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The new combination of oxygen saturation with age shock index predicts the outcome of COVID-19 pneumonia

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Abstract

Introduction: Emergency departments around the world have been struggling to deal with patients with COVID-19 and presumed COVID-19. Triaging patients who need further medical support is the key matter to emergency physicians as the delay of proper treatment may worsen the results. The aim of this study was to validate the ability of age shock index and hypoxia-age-shock index at the time of presentation to the emergency department to predict case fatality in patients with COVID-19 pneumonia.

Methods: We only included patients who had COVID-19-associated pneumonia who needed in-hospital treatment. The vital signs and oxygen saturation used in the study were collected, especially from the triage sector, before patients were given supplemental oxygen.

Results: A total of 241 patients enrolled in the study. The case fatality rate was 27%. The median age of the study samples was 78 (66–86) years with 133 male and 108 female patients. Hypoxia-age-shock index showed the best performance in analysis (odds ratio 15.1, 95% confidence interval: 5.1–44.4; adjusted odds ratio 8.6, 95% confidence interval: 2.8–26.8).

Conclusion: The hypoxia-age-shock index was a strong predictor for in-hospital mortality of COVID-19 pneumonia. Furthermore, when it was compared with age shock index, hypoxia-age-shock index showed better performance in predicting fatality of the disease.

Keywords

COVID-19, pneumonia, emergency medicine, hypoxia

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Introduction

In December 2019, a new type of coronavirus was discovered in Wuhan, China, and World Health Organization officially announced the outbreak of the pandemic.[1] As of March 2023, more than 670 million confirmed cases and 6 million fatalities of coronavirus 2019 (COVID-19) have been seen worldwide.[2] COVID-19 is a viridae of coronavirus characterized as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which causes various symptoms from the upper airway to the entire respiratory system and even vital organ failure. The case-specific mortality rate of COVID-19 in whole population was 1%, while in hospitalized patients it was 13% and even up to 37% in patients who needed intensive care.[3]

A recent study showed the possibility of technology to help diagnose and provide healthcare services remotely in the pandemic era.[4] The study discussed the potential of the world of technology in terms of the healthcare system, especially in the COVID-19 era. Numerous tools can be used for this technology and adapted for better healthcare systems. However, addressing the situation of the pandemic, simplifying tools for triaging the patients must be investigated further.

Since the pandemic era, emergency physicians have been struggling to deal with patients with COVID-19 and presumed COVID-19 globally. It is of critical importance to triage patients who need further medical support, as the delay of proper treatment may worsen the patient's outcome. Even

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though there have been many predicting scores suggested, it is still evolving in ways of simplifying and adapting in an emergency setting.[5]

The shock index (SI), known as the ratio of heart rate to systolic blood pressure, is an easy to use and well-proven ratio for determining the severity in traumatic and septic patients.[6–9] Age SI, multiplying SI by age, was first used in predicting mortality in traumatic elderly patients.[10] Besides, age SI has been validated for the prediction of mortality of patients presenting to the emergency department (ED).[11–13]

The clinical mainstay of COVID-19 pneumonia is respiratory distress that exhibits cyanotic features. Xie et al.[14] focused on oxygen saturation as a prognostic biomarker of the disease and profound hypoxemia was related to the mortality of COVID-19 patients. However, increasing age has also been nominated as a strong predictor of fatality in this disease entity.[15–19] Thus, a recent study showed the new score combined age and oxygen saturation for the SI.[20]

We aimed to prove the ability of age SI and hypoxia-age-shock index (HASI) at the triage level in the ED to predict the case-specific fatality in patients with COVID-19 pneumonia.

