



Original Contribution

Soft tissue oxygen saturation to predict admission from the emergency department: A prospective observational study



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ABSTRACT

Objective: We evaluated a soft tissue oxygen saturation (Sto2) measurement at triage for predicting admission to the hospital in adults presenting to the emergency department (ED) in addition to data routinely gathered at triage.

Methods: This was a prospective, observational, single center study of adults presenting to the ED for evaluation. Research assistants obtained thenar eminence Sto2 measurements on subjects in ED triage. ED providers not involved in the study then made all management and disposition decisions. We prospectively collected data on each subject's final ED disposition (admission versus discharge). We identified the optimal Sto2 cutoff value for predicting admission. We then used logistic regression modeling to describe the added predictive value of Sto2 beyond routinely collected triage data including Emergency Severity Index level, age, and vital signs.

Results: We analyzed 2588 adult (>17 years) subjects with 743 subjects (28.7%) admitted to the hospital. Sto2 < 76% was the optimal diagnostic cutoff for predicting admission. Of subjects with Sto2 < 76%, 158 of 384 (41.1%) underwent admission versus 585 of 2204 (26.5%) subjects with Sto2 ≥ 76. After controlling for age, vital signs, and ESI level in the logistic regression analysis, Sto2 < 76% had an odds ratio of 1.54 (95% confidence interval (CI), 1.19 to 1.98) for predicting admission.

Conclusions: Sto2 may provide additional prognostic data to routine triage assessment regarding the disposition for undifferentiated adult patients presenting to the ED.

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1. Introduction

1.1. Background

Near-infrared spectroscopy (NIRS) uses light spectroscopy to evaluate relative amounts of oxyhemoglobin and deoxyhemoglobin. This technology has mostly been studied during resuscitation to identify regional tissue hypoxia as a potential early precursor to shock before systemic signs or lab abnormalities are present [1]. Decreased Sto2 measurements in various trauma populations have been associated with a range of clinical outcomes to include development of multi-organ dysfunction syndrome (MODS), requirement for blood product transfusion, or requirement of emergent surgery [2–6]. Sto2 < 75% has

been associated with the development of MODS in ED trauma patients [7]. A meta-analysis of Sto2 measurements at the thenar eminence found that patients with sepsis had lower Sto2 values [8]. Sto2 < 75% after resuscitation is associated with increased mortality in patients with severe sepsis or septic shock [9]. Limited data is available regarding this technology's utility for prognosticating outcomes among undifferentiated ED patients who have not yet undergone resuscitation.

1.2. Importance

Accurate ED triage is essential to guiding timely care and resource management in the setting of high patient demand for ED resources [10]. Sto2 is a rapid, noninvasive test which could provide prognostic information in addition to that provided by validated ED triage assessment tools such as the Emergency Severity Index (ESI) [11,12].

1.3. Goals of this investigation

The objective of this study was to evaluate the additional prognostic information provided by a single Sto2 measurement at triage in the

Abbreviations: Sto2, soft tissue oxygen saturation; NIRS, near-infrared spectroscopy; MODS, multi-organ dysfunction syndrome; ESI, Emergency Severity Index; CI, confidence interval.

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setting of routine triage data to identify adult patients presenting to the ED requiring hospital admission. In accordance with the existing Sto2 literature, we anticipated that utilization of Sto2 as a binary variable would provide better prognostic value than as a continuous variable [7,9,13]. Therefore, our a priori goal was to determine the optimal Sto2 cut-off value for identifying subjects requiring admission and use this value to analyze the predictive power of Sto2 beyond that provided by routine triage data. We hypothesized that patients with Sto2 values below the optimal cut-off would be more likely to undergo hospital admission than patients with Sto2 values above the optimal cut-off even after controlling for other routinely collected triage data such as vital signs, age, and ESI.

2. Methods

2.1. Study design and setting

This was a prospective, observational, single center study conducted at San Antonio Uniformed Services Health Education Consortium. This facility is an urban tertiary care hospital serving active duty military personnel, retirees, and beneficiaries in the San Antonio metropolitan area. The annual ED census during the study period was 76,959 patients. The hospital institutional review board approved the study protocol. We adhered to strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement guidelines in our research design, reporting, and analysis [14].

2.2. Selection of participants

We enrolled a convenience sample of adult patients presenting to the ED from November 2012 to November 2013. All adults (>17 years old) presenting to the ED during this time period were potentially eligible for inclusion. We excluded patients with cardiac arrest, major trauma activation, peripheral vascular disease, amputated upper extremities, skin abnormalities at the thenar eminence, or clinical evidence of intoxication.

