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Outcome analysis of 286 severely burned patients: retrospective study

286名嚴重燒傷患者的治療結果分析：回顧性研究

Objective. To evaluate the outcomes of severely burned patients treated at a regional burns unit and to develop a predictive model for survival and length of hospital stay for major burn patients in Hong Kong.
Design. Retrospective study.
Setting. Burns unit of a regional public hospital, Hong Kong.
Patients. Two hundred and eighty-six severely burned patients treated from March 1993 to February 2000.
Main outcome measures. Details of demographics, mechanism of burn, extent of burn, incidence of inhalation injury, length of hospital stay, and mortality rate were recorded and entered into a database. Stepwise logistic regression and linear regression were applied to develop a predictive model for mortality and morbidity, respectively.
Results. Of 286 major burn patients treated in this 7-year period, 25 patients died from their injuries, yielding a mortality rate of 8.7%. Stepwise logistic regression was applied to develop a predictive model for mortality. We found that inhalation injury, age, and total body surface area involvement were independent significant predictors of death. Accuracy of this predictive model reached 93%. Similarly, stepwise linear regression was used to develop a predictive model for length of hospital stay. Sex, inhalation injury, total body surface area of burn, and total body surface area^2 of burn were significant predictors of length of hospital stay (R^2=0.2). Only three patients' duration of hospital stay was more than three standard deviations from the predicted length of hospital stay.
Conclusion. A predictive model for mortality and length of hospital stay has been developed for major burn patients in Hong Kong. This model may help clinicians to counsel patients and relatives at an early stage of care, to provide a basis from which new treatment plans can be compared, and to facilitate efficient allocation of valuable medical resources.

目的：評估於一所地區醫院的嚴重燒傷患者的治療結果，並編製香港嚴重燒傷患者的存活與住院期的預測模型。
設計：回顧性研究。
安排：香港一所地區醫院燒傷科。
患者：286 名在 1993 年 3 月至 2000 年 2 月期間接受治療的嚴重燒傷患者。
主要結果測量：把人口統計學數據、燒傷機制、燒傷程度、吸入傷害的影響範圍、住院期長短及死亡率等資料記錄，並輸入資料庫。分別應用分析式邏輯回歸和線性回歸方法，以編製死亡率和併發症發生率的預測模型。
結果：在 7 年期間接受治療的 286 名嚴重燒傷患者中，有 25 人因傷死亡，死亡率為8.7%。死亡率的預測模型是使用分析式邏輯回歸方式編製的。我們發現吸入傷害、年齡和身體燒傷的總面積是死亡預測的獨立重要指標。本預測模型的精確度達到 93% 。利用類似方法，應用分析式線性回歸方法編製了一個住院期的預測模型。性別、吸入傷害、身體燒傷的總面積及身體燒傷的總平方面積是住院期的重要指標(R^2=0.2)。只有 3 名患者的住院期與預測模型推斷的超過 3 個標準差。
結論：有關香港嚴重燒傷患者的死亡率和住院期長短的預測模型已經編製出來。這模型有助於臨床醫生在治療早期為患者及其親屬提供建議，並為新治療方案的比較提供基礎，從而有效地運用寶貴的醫藥資源。

Key words:
Burns;
Length of stay;
Mortality

關鍵詞：
燒傷；
住院時間；
死亡率

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Introduction

Attempts at developing a predictive model for burn patients are usually fraught with frustration. On the one hand, the model should be simple enough to facilitate clinical application; on the other hand, it should encompass enough clinical variables to reflect the real situation. A good predictive model helps clinicians to counsel patients and relatives at an early stage of care. It also provides a basis from which new treatment plans can be compared. Accurate prediction of length of hospital stay (LOS) can facilitate efficient allocation of valuable medical resources.

In this study, we reviewed the outcomes of severely burned patients treated at a regional burns centre during a 7-year period from March 1993 to February 2000. Predictive models for mortality and morbidity were derived from these data. The aim was to develop a simple, objective, and reliable predictive model for morbidity and mortality in major burn patients in order to help us identify the crucial determinants of clinical outcome, to establish a basis for treatment standards, and to allow future comparison of new treatment strategies.

