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Original Article

Is the Shock Index Associated with Adverse Outcomes among Geriatric Patients with COVID-19 in the Emergency Department Triage?

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SUMMARY

Background: The COVID-19 outbreak presents challenges to the emergency care system. Advanced age is a risk factor for mortality. This study aimed to investigate whether the shock index (SI) is an early predictor of adverse outcomes in geriatric patients with COVID-19.
Methods: Patients aged ≥ 60 years with COVID-19 between May 1, 2021, and February 1, 2022, were included in a retrospective cohort study. These patients were divided into two groups based on ICU admission. Variables were compared for the two groups. The receiver operating characteristic analysis of the SI and age–SI (ASI) was used to detect deteriorating outcomes early.
Results: In total, 156 patients were included, and the mean age was 68.52 ± 7.25 years. ICU admission, intubation, and mortality were recorded in 46 (29.49%), 32 (20.51%), and 16 (10.26%) patients, respectively. The mean body weight, pulse rate, respiratory rate, pulse oximetry, SI, and ASI were significantly different between the two groups (p = 0.018, 0.032, 0.007, < 0.001, 0.004, and 0.007, respectively). CRP, LDH, ALT, ferritin, D-dimer, and sodium levels were significantly associated with ICU admission. Regarding ICU admission, intubation, and mortality, the areas under the curve (AUC) of the SI and ASI showed acceptable discrimination. The predictive power of the ASI was significantly higher than that of the SI for mortality (AUC difference, 0.088 ± 0.036 (95% CI 0.017–0.160); p = 0.016).
Conclusion: The ASI is a useful triage tool for mortality prediction in geriatric patients with COVID-19. The SI and ASI can be used in conjunction with vital signs, oxygen saturation, and laboratory biomarkers for the early detection of ICU admission.

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1. Introduction

The Chinese health officials notified the World Health Organization (WHO) of cases of pneumonia of unknown etiology detected in Wuhan City on December 31, 2019. Following a surge in cases worldwide, the WHO announced that the coronavirus disease-2019 (COVID-19) as a pandemic in March 2020.[1] An outbreak of COVID-19 (alpha variant) also occurred in Taiwan in May 2021.

The geriatric population is among population with the highest risk for severe COVID-19. Patients aged > 59 years are evaluated to be five times more likely to die after the onset of COVID-19 than those aged 30–59 years.[2] Advanced age is a risk factor for mortality in patients with COVID-19 pneumonia, which can quickly result in acute respiratory distress syndrome, leading to multiple organ failure.[2–4] Moreover, older adults are vulnerable to COVID-19 and have higher rates of lethal complications, hospital admission, mechanical ventilation, intensive care, and mortality.[3–6] Therefore, the early detection of at-risk geriatric patients and recognition of clinical presentation are important to prevent mortality.

COVID-19 has caused a health crisis and economic burden. It presents challenges to the emergency care system, resulting in emergency department (ED) and intensive care unit (ICU) crowding.[7,8] Therefore, early diagnosis and timely treatment are vital in patients with critical illness. A prognostic measure is urgently needed to predict the mortality and disease severity in the early stage of geriatric patients with COVID-19. An easy and cheap predictive tool that can be rapidly evaluated upon initial presentation to the ED could contribute to the reduction of adverse outcomes.[9,10]

The shock index (SI) is a ratio calculated by dividing the heart rate (HR) by the systolic blood pressure (SBP). It is a simple formula to estimate the changes in cardiovascular performance and the level of tissue perfusion before systemic hypotension for early decision making.[11] Allgöwer introduced the SI as an effective and non-invasive method of measuring the degree of hypovolemia and it provides information about hemodynamics in patients with shock.[11] The SI can be used as a an evaluation marker of hypovolemic shock in trauma cases and hemodynamic instability in patients with myocardial infarction. The SI has been reported to be a useful predictor of mortality in COVID-19, trauma, pneumonia, septic shock, and pulmonary embolism.[12–14] Moreover, patients with COVID-19 induced

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acute hypoxic respiratory failure often develop shock.[15] Several studies have shown that the incidence of hypotension in patients with COVID-19 ranges from 30% to 40%. Patients with COVID-19 suffering from hypoxia and hypotension had the highest mortality rate.[16] The SI is a useful tool for hospitalization, early intervention, and mortality prevention of geriatric patients with COVID-19 in the ED.[9]

This study aimed to investigate the power of the SI at the time of ED triage as an early predictor of adverse outcomes in geriatric patients with COVID-19.

