Online publication ahead of print, AJMHS Vol 55, 2021

Comparing the Real Outcome to the Probability for that Outcome by Generation of a Computer Model: a Minimum Standard of Burn Survival

Monika Belba*

Biomedical and Experimental Department, Section of Pharmacology, Faculty of Medicine, University of Medicine, Tirana; Albania
Department of Surgery, Service of Burns and Plastic Surgery, Service of Anesthesiology, University Hospital Center “Mother Teresa”, Tirana, Albania

Abstract

Background: Survival following burn injury has increased not only in developed countries over the past 20 years which is reflected with improvements in Lethal Area 50(LA50) or the burn size in which 50% of patients survive.

Aims: The aim of this study is to analyze mortality through LA50 and develop an objective predictive probability model for outcome in major burn patients based on age and BSA(%) which will help us to identify the patients with bad prognosis in order to help them during the course of the disease.

Study design: The study was retrospective clinical and analytical regarding outcome after severe burns. The data used are obtained by the analysis of the medical records of 5033 patients hospitalized with burns in the ICU of the service of burns and plastic surgery near UHC in Tirana, Albania during 1992-2019.

Methods: SPSS 23 software was used for the conduction of the statistical analysis. We have used Inferential Statistics through probability theory to draw conclusions. Concretely Simple Linear Regression for estimating Lethal Area 50 (LA 50), Binary logistic regression for creating the death probability chart. Statistical significance was defined as $p<0.05$.

Results: In the 28-year period, 5033 patients were admitted to Intensive Care Unit. Mean age (SD) was 20 (23.4) years old. Mean (SD) body surface area burn was 23.9 (16.9) %. Mortality was 12.3%. The mean LOS (Length of Hospital

Address for correspondence: Monika Belba* Biomedical and Experimental Department, Section of Pharmacology, Faculty of Medicine, University of Medicine, Tirana; Albania. Budi Street No.50, Tirana, Albania,1000. E-mail: piet_amy@yahoo.com

Stay) was 11.1±2.1 days while LOS in deaths was 8±10.7 days.LA 50 was improved in the last decade arriving 82.2%. From Logistic regression equation we calculate the death probability from 0-100% and present it as a surface contour chart.
Conclusion: There was a significant decrease in mortality in the last two decades which suggest major efforts have been made in burn care in Albania. We have developed a predictive model for mortality in major burn patients based only in age and burn size. Our opinion is that it is the responsibility of the burn team to continuously refresh and improve the probability chart in order to compile a chart after each year which should serve as a more accurate predictor for the patients of the following year. The probability for survival that the model assigns to the patients is the minimum standard because it is necessary to include in the model many other factors. The improvements in burn mortality should produce changes in the expectations of the burn care providers.

Key Words: Burns, Mortality, Death probability

INTRODUCTION

Burn is a severe traumatic injury with considerable morbidity and mortality. The clinical course of severely burned patients may be difficult and the outcome tends to be poor in patients with multiple comorbidities and especially in those with inhalational injury. Burns are a global public health problem, accounting for an estimated 180 000 deaths annually with the majority of these occurring in low- and middle-income countries (1). Many predictive models for mortality are developed in order to identify the most important factors which can influence the outcome and many prognostic scores are created, such as: Revised Baux score, Abbreviated Burn Severity Injury Score(ABSI), Ryan score, Belgium Outcome Burn Injury (BOBI) score, Fatality by Longevity, APACHE II score, Measured Extent of burn, and Sex score (FLAME). These scores are validated in many studies according to the characteristics of each country (2-6).

Survival following burn injury has increased not only in developed countries over the past 50 years which is reflected with improvements in Lethal Area 50 (LA50) or the burn size in which 50% of patients survive. This can be attributed to the advances in understanding of pathophysiology of burn injury, early nutrition, improved critical care, infection control and surgical interventions well-timed within a multidisciplinary burn care staff working as a team (7).

Objective estimates of the probability of death from burn injuries is difficult. The primary objective of this study is to examine data from a burn registry database in the Statistic's Department in the University Hospital Center in Tirana (UHC) and identify factors associated with increased mortality.

The aim of this study is to describe the characteristics of the patients admitted to our Intensive Care Unit (ICU) and to develop an objective predictive probability model for mortality in major burn patients based on Age and Burn Surface Area (%) (BSA). This model will help us quickly identify patients at risk and help them as much as possible to cope with this traumatic and devastating disease.

MATERIAL AND METHODS

Settings

The study is performed in the service of burns which consists of 35 hospital beds distributed between patients with severe acute burns, reconstructive burn patients, trauma patients, and plastic surgery patients. It consists of Emergency, the Operating theatre, the ICU with 10 beds and the Ward.

Study design

The study was retrospective, clinical and analytical regarding outcome after severe burns. Data are obtained by the analysis of the medical records of 5033 patients hospitalized with burns in the ICU of the service of burns and plastic surgery near UHC in Tirana, Albania during the period 1992-2019.

Patients with Steven-Johnson, Toxic Epidermal necrolysis as well as with degloving injuries were excluded from the study.

Information collected included:

- Year of admission
- Age, Group-Age (< 10 years; 10-19 years; 20-29 years; 30-39 years; 40-49 years; 50-59 years; 60-69 years; 70-79 years; > 80years)
- Gender (Male, Female)
- Etiology of burns (Scalds; Flame; Electrical; Chemical; Others)
- Body Surface Area (BSA) (%) burned: (0-10%; 11-20%; 21-30%; 31-40%; 41-50%; 51-60%; 61-70%; 71-80%; 81-90%; 91-100%)
- Degree (Partial-thickness; Full-thickness)
- Presence of Inhalation injury (Yes; No). Inhalation injury included cases when there was exposure to flame, steam or products of combustion together with laboratory findings and with positive bronchoscopy findings below the vocal cords.
- Length of Hospital Stay (LOS) (days)
- Outcome (Deaths; Survivors)

Statistical analysis

SPSS 23 software was used for the statistical analysis. Descriptive Statistics were conducted to summarize data for the central tendency (Mean) and variability (Standard Deviation). We used different graphs for the presentation of our data (Column graphs, surface contour graphs). We used Inferential Statistics through probability theory to draw conclusions. Concretely Simple Linear Regression for estimating Lethal Area 50 (LA 50) and Binary Logistic Regression for creating the death probability chart. Statistical significance was defined as $p<0.05$.

RESULTS

1. *Patient demographics and burn injury characteristics*

In table 1 is presented the demographic and clinical profile of our patients during the period 1992-2019. Of 5033 patients, 38.8% were female, 55.9% were of <10 years age and 61.5% have scalds as causative agent. The mean age of the patients was 20±23.4 years, the mean BSA (%) was 23.9±16.9, presence of full-thickness burn was in 20.5%, presence of inhalation burn was in 13.8% (n=694). The mean LOS was 11.1±2.1 days while LOS in deaths was 8±10.7 days.

Table 1. Demographic, clinical and burn injury characteristics 1992-2019 (n=5033)

Age, mean (SD)	20(23.4)
Gender, % female (n)	38.8(1955)
Group ages (years), % (n)	
<10	55.9(2815)
10-19	7(353)
20-29	6.4(323)
30-39	6.6(334)
40-49	8.7(437)
50-59	6.3(317)
60-69	4.5(224)
70-79	3(150)
>80	1.6(80)

Etiology of burns, %(n)	
Scalds	61.5(3095)
Flame	28(1407)
Electrical	4(202)
Chemical	5.5(4339)
Others	1(50)
BSA% burned, mean (SD)	23.9(16.9)
Full-thickness burn, %(n)	20.5(1032)
Inhalation injury, %yes (n)	13.8(694)
LOS, mean (SD)	11.3(13)
Mortality, %(n)	12.3(617)
Mortality in patients with inhalation injury, %(n)	47.2(328)
Mortality in patients without inhalation injury, %(n)	6.6(289)

2. *Data regarding mortality*

The overall mortality was 12.3% (617 deaths of 5033 patients). Of 4339 patients without inhalation burn there were 289 deaths, while of 694 patients with inhalation burn there were 328 deaths. Mortality in patients with inhalation injury was 47.2% vs. 6.6% in patients without it. In Figure 1 we have presented the mortality during years. It is evident that mortality has improved especially during the last decade.

