Comparison of 4 Different Threshold Values of Shock Index in Predicting Mortality of COVID-19 Patients

Rohat Ak MD1 and Fatih Doğanay MD2

1Specialist of Emergency Medicine, Department of Emergency Medicine, Kartal Dr. Lütfi Kirdar Şehir Hastanesi, Istanbul, Turkey and 2Specialist of Emergency Medicine, Department of Emergency Medicine, Edremit Devlet Hastanesi, Balıkesir, Turkey.

Abstract
Objective: The object of this study was to examine the accuracy in prehospital shock index (SI) for predicting intensive care unit (ICU) requirement and 30-d mortality among from coronavirus disease 2019 (COVID-19) patients transported to the hospital by ambulance.

Methods: All consecutive patients who were the age ≥18 y, transported to the emergency department (ED) by ambulance with a suspected or confirmed COVID-19 in the prehospital frame were included in the study. Four different cutoff points were compared (0.7, 0.8, 0.9, and 1.0) to examine the predictive performance of both the mortality and ICU requirement of the SI. The receiver operating characteristic (ROC) curve and the area under the curve (AUC) was used to evaluate each cut-off value discriminatory for predicting 30-d mortality and ICU admission.

Results: The total of 364 patients was included in this study. The median age in the study population was 69 y (range, 55-80 y), of which 196 were men and 168 were women. AUC values for 30-d mortality outcome were calculated as 0.672, 0.674, 0.755, and 0.626, respectively, for threshold values of 0.7, 0.8, 0.9 and 1.0. ICU admission was more likely for the patients with prehospital SI > 0.9. Similarly, the mortality rate was higher in patients with prehospital SI > 0.9.

Conclusions: Early triage of COVID-19 patients will ensure efficient use of health-care resources. The SI could be a helpful, fast, and powerful tool for predicting mortality status and ICU requirements of adult COVID-19 patients. It was concluded that the most useful threshold value for the shock index in predicting the prognosis of COVID-19 patients is 0.9.
and ICU. ED, grouping was made as outpatient (OP), inpatient unit (IU), the secondary outcome in this study. For the way of leaving the survivor and nonsurvivor. The determination of the relationship to ascertain the association between prehospital SI and 30-d mortality outcome, grouping was done as survivors and nonsurvivors. The primary outcome is mortality rate. For 30-d mortality outcome, grouping was done as survivors and nonsurvivors. The primary outcome is 30-d mortality outcome. Grouping was done as survivors and nonsurvivors.

**Outcome Measures**

The SI at first presentation was calculated in prehospital setting. If vital signs were measured more than once in the prehospital phase, we used the lowest values of shock index. The primary outcome is to ascertain the association between prehospital SI and 30-d mortality rate. For 30-d mortality outcome, grouping was done as survivor and nonsurvivor. The determination of the relationship between prehospital SI and the way patients leave the ED was the secondary outcome in this study. For the way of leaving the ED, grouping was made as outpatient (OP), inpatient unit (IU), and ICU.

| Variables | All Patients (n = 364) | ED outcome groups Median (25th-75th) | P-Value | Mortality groups Median (25th-75th) | P-Value |
|-----------|-----------------------|-------------------------------------|---------|------------------------------------|---------|
| Age (y)   | 69 (55-80)            | 50 (66-79)                          | 0.003*  | 63.5 (51-77)                       | <0.001  |
| SBP (mmHg)| 120 (110-133)         | 125 (114-140)                       | <0.001* | 121.5 (110-138)                    | <0.001  |
| DBP (mmHg)| 73.5 (63-80)          | 77 (65-85)                          | 0.031*  | 76 (65-84)                         | 0.017   |
| HR (bpm)  | 92 (79-104)           | 83 (75-96)                          | <0.001* | 88 (77-98)                         | <0.001  |
| RR (bpm)  | 20 (16-28)            | 16 (14-18)                          | <0.001* | 18 (16-22)                         | <0.001  |
| spO2 (%)  | 95 (89-97)            | 96 (95-98)                          | <0.001* | 96 (93-97)                         | <0.001  |
| Body temperature (°C) | 36.8 (36.3-37.4) | 36.7 (36.2-37.2) | 0.268*  | 36.8 (36.3-37.3)                  | 0.631   |
| SI        | 0.76 (0.62-0.91)      | 0.66 (0.57-0.77)                    | <0.001* | 0.69 (0.59-0.83)                   | <0.001  |

**Selection of Patients**

The consecutive patients whose age of ≥18 y and transported to the hospital by ambulance with a suspected or confirmed COVID-19 in the prehospital setting were included in the study. Exclusion criteria for the study were: atrial fibrillation that interfered with blood pressure measurement, patients transferred from other hospitals, prehospital cardiac arrest patients, patients whose reverse transcriptase polymerase chain reaction (RT-PCR) test negative, patients who had deficiency in parameters, and SI variables. Normality assumption was rejected for both outcome groups. Because the continuous variables did not conform to the normal distribution, the analysis was continued with the Mann-Whitney U- and Kruskal-Wallis H-tests (Table 1). The results were reported as median and interquartile ranges (Table 1).