2. Materials and methods

2.1. Study setting and design

This retrospective observational cohort study was conducted in a tertiary center of Taiwan. Approximately 120,000 annual visits to the ED in the Far Eastern Memorial Hospital (FEMH) are recorded. Nearly 10,000 patients visit the ED per month, with 50% of hospital admissions generated at the ED. This study included all patients aged > 60 years who were hospitalized with COVID-19 by the ED of the FEMH between May 1, 2021, and February 1, 2022. The diagnosis of SARS-CoV-2 alpha variant was confirmed with reverse-transcription polymerase chain reaction on nasopharyngeal swabs. The exclusion criteria were as follows: age < 60 years, patients with COVID-19 and other prevalent acute conditions (surgical emergencies, and pathologies with high risk of fatal outcomes), and patients discharged from or who died at the ED. The patients were divided into two groups: ICU admission and non-ICU admission. This study was approved by the Institutional Review Board of FEMH (110233-E).

2.2. Data collection and outcome measures

For all patients, data were collected in the ED, including demographics such as age, sex, medical history, and chronic diseases; clinical manifestations such as presenting signs and symptoms, vital signs, pulse oxygen saturation (SpO_2); laboratory values such as arterial blood gas analysis, complete blood count, electrolytes, renal and liver function tests, C-reactive protein, troponin, D-dimer, and ferritin; treatments such as oxygen therapy, and mechanical ventilation; and disposition such as ICU admission, and non-ICU ward admission. Follow-up ended at death or discharge from the hospital. The SI was defined as the ratio of the HR to the SBP, and the age–shock index (ASI) was calculated as age multiplied by SI.[14,19] The SI and ASI were calculated from the first SBP and HR measurements of the ED visit in all enrolled patients and analyzed for their discriminative value on ICU admission. The outcomes were intubation, mortality, ICU length of stay, and hospital length of stay.

2.3. Statistical analysis

Data were analyzed using descriptive statistics. Categorical values were expressed as % of total, other values as mean ± standard deviation (SD). The rates of ICU admission, intubation, and mortality were calculated with the total number of hospital admissions as the denominator. Patients were divided into two groups based on ICU requirement. Variables were compared for the two groups using Pearson's chi-square test, Student t-test, and Mann-Whitney U test when appropriate. Multivariate logistic regression analysis was used to evaluate the statistically significant differences between non-ICU and ICU admission, applying corrections for confounding factors such as age, sex, and comorbidities. We included variables in this model with a $p < 0.05$ in the univariate analysis. Receivers operating characteristic (ROC) curve analyses were performed to determine the predictive power of the SI and ASI on the mortality, intubation, and ICU admission. The optimal cutoff point for specificity and sensitivity was estimated using the Youden method. The area under the curve (AUC) of the ROC curves of the SI and ASI was compared with a DeLong's test using pairwise comparison method. A 2-sided p-value < 0.05 was considered statistically significant. All statistical analyses were conducted using the IBM SPSS Statistics 24.0 software (SPSS Inc., Chicago, IL).

3. Results

The study was completed with 156 patients after applying the selection criteria. The mean age of the patients was 68.52 ± 7.25, and 83 (53.21%) were men and 73 (46.79%) were women. The most common comorbidity was hypertension (91; 58%), followed by diabetes mellitus (52; 33%) and coronary artery disease (23; 15%). Other demographic and comorbidity data of the study population are presented in Table 1. In this study, 16 (10.26%) patients died. ICU admission was required in 46 (29.49%) patients. The average lengths of stay in the hospital and ICU were 7 and 19 days, respectively (Table 1).

Moreover, the mean of the body weight, respiratory rate, pulse rate, SpO_2, SI, and ASI were significantly different between the two groups (p = 0.018, 0.007, 0.032, 0.000, 0.004, and 0.007, respectively). Intubation was performed in 32 (20.51%) patients, and 25 (16%) patients received nasal high-flow oxygen therapy. The mean hospital length of stay in the ICU admission group was 35.61 ± 23.84 days, whereas that in the non-ICU admission group was 12.08 ± 7.62 days. A statistically significant difference was found between the two groups ($p < 0.001$) (Table 1).