Mortality is increased according to the burn size and the age as well as with the presence of inhalation injury (Figure 2). From Linear Regression for each unit increase of BSA (%) there is increasing odds of a bad outcome by 1.0 and for each unit increase of age (year) there is increasing odds of a bad outcome by 1.0.

3. *Calculation of LA 50*

LA50 is a well-established index suitable for the assessment of quality of care in burn patients taking in consideration only age and BSA (%) burned. We calculate this index for all the patients as well as for each of three periods with Linear regression. LA50 for all patients was 66.4%

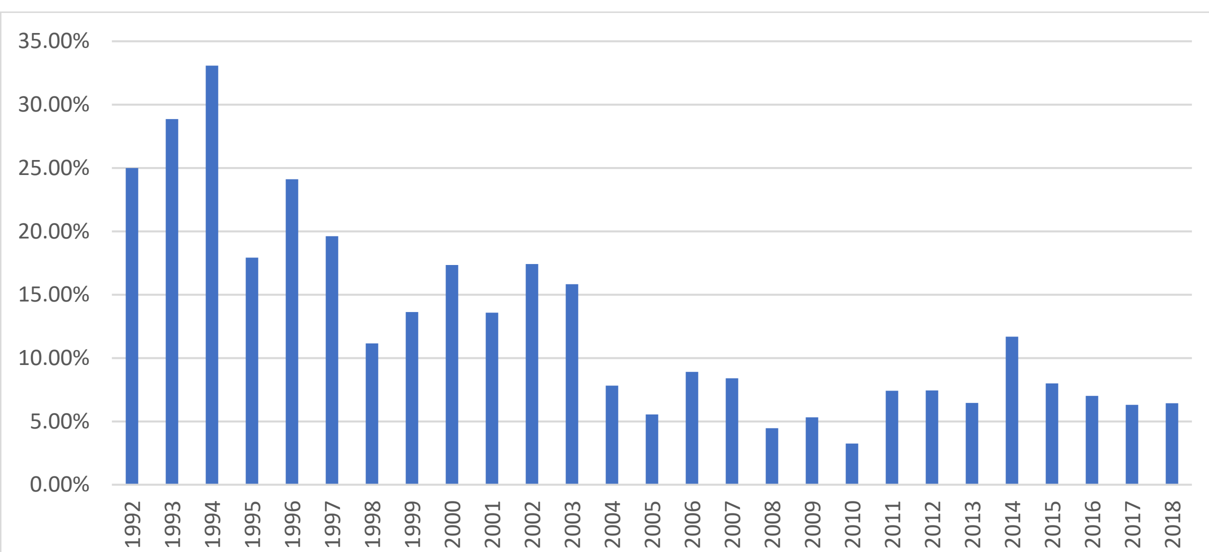

Figure 1. Mortality in years 1992-2019

while for the first decade 1992-2000 was 49.8%, for 2000-2009 was 73.3% and for the period 2010-2019 was 82.2% (Figure 3).

4. The death probability model

Logistic regression was used for the prediction of death probability by two risk variables, BSA (%)