Methods

Study design

This is a retrospective study done at Myongji Hospital in Goyang City, South Korea, from January 2020 to December 2022. We conducted a standardized record review of confirmed cases by SARS-CoV-2 reverse transcription polymerase chain reaction (RT-PCR) of oropharyngeal or nasopharyngeal swabs in patients aged over 18 years at an urban, tertiary-care teaching hospital. Inclusion cases had to meet the criteria who had COVID-19-associated pneumonia and needed hospital treatment. Diagnosis of COVID-19 pneumonia was made based on the previous literature.[21]

The exclusion criteria were as follows; (1) patients transferred to other hospitals after confirmed COVID-19 pneumonia and (2) patients who were initially treated in another hospital.

Our study was approved by the Institutional Review Board of Myongji Hospital (2022-12-001), and the need for informed consent was waived due to the retrospective nature of this study.

The outcome measurement was in-hospital mortality during the period of treatment.

Data collection

Identification of patients via an electronic chart review was done after searching all potential subjects with a diagnosis code of U071 (Coronavirus disease 2019, virus confirmed) with ICD-10. Chart review and data assortment were done by three independent reviewers. The data of patients such as demographics, comorbidities, clinical variables, and laboratory tests were collected. Notably, the vital sign and oxygen saturation were gathered at the triage sector before patients were given with supplemental oxygen. The ratio of age SI to oxygen saturation was regarded as HASI.

Statistical analysis

The divided subgroups were analyzed using the Mann–Whitney *U* test or independent *t* test for numerical variables. Categorical variables were assessed by the chi-squared test or Fisher's exact test. All numerical data were examined for normal distribution using Kolmogorov–Smirnov test. To identify the association of SI, age SI and HASI with the case fatality, the receiver operating characteristic curves were drawn. The area under the receiver operating curve (AUROC) related to mortality was evaluated using a test developed by DeLong et al.[23] with the use of MedCalc Statistical Software version 20.218 (MedCalc Software bvba, Ostend, Belgium). The interval likelihood ratio (LR) of SI, age SI, and HASI were shown with the odds ratio (OR) and adjusted odds ratio (aOR). The aORs and 95% confidence intervals (CIs) for mortality were examined using logistic regression analysis which comprised all related variables predicting hospital mortality in the binary logistic regression model. IBM SPSS Statistics package version 21.0 (SPSS Inc., Chicago, IL, USA). *p* Value under 0.05 was regarded to be statistically significant.

Results

Baseline characteristics

A total of 241 patients finally enrolled in the study after the exclusion of 249 patients who were transferred to other medical facilities and 74 patients who had already been managed in other hospitals (Figure 1). The median age of the study samples was 78 (66–86) years with 133 male and 108 female patients. Among all study subjects, 151 were deposited to the intensive care unit (ICU) in our hospital and 35 patients needed intubation. A total of 128 patients were managed with high-flow oxygen.

Of the 241 patients, 66 (27%) died during the treatment. One patient died on the day of admission and the median survival day was 14.5 days for all study subjects. The non-survivor group was older and showed lower oxygen saturation than the survivor group. There were no significant differences in variables of comorbidities or laboratory results between the groups (Table 1).

Predictive performance and comparison of HASI, age SI, and SI

The AUROC of HASI, age SI, and SI in predicting in-hospital mortality were 0.733 (95% CI: 0.67–0.79), 0.647 (0.58–0.71), and 0.549 (0.49–0.61), respectively. The cutoff values using Youden index for HASI, age SI, SI were 0.7, 52, and

