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A New Triage Method for Burn Disasters: Fast Triage in Burns (FTB)

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Study Design A
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Background: There are few triage methods based on patient age and extent of burn. However, in case of mass casualties, age might be hard to define. Burn segregation in mass-casualty accidents requires an easy, fast, and effective method. Triage in burns should also segregate casualties requiring treatment in burn centers. The aim of this study was to create a proprietary segregation algorithm dedicated to mass-casualty incidents.

Material/Methods: A retrospective analysis of 939 burned patients admitted to the Clinical Department of Burns, Plastic and Reconstructive Surgery, Military Institute of Medicine (MIM) in Warsaw and to the Center for the Treatment of Burns (CTB) in Siemianowice Śląskie in 2012 and 2013 was performed. The aim was to reveal which early factors could be used during segregation of burn victims in mass-casualty incidents on the battlefield and in civilian circumstances. Only easy and quick-to-evaluate factors that can be examined without medical equipment and laboratory tests were used in creating the proprietary triage algorithm.

Results: As a result of our study, we created an algorithm for fast triage in mass-casualty situations. The algorithm is based on parameters that can be easily evaluated without additional equipment. To create the algorithm, we used factors that had the strongest impact on mortality prediction in severely burned patients, in multifactor analysis: advanced age ($p<0.001$. OR=1.04), extent of the deep burn ($p<0.001$. OR=1.1), and low systolic arterial pressure ($p<0.001$. OR=0.96).

Conclusions: The FTB (Fast Triage in Burns) algorithm is a new triage method dedicated for massive burn events in civilian circumstances. The FTB algorithm is a simple, quick, and credible means of segregating burn victims. The algorithm is dedicated to use in pre-hospital care, during mass-casualty events both in civilian and battlefield circumstances. The aim is to be able to evaluate burn victims immediately, without access to medical equipment or additional tests and to evaluate indications for burn center care. It is a unique method designed to be used during segregation in isolated burn mass-casualty incidents.

MeSH Keywords: **Burns • First Aid • Mass Casualty Incidents • Triage**

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Background

In the event of mass-casualty incidents, both in civilian and war-related circumstances, paramedics may face an excessive number of casualties in relation to their actual capabilities for providing medical help [1–3]. 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 optimize rescue activities and provide the right care to the greatest possible number of victims [4,5]. The triage motto is a quote from Jeremy Bentham, an English positivist lawyer and philosopher: triage is *the greatest good for the greatest number* rather than *the sickest first* [6,7].

The purpose of triage in mass-casualty events is to provide the greatest benefit to the greatest number of casualties. Triage pursuant to NATO guidelines, or the so-called DIME standard, distinguishes 5 groups of casualties: white, black, red, yellow, and green [1]. The methods and algorithms that list the criteria for allocating victims to the individual categories are numerous. Such algorithms differ for non-war-related and war-related mass-casualty events. There are several triage methods in burns, but they rely on age. In case of mass anonymous casualties, defining age might be troublesome. Moreover, in circumstances of armed conflict, the casualties are primarily young person; therefore, the authors believe that prognostic methods that rely on patient age may be of lower significance in such cases. Several different ways to proceed can be distinguished for burn disasters, and they will be discussed later on. The first of such methods is the *American Burn Association's* algorithm [8]. During triage, casualties are grouped according to burned area of the body expressed as percentage of the TBSA, and age. Another method, based on Australian trauma center guidelines, suggests a 4-grade score. When life-threatening conditions resulting from respiratory disorders, hemorrhaging, and disturbances of consciousness are ruled out, the next stage of triage involves burn assessment. If isolated burns are found, the guidelines suggest sending the patient to a burn treatment center [9].

There is no single universal algorithm for handling burn victims in mass-casualty events or war-related events. In trauma center guidelines, instructions concerning segregating isolated burns are fourth in order of importance, after evaluation of GCS score, arterial pressure, number of breaths per minute, and other concomitant injuries. It is suggested that isolated burns are referred to specialized burn treatment facilities [9].

There is, however, a report on a triage during mass-casualty events from China. The summary of that study contained guidelines for triage and evacuation of burn victim in mass-casualty events. According to the authors, casualties with burns below 30% TBSA can be transported to a burn treatment facility or hospital at a convenient time. Patients from the second group need to be transported to a hospital within 8 hours. Group 3 casualties, with 50–69% TBSA burns need to be transported to a hospital within 4 hours from the event, and they require immediate administration of fluid resuscitation. Casualties from group 4 need to be transported to the nearest hospital within 1 hour. Following initial treatment, patients with over 70% TBSA burned can be transported to a burn treatment facility only after 48 hours and when their general condition is stabilized [10].

Prognostic burn scores, however, are not optimal for critical situations, when the number of the victims surpasses the number of the rescuers. Burn segregation in mass-casualty accidents requires an easy, fast, and effective method.

Our aim here was to develop a proprietary prognostic scale that would be useful mainly for burn victim triage in both civilian and military mass-casualty events.

Material and Methods

We performed a retrospective analysis of 939 histories of burn victims admitted to 2 facilities in 2012 and 2013: the Burn Treatment Center (CLO) in Siemianowice Slaskie, and the Plastic Surgery, Reconstructive Surgery, and Burn Treatment Clinical Unit of the Military Institute of Medicine (WIM) in Warsaw. Thermal burns were used as an inclusion criterion, with chemical, electrical, and mixed burns excluded. The analysis was performed on data on patients of both sexes, above the age of 18 years. The tested group comprised 842 victims of thermal burns (burns caused by flame, steam, or boiling water) out of the 939 burn victims admitted to the facilities in the study period. CLO patients accounted for 85% of the group (719/842), with the remaining 15% constituted by WIM patients. We included 615 male patients (73% of the tested group) and 227 female patients (26%).

The Bioethics Committee of the Military Institute of Medicine in Warsaw gave consent for the study to be conducted (decision no. 34/WIM.2013 dated 19/06/2013).

The data extracted from the patients' histories were saved in a Microsoft Excel® file. The statistical analysis was performed using Statistica software, ver. 12.

The extent of the burn, expressed as a percentage of the TBSA, was evaluated at both facilities according to the Lund and Browder chart, taking into consideration the percentage of the TBSA burned, percentage of deep burns, surface burns, and graphical imaging of wound location. Deep burn was recognized as IIb-, III-, and IV-degree burns. In all cases, suspected

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inhalation burns were verified by a bronchoscopic examination and treated, depending on the degree of the burn and the patient's general condition, by respiration therapy, steroid therapy, administration of mucolytic agents and antibiotics, and hyperbaric oxygenation (HBO) therapy at CLO.

Furthermore, the initial examination sheets contained information about concomitant diseases, provided if it was possible to interview, either immediately from the patient or their family.

On admission, the patients' consciousness was evaluated on the Glasgow Coma Scale. Analgosedation of previously-intubated patients proved to be problematic in retrospective analysis, as it made unbiased analysis of consciousness more difficult. For the purpose of the study, it was methodologically assumed that these particular patients presented as below 8 on the GCS.

The analysis included parameters known to influence survival and those used in prognostic scales. New factors that had not been previously used in predicting mortality in burns were also analyzed. The patients' vital signs were evaluated at the time of admission to the facility. These included: systolic and diastolic blood pressure, heart rate, breaths per minute, body temperature, and height and weight for the purpose of calculating the patients' BMI. Mean arterial pressure was calculated according to the following formula: MAP=$^2/_3$ systolic pressure +1/3 diastolic pressure. Both facilities used fluid resuscitation on the first day, pursuant to the Parkland rule (4 ml/kg of body weight/burned TBSA percentage; 50% in the first 8 hours, 50% in the next 16 hours). The patients' fluid requirement was calculated up to a maximum of 50% TBSA for burns in excess of this value. On subsequent days, administrated and excreted fluids were balanced out on the basis of clinical tests (arterial blood pressure, diuresis, and central venous pressure), and lab test results.

On admission to the facility, patients with risk of respiratory failure or intubated patients had a blood sample taken for gasometrical analysis. All patients who required intubation remained under constant supervision of an anesthetist. The date and time of intubation and the moment the patients were extubated were noted in the medical documentation.

The day of the patient's death or release from the facility was considered the end point.

All of the examined factors were tested for the presence of values in a system with normal distribution, by means of the Kolmogorov-Smirnov test. In the case of $p<0.05$, the system differed from normal. Impact on the patients' survival was analyzed for all of the variables. Statistically significant impact of the individual variables on the risk of death, in a dichotomic system, was evaluated by means of the Mann-Whitney independent sample non-parametric test. In the case of a statistically significant connection between the tested aspect and death ($p<0.05$), a logistic regression model was created to establish the relationship between the risk of death and the value of the tested variable. Factors that proved to have statistically significant impact on death in single-factor analysis were subjected to multifactor analysis to establish their predictive value.