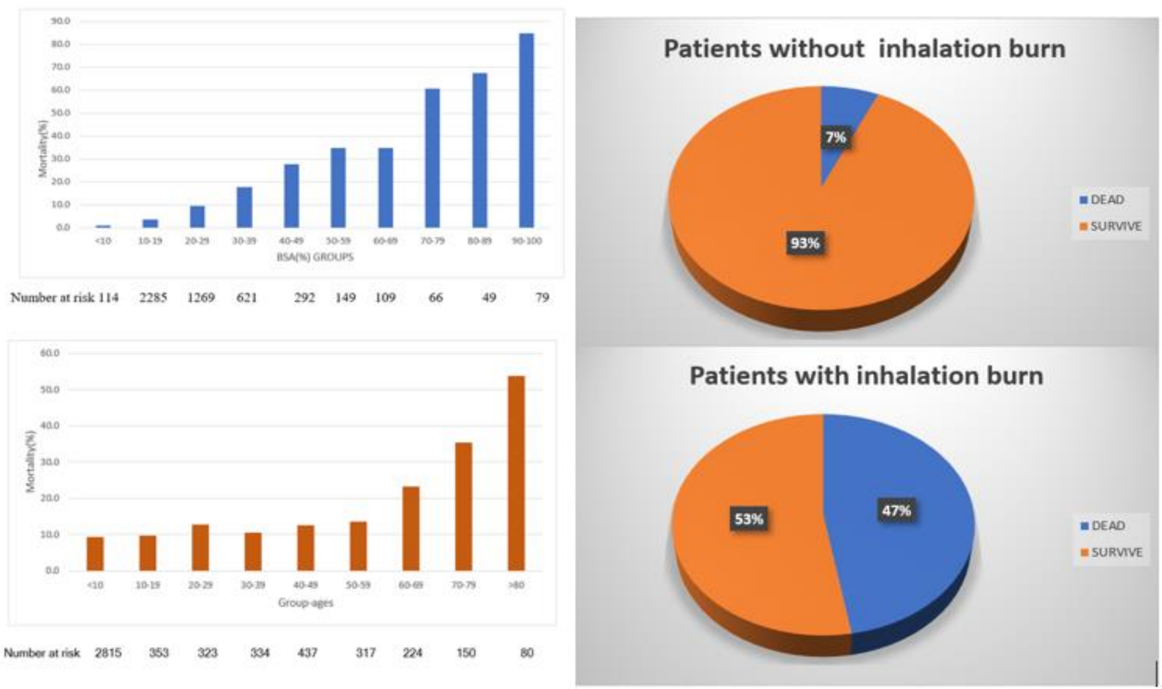

Figure 2. Mortality associated with percentage burn size, age and inhalation injury in 5033 patients (1992-2019)

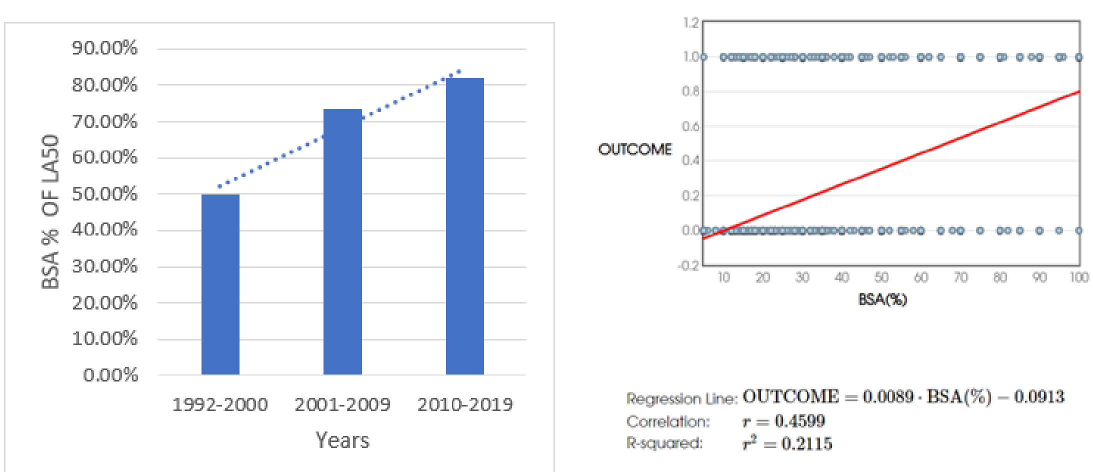

Figure 3. Improvement of LA 50 of patients in three periods of the study (From 50% to 82.2%) Mean LA50 for all the period was 66.4%. BSA (%) is responsible for 21% of the variance of outcome

Model: $$P = \frac{1}{1+e^{-(-3.9495+0.0099x_1+0.0584x_2)}}$$

Chi-Square $= 810.4530$ $\quad df = 2 \quad$ p-value $= 0.0000$

Variable	Coefficient	Standard Error	p-value	Odds Ratio	95% Confidence Interval
AGE	0.0099	0.0020	0.0000	1.0099	(1.0060, 1.0138)
BSA (%)	0.0584	0.0025	0.0000	1.0602	(1.0549, 1.0654)
Constant	-3.9495	0.1029	0.0000		

Figure 4. Logistic regression of age and BSA (%) for calculating death probability (%)

burned and age (years). According to the logistic regression methodology, both variables are transformed from continues to nominal and then logical. The equation of logistic regression for age and BSA (%) as continous variables without categorization has Odds more than 1.0 which indicates for positive correlation. Based on the weight of evidence the variables were grouped on strata by 10 units each. Then we performed binary logistic variable for both variables grouped in strata. In the figure 4 we present the logistic regression equation for age and BSA (%).

