Outcome Analysis through Predictive Models in Severe Burn Patients

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Abstract

Background: Treatment of severe burned patient in the Service of Burns and Plastic Surgery of the University Hospital Center "Mother Teresa" in Tirana, Albania is improved but despite advances burns remain a frequent cause of traumatic injury, resulting in considerable morbidity and mortality. Severity scoring systems have been developed to evaluate changes over time in the outcome following burns.

Aims: The aim of this study is to compare outcome in severe burn patients in two periods 1998-2008 and 2009-2019 applying ABSI score, BAUX score, Revised BAUX score and Ryan model.

Study design: We retrospectively analyzed the data of all burned patients admitted to our burn 2009-2019. We have applied some prediction models for analyzing outcome.

Methods: SPSS 23 software was used for the conduction of the statistical analysis. T-test was used for comparing two means and Chi-squared test for comparing two proportions. Receiver Operator Characteristic (ROC) Curve was used to test the sensitivity and specificity of different score indexes against each other.

Results: Mortality is reduced from 10.5% in the first decade to 6.8% in the second decade. There is a marked reduction in children from 8.9% to 1.05% with statistical significance. All three scores were excellent in predicting outcome (AUC more than 0.9) but ABSI score showed superiority in accuracy (AUC of 0.966) for

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predicting the outcome.

Conclusion: Our data confirm that the strength of Ryan model is that mortality in the absence of all risk factors is rare but in the presence of all three risk factors mortality is extremely high. Use of prediction models (ABSI, Baux and Revised Baux score) should serve as guidance of the clinical decision because many other factors are associated with an increased mortality risk of the burned patients.

Keywords*:* Thermal injury, Burns, Mortality, Prediction models.

INTRODUCTION

Treatment of severe burned patient in the Service of Burns and Plastic Surgery of the University Hospital Center (UHC) "Mother Teresa" in Tirana, Albania is improved but despite advances burns remain a frequent cause of traumatic injury, resulting in considerable morbidity and mortality. Major efforts for improving prevention and treatment of burn injuries have been developed throughout the last decade in The Service of Burns. This progress corresponds with increased investments and improvements in the infrastructure of the Service of Burns. Management of burn injuries in the UHC differs in comparison to the previous decade in the increase in application of standardized protocols and optimization of resources.

During the last century, over 40 new or modified mortality prediction models have been presented and validated to assess mortality risks in populations with severe burns (1-10).Severity scoring systems have been developed to evaluate changes over time in the outcome following burns. One of the predictive models is Ryan model which has developed a system that predicts mortality taking into account three major risk factors: age 60 years or over, a total burned surface area (TBSA) of at least 40%, and the presence of an inhalation injury (10).This formula predicts 0.3%, 3%, 33%, and approximately 90% mortality when, respectively, zero, one, two, or three risk factors are present. Several investigators have confirmed the validity of these three risk factors (2-6).

The objective of the present study was to evaluate outcome in severe burn patients admitted to our unit between 1998 and 2019 and to assess trends in risk profile and survival. The aim of this study is to compare outcome in severe burn patients in two periods 1998-2008 and 2009-2019 applying ABSI score, BAUX score and Ryan model. These data should serve as a basis for further studies on burn prevention, cost-containment and outcome measures.

MATERIAL AND METHODS
Setting

The study is performed in the Service of Burns and Plastic Surgery in Tirana which is the only burn center in Albania, serving for the congregation of burn patients from the whole geographic area of Albania which includes 2,8 million inhabitants (11). It consists of 35 hospital beds where priority is attributed to acute burns followed by reconstructive burn and trauma patients. The Burn Intensive Care Unit (ICU) has a capacity of 10 hospital beds. The patients eligible for intensive treatment should be experiencing severe burns, corresponding to almost half of the total admissions. These are the patients that need close monitoring during the resuscitation phase as well as during the sepsis phase. Intensivists and plastic surgeons of our Service are responsible for intensive care treatment and wound care. We use a mixed colloid-crystalloid scheme for fluid resuscitation based on Parkland formula for adults and Shriner's Galveston formula for children.

