American Journal of Emergency Medicine 37 (2019) 506–509

Contents lists available at ScienceDirect

American Journal of Emergency Medicine

journal homepage: www.elsevier.com/locate/ajem

Brief Report

# Respiratory adjusted shock index for identifying occult shock and level of Care in Sepsis Patients

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ARTICLE INFO

*Article history:*
Received 3 October 2018
Received in revised form 20 December 2018
Accepted 14 January 2019

*Keywords:*
Sepsis
Screening
Shock index

ABSTRACT

*Objective:* Early identification of shock allows for timely resuscitation. Previous studies note the utility of bedside calculations such as the shock index (SI) and quick sepsis-related organ failure assessment (qSOFA) to detect occult shock. Respiratory rate may also be an important marker of occult shock. The goal of our study was to evaluate whether using a modified SI with respiratory rate would improve identification of emergency department sepsis patients admitted to an ICU or stepdown unit.

*Methods:* A prospective, observational cohort study of the respiratory adjusted shock index (RASI), defined as HR/SBP × RR/10, was conducted. RASI was calculated from triage vital signs and compared to serum lactate. Primary outcome was admission to a higher level of care defined as ICU or stepdown unit. A multivariable logistic regression model including RASI, SI, lactate, age and sex was performed with disposition as the outcome variable. Areas under the curve (AUC) were calculated to detect occult shock and level of care for RASI, SI, and qSOFA.

*Results:* 408 patients were enrolled, 360 were included in the analysis. Regression analysis revealed that lactate (OR 1.55, $z = 4.38$, $p < 0.0001$) and RASI (OR 2.27, $z = 3.03$, $p < 0.002$) were predictive of need for higher level of care. The AUC for RASI, SI, and qSOFA to detect occult shock were 0.71, 0.6, and 0.61 respectively. RASI also had a significant AUC in predicting level of care at 0.75 compared to SI (0.64) and qSOFA (0.62).

*Conclusions:* RASI may have utility as a rapid bedside tool for predicting critical illness in sepsis patients.



## 1. Introduction

Sepsis is the 11th leading cause of death and among the costliest disease conditions across U.S. hospitals [1]. Emergency physicians play a crucial role in early identification and management of sepsis. Timely resuscitation in the emergency department (ED) has been associated with significant improvement in near and long-term patient outcomes, such as mortality and hospital length of stay [2,3]. Given the importance of time-sensitive interventions and treatments, past work has sought to create early identification schemes in the ED. While vital signs are a key component in identifying shock, they often do not change until later in a patient's course of illness [4]. One commonly used index, the shock index (SI) [heart rate (HR) / systolic blood pressure (SBP)] assesses shock severity with a normal range defined as 0.5–0.7 [5]. It presents a sensitive marker for occult hypoperfusion states compared to individual vital signs alone [6]. The SI has already been applied to trauma patients to determine severity of illness and has been extrapolated to sepsis and post-intubation patients [5,6]. The limitations of SI pertain to cardiovascular compensation, especially in younger patients. This means that as SI increases, the patients are already starting to declare their hypo-perfused state, often obviating the need for the screen itself.

Prior studies have found that tachypnea is a predictor of cardiac arrest both in and out of hospital wards, often presenting before changes in heart rate or systolic blood pressure [7-10]. While tachypnea has been thought to represent a sensitive marker of critical disease and has been used in some scales, such as the quick Sequential Organ Failure assessment (qSOFA) score and SIRS criteria, few bedside screening measures of sepsis have broadly attempted to include respiratory rate in the past [11]. A recently developed assessment of disease severity called the Respiratory Adjusted Shock Index (RASI), integrates the use of respiratory rate along other markers of acute physiologic stress assessed in the SI and has been found to successfully identify occult shock – as defined by elevated lactate - in a cohort of trauma patients [12]. We sought to build on this work by examining if using such a bedside tool as the RASI would help identify clinical course in another disease process such as potential sepsis. Specifically, the goal of our study was to

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https://doi.org/10.1016/j.ajem.2019.01.026
0735-6757/

evaluate if RASI score calculated in suspected ED sepsis patients predicted subsequent hospital disposition to a stepdown or intensive care unit (ICU) level.