After calculating probability for each record, we have made respective grouping according mortality 0-100%. In the table 2 we have presented the mortality (%) in each corresponding pair (Age and BSA).

Table 2. Probabilities of death(%) according BSA(%) and Age(years)for 5033 patients

	BSA(%)									
Age(years)	**<10**	**10-19**	**20-29**	**30-39**	**40-49**	**50-59**	**60-69**	**70-79**	**80-89**	**90-100**
<10	0	2.6	10.1	23.2	28.2	34.6	37.0	70.6	66.7	75.0
10-19	0	1.3	7.4	9.8	20.0	33.3	20.0	50.0	80.0	83.3
20-29	0	4.7	2.4	4.9	17.6	25.0	30.0	81.8	75.0	83.3
30-39	0	0.0	0.0	1.8	17.9	15.4	19.0	14.3	88.9	93.3
40-49	0	0.8	3.3	6.2	25.0	28.6	27.3	58.3	40.0	80.0
50-59	10	2.7	6.6	9.8	26.7	30.0	42.9	40.0	33.3	81.8
60-69	0	9.9	12.5	15.0	26.1	70.0	61.5	50.0	75.0	100.0
70-79	0	16.2	29.0	55.0	55.6	100.0	100.0	100.0	100.0	100.0
>80	0	29.6	61.1	72.7	72.7	75.0	50.0	100.0	100.0	100.0

