American Journal of Emergency Medicine 37 (2019) 391–394

Contents lists available at ScienceDirect

American Journal of Emergency Medicine

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

Original Contribution

Shock index predicted mortality in geriatric patients with influenza in the emergency department

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ARTICLE INFO

Article history:
Received 7 April 2018
Received in revised form 20 May 2018
Accepted 28 May 2018

Keywords:
Death
Emergency department
Geriatric
Influenza
Mortality
Prediction
Shock index

ABSTRACT

Background: The shock index is a rapid and simple tool used to predict mortality in patients with acute illnesses including sepsis, multiple trauma, and postpartum hemorrhage. However, its ability to predict mortality in geriatric patients with influenza in the emergency department (ED) remains unclear. This study was conducted to clarify this issue.

Methods: We conducted a retrospective case-control study, recruiting geriatric patients (≥ 65 years) with influenza visiting the ED of a medical center between January 01, 2010 and December 31, 2015. Demographic data, vital signs, shock index, past histories, subtypes of influenza, and outcomes were included for the analysis. We investigated the association between shock index ≥1 and 30-day mortality.

Results: In total, 409 geriatric ED patients with mean age of 79.5 years and nearly equal sex ratio were recruited. The mean shock index ± standard deviation was 0.7 ± 0.22 and shock index ≥1 was accounted for in 7.1% of the total patients. Logistic regression showed that shock index ≥1 predicted mortality (odds ratio: 6.80; 95% confidence interval: 2.39–19.39). The area under the receiver operating characteristic was 0.62 and the result of the Hosmer–Lemeshow goodness-of-fit test was 0.23. The sensitivity, specificity, positive predictive value, and negative predictive value of a shock index ≥1 were 30.0%, 94.1%, 20.0%, and 96.4%.

Conclusions: A shock index ≥1 has a high specificity, negative predictive value, and good reliability to predict 30-day mortality in geriatric ED patients with influenza.

1. Introduction

Influenza is a very important issue in public health because it is associated with considerable annual morbidity and mortality [1]. >90% of deaths and complications caused by influenza occur in the elderly (≥65 years) [2]. During influenza epidemics that occurred from 1970 to 1995, there were an estimated number of 142,000 influenza-related hospitalizations, and >40% of these hospitalizations were of the elderly [3]. Therefore, accurate predictions of the prognosis, including mortality, disposition, and proper utilization of medical resources via developing a disease severity prediction in the geriatric patients with influenza, is an important issue, especially during influenza outbreaks [4]. Laboratory information often plays an important role in predicting severity and physician decision-making in patients with influenza [5]. However, the time-consuming process of examination results may delay the recognition of severe influenza during an outbreak with numerous

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https://doi.org/10.1016/j.ajem.2018.05.059
0735-6757/

patients. In addition, many countries and areas may lack the facilities for laboratory testing, therefore, non-laboratory methods, including assessment by vital signs, may be a more practical way for timely management of influenza patients.

The shock index is defined as heart rate divided by systolic blood pressure, with a normal range of 0.5 to 0.7 in healthy adults [6]. It was initially introduced as a simple and effective method of detecting the degree of hypovolemia in hemorrhagic and infectious shock states [6]. Previous studies have shown that shock index is related to physiologic parameters, such as cardiac index, stroke volume, left ventricular stroke index, mean arterial pressure, and acute circulatory failure [7,8]. Shock index is also suggested to be a valuable tool for early recognition of critical illness and patient disposition in the emergency department (ED) [9] and an independent predictor for 6-week mortality in patients with community acquired pneumonia [10]. However, the role of the shock index in the prediction of mortality in geriatric patients with influenza is still unclear. After we conducted a keywords search with “death”, “geriatric”, “influenza”, “mortality”, “prediction”, and “shock index” in PubMed and Google Scholar, we did not find associated studies on this issue. Therefore, we conducted this study intending to clarify it.

2. Methods

2.1. Study design, setting, and participants

This study was conducted in a 700-bed university-affiliated medical center with a 40-bed ED in Southern Taiwan. The study ED is staffed with board-certified emergency physicians that provide care for approximately 55,000 patients per year [11]. About 33% of the ED patients in the study hospital were the elderly [12,13]. Geriatric patients (≥ 65 years) who visited the ED between January 1, 2010 and December 31, 2015, were recruited when they met the following criteria: (1) tympanic temperature (TM) ≥ 37.2 °C or a baseline TM elevated ≥1.3 °C [12,13], and (2) influenza infection defined as positive influenza pharyngeal or throat swab test [14].