## 2. Methods

### 2.1. Study design

A prospective observational cohort study was performed. The study was reviewed and approved by the institutional review board and waiver of informed consent and authorization were granted.

### 2.2. Study setting and population

Between July 2017 to January 2018, patients presenting at a single academic adult emergency department in New York City deemed to have a suspicion for sepsis by the treating provider and who had an initial lactate drawn within the first hour of care were included. Physicians were prospectively asked to identify eligible patients that they suspected had an infection, including possibly sepsis. Pediatric patients were excluded. Any patient who may have had an elevated lactate for reasons other than sepsis (e.g. bleeding, cardiogenic shock etc. as determined by review of the patient's ultimate admission or discharge diagnosis) were also excluded.

### 2.3. Measurements/outcomes

The RASI score was calculated by HR/SBP*(RR/10). RASI was calculated from triage vital signs for eligible patients and compared to serum lactate drawn within 1 h of ED presentation. Primary outcome was final ED disposition. Final disposition was operationalized into two categories – those at a general level of care who were admitted to the floor and those with more critical illness as defined by requiring a higher level of care (i.e. admission to stepdown or ICU). Data collected on patients who were discharged home were removed from the final data analysis. Final emergency department admission or discharge diagnosis of infection was confirmed by chart review. Patients were not followed beyond emergency department disposition. No intervention or change in management was performed on study participants.

### 2.4. Data analysis

Descriptive statistics including demographics, lactate, and white blood count levels were recorded. Variables included were based on literature review of potential variables that have been examined in the past for association with severe sepsis including demographics such as age, white blood cell count, and lactate level. We coded the following variables as continuous (age, WBC, RASI, lactate level) and the following variable as categorical (sex). The association between RASI score and hospital disposition was analyzed by logistic regression with RASI as a predictor and hospital disposition as outcome. Correlation of RASI and lactate was also recorded with “occult shock” being defined as an elevated lactate >2. Receiver operator characteristics and area under the curve (AUC) were created for test characteristics and comparative states for RASI, shock index, and qSOFA. Bland-Altman was used to determine agreement between lactate and RASI to determine level of care.

## 3. Results

408 participants were included in the study. Of the original 408 sample, 48 individuals were discharged home and subsequently removed from data analysis, leading to an updated sample of 360. Average age was 62 years old (median 63, SD 18.4 years; min 20; max 99). 174 participants were female (48.3%), 186 were male (51.7%). Fifty-three patients were admitted to a higher level of care, defined as stepdown and ICU, including three patients who expired in the emergency room. Average age of this cohort was 66 years old and 51% were female. Of those with a lower level of care, average lactate was 2 (median 1.7; SD 1.1). Those with more critical illness had an average lactate of 4.1 (median 2.88; SD 3.4).

Using a logistic regression model with higher level of care disposition as the outcome variable, lactate level significantly predicted subsequent higher level of care disposition (OR 1.55, $z = 4.38$, $p \leq 0.0001$) adjusting for age, sex, and serum white blood cell count. In this model, RASI also significantly predicted disposition after being adjusted for age, gender, white blood cell level, and lactate level (OR 2.27, $z = 3.03$, $p \leq 0.002$) (Table 1). Pearson's correlation between RASI and lactate was low ($r = 0.24$) however, suggesting these variables were not significantly associated. Bland-Altman analysis demonstrated the two measures of determination of level of care (i.e. lactate and RASI) though not highly correlated, are in agreement (Fig. 1). RASI also had a significant AUC in predicting level of care at 0.75 compared to shock index (0.64) and qSOFA (0.62) (Fig. 2). The AUC for RASI, SI and qSOFA to detect occult shock were 0.71, 0.6 and 0.61, respectively.

## 4. Discussion

Our study found that RASI scores significantly predicted ED disposition in a sample of patients with suspected sepsis. While existing tools such as the shock index have been found to aid in the identification of sepsis in the ED [13], such scoring systems may be less sensitive identifying patients with early/occult shock as it relies largely on cardiovascular measures that may not change until later on in a patient's course of illness [14]. This study represents a new application for RASI in a novel patient population (i.e. suspected sepsis).