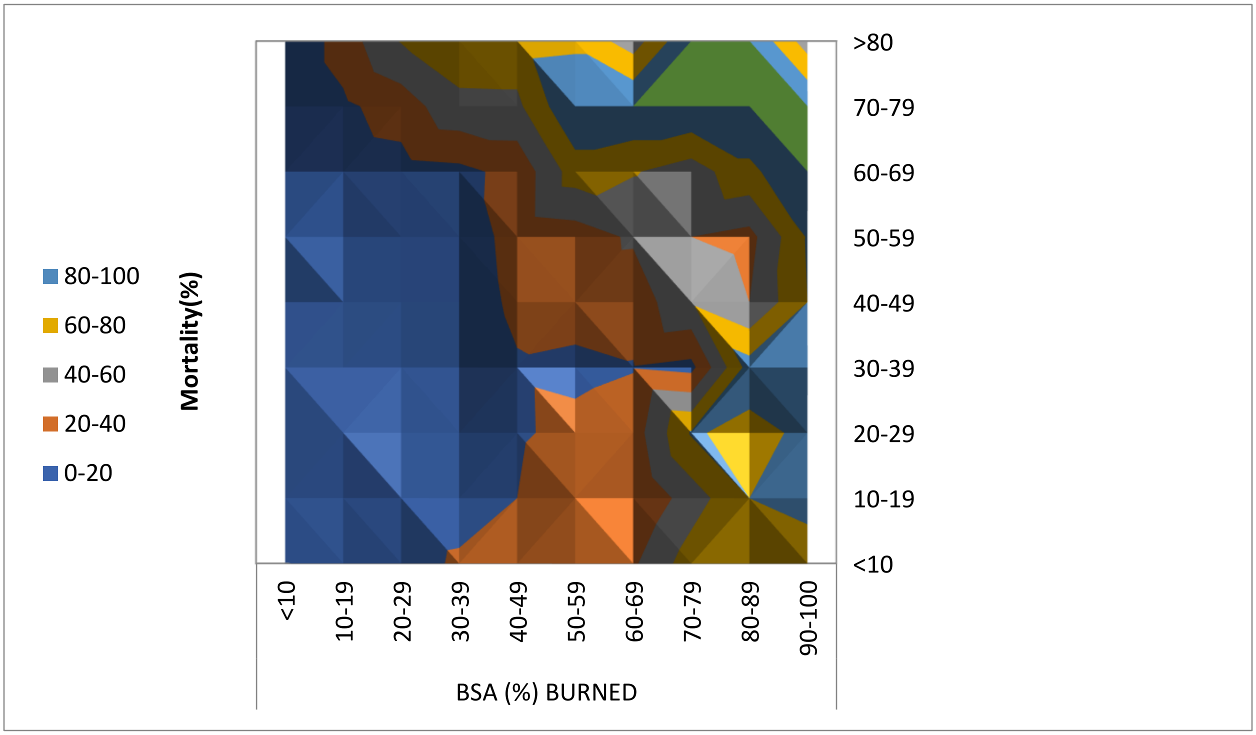

Figure 5. Model of death probability based on Age and BSA (%) for patients during 1992-2019

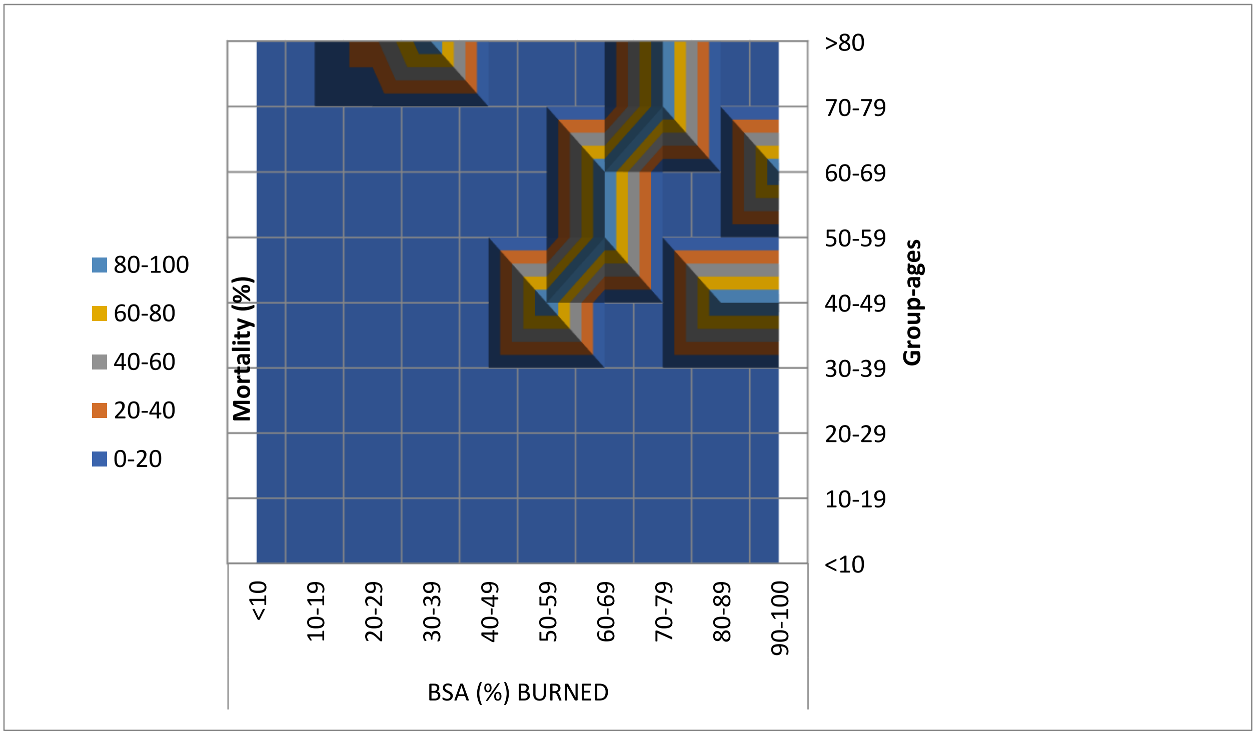

Figure 6. Death probability for patients hospitalized during 2019

We have used surface charts (type contour) to present the computer model of death probability.

