Archives of Academic Emergency Medicine. 2023; 11(1): e34

ORIGINAL RESEARCH

Modified Shock Index as a Predictor of Admission and In-hospital Mortality in Emergency Departments; an Analysis of a US National Database

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Received: February 2023; Accepted: March 2023; Published online: 29 April 2023

Abstract: **Introduction:** The modified shock index (MSI) is the ratio of heart rate to mean arterial pressure. It is used as a predictive and prognostic marker in a variety of disease states. This study aimed to derive the optimal MSI cut-off that is associated with increased likelihood (likelihood ratio, LR) of admission and in-hospital mortality in patients presenting to emergency department (ED). **Methods:** We retrospectively reviewed data from the National Hospital Ambulatory Medical Care Survey between 2005 and 2010. Adults>18 years of age were included regardless of chief complaint. Basic patient demographics, initial vital signs, and outcomes were recorded for each patient. Then the optimal MSI cut-off for prediction of admission and in-hospital mortality in ED was calculated. LR ≥ 5 was considered clinically significant. **Results:** 567,994,402 distinct weighted adult ED patient visits were included in the analysis. 15.7% and 2.4% resulted in admissions and in-hospital mortality, respectively. MSI > 1.7 was associated with a moderate increase in the likelihood of both admission (Positive LR (+LR) = 6.29) and in-hospital mortality (+LR = 5.12). +LR for hospital admission at MSI >1.7 was higher for men (7.13; 95% CI 7.11-7.15) compared to women (5.49; 95% CI 5.47-5.50) and for non-white (7.92; 95% CI 7.88-7.95) compared to white patients (5.85; 95% CI 5.84-5.86). For MSI <0.7, the +LRs were not clinically significant for admission (+LR = 1.07) or in-hospital mortality (LR = 0.75). **Conclusion:** In this largest retrospective study, to date, on MSI in the undifferentiated ED population, we demonstrated that an MSI >1.7 on presentation is predictive of admission and in-hospital mortality. The use of MSI could help guide accurate acuity designation, resource allocation, and disposition.

Keywords: Modified shock index; Hospitalization; Inpatients; Hospital Mortality; Emergency Service, Hospital; Probability

Cite this article as: Hamade B, Bayram JD, Hsieh Y, Khishfe B, Al Jalbout N. Modified Shock Index as a Predictor of Admission and In-hospital Mortality in Emergency Departments; an Analysis of a US National Database. Arch Acad Emerg Med. 2023; 11(1): e34. https://doi.org/10.22037/aaem.v11i1.1901.

1. Introduction

The shock index (SI) is a clinical metric obtained by dividing the heart rate (HR) by the systolic blood pressure (SBP). It was first described by Allgower and Burri (1) in 1967 and has been proposed to serve as an early indicator of clinical deterioration (2, 3). Originally investigated in shock states, the SI has been studied as a prognostic metric in a variety of disease states including trauma, pneumonia, sepsis, gastrointestinal bleeding, and ST segment elevation myocardial infarction (4-11). In the undifferentiated emergency department (ED) population, one recent large retrospective multicenter study found that SI>1.3 was associated with a higher likelihood of hospital admission and in-hospital mortality (12).

Currently, most EDs measure blood pressure non-invasively via automated blood pressure machines that rely on oscillometry. These machines measure mean arterial pressure (MAP) and extrapolate SBP and diastolic blood pressure (DBP), overestimating SBP compared to invasive arterial monitoring (13), which can lead to false hemodynamic reassurance. MAP is an important clinical metric driven

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Table 1: Baseline characteristics of studied emergency department patient visits

Variable	Number (%)
Age (years)	
18-44	279,660,193 (53.1)
45-64	144,066,977 (27.4)
≥65	102,054,146 (19.5)
Sex	
Male	299,216,051 (56.9)
Female	226,565,265 (43.1)
Race	
Non-white	137,426,759 (26.1)
White	388,354,557 (73.9)
Disposition	
Admission	82,501,250 (15.7)
In-hospital mortality	1,917,737 (2.4)

by early changes in DBP, which defines perfusion pressure, and guides therapy in septic patients and early hemorrhagic states (14-16). In 2012, Liu et al. introduced the modified shock index (MSI), which is the HR divided by the MAP. They demonstrated that MSI <0.7 or >1.3 were significantly associated with higher in-hospital mortality in a single center ED population (17). In another large prospective study of 9860 trauma patients, the same MSI cut-offs outperformed SI and traditional vital signs as predictors of mortality (18). Since then, the predictive and prognostic utilities of MSI have been studied in a variety of disease states such as sepsis and myocardial infarction (19-25). However, literature regarding its optimal predictive cut-offs and utility in the general undifferentiated ED population is limited (26, 27).