The analysis included selected data that can be obtained by means of observing patients, and ones that did not require any additional medical equipment. Parameters with statistically significant impact on patient survival were chosen for inclusion in the algorithm. The tested group was randomly divided into 2 parts, comprising 2/3 and 1/3 of the population, respectively. Analysis of 2/3 of the population was used to create the algorithm, which was tested with the data for the remaining 1/3 of the population.

Results

Characteristics of the tested material

The tested group consisted of 842 burn victims with an average age of 48 years (SD17, range 18–96). The average age of women was 8 years older than the average age of men (54 years, SD 19, range 19–96 *vs.* 46 years, SD 17, range 18–92). The group's median burned TBSA expressed as a percentage was 12.5% (range 1–100), whereas full-thickness burns were 2% of the TBSA (range 0–100). Burns in men were more extensive than burns in women. The female group had a median burned TBSA percentage of 12% (range 1–100) and 2% TBSA with III-degree burns (range 0–100). In the male group, the median burned TBSA percentage was 13% (range 1–100), with 2% TBSA with III-degree burns (0–100 range). Inhalation burns were diagnosed in 363 patients (43%), including 299 men, which amounted to 82% of the patients with inhalation burns. The median age of this subgroup was 48years (range 18–96); and a median of 46years for men (range 18–92), and a median age of 54 for women (range 18–96). The median burn concomitant to respiratory tract burns was 22% TBSA on average (range 1–100), and 2% TBSA for deep burns (range 0–100). In the case of men, the total extent of burns concomitant to respiratory tract burns was lower than in women (median: 20% *vs.* 22%, respectively). The vital signs on admission (median values) were: MAP: –96.67 mmHg (range 0 [which amounted to undetectable]–150). HR: -84/min (range 26–145), body temperature: 36.6 degrees (range 32–39), 16 breaths per minute (range 8–24), and GCS 15 (range 8 [which amounted to analgosedation]–15) (Table 1).

Risk of death was dependent on: age ($p<0.001$), extent of burn ($p<0.001$), extent of full-thickness burn ($p<0.001$), presence of

Table 1. Vital signs in the burn victims group evaluated on admission to the facility.

Variables	N	Average	Median	Minimum	Maximum	Percentile 25	Percentile 75	St. dev.
HR	820	85.70	84.00	26.00	145.00	78.00	90.00	15.34
Body temperature	707	36.50	36.60	26.60	39.00	36.60	36.60	0.57
Breaths per minute	681	14.88	16.00	8.00	24.00	13.00	16.00	2.32
GCS	834	14.07	15.00	8.00	18.00	15.00	15.00	2.37
Systolic pressure	813	130.83	130.00	0.00	210.00	120.00	142.00	25.44
Diastolic pressure	812	80.01	80.00	0.00	130.00	70.00	90.00	15.04

Table 2. Summary of multiple regression analysis for vital signs and burn data with statistically significant impact on death in the single-factor analysis.

N=764	b*	St. error	B	St. error	t(756)	P
Offset			–0.117341	0.073490	–1.59669	0.110752
Age	0.223584	0.024668	0.004680	0.000516	9.06355	0.000000
%TBSA	0.258839	0.043183	0.004422	0.000738	5.99406	0.000000
Respiratory tract	0.092895	0.026419	0.067940	0.019322	3.51618	0.000464
%III	0.395509	0.041114	0.008500	0.000884	9.61971	0.000000
HR	0.027248	0.025598	0.000651	0.000611	1.06446	0.287459
Systolic pressure	–0.113280	0.036602	–0.001614	0.000521	–3/09495	0.002041
Diastolic pressure	–0.001242	0.036126	–0.000030	0.000863	–0.03437	0.972592

Table 3. Comparison of mortality in the random test group (2/3 of the population) and the control group (1/3 of the population).

	Mortality			
	Black group	Red group	Yellow group	Green group
2/3 group	100%	60%	20%	2%
1/3 control	100%	64%	22%	0.50%
Expected mortality	>95%	50–95%	5–50%	<5%

respiratory tract burns (p<0.001), heart rate (p<0.001), and systolic and diastolic blood pressure values (p<0.001).

A general multiple regression model (statistical function) was created for the parameters that showed a statistically significant impact on death in the single-factor analysis (Table 2).

Among all factors, we selected ones that had statistically significant impact on the burn victims' survival and allowed emergency services to perform immediate evaluation during mass-casualty events. These include: age, TBSA% burned, deep burn extent, presence of inhalation trauma, heart rate, and systolic pressure. The tested population was randomly divided into 2/3 for the purpose of creating the algorithm, and 1/3 for the purpose of the effectiveness of the method (Table 3).