In the figure 5 we have presented the probability of death chart for patients 1992-2019.

During 2020, patients admitted to the burn center with a determined burn injury are plotted in the graphic and are assigned a probability of death. Because the model has used data from 1992, we decided to perform a new chart only with patients hospitalized in ICU during 2019 because the first chart did not represent the actual outcome. The new patients plotted in the new chart till now had a similar outcome with the chart prediction. We have presented it in the figure 6.

DISCUSSION

This study characterized the trends of mortality after burn injuries in Albania over a 28-year period, taking in consideration only burn characteristics on admission. Older age, a larger burn TBSA and inhalation injury are well-known predictors of burn mortality but in mortality had greater impact infection and sepsis as well as the concomitant illness and the immunity of the burned patients.

Burn mortality is still one of the major outcome measurements in burn centers. From our data we have an important improvement in mortality from 25% in 1992 to 7% in 2019. The mortality rate of the last decade is comparable with rates of other European countries like in Belgium (7.1%), Turkey (6.3%), France (9%) and Hong Kong (8.7%) (7,8,9,10). Different studies show better outcomes in Sweden (3%), Netherlands (4.1%), Spain (3.4%) and Portugal (3.7%) (11,12,13,14,). Although every burn center has its own particular limitations, it is clear that exists a minimum standard of survival after burn injury which is LA50. In the 1940s, LA50 in the United States was 40% (15). With the development of broad-spectrum antibiotics and specialized burn units, also with standardization of a multidisciplinary approach instituted at tertiary health care centers, LA50 increased to approximately 60% in the 1970s (16). Currently, most burn centers in the United States report LA50 over 90% (16). Europe experienced a similar improvement in LA50 over time. Wasserman showed an overall mortality of 11.8% and LA50 of 60% in 1985 in France (17). In 1999, Barrett et al. demonstrated an overall mortality of 3.5% and LA50 of 90% in Spain (18). Our LA50 is improved from 49.5% in 1992-2000 to 82.2% in the last period 2010-2019 which speaks for a better work of the staff in the service of burns.

Comparing burn centers, since many geographic and social parameters differ, the generation of computer probability models has proven useful in surveying the outcome having the benefit of comparability (19,20,21,22).

It is important to explain the model mechanism. In the model are presented the age, BSA (%) and the probability of death. When a patient is hospitalized in the service of Burns, we plot the age and BSA (%) burned and see the corresponding probability for survival. Afterwards, the real outcome of the patient is compared to the probability for that outcome and disparities are analyzed on a case per case basis.

We built the first model with a big number of patients (n=5033), taking in consideration the fact that the more cases, the more accurate the predictive model, but we did not take into account that especially the first 10 years were accompanied with higher mortality. Because our model has included all cases with different prognosis for a long period it was not reliable for the recent situation of improved mortality values. So, we created a chart of the last year (2019) and we are analyzing the correlation of prediction and observed mortality with the aim of validating the predictive chart. We are looking forward for the decreasing of mortality in the future which is going to lead into the adaptation of new models.

CONCLUSION

This study evidenced that the overall registered mortality was 12.3% and survival following severe burns has improved over the past 28 years and LA50 for all patients was 82.2%. Our opinion is that it is the responsibility of the burn team to continuously refresh and improve the probability chart in order to compile a chart after each year which should serve as a more accurate predictor for the patients of the following year. Improvement in the treatment of severe burns has been accomplished due to a combination of preventive health care, appropriate treatment protocols and improvements in equipment and infrastructure. The probability for survival that the model assigns to the patients is the minimum standard because it is necessary to include in the model many other factors. The improvements in burn mortality should produce changes in the expectations of the burn care providers.

The strengths and limitations of the study. This study being at the same time descriptive retrospective and analytical provides the basic requirements for further epidemiological studies as the prerequisite for better planning and implementing of prevention programs. The advantage of the probability model is that it excludes all the local geographic and social differences between the burn centers and the results are comparable. The disadvantage is that the prediction is based only in BSA (%) and age and did not take in consideration other burn and clinical characteristics.

Acknowledgements: None declared.

Conflict of Interest Disclosure: The authors declare that they have no conflict of interest.

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