Disaster Medicine and Public Health Preparedness

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

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Original Research

Cite this article: Ak R and Doğanay F. Comparison of 4 different threshold values of shock index in predicting mortality of COVID-19 patients. *Disaster Med Public Health Prep*. **17**(e99), 1–5. doi: https://doi.org/10.1017/dmp.2021.374.

Keywords:
prehospital; shock index; mortality; intensive care units; triage; COVID-19

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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.

Since March 11, 2020, the World Health Organization has declared coronavirus disease 2019 (COVID-19) caused by severe acute respiratory coronavirus 2 (SARS-CoV-2) as an international pandemic and public health emergency.[1] The pandemic has caused serious conditions such as mortality and morbidity all over the world. Due to the great number of people harmed by the disease, overcapacity has occurred in hospitals and emergency departments (EDs). For this reason, there were insufficiencies in the provision of health care.[2,3] Therefore, it is necessary to quickly identify patients who may require critical care.[4]

Shock index (SI) first performed by Allgöwer and Buri in 1967 and used to ascertain the hypovolemia degree in hemorrhagic shock.[5] SI, which is described as the division of heart rate over systolic blood pressure, is a fast, noninvasive method. The value of SI is normally between 0.5 and 0.7 in healthy adults. In the literature, some studies reporting that high SI values predict mortality risk, furthermore critical care requirements.[6–8] In a study in which higher than 0.9 value of SI was considered as a severity indicator in triage, it was observed that hospitalization and intensive care requirements were high in patients with high SI value.[9] This suggests that SI can be a valuable parameter for early diagnosis and evaluation of critical illnesses in the ED, and can also be used as a prognostic predictor. This study aims to ascertain whether prehospital SI could be used to predict the requirement for intensive care unit (ICU) of these patients and their mortality status in patients visited to the hospital by ambulance in terms of COVID-19.

Methods

Study Design

This observational study was conducted in the ED of Kartal Dr. Lütfi Kırdar City Hospital, retrospectively, between November 1, 2020, and February 1, 2021. The institutional review board confirmed the analysis and declared a waiver of approval (Date:24.02.2021, Ethics Committee Ruling number: 514/196/25). Ambulance care in the Turkey is provided by national Emergency Medical Services (EMS). Patient transported by ambulance has been standardized

Table 1. Descriptive statistics for age, vital parameters, and SI values of the groups

Variables	All Patients (*n* = 364)	ED outcome groups Median (25th-75th) OP (*n* = 131)	IU (*n* = 158)	ICU (*n* = 75)	*P*-Value	Mortality groups Median (25th-75th) Survivor (*n* = 254)	Nonsurvivor (*n* = 110)	*P*-Value
Age (y)	69 (55-80)	50 (66-79)	64 (53-79)	75 (66-80)	0.003*	63.5 (51-77)	75 (66-82)	<0.001
SBP (mmHg)	120 (110-133)	125 (114-140)	120 (110-140)	110 (104-118)	<0.001*	121.5 (110-138)	110 (107-120)	<0.001
DBP (mmHg)	73.5 (63-80)	77 (65-85)	72 (65-82.5)	70 (61-80)	0.031*	76 (65-84)	70 (65-80)	0.017
HR (bpm)	92 (79-104)	83 (75-96)	90 (80-101)	108 (100-115)	<0.001*	88 (77-98)	103.5 (90-112)	<0.001
RR (bpm)	20 (16-28)	16 (14-18)	22 (18-26)	40 (34-44)	<0.001*	18(16-22)	34 (24.8-42)	<0.001
spO2 (%)	95 (89-97)	96 (95-98)	94.5 (90-97)	84 (80-87)	<0.001*	96 (93-97)	87 (81-93.3)	<0.001
Body temperature (ºC)	36.8 (36.3-37.4)	36.7 (36.2-37.2)	36.9 (36.3-37.4)	37 (36.4-37.4)	0.268*	36.8 (36.3-37.3)	36.7 (36.3-37.4)	0.631
SI	0.76 (0.62-0.91)	0.66 (0.57-0.77)	0.74 (0.63-0.89)	0.96 (0.90-1.10)	<0.001*	0.69 (0.59-0.83)	0.91 (0.78-1.01)	<0.001

Abbreviations: OP, Outpatient; IU, Inpatient Unit; ICU, Intensive Care Unit; SBP, Systolic blood pressure; DBP, Diastolic blood pressure; HR, Heart rate; RR, Respiratory rate; spO2, Blood oxygen saturation; SI, Shock index; Temp, Body temperature.
*Fisher-Freeman-Halton exact test.

appropriately to the "COVID-19 Diagnosis and Treatment Guide" published in Turkish by Ministry of Health.[10]

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,[11] patients transferred from other hospitals, prehospital cardiac arrest patients, patients whose reverse transcriptase polymerase chain reaction (RT-PCR) test negative,[12] patients who had deficiency in prehospital vital signs and patients who could not be followed-up.

