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Assessment of mortality prediction models in a Ghanaian burn population

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ABSTRACT

Purpose: Over 40 new or modified outcome prediction models have been developed for severe burns; with age, total burned surface area (TBSA) and inhalation area as major determinants of mortality. The objective of this study was to assess their applicability in a developing country.
Procedures: Data were collected retrospectively of a consecutive series of 261 patients (2009–2011) admitted to a Burns Intensive Care. Five outcome prediction models based on admission criteria were evaluated: Bull grid, Abbreviated Burn Severity Index – ABSI, Ryan-model, Belgian Outcome in Burn Injury – BOBI and revised Baux. Discriminative power and goodness-of-fit were assessed by receiver operating characteristic analyses (area under the curve – AUC) and Hosmer–Lemeshow tests.
Findings: Median age was 10.5 years (IQR: 2.5–27 years), median TBSA 21% (IQR: 11–34%); 55.2% were male, 28 patients died (10.7%). Only 2 patients were intubated (0.8%). The AUC were between 77 and 86%. The ABSI model showed the best calibration (28.7 expected deaths). Ryan, BOBI and rBaux significantly underestimated mortality, whereas Bull showed an overestimation.
Conclusion: This study on a young group of burn patients showed moderate to good discriminative power using all five prediction models. The expected number of deaths tended to be underestimated in the three most recent prediction models.

1. Introduction

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 [1–7]. Besides assessing the mortality risk of an individual patient, prediction models are crucial to assess and compare the severity and mortality of burn populations; and to assess trends in survival over time [1]. Comparing absolute percentages of mortality between different populations (in time and/or place) may merely represent a difference in severity of illness of the cohort than a difference in treatment and prognosis.

It is well known that survival improved drastically due to the improvements in burn management during the last 65 years. The LA50, or the total burned surface area (TBSA) 'lethal to 50% of the burn victims', has increased from approximately

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9% in 1949 to values above 65–75%, although it clearly relates to age [7–11]. Yet therapeutic limits to improve survival are almost reached, if the patient is admitted – in time – to a specialised burn unit [12,13]. The patient and burn trauma characteristics with the highest impact and/or incidence could be included in a prediction model, to assess probability of death. For burns, most popular models are based on risk factors present at admission of the burn patient, which can be assessed easily and objectively. Increasing age and total burned surface area (TBSA) have always been considered the most important risk factors for mortality [1,13,14]. The first models, of which the Bull grid and Baux score are best known, were exclusively based on those two risk factors; though modified versions also included inhalation injury [2,8,10,15–21]. Inhalation injury has been included in several models as a third major risk factor for mortality [14,17,22–27], but discussion remains on the diagnosis and exact definition [28]. While included in some prediction models, the exact impact on mortality of other factors, e.g. gender, is often difficult to assess due to confounders; or the increased risk is too obvious for the individual patient yet too rare in a burn population (e.g. co-morbidities) [29–32]. Other models merely evaluate the clinical evolution during the acute phase, by including APACHE scores, other physiological parameters or even development of pneumonia [33–36]. Remarkably, almost all models are developed and validated on populations from very highly developed countries [37].

To our knowledge, only the revised Baux-model of Godwin (South-Africa, $N = 377$), and the Egyptian model of Attia et al. ($N = 533$), were published in countries with a 'medium' human development index, in contrast to all other studies from countries with 'very high' human develop indexes [17,37,38]. Also noteworthy, is that most studies on outcome prediction in burns, do cover a new or modified model. Only a few validation studies have been published, or used a prediction model to describe the burn cohort [1,5,10,11,26,39–45].

Therefore, the objective of this study was to analyse severity of a burn population from a developing country, and to assess the accuracy of five different well-known outcome prediction models in this cohort, based on a limited set of clinical characteristics present at admission.

2. Methods

Data were collected prospectively of a consecutive series of 261 patients with severe burns (May 2009–April 2011) admitted to the Burns Intensive Care Unit (BICU) of the Reconstructive Plastic Surgery and Burns Unit of the Komfo Anokye Teaching Hospital (KATH) in Kumasi, Ghana [46]. The following data were collected from admission and discharge/death book: age, TBSA and involved body area, aetiology, length of hospital stay, inhalation injury and mortality. TBSA was determined by the Lund–Browder chart. The primary outcome studied was mortality during hospitalisation, and the secondary outcome was length of stay.

