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Original Contribution

Acute Care Diagnostics Collaboration: Assessment of a Bayesian clinical decision model integrating the Prehospital Sepsis Score and point-of-care lactate

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ABSTRACT

Previous research demonstrated that shock index and respiratory rate are highly predictive of intensive care unit admissions.

Objective: The objective of the study is to evaluate the integration of the prehospital sepsis project score (PSP-S) and point-of-care lactate in assisting prediction of severity of illness using Bayesian statistical modeling.

Methods: The PSP-S incorporates fever (38°C [100.4°F]) allotted with 1 point, shock index greater than or equal to 0.7 given 2 points, and a respiratory rate greater than or equal to 22 breaths per minute given 1 point for a total maximum score of 4 points. The patient population was stratified based on the PSP-S: 1 point is low risk, 2 points is moderate risk, and 3 to 4 points is high risk. Percentage risk was obtained based on intensive care unit admissions and used as pretest probability. Prehospital lactate pooled data were obtained and used to calculate likelihood ratio (LR). Percentage risk used as pretest probability and LRs for prehospital lactate were charted into the Bayesian nomogram to obtain posttest probabilities. Absolute diagnostic gain (ADG) and relative diagnostic gains (RDG) were then calculated.

Results: Pooled data for prehospital point of care lactate demonstrated a positive LR of 1.6 and negative LR of 0.44. Posttest probability for low risk was 16% with an ADG of 6% and RDG of 160%. Moderate risk population yielded a posttest probability of 47%, ADG of 12.5%, and RDG of 136.2%. High-risk population resulted in a posttest probability of 72%, ADG of 12%, and RDG of 120%.

Conclusion: We found that PSP-S can be clinically complemented with the use of point-of-care lactate.

1. Introduction

The care of the critically sick and injured often begins in the prehospital setting; several recent studies evaluate out-of-hospital predictive variables in critical illness, including diagnostic value of point-of-care lactate measurements [1-8] in predictors and interventions specific in the prehospital area [3-8]. Recent studies have also demonstrated that early aggressive fluid resuscitation can improve the outcomes of patients with sepsis [9,10].

Severe sepsis and septic shock are common and expensive medical problems [11,12]. With an estimated yearly incidence of 751 000 cases (3.0 per 1000 population) in the United States each year, severe sepsis and septic shock are associated with significant mortality and consumption of health care resources with estimated costs of $16.7 billion annually.

The initial component of the sepsis continuum is the systemic inflammatory response syndrome (SIRS). Initiated by a proinflammatory state, this condition is characterized by hypotension, tachycardia, tachypnea, hypo perfusion, oliguria, alterations in white cell count, thermal dysregulation, and the need for volume resuscitation, in the absence of a documented source of infection. Sepsis, severe sepsis, and septic shock are all considered a progression of SIRS [13,14]. Early identification and the institution of goal-oriented therapies can improve outcomes and mitigate progression to a state of shock and even multiorgan dysfunction [9-15].

The Acute Care Diagnostic Collaboration is a multinational effort that introduces a Bayesian method and statistical modeling [16] on pretest probability with Emergency Medicine Clinical Decision Rules, combined with assessments on diagnostic quality and cost-effectiveness of clinical diagnostic tools in various patient populations [17-21]. Using Bayes theorem, the initial clinical assessment is graded by means of probability, where merging clinical suspicion and diagnostic test likelihood ratios (LRs) result in improved clinical decision making.

The Prehospital Sepsis Project is a multifaceted study that aims to improve the out-of-hospital care of patients with sepsis by means of knowledge translation and enhancement of skills [22,23]. The Prehospital Sepsis Project score (PSP-S) was developed based on previous research [22] where it demonstrated that out-of-hospital shock index and respiratory rate are highly predictive of intensive care unit

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admissions for patients presenting sepsis. The objective of this study was to evaluate the integration of the PSP-S and prehospital point-of-care lactate in assisting prediction of severity of illness using Bayesian statistical modeling.

2. Methods

The PSP-S (Figure) was derived based on a prior study that used retrospective chart review of emergency medical services (EMS) patient care reports linked with emergency department (ED) and hospital admission records in a US academic medical center. Adult patients 18 years and older were identified using *International Classification of Diseases, Ninth Revision*, codes for sepsis, septic shock, or severe sepsis. Data extracted from the medical records include patient demographics and diagnosis. Emergency medical services charts were reviewed, and the following data were collected: referral source, level of provider, vital signs, serum glucose level, interventions initiated in the prehospital setting, the need for airway management/cardiopulmonary resuscitation/fluid resuscitation, and total prehospital time. Outcomes to be studied include mortality and hospital and/or intensive care unit length of stay. Institutional review board approval was obtained.