**Data Collection and Variables**

The data, that consists of this study were obtained from the hospital records and the forms, which were filled in ambulance. These are covered age, sex, prehospital vital signs (body temperature [Temp], heart rate [HR], systolic blood pressure [SBP], diastolic blood pressure [DBP], respiratory rate [RR], blood oxygen saturation [spO2], body temperature [Temp]) and SI. The SI was assessed as the rate of HR to SBP (SI = HR/SBP).5

**Statistical Analysis**

IBM SPSS Statistics 26 (SPSS) and MedCalc Version 19 software were used for statistical analysis. While the characteristics of the study population were reported, sustained data were signified as median and interquartile ranges (25th-75th), and certain data as frequency and percentage. Kolmogorov-Smirnov test was performed to examine the reason of distributions for age, vital parameters, and SI variables. Normality assumption was rejected for both outcome groups. Because the continuous variables did not conform to the normal distribution, the analysis was continued with the Mann-Whitney U- and Kruskal-Wallis H-tests (Table 1). The results were reported as median and interquartile ranges (Table 1).

The statistically significant difference between the groups for the SI value made it necessary to determine which threshold value is more useful. Chi-squared and Fisher-Freeman-Halton tests were performed to analyze the statistical significance of SI thresholds of 0.7, 0.8, 0.9, and 1.0 for both endpoints (Table 2).13 Statistically, significant differentiation was perceived between the groups for all 4 threshold values. The ROC analysis was made to compare the accuracy of these 4 threshold values; sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) were calculated (Table 3). To compare the estimation accuracy, both the area under the curve (AUC) and the Youden J index were measured (Table 3).14 DeLong et al. method was used while performing ROC analysis.15 The mortality and ICU requirement prediction performances of different threshold values were demonstrated by decision curve analysis. A P value of less than 0.05 was accepted as statistically significant.

**Results**

This study was conducted with data from 364 patients after the inclusion and exclusion criteria were applied. The survivor group was including a total of 254 patients, 110 in the nonsurvivor group, 131 in the OP group, 158 in the IU group, and 75 in the ICU group. In the study population, 196 patients were men and 168 patients were women. There was no significant difference according to both 30-d mortality and ED outcomes in terms of sex (Table 1).
The median age in the study population was 69 y (range, 55-80 y). A significant difference was observed for 30-d mortality and ED outcomes in terms of patient age. The median age of the nonsurvivor group was significantly higher than the survivor group. In ED outcome groups, median age was 55-80 y). A significant difference was observed for 30-d mortality outcome groups, while there was no significant difference between the 0.7 with 0.8 (P = 0.001), 0.8 with 0.9 (P < 0.001), and 0.9 with 1.0 (P = 0.001) thresholds (Table 3).

In the pairwise comparisons of SI thresholds for ICU requirement, there was no statistical significance between 0.7 with 0.8 (P = 0.291), 0.7 with 1.0 (P = 0.302), and 0.8 with 1.0 (P = 0.069) thresholds while there were statistically significant differences between 0.7 with 0.9 (P < 0.001) with 0.9, 0.8 (P < 0.001) with 0.9, and 0.9 with 1.0 (P < 0.001) thresholds (Table 3; Figure 2).

YJİ values of 0.7, 0.8, 0.9, and 1.0 threshold values of SI in terms of ED outcome were calculated as 0.4919, 0.5379, 0.6715, and 0.4246, respectively. YJİ values for 30-d mortality outcome were calculated as 0.3442, 0.3472, 0.5104, and 0.2513, respectively (Table 3).

### Table 2. SI thresholds and sex descriptives of the study population

| Variables | Category | ED outcome groups | Mortality groups |
|-----------|----------|-------------------|------------------|
|           | OP (n = 131) | IU (n = 158) | ICU (n = 75) | N (%) | N (%) | P-Value | N (%) | N (%) | P-Value |
| Sex       | Male | 63 (48.1) | 87 (55.1) | 46 (61.3) | 0.177* | 135 (53.1) | 61 (55.5) | 0.685 |
|           | Female | 68 (51.9) | 71 (44.9) | 29 (38.7) | | 119 (46.9) | 49 (44.5) | |
| SI 0.7    | SI ≤ 0.7 | 78 (50.5) | 68 (43) | 1 (1.3) | <0.001* | 129 (50.6) | 18 (16.4) | <0.001 |
|           | SI > 0.7 | 53 (40.5) | 90 (57) | 74 (98.7) | | 125 (49.2) | 92 (83.6) | |
| SI 0.8    | SI ≤ 0.8 | 103 (78.6) | 91 (57.6) | 10 (13.3) | <0.001* | 169 (66.5) | 35 (31.8) | <0.001 |
|           | SI > 0.8 | 28 (21.4) | 67 (42.4) | 65 (86.7) | | 85 (33.5) | 75 (68.2) | |
| SI 0.9    | SI ≤ 0.9 | 124 (94.7) | 124 (78.5) | 14 (18.7) | <0.001* | 222 (87.4) | 40 (36.4) | <0.001 |
|           | SI > 0.9 | 7 (5.3) | 34 (21.5) | 61 (81.3) | | 32 (12.6) | 70 (63.6) | |
| SI 1.0    | SI ≤ 1.0 | 125 (95.4) | 148 (93.7) | 38 (52) | <0.001* | 237 (93.3) | 75 (68.2) | <0.001 |
|           | SI > 1.0 | 6 (4.6) | 10 (6.3) | 36 (48) | | 17 (6.7) | 35 (31.8) | |

