

Mortality prediction and outcomes among burns patients from Australian and New Zealand intensive care units

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Throughout Australia, about 46 600 patients were hospitalised as a result of burns between 1999 and 2004.¹ The critical care management of burns patients is often technically demanding, resource-intensive and costly. Prediction of mortality in this group of patients could provide a framework to which resource utilisation could be provided and new therapies evaluated.² Previous mortality prediction models for critically ill burns patients have attempted to incorporate total burn surface area, inhalational injury, mechanical ventilation³ and age.^{4,5}

The Acute Physiology and Chronic Health Evaluation (APACHE) III scoring system is widely used to assess severity of illness of patients admitted to the intensive care unit and to compare risk-adjusted outcomes between ICUs.² Age, level of consciousness, biochemical, physiological, and chronic health variables from the first 24 hours of ICU admission are incorporated into the score. When combined with a specific diagnostic co-efficient, an individual's predicted risk of death can be estimated. APACHE III has been shown to be an accurate predictor of mortality for general ICU populations within Australia.⁶ Burns patients were excluded in the original design of APACHE III and were not assigned a specific diagnostic coefficient to allow calculation of a predicted risk of death. Consequently, there is also no specific information such as burns area included in the calculation of the APACHE score. Nevertheless, APACHE II and III scores have subsequently been shown to correlate well with mortality for patients with burn injuries, but neither has been used to develop an accurate "predicted risk of death" or used to compare outcomes.^{7,8}

The Australian and New Zealand Intensive Care Society (ANZICS) Adult Patient Database (APD) began in 1987 and is the largest single ICU data repository in the world. It holds approximately 900 000 ICU admission records from ICUs in Australia, New Zealand and Hong Kong.⁹ (A list of contributing ICUs can be found at http://www.anzics.com.au/downloads/doc_download/305-contributing-core-sites). The APD has included burns as a diagnostic subgroup since its creation. However, no specific information about percentage body surface area affected, inhalational injury or burn thickness is recorded. All regional burns units in Australia, New Zealand and Hong Kong, with the exception of one Australian unit that does not collect data for APACHE III-j (the 10th iteration of APACHE III), are repre-

ABSTRACT

Background: Acute Physiology and Chronic Health Evaluation (APACHE) III scores have been shown to correlate with outcomes for patients with burn injuries. It is unknown whether they can be used to compare outcomes between intensive care units that admit patients with burns in Australia and New Zealand.

Objective: To assess the APACHE III-j score as a predictor of mortality for burns patients and use it to compare risk-adjusted outcomes between different ICUs.

Design, setting and participants: Retrospective cohort study of all patients listed in the Australian and New Zealand Intensive Care Society Adult Patient Database with a diagnosis of burns between 1 January 2001 and 30 June 2008. Logistic regression analysis was used to assess the relationship between APACHE III-j score and mortality, and to derive a predicted risk of death for each patient. Standardized mortality ratios for individual ICUs were calculated and outcome variation assessed.

Results: Data on 1618 patients were included in the analysis (mean age, 40.6 years; mortality, 13.2%). Increasing APACHE III-j scores were significantly associated with increasing likelihood of death (odds ratio, 1.05 [95%CI, 1.04–1.06]). The largest ICU and two small ICUs had risk-adjusted outcomes that were significantly better than the rest. Over the study period there was a decline in observed mortality accompanied by a parallel reduction in predicted risk of death.

Conclusion: The APACHE III-j score is a good predictor of death among burns patients admitted to ICUs in Australia and New Zealand. It can be used to compare risk-adjusted outcomes between individual ICUs and over time.

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sented within the dataset. APACHE III-j is one of three scoring systems routinely recorded within the APD and used to compare risk-adjusted outcomes among all ICUs in Australia, New Zealand and, more recently, Hong Kong. It is unknown whether APACHE III-j can be used to benchmark performance for the specific population of patients with burns injuries admitted to the ICU.

The objectives of our study were to:

- assess the APACHE III-j score as a predictor of mortality among patients with burns;
- develop a mortality prediction tool using the APACHE III-j score;
- compare risk-adjusted outcomes for individual ICUs that admit patients with burns; and
- examine trends in outcome for patients with burns over time.