The main objective of this study is to derive an MSI threshold that predicts both admission and in-hospital mortality in the undifferentiated ED population based on the initial presenting HR and MAP, irrespective of clinicians' subjective clinical judgements. The secondary objective is to analyze the performance of different MSI thresholds when performing subgroup analysis based on age, sex, and race.

2. Methods

2.1. Study design and setting

We retrospectively analyzed ED visits from 2005 to 2010 from the National Hospital Ambulatory Medical Care Survey (NHAMCS), the largest nationally representative database of utilization and provision of ED services in the United States, using a weighted sample of all U.S. ED visits reported in the survey. The study was granted exempt status by our institution's review board (IRB00151493).

The NHAMCS is a nationally representative survey conducted by the Centers for Disease Control and Prevention (CDC) and the National Center for Health Statistics (28). It includes an estimated 120 million encounters annually obtained from probability sampling of ED visits in the 50 states and the District of Columbia, excluding visits to federal, military and Veteran Administration hospitals.

2.2. Participants

Adult patient visits above 18 years of age were included. Encounters with insufficient data to calculate the MSI in addition to encounters resulting in ED deaths were excluded (since our main outcomes of interest were admissions and in-hospital mortality).

2.3. Data gathering

Data is collected from ED visit medical records during a randomly assigned four-week period by NHAMCS personnel under the supervision of field representatives. Staff members independently checked 10% of the data for accuracy with an error rate ranging from 0.3% to 0.9% for various items on the survey (28). Between 352 and 389 hospitals agreed to participate in the survey from the year 2005 to 2010, which constituted our study period. This data was publicly available with free access. The NHAMCS does not include information on specific ED clinical management and condition fluctuation details.

For each patient visit, basic patient demographics including age, sex and race, initial HR, SBP and DBP, and visit outcomes were recorded by trained coders following CDC's National Center for Health Statistics standardized NHAMCS data collection protocol (28).

From the initial SBP and DBP, MAP and subsequently the MSI were calculated. The SBP and DBP were measured non-invasively at triage, as this is the standard across Emergency Rooms. For this exploratory study, effect modifiers were not considered in the data analysis plan.

MSI, the HR divided by the MAP, which was calculated as (2*DBP+SBP)/3, was the predictor of the primary outcomes.

2.4. Outcome measures

The primary outcome measures of our study were hospital admission and in-hospital mortality, which were based on the data coding on ED disposition and hospital discharge status, respectively.

2.5. Data analysis

Descriptive data analysis was first performed to summarize key descriptive statistics of the study population. Likelihood ratios (LRs) for a broad range of thresholds of MSI for both outcomes were then calculated. Positive LRs (+LRs) were used since they represent statistically robust measures of diagnostic accuracy independent of pretest probability, unlike positive and negative predictive values (29). Since prior data suggests different likelihood of admission based on age, sex

and race, these variables were considered as potential confounders a priori. For this exploratory study, we performed sub-group analysis stratified by race (white vs. non-white), sex (women vs. men) and age group (18-44, 45-64 and ≥65 years) for the outcome of hospital admission to minimize the bias resulting from the potential confounding effect by age, sex, and race (30-32). With regards to in-hospital mortality, the original weighted sample size was less than 30 in each subgroup, and thus prevented stratifying the data by demographics due to the concern of generating invalid estimates.
Values of + LR are considered to be clinically significant when they are ≥ 5, with the range between 5 and 10 considered moderate increase in the likelihood of the outcome and ≥10 considered large and often conclusive for the likelihood of the outcome (29).