Abbreviations: Sig, significance; op, outpatient; IU, inpatient unit; ICU, intensive care unit; SI, shock index.

*Fisher-Freeman-Halton exact test.

### Table 3. Prognostic accuracy of different SI thresholds by ROC analysis

| SI     | Sens. | Spec. | PPV | NPV | AUC (95% CI) | YJİ | P (AUC) |
|--------|-------|-------|-----|-----|--------------|-----|---------|
| 0.7    | 83.64% | 50.79% | 42.4% | 87.8% | 0.672 (0.621-0.720) | 0.3442 | <0.001 |
| 0.8    | 68.18% | 66.54% | 46.9% | 82.8% | 0.674 (0.623-0.722) | 0.3472 | <0.001 |
| 0.9    | 63.64% | 87.40% | 68.6% | 84.7% | 0.755 (0.708-0.799) | 0.5104 | <0.001 |
| 1.0    | 31.82% | 93.31% | 67.3% | 76.0% | 0.626 (0.574-0.676) | 0.2513 | <0.001 |

Abbreviations: \( \text{SI} \), shock index; Sens., sensitivity; Spec., specificity; PPV, positive predictive value; NPV, negative predictive value; AUC, area under the curve; \( p (\text{AUC}) \), statistical significance for AUC; YJİ, Youden’s J index.

*95% Confidence interval.
Discussion

The COVID-19 outbreak is putting unprecedented pressure on health-care systems to examine an unexpected number of patients. The triage of COVID-19 patients and the corresponding use of health-care resources is a continuous state of study. This study has been revealed that SI can predict the ICU requirements of patients and their mortality risks. Patients whose prehospital SI higher than 0.9 were more presumably to admission to the ICU. Similarly, patients with prehospital SI higher than 0.9 had a higher mortality rate.

Vital signs are objective indicators that can be obtained in prehospital triage. SI can be easily calculated using vital signs and can be used in prehospital triage where there is a limited time. While it has been used in patients with hemorrhagic shock or trauma,5 it has recently been used as a prognostic predictor in critically ill patients and patients with sepsis.6–8 In a study conducted for the early diagnosis of sepsis, the negative predictive value of a shock index above 0.7 was found to be similar to systemic inflammatory response syndrome (SIRS).9 In the same study, it was shown that a SI of higher than 1 is a specific predictor of both hyperlactatemia and 28-d mortality. Kenzaka et al. conducted a study in 206 patients who were visited to the ED due to sepsis. They reported that there was a significant relationship between the development of organ failure and SI.10

There is no consensus on the appropriate threshold value of SI (0.8, 0.9, or 1) that should be used clinically.11–13 In a study by McNab et al., the relationship between prehospital SI for trauma and hospital resource use and mortality risk was investigated. In the study, 19.7% of total patients (16,269) had a SI value higher than 0.9. The relative mortality risk was reported as 1.5% in the main area and 1.7% in the trauma center of those with prehospital SI higher than 0.9. This group also pointed an association between prehospital SI and ICU time of stay and blood product use.14 In a study, Jehan et al. examined the relationship between prehospital SI with mortality and transfusion requirement for patients with trauma. They reported an increase of 7.1% in mortality risk when prehospital SI was higher than 1.21 Doğanay et al. emphasized that a SI value higher than 0.93 may be a predictor for mortality risk in COVID-19 pneumonia patients.22 This study has been shown that a prehospital SI higher than 0.9 may be a predictor for determining mortality risk and ICU requirements.

This study has some limitations. Patients’ data were limited to retrospective and medical records. Therefore, our results in a limited number of patients are not able to reflect in general. Repeatedly, it should be known that the existence of fundamental comorbidities such as hypertension, diabetes mellitus, and coronary artery disease may suppress the predictive value of the SI.23

Conclusion

Early triage of COVID-19 patients will ensure efficient use of health-care resources. Prehospital SI might be a useful, fast, and reliable triage parameter for predicting mortality risk and ICU requirements of adult COVID-19 patients. It was concluded that the threshold value of 0.9 for the shock index in our study population was superior to other threshold values in predicting the prognosis of COVID-19 patients.

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Figure 1. ROC curves of SI thresholds in mortality prediction.

Figure 2. ROC curves of SI thresholds in ICU requirement prediction.
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