Methods

Data analysed

We conducted a retrospective cohort study of all patients listed within the ANZICS APD with a diagnosis of burns between 1 January 2001 and 30 June 2008. Patients were excluded from the analysis if there was no recorded outcome at hospital discharge or if the outcome was listed as "transferred to another ICU" (ie, the eventual outcome was unknown). Patients were also excluded if their ICU length of stay was less than 4 hours (in keeping with the APACHE III-j algorithm), if no APACHE III-j score was recorded, or the admission listed represented a readmission to the ICU.

All individual data were de-identified. Hospitals from all three countries were represented within the dataset, but the identities and locations of the individual hospitals were not known to the investigators. The study was reviewed and approved by the Human Research Ethics Committee of the Alfred Hospital, Melbourne, Australia (the site of the Victorian Adult Burns Service).

Mortality prediction model development

Logistic regression analysis was used to assess the relationship between APACHE III-j score and mortality and to develop a predicted risk of death for each individual patient. The model was developed on a random split of half of the available data, and the model performance was validated on the remaining unseen half. Discrimination of the model was assessed by the area under the receiver operating characteristic (ROC) curve, where an area greater than 0.8 indicated good discriminatory power. Calibration of the model was assessed with the Hosmer–Lemeshow *C* statistic, where a low *C* statistic (less than 10) and high *P* value indicated a well calibrated model.

Examination of risk-adjusted outcomes

The predicted risk of death was used to calculate standardised mortality ratios (SMRs) ($\text{SMR} = \text{observed deaths} \div \text{predicted deaths}$) for individual ICUs. An $\text{SMR} > 1$ indicated more deaths than predicted. SMRs for all units were displayed using a funnel plot with 95% and 99% confi-

dence intervals calculated around an SMR of 1. The x axis for the funnel plot represents the number of patients at each contributing ICU in the analysis. Confidence intervals were calculated using an *F* distribution, in keeping with standard methods for the ANZICS APD.

Changes in outcome over time were displayed using an exponentially weighted moving average (EWMA) chart using a weighting of 0.005, in keeping with standard methods for the ANZICS APD. Observed mortality was plotted on the y axis as a running mean of the previous observations, where the most recent observations were given exponentially more weight than historically distant observations. Control limits were derived from a similarly weighted running mean of the predicted risk of death (in this case, using the 95% and 99% confidence intervals). Specific details of the use of these charting techniques are described elsewhere.¹⁰ Descriptive data were presented as proportions, mean (SD) or median (interquartile range) where appropriate, depending on distribution.

Results

Between January 2001 and June 2008, there were 1944 admissions to Australasian ICUs recorded within the ANZICS APD. After exclusion of readmissions to the ICU and patients with unknown outcomes or no recorded APACHE III-j score, data on 1618 patients were available for analysis. Characteristics of these patients and overall outcomes are listed in Table 1.

The relationship between the APACHE III-j score and mortality is shown in Figure 1. Logistic regression analysis showed increasing APACHE III-j scores to be strongly associated with increasing risk of death (odds ratio [OR], 1.05 [95% CI, 1.04–1.06]; $P < 0.001$). The predicted risk of death for individual patients was derived from the APACHE III-j score using the coefficient (0.0496) and constant (–4.783) derived from the logistic regression. The model demonstrated high levels of discrimination in both the development and validation datasets, with areas under the ROC curves of 0.874 (95% CI 0.841–0.906) and 0.878 (95% CI, 0.843–0.914), respectively. A contingency table showing the performance of the prediction model over deciles of risk or the whole dataset is shown in Table 2. The prediction model was well calibrated, with a Hosmer–Lemeshow *C* statistic of 9.5 ($P = 0.487$).

SMRs (derived using the mortality prediction model) for all units that had reported admissions with burns are shown in Figure 2. Two smaller ICUs, with less than 30 admissions each, appeared to have outcomes better than predicted, with SMRs less than the lower 95% confidence interval. Both units reported no deaths for their patients. The largest unit had an SMR that lay exactly on the lower 95%

confidence interval, indicating a 97.5% likelihood that outcomes were better than predicted at this ICU. All other ICUs had outcomes within expected parameters.

There has been a reduction in predicted mortality since 2001 (Figure 3), accompanied by a decline in observed mortality. Over this period, observed mortality has generally remained within the expected range (as predicted by APACHE III-j scores), except during one period in 2005, when observed mortality transiently rose above the upper 95% confidence interval for predicted risk of death.