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]

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.

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).

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

		ED outcome groups				Mortality groups		
		OP (*n* = 131)	IU (*n* = 158)	ICU (*n* = 75)	Sig.	Survivor (*n* = 254)	Nonsurvivor (*n* = 110)	Sig.
Variables	Category	N (%)	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 (50.8)	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

	Sens.	Spec.	PPV	NPV	AUC (CI 95%)*	YJI	*P* (AUC)
Prediction accuracy for 30-d mortality							
SI 0.7	83.64**%**	50.79**%**	42.4**%**	87.8 **%**	0.672 (0.621-0.720)	0.3442	<0.001
SI 0.8	68.18**%**	66.54**%**	46.9**%**	82.8**%**	0.674 (0.623-0.722)	0.3472	<0.001
SI 0.9	63.64**%**	87.40**%**	68.6**%**	84.7**%**	0.755 (0.708-0.799)	0.5104	<0.001
SI 1.0	31.82**%**	93.31**%**	67.3**%**	76.0**%**	0.626 (0.574-0.676)	0.2513	<0.001
Prediction accuracy for ED outcome							
SI 0.7	98.67%	50.52%	34.1%	99.3%	0.746 (0.698-0.790)	0.4919	<0.001
SI 0.8	86.67%	67.13%	40.6%	95.1%	0.769 (0.722-0.811)	0.5379	<0.001
SI 0.9	81.33%	85.81%	59.8%	94.7%	0.836 (0.794-0.872)	0.6715	<0.001
SI 1.0	48.00%	94.46%	69.2%	87.5%	0.712 (0.663-0.758)	0.4246	<0.001

Abbreviations: \ SI, shock index; Sens., sensitivity; Spec., specificity; PPV, positive predictive value; NPV, negative predictive value; AUC, area under the curve; p (AUC), statistical significance for AUC; YJI, Youden's J index.
*95% Confidence interval.

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 revealed as OP, IU, and ICU from younger to older (Table 1).

A significant difference among the groups for prehospital vital parameters (SBP, DBP, HR, RR, spO2), and SI in terms of both 30-d mortality and ED outcomes, while there was no significant difference for Temp (Tables 1 and 2).

AUCs of 0.7, 0.8, 0.9, and 1.0 threshold values of prehospital SI for ED outcome were calculated as 0.746, 0.769, 0.836, and 0.712, respectively, with the ROC analysis. AUC values for 30-d mortality outcome were calculated as 0.672, 0.674, 0.755, and 0.626, respectively (Table 3; Figure 1).

Pairwise comparisons of SI thresholds for 30-d mortality, there was no statistically significance between 0.7 with 0.8 ($P = 0.944$), 0.7 with 1.0 ($P = 0.103$) and 0.8 with 1.0 ($P = 0.075$). There were statistically significant difference between the 0.7 with 0.9 ($P < 0.001$), 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 difference between the 0.7 ($P < 0.001$) 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).

YJI 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, 0.4246, respectively. YJI values for 30-d mortality outcome were calculated as 0.3442, 0.3472, 0.5104, and 0.2513, respectively (Table 3).

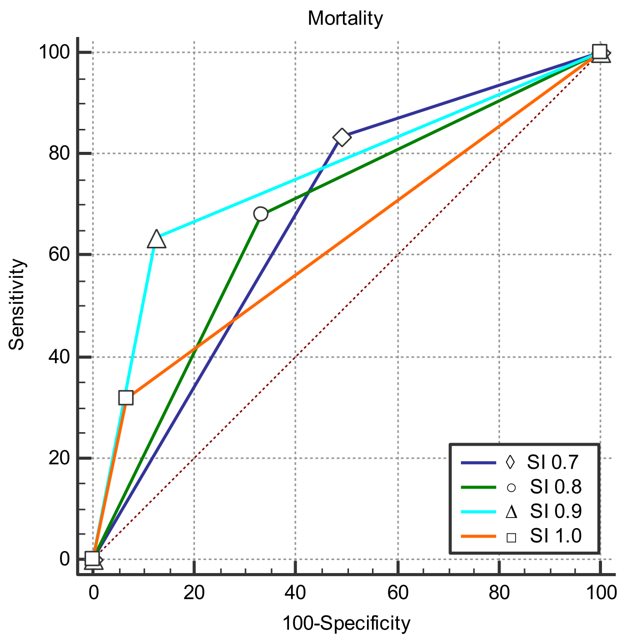

Figure 1. ROC curves of SI thresholds in mortality prediction.

