than 75, and unfavorable if FI was more than 100–120 points [13]. In the 2005 guidelines, inhalation injury scores were changed to 15 for grades I and II and 30 for grades III and IV. The threshold value of the prognosis was defined as 100 [14].

According to Russian authors, the modern version of FI has a low prognostic value [15]. It is the only one of the above indexes that does not take into account in its formula the age of the patient, which is one of the main predictors of death in patients with burn injury [2]. Uncertainty in relation to the assessment of scores for inhalation injury, the lack of an adequate threshold for predicting a fatal outcome in patients with thermal injury motivated us to this work.

**Aim of study:** to improve the Frank index in order to increase its predictive value for mortality.

## MATERIAL AND METHODS

The retrospective study included 307 patients admitted to the intensive care unit of the Burn Center of the N.V. Sklifosovsky Research Institute for Emergency Medicine in 2019–2021. Inclusion criteria: thermal burns (flame, hot liquids, contact), age ⩾18 years, admission to the Burn Center on the first day after injury. There were no exclusion criteria. The sampling method was continuous.

Statistical analysis of the data was carried out using the SPSS v. 18 (IBM SPSS Statistics, USA). Th descriptive statistics is presented in the form of absolute (n) and relative values (%) for qualitative characteristics, medians (Me), interquartile ranges (Q1; Q3), minimum (min) and maximum (max) values for quantitative characteristics. To compare groups, two-sided Fisher's exact test (FET) and Mann–Whitney test (U test) were used. The threshold level of statistical significance was taken to be 0.05, and p-values in the range (0.05–0.10) were considered as evidence of a statistical trend. To assess the discriminatory ability of mortality prediction indices, ROC analysis was performed, with the help of which the area under the ROC curve (AUC) was calculated and the cut-off point was selected. The optimal cut-off point was determined by the maximum sum of sensitivity and specificity. The predictive value of positive (PPV) and negative (NPV) results was also calculated. Confidence intervals for proportions were calculated using the Clopper–Pearson method.

## RESULTS

The study included 307 patients, including 220 (72%) men and 87 (28%) women. General characteristics of patients are presented in Table 1. Inhalation injury was detected in 98 (32%) patients.

Table 1

**General characteristics of patients**

| Index | Patients, n | Me (Q1; Q3) | Min–max |
|---|---|---|---|
| Age, years | 307 | 51 (35; 67) | 18–93 |
| Total area of burns, % b.s. | 307 | 30 (20; 40) | 2.5–95 |
| Area of superficial burns, % b.s. | 299 | 20 (10; 30) | 0.5–86 |
| Area of deep burns, % b.s. | 193 | 8 (3; 20) | 0.1–95 |

Note: b.s. — body surface

Of the 307 patients, 227 were discharged from the hospital (74%), 80 (26%) died. Comparative characteristics of surviving and deceased patients are presented in Table 2. In the group of the dead, the values of age, the total area of burns and the area of deep burns are larger, the area of superficial burns is smaller, the proportion of women and patients with inhalation injuries higher.

Table 2

**Comparative characteristics of discharged and deceased patients**

| Index | Outcome, patients | | | | p, U-test or FET |
|---|---|---|---|---|---|
| | survived (n =227) | | died (n =80) | | |
| | n | Me (Q1; Q3) or n (%) | n | Me (Q1; Q3) or n (%) | |
| Age, years | 227 | 46 (33; 59) | 80 | 66 (52; 80) | <0.001 |
| Male, female | | 51 (22) | | 36 (45) | 0.002 |
| Inhalation injury, % | | 53 (23) | | 45 (56) | <0.001 |
| Total area of burns, % b.s. | | 25 (15; 34) | | 40 (25; 60) | <0.001 |
| Area of superficial burns, % b.s. | 225 | 21 (12; 30) | 74 | 15 (8; 25) | 0.009 |
| Area of deep burns, % b.s. | 118 | 4 (2; 10) | 75 | 28 (10; 39) | <0.001 |

Notes: b. s. — body surface; FET — two-tailed Fisher's test; U-test—Mann-Whitney test

We targeted to improve the predictive ability of the existing FI by gradually adding inhalation injury scores, taking into account the age and gender of the patient, and also defining a threshold separating the prognosis into favorable and unfavorable (lethal). We compared the results with the currently used Frank index: $FI = S_{\text{of superficial burns}}$ (% b.s.) + 3 × $S_{\text{of deep burns}}$ (% b.s.), and patients with inhalation injury were additionally added 15 points for inhalation injury1– 2$^{nd}$ degree or 30 points for inhalation injury3-4$^{th}$ degree.

To determine the optimal score of inhalation injury we successively added points from 10 to 100 (indices S 10–S 100) to the scores for the area and depth of burns (as in FI). The areas under the ROC curves obtained using ROC analysis were compared to each other and to FI (Table 3).