2.2. Definitions of the variables and primary outcome

We defined a shock index ≥1 as a categorical variable, which was found to be related to hyperlactatemia and 28-day mortality in adult patients with severe sepsis [15] and in-patient death in the oldest elderly [16]. Hypotension was defined as systolic blood pressure < 90 mm Hg [11,17]. Tachycardia was defined as heart rate > 100/min [18]. Bandemia was defined as immature band form count >10% [19,20]. The primary outcome is 30-day mortality [11,18,21]. Patients who survived at least 30 days were considered “survivors” for this analysis [11,18]. Telephone follow-up was used to ascertain 30-day mortality if the information could not be obtained from the medical records.

2.3. Data collection and assignments for the case and control groups

We collected geriatric ED patients who fit the criteria of influenza infection through a retrospective chart review. Patients' demographic characteristics, vital signs, past history, laboratory data, influenza subtype, influenza vaccination, do not resuscitate (DNR), admission, and 30-day mortality were collected by an emergency physician. Past history, influenza vaccination, and DNR which were not recorded in the patient's medical record was considered negative.

Overall, 479 geriatric ED patients met the criteria of influenza infection. Four hundred and nine patients were finally recruited after excluding 70 patients without the data for 30-day mortality, admission or not, influenza subtype, and sex, and transferred patients who had been treated in other hospitals. The recruited patients were divided into two groups based on their 30-day outcome, case group (i.e., survival), and control group (i.e., mortality). All of the variables were used for comparison between the two groups (Table 1).

2.4. Ethical statement

This study was approved by the Institutional Review Board in the Cathay General Hospital and conducted according to the Declaration of Helsinki. Because this was an observational study, the need for informed consent from the patients was waived.

2.5. Statistical analysis

SPSS 23.0 for Mac (Chicago, IL, USA) was used for all the statistical analysis. The power was 0.82 using G-power 3.0 for analysis. Continuous data are presented as means ± standard deviation (SD). In the uni-variate analyses, we used an independent samples *t*-test, or the Mann-Whitney-Wilcoxon test for continuous variables. Pearson's chi-square test or Fisher's exact test was used for categorical variables. We used logistic regression to investigate the association between a shock index ≥1 and 30-day mortality. The significance level was set at 0.05 (2-tailed). The area under the receiver operating characteristic curve (AUC) was used to evaluate the ability of discrimination of a shock index ≥1. The Hosmer-Lemeshow goodness-of-fit test was performed to evaluate the reliability of a shock index ≥1. Sensitivity, specificity, positive predictive value, and negative predictive value were also analyzed for the performance of a shock index ≥1.

3. Results

We recruited 409 patients into this study with a 30-days mortality rate of 4.9% (20/409) (Table 1). The mean age ± SD was 79.5 ± 8.3 and the percentages of the two sexes were nearly equal. The mean ± SD of systolic blood pressure, heart rate, and shock index were 146.1 ± 30.5 (mm Hg), 98.8 ± 20.5 (beats/min), and 0.7 ± 0.22, respectively. The percentage of patients with a shock index ≥1 was 7.1%, and higher in the mortality group than in the survival group. Patients with mortality had a higher prevalence of cancer history, but a lower prevalence of chronic obstructive pulmonary disease (COPD) than the patients with survival. In the analyses of laboratory data, patients with mortality had a higher white blood cell count, percentage of bandemia, and co-infection (i.e., Influenza A + B) than the patients with survival. There was no statistical difference of DNR between mortality and survival groups. All of the patients were treated with either Oseltamivir or Zanamivir as soon as influenza infection was diagnosed.

The logistic regression showed that the odds ratio (95% confidence interval [CI]) of shock index ≥1 was 6.80 (2.39–19.39) (Table 2). The AUC and Hosmer-Lemeshow goodness-of-fit test of shock index ≥1 were 0.62 and 0.23, respectively. The performance of a shock index ≥1 were: sensitivity (30.0%), specificity (94.1%), positive predictive value (20.0%), and negative predictive value (96.4%) (Table 3).

Causes of mortality in 20 patients were sepsis (70%, 14 patients), respiratory failure (15%, 3 patients), and cardiovascular event (15%, 2 patients with acute myocardial infarction and 1 patient with myocarditis).