In our study, we integrated respiratory rate into the shock index, and found greater predictive ability of RASI for identifying ED sepsis patients who ultimately were dispositioned to a higher level of care compared to lactate alone, as well as compared to other common bedside screening instruments such as the SI and qSOFA. RASI was not found to be significantly correlated with lactate, however the Bland-Altman analysis demonstrates agreement between the measures, suggesting that both assessments can be used to significantly predict hospital disposition in ED patients with sepsis. A possibility for this agreement yet lack of correlation is that while both lactate and RASI may be capturing much of the same underlying pathology of disease, potential differences in time to manifestation may exist with regards to changes in serum circulating lactate versus dynamic vital sign changes [15]. Future research exploring such relationships may elucidate the potential associations between such variables in sepsis.

The findings of our study build on the existing literature using rapid bedside screening assessments for potential sepsis severity [5,6]. By including a commonly assessed vital sign, respiratory rate, clinicians may gain additional information with regards to potential clinical prognosis and course for suspected sepsis patients in the ED. Given the existing collection of respiratory rates and the ease of calculation at the bedside, applications for the RASI in sepsis patients include its use in early triage systems to detect early potential sepsis. This could easily by integrated into triage and care systems that utilize physician extenders and nurses. When used in conjunction with clinical judgement and other testing in the ED, such as serum lactate and blood gas, RASI helps to complement

**Table 1**
Logistic regression for RASI and level of care disposition

| Dispo | Odds ratio | Std. error | Z | P | 95% CI |
|---|---|---|---|---|---|
| RASI | 2.272 | 0.616 | 3.03 | 0.002 | 1.34–3.87 |
| AGE | 1.005 | 0.010 | 0.50 | 0.617 | 0.99–1.02 |
| SEX | 0.866 | 0.295 | −0.42 | 0.674 | 0.44–1.69 |
| WBC | 1.008 | 0.019 | 0.42 | 0.672 | 0.97–1.05 |
| LACT | 1.551 | 0.156 | 4.38 | 0.00 | 1.27–1.89 |
| LR-52.11 | | | | | |

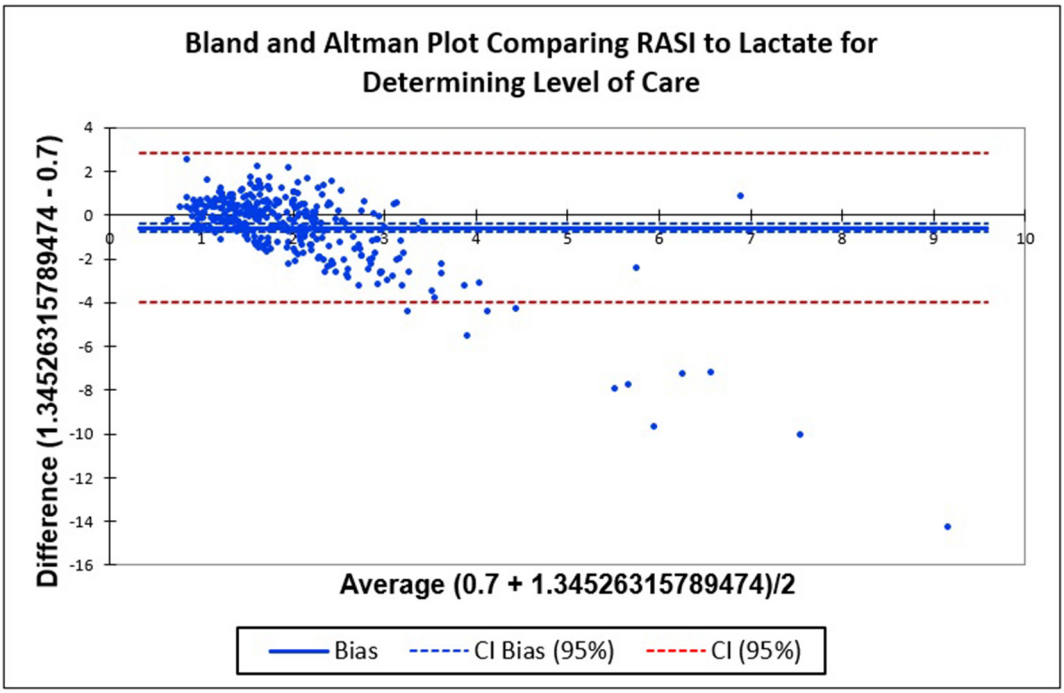


**Fig. 1.** Bland and Altman plot comparing RASI to lactate for determining level of care.

these tools by offering a quick and easily applied assessment that can be calculated immediately on patients' ED arrival.