For medication of the wounds is used Chlorhexidine solution, as well as Betadine solution. Partial thickness burns are covered with antibiotic ointments, Silver Sulphadiazine cream or hydrocolloid dressings, while full-thickness burns are covered only with Silver Sulphadiazine cream. Early excisions were done whenever it was judged necessary from the staff but do not form a routine procedure. Microbiological monitoring, performed twice a week, indicates the patient's colonization status. This study is approved by the Ethics Committee at the Ministry of Health and Social Protection in Tirana.

Study Design

We retrospectively analyzed the data of all burned patients admitted to our burn unit over two decades 1998 to 2009 and 2009-2019. Patients with Steven-Johnson, Toxic Epidermal necrolysis as well as with degloving injuries were excluded from the study. Information collected included: Year of admission, Month of admission, Age, Group-Age [Children (0-14 years); Adults (15-60 years); Elderly (>60 years)], Age, Age Subgroups (0-1.9years;2-4.9 years;5-9.9 years;10-14.9 years;15-19.9 years;20-29.9 years;30-39.9 years;40-49.9 years;50-59.9 years;60-69.9 years;70-79.9 years;>80 years), Age Subgroups (<40 years,≥40 years), Gender (Male, Female), Etiology of burns (Scalds; Flame; Electrical; Chemical; Others), Body Surface Area (BSA) (%) burned: (0-10%; 11-20%; 21-40%; 41-60%; 61-80%; 81-100%), 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) in days and Outcome (Deaths; Survivors). We have applied some prediction models for outcome:

- Abbreviated Burn Score Index (ABSI). The ABSI originally published in 1982 ranges between 2 and 18 points, resulting in six risk categories, with a probability of survival ranging from more than 99% to less than 10%. The ABSI considers the following risk factors: female gender (1 point), increasing age (1–5 points), increasing BSA (%) burned (1–10 points), presence of inhalation injury (1 point) and presence of full thickness burns (1 point) (8).

- Baux Score and Score R Baux (Revised Baux). The Baux-index, originally published in 1961, revised by Osler et al., is a continuous score based on age, BSA (%) burned and presence of inhalation injury, with a probability of death ranging between 0 and 100%. Concretely Baux score: Age (years)+Total Body Surface Area Burn (%) = percentage of mortality. Revised Baux score: Age (years)+Total Body Surface Area Burn (%) + 17 (if presence of inhalation injury) = percentage of mortality (9).

- Ryan model. It is a system that predicts mortality taking into account three major risk factors: age 60 years or over, the burned surface area (BSA) of at least 40%, and the presence of an inhalation injury. This formula predicts 0.3%, 3%, 33%, and approx. 90% mortality when,

respectively, zero, one, two, or three risk factors are present (10).

Statistical analysis

SPSS 23 software was used for the conduction of the statistical analysis. Incidence density rates are calculated as the number of burn admissions in any age category in one year multiplied by 100 000 and divided by the total persons at risk (the population at specific year taken from Institute of Statistic in Albania). Descriptive Statistics were conducted to summarize data for the central tendency (Mean) and variability (Standard Deviation). T-test was used for comparing two means and Chi-squared test for comparing two proportions. Receiver Operator Characteristic (ROC) Curve were used to test the sensitivity and specificity of different score indexes against each other. Statistical significance was defined as $p<0.05$.

RESULTS

A total of 4362 patients had a burn-related primary admission in the Service of Burns and Plastic Surgery of the UHC in Tirana, Albania from 1998 to 2008, from which 2337 were admissions in the Intensive Care Unit. The mean annual number of ICU admitted patients was 210, which decreased from 224 in 1998 to 202 in 2008. On the other side a total of 3355 patients had a burn-related primary admission in the Service of Burns and Plastic Surgery of the UHC in Tirana, Albania from 2009 to 2019, from which 1684 were admissions in the Intensive Care Unit. The mean annual number of ICU admitted patients

was 153, which decreased from 169 in 2009 to 139 in 2019.

Demographic, clinical and burn injury characteristics are presented in table 1. The mean age of burned patients in two periods was similar which speaks generally for a young population. Children remain the most affected group age 67% in the first decade and 50.7% in the last, while there is increasing of percentage of adults and especially of elderly people with statistical significance in three group ages.