Subjects and methods

The Burns Unit of Prince of Wales Hospital is the major regional referral centre for burn injury in the eastern New Territories, Hong Kong. Besides servicing a population of 1.5 million, the unit also receives tertiary referrals from other regional hospitals in Hong Kong. The Burns Unit consists of 16 beds with two high-dependency beds. Burn patients presenting at the Accident and Emergency Department are managed by an on-call basic surgical trainee and patients in need of in-hospital treatment are reassessed by a plastic surgeon. Patients with inhalation injury and respiratory compromise which requires intubation are admitted directly to the Intensive Care Unit (ICU) for ventilatory support. Fluid resuscitation is carried out according to the modified Parkland's formula using Hartman's solution. Adequacy of fluid therapy is closely monitored and enteral nutritional support is started within 24 hours of admission. Burn wounds are cleansed with normal saline gauze and photographs are taken for documentation. Extent and depth of burns are assessed and charted serially. Superficial wounds are covered with tulle gras while deep wounds are dressed with silver sulphadiazine cream. Early surgery for burn wound excision and skin graft is performed routinely within 72 hours of injury if the patient's condition allows. Early mobilisation and splinting are instigated as soon as is appropriate.

The medical records of all acute burn patients admitted to the Burns Unit of Prince of Wales Hospital between March 1993 and February 2000 were reviewed retrospectively. Adult patients (age ≥15 years) suffering from more than 15% total body surface area (TBSA) of burn, children (age <15 years) with 10% or more TBSA of burn, and all patients with documented inhalation injuries were identified as having major burns and were recruited for the study. Inhalation injury was diagnosed by the presence of facial burns, singed nasal vibrissae, soot in the mouth, and a history of closed space injury. In most cases, bronchoscopic findings of airway oedema, inflammation, and mucosal necrosis were documented. Patients with inhalation injuries were intubated and admitted to the ICU for ventilatory support. Details of demographics, mechanism of burn, extent of burn, incidence of inhalation injury, LOS, and mortality rate were recorded and entered into a database. Statistical analyses were conducted using the Statistical Package for the Social Sciences (Windows version 9.0; SPSS Inc., Chicago, US). Stepwise logistic regression and linear regression were applied to develop a predictive model for mortality and morbidity, respectively. The different variables considered are listed in Table 1. As the variable (death) was categorical, multivariate logistic regression model was chosen and linked variables were eliminated in a stepwise fashion. Length of hospital stay was regarded as the most important parameter for measuring morbidity. There was a clinical impression that LOS directly corresponded to the length of posthospital rehabilitation and likewise the total days off work. The linear regression model was adopted for LOS to analyse all variables, and linked variables were eliminated in a stepwise fashion.

Table 1. Characteristics of all variables

Type	Variables
Categorical	Sex, mechanism of burn, caustic agent, inhalation injury, death
Interval	Age, age-groups, TBSA*, TBSA groups, length of hospital stay

* TBSA total body surface area of burn

Results

Patient profile

Altogether 1262 acute burn patients were admitted to the Burns Unit of Prince of Wales Hospital during the 7-year period between March 1993 and February 2000. There were 286 patients who suffered from major burns and were recruited for the study. Among them 206 were males and 80 were females with a male to female ratio of 2.58:1. The median age was 23 years (range, 1 month-93 years) and the

Table 2. Circumstances in which major burns occurred

Circumstance	Frequency (%)
Domestic	175 (61.2)
Industrial	61 (21.3)
Assault	11 (3.8)
Suicide	10 (3.5)
Play	9 (3.1)
Hill fire	6 (2.1)
Barbecue	4 (1.4)
Child abuse	2 (0.7)
STVJ*	2 (0.7)
Iatrogenic	1 (0.4)
Substance abuse	1 (0.4)
Others	4 (1.4)
Total	286 (100)

* STVJ Stevens-Johnson's disease

Table 3. Cause of burns

Cause	Frequency (%)
Scald	148 (51.7)
Flame	124 (43.4)
Chemical	7 (2.4)
Electrical	3 (1.1)
Unknown	4 (1.4)
Total	286 (100)

median TBSA of burn was 18% (range, 10%-95%). The median LOS was 21 days (range, 5-302 days). Forty-nine (17.1%) patients suffered from smoke inhalation injury that required immediate intubation and ventilatory support. As shown in Table 2, domestic and industrial burns were responsible for over 80% of major burns admission. While scalds caused 148 (51.7%) injuries, 124 (43.4%) patients were burned by flame (Table 3). One hundred and fifty patients required wound excision and skin graft. Among them, 51 patients had one operation and 99 patients had more than one operation.

