

## Review Article

# The History of Mortality Prognostic Scales in Severe Burns

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**Abstract**

The aim of this review was to highlight major steps in the modern history of mortality prediction in burns. We decided to draw eras in burn treatment with most important surgical achievements and development of prognostic scales. First decades of XXth century brought development in basic science, understanding of the backgrounds of burn disease and crucial steps in surgical techniques. Recognition of burn pathology was followed with progress in treatment. Main factors that predicted mortality were age and extent of burn. Nowadays, new technologies enter burn surgery and intensive care of burns. The prognosis of mortality in burned patients depends on many other factors. Nevertheless, easy prognostic scales are useful not only in predicting course of the treatment, but also in legal issues.

**INTRODUCTION**

Over the course of decades, knowledge about burn pathogenesis has been improving. Milestones in combustiology were parallel to achievements in predicting survival. Although, modern equipment, it is still the extent of the burn (expressed as TBSA percentage) and patients' age that most importantly predict survival. Intensive care of burned patients, not only extended the boundaries for extensive burns with chance to survive but also changed the perception of burn shock. Also more factors influence survival. Presence of respiratory burn damage (inhalation injury), other concomitant injuries and diseases, acute renal failure (AKI), infection, malnutrition, psychiatric disorders are recognized to determine the process of treatment. The aim of this report is to sketch a history of combustiology relying on development of surgical techniques and mortality selected scores.

**WEINDERFELD AND ZUMBUSCH**

One of the first attempts to assess the risk of death in burned patient was carried out in 1905. The Weinderfeld and Zumbusch methods predicted survival time expressed in hours. The authors attributed the time till death to the severity and extent of the burn. The prognosis for full-body, partial-thickness burns was 40 hours, 70 hours if 1/3 of the patient's TBSA was affected, and 120 hours if 1/5 of the TBSA was burned. The prognosis for deep burns was much less favourable, with death predicted to occur in 7, 13, 43, and 90 hours for burns affecting 100%, 50%, 25%,

and 1/7 of the TBSA respectively. Underhill, who suggested that mortality in burns depended on volume loss, rather than exuded toxins (as had been previously believed), also conducted studies on fluid therapy in the 1920s. Work on developing adequate fluid resuscitation in the initial hours after the occurrence of the burn had been carried out into the 1940s. At that time, Moore developed the first fluid replacement formula, which specified the amount of replacement fluid required by a burn patient depending on the extent of the burn [1]. Weinderfeld and Zumbusch were also among the pioneers of surgical treatment of burns, including early excision of the burn wound in order to extend the time of the patient's survival. They excised necrotic tissue either on admission or up to the third day from the occurrence of the burn. Their method included a simultaneous closing of the wound with grafts [1]. This was possible due to the fact that Reverdin, a Swiss medical student, developed a grafting method in 1869. This method was later popularised in Europe in the 1970s by the British surgeon, Pollock. Skin grafting techniques were developed alongside burn wound cleansing techniques. Reverdin's method, known today as *pinch grafting*, relies on grafting small, insular patches of skin [1]. Leopold Ollier (1830-1900) was the first one to use a partial-thickness skin graft for the purpose of sealing wounds [2]. Carl Thiersch (1822-1895), who developed the first pre-grafting wound cleansing technique, was another of the skin grafting pioneers [2]. James Carlton Tanner performed the first mesh skin graft. First reports of use of the amnion to treat burn wounds emerged in 1910 [3]. Methods of grafting frozen allogeneic skin grafts sourced from cadavers

and live donors were in development at the time of WWII [3]. Early excision of the burn wound followed by sealing the wound improved the prognosis, though it also resulted in considerable blood loss. A breakthrough in surgical treatment of burns came when Zora Janzekovic developed the tangential burn wound excision method in Yugoslavia in the 1960s [1].

## BULL AND FISHER

Numerous substantial discoveries were made in combustiology in the 1950s and 1960s. In 1954, Bull and Fisher proposed a graphical mortality risk assessment method in burn patients, which relied on two variables: extent of the burn and the patient's age. Their method was based on the analysis of nearly 3000 burn patients treated at burn treatment centres in Glasgow and Birmingham in the years 1942 - 1943 and 1944 - 1953. Since 1963, their system has been in clinical usage being modified by Monsaingeon.

In 1956, Schwartz proposed an index based on Bull and Fisher's table. Schwartz distinguished between partial- and full-thickness burns. According to this method, the burned area is calculated with the formula from Bull and Fisher's table.

$$1\% \text{ III}^\circ \text{ burn} = 1 \text{ point}$$

$$1\% \text{ II and I}^\circ \text{ burn} = \frac{1}{2} \text{ point}$$

Another evaluation method is Clark's index, which allows predicting death without complete knowledge of the patient's condition, and especially with the lack of data on the severity and degree of burns. The four formulas used in this method are listed below. Y represents the risk of death.