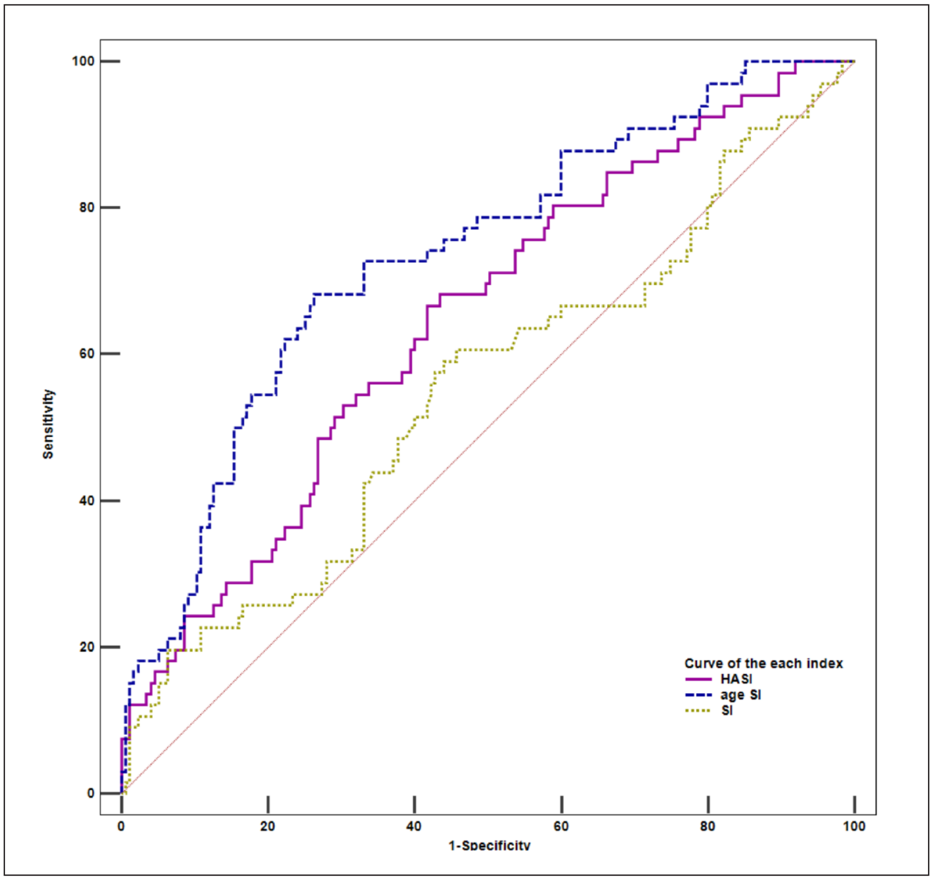

Figure 1. The receiver operation curves of SI, age SI, and HASI to predict in-hospital mortality.

0.7, respectively (Table 2). The prognostic performance of HASI for predicting fatal outcome was better than age SI and SI (Table 3). The AUROC of the pneumonia severity index, Multi-lobar infiltration, hypo lymphocytosis, bacterial co-infection, smoking history, hyper-tension and age score (MuLBSTA), and Confusion, Blood urea, Respiratory rate, Blood pressure, age 65 (CURB-65) were 0.524, 0.550, and 0.518, respectively.

Likelihood ratio and OR

For validation of probable cutoff points in each index, study subjects were divided into three groups and analyzed (Table 4). The likelihood of patients with HASI ⩾ 0.7 determining mortality was almost doubled (LR 2.3), and the OR was increased more than fivefold in univariable and multivariable analysis than the reference range (OR 5.3, 95% CI: 2.6–10.7, $p < 0.001$; aOR 5.4, 95% CI: 2.6–11.2, $p < 0.001$). Subjects with HASI ⩾ 0.9 showed more power for prediction of fatality (LR 3.0, OR 6.8, 95% CI: 3.1–14.9; aOR 7.8, 95% CI: 3.4–18.0). Subjects with age SI ⩾ 50 tended to have worse outcome than the reference range (LR 1.3, OR 2.1, 95% CI: 1.1–4.1; aOR 2.6, 95% CI: 1.3–5.1). The SI ⩾ 0.7 failed to show statistical significance to predict mortality in both univariable and multivariable analysis (OR 1.7, 95% CI: 0.9–3.2, $p = 0.123$; aOR 1.4, 95% CI: 0.7–2.8, $p = 0.422$).