3. Results

3.1. Baseline characteristics of ED visits

We identified 567,994,402 distinct weighted adult ED patient visits between the years 2005 and 2010. We excluded 660,207 (0.12%) visits of patients who died in the ED in addition to 42,213,086 (7.43%) visits due to incomplete records. 525,781,316 weighted patient visits were included in the final analysis, of which 299,216,051 (57%) were female, 388,354,557 (74%) were white and 279,660,193 (53%) were between the ages of 18 and 44 years. Table1 summarizes the baseline characteristics of the studied ED visits. Out of the 525,781,316 weighted patient visits included in this study, 82,501,250 (15.7%) unique ED visits resulted in in-hospital admissions, and 1,917,737 (2.4%) resulted in in-hospital mortality.

3.2. Predictive value of MSI for admission and in-hospital mortality

An initial MSI value of >1.7 was associated with a moderate increase in the likelihood of both admission and in-hospital mortality with a +LR of 6.29 (95% CI: 6.28-6.31) and 5.12 (95% CI: 5.10-5.14), respectively. For patients with an initial MSI value of <0.7, the +LRs for admission and in-hospital mortality were not clinically significant with values of 1.07 (95% CI: 1.07-1.07) and 0.75 (95% CI: 0.75-0.75), respectively. Likewise, for patients with MSI value of >1.3, the +LRs for admission and in-hospital mortality were 2.55 (95% CI: 2.55-2.55) and 2.69 (95% CI: 2.68-2.70), respectively (Tables 2 and 3).
Out of the 82,501,250 admitted patients, 2,011,388 (2.4%) had an initial MSI value >1.7, and out of 1,917,737 patients who died, 215,337 (11.2%) had an MSI>1.7 (Tables 2 and 3). A total of 23,713,531 (4.51%) admitted patient encounters had MSI <0.7 or MSI >1.3 (Table 2). Among them, 800,831 (0.15%) patients died during hospitalization (Table 3). The frequency of both outcomes at every MSI cut-off is presented in Tables 2 and 3.
The areas under the receiver operating characteristic (ROC) curve of MSI in predicting the admission and in-hospital mortality were 0.454 (95%CI: 0.450-0.459) and 0.366 (95%CI: 0.339-0.393), respectively (Figure 1).

3.3. +LR of MSI stratified by age, sex, and race

When stratified by age, sex, and race, +LR for hospital admission at MSI >1.7 was higher for men (7.13; 95% CI: 7.11-7.15) compared to women (5.49; 95% CI: 5.47-5.50) and for non-white (7.92; 95% CI: 7.88-7.95) compared to white patients (5.85; 95% CI: 5.84-5.86) (Table 4). Admission +LRs for all age groups increased with increasing MSI values, with the highest +LR being for patients aged 45-64 years (7.48; 95% CI 7.45-7.51) (Table 4).
Sub-group analysis for in-hospital mortality outcome was not performed due to the small sample size, rendering +LR estimates unreliable.

4. Discussion

In the undifferentiated ED population, our study shows an association between an initial MSI value >1.7 and a clinically significant increase in the likelihood of both outcomes, admission and in-hospital mortality, with +LRs of 6.29 and 5.12, respectively. To the best of our knowledge, this is the largest multicenter retrospective study of the general ED population, with 525,781,316 weighted ED patient encounters. These results are in line with a recent study describing an MSI of >1.7 as a strong predictor of mortality. In this study, Smischney et al. showed that within the first 24 hours of ICU admission, patients with an elevated MSI have a significant mortality risk (23).
Our study results indicate that the MSI cut-off values of <0.7 and >1.3 introduced by Liu et al. are not reliable predictors of mortality in the general ED population, with +LRs being significantly less than 5. It is important to note that there are important differences in the methodology between our study and that of Liu et al. that may explain the differences in MSI values. While both studies are similar in calculating the MSI from the triage vital signs and defining one of the primary outcomes as in-hospital mortality, our study was a large multicenter study encompassing a more diverse patient population with a variety of disease states and complaints. Liu et al. included only those patients that received intravenous (IV) fluids because they were considered “real emergency” patients. The study of Liu et al. analyzed a smaller total number of patients (22,161) in a different setting (China), with a wider age range, including those aged 10 years up to 100 years. Our study analyzed more than 525 million ED visits, and was limited to those 18 years old and above. In our study, only 4.51% of the admitted patients and 0.15% of those who died as in-

Table 2: Screening performance characteristics of modified shock index (MSI) in different cut-offs for predicting the need for hospital admission