Ethical approval was obtained from the Kwame Nkrumah University of Science and Technology School of Medical Sciences/Komfo Anokye Teaching Hospital Ethical Committee.

Five well-known and frequently used prediction models for burns – based on clinical risk factors present at admission – were selected for this study.

(i) The modified Bull grid (1971, $N = 1922$) gives probabilities of mortality ranging between 0% and 100% (11 categories), based on increasing age (17 groups) and increasing TBSA (20 groups) [16].
(ii) The ABSI index (1982, $N = 590$) ranges between 2 and 18 points, resulting in six risk categories, with a probability of survival ranging between $<10\%$ and $>99\%$. The ABSI index considers the following risk factors: presence of female gender (1 point), increasing age (1–5 points), increasing TBSA (1–10 points), presence of inhalation injury (1 point) and presence of full thickness burns (1 point) [29]. Since presence of full thickness burns could not be assessed, the model was evaluated twice: considering all versus none of the patients as having full thickness burns.
(iii) The model of Ryan et al. (1998, $N = 1665$) is based on the presence or absence of three risk factors: age ≥ 60 years, TBSA $\geq 40\%$ and presence of inhalation injury, resulting in four risk categories (0–3 risk factors present), corresponding with probability of death 0.3%, 3%, 33%, 90% [14].
(iv) The Belgian Outcome in Burn Injury – BOBI-score (2009, $N = 6227$) ranges between 0 and 10 points, by dividing increasing age in 4 groups (0–3 points), TBSA in 5 groups (0–4 points) and presence of inhalation injury (3 points). The BOBI score results in 11 risk categories, with probabilities of death ranging between $<1\%$ and $>90\%$ [23].
(v) The Baux-index, originally published in 1961, was revised by Osler et al. (rBaux, 2010, $N = 39{,}888$), and is a continuous score based on age, TBSA and presence of inhalation injury, with a probability of death ranging between 0 and 100% [18].

For the sub-analyses, TBSA was divided in two groups, in which burns of $\geq 40\%$ were considered 'high' TBSA', based on a cut-off used in three of the prediction models [14,23,29]. Patients younger than 15 years of age were considered children.

Statistical analyses were performed with STATA/MP4 (release 11; StataCorp LP, Texas, USA). Data are presented as N (%), median (interquartile range – IQR), or mean (standard deviation – SD). Wilcoxon-rank-sum tests and Pearson Chi-square tests were used to compare groups. Probit regression analyses were used to calculate the LA50.

The Hosmer and Lemeshow test for goodness of fit was used to determine adequate calibration of the prediction models, where small p-values indicate a lack of fit of the model (thus important differences between the number of observed and expected deaths). The discriminative ability was evaluated by assessing Receiver Operator Characteristics (ROC) curves. The area under the curve (AUC) ranges from 0 to 100%, where 100% indicates perfect discrimination between survivors and non-survivors, and 50% indicates chance discrimination. Values above 80% are considered good discrimination [47].

3. Results

Of all 261 patients, 144 patients were younger than 15 years (55.2%), and only 2 patients were older than 60 years (0.8%) (Table 1). Median age was 10.5 years (IQR: 2.5–27 years),

Table 1 – Demographics of 261 Ghanaian patients with severe burn injury.