When focusing on each index as continuous variables in predicting mortality, HASI showed the best performance in analysis (OR 15.1, 95% CI: 5.1–44.4; aOR 8.6, 95% CI: 2.8–26.8) (Table 5). Whereas, SI failed to show significance after adjusting with age and oxygen saturation (aOR 2.7, 95% CI: 0.8–9.2, $p = 0.106$).

Discussion

The major findings of our study were as follows. Age SI and HASI were all statistically significant in predicting case-specific fatality in patients with COVID-19 pneumonia. Moreover, the prognostic performance of HASI was better than age SI in prediction of in-hospital mortality. This study validated the power of the new index related to fatal outcome of patients with COVID-19 pneumonia. Our study showed the power of simple index to predict fatal outcome in patients of COVID 19 who needed hospital admission and intensive care.

A recent study proposed the HASI as a new predictor of intubation and ICU admission of COVID-19 patients.[20] The study tried to implement a new simple tool for determining prognosis of COVID-19 patients using oxygen saturation

Table 1. Demographic and clinical characteristics compared by subgroups.

Variables	Total (n = 241)	Survival discharge (n = 175)	In-hospital death(n = 66)	p
Age in years	78 (66–86)	74 (61–85)	81 (71–91)	<0.001
Male sex	133 (55)	96 (55)	37 (56)	0.867
Hemodynamic variables				
SpO2, %	89 (79–96)	92 (85–97)	77 (64–90)	<0.001
RR, in rate/min	20 (18–22)	20 (18–21)	20 (19–24)	0.949
SI	0.70 (0.60–0.86)	0.68 (0.61–0.85)	0.75 (0.59–0.90)	0.076
Age SI	51.6 (41.2–66.1)	49.9 (39.3–63.8)	58.7 (17.6–75.5)	0.001
HASI	0.60 (0.46–0.81)	0.55 (0.44–0.71)	0.81 (0.58–0.97)	<0.001
Laboratory value				
pH	7.43 (7.38–7.46)	7.44 (7.40–7.47)	7.39 (7.31–7.44)	0.497
PCO2, mmHg	35 (31–40)	35 (31–40)	34 (28–41)	0.522
PaO2, mmHg	80 (64–103)	82 (68–108)	66 (56–90)	0.289
Bicarbonate, mmol/L	23 (20–26)	24 (21–26)	21 (15–26)	0.246
Lactate, mmol/L	1.9 (1.4–3)	1.7 (1.3–2.5)	2.5 (1.5–3.8)	0.676
Leukocyte count, 10^3/μL	7.5 (5.6–10.5)	7.5 (5.7–9.8)	8.8 (3.9–13.6)	0.853
Platelet count, 10^3/μL	185 (145–239)	198 (144–254)	168 (141–212)	0.853
Hemoglobin, g/dL	12.3 (10.1–14.5)	12.4 (10.2–14.5)	12.2 (10–14.3)	0.771
Sodium, mmol/L	138 (135–141)	138 (135–140)	139 (133–145)	0.282
Potassium, mmol/L	4.1 (3.7–4.6)	4.1 (3.7–4.5)	4.4 (3.4–5.3)	0.279
BUN, mg/dL	23.7 (15.1–39.6)	20.1 (14.2–30.7)	37.6 (22.9–61.4)	0.065
Creatinine, mg/dL	1.0 (0.7–1.5)	0.9 (0.6–1.3)	1.4 (1.0–2.1)	0.312
AST, U/L	38 (26–60)	35 (25–54)	51 (30–78)	0.736
ALT, U/L	25 (16–47)	25 (16–45)	27 (19–48)	0.381
CK, U/L	99 (56–219)	88 (55–181)	128 (63–337)	0.657
CK-MB, ng/mL	1.3 (0.6–3.1)	1.1 (0.6–2.4)	2.4 (0.8–5.4)	0.391
CRP, mg/dL	10.0 (3.4–15.5)	7.0 (3.0–13.3)	14.2 (5.1–23.3)	0.858
Comorbidities				
CAOD	21 (9)	16 (21)	5 (8)	0.700
DM	81 (34)	57 (33)	24 (36)	0.578
Hypertension	144 (60)	104 (59)	40 (61)	0.868
Heart failure	13 (5)	11 (6)	2 (3)	0.318
Chronic renal failure	20 (8)	12 (7)	8 (12)	0.186
COPD	7 (3)	6 (3)	1 (0)	0.430
Cancer	21 (9)	14 (8)	7 (11)	0.522