Most of the laboratory findings did not reach statistical significance between the two groups, except for the C-reactive protein (CRP), lactate dehydrogenase (LDH), alanine transaminase (ALT), ferritin, D-dimer, and sodium ($p = 0.001$, $p < 0.001$, $p = 0.001$, $p = 0.008$, $p < 0.001$, and $p = 0.036$, respectively). The parameters that reached a statistically significant association with ICU admission are presented in Table 2. The odds ratios for variables significantly associated with ICU admission after multivariate logistic regression and correction for different confounders were SI, ASI, SpO_2, D-dimer, ferritin, and LDH (3.584, 1.028, 0.919, 1.000, 1.000, and 1.011, respectively) (Table 3).

According to Youden's index, the optimal cutoff values for predicting ICU admission were 0.745 for the SI (AUC, 0.644 ± 0.049; p = 0.005) and 51.925 for the ASI (AUC, 0.620 ± 0.049; p = 0.018). Besides, the ability of the indexes to predict intubation was 0.715 for the SI (AUC, 0.625 ± 0.061; p = 0.030), whereas it was 52.365 for the ASI (AUC, 0.634 ± 0.059; p = 0.020). However, the optimal cutoff value of the SI to predict mortality was 0.725 (AUC, 0.584 ± 0.075 (95% CI 0.436–0.732); p = 0.247), whereas it was 52.470 for the ASI (AUC, 0.672 ± 0.065 (95% CI 0.544–0.800); p = 0.018) (Table 4, Figures 1–3).

When the predictive power of ICU admission and intubation was compared, no statistically significant difference was found between the AUCs of the two indices. Nevertheless, when comparing the predictive power of the SI and ASI for mortality, a significant difference was found between the two indices, and the ASI was significantly more successful than the SI (AUC difference, 0.088 ± 0.036 (95% CI 0.017–0.160); p = 0.016; DeLong's test). The ROC analysis results for the adverse outcome prediction by the SI and ASI are presented in Table 4 and Figures 1–3.

Table 1
Baseline characteristics of the patients.

	Total patients	ICU admission	Non-ICU admission	*p* value
Demographics				
No. of patients	156	46 (29.49)	110 (70.51)	-
Age, years (SD)	68.52 ± 7.25	68.45 ± 6.34	68.28 ± 7.84	0.812
Male, No. (%)	83 (53.21)	30 (65.22)	53 (48.18)	0.052
Female, No. (%)	73 (46.79)	16 (34.78)	57 (51.82)	0.052
Body weight, kg	63.76 ± 11.34	67.08 ± 10.94	62.38 ± 11.27	0.018
Comorbidities, No. (%)				
Asthma	2 (1)	1 (2)	1 (1)	0.522
Cancer	11 (7)	3 (7)	8 (7)	0.867
CAD	23 (15)	10 (22)	13 (12)	0.111
CHF	9 (6)	4 (9)	5 (5)	0.311
CKD	10 (6)	4 (9)	6 (5)	0.451
COPD	2 (1)	1 (2)	1 (1)	0.522
DM	52 (33)	18 (39)	34 (31)	0.321
Hypertension	91 (58)	25 (54)	66 (60)	0.514
Liver disease	8 (5)	3 (7)	5 (5)	0.610
Neurological disease	7 (4)	2 (4)	5 (5)	0.957
Vital signs				
Temperature, °C	36.85 ± 0.85	36.95 ± 0.82	36.81 ± 0.86	0.374
Pulse rate, beat/min	99.42 ± 20.47	104.85 ± 22.62	97.15 ± 19.15	0.032
Respiratory rate, br/min	20.63 ± 8.37	23.43 ± 14.78	19.46 ± 2.20	0.007
SBP, mmHg	134.03 ± 29.21	129.5 ± 30.34	135.92 ± 28.66	0.213
DBP, mmHg	78.03 ± 19.36	73.61 ± 17.14	79.88 ± 20.01	0.065
Pulse oximetry (%)	92.59 ± 11.29	85.97 ± 16.97	95.35 ± 6.02	< 0.001
Shock index	0.77 ± 0.23	0.86 ± 0.27	0.73 ± 0.21	0.004
Age shock index	53.20 ± 15.71	58.37 ± 17.92	51.04 ± 14.22	0.007
Outcomes				
Intubation	32 (20.51)	31 (67.4)	1 (0.9)	< 0.001
HFNC	25 (16)	23 (50)	2 (1.82)	< 0.001
Mortality	16 (10.26)	12 (26.09)	4 (3.64)	< 0.001
ICU length of stay, day	6.42 ± 14.92	21.76 ± 20.63	0 ± 0	< 0.001
Hospital length of stay, day	19.02 ± 17.93	35.61 ± 23.84	12.08 ± 7.62	< 0.001

Data are presented as Numbers/Total (%) or as mean ± SD.
CAD, coronary artery disease; CHF, congestive heart failure; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; DBP, diastolic blood pressure; DM, diabetes mellitus; HFNC, high flow nasal cannula; SBP, systolic blood pressure.