	All	Children (<15 years)	Adults	p
N	261	144	117	–
Age: median years (IQR)	10.5 (2.5–27)	2.5 (1.5–5)	30 (23–38 years)	–
Mean years (SD)	16.6 (16.6)	4.0 (3.5)	32.1 (12.6)	
TBSA, median % (IQR)	21.0 (11.0–34.0)	18.0 (9.8–27.0)	26.0 (16.0–43.5)	0.642
Mean % (SD)	25.8 (19.3)	21.6 (16.6)	31.1 (21.0)	
→ *High TBSA* (≥40%), N (%)	50 (19.2)	17 (11.8)	33 (28.2)	0.001
Male gender, N (%)	144 (55.2)	76 (52.8)	68 (58.1)	0.388
Inhalation injury, N (%)	2 (0.8)	1 (0.7)	1 (0.9)	0.883
Aetiology				<0.001
→ Scalds, N (%)	112 (43.4)	99 (68.8)	13 (11.4)	<0.001
→ Flame, N (%)	108 (41.9)	27 (18.8)	81 (71.1)	<0.001
→ Electrical, N (%)	9 (3.5)	1 (0.7)	8 (7.0)	0.006
→ Chemical, N (%)	9 (3.5)	2 (1.4)	7 (6.1)	0.039
→ Hot oil, N (%)	18 (7.0)	13 (9.0)	5 (4.4)	0.146
→ Other, N (%)	2 (0.8)	2 (1.4)	–	–
Orofacial burns, N (%)	79 (30.3)	29 (20.1)	50 (42.7)	<0.001
Perineum/genital burns, N (%)	48 (18.4)	33 (22.9)	15 (12.8)	0.036
Length of stay, days	5 (1–11)	4.5 (1–9)	6 (2–12)	0.047
Observed mortality, N (%)	28 (10.7)	10 (6.9)	18 (15.4)	0.028

Values are presented as N (%), as median (IQR: interquartile range), or as mean (SD: standard deviation).
TBSA, total burned surface area; *p*-values represent the differences between children and adults.

ranging 0–84 years. Median TBSA was 21.0% (11.0–34.0%) and 144 patients (55.2%) were male. Most burns were scalds (42.9%) and flame burns (41.4%).

In total, 10.7% died (*N* = 28), respectively 6.9% (*N* = 10/144) and 15.4% (*N* = 18/117) in children and adults. Only 2 patients were intubated (0.8%). Median length of stay was 5 days (IQR: 1–11 d). Orofacial burns were present in 79 cases (30.3%) and the buttocks or perineum was involved in 48 cases (18.4%).

LA50 was 65.5% in all patients, and above the age of 10, it inversely correlated with age (Table 2), meaning that younger patients have a higher probability of survival for a similar TBSA. Yet, children younger than 3 years had an LA50 of only 48%. Univariate analyses demonstrated that TBSA clearly correlated with mortality with OR = 1.07 (95%CI: 1.05–1.10, $p < 0.0001$). Thus for every % increase in TBSA, there is on average a 7% increase in the mortality risk. Increasing age corresponded with an OR = 1.10 per 5 years increase, which was borderline significant (95%CI: 0.99–1.23; $p = 0.071$). Flame burns (compared with all other burns) were clearly associated with increased mortality: OR = 3.42 (95%CI: 1.48–7.88, $p = 0.004$). Orofacial burns also showed an increased odds of mortality of 2.19 (95%CI: 0.99–4.86, $p = 0.053$). No other risk factors showed a noteworthy association.

Table 2 – Lethal area 50 (LA50), or total burned surface area lethal to half of the burn victims.

Age group	LA50 (% TBSA)	N
Child (<15 years)	67.09	144
Adult (≥15 years)	64.83	117
0–2 years	47.58	41
2–4 years	77.92	59
5–9 years	59.00	28
10–19 years	71.98	35
20–29 years	71.98	38
30–39 years	58.47	34
40–49 years	56.86	12
50–59 years	57.54	12
>60 years	Insufficient data	2
All	65.49	261

TBSA, total burned surface area.

Multivariate regression modelling was conducted to analyse which correlations were significant in the whole cohort. Only TBSA remained significantly associated with mortality (OR: 1.07; 95%CI: 1.05–1.10, $p < 0.001$).

Compared with the cohorts on which the five prediction models were developed, the crude mortality risk was higher in the Ghanaian cohort (except for the ABSI cohort), as well as the mean TBSA (Table 4). When analysing the categories of the different prediction models (Table 3), ROC-curve analyses showed good discrimination, thus a high area under the curve, in all models except the model of Ryan, showing only moderate discrimination (Fig. 1). No noteworthy differences were seen between children and adults, only a slightly (non-significant) better discriminative power was found for the children for both Bull and revised Baux scores (as seen in Table 3, although the confidence intervals clearly overlap).