Discussion

Burns patients in Australian and New Zealand ICUs tend to have a prolonged stay.¹¹ We found that the APACHE III-j score was strongly associated with an increasing risk of death (Figure 1), and a mortality prediction model derived from the APACHE III-j score performed well, with good discrimination and calibration (Table 2). Predicting the risk of death in burns patients has previously used variables such as age, burn size, coexistent trauma, inhalational injury and the presence of pneumonia in model equations.¹² Mortality was a function of the number of risk factors present.¹³

We wanted to evaluate whether the risk of death could be predicted using only the APACHE III-j score, as the other characteristics such as total burns area, presence of inhalational injury, mechanism of burn and proportion of full thickness involvement are not routinely recorded in ICU admission data and are not included in the calculation of the APACHE III-j score. The APACHE III-j score incorporates

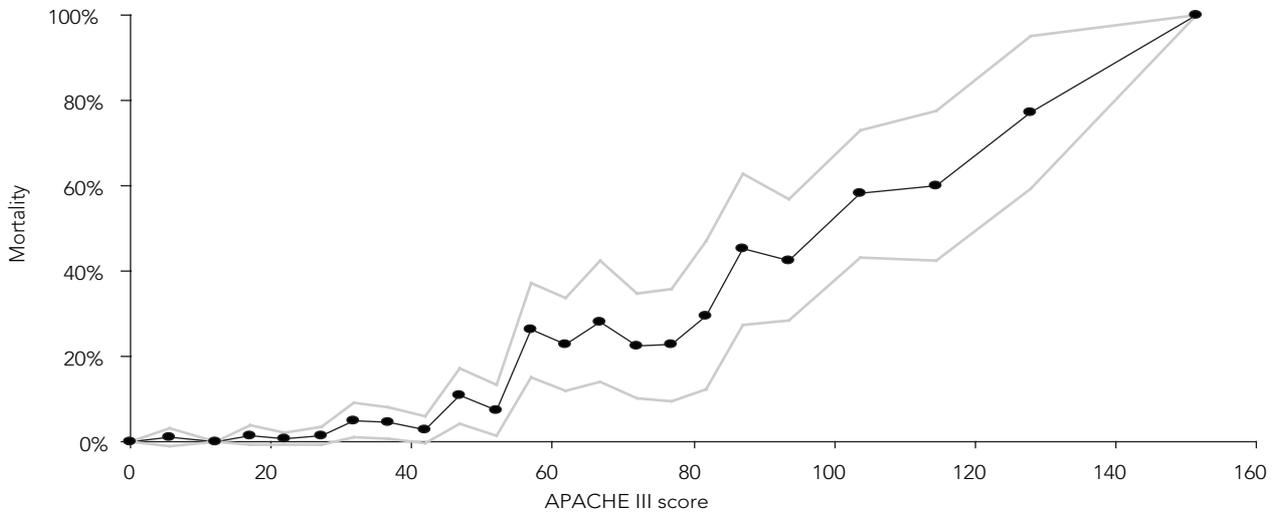
Table 1. Demographics of 1618 patients with burns admitted to 82 ICUs in Australia, New Zealand and Hong Kong, January 2001 to June 2008

| | |
|---|------------------|
| Number of ICUs admitting ≥ 10 burns patients | 20 |
| Number of ICUs admitting ≥ 50 burns patients | 6 |
| Deaths, <i>n</i> (%) | 213 (13.2%) |
| Male, <i>n</i> (%) | 1284 (79.3%) |
| Mean age (years) (SD) | 40.5 (18.1) |
| Mean APACHE III-j score (SD) | 43.9 (29.8) |
| Median length of ICU stay (days) (IQR) | 2.4 (0.9–8.8) |
| Median length of hospital stay (days) (IQR) | 16.3 (3.6–37.9) |
| Mechanical ventilation in first 24 hours of ICU admission, <i>n</i> (%) | 1060 (65.6%) |
| Mortality (patients ventilated in first 24 hours), <i>n</i> (%) | 169/1060 (15.9%) |
| Mortality (patients not ventilated in first 24 hours), <i>n</i> (%) | 44/558 (7.9%) |
| Source of admission to hospital, <i>n</i> (%) | |
| Home | 724 (44.7%) |
| Another hospital | 695 (42.9%) |
| Another ICU | 73 (4.5%) |
| Chronic care facility | 16 (1.0%) |