MSI	Number*	Admitted	PLR	Sensitivity	Specificity
<0.3	781,336	126,089	1.03 (1.03-1.04)	0.15 (0.15-0.15)	99.85 (99.85-99.85)
<0.4	1,462,308	374,241	1.85 (1.84-1.85)	0.45 (0.45-0.46)	99.75 (99.75-99.76)
<0.5	6,658,809	1,623,417	1.73 (1.73-1.73)	1.97 (1.96-1.97)	98.86 (98.86-98.87)
<0.6	30,810,315	6,097,638	1.33 (1.32-1.33)	7.39 (7.39-7.40)	94.43 (94.42-94.43)
<0.7	89,440,729	14,817,168	1.07 (1.07-1.07)	17.96 (17.95-17.97)	83.17 (83.16-83.17)
0.5≤ & ≤0.7	83,149,111	69,917,576	0.98 (0.98-0.98)	15.77 (15.77-15.78)	83.96 (83.16-83.17)
>0.7	435,973,396	67,646,298	0.99 (0.99-0.99)	81.99 (81.99 – 82.0)	16.91 (16.91-16.91)
>0.8	344,098,058	55,261,912	1.03 (1.03-1.03)	66.98 (66.97-66.99)	34.84 (34.84-34.85)
>0.9	239,969,027	41,744,323	1.13 (1.13-1.13)	50.60 (50.59-50.61)	55.28 (55.28-55.29)
>1.0	148,962,698	29,618,270	1.33 (1.33-1.33)	35.90 (35.89-35.91)	73.08 (73.07-73.08)
>1.1	87,173,982	20,246,957	1.63 (1.62-1.63)	24.54 (24.53-24.55)	84.90 (84.90-84.91)
>1.2	49,130,138	13,537,356	2.04 (2.04-2.05)	16.41 (16.40-16.42)	91.97 (91.97-91.97)
>1.3	27,631,575	8,896,363	2.55 (2.55-2.55)	10.78 (10.77-10.79)	95.77 (95.77-95.78)
>1.4	15,649,057	6,045,761	3.38 (3.38-3.39)	7.33 (7.32-7.33)	97.83 (97.83-97.83)
>1.5	9,131,844	3,972,421	4.14 (4.13-4.14)	4.81 (4.81-4.82)	98.84 (98.84-98.84)
>1.6	5,678,149	2,779,613	5.15 (5.14-5.16)	3.37 (3.37-3.37)	99.35 (99.35-99.35)
>1.7	3,728,673	2,011,388	6.29 (6.28-6.31)	2.44 (2.43 -2.44)	99.61 (99.61-99.61)
>1.8	2,530,265	1,375,089	6.40 (6.38-6.41)	1.66 (1.66-1.67)	99.74 (99.74-99.74)

Data are presented with 95% confidence interval. *Denotes the number of patient encounters included in the study in each specific MSI category. PLR: positive likelihood ratio.