The largest area under the ROC-curves had indices S30 and S40, which significantly, although not statistically significant, exceeded the area under the ROC-curve FI.

The next stage of the work was the introduction of the patient's age index into the formula. To do this, for each patient, to the indices S30 and S40, which showed the best discriminatory ability, we added the age in absolute figures (number of years), S30 age and S40 age, and compared them with each other and with FI using ROC analysis.

The ROC analysis performed showed that S30 age and S40 age had an arithmetically larger area under the ROC curve than FI, which indicated their better discrimination ability: FI — 0.879, 95% CI [0.828–0.929], S30 age — 0.940 [0.911–0.969] and S40 age — 0.941 [0.913–0.968] (Fig. 1).

Table 3

**Areas under ROC curves FI and S10– S100**

| Index options | Number of points for inhalation injury | Area under the ROC curve and 95% CI |
|---|---|---|
| FI | 15 or 30 | 0.879 [0.828–0.929] |
| S10 | 10 | 0.872 [0.821–0.923] |
| S20 | 20 | 0.885 [0.836–0.933] |
| S30 | 30 | 0.892 [0.843–0.940] |
| S40 | 40 | 0.893 [0.845–0.941] |
| S50 | 50 | 0.889 [0.841–0.938] |
| S60 | 60 | 0.882 [0.833–0.932] |
| S70 | 70 | 0.877 [0.827–0.927] |
| S80 | 80 | 0.872 [0.821–0.922] |
| S90 | 90 | 0.864 [0.813–0.915] |
| S100 | 100 | 0.857 [0.806–0.908] |

Notes: CI — confidence interval

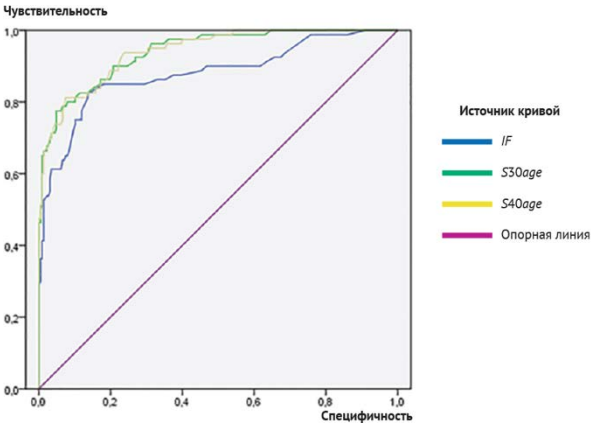


Fig. 1. ROC curves FI, S30 age And S40 age

To compare the S30 age and S40 age indices, we further chose the optimal cut-off points. For FI, this point was 51.5, for S 30 age and S 40 age it was 131.5 points. For the convenience of practical use, we rounded the last number to the nearest multiple of 10-130 points.

To select the optimal score for inhalation injury, we determined the sensitivity, specificity, PPV and NPV for FI, S30 age and S40 age (Table 4).

The two new indices do not statistically differ from the original FI in sensitivity and NPV, however, the S 30 age index surpasses it in specificity, and there is also a statistical trend towards greater PPV. Similar patterns for S40 age have not been identified. Therefore, there are reasons to prefer S30 age.

Thus, the best prediction of the outcome of a burn injury was shown by the index, which is calculated using the formula:

$\sum = S_{\text{superficial burns}}$ (% f.t.) + 3× $S_{\text{deep burns}}$ (% f. t.) + age (number of years) + 30 (inhalation injury points).

We called this revised Frank`s index (RFI).

Table 4

**Sensitivity, specificity, negative predictive value and positive predictive value FI, S30age and S40age**

| Indices | Cut-off point | Number of outcomes, n | | | | Sensitivity, % [95% CI] | Specificity, % [95% CI] | PPV, % [95% CI] | NPV, % [95% CI] |
|---|---|---|---|---|---|---|---|---|---|
| | | Above the cut-off point | | Below the cut-off point | | | | | |
| | | died | alive | died | alive | | | | |
| FI | 51.5 | 66 | 31 | 14 | 196 | 83 [74–89] | 86 [83–89] | 68 [61–73] | 93 [90–96] |
| S 30 age | 130 | 62 | 14 | 18 | 213 | 78 [70–84] | 94 [91–96] | 82 [73–88] | 92 [90–94] |
| S 40 age | 130 | 65 | 19 | 15 | 208 | 81 [73–88] | 92 [89–94] | 77 [70–83] | 93 [90–96] |
| p, FET | | | | | | | | | |
| *FI–S30age* | | | | | | 0.554 | 0.011 | 0.055 | 0.715 |
| *FI–S40age* | | | | | | 1.0 | 0.098 | 0.184 | 1.0 |
| *S30age–S40age* | | | | | | 0.696 | 0.470 | 0.561 | 0.720 |

Notes: CI - confidence interval; FET - two-tailed Fisher's test; NPV - negative predictive value; PPV- positive predictive value

Next, we decided to check how the predictive value would change if scores for the female gender were added to the RFI index formula. We have added to the above formula from 10 to 100 points for the female gender ($RFI10_{female}$–$RFI100_{female}$). The conducted ROC-analysis showed that the addition of points for gender worsened the discriminatory ability of the formula, as indicated by the arithmetic decrease in the area under the ROC-curve (Table 5).