### 4.1. Limitations

This study was a single site study conducted at an urban medical center which may raise questions of generalizability in different clinical environments and local disease prevalence. Our choice of primary outcome being level of care could be influenced by other confounding factors such as bed availability and physician preference. At the institution where the study was conducted, the flow is such that disposition choice is reflected by patient severity such as unstable vital signs or increased service needs rather than other operational factors, even if this leads to ED boarding. Such findings may not be generalizable to other hospital systems, however, that have a different bed flow management system. Additionally, in creating only two categories for higher level of care (e.g. ICU vs Step Down), the spectrum of clinical disposition may have been too simplified. Future work may examine other assessments of care utilization, such as amount of critical care billed or the presence or absence of acute medical events or need for more invasive

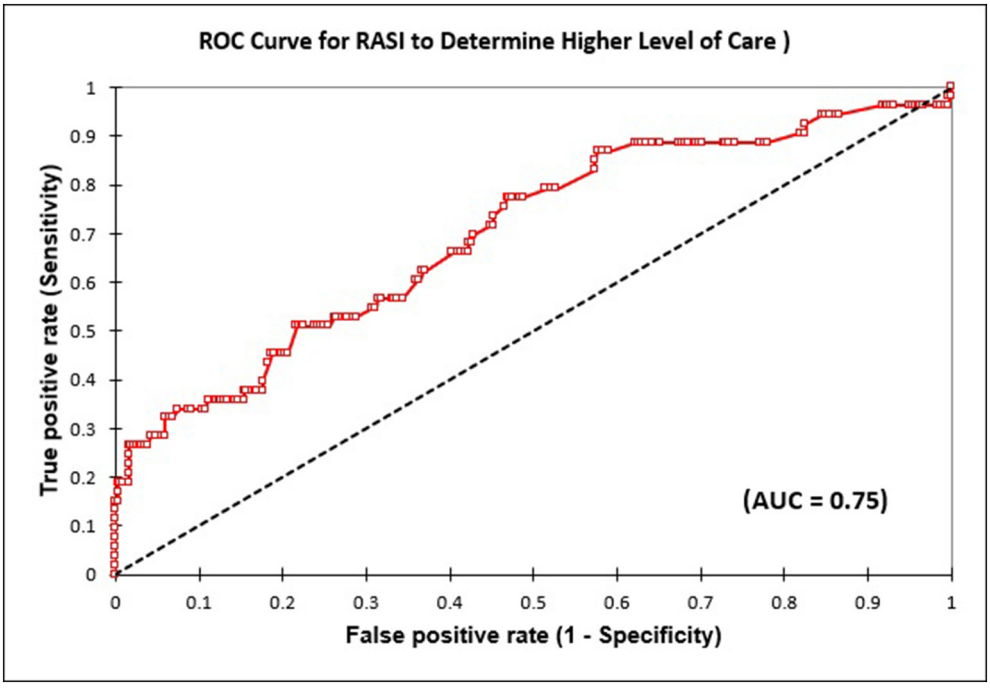


**Fig. 2.** AUC for RASI to determine higher level of care.

monitoring to better operationalize level of care. Further analysis that divides level of care into even further categories could provide a more detailed picture of RASI's correlation with overall level of care.

Physician gestalt was also not well incorporated into the RASI analysis, an overall limitation of many clinical decision rules that cannot account for the variety of factors physicians consider [16]. By not including this, we may overlook the fact that some providers may already use the components of RASI (such as triage vital signs) in identifying and dispositioning potentially critically ill sepsis patients. Future studies could include an assessment of providers' overall gestalt or impression of included patients' degree of illness to see if this also correlated with disposition outcomes. While this is a limitation, the results still suggest that objective vitals signs taken at triage may be useful in identifying a subset of suspected sepsis patients that are at risk for developing a more severe ED – and possibly hospital – course. RASI may be useful in complementing clinical expertise to identify ill patients in a timelier manner.

Finally, RASI being calculated from triage vital signs brings to question the accuracy of respiratory rate measured in triage. For some institutions, respiratory rate is only cursorily measured leading to default 'normal' respiratory rates rather than an accurate measurement. Future work may focus on other more objective assessments of respiratory rate to help ensure reliability and accuracy.