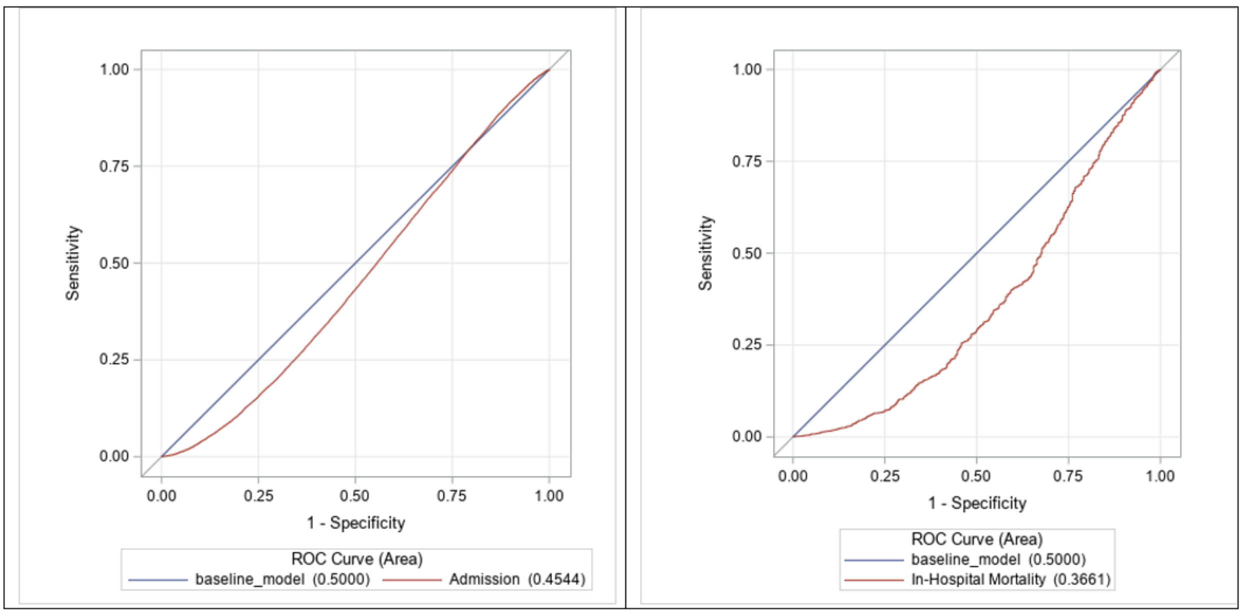

Figure 1: Area under the receiver operating characteristic (ROC) curve of modified shock index in predicting the need for admission (left) and in-hospital mortality (right).

patients had an MSI<0.7 or >1.3. Finally, our study showed that MSI <0.7 was not a strong predictor of admission and inpatient mortality, which could mean that in the general ED population, a hypodynamic circulatory state is much more indicative of serious underlying pathology than a hyperdynamic state as Liu et al. concluded.

When stratified by groups, +LR for hospital admission stratified by race and sex were highest for non-white (7.92; 95% CI 7.88-7.95) and male patients (7.13; 95% CI 7.11-7.15). We could not identify specific causes for these differences without substratifying for confounders like age and comorbidities; however prior data demonstrates higher admission rates for non-white patients and males in certain disease states (30-32).

Table 3: Screening performance characteristics of modified shock index (MSI) in different cut-offs for predicting the in-hospital mortality

MSI	Number*	Admitted	PLR	Sensitivity	Specificity
<0.3	113,160	1,737	0.58 (0.55-0.61)	0.09 (0.09-0.10)	99.84 (99.84-99.84)
<0.4	319,606	9,786	1.17 (1.15-1.20)	0.51(0.50-0.52)	99.56 (99.56-99.57)
<0.5	1,437,215	42,745	1.14 (1.13-1.15)	2.22 (2.21-2.25)	98.04 (98.04-98.04)
<0.6	5,464,331	110,687	0.77 (0.76-0.77)	5.77 (5.74-5.80)	92.47 (92.47-92.49)
<0.7	13,181,503	260,138	0.75 (0.74-0.75)	13.56 (13.52-13.61)	81.84 (81.84-81.86)
0.5≤ & ≤0.7	11,782,072	11,564,679	1.43 (1.43-1.44)	16.24 (16.24-16.25)	88.66 (88.62-88.71)
>0.7	59,889,401	1,657,599	1.06 (1.06-1.06)	86.43 (86.39-86.48)	18.20 (18.19-18.21)
>0.8	48,768,358	1,466,088	1.15 (1.15-1.15)	76.44 (76.39-76.51)	33.55 (33.54-33.57)
>0.9	36,826,926	1,299,048	1.36 (1.36-1.36)	67.73 (67.67-67.80)	50.09 (50.08-50.11)
>1.0	26,225,851	1,106,980	1.64 (1.63-1.63)	57.72 (57.65-57.79)	64.71 (64.71-64.73)
>1.1	17,910,296	894,677	1.95 (1.95-1.96)	46.65 (46.58-46.72)	76.09 (76.09-76.11)
>1.2	12,014,175	717,380	2.36 (2.36-2.36)	37.40 (37.34-37.48)	84.13 (84.12-84.14)
>1.3	8,004,628	540,693	2.69 (2.68-2.70)	28.19 (28.13-28.26)	89.51 (89.51-89.52)
>1.4	5,458,320	453,297	3.36 (3.35-3.37)	23.63 (23.58-23.70)	92.96 (92.96-92.98)
>1.5	3,596,224	319,161	3.62 (3.60-3.62)	16.64 (16.59-16.70)	95.39 (95.39-95.40)
>1.6	2,519,176	274,000	4.53 (4.51-4.54)	14.28 (14.24-14.34)	96.84 (96.84-96.85)
>1.7	1,777,416	215,337	5.12 (5.10-5.14)	11.22 (11.18-11.27)	97.80 (97.80-97.81)
>1.8	1,223,325	156,472	5.44 (5.42-5.47)	8.15 (8.12-8.20)	98.50 (98.50-98.50)

Data are presented with 95% confidence interval. *Denotes the number of patient encounters included in the study in each specific MSI category. PLR: positive likelihood ratio.