Data are expressed as number (%) and median (interquartile range).
HASI = Hypoxia-age-shock index; SI = shock index; CAOD = coronary artery obstructive disease; COPD = chronic obstructive lung disease; RR = respiratory rate; SpO2 = pulse oxymetry; PCO2 = partial pressure of carbon dioxide; PaO2 = partial pressure of oxygen; BUN = blood urea nitrogen; AST = aspartate transaminase; ALT = alanine transaminase; CK = creatine kinase; CK-MB = creatine kinase muscle brain; CRP = C reactive protein; DM = diabetes mellitus.

Table 2. The predictive value and cutoff point of HASI, age SI, and SI for in-hospital mortality.

Variables	Cutoff point	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	AUC (95% CI)	p
HASI	0.73	68.18	73.71	49.45	86.00	0.733 (0.672–0.788)	<0.001
Age SI	51.74	66.67	58.29	37.61	82.26	0.647 (0.583–0.707)	<0.001
SI	0.71	59.09	56.00	33.33	78.23	0.549 (0.484–0.613)	0.549

PPV = positive predictive value; NPV = negative predictive value; AUC = Area under the curve.

Table 3. Comparison of the predictive performance of HASI, age SI, and SI for in-hospital mortality.

Variables	z-Statistic	Standard error	p	Difference between areas
HASI versus age SI	5.904	0.0170	<0.001	0.087
HASI versus SI	6.438	0.0285	<0.001	0.184
Age SI versus SI	4.251	0.0229	<0.001	0.097

Table 4. Likelihood ratio and odds ratio for prediction of in-hospital mortality.

HASI	Total $n=241$	Mortality $n=66$	LR	OR (95% CI)	p	aOR (95% CI)	p
<0.7	149	21 (14%)	0.4	Reference			
0.7–0.9	54	25 (46%)	2.3	5.3 (2.6–10.7)	<0.001	5.4 (2.6–11.2)	<0.001
0.9	38	20 (53%)	3.0	6.8 (3.1–14.9)	<0.001	7.8 (3.4–18.0)	<0.001
Age SI	**Total $n=241$**	**Mortality $n=66$**	**LR**	**OR (95% CI)**	**p**	**aOR (95% CI)**	**p**
<50	108	20 (19%)	0.6				
50–70	84	27 (32%)	1.3	2.1 (1.1–4.1)	0.031	2.6 (1.3–5.1)[a]	0.008
⩾70	49	19 (39%)	1.7	2.8 (1.3–5.9)	0.008	3.4 (1.6–7.2)[a]	0.002
SI	**Total $n=241$**	**Mortality $n=66$**	**LR**	**OR (95% CI)**	**p**	**aOR (95% CI)**	**p**
<0.7	120	26 (22%)	0.7				
0.7–0.9	76	24 (32%)	1.2	1.7 (0.9–3.2)	0.123	1.4 (0.7–2.8)[b]	0.422
⩾0.9	45	16 (36%)	1.5	2.0 (0.9–4.2)	0.071	1.7 (0.7–4.0)[b]	0.217

LR = likelihood ratio; OR = odds ratio; aOR = adjusted odds ratio; CI = confidence interval.
[a]Adjusted for oxygen saturation.
[b]Adjusted for age and oxygen saturation.

Table 5. Logistic regression analysis for predicting in-hospital mortality.