The population was analyzed in terms of factors affecting early death (days 0 to 4) and in terms of death prognosis on subsequent days despite the administration of multi-specialist treatment.

It was assumed that 4 groups would be formed as the end result:

- Black – risk of death over 95% – patients without a chance of survival, 'expectant'.

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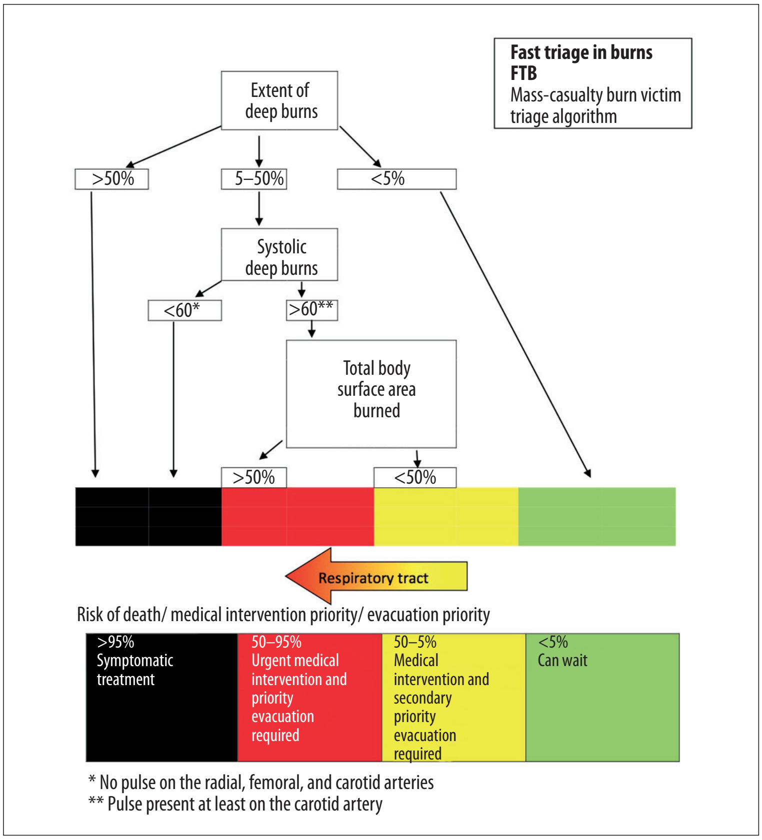

Figure 1. The FTB algorithm.

- Red – risk of death between 50% and 95% – patients who require quick, priority medical intervention/and or evacuation. Failure to administer early treatment (e.g., intubation, fluid therapy) involves significant risk of the patient's status changing to black.
- Yellow – risk of death between 5% and 50% – patients who are second in line for medical intervention.
- Green – risk of death below 5% – patients who do not require medical intervention, outpatients, able to self-medicate.
- Outpatients, able to self-medicate.

The FTB algorithm was created by conducting a multiple regression analysis for parameters strongly predicting early death on days 0–4 (Figure 1). The extent of deep burns and systolic pressure had the greatest impact on early death. Presence of inhalation trauma was the next factor in order of importance.

Deep burns proved to be a strong predictive factor for both early deaths and deaths occurring after day 4 (OR=1.06). A multiple regression model was created for the extent of deep burns (OR=1.06). Risk of death evaluated below 5% (therefore indicative of the green group) reflected extent of deep burns below 5% of the TBSA. For the remaining group, comprising patients with deep burns affecting 5% to 50% of the TBSA, a logistic regression model was built explaining the relation between systolic pressure and risk of death (early deaths: p=0.0003). The model indicated an over 95% risk of death for patients with deep burns on between 5% and 50% of the TBSA, with systolic pressure in excess of 60 mmHg. These patients can be allocated to the black group. In battlefield conditions, tentative systolic blood pressure measurement requires pulse to be present at only 3 sites: the carotid artery (if pulse is palpable, systolic pressure is higher than 60 mmHg), femoral artery (if pulse is present, systolic pressure is higher than 70 mmHg), and radial artery (if pulse is present, systolic pressure is higher than 80 mmHg). Therefore, patients with 5% to 50% of III-degree burns with no pulse at all at the above-mentioned sites have no chance of survival. No pulse on peripheral arteries, with heart rate and low blood pressure, are signs of centralization of vascular system. This group's mortality in the tested population was 100%. Multiple regression analysis was performed for patients with blood pressure in excess of 60 mmHg, showing that TBSA had a significant impact on early and late death (p<0.005). A logistic regression model was created, which indicated that patients with a risk of death above 50% had over 50% of their TBSA burned. Risk of death below 50% was found in patients with less than 50% of the TBSA burned. The final parameter that affected both late and early death was presence of respiratory tract trauma. Inhalation trauma showed an odds ratio of 31 for the occurrence of early death. This means that inhalation trauma concomitant with extensive deep burns was less significant in terms of early death.