### *4.2. Conclusions*

Our study presented preliminary data on a bedside application of vital signs to aid in the screening for possible clinical severity. There are already existing panels of blood work and other measures to predict sepsis progression but RASI offers a rapid, easy bedside assessment that can be calculated within seconds. It could provide an important measure of impending critical illness and quickly identify patients that may require more aggressive intervention and a higher level of care going forward.

## Grant

BC is supported in part by an R01 grant from NIH/NHLBI 141811.

## Meetings

Preliminary analysis and results of this work was presented at the Society for Academic Emergency Medicine on May 16, 2018 in Indianapolis, Indiana.

## References

[1] Torio CM, Andrews RM. National inpatient hospital costs: the most expensive conditions by payer, 2011. Statistical Brief No. 160. Health Care Cost and Utilization Project (HCUP). Rockville, MD: Agency for Healthcare Research and Quality; August 2013.
[2] Rivers E, Nguyen B, Havstad S, et al. Early goal-directed therapy in the treatment of severe sepsis and septic shock. N Engl J Med 2001;345:1368–77.
[3] Pittet D, Tarara D, Wenzel RP. Nosocomial blood stream infection in critically ill patients: excess length of stay, extra costs, and attributable mortality. JAMA 1994;271(20):1598–601.
[4] Rady MY, Rivers EP, Nowak RM. Resuscitation of the critically ill in the ED: responses of blood pressure, heart rate, shock index, central venous oxygen saturation, and lactate. Am J Emerg Med 1996;14:218–25.
[5] Singh A, Ali S, Agarwal A, et al. Correlation of shock index and modified shock index with the outcome of adult trauma patients: a prospective study of 9860 patients. N Am J Med Sci Sep 2014;6(9):450–2.
[6] Berger T, Green J, Horeczko T, et al. Shock index and early recognition of sepsis in the emergency department: pilot study. West J Emerg Med 2013;14(2):168–74.
[7] Fieselmann JF, Hendryx MS, Helms CM, et al. Respiratory rate predicts cardiopulmonary arrest for internal medicine patients. J Gen Intern Med 1993;8:354–60.
[8] Mochizuki K, Shintani R, Mori K, et al. Importance of respiratory rate for the prediction of clinical deterioration after emergency department discharge: a single-center, case-control study. Acute Med Surg 2017;4:172–8.
[9] Straub R, Ewig S, Richter K, et al. The prognostic significance of respiratory rate in patients with pneumonia. Dtsch Arztebl Int Jul 2014;111(29–30):503–8.
[10] Subbe CP, Davies RG, Williams E. Effect of introducing the Modified Early Warning score on clinical outcomes, cardio-pulmonary arrests and intensive care utilization in acute medical admissions. Anaesthesia Aug 2003;58(8):797–802.
[11] Bone RC, Balk RA, Cerra FB, et al. Definitions for sepsis and organ failure and guidelines of the use of innovative therapies in sepsis. Chest 1992;101(6):1644–55.
[12] Caputo N, Reilly J, Kanter M, et al. A retrospective analysis of the respiratory adjusted shock index to determine the presence of occult shock in trauma patients. J Trauma Acute Care Surg 2018 Apr;84(4):674–8.
[13] McLymont N, Glover GW. Scoring systems for the characterization of sepsis and associated outcomes. Ann Transl Med 2016;4(24):527.
[14] Caputo N, Fraser R, Paliga A, et al. Triage vital signs do not correlate with serum lactate or base deficit, and are less predictive of operative intervention in penetrating trauma patients: a prospective cohort study. Emerg Med J Jul 2013;30(7):546–50.
[15] Arnold RC, Sherwin R, Shapiro NI, et al. Emergency Medicine Shock Research Network (EM Shock Net) Investigators. Multicenter observational study of the development of progressive organ dysfunction and therapeutic interventions in normotensive sepsis patients in the emergency department. Acad Emerg Med May 2013;20(5):433–40.
[16] Schriger DL, Elder JW, Cooper RJ. Structured clinical decision aids are seldom compared with subjective physician judgment, and are seldom superior. Ann Emerg Med Sep 1 2017;70(3):338–44.