None of the patients had a high probability of death (≥50%) according to the models of Ryan and BOBI. According to Ryan maximally two out of three risk factors were present (associated probability of death = 33%); and the maximal BOBI score was five out of ten (associated probability of death = 45%). The Bull grid showed a high mortality risk in 27 patients (maximum probability 100%); where ABSI showed a high probability of death (maximally > 90%) in respectively 13 and 20 patients, considering all patients or none of the patients as having full thickness burns. The rBaux showed 4 patients with a high probability of death (maximum probability = 72%).

Hosmer and Lemeshow tests were used to assess calibration of the models. As seen in Table 3, the ABSI model provided the best estimate of the number of deaths, under condition

Table 3 – Outcome prediction according to the five prediction models.

	All	Children (<15 years)	Adults
ROC analysis	*Area under the curve (AUC)*		
Bull	84.8 (77.2–92.4)	85.1 (71.1–99.1)	82.8 (72.2–93.4)
ABSI-1	85.7 (78.3–93.2)	83.7 (68.7–98.7)	84.9 (76.2–93.6)
ABSI-2	83.8 (75.6–91.9)	82.4 (68.7–96.2)	83.1 (72.1–94.1)
Ryan	77.0 (67.8–86.1)	76.3 (60.0–92.7)	74.6 (63.3–86.0)
BOBI	85.7 (78.5–92.8)	84.0 (69.7–98.2)	84.1 (75.1–93.2)
rBaux	83.8 (76.0–91.6)	87.1 (75.6–98.6)	83.5 (72.8–94.3)
Observed mortality, N (%)			
Mortality	28 (10.7)	10 (6.9)	18 (15.4)
Hosmer and Lemeshow test	*Predicted mortality, N (%)*		
Bull	32.9 (12.6) (+)	7.1 (4.9)	25.8 (22.1) (+)
ABSI-1	28.7 (11.0)	7.3 (5.1)	21.4 (18.3)
ABSI-2	43.5 (16.7) (+)	13.4 (9.3) (+)	30.1 (25.7) (+)
Ryan	2.8 (1.1) (−−)	1.2 (0.8) (−−)	1.6 (1.4) (−−)
BOBI	6.5 (2.5) (−−)	2.5 (1.7) (−−)	4.0 (3.4) (−−)
rBaux	9.0 (3.5) (−−)	0.9 (0.6) (−−)	8.2 (7.0) (−−)

ABSI, abbreviated burn severity index (ABSI-1: considering none of the patient as having full thickness burns, ABSI-2: considering all patients as having full thickness burns); BOBI, Belgian Outcome in Burn Injury; rBaux, revised Baux index. Compared with the observer mortality, significant over- and underestimation are represented as respectively (+)/(++) or (−)/(−−), depending on the *p*-value (<0.05/<0.001). Smaller *p*-values indicate a lack of fit of the model.

that none of the patients was considered as having full thickness burns. The high *p*-value means that the model fits the data well ($p = 0.4568$). The ABSI-model fitted in both adults ($p = 0.5779$) as children ($p = 0.3495$). When all patients were considered as having full thickness burns, the model still fitted for children ($p = 0.3480$), but not for adults ($p = 0.0019$) nor overall ($p = 0.0011$). The Bull grid overestimated the number of deaths (33 deaths, were 28 were expected, $p = 0.0072$), especially among adults ($p = 0.0040$). Yet, the Bull-grid fitted well for children, although a small, non-significant, underestimation was found ($p = 0.4403$). The other three models (BOBI, Ryan and rBaux) significantly underestimated the number of deaths in all age groups ($p < 0.0001$).

4. Discussion

Although most mortality prediction models for burns have been developed on populations in highly developed countries, these models are certainly useful for severity assessment in other burn populations as well. These models give a bedside indication of severity for the individual patient, but are especially valuable for comparing populations. There are certainly important differences between burn cohorts, even within regions and countries considered to have the same standards of development: in Europe the overall mortality in hospitalised burn patients varied between 1.4 and 34% and in the Mediterranean region between 1 and 49% [12,48]. These differences may be due to different admission policies, demographics, burn characteristics, study criteria or be due to true differences in survival. Besides regional differences, the odds of survival also clearly changed (increased) over the last half century, in particular since the first outcome prediction models have been developed [2,8,12,15]. Not surprisingly, comparing outcome between different study populations is a difficult task to perform. The crude mortality rate of 10.7% in this Ghanaian cohort gives little information on neither severity nor the mortality risk.