Length of hospital stay

The variables listed in Table 1 correlated individually with the LOS using *t* tests and analysis of variance (ANOVA). Sex, inhalation injury, TBSA of burn, and $TBSA^2$ of burn were factors found to be significant predictors of LOS (R^2=0.2) and the final prediction model was as follows:

LOS=8.7 + 2.1(TBSA of burn) – 0.0018$(\text{TBSA of burn})^2$ + 16.7(Inhalation injury)* – 9.4(Sex)†

* = Inhalation injury (no=0, yes=1)
† = Sex (female=1, male=2)

Female sex, patients with inhalation injury, and larger burn size required a longer LOS.

According to the above formula, a man with 50% TBSA of burn would be hospitalised for 90.4 days (8.7 + 2.1[50] – $0.0018[50]^2$ + 16.7[0] – 9.4[2]), and an extra 16.7 days if he has an inhalation injury.

Mortality

Twenty-five patients died from their injuries, yielding a mortality rate of 8.7%. Seventeen were males and eight were females, ie a male to female ratio of 2.13:1. The median age was 48 years (range, 14-93 years) and the median TBSA of burn involvement was 76% (range, 15%-95%). Fifteen (60%) had smoke inhalation injury. Statistical analyses were performed comparing the survivors and non-survivors. We found that the mortality group had significantly larger burn size (P<0.001), a higher incidence of inhalation injury (P<0.001), and older age (P=0.004) compared to the survivors (Table 4).

Again, variables listed in Table 1 were analysed individually in relation to mortality. The Chi squared test was applied for categorical variables and the *t* test was used for interval data. Age^2, inhalation injury, and $TBSA^2$ of burn

Table 4. Statistical analyses of survivors and non-survivors

Characteristic	Survivors	Non-survivors	P value
Male:female	2.58:1	2.13:1	0.67
Median age (years)	23	48	0.004
Median total body surface area of burn	18%	76%	<0.001
Inhalation injury	13%	60%	<0.001

were significantly related to mortality. By using stepwise multivariate logistical regression, a predictive model for mortality was developed as follows:

Probability of death=$(1 + e^y)^{-1}$

where *e*=2.718, y=–3.6 - 1.7(inhalation injury)* + $0.001(\text{age})^2$ + $0.001(\text{TBSA of burn})^2$,

* = Inhalation injury (no=1, yes=0)

Older age, inhalation injury, and larger burn size were associated with a higher likelihood of mortality (Fig 1).

A 55-year-old patient with 50% TBSA of burn has a probability of death=0.56 ($[1 + 2.718^{-3.6-1.7[1]+0.001[55 \times 55] + 0.001[50 \times 50]}]^{-1}$), and his probability of death will increase to 0.87 if he has inhalation injury.

Discussion

This study attempted to develop a predictive model for mortality and LOS for local reference. In contrast with other studies,[1-6] which analysed the whole burn group to develop predictive models for treatment outcomes, we only recruited major burn patients. This was because the majority of our patients (>70%) suffered from small area burns that required only conservative dressing care and short hospital stay. If we formulated a predictive model based on a sample that was not at risk of death and had a short hospital stay, the sensitivity and accuracy of the model would be jeopardised.

We found that age^2, $TBSA^2$ of burn, and inhalation injury were significant predictive factors for mortality. Similar predictors were also reported by other authors, and inhalation injury was the unanimous predictive factor among all these studies.[2-7] Nevertheless, the predictive models developed from these authors had many variations. This may be partly due to differences in patient composition, and also reflects the lack of standardised burn care protocols among different institutions. One might argue that this phenomenon illustrates the need for an individualised predictive model for each institution, but one should not overlook the direction of future burn care development through multicentre collaborations.