APACHE = Acute Physiology and Chronic Health Evaluation. ICU = intensive care unit. IQR = interquartile range.

points for level of consciousness, biochemical and physiological derangements, chronic comorbidities and age,² which have been used in burns mortality prediction models.¹² The effect of age and the presence of comorbidities, which

Figure 1. Relationship between Increasing APACHE III-j score and mortality*



APACHE = Acute Physiology and Chronic Health Evaluation. * Black dots represent mortality plotted by increments of five units in APACHE III-j score. Grey lines indicate 95% CIs.

compromise the body's ability to recover from a physiological insult such as a severe burn, have been described.^{4,12,14} A previous study of 86 burns patients, who had slightly higher mortality (15%) and mean age (> 50 years in survivors and non-survivors) than our cohort, found that APACHE III might be a useful predictor of mortality. (Patients with inhalational injuries were excluded from the analysis.)⁷ It was found that the APACHE III score of these patients worsened substantially with time and that the score at 24 hours may have underestimated the effect of the injury. Despite the suggestion that the natural history of burn injury is towards worsening physiological derangement after 24 hours, we found that the score evaluated within this time was predictive of the patients' outcome.

We had no specific data about the presence of inhalational injury, but in the critical care setting the early application of mechanical ventilation may be a more accurate prognostic indicator. A previous study among critically ill patients found that the requirement for early mechanical ventilation increased the risk of death six-fold, but that the presence of an inhalational injury was not associated with mortality.³ In our study, we found that two-thirds of patients were ventilated within the first 24 hours of admission, with a mortality of 15.9%, compared with a mortality of 7.9% in non-ventilated patients ($P < 0.001$). The requirement for mechanical ventilation and physiological abnormalities caused by a lung or systemic insult are represented in the APACHE III-j score. The physiological derangement

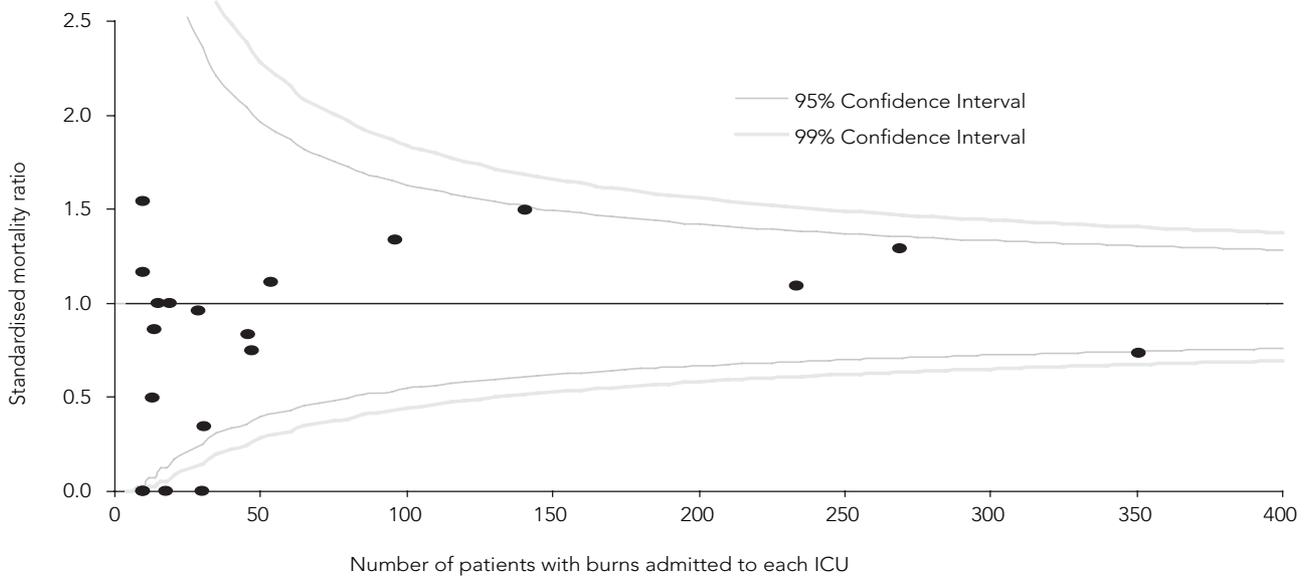
caused by an acute lung injury, such as increased respiratory rate or reduced arterial partial pressure of oxygen (P_{aO_2}), would take into account both the presence of a severe inhalational injury and an acute lung injury as a result of the insult. However, future research should validate our model in patients with known inhalational injury.