Two research assistants screened adults presenting to the ED and obtained consent from all subjects during 112 shifts covering 8 h periods when research assistant staffing was available from Monday through Friday between the hours of 8 AM and midnight. Research assistants collected an Sto2 reading at triage and recorded the chief complaint and initial vital signs for each subject. Triage nurses assigned each subject an ESI score as part of routine ED triage processes using ESI version 4, (Agency for Healthcare Research and Quality, Rockville, Maryland) [15]. In the event that the patients actively undergoing triage outnumbered the research assistants, we instructed the research assistants to screen the most recently triaged patient. Research assistants prospectively collected data on each subject to include discharge diagnosis, and subject disposition (binary variable: admission versus discharge). All enrolled subjects received routine care from our institution. Treating providers were not privy to the Sto2 result, so these data were not available for diagnostic decision making.

2.3. Methods of measurement

Research assistants applied the tissue saturation oximeter, (Inspectra Model 300 Sto2 Spot Check, Hutchinson Technology Inc., Hutchinson MN) to the thenar eminence of each participant. The research assistants obtained these measurements in a standardized fashion. Specifically, patients were in a relaxed position several minutes prior to this measurement and held the measured arm flat on the bed during the Sto2 measurement to reduce variability in measurements. This handheld device uses NIRS technology to measure an approximate percent oxygen saturation (0–99%) of the hemoglobin circulating in the thenar muscle [16,17]. We chose the thenar eminence given its previous validation as a Sto2 measurement site [7,18,19].

We coded free text chief complaint data recorded by nursing staff in accordance with the most common reasons for ED visits from the National Hospital Ambulatory Care Survey (NHACS) [20]. We coded final diagnosis data according to primary diagnoses from the NHACS [20]. A second evaluator used a random number generator and coded 10% of the data. We calculated measures of inter-rater reliability (kappa coefficients) for both of these variables.

2.4. Outcome measures

Our primary outcome was the binary variable of subject disposition from the ED: admission versus discharge. We defined admission as subject transport from the ED to an inpatient care floor or to another hospital for further care. We stored all data in a secure Excel database (version 14; Microsoft, Redmond, WA).

2.5. Data analysis

The primary analysis evaluated the test characteristics of Sto2 to predict admission to the hospital. We described continuous variables with means, ordinal variables with medians, and nominal variables with frequencies or percentages. We used bootstrapping techniques to calculate 95% confidence intervals (CIs) around main outcomes and differences in baseline characteristics [21]. We performed multivariate logistic regression on the decision of patient admission. We added terms in a step-wise fashion using forward model-selection procedure to keep the model as parsimonious as possible and to assess the stability of the statistical estimates across multiple model specifications [22]. We included Sto2, age, temperature, heart rate, blood pressure, and ESI as explanatory terms. We treated Sto2 as a curved exponential parameter and calculated the profile log-likelihood for all cutoff values from 0% to 99%. We constructed a plot of the resulting curve to evaluate the appropriateness of analyzing Sto2 as a continuous variable (indicated by a plateau) versus a binary variable with evidence of an optimal cut-off value (indicated by a peak) [23]. We used R (version 3.3.1, Foundation for Statistical Computing, Vienna, Austria) for all data analysis [24]. We excluded subjects with missing data from the final analysis.

Our sample size estimate assumed $\alpha = 0.05$, $\beta = 0.20$, and two-sided statistical testing. We powered our study to detect a 5% difference in probability of admission for subjects with Sto2 values above versus below the diagnostic cutoff. We anticipated a 17% admission rate based on internal performance improvement data. Our estimated sample size was 2046 subjects.

3. Results

3.1. Characteristics of study subjects

Approximately 6430 patients presented to the ED during the 112 shifts of active enrollment. We calculated this value by subtracting total pediatric visits from our total ED census during the study period, (76,595 minus 13,671), and multiplying this result by hours of active enrollment divided by total hours of the study period. Ultimately, 2968 screened subjects were eligible for the study. Of the eligible subjects, 326 declined consent, and we excluded 54 subjects due to missing data. We included 2588 subjects in the final analysis (Fig. 1). Seven hundred forty-three subjects (28.7%) underwent admission. Older subjects and males were more likely to experience admission (Table 1). Mean Sto2 was 79.4% in admitted patients (standard deviation 5.3%) compared to 80.4% in not admitted patients (standard deviation 4.8%). When stratified by ESI level, the median Sto2 values were lower in admitted patients than not admitted patients across each ESI level with more divergence noted in patients with ESI 1 or 5 (Fig. 2).

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