4. Discussion

The shock index is known as a predictor for hemodynamic stability and used widely to predict mortality and morbidity in various diseases, especially under the circumstances of shock. The shock index is most frequently used to evaluate the amount of blood loss and degree of hypovolemic shock [22]. However, it can also be used as a severity predictor for non-hypovolemic shock [15,23]. A study about acute pulmonary embolism (i.e., a disease of possible obstructive shock) reported that a shock index ≥1, independent of echocardiographic findings, was associated with increased in-hospital mortality [23]. In another study about severe sepsis in adult patients, a shock index ≥1 had a high specificity

Table 1
Characteristics of geriatric ED patients with influenza.

Characteristics	Total patients ($n = 409$)	Mortality ($n = 20$)	Survival ($n = 389$)	p-Value
Age, yr	79.5 ± 8.3	81.2 ± 8.5	79.5 ± 6.4	0.36
Age subgroup				
Young elderly (65–74 yr)	125 (30.6)	4 (20.0)	121 (31.1)	0.31
Moderately elderly (75–84 yr)	174 (42.5)	10 (50.0)	164 (42.1)	0.51
Old elderly (≥85 yr)	110 (26.9)	6 (30.0)	104 (26.8)	0.76
Male sex	205 (50.1)	13 (65.0)	192 (49.3)	0.17
Vital signs				
SBP (mm Hg)	146.1 ± 30.5	135.1 ± 31.2	146.7 ± 30.5	0.28
Heart rate (beats/min)	98.8 ± 20.5	103.0 ± 21.6	98.6 ± 20.5	0.55
Shock index	0.7 ± 0.2	0.8 ± 0.2	0.7 ± 0.2	0.33
Shock index ≥1	29 (7.1)	6 (30.0)	23 (5.9)	0.002
Hypotension (SBP < 90 mm Hg)	30 (3.4)	4 (20.0)	26 (6.0)	0.74
Tachycardia (heart rate > 100/min)	189 (49.1)	13 (65.0)	176 (45.2)	0.15
Past history				
Hypertension	263 (64.3)	17 (85.0)	246 (63.2)	0.06
Diabetes	163 (39.8)	7 (35.0)	156 (40.1)	0.66
Coronary artery disease	103 (25.1)	10 (50.0)	93 (23.9)	0.09
Stroke	65 (15.9)	4 (20.0)	61 (15.7)	0.63
Cancer	61 (14.9)	7 (35.0)	54 (13.9)	0.02
COPD	111 (27.1)	0 (0)	111 (28.5)	0.03
Laboratory data				
White blood cell count (cells/mm^3)	10,590.0 ± 5820.0	14,530.0 ± 6.2	10,380.0 ± 5.8	0.002
Platelet (10^3/mm^3)	186.2 ± 158.8	198.9 ± 140.3	185.6 ± 159.9	0.68
c-reactive protein (mg/dL)	8.2 ± 10.1	11.7 ± 9.2	8.0 ± 10.2	0.09
Bandemia (band form >10%)	43 (10.2)	7 (35.0)	36 (9.2)	0.004
Influenza subtypes				
Influenza A	278 (68.0)	12 (60.0)	266 (68.3)	0.45
Influenza B	120 (29.3)	5 (25.0)	115 (29.5)	0.67
Influenza A + B	11 (2.7)	3 (15.0)	8 (2.1)	0.002
Influenza vaccination	8 (1.9)	1 (5.0)	7 (1.8)	0.55
DNR	4 (1.0)	2 (10.0)	2 (0.5)	0.08
Admission rate[a]	343 (83.9)	20 (100.0)	323 (83.0)	0.06

Data were presented as % or Mean ± SD. ED, Emergency Department; SD, standard deviation; SBP, systolic blood pressure; COPD, chronic obstructive pulmonary disease; DNR, Do not resuscitate.
[a] Admission to general ward or intensive care unit.

(80%) and negative predictive value (88%) for predicting 28-day mortality, better than the systemic inflammatory response syndrome (SIRS) criteria [15].

This study revealed that there was a 4.9% of mortality rate in geriatric ED patients with influenza in the study hospital. The mean ± SD of shock index was 0.7 ± 0.22 and the percentage of a shock index ≥1 was higher in the mortality group than in the survival group. Geriatric ED patients with a shock index ≥1 had a nearly 7-fold risk for mortality than those without. In addition, a shock index ≥1 has a high specificity and negative predictive value and good reliability for predicting 30-day mortality.

