Extremes of shock index predicts death in trauma patients

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ABSTRACT

Context: We noted a bimodal relationship between mortality and shock index (SI), the ratio of heart rate to systolic blood pressure. Aims: To determine if extremes of SI can predict mortality in trauma patients. Settings and Designs: Retrospective evaluation of adult trauma patients at a tertiary care center from 2000 to 2012 in the United States. Materials and Methods: We examined the SI in trauma patients and determined the adjusted mortality for patients with and without head injuries. Statistical Analysis Used: Descriptive statistics and multivariable logistic regression. Results: SI values demonstrated a U-shaped relationship with mortality. Compared with patients with a SI between 0.5 and 0.7, patients with a SI of <0.3 had an odds ratio for death of 2.2 (95% confidence interval [CI] 21.2–4.1) after adjustment for age, Glasgow Coma score, and injury severity score while patients with SI >1.3 had an odds ratio of death of 3.1. (95% CI 1.6–5.9). Elevated SI is associated with increased mortality in patients with isolated torso injuries, and is associated with death at both low and high values in patients with head injury. Conclusion: Our data indicate a bimodal relationship between SI and mortality in head injured patients that persists after correction for various co-factors. The distribution of mortality is different between head injured patients and patients without head injuries. Elevated SI predicts death in all trauma patients, but low SI values only predict death in head injured patients.

Key Words: Mortality in trauma, shock, shock index

INTRODUCTION

In an attempt to identify otherwise well-appearing individuals who have occult shock, the shock index (SI), the ratio of heart rate to systolic blood pressure (SBP), has been proposed as a quick and reliable indicator of perfusion in trauma patients. It has been suggested that SI ≥ 0.9 upon admission can identify most critically ill patients despite having “stable” or “normal” vital signs. Recent data in trauma patients suggest that hypotension as well as hypertension can predict mortality in trauma patients. Zafar et al. have demonstrated that both hypertensive and hypotensive traumatic brain injured patients have increased mortality. The absence of tachycardia in the presence of other markers of hypoperfusion (e.g. lactate, base deficit) is associated with poor outcome in trauma. We hypothesize that both low and high SI will predict death in a large cohort of trauma patients.

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MATERIALS AND METHODS

A retrospective review of all trauma patients at Beth Israel Deaconess Medical Center, an urban ACS-verified level one trauma center, was performed from January 1, 2000 to September 1, 2012. Institutional Review Board approval was obtained prior to initiating this study and a waiver of informed consent was granted.

All patients ≥18-year-old admitted to the trauma service were included. Only first admissions were included to preserve independence of observations. We excluded patients without vital signs on admission and those whose values were missing or invalid. Demographic data (age, sex, mechanism of injury), vital signs on admission (heart rate, SBP) as well as trauma scores (Glasgow Coma score [GCS], injury severity score [ISS], and abbreviated injury score) were determined. Hospital discharge status (i.e., alive or dead) was determined. SI was calculated as follows:

\[
SI = \frac{\text{First recorded heart rate}}{\text{first recorded SBP}}.
\]

Our primary outcome was in-hospital mortality and our principal independent variable of interest was SI. We report continuous data as means with standard deviations and categorical data as proportions. Ordinal data were reported as medians with interquartile ranges (IQRs).

For unadjusted analyses, we performed tests of difference using Fisher’s exact test for categorical data. For continuous data, we used the t-test or Wilcoxon rank-sum, depending on the distribution of the variable. To estimate the independent relationship of SI to mortality, we performed multivariable logistic regression. Statistical significance was defined as a \( P < 0.05 \).

RESULTS

Our cohort included 10,420 patients in our trauma registry who had a recorded initial SBP and heart rate (HR), of whom 318 (3.05%) died during the hospital admission [Table 1]. The mean age of survivors was 55.9 years (standard deviation [SD] 23.6) versus 67.6 years (SD 22.83) for nonsurvivors. The median GCS of 15 (IQR 15–15) in survivors was higher than in nonsurvivors (6, IQR 3–14). The median ISS was 9 (IQR 4–13) in survivors and was significantly higher than in nonsurvivors in every category except for facial and external injuries. In terms of vital signs, the average HR was higher and the mean SBP was lower in nonsurvivors. There was no difference in SI between survivors and nonsurvivors.

In univariate analysis treating SI as a continuous variable, SI was not associated with mortality (\( P = 0.6 \), Wilcoxon rank-sum). Increasing age and increasing ISS were both associated with increasing mortality [Table 2]. The highest SI values were associated with increased mortality in patients with an isolated head injury, and were associated with death at both low and high values in patients with torso injuries and no head injury [Table 2].

SI values for the entire cohort demonstrated a U-shaped relationship with mortality [Figure 1]. This relationship was maintained in multivariable analysis. Compared with patients with a SI between 0.5 and 0.7, patients with a SI of <0.3 had an odds ratio for death of 2.2 (95% CI 2.12–4.1) after adjustment for age, Glasgow Coma Score, and ISS while patients with SI > 1.3 had an OR of death of 31 (95% confidence interval 1.6–5.9) [Table 3]. This model had good discrimination and calibration (c statistic = 0.87; Hosmer–Lemeshow Chi-square 8.1).