Table 2
Comparison of the laboratory findings between groups.

	Total patients	ICU admission	Non-ICU admission	*p* value
Leukocytes, $\times 10^3$	7.17 ± 3.25	7.78 ± 4.01	6.91 ± 2.86	0.127
CRP, mg/dL	6.62 ± 8.48	10.10 ± 6.76	5.22 ± 8.75	0.001
LDH, U/L	380.15 ± 219.09	570.28 ± 243.25	300.64 ± 148.98	< 0.001
ALT, U/L	28.43 ± 23.04	38.07 ± 24.35	24.40 ± 21.33	0.001
Ferritin, ng/mL	1251.76 ± 2519.83	2073.30 ± 3840.76	908.20 ± 1592.24	0.008
D-Dimer, ng/mL FEU	1553.69 ± 2337.56	2644.78 ± 3441.25	1097.41 ± 1472.64	< 0.001
Hb, g/dL	13.09 ± 1.84	13.40 ± 1.80	12.95 ± 1.86	0.167
Platelet, 10^3/uL	201.24 ± 102.49	180.96 ± 70.90	209.72 ± 112.33	0.110
Sodium, mmol/L	133.78 ± 4.79	132.54 ± 4.83	134.3 ± 4.70	0.036
Potassium, mmol/L	3.81 ± 0.69	3.94 ± 0.73	3.75 ± 0.67	0.117

Data are presented as mean ± SD.
ALT, alanine aminotransferase; CRP, C reactive protein; Hb, hemoglobin; LDH, lactate dehydrogenase.

Table 3
Odds ratio for variables significantly associated with ICU admission after multivariate logistic regression and correction for confounders.

	Odds ratio	95% CI	SE	*p* value
Shock index	3.584	1.016–5.157	0.369	0.047
Age shock index	1.028	1.004–1.051	0.012	0.020
Pulse oximetry (%)	0.919	0.849–0.994	0.040	0.031
D-Dimer	1.000	1.000–1.016	0.005	0.009
Ferritin	1.000	1.000–1.020	0.014	0.024
LDH	1.011	1.006–1.014	0.002	< 0.001

LDH, lactate dehydrogenase.

4. Discussion

The surge of COVID-19 cases has resulted in many countries experiencing unprecedented strain on the ED and high demand for ICU capacity.[7] As of May 2020, the largest number of patients with critical COVID-19 admitted to the ICU of FEMH during the peak of the pandemic in Taiwan. The COVID-19 (alpha variant) outbreak also presented great challenges to the emergency care system leading to ED crowding. Therefore, effective early prediction of patients at high risk of adverse outcomes is important for ED disposition and resource allocation.

Table 4
The ROC analysis for adverse outcomes of SI and ASI.

	Cutoff point	Sens (%)	Spec (%)	PPV (%)	NPV (%)	AUC	SE	95% CI	*p*
ICU admission									
SI	0.745	0.761	0.518	39.6	80.0	0.644	0.049	0.548–0.740	0.005
ASI	51.925	0.609	0.545	36.5	76.8	0.620	0.049	0.524–0.716	0.018
Comparison SI-ASI						0.023	0.020	-0.016–0.063	0.243
Intubation									
SI	0.715	0.688	0.468	24.1	83.1	0.625	0.061	0.505–0.744	0.030
ASI	52.365	0.625	0.573	26.4	84.5	0.634	0.059	0.517–0.750	0.020
Comparison SI-ASI						0.009	0.019	-0.028–0.045	0.642
Mortality									
SI	0.725	0.556	0.486	30.2	89.6	0.584	0.075	0.436–0.732	0.247
ASI	52.470	0.778	0.522	34.6	91.9	0.672	0.065	0.544–0.800	0.018
Comparison SI-ASI						0.088	0.036	0.017–0.160	0.016

ASI, age shock index; AUC, area under the curve; NPV, negative predictive value; PPV, positive predictive value; SE, standard error; Sens, sensitivity; SI, shock index; Spec, specificity.