Variables	OR (95% CI)	p	AOR (95% CI)	p
HASI	15.1 (5.1–44.4)	<0.001	8.6 (2.8–26.8)	<0.001
ASI	1.0 (1.0–1.1)	<0.001	1.0 (1.0–1.1)[a]	0.002
SI	2.9 (1.0–8.0)	0.045	2.7 (0.8–9.2)[b]	0.106

[a]Adjusted for oxygen saturation.
[b]Adjusted for age and oxygen saturation.

combined with age SI. The importance of hypoxia cannot be denied from the physicians who deal with COVID-19 patients. Moreover, hypoxia itself has been proved as a significant predictor of COVID-19 pneumonia.[22–24] However, they showed limited result of prognostic performances of age SI and HASI related to mortality of COVID 19 patients.

The significance of age SI in predicting the outcome of COVID-19 pneumonia was less than HASI in this study which was similar to the original literature. HASI, indeed, has strong components such as age and oxygen saturation, which have already proven their efficacy on outcome measurement of COVID-19. Regardless of comorbidities and laboratory values, the simplified new tool could provide effective guidance to emergency physicians who need to triage COVID-19 patients.

The pandemic era might be almost over; however, emergency physicians are still struggling to determine the severity of the patients with the virus. During the period, several scores have been proposed to predict the prognosis of COVID-19. The 4C (Coronavirus Clinical Characterization Consortium) score is one of the most validated scores to predict mortality. The 4C score has power from thousand of patients with COVID-19. It is a combination off age, sex, comorbidities, respiratory rate, and oxygen saturation of room air.[25] The quick COVID severity index (qCSI) was originally made for determining the risk of progression to critical illness within a day, and is comprised of respiratory rate, pulse oximetry, and supplemental oxygen flow rate.[26] National Early Warning Score 2 is different score comprising respiratory rate, saturation, systolic blood pressure, pulse, consciousness, and temperature. This score has power in predicting progression of disease over 24 h and mortality.[27–29]

Numerous clinical tools have been proposed for physicians to make decisions, yet most of them may have several limitations when used in the emergency field. Usually, they are a combination of clinical, laboratory, and image findings, so it is hard to memorize, calculate and apply in the emergency setting. Besides, most scores have their points in combination with loss of main components such as age or vital signs. Recently, a retrospective study failed to show the relationship of SI and mortality in COVID-19 patients.[30] The main clinical feature of patients with COVID-19 is hypoxia which could be missed only by simple vital signs. Besides, increasing age has been shown as an important predictor of COVID-19 mortality. HASI, the new index regarding age and hypoxia, could be a useful predictor for patients with COVID-19 pneumonia in a triage setting of the ED. Furthermore, using a simplified index can help to reduce the burden of pandemic combined with the technology-based methods for diagnosis and disposition of COVID-19 patients.[4]

Our study has several limitations. First, this was a retrospective study so possible confounders and selection bias could exist. Second, we reviewed patient records from a single center. Further cohort studies should be followed to assess the outcome of COVID-19 on a larger scale. Third, we used a pulse oximeter at scene and noninvasive tool for blood pressure measurements, therefore, there could be undetected hemodynamic changes. Lastly, a power analysis for sample size was not done.

Conclusion

The HASI was a strong predictor for in-hospital mortality of COVID -19 pneumonia. Furthermore, compared to age SI, HASI showed a better performance in predicting the fatality of the disease. Since the pandemic era, patients with COVID-19 have been overwhelming in the ED, and a fast and precise triage tool was needed for the disposition of patients. We hope this study can help emergency physicians make proper decisions for patients with COVID-19 in the field.

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None.

Author contributions

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

Declaration of conflicting interests

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Research ethics

This study was waived by the Institutional Review Board of Myongji Hospital (case number: 202212001). The study is retrospective chart review from our hospital, thus informed consent was not needed. Collected data had no personal information.

Informed consent

Informed consent was not sought for the present study because there is no personal information relevant to patients.

Trial registration

Not applicable.

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