Risk stratification and standardisation, as in mortality prediction models, enables to compare groups of patients with the same risk of death. Unfortunately, except for the study of Godwin, studies on burns in sub-Saharan Africa only report crude mortality risks (between 10 and 35%), and do not apply mortality prediction models, which makes objective comparison extremely difficult [17,49–54].

Although this Ghanaian burn population is clearly different from populations on which these five prediction models were developed (Table 4), they are certainly useful to put the Ghanaian data in perspective. It might even be of particular interest, since, in contrast to a worldwide increase in elderly

Table 4 – Demographic and burn characteristics of the Ghanaian cohort versus the development cohorts of the five prediction models.

	Crude mortality	Mean age	Mean TBSA	% Male	% inhalation injury	N
Ghanaian cohort	10.7%	17 years	26%	55%	0.8%	261
Bull 1971	6.3%	n.r.	n.r.	n.r.	n.r.	1922
ABSI 1982	15%	32 years	n.r.	72%	9%	590
Ryan 1998	4.0%	21 years	14%	69%	15%	1665
BOBI 2009	4.6%	34 years	11%	n.r.	9%	6227
rBaux 2010	3.7%	31 years	10%	70%	7%	39,888

n.r. not reported; TBSA, total burned surface area.

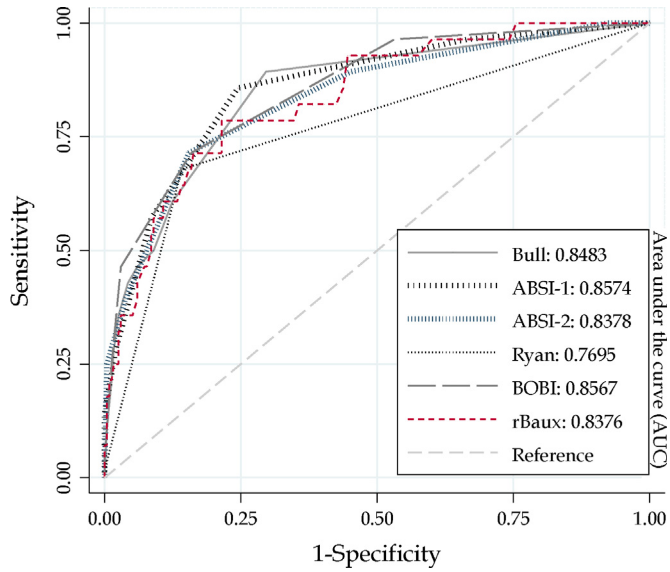

Fig. 1 – Receiver operator characteristics analysis of all five prediction models. ABSI, abbreviated burn severity index (ABSI-1: considering none of the patient as having full thickness burns, ABSI-2: considering all patients as having full thickness burns); BOBI, Belgian Outcome in Burn Injury; rBaux, revised Baux index.

burn patients [12,55–57], only few Ghanaian patients were older than 60 years, which explains why only few patients are in the higher risk categories. Due to the more restricted budget for specialised health care in developing countries, there is without any doubt, a difference in burn management, both for hospital and pre-hospital management, which may influence survival.

When evaluating these five prediction models, we do see a moderate to good discriminative power for all models, meaning that most patients who died were predicted to die. The model of Ryan performed less well than the others, which might be explained by the large focus on elderly patients (age was only considered a risk factor when older than 60 years). Consequently, the small number of risk categories (only four) appears to be a disadvantage.

The calibration of the five models, or goodness of fit, compared the number of expected deaths with those observed. These analyses showed an overestimation of the number of deaths in the oldest model (Bull), a rather well estimate by ABSI, and an underestimation in the three most recent models. This underestimation in the recent models was found both in adults and children. Thus, based on the most recent models (published after 1995), more deaths were observed than expected in the Ghanaian cohort. These findings might be in line with the increasing odds of survival over time, since the models do span a study period of almost 40 years, roughly locating the Ghanaian cohort on the timeline somewhere between the 1980s and 1990s. This is also suggested by the LA50 of 65%, which is similar in the studies of Curreri, Rashid and Galeiras et al. – yet higher in the older age groups. The more recent study of Roberts et al. reported a markedly higher LA50 (75%) [7–11]. Although merely an observation of a trend based on little data, these results suggest that there is still potential for improving survival in the Ghanaian burn population.