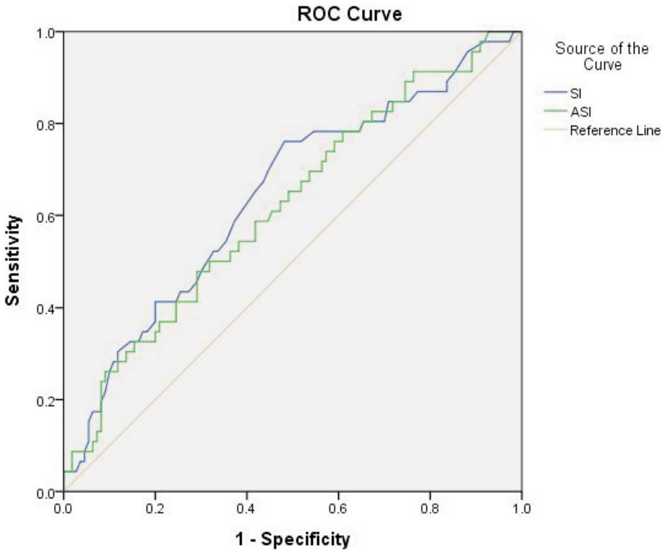

Figure 1. The ROC curve of SI and ASI for ICU admission.

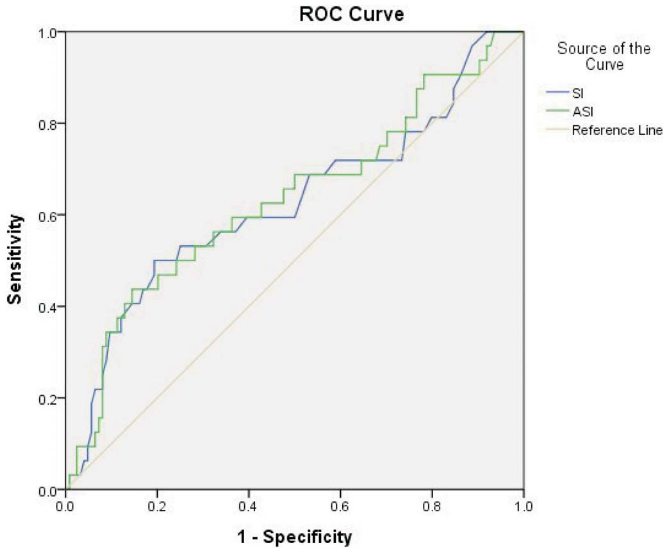

Figure 2. The ROC curve of SI and ASI for intubation.

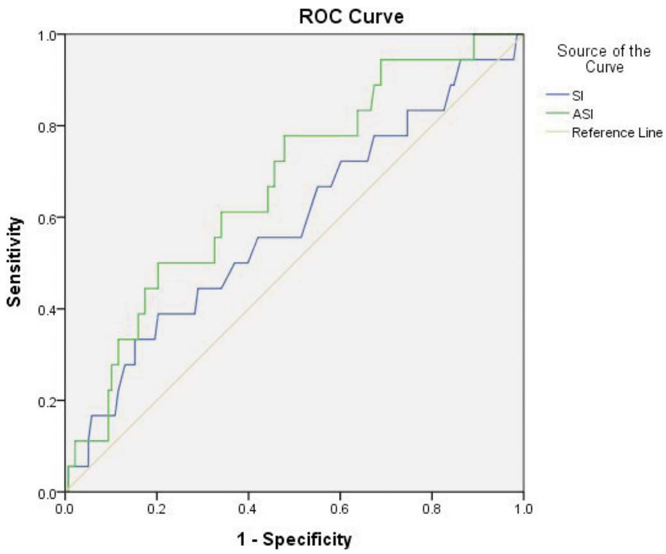

Figure 3. The ROC curve of SI and ASI for mortality.

SARS-CoV-2 is highly contagious and potentially deadly for geriatric patients with underlying comorbidities. Age plays a key role in the estimation of adverse outcomes. Previous studies have shown that most mortalities occur in patients aged ≥ 60 years with COVID-19.[2–6] Studies have reported that advanced age is a single risk factor in COVID-19 pneumonia.[17,18] Since the ASI is obtained by adding age to the SI, we compared the SI and ASI in terms of their ability to predict mortality, intubation, and ICU admission in geriatric patients with COVID-19 in the ED.[19]

In this study, the AUCs of the SI and ASI for adverse outcomes showed only acceptable discrimination. With regard to the optimal cutoff point of the SI and ASI for ICU admission and intubation, the sensitivity and specificity were both unsatisfying. The SI had poor sensitivity in predicting mortality. However, according to DeLong's test, the ASI measured in the ED was discriminative for mortality (95% CI 0.017–0.160; $p = 0.016$), and it was useful in identifying early geriatric patients with COVID-19 at high risk of acute deterioration. Thus, intensive monitoring and early stabilization should be established in geriatric patients with an elevated ASI.