In the first decade scalds were the main cause of the burn in 61.8% of the cases followed by flame (23%), chemicals (10.7%) and electrical injury (4.5%). In the second decade there is also a predomination of scald burns but with a decline 49.6% vs.61.8% with statistical difference. Burns from flame have increased 39.5% vs.23%, chemical burns have been decreased in half while there was no statistical difference regarding electrical burns. Of all burns in the second decade 2009-2019, 49.6% (835) were burns from scalds,39.5% (666) were burns from flame,5.1% (86) were electrical burns and 5% (85) were chemical burns while 0.7% (12) were with unknown cause. Scalds were the predominant cause of burns in children (82% of them) admitted to the burn ICU particularly in the subgroup age 2-4.9 years. In other groups, flame was the predominant cause (66% of adults and 74% of elderly patients) with the peak in subgroup age 40-69.9 years.

In the first decade the mean BSA % burned was 22.8 ±14.7 while in the second decade 25.6±19.1.

Table 1. Demographic, clinical and burn injury characteristics

	1998-2008 (n=2337)	2009-2019 (n=1684)	p
Age, mean(SD)	21.2(11.9)	24.9(19,1)	< 0.0001
Group ages			< 0.0001
Children (0-14y), % (n)	67.0(1562)	50.7 (855)	
Adults (15-60y), % (n)	27.0(629)	36.0 (607)	
Elderly ≥ 60 y, % (n)	6.0(146)	13.2 (222)	
Gender, % female (n)	37.6(878)	38.7(651)	0.4785
Etiology of burns, %(n)			
Scalds	61.8(1445)	49.6(835)	< 0.0001
Flame	23.0(537)	39.5(666)	< 0.0001
Electrical	4.5(105)	5.1(86)	0.377
Chemical	10.7(250)	5.0(85)	< 0.0001
Others	0(0)	0.7(12)	
BSA% burned, mean(SD)	22.8(14.7)	25.6(19.1)	0.0001
Full-thickness burn, %(n)	46.1(1077)	17.0(287)	< 0.0001
Inhalation injury, %yes (n)	10.6(248)	15.4(260)	< 0.0001
Time of hospitalization, mean(SD)	3.7(3.4)	2.8(2.9)	< 0.0001
LOS , mean(SD)	11.6(10)	11.2(15.58)	< 0.0001
ABSI, mean(SD)	7.2 (2.8)	5.4(2.87)	< 0.0001
BauxScore, mean (SD)	40.1 (28.5)	50.5(36.28)	< 0.0001
Revised BauxScore, mean (SD)	42.1(31.4)	53.2(39.8)	< 0.0001
Mortality , %(n)	10.5(255)	6.8(116)	0.0001
Mortality Children (0-14y), % (n)	8.9(139)	1.0 (9)	< 0.0001
Mortality Adults (15-60y), % (n)	11.1(70)	7.9 (48)	0.569
Mortality Elderly ≥ 60 y, % (n)	31.5(146)	26.6(59)	0.4807

Full-thickness burns were 46.1% vs. 17% respectively. Presence of inhalation injury was increased in the second decade 15.4% vs.10.6% while time of hospitalization in reduced 2.8±2.9 hour in the second decade vs.3.7±3.4 hours previously.

Mortality is reduced from 10.5% in the first decade to 6.8% in the second decade. There is a

marked reduction in children from 8.9% to 1.05% with statistical significance while mortality in adults and elderly although is reduced has no statistical significance. Length of hospital stay was the same in two periods without statistical difference. Mortality from severe burns and especially from flame expressed per 100 000 persons is presented in figure 1. From the figure we noticed that there is reduction through years of the mortality of severe burns per 100 000 persons but flame remains an important cause for mortality.
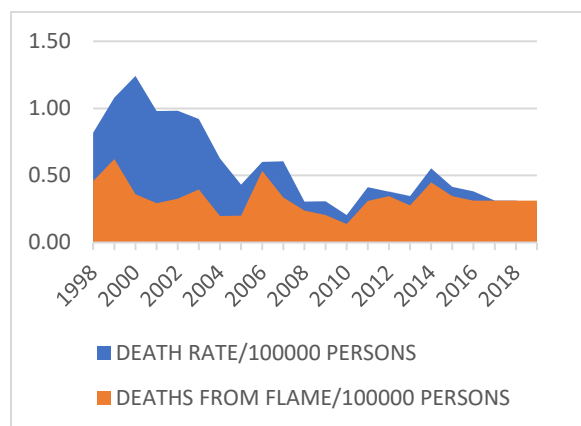