In 1964, Tanner introduced the mesh skin graft method to burn wound treatment, which allowed sealing more extensive wounds [1]. This is also the time when the Baux score (the so called *French score*) was developed (in 1961), which relied on patient age and extent of the burn as burn patient survival prediction factors. Prognosis was unfavourable for patients with over 75 points. Wallace's or Lund and Browder's diagrams of 1944 were used to assess the extent of the burn. The Baux score was never published, it was only introduced in practice. Stern and Waisbren modified the Baux score in the 1970s, excluding patients below the age of 20 from the consideration. Patients with over 100 points were facing the highest risk of death, and had the highest mortality. Patients below 75 points had an actual chance of surviving the burn [4].

Similar parameters were also used in the German score, wherein a higher risk of death started at 80 points or above. The formula for the German score is listed below. X represents the risk of death.

$$X = \%TBSA + \text{age}; >80 \text{ unfavorable prognosis}$$

## WATSON AND SACHS

Another breakthrough in death prediction in burn patients came in 1969, when Sachs and Watson introduced the burn unit surface (BUS). They stated that presence of full-thickness burns was a substantial predictive factor. For burn patients below the age of 65, BUS is calculated as the sum of the TBSA burned and three-fold deep burn surface.  $BUS = \% \text{ of body surface burned} + 3 \times$

body surface with third degree burn BUS below 100 indicated a good prognosis, with the exception of patients older than 65. BUS of 100 indicated increased risk of death and higher mortality.

Tangential excision with partial-thickness skin auto-grafting was improved in the 1970s. In 1975, Rheinwald and Green developed the *cultured epithelial autografts* method (CEA). CEA allows covering an extensive wound while generating only a small injury at the graft source site. Another major development in combustiology was the discovery of skin substitute substances. In 1981, Burke and Yannas developed conceptually the first synthetic substitute of the dermis; Integra<sup>DRT</sup>. It is a double-layer dressing that consists of a porous bovine-collagen-and-shark-cartilage matrix and an external silicone surface. The collagen matrix acts as scaffolding for the incoming autologous dermis cells, which results in the remodeling of the wound and recreation of the dermis with the patient's own cells [5]. After approximately 21 days, the newly formed dermis (Lat. *neodermis*) is covered with a thin autologic skin graft. This method is optimal for application in deep wounds, and it limits the occurrence of burn scar contractures, therefore Integra<sup>DRT</sup> is frequently used on the neck and around joints. Furthermore, it can be used in a multi-layered manner, which allows rectifying deep damage of the dermis.

## TOBIASEN

As the technical aspect of medicine progressed, the survivability of burn patients increased. Subsequent prognostic factors were discovered, which had substantial impact on the prognosis. The seven-variable prognostic scale proposed by Tobiasen et al., in the early 1980s included the patient's gender, age, percentage of body surface burned, percentage of partial and full-thickness burn, burn location, and respiratory tract burn presence [5,6] (Table 1 & 2).

Tobiasen's modified war-related death risk assessment score, i.e. the *Abbreviated Burn Severity Index* (ABSI) [6], uses also the patient's gender and presence of inhalation burns as assessment factors next to the patient's age, burn surface area, and presence of III<sup>rd</sup> degree burns. In the case of this prognostic method, presence of respiratory tract burns was the most severe death risk factor. Although, the ABSI score does not take wound location into account, concomitant respiratory tract burns add 3

**Table 1:** Tobiasen Score.

1.	v
2.	Age (each full year of life x 0.055) =
3.	Surface area of II <sup>nd</sup> degree burns (%x- 0.77) =
4.	Surface area of III <sup>rd</sup> degree burns (%x0.31) =
5.	TBSA (%x0.068) =
6.	Respiratory tract burn (no=0. yes=1.18) =
7.	Head burn (no=0. yes=1.079) =
8.	Abdominal burn (no=0. yes=1.079) =
9.	Back burn (no=0. yes=1.079) =
10.	Arm burn (no=0. yes=1.079) =
11.	Foot burn (no=0. yes=1.079) =
BSI= 17+ (2x the result)	

points to the score, whereas presence of deep burns adds only a single point (Table 1). Franke published ABSI as a recommended guideline for battlefield treatment of burn victims for the American army. The authors pointed to the complex mechanism of combat-related burn formation, which involves the co-existence of numerous burning factors, including blasts. With the increasingly common use of IEDs (*Improvised Explosive Devices*), suicide bomber attacks, and combination injuries resulting from the use of Nuclear, Biological, or Chemical Weapons (NBC Warfare), burns often occur with concomitant trauma. Mixed and combination injuries mark a significant challenge for military medical services (Table 3).