With less extensive deep burns (below 50%), presence of inhalation trauma greatly increased mortality. Therefore, burn victims from the yellow group with suspected inhalation trauma need to be allocated to the red group, so that they can be the first in line to receive medical help. Suspected inhalation trauma involves clinical signs and signs such as charring in the nasal and oral cavities, swelling of the oral cavity, hoarseness, respiratory failure signs, and burns sustained in closed spaces. The suggested algorithm was tested on 1/3 of the population, the result being compatible data. FTB (Fast Triage in Burns) for burn victim triage is intended for use both on the battlefield and in civilian mass-casualty events.

Discussion

Triage, from the French '*trier*', or sieve, was created for military purposes. It was invented by Dominique Jean Larrey, Napoleon's surgeon general [11,12]. Soldier triage and evacuation was intended to select the lightly wounded casualties who could quickly return to duty [9,12]. Modern-day triage has a different purpose: *the greatest good for the greatest number*, rather than prioritizing the *sickest first* [9,13].

Results of a multi-layered statistical analysis outputted parameters that strongly predicted death in burn victims and can be evaluated without access to medical equipment; therefore, they allow performing credible evaluation even in the most adverse conditions. Factors that strongly predict early death (i.e., death in the first 4 days after the occurrence of the burn) were also adopted for triage purposes. The parameters yielded by the analysis included the extent of deep burns ($p<0.00001$. OR=1.06), systolic pressure ($p<0.00001$. OR=0.95), and presence of inhalation trauma ($p=0.0019$, OR=31). The second element used in the algorithm's design comprised parameters that strongly predict death despite administration of multi-disciplinary treatment. Extent of deep burns ($p<0.00001$. OR=1), TBSA ($p<0.00001$. OR=1.01), and presence of inhalation trauma ($p=0.0002$, OR=6.05) were included in the analysis.

The analysis indicates that the extent of deep burns is the parameter that needs to be evaluated first. If over 50% of the patient's body is affected by a deep burn, there is no chance of survival and the patient has to be marked as *black*. If the patient is diagnosed with less than 5% of deep burns, then the risk of death is also below 5%. Such patients can wait for medical help, and are able to self-medicate or assist others. Patients estimated to have below 50% and above 5% TBSA affected by deep burns require further triage. At the second stage of segregation, FTB suggests evaluating systolic pressure, thus indicating presence (or lack thereof) of signs of shock. Overview evaluation of systolic pressure can be performed by means of pulse palpation at 3 sites: the radial, femoral, and carotid arteries. Presence of a pulse on the radial artery indicates that systolic pressure is above 80 mmHg, on the femoral artery indicates over 70 mmHg, and on the carotid artery indicates over 60 mmHg. Lack of a pulse at the sites listed above indicates that systolic pressure is below 60 mmHg, despite symptomatic treatment. This signifies centralized blood circulation, insufficient perfusion of the key organs, and a risk of death above 95%. Such patients need to be treated symptomatically. If the patient's systolic pressure is estimated to be above 60 mmHg, their entire body surface area affected by the burn needs to be evaluated. Burn victims with over 50% TBSA burned are priority patients, who are more likely to die if they do not receive medical help. On the other hand, patients with less than 50% TBSA burned can be second in line to be assisted. If patients from this "yellow" sub-group are affected by inhalation trauma, they need to be moved to the red group, so that they can be treated first. Suspected inhalation trauma involves clinical signs and signs such as charring in the nasal and oral cavities, swelling of the oral cavity, hoarseness, respiratory failure signs, and burns sustained in closed spaces [14,15].

Melorio developed a different triage system; apart from the total body surface area, he considered the Watson-Sachs rule, or the BUS score [16]. Burn victims were divided into 3 groups. The first group, which according to Melorio is supposed to be first in line for evacuation, comprised patients with over 20% TBSA burned and BUS score under 100. The second group (to be evacuated second, third, or further) comprised patients with less than 20% TBSA burned. The third group was expectant patients with over 20% TBSA burned and BUS score over 100. Factors considered at the next stage included presence of inhalation trauma, gas intoxication, and presence of burns in areas of the body likely to cause shock [16]. Analysis of CLO and WIM material showed that the BUS index is highly effective in evaluating burn victims' prognosis (AUC=0.94), which is further corroborated by the significant impact of full-thickness burns on the prognosis.