2.1. Subject selection

A retrospective review of 3 years of hospital data was used (2004-2006) to select cases of admitted adult patients (>18 years old) with a diagnosis of SIRS, sepsis, or septic shock who were transported to the hospital by EMS. Diagnosis was based on ED admission criteria and *International Classification of Diseases, Ninth Revision*, codes:

- 038.9 Sepsis/septicemia NOS
- 995.9 SIRS
- 995.91 SIRS w/o organ failure
- 995.92 SIRS with organ failure

Descriptive statistics and SDs were used to present group characteristics. χ^2 Test was used for statistical significance; and odds ratio, to assess strength of association. Statistical significance was set at the 0.05 level. Physiologic variables studied included shock index, mean arterial pressure, heart rate, and respiratory rate. Posttest probability (Post) was obtained from Bayesian statistical modeling integrating low, intermediate, and high pretest for the PSP-S and LRs for point-of-care lactate. Relative diagnostic gain (RDG) and absolute diagnostic gain (ADG) were calculated based on the differences deducted from pretest and posttest probabilities (ADG = Post − Pre), (RDG = 100 × ADG/Pre). SPSS for Windows version 20.0 (IBM Corp, Armonk, NY) was used for analysis and modeling. Ethics committee approval was obtained, under a minimal risk protocol.

The PSP-S was developed integrating fever, respiratory rate, and shock index. Fever is defined as core body temperature of greater than or equal to 38°C (100.4°F) and is the only obligate variable allotted with 1 point. Shock index greater than or equal to 0.7 is given 2 points, and a respiratory rate greater than or equal to 22 breaths per minute is given 1 point for a total maximum score of 4 points (Figure). The patient population was stratified based on the PSP-S: 1 point is low risk, 2 points is moderate risk, and 3 to 4 points is high risk. Percentage risk was obtained based on PSP-S and used as pretest probability.

The Prehospital Sepsis Score	
☐ body temperature ≥ 38°C/100.4°F (Obligate item)	1 point
☐ Respiratory Rate ≥22 BPM	1 point
☐ Shock index ≥0.7	2 points

Figure. Prehospital sepsis score system (a score of 4 prompts activation).

3. Results

Pooled data for prehospital point-of-care lactate demonstrated a sensitivity of 76% and a specificity of 55% [3], yielding a positive LR of 1.6 and negative LR of 0.44 (Table 1). Integration of the PSP-S and point-of-care lactate was inserted in a Bayesian Nomogram for calculation of posttest probabilities. Using positive LR, posttest probability for low risk was 16% with an ADG of 6% and RDG of 160%. Moderate-risk population yielded a posttest probability of 47%, ADG of 12.5%, and RDG of 136.2%. High-risk population resulted in a posttest probability of 72%, ADG of 12%, and RDG of 120% (Table 2). Low-risk cohort and negative LR for prehospital lactate of 0.44 yielded a posttest probability of 5% and RDG of 50%. The moderate-risk group had a posttest probability of 19% and RDG of 55.1%. We also found that patients in the high-risk population (based on PSP-S) had a posttest probability of 40% and RDG of 66.7% (Table 3).

4. Discussion

In a 2001 study, Rivers et al [15] demonstrated that aggressive resuscitation and early goal-directed therapy of patients with severe sepsis or septic shock resulted in an absolute mortality reduction of 16%, an effective reduction in the incidence of multiorgan dysfunction, and a decline in the use of health care resources. Since then, several studies have looked at the value of aggressive simple interventions such as early identification and fluid resuscitation in the first 3 hours of care of the patient with sepsis syndromes [9,10]. The surviving sepsis campaign guidelines recommend a "3-hour bundle" that includes early identification and fluid resuscitation [9]; our study group believes that this bundle is amenable to initiation in the prehospital setting, which would lead to earlier, more aggressive resuscitative care and the potential to positively affect outcomes.

Although care of the sick and injured often begins in the prehospital setting, there are limited data available related to predictors and interventions specific to sepsis in the prehospital work environment. Knowledge of sepsis is relevant to the EMS provider, as the prehospital team has first contact with the patient. Improved recognition of the sepsis would allow the EMS team to appreciate the patients' acuity and, presumably, lead to a more informed decision but also would allow for improved communication between the crew and medical control or the receiving facility.

Analogous to prehospital alert protocols for trauma, stroke, or patients with myocardial infarctions [24,25], improved recognition of sepsis may not only decrease time to treatment but also allow for advance notice to be provided to the receiving ED. As sepsis has been increasingly recognized by the medical community as an illness that requires immediate treatment and a large amount of resources, advance notification from EMS providers that they are transporting a septic patient may allow the receiving hospital to prepare for their arrival.

Studies look at out-of-hospital predictive variables in critical illness, including diagnostic value of point-of-care lactate measurements [1-8] and predictors and interventions specific to sepsis in the prehospital arena [7,8].

Lactate measurements have been validated as hypoperfusion surrogates and severity of illness indicators. Casserly et al [1] found that serum lactate was commonly measured within 6 hours of presentation in the management of severe sepsis or septic shock in a subset analysis of the Surviving Sepsis Campaign database demonstrating that elevated

Table 1
Prehospital point-of-care lactate diagnostic values

Sensitivity, specificity, and LRs for diagnostic test				
Diagnostic test	Sensitivity	Specificity	LR (+)	LR (−)
Prehospital lactate	0.76	0.55	1.69	0.44