**Figure 1.** Overall Death rate and Deaths from flame per 100 000 persons

Severity scoring systems have been developed to evaluate changes in the outcome following burns. We used ABSI, Baux score and Revised Baux score to calculate our patients' probability of death. The predicted mortality was compared with observed mortality. For all patients mean ABSI score was 5.4±2.87 in the second decade vs.7.2±2.8 in the first, mean Baux score was 50.6±36.28 vs.40.1±28.5 and mean Revised Baux score was 53.2±39.8 vs.42.1±31.4 respectively. Mean ABSI score in deaths was 11.9±2.74, mean

Baux score was 120.6±29.34, mean Revised Baux score 134.5±31.87.

We used the ROC curves for the three diagnostic tests to predict the outcome against each other ABSI, Baux and Revised Baux score as models for predicting outcome. In figure 2, we noticed that all three scores were excellent in predicting outcome (AUC more than 0.9) but ABSI score showed superiority in accuracy (AUC of 0.966) for predicting the outcome.

In table 2, we present data from the evaluation of the outcome of our patients by applying the Ryan model in relation to the three identified major risk factors for death: age $\geq$ 60 years, TBSA $\geq$ 40% and the presence of an inhalation injury. During 2009-2019 the observed mortality was 0.09%, 5.6%, 35.2% and 81.4% when, respectively, zero, one, two, or three risk factors were present and there is statistical significance for the difference between two decades. In the case of patients without concomitant factors the risk in the first decade mortality was 4.3% while in the second decade it was almost 0.

There has been an improvement in the case of patients with a risk factor from 20.2% in the first decade mortality has dropped to 5.6% in the second decade. Also, in the case of two risk factors mortality has been halved from 56.8% to 35.2%, while it remains same for patients with three risk factors 81% but lower than the Ryan model.

ROC Curve

Diagonal segments are produced by ties.
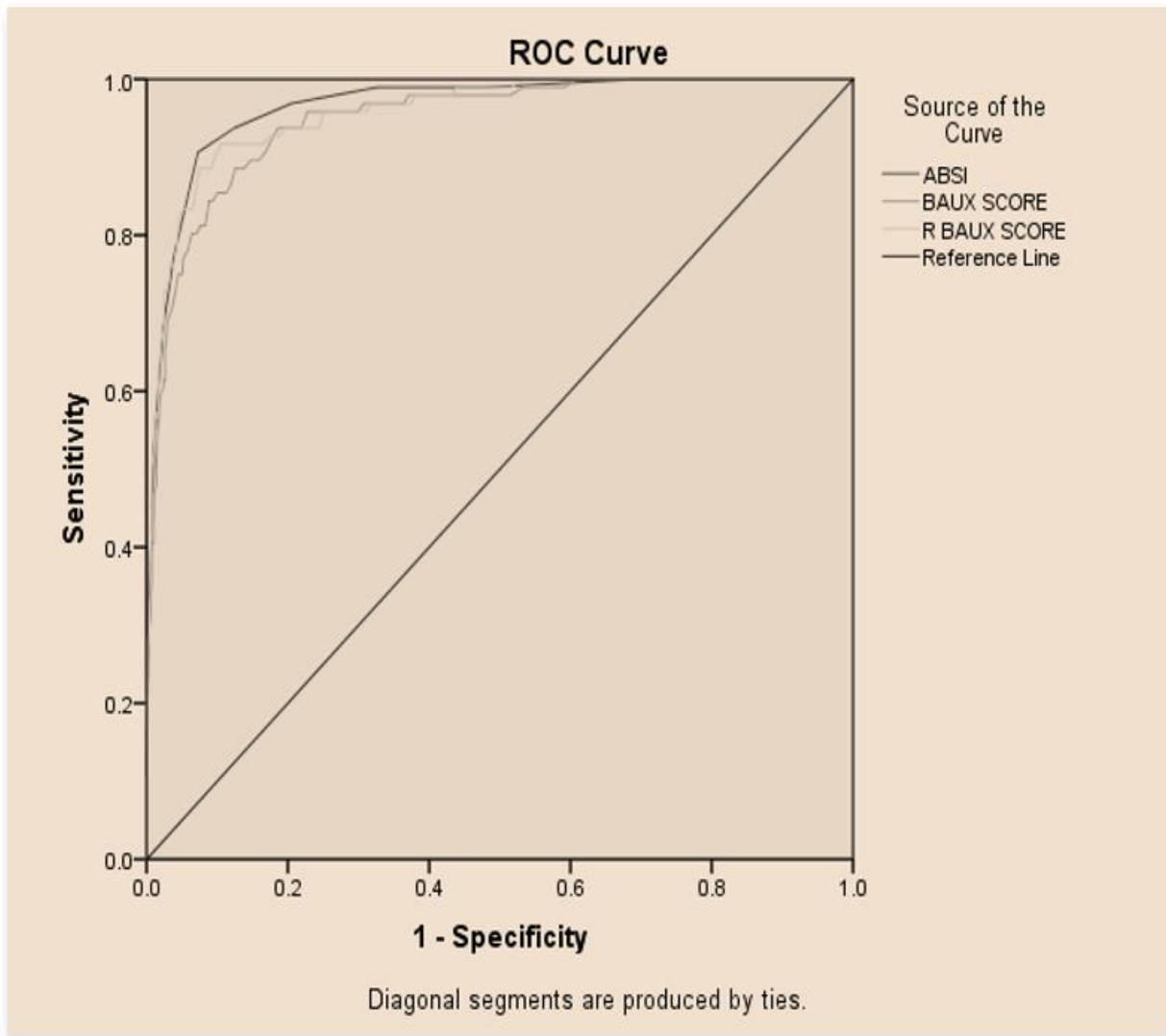
Area Under the Curve