Table 2. Contingency table showing predicted number of deaths derived from logistic regression for APACHE III-j score and observed number of deaths*

| Decile of risk | Number of patients | Predicted deaths | Observed deaths |
|----------------|--------------------|------------------|-----------------|
| 1 | 139 | 2 | 1 |
| 2 | 176 | 3 | 2 |
| 3 | 167 | 4 | 1 |
| 4 | 159 | 5 | 2 |
| 5 | 155 | 7 | 8 |
| 6 | 164 | 9 | 5 |
| 7 | 166 | 14 | 13 |
| 8 | 165 | 22 | 38 |
| 9 | 158 | 42 | 45 |
| 10 | 169 | 104 | 97 |
| <i>Total</i> | <i>1618</i> | <i>212</i> | <i>212</i> |

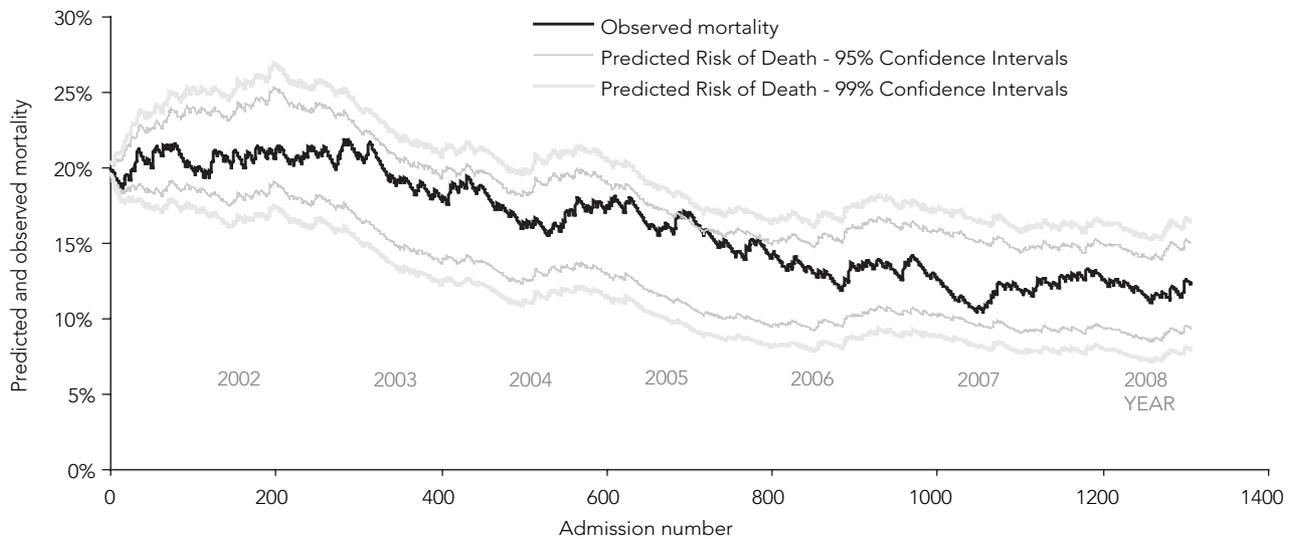
APACHE = Acute Physiology and Chronic Health Evaluation.
* Hosmer-Lemeshow C statistic = 9.5, $P = 0.487$.

Figure 2. Standardised mortality ratio* for patients with burns admitted to ICUs in Australia, New Zealand and Hong Kong, January 2001 to June 2008†



ICU = intensive care unit. * Observed deaths divided by predicted deaths. † Only hospitals with more than 10 admissions between January 2001 and June 2008 are shown. Light and dark grey lines represent 95% and 99% confidence intervals for the standardised mortality ratio.

Figure 3. Exponentially weighted moving average chart showing change over time for predicted risk of death derived from APACHE III-j score*



APACHE = Acute Physiology and Chronic Health Evaluation. * Light and dark grey lines represent 95% and 99% confidence intervals for the observed mortality.