A study reported that an SI of > 0.93 indicated a significant association with mortality in geriatric patients with COVID-19 and $SpO_2 \leq 95\%$.[9] However, in our study, the lack of correlation between the SI and mortality was inconsistent with the results of previous studies, which could be explained by as follows: our study included patients aged ≥ 60 years with COVID-19, and 58% of these patients had hypertension and took antihypertensive medications such as beta-blockers or calcium channel blockers that may blunt the tachycardia in response to hypovolemia and alter the association of SI with outcomes. Moreover, Taiwan has one of the best healthcare systems in the world. The National Health Insurance program is accessible and low cost and has short waiting times and comprehensive population coverage. Most patients with confirmed or suspected

COVID-19 were sent timely to our ED, including asymptomatic or mildly symptomatic cases. These may lead to contradicting results and significant differences in COVID-19 severity between studies.

Moreover, the mean body weight, pulse rate, respiratory rate, SpO_2, SI, ASI, CRP, LDH, ALT, ferritin, D-dimer, and sodium showed significant differences between the ICU and non-ICU admission groups. Of the variables evaluated, only the SI, ASI, SpO_2, D-dimer, ferritin, and LDH were significantly associated with ICU admission after adjusting for confounding factors. Therefore, the SI and ASI may be used in combination with SpO_2, vital signs, and laboratory markers in the clinical decision making for patients with COVID-19 at risk for adverse outcomes in the ED. This information could help the ED anticipate the need for ICU admission to deal efficiently with the challenges arising from the COVID-19 pandemic. Specifically, ED ventilator demand/capacity mismatch may occur at the peak of the pandemic.[20] Thus, predicting the need for ventilator and ICU beds can help in the management of patients with COVID-19 and the necessary ancillary equipment in advance.[7,8]

The univariate analysis of our laboratory findings showed that geriatric patients with COVID-19 admitted to the ICU had lower sodium and higher levels of inflammatory markers, including CRP, LDH, ALT, ferritin, and D-dimer. In addition, when compared with younger populations, geriatric patients with COVID-19 had significantly higher CRP levels and lower lymphocyte proportions.[17] Monitoring the levels of albumin, urea nitrogen, neutrophil-to-lymphocyte ratio, D-dimer, and LDH could be applied to detect early geriatric patients ($\geq$ 60 years old) with critical COVID-19.[21] Moreover, some studies have indicated that hyponatremia was associated to a 2.18-fold increased likelihood of requiring mechanical ventilation in patients hospitalized for COVID-19.[22] Serum sodium could be an early prognostic predictor of disease severity in patients with COVID-19.

5. Limitations

This study had several limitations. First, as this was a retrospective cohort study, data were collected retrospectively with potential limitations, including residual confounding, selection bias, and reporting accuracy. Smoking and body mass index are also potential confounders. Second, the results were also limited to a single tertiary-level hospital setting near the epicenter of the COVID-19 pandemic; therefore, multicenter prospective studies are needed to verify clinical data. Third, ICU admission was an institution-dependent outcome, inevitably limiting the generalizability of the results during the initial surge of this pandemic. Fourth, the study sample size was limited to 156 patients because of the selection criteria, including a specific age group. It could be improved by conducting further studies with larger sample sizes to draw causal conclusions. Finally, the SI and ASI values were based on the initial presentation to the ED. However, changes in the SI, ASI, SpO_2, and vital signs over time may be critical in predicting adverse outcomes. Therefore, we plan to put consecutive data into an artificial intelligence system to detect clinical deterioration and further improve predictions in the ED.

6. Conclusions

The ASI is a rapid, easy, and effective triage tool for mortality prediction in geriatric patients with COVID-19 in the ED. Although the SI is only discriminative for intubation and ICU admission, the SI and ASI can be used in conjunction with SpO_2, vital signs, and laboratory markers for the early identification of geriatric patients with COVID-19 at risk for outcomes at ED presentation. Further studies are needed to validate the cutoff of the indices, assess their values as clinical decision tools, and compare their accuracy with other early warning scores.

Conflicts of Interest

None declared.

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