Test Result Variable(s)	Area
ABSI	.966
BAUX SCORE	.948
R BAUX SCORE	.958

Figure 2. The Area Under the Curve of variable(s): ABSI, Baux, R Baux scores by Outcome.

Table 2. Analysis of Mortality in two periods according Ryan model

Number of risk factors	1998-2008						2009-2019				
	Patients (n=2337)		Deaths (n=255)		Mortality (%)	Mortality (%)	Patients (n=1684)		Deaths (n=116)		Mortality (%)
	Number	%	Number	%	Observed	Predicted	Number	%	Number	%	Observed
NO RISK FACTOR	1814	77.6	78	30.6	4.3	0.3	1144	67.9	1	0.9	0.1
ONE RISK FACTOR											
Age≥ 60 years	98	4.2	8	3.1			119	7.1	3	2.6	
BSA ≥40%burned	136	5.8	37	14.5			134	8.0	11	9.5	
Presence of Inhalation injury	106	4.5	24	9.4			68	4.0	4	3.5	
Σ	340	14.6	69	27.1	20.3	3	321	19.1	18	15.5	5.6
TWO RISK FACTORS											
Age≥ 60 years +BSA ≥40%burned	9	0.4	4	1.6			27	1.6	6	5.2	
Age≥ 60 years +Presence of Inhalation injury	34	1.5	21	8.2			34	2.0	15	12.9	
BSA ≥40%burned+Presence of Inhalation injury	124	5.3	70	27.5			115	6.8	41	35.3	
Σ	167	7.2	95	37.3	56.9	33	176	10.5	62	53.5	35.2
THREE RISK FACTORS											
Age≥ 60 years +BSA ≥40%burned+Presence of Inhalation injury	16	0.7	13	5.1	81.3	90	43	2.6	35	30.2	81.4
Overall Mortality %	10.5						6.8				

We have presented data for ABSI, Baux and Revised Baux scores: the predicted and the observed mortality in table 3.