Table 5

**Areas under ROC curves RFI, $RFI10_{female}$–$RFI100_{female}$**

| RFI version with floor | Number of points for the female gender | Area under the ROC curve and 95% CI |
|---|---|---|
| RFI | – | 0.940 [0.911–0.969] |
| RFI 10 $_{female}$ | 10 | 0.938 [0.908–0.968] |
| RFI 20 $_{female}$ | 20 | 0.936 [0.905–0.967] |
| RFI 30 $_{female}$ | 30 | 0.931 [0.899–0.963] |
| RFI 40 $_{female}$ | 40 | 0.925 [0.892–0.959] |
| RFI 50 $_{female}$ | 50 | 0.919 [0.885–0.954] |
| RFI 60 $_{female}$ | 60 | 0.911 [0.876–0.947] |
| RFI 70 $_{female}$ | 70 | 0.903 [0.867–0.940] |
| RFI 80 $_{female}$ | 80 | 0.896 [0.869–0.934] |
| RFI 90 $_{female}$ | 90 | 0.889 [0.851–0.927] |
| RFI 100 $_{female}$ | 100 | 0.883 [0.844–0.922] |

Notes: CI — confidence interval; RFI-Revised Frank Index

The answer to the question why the addition of points for gender did not improve the discriminatory ability of RFI was obtained after we conducted a comparative analysis of deceased men and women (Table 6). It turned out that the age of the deceased women was statistically significantly greater than the age of the deceased men. Since age is already accounted for in the RFI formula, additional scores for gender failed to improve its discriminatory ability, and therefore gender is not an independent factor in burn injury outcome. Note that the areas of burns did not differ in deceased men and women.

Table 6

**Comparative characteristics of deceased men and women with burns**

| Index | Gender | | | | p, U-test |
|---|---|---|---|---|---|
| | Women | | Men | | |
| | n | Me (Q1; Q3) | n | Me (Q1; Q3) | |
| Age, years | 36 | 76 (63; 81) | 44 | 59 (50; 71) | <0.001 |
| Total area of burns, % b.s. | 36 | 40 (25; 60) | 44 | 40 (26; 63) | 0.620 |
| Area of superficial burns, % b.s. | 35 | 15 (7; 20) | 39 | 20 (8; 28) | 0.267 |
| Area of deep burns, % b.s. | 33 | 25 (15; 35) | 42 | 30 (10; 39) | 0.762 |

Note: b. s. — body surface

## DISCUSSION

The Frank index in the form in which it is currently used in the Russian Federation does not take into account the age of the patient, and the number of points for inhalation injury was determined by an expert. However, this is the only known scoring index that takes into account the area of deep burns. The PBI and ABSI indices take into account only the presence of deep burns, adding a fixed number of points regardless of their area [5, 6], the other indices do not take into account the depth of burns.

G. Frank suggested scoring points for each degree of burn with a four-degree classification [3]. Currently, this scheme has lost its relevance due to the introduction of a three-degree classification of burns according to ICD-10. It seems to us optimal to keep 1 point for 1% b.s. for burns of I–II degrees and 3 points for 1% b.s. for third degree burns.

Domestic authors suggested different numbers of points for inhalation injury, depending on its degree, determined by bronchoscopy [11, 13]. From our point of view, this is not convenient, because clinics often use different classifications of degrees of inhalation injury [12, 16-18], and linking to any of them could complicate the use of a prognostic index.

Gender is included in the predictive factors for mortality in burn patients, but data from different studies are not unambiguous; sometimes female [6], sometimes male [19] is called a predictor of death. According to our data, mortality among women was 2 times higher compared to men. However, a detailed analysis showed that these differences were related to the age of the victims; hospitalized and deceased women were significantly older than men.

**Limitations of the study:** Although this study was conducted in a specialized hospital with a sufficient number of patients, it was a single center study. A multi-center study is required to confirm the results.

## CONCLUSIONS

1. The predictive power of the revised Frank index is higher than the Frank index currently used in the Russian Federation.

2. The threshold value of the revised Frank index, dividing the prognosis into favorable and unfavorable, is 130 points.

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