The model suggested by Galeiras et al., in 2009 assumes that the patient's gender, age, burned surface area, full-thickness burn presence, and respiration therapy affect the odds of survival. The authors showed that the indications for applying mechanical ventilation in burn treatment are much broader than just concomitant respiratory tract burn trauma alone [7-9]. Galeiras

believes that mechanical ventilation substantially impacts the prognosis. In 2010 Osler published a modified version of the Baux score, in which additional 17 points were added if respiratory tract burn trauma was present [10].

$$\text{Age} + \%TBSA + 17^* \text{ (respiratory tract burn trauma, 1 = yes, 0 = no)}$$

### INTENSIVE CARE UNITS

Severely burned patients require multi-directional and multi-disciplinary treatment. In most cases, they are hospitalized at intensive care units and require multi-directional burn complication preventive care. One of the most severe complications in severely burned patients is multi-organ failure. The American Burn Association states that multi-organ failure accounts for approximately 28% of deaths of burn patients admitted to specialist burn treatment units [9]. That is why prognostic methods providing the most complete information on the patient's condition and the prognosis, based on prognostic tables used at intensive care units, such as APACHE II (*Acute Physiology and Chronic Health Evaluation II*) or SOFA (*Sepsis-related organ failure assessment score*), have such an extensive application. The APACHE II score, primarily used to evaluate acute pancreatitis, looks at body temperature, average blood pressure, heart rate, breaths per minute, pO2 or FiO2 ventilation factors, arterial blood pH, sodium, potassium, creatinine, haematocrit, white blood cells count, GCS (*Glasgow Coma Scale*), patient's age, and history of chronic diseases. Vergin's score adds lung and kidney function analysis, haemo concentration and arterial blood pressure to the set. The score is based on the APACHE II score (Table 4) [10].

Another prognostic scale is the BEAMS score (Burns Evaluation and Mortality), which relies on data expanded by the APACHE II scale. The variables required for the calculation of survival odds are the patient's age, body surface area burned,

**Table 2:** Odds of survival according to the Burn Severity Index.

BSI	Survival
0-11.2	0.99
11.3-13.7	0.9
13.8-14.7	0.8
14.8-15.7	0.7
15.8-16.5	0.6
16.6-17.4	0.5
17.5-18.2	0.4
18.3-19.0	0.3
19.1-20.4	0.2
20.5-23.1	0.1
≥23.2	<0.10

**Table 3:** Military survival rate assessment method.

GENDER	FEMALE	1 point	MALE	0 points
AGE	EACH 20 YEARS		1 point	
BBSA	EACH 10%		1 point	
INHALATION	IF PRESENT		3 points	
BURNS				
IIIRD				
DEGREE	IF PRESENT		1 point	
BURNS				
Points	Prognosis		Survival rate in %	
2-3	Good		99	
4-5	Moderate		90-99	
6-7	Moderate-serious		80-90	
8-9	Serious		50-70	
10-11	Poor		20-40	
12-13	Very poor		<10	
>13	Infaust		<1	

**Table 4:** Vergin's Algorithm [based on 10].

Vergin's score		
A	TBSA	General factors
	Full thickness burn	
	Clothing combustion	
	Age	
B	Body temperature	
	Respiratory tract	Respiratory function indicators
	burn trauma	
	Breaths per minute	
	P02	
C	pH	Kidney function indicators
	K+, Na+	
	Ht	Haemoconcentration indicators
	WBC	
	Arterial blood pressure	

and APACHE II score. The BEAMS calculator can be found online, and the score can be calculated by inputting the patient's data [11,12]. Another predictive scale based on the APACHE II score is the FLAME score, published by Ospin in 2001. FLAME is an acronym of *Fatality by Longevity, Apache II score, and Measured Extent of Burn* [13-15].

The flame score ranges between 5 and 49 points. 21 points for females and 24 points for males signify a 50% survival rate. High risk of death (over 51%) begins at FLAME score 22 and above. Another specific outcome prediction scores such as the Belgian Outcome of Burn Injury (BOBI), Ryan score and SAPS II (Simplified Acute Physiology Score) and revised

Baux score have been extensively studied [16-18]. Pantet et al., stated that the revised Baux score and ABSI were confirmed as excellent and accurate predictive performance of classic scores. SAPS II was nearly as accurate, particularly in burns <40% TBSA. Ryan and BOBI scores were in studies least accurate, as they heavily weight inhalation injury [18]. The best estimation of predicted mortality was obtained in Salehi et al. [19], with the ABSI model (67%).

## RECAPITULATION

Following Albert Einstein, the only source of knowledge is experience. Gaining from experience of great surgeons leads us to new discoveries and improvements in severe burns treatment. In recent years considerable advances have been made in the modern treatment of severe burns. Furthermore the identification of patients who are likely to survive and recover remains of the high importance.

Predicting scores are of a high value in situations that require quick decision-making, like for segregation in civil and military circumstances. Providing medical help to those who have highest chance for survival is relevant the triage motto, a quote from Jeremy Bentham, an English positivist lawyer and philosopher. Thus, triage is *the greatest good for the greatest number* rather than *the sickest first* [14,15]. Triage, from the French word for "select", is the process of segregating patients. In circumstances of war and mass-casualty events, its purpose is to optimise rescue activities and provide the right care to the highest possible number of victims [16,17,19].

Another discussing issue is supercritical burns, over 80% of TBSA and moral aspects of palliative therapy in those patients. Is using prognostic scales and surgeons experience enough to withdraw intensive treatment?

From our experience it is always beneficiary to include prognosis in patients' history in case of lawsuits. Despite of developing mortality prediction scores in burns the main practical factors of mortality have consistently: age of burn victim, total body surface area burned and presence or absence of fatal inhalation injury.

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