Table 3. Analysis of Mortality according ABSI ,Baux and Revised Baux scores

		1998-2008 (n=2337)					2009-2019(n=1684)			
		SURVIVE	**DEAD**	**TOTAL**	**MORT-ALITY**	**MORT-ALITY**	**SURVIVE**	**DEAD**	**TOTAL**	**MORTALITY**
					Observed (%)	Predicted (%)				Observed(%)
ABSI score	**POINTS**									
	2-3	754	10	764	1.3	**1**	473	0	473	0.0
	4-5	842	69	911	7.6	**2**	576	1	577	0.2
	6-7	324	59	383	15.4	**10-20**	316	5	321	1.6
	8-9	122	54	176	30.7	**30-50**	138	20	158	12.7
	10-11	31	36	67	53.7	**60-80**	48	25	73	34.2
	>12	9	27	36	75.0	**90**	17	65	82	79.3
TOTAL		2082	255	2337			1568	116	1684	
Baux score	**POINTS**									
	0-20	728	14	742	1.9	**0-20**	462	0	462	0.0
	21-40	661	70	741	9.4	**21-40**	373	2	375	0.5
	41-60	277	42	316	13.3	**41-60**	227	1	228	0.4
	61-80	276	32	301	10.6	**61-80**	250	7	257	2.7
	80-100	113	37	150	24.7	**80-100**	161	14	175	8.0
	>100	27	60	87	69.0	**>100**	95	92	187	49.2
TOTAL		2082	255	2337			1568	116	1684	
Revised Baux score	**POINTS**									
	0-20	723	13	736	1.8	**0-20**	457	0	457	0.0
	21-40	641	70	711	9.8	**21-40**	371	1	372	0.3
	41-60	274	37	311	11.9	**41-60**	220	2	222	0.9
	61-80	263	32	295	10.8	**61-80**	211	4	215	1.9
	80-100	113	17	130	13.1	**80-100**	178	5	183	2.7
	>100	68	86	154	55.8	**>100**	131	104	235	44.3
TOTAL		2082	255	2337			1568	116	1684	

DISCUSSION

The magnitude of the public health problem represented by burns is indicated by the fire and burn deaths. According to the Global Burden of the Disease (GBD) which estimates the number of deaths by cause, the death rate from fire and burns in Albania has experienced a notable decline from 1.07 in 1990 to 0.52 per 100 000 people in 2017 (12).

As our center is the only burn unit in our country, we can draw national conclusions. The death rate from fire and burns for the period 2009-2019 has been improved at 0.3 patients per 100000 population/year which lies very close to the death rate from all burns (0.35 patients per 100000 population/year.

While comparing the decade (2009-2019) with the previous one (1998-2008) there is a progressive decrease of mortality (6.89% versus 10.5%) of our burn patient population although mean BSA (%) burned increased to 25.6±19.1 % (versus 22.8±14.7%). There were improvements in mortality despite more patients were affected by flame burns (39.5% versus 23%), more patients had inhalation burns (15.5% versus 10.6%) as well as there is evidence of an increase of the number of adults with burns and more than double of the number of elderly with burns with greater burn size and full thickness burns.

The data derived from this study confirm the strength of the Ryan model (10).So, mortality in the absence of all risk factors is better than the prediction 0.09% versus 0.3%, in patients with one of risk factor mortality was near the prediction 5.61% versus 3 %, in patients with two risk factors 35.23% versus 33% and in the presence of all three risk factors mortality was better than prediction 81.4% versus 99%.

Our data indicates that the ABSI, Baux and R Baux scoring system are still accurate and valuable tools in the prediction of burn patient mortality. In the present study, the three specific burn outcome models were validated, with the ABSI scoring system showing the best performance in predicting mortality. As an area under the curve (AUC) of more than 0.9 indicates high accuracy, all the scoring systems were accurate and the AUC of ABSI model was higher than the other models (AUC of 0.966). This is in accordance with other studies (13-16).

CONCLUSION

There is a decline in severe burn admissions in the Service of Burns UHC" Mother Teresa" in Tirana of children and adults but there is an increase of admissions in the elderly group. Etiology of burns has changed towards an increase of flame burns especially in adults and the elderly population. Overall mortality was improved arriving in the second decade in 6.8% and survival following severe burns has improved even in patients with three risk factors (age≥60, BSA (%) burned ≥ 40% and presence of inhalation burn). Our data confirm that the strength of this model is that mortality in the absence of all risk factors is rare but in the presence of all three risk factors mortality is extremely high. Use of prediction models

(ABSI, Baux and Revised Baux score) should serve as guidance of the clinical decision because many other factors are associated with an increased mortality risk of the burned patients.

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

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