The reduction in mortality in burns patients admitted to Australian and New Zealand intensive care units since 2001 (Figure 3) is comparable to outcomes among critically ill patients in Europe³ and elsewhere in Asia over a similar period.⁷ In the past 20 years, developments such as improved resuscitation, early surgery, nutritional support and novel skin replacement techniques have all improved outcomes.¹⁵ Year of admission may be just a surrogate marker for better ICU care over time, with good resuscitation and patient management resulting in a lower risk of death and better outcomes when measured by APACHE III scores taken 24 hours after ICU admission.¹⁶ However, the absence of specific information, such as burn surface area, limits the interpretation of these findings. We cannot tell whether our findings represent better surgical and resuscitative care of patients with the same severity of primary burn injury (resulting in lower APACHE scores and concomitant reduction in mortality), or alternatively, whether a greater proportion of patients admitted to the ICU in latter years have had less severe burns. (Less severe thermal injuries are likely to be reflected in lower APACHE scores and lower mortality.) In addition, the number of patients who died (either through inadequate treatment or as a consequence of appropriate early palliative care given when survival was not considered possible) before admission to the ICU was unknown and their impact on our study could not be assessed.

Nearly half of the ICU admissions in our study originated from other hospitals (Table 1). The location of patients prior to ICU admission is important, as burns management in Australian and New Zealand regional ICUs may vary with

regard to resuscitation, especially within the first 24 hours, and this may affect the outcome. The adverse effects of under- and over-resuscitation with regard to renal failure and abdominal compartment syndrome, respectively, have been described.¹⁷ The time delay (with more hours of resuscitation) may also mean that the physiological derangement may appear to be less among transferred patients, resulting in a lower APACHE score and lower predicted risk of death. This might bias results from the larger units towards appearing to underperform. Although the APACHE III-j score improves on APACHE II by incorporating a new patient's location weighting (aimed at correcting selection bias),² this may explain why the perceived benefits of transfer to a burns unit are not obviously reflected in our study and why there does not appear to be an obvious relationship between ICU patient volume and risk-adjusted outcome.

The majority of Australian and New Zealand ICUs had outcomes within expected 95% confidence intervals (Figure 2). However, a few (the largest ICU among them) appeared to have outcomes better than the rest of the group. It is worth noting that the calculation of appropriate confidence intervals for very small numbers is problematic. This limits the interpretation of the performance of the smallest units with SMRs below the 95% confidence interval. In addition, outcomes for each ICU represent data that have been aggregated over a 7-year period and may not reflect current practice or outcomes. The APACHE III-j score is dependent on the quality of the data recorded, and this may vary between units. Poor data collection and entry errors resulting in under- or over-scoring patients' APACHE III-j scores

will make a unit appear to under- or over-perform, respectively. The SMRs are also dependent on each unit accurately recording its outcomes. The quality of data collection at individual units was not known.

We cannot tell whether the variation in SMRs represents true variation in treatment between units. However, it is only by attempting to identify units that appear to be performing better (or indeed worse) than others that we can highlight practices that may improve care for all patients with burns. Other factors may be important, such as whether the burns unit also acts as a regional trauma centre, admitting patients with coexisting trauma and thus potentially increasing mortality.¹² Ideally, further work should look at both the APACHE data and burn severity information. This would also allow comparison of the APACHE III-j score as a predictor of death with other mortality prediction tools for burns patients such as the FLAMES (Fatality by Longevity, APACHE II score, Measured Extent of Burn, and Sex)⁸ or Burn Mortality¹⁸ scores, which was not possible from our study.

Conclusion

APACHE III-j scores can be used to predict risk of death in burns patients admitted to ICUs, even without the knowledge of burn surface area or inhalational injury. In addition, they can be used to examine risk-adjusted outcomes over time and between individual ICUs. However, future work should prospectively validate the role of the APACHE III-j score in mortality prediction for burns patients both alone and in conjunction with burns-specific information. Our retrospective analysis suggests that there may be scope to standardise the management of burns throughout Australia and New Zealand and to learn from the best-performing units. This may also facilitate decision making and strategic planning for resources in an area of the world where burn injuries continue to be a significant problem.¹⁹

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