Numerous factors are decisive in the effectiveness of mass-casualty event rescue operations. The right planning, prediction, risk assessment, and emergency services training and experience are all highly important. Introducing algorithms to the repertoire of paramedics and conducting the right training limits the risk of errors and makes work in extremely stressful conditions easier. Simple guidelines guarantee reproducibility of the task. The suggested algorithm is a simple method that, however, requires paramedics are able to assess the depth of the wound. One of the assumptions made in FTB is that the patient will be re-assessed, as the general condition of burn victims can change rapidly, especially if the right medical help is not provided. Hypovolemic shock, resulting directly from the extent and depth of the burn and pre-existing diseases, seem

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to be the initial manifestation of decompensation of homeostasis. However, if fluid resuscitation is effectively carried out, hypovolemia is reversible.

The concept of the FTB algorithm used in mass-casualty events at times of peace is a method dedicated to pre-hospital treatment. The purpose of FTB is to categorize the casualties into 4 treatment and evacuation urgency groups. There are 2 main approaches to providing first aid. "Scoop and run" is intended to transport the victims to the nearest hospital as soon as possible. Only after their general condition is stabilized, the most heavily wounded are transported to higher-reference facilities, including trauma centers and, in the case of burns, burn treatment centers. "Stay and play" involves providing first aid on site, and transport only after life-threatening injuries are contained. The choice of approach, quick transport *vs.* treatment on site, depends on the patient's general condition and injuries.

The concept of the FTB algorithm for civilian mass-casualty events regards the extent of deep burns as the most important risk factor. Contrary to what the ABA guidelines state, not all full-thickness burns in crisis situations are going to require immediate treatment and transport to a burn treatment center. In the tested burn victim population, III-degree burns below 5% TBSA resulted in low mortality (risk of death <5%). Therefore, there is no rationale for providing medical help to such patients first, or to refer them to highly-specialized centers, during mass-casualty events. Additionally, in exceptional circumstances where the number of casualties is excessive in relation to capabilities of paramedics and medical facilities, patients from the green group might not require transport to the hospital, and can be treated on site instead. In any other circumstances, patients from the green group can be referred to level-I reference hospitals.

Group 4 patients need to be approached differently. Statistical analysis of the data showed that burn victims with deep burns on over 50% TBSA are unlikely to survive despite treatment at burn treatment centers (CLO and WIM). Patients from the black group had a 95% risk of death in the study. In the analyzed material, early admission to the facility after occurrence of the burn was a significant death risk factor (p<0.001), mainly because the most severely burned patients were admitted to burn treatment centers. Burns affecting over 80% TBSA involve a 100% risk of death regardless of the age group. Similarly, according to Bull and Fischer's method, all burns affecting over 78% TBSA yielded 100% risk of death in all groups [17]. In their study, Guo et al. reported 95% mortality for the group of victims with over 80% TBSA burned, and more than 50% of deep burns between 1987 and 1996, and a decrease in mortality to nearly 80% after 1996 onwards [18]. Survival time increased, but MODS was diagnosed much more frequently after 1996 [18]. Despite the longer survival time, patients with supercritical burns in mass-casualty events need to be treated as "expectant" patients subjected solely to symptomatic treatment. Such patients do not have to be transported to burn treatment centers. Palliative therapy (fluid therapy, pain treatment, sedation, respiration therapy, antimicrobial therapy, supportive therapy, and wound cleansing) can be administered at less experienced facilities.

A limitation of our study in its retrospective character. However, it is difficult to plan a model study on burn catastrophes. Our algorithm has good sensitivity (91%) and specificity (79%).

Conclusions

The FTB algorithm is a simple, quick, and credible means of segregating burn victims. The algorithm is dedicated to use in pre-hospital care during mass-casualty events both in civilian and battlefield circumstances. The intention is to be able to evaluate burn victims immediately, without access to medical equipment or additional tests. The result is the ability to quickly assign the patients into 4 categories of medical assistance and evacuation urgency. The fundamental patient evaluation tools of the FTB are: the extent of deep burns, systolic pressure (measured during segregation), total extent of the burn, and presence of inhalation trauma.

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