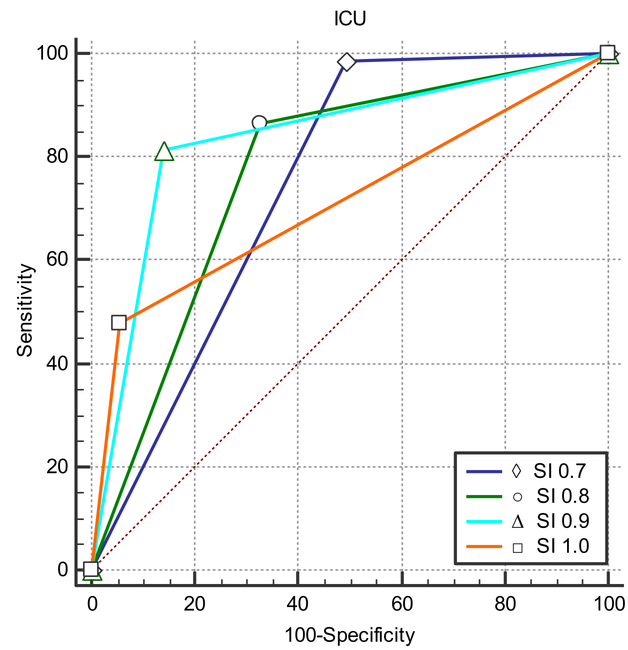

Figure 2. ROC curves of SI thresholds in ICU requirement prediction.

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.[16–18] 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).[19] 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.[20]

There is no consensus on the appropriate threshold value of SI (0.8, 0.9, or 1) that should be used clinically.[21–23] 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.[22] 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.[24] Doğanay et al. emphasized that a SI value higher than 0.93 may be a predictor for mortality risk in COVID-19 pneumonia patients.[25] 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.[26]

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.

Author Contributions. R.Ak.: conceptualization (lead), data curation (lead), formal analysis (lead), funding acquisition (equal), investigation (equal), and methodology (equal); F.D.: conceptualization (equal), data curation (equal), formal analysis (equal), funding acquisition (equal), investigation (equal), methodology (equal), project administration (equal), resources (equal), software (equal), supervision (equal), validation (equal), visualization (equal), writing-original draft (equal), and writing-review and editing (equal)

Funding statement. The author(s) received no financial support for the research, authorship, and/or publication of this article

Conflict(s) of interest. Authors declare that they have no conflicts of interest.