Table 4: Positive likelihood of modified shock index (MSI) in different cut-offs for predicting the need for admission stratified by sex, race, and age category

MSI	Sex		Race		Age (year)		
	Female	Male	Non-white	White	18-44	45-64	≥65
<0.3	0.74 (0.73-0.75)	1.45 (1.44-1.46)	0.45 (0.45-0.46)	1.14 (1.13-1.15)	0.71 (0.70-0.72)	0.76 (0.75-0.77)	1.11 (1.10-1.11)
<0.4	1.65 (1.64-1.66)	2.03 (2.02-2.04)	1.67 (1.66-1.69)	1.87 (1.87-1.88)	0.82 (0.81-0.83)	1.65 (1.64-1.66)	1.35 (1.34-1.35)
<0.5	1.67 (1.66-1.67)	1.74 (1.74-1.74)	1.85 (1.84-1.85)	1.70 (1.70-1.71)	1.74 (1.73-1.75)	1.35 (1.34-1.35)	0.87 (0.87-0.87)
<0.6	1.55 (1.55-1.55)	1.12 (1.12-1.12)	1.32 (1.32-1.33)	1.33 (1.33-1.34)	1.34 (1.34-1.34)	0.93 (0.93-0.93)	0.76 (0.76-0.76)
<0.7	1.23 (1.23-1.23)	0.91 (0.91-0.91)	1.03 (1.03-1.04)	1.08 (1.08-1.08)	0.98 (0.97-0.98)	0.81 (0.81-0.81)	0.74 (0.74-0.74)
0.5≤ &≤0.7	0.83 (0.83-0.83)	1.18 (1.1-1.18)	1.02 (1.02-1.03)	0.97 (0.96-0.97)	1.07 (1.07-1.07)	1.30 (1.30-1.30)	1.37 (1.37-1.37)
>0.7	0.96 (0.96-0.96)	1.02 (1.03-1.03)	0.99 (0.99-0.99)	0.98 (0.98-0.98)	1.00 (1.00-1.00)	1.05 (1.05-1.05)	1.11 (1.10-1.11)
>0.8	0.98 (0.97-0.98)	1.11 (1.11-1.11)	1.05 (1.05-1.05)	1.02 (1.02-1.02)	1.05 (1.05-1.05)	1.16 (1.16-1.16)	1.26 (1.26-1.26)
>0.9	1.05 (1.05-1.05)	1.29 (1.29-1.29)	1.15 (1.15-1.15)	1.12 (1.12-1.12)	1.13 (1.13-1.13)	1.38 (1.38-1.38)	1.48 (1.48-1.48)
>1.0	1.19 (1.19-1.19)	1.61 (1.61-1.61)	1.39 (1.38-1.39)	1.31 (1.31-1.31)	1.32 (1.32-1.32)	1.71 (1.71-1.72)	1.76 (1.76-1.76)
>1.1	1.40 (1.40-1.40)	2.10 (2.10-2.10)	1.68 (1.68-1.68)	1.60 (1.60-1.60)	1.52 (1.52-1.52)	2.13 (2.13-2.13)	2.22 (2.22-2.22)
>1.2	1.73 (1.73-1.73)	2.72 (2.71-2.72)	2.20 (2.20-2.20)	1.99 (1.99-1.99)	1.88 (1.88-1.88)	2.74 (2.74-2.74)	2.56 (2.56-2.56)
>1.3	2.17 (2.16-2.17)	3.34 (3.34-3.35)	2.77 (2.76-2.77)	2.48 (2.48-2.48)	2.30 (2.30-2.30)	3.27 (3.27-3.28)	2.83 (2.83-2.84)
>1.4	2.87 (2.87-2.87)	4.35 (4.34-4.35)	4.01 (4.00-4.02)	3.20 (3.20-3.20)	3.18 (3.17-3.18)	4.18 (4.17-4.18)	3.19 (3.18-3.19)
>1.5	3.46 (3.46-3.47)	5.28 (5.27-5.29)	5.53 (5.52-5.55)	3.78 (3.77-3.78)	4.16 (4.15-4.16)	4.70 (4.69-4.71)	3.47 (3.46-3.47)
>1.6	4.40 (4.39-4.40)	6.17 (6.16-6.19)	7.05 (7.03-7.08)	4.67 (4.66-4.68)	4.84 (4.82-4.85)	5.53 (5.51-5.55)	4.18 (4.16-4.19)
>1.7	5.49 (5.47-5.50)	7.13 (7.11-7.15)	7.92 (7.88-7.95)	5.85 (5.84-5.86)	5.85 (5.83-5.87)	7.48 (7.45-7.51)	4.82 (4.80-4.83)
>1.8	5.73 (5.70-5.75)	6.98 (6.96-7.00)	8.79 (8.74-8.83)	5.80 (5.79-5.82)	6.03 (6.00-6.05)	7.13 (7.10-7.17)	4.78 (4.76-4.80)

Data are presented with 95% confidence interval.

+LR for admission increased with increasing MSI values in each age group; however, elderly patients ≥65 years demonstrated the lowest +LR of 4.81 (95% CI 4.79-4.83) for MSI>1.7 compared to +LRs of 5.85 (95% CI 5.83-5.87) and 7.48 (95% CI 7.45-7.51) in those 18-44 years old and 45-64 years old, respectively. An explanation to this finding could be the use of antihypertensives in elderly, including beta blockers that may blunt HR response, which results in lower MSI values. Another explanation could be the lower threshold of admitting elderly patients regardless of MSI due to polypharmacy and multiple comorbidities.

Our study showed promising results and the findings can be used in the general ED population, to help identify sick patients and allow the ED team to allocate resources effectively and efficiently.

5. Limitations

Our study has certain limitations. This was a retrospective study that used a representative national data, of which 41,552,879 (7.23 %) encounters were excluded due to missing data. The cohort was not uniform in terms of diagnosis, and thus patients presenting with disease states that do not affect stroke volume might have potentially skewed our results and generated a different MSI threshold than described in previous studies. As data was not available to us, we also could not account for pre-ED interventions, such as crystalloid and blood product administration, nor could we account for medication profiles, both of which could have potentially affected our results; specifically, the use of beta blockers altering the heart rate, or oral peripheral vasoconstrictors and other antihypertensive medications that would affect physiological responses to illness, thus affecting MSI values. We could not account for the way MAP and BP were measured non-invasively by using automated machines such as oscillometry or manually via sphygmomanometer, which sometimes yields different values (13). Data on serial vital signs was not available to study serial MSI measurements, which can have significant prognostic reliability. We also did not have data regarding level of care upon admission. Our study derived MSI thresholds for all ED comers and more research is needed in specific patient populations, such as trauma and sepsis, as different MSI threshold maybe derived. In addition, our research focused on one compound variable -the MSI- and future studies are needed conducting multivariate analysis including the MSI in order to construct a more comprehensive best fit model. Finally, mortality could have been a result of different complications during the hospital course, and not a direct effect of the presenting ED complaint, but the limitation is due to our date set.

6. Conclusion

Our large nationally representative retrospective study of all adult ED patients suggests that an initial MSI >1.7 in the general adult ED population is an important predictor of admission and in-hospital mortality. Further studies on MSI are needed in various specific patient populations to further assess its relationship to the current triage systems, its impact on resource utilization and allocation in the ED, and on the decision making regarding the level of care of the admitting unit.

7. Declarations

7.1. Acknowledgments

None.

7.2. Conflict of interest

None.

7.3. Fundings and supports

None.

7.4. Authors' contribution

BH, JDB, and NAJ conceived the study. JDB and NAJ obtained IRB approval. BH, JDB, and NAJ designed the study. YH obtained the data and provided statistical analysis of the data. BH, JDB and NAJ interpreted the data analysis. BH, JDB, BK, and NAJ drafted various sections of the manuscript, and all authors contributed substantially to its revision. BH takes responsibility for the paper as a whole. The corresponding author (NAJ) attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

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