Vital signs, including systolic blood pressure, diastolic blood pressure, and heart rate are commonly used to rapidly evaluate hemodynamic stability of patients in the ED [9]. However, normal values of vital signs may conceal significant deficiencies in systemic oxygenation and cardiac function, both of which are related to an increased risk for death [9,24-26]. By calculating the ratio of heart rate and systolic blood pressure, the shock index has been shown to have an inverse linear relationship with left ventricular stroke work in acute circulatory failure [7]. An elevated shock index indicates a reduction of left ventricular stroke volume and deterioration in left ventricular mechanical performance induced by sepsis, trauma, or hemorrhage [7,9,27].

Recent studies revealed that elevated shock index was associated with poorer outcomes in geriatric patients [16,28,29]. A national study about geriatric trauma reported that 3% of the patients had a shock index ≥1 and the patients with a shock index ≥1 were more likely to require blood product transfusions, an exploratory laparotomy, and have in-hospital complications [28]. A shock index ≥1 was also the strongest predictor of mortality (odds ratio: 3.1; 95% CI: 2.6–3.3; p-value = 0.001), while systolic blood pressure and heart rate were not [28]. A study in the UK reported that a shock index >1 was an independent predictor for in-patient death in the oldest elderly (≥ 90 years) [16]. This study recruited 405 oldest elders from three UK centers admitted with acute medical problem [16]. After uni-variate and multi-variate logistic regression analyses, a shock index >1 was found to be independently related to death (odds ratio: 2.65; 95% CI: 1.20–5.86; p-value = 0.016) [16].

Furthermore, a shock index ≥1 had a high specificity and negative predictive value for predicting mortality, which indicates that a geriatric ED patient with influenza is less likely to die if his/her shock index was <1. In spite of the low sensitivity and positive predictive value due to the low mortality in this study, it still may be helpful for clinicians to decide whether or not the patient is discharged or hospitalized, especially in the situations or facilities without laboratory tests.

Table 2
Logistic regression, AUC, and Hosmer-Lemeshow goodness-of-fit test of the shock index ≥1.

Variable	B	Odds ratio	95% CI
Shock index ≥1	1.92	6.80	2.39−19.39
AUC			0.62
Hosmer-Lemeshow goodness-of-fit			0.23

CI, confidence interval; AUC, area under the curve.

Table 3
Performance of the shock index ≥1 in predicting mortality in geriatric ED patients with influenza.

Shock index ≥1	
Sensitivity	30.0
Specificity	94.1
Positive predictive value	20.0
Negative predictive value	96.4

Data were presented as %. ED, emergency department.

The major strength of this study is that it is the first study to report about the association between the shock index and mortality in the geriatric ED patients with influenza. This study also has some limitations. First, this was a retrospective study, and some variables were not completely documented in the medical records. Second, the severity of influenza may be higher in the study hospital because it is a medical center. Third, the number of included patients over 5 years was relatively low, which may be related to that the inclusion criteria was positive swab test rather than the clinical diagnosis. Because the swab test has a modest sensitivity of 58–67% and a high specificity of 98%, some patients who were diagnosed as influenza clinically might not be included into this study due to the false negative result [30]. Fourth, the criteria of influenza infection by fever and swab test in this study may have false positive or negative results. The swab test had a positive predictive rate of 85.7% and negative predictive rate of 89.8% for influenza A; positive predictive rate of 66.7% and negative predictive rate of 93.9% for influenza B [31]. Advanced examinations, such as reverse transcriptase-polymerase chain reaction, immunofluorescence assay or viral culture, are needed to confirm the diagnosis of influenza. However, the criteria we adopted in this study has the advantage of simple and practicality for the research. Further studies about prospective design, validation in other hospitals or nations, and recruiting more patients are warranted in the future.

5. Conclusions

A shock index ≥1 is a rapid, simple, and practical tool to predict 30-days mortality in geriatric ED patients with influenza. Geriatric ED patients who met the criteria had a nearly 7-fold risk for 30-days mortality than those without. On the other hand, geriatric ED patients who did not meet the criteria may consider to be discharged with close follow-up in out-patient clinics. The shock index could help clinicians to make decisions on patient disposition and utilization of medical resources. However, further studies are needed to validate the findings of this study.

Acknowledgments

We thank Miss Ti Hsu for the English revision. This work was supported by Chi-Mei Medical Center [Grant number CMNCKU10620].

Author contributions

JYC, CC Hsu, CC Huang, and HRG designed and conceived this study and wrote the manuscript. JYC performed the statistical analysis. JHC, WLC, and HJL provided professional suggestions and wrote the manuscript. All authors read and approved the final manuscript.

Conflict of interest

All authors denied any conflict of interest.

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