References

1. **Tian S, Hu N, Lou J, *et al.*** Characteristics of COVID-19 infection in Beijing. *J Infect.* 2020;80(4):401-406. doi: 10.1016/j.jinf.2020.02.018
2. **Assiri A, Al-Tawfiq JA, Al-Rabeeah AA, *et al.*** Epidemiological, demographic, and clinical characteristics of 47 cases of Middle East respiratory syndrome coronavirus disease from Saudi Arabia: a descriptive study. *Lancet Infect Dis.* 2013;13(9):752-761. doi: 10.1016/S1473-3099(13)70204-4
3. **Lu R, Yu X, Wang W, *et al.*** Characterization of human coronavirus etiology in Chinese adults with adults with acute upper respiratory tract infection by real-time RT-PCR assays. *PLoS One.* 2012;7(6):e38638.
4. **Remuzzi A, Remuzzi G.** COVID-19 and Italy: what next? *Lancet.* 2020;395(10231):1225-1228.
5. **Allgöwer M, Buri C.** Shock index (Article in German). *Dtsch Med Wochenschr.* 1967;43:1947-1950. doi: 10.1055/s-0028-1106070
6. **King RW, Plewa MC, Buderer NM, *et al.*** Shock index as a marker for significant injury in trauma patients. *Acad Emerg Med.* 1996;3(11):1041-1045.
7. **Sankaran P, Kamath AV, Tariq SM, *et al.*** Are shock index and adjusted shock index useful in predicting mortality and length of stay in community-acquired pneumonia? *Eur J Intern Med.* 2011;22(3):282-285.
8. **Talmor D, Jones AE, Rubinson L, *et al.*** Simple triage scoring system predicting death and the need for critical care resources for use during epidemics. *Crit Care Med.* 2007;35(5):1251-1256.
9. **Rady MY, Smithline HA, Blake H, *et al.*** A comparison of the shock index and conventional vital signs to identify acute, critical illness in the emergency department. *Ann Emerg Med.* 1994;24(4):685-690. doi: 10.1016/S0196-0644(94)70279-9
10. **Bilim Kurulu Çalışması**. COVID-19 (SARS-CoV-2 enfeksiyonu) Rehberi. TC. Sağlık Bakanlığı Halk Sağlığı Genel Müdürlüğü (2 Nisan 2020) Ankara. 2020. https://covid19rehberi.com/wp-content/uploads/2020/04/COVID19_Eriskin_Hasta_- Tedavisi_02042020.pdf
11. **Yu T, Tian C, Song J, *et al.*** Derivation and validation of shock index as a parameter for predicting long-term prognosis in patients with acute coronary syndrome. *Sci Rep.* 2017;7(1):1-7.
12. **Seyhan AU, Doğanay F, Yılmaz E, *et al.*** The comparison of chest CT and RT-PCR during the diagnosis of COVID-19. *J Clin Med Kazakhstan.* 2021;18(1):53-56.
13. **Freeman GH, Halton JH.** Note on an exact treatment of contingency, goodness of fit and other problems of significance. *Biometrika.* 1951;38(1/2):141-149.
14. **Zhou H.** (2011). Statistical inferences for the Youden Index. Dissertation, Georgia State University. 2011. Accessed February 7, 2022. https://scholarworks.gsu.edu/cgi/viewcontent.cgi?article=1004&context=math_diss
15. **DeLong E, DeLong D, Clarke-Pearson D.** Comparing the areas under two or more correlated receiver operating characteristic curves: a nonparametric approach. *Biometrics.* 1988;44(3):837-845.
16. **Tseng J, Nugent K.** Utility of the shock index in patients with sepsis. *Am J Med Sci.* 2015;349:531-535.
17. **Harada M, Takahashi T, Haga Y, *et al.*** Comparative study on quick sequential organ failure assessment, systemic inflammatory response syndrome and the shock index in prehospital emergency patients: single-site retrospective study. *Acute Med Surg.* 2019;6(2):131-137.
18. **Torabi M, Mirafzal A, Rastegari A, *et al.*** Association of triage time Shock Index, Modified Shock Index, and Age Shock Index with mortality in Emergency Severity Index level 2 patients. *Am J Emerg Med.* 2016;34(1):63-68.
19. **Berger T, Green J, Horeczko T, *et al.*** Shock index and early recognition of sepsis in the emergency department: pilot study. *West J Emerg Med.* 2013;14(2):168-174.
20. **Kenzaka T, Okayama M, Kuroki S, *et al.*** Importance of vital signs to the early diagnosis and severity of sepsis: association between vital signs and sequential organ failure assessment score in patients with sepsis. *Intern Med.* 2012;51:871-876.
21. **El-Menyar A, Goyal P, Tilley E, *et al.*** The clinical utility of shock index to predict the need for blood transfusion and outcomes in trauma. *J Surg Res.* 2018;227:52e59.
22. **McNab A, Burns B, Bhullar I, *et al.*** A prehospital shock index for trauma correlates with measures of hospital resource use and mortality. *Surgery.* 2012;152(3):473-476.
23. **Wang IJ, Bae BK, Park SW, *et al.*** (2020). Pre-hospital modified shock index for prediction of massive transfusion and mortality in trauma patients. *Am J Emerg Med.* 2020;38(2):187-190.
24. **Jehan F, Con J, McIntyre M, *et al.*** Pre-hospital shock index correlates with transfusion, resource utilization and mortality; the role of patient first vitals. *Am J Surg.* 2019;218(6):1169-1174.
25. **Doğanay F, Elkonca F, Seyhan AU, *et al.*** Shock index as a predictor of mortality among the Covid-19 patients. *Am J Emerg Med.* 2012;40:106-109.
26. **Rau C-S, Wu S-C, Kuo SCH, *et al.*** Prediction of massive transfusion in trauma patients with shock index, modified shock index, and age shock index. *Int J Environ Res Public Health.* 2016;13(7):683.

https://doi.org/10.1017/dmp.2021.374 Published online by Cambridge University Press