Taking 95% confidence intervals, the accuracy of the overall predictive value for mortality was 93%. This was comparable to other studies.[3-6] Relatively few studies explored a predictive model for LOS except Wong and Ngim,[5] and they found similar predictors to this study.

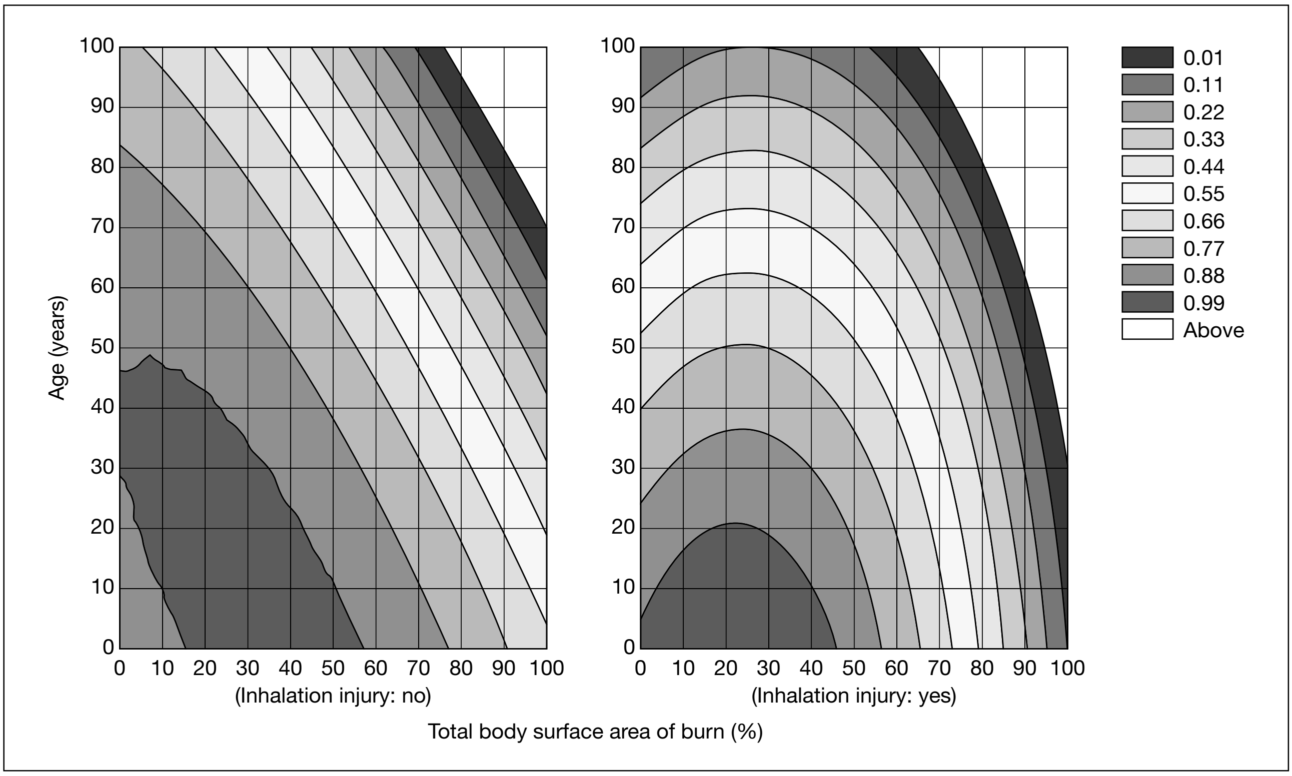

Fig 1. Probability of death with respect to age, total body surface area of burn, and inhalation injury status

Such similarity might be due to the fact that we had a similar burn patient population. In this study, only three patients had a LOS more than three standard deviations from the predicted LOS. Interestingly, age was not a predictor of LOS. This was due to the fact that patients suffering from larger surface area burns were mainly in the age-group 20 to 50 years, whilst patients suffering <20% TBSA of burn were more evenly distributed across the age-groups (Fig 2).

The outcome of burn care has been measured by mortality and LOS for many years. This has rendered mortality a moving target, as patients who would previously have been

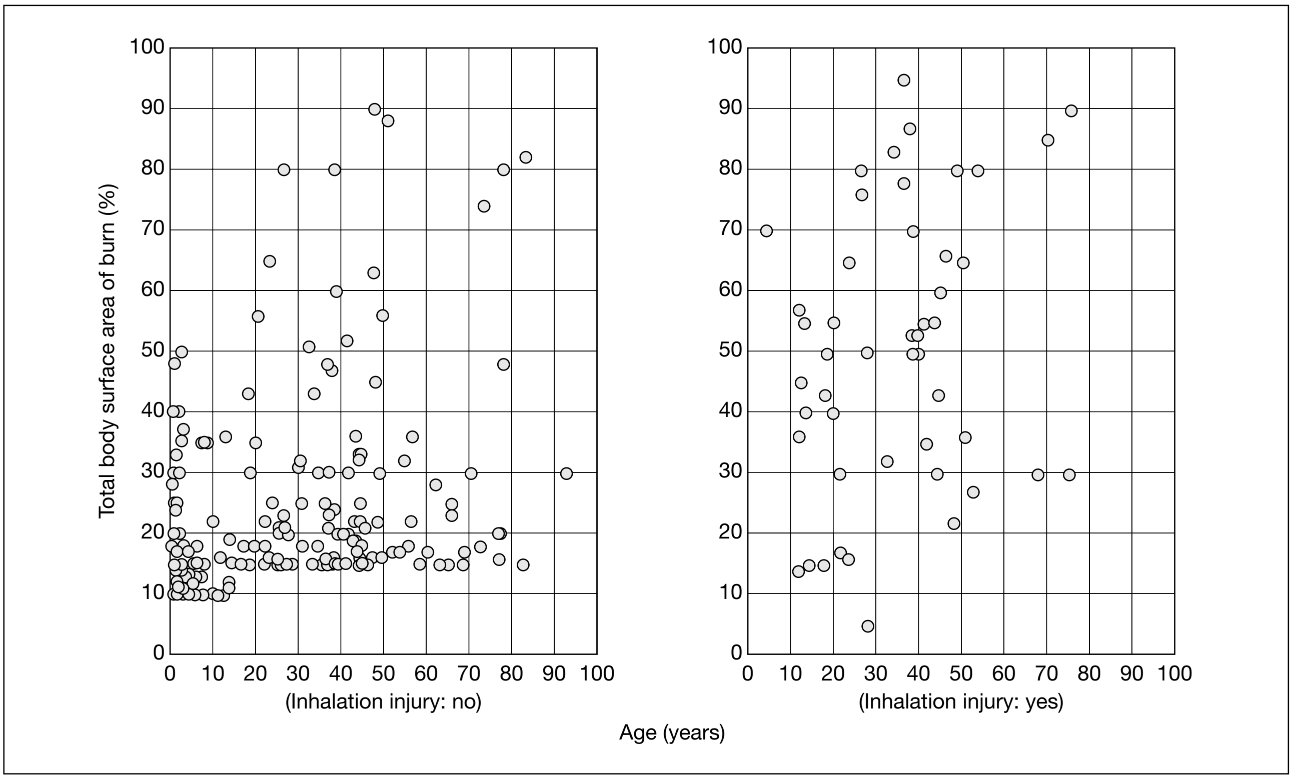

Fig 2. Scatter plot of total body surface area of burn against age

non-survivors can nowadays be saved and rehabilitated with good functional outcomes. If we continue on this path of improved care, the resources allocated to each burn centre will not be able to meet this increasing demand. Multicentre collaboration to develop standardised clinical management protocols and reliable predictive models for burn treatment outcome measurement is required. A final observation is that this study has looked at variables determined at presentation. It is, however, clinically apparent that the response to treatment is a major factor in determining outcome. The development of predictive models using clinical criteria will ultimately be more accurate, but to assess such an approach would necessitate a prospective multicentre trial.

Conclusion

A predictive model for treatment outcome in major burn patients has been developed based on local data. This model may assist burn surgeons to prepare treatment plans for their patients, and perhaps more importantly, help to identify which group of burn patients are unlikely to survive despite aggressive treatment.

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