The most important limitation of this study is the small sample size ($N = 261$). Consequently, only few patients were older than 50 ($N = 14$). Besides the small sample size, this age group is also underrepresented due to the clearly different age distribution compared to burn cohorts in most highly developed countries. Another limitation is the retrospective study design. It could however be questioned if and how a prospective design would have influenced the outcome. A predicted high mortality risk might become a self-fulfilling prophecy, by restricting the efforts for those patients with the worst prognosis. On the other hand, there might be more therapeutic persistence in cases with a high probability of survival, depending on the availability of resources and policy. Therefore, statistical models should never replace clinical judgement. Another important limitation of this study is that no information is available on which patients do not get admitted to the burn unit. It is possible that an important proportion of the burn patients never reach the burn unit, although they would have been admitted in a more developed country. This could be the case for patients with a high probability of survival (which would improve the overall observed mortality risk), but also for patients who died. Unfortunately, it could not be assessed if this influenced the results. Other important outcome parameters such as short and long-term morbidity could not be assessed.

To put this study in a broader perspective, we would like to open the discussion which prediction model should be preferred. Since over 40 prediction models have been developed, and none of them will work perfectly on every burn population, we do not believe these models should be 'adjusted' for developing countries, and we do not believe yet another model should be developed One of the aims in burn care should be to improve the worldwide odds of survival of burn patients to the same level as in highly developed countries. We should also strive for a more objective and consistent scientific reporting of outcome, since if the same model (or limited number of models) is used, populations can more easily be compared, and important area for improvement may be detected more effectively (e.g. certain age groups, type of burns, etc.). In this era of increasing burn care costs and restricted health care budgets, mortality prediction models can also be used as an objective tool for quality assessment and benchmarking; since burns remain one of the most expensive pathologies to treat in hospital. Although burn care is not only about survival, especially in the developed world, everyone 'knows' that there are still considerable differences worldwide. Yet, crude mortality rates are insufficiently detailed, since they are highly dependent on the case-mix. The stratification in risk groups, as in mortality models, certainly provides a more objective comparison.

Although the (adjusted) ABSI model did perform rather well in this cohort, it might be wondered why risk factors such as gender and full thickness burns should be implemented in a prediction model, since these are not as strongly associated with mortality, especially compared with the other four models, which were based on only 2–3 risk of the most often reported risk factors for mortality (age, TBSA, inhalation) [1,14,23,27]. Although the (adjusted) ABSI model did perform rather well in this cohort, and in some other recent studies [39], it is based on an old cohort of patients (30 years), especially when considering the recent advancements in burn care which are likely to have led to improvements in survival, at least in the highly developed world. In addition, more clinical data are required, and not always available (e.g. full thickness burns in this Ghanaian cohort). In our opinion, mortality prediction models for burns should be easy-to-use and based on a minimal set of data, registered at admission, even for research purposes. Models requiring more detailed patient characteristics cannot be used when data collection is limited, and offer little additional benefit. Statistically complicated models, e.g. continuous scores instead of risk categories (although they can be grouped), may hamper implementation by clinicians with little statistical knowledge. Yet, when too few categories are used, the discriminative power may be lower.

To conclude, mortality prediction models are certainly useful for risk stratification and evaluation of mortality in burn cohorts originating from developing countries. Although these models have been developed on cohorts with specific patient and burn characteristics, they can be helpful for a more objective evaluation of other burn cohorts. Evaluation of the distribution of risk factors is therefore an essential part of outcome prediction. Without any doubt, several other factors are associated with an increased mortality risk, so clinical decision making should never be purely based on statistics. Yet, for research purposes, and 'guidance' of clinical decision making, we believe a simple model, based on a minimal set of variables and a limited number of risk categories, is to be preferred.

Conflicts of interest

None declared.

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