Figure 2 demonstrates that the U-shaped association between mortality and SI only applies to patients with an isolated head injury. Patients without head injury have an increased mortality at SI > 0.8, but there is no increased mortality at low SI levels. Indeed, hypotension is the only clearly associated variable with mortality in patients without head injury and both hypotension and hypertension are associated with mortality in isolated head injuries. Likewise, tachycardia and bradycardia are associated with increased mortality in isolated head injured patients.

DISCUSSION

Our data indicate a bimodal relationship between SI and mortality in head injured patients that persists after correction for various co-factors. The distribution of mortality is different between
head injured patients and patients without head injuries. Elevated SI predicts death in all trauma patients, but low SI values only predict death in head injured patients. The difference is primarily related to differences in blood pressure. Namely, hypotension is a severe problem in all trauma patients, but hypertension is also associated with increased mortality in head injured patients.

Recent associations have been shown between hypertension and mortality after traumatic brain injury. The authors postulate that intracranial hyperperfusion and resultant cerebral edema result from this systemic hypertension. In this study, initial hypotension was associated with early death, while hypertension was associated with late death, for unclear reasons.

Early recognition of shock is critical to survival in trauma. Numerous scoring systems have been developed based on physiologic or mechanistic criteria that attempt to predict trauma patients that are at high risk of mortality. Lactate is a known marker of tissue hypoperfusion, even in the absence of other clinical markers of shock. Also, the clearance of lactate is an independent predictor of mortality in trauma. It is known that elevated SI is correlated with mortality in trauma patients. Specifically, SI ≥ 0.9 has been used as a cut-off to predict increased mortality.

In traumatic brain injury, both low and high SI is correlated with mortality. Only high SI predicts death in patients without head injury. SI is a better predictor of shock than either blood pressure or heart rate alone in both head injured patients and patients without head injury.

### Table 2: Analysis of cohort

| Variable          | OR   | 95% CI     | P    |
|-------------------|------|------------|------|
| Age (years)       |      |            |      |
| <30               | 1.0  | -          | -    |
| 30-39             | 1.7  | 0.8-3.7    | 0.16 |
| 40-49             | 2.2  | 1.1-4.3    | 0.03 |
| 50-59             | 1.7  | 0.8-3.5    | 0.14 |
| 60-69             | 3.4  | 1.8-6.4    | <0.001|
| ≥70               | 8.1  | 4.7-13.9   | <0.001|
| Injury severity score |     |            |      |
| <15               | 1.0  | -          | -    |
| 15-25             | 4.3  | 2.8-6.5    | <0.001|
| >25               | 28.3 | 12.0-72.8  | <0.001|
| Shock index       |      |            |      |
| No head injury    |      |            |      |
| 0.40-0.49         | 0.7  | 0.7        | 0.2-2.2|
| 0.5-0.79          | 1.0  | 1.0        | -    |
| 20.80             | 3.0  | 3.0        | 1.7-5.4|
| Isolated head injury |    |            |      |
| 0.40-0.49         | 5.4  | 5.4        | 3.0-9.8|
| 0.5-0.79          | 2.7  | 2.7        | 1.6-4.3|
| 20.80             | 5.3  | 5.3        | 3.0-9.2|

### Table 3: Multivariable analysis showing U-shaped relationship between shock index and mortality

| Variable          | OR (95% CI) |
|-------------------|-------------|
| Shock index       |             |
| <0.3              | 2.2 (1.2-4.1)|
| 0.3-0.5           | 1.3 (0.9-1.7)|
| 0.5-0.7           | 1.0 (reference)|
| 0.7-0.9           | 1.6 (1.2-2.1)|
| 1.0-1.1           | 1.2 (0.7-1.9)|
| 1.1-1.3           | 3.5 (1.9-6.6)|
| >21.3             | 3.1 (1.6-5.9)|
| Injury severity score |     |            |      |
| <20               | 1.0 (reference)|
| 20-29             | 3.7 (2.9-4.8)|
| 30-39             | 4.1 (2.5-6.5)|
| ≥40               | 9.8 (6.1-15.8)|
| Glasgow coma score |        |            |      |
| 3-6               | 9.6 (7.2-12.8)|
| 7-9               | 7.6 (4.4-12.9)|
| 10-12             | 3.0 (1.5-5.9)|
| 13-15             | 1.0 (reference)|
| Age (years)       |             |
| <30               | 1.0 (reference)|
| 30-39             | 1.5 (0.8-2.8)|
| 40-49             | 2.6 (1.5-4.5)|
| 50-59             | 2.9 (1.7-5.0)|
| 60-69             | 4.5 (2.6-7.6)|
| ≥70               | 14.6 (9.4-22.6)|

OR: Odds ratio, CI: Confidence interval.
CONCLUSION

A bimodal relationship between SI and mortality exists in trauma patients, but a difference exists in the head injured and the non-head injured patients. Elevated SI predicts death in all trauma patients, but low SI only predicts death in head injured patients.

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Conflicts of interest
There are no conflicts of interest.

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