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Correlation Between Age Shock Index and Perfusion Index with Emergency Severity Index and its Predictive Value on In-hospital Mortality

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Abstract

Objective: Perfusion index (PI), shock index (SI), modified SI (MSI), and age SI (ASI) are valuable markers used to predict the clinical course and mortality of patients in various intensive care units and emergency departments (ED). We investigated the relationship between these markers and emergency severity index (ESI) and their value in predicting in-hospital mortality.

Materials and Methods: In this prospective, cross-sectional, single-centered study, the vital values of the patients and the PI were measured and categorized according to ESI. The correlation between SI, MSI, ASIs, and PI among the ESI categories and their predictive values for in-hospital mortality were calculated.

Results: We established statistically significantly lower PI values and significantly higher values in the ASI in the group with in-hospital mortality compared to survivors (p=0.001, <0.001, respectively). The area under curve score for in-hospital mortality of the PI of 0.723 and ASI are 0.723 and 0.807, respectively. The specificity of PI and the sensitivity of ASI are 91.62% and 91.67%, respectively, and negative predictive values of those are 98.66% and 99.67%, respectively.

Conclusion: Adding PI and ASI to existing triage scores, such as ESI, may improve triage specificity in unselected patients who are admitted to the ED.

Keywords: Perfusion index, shock index, mortality, triage

Introduction

Emergency departments (ED) have the most important place for the global health crisis worldwide due to their easy accessibility; they have become the preferred admission points to healthcare services. As a solution to this crowded environment of EDs, triage practices have been developed to reduce crowding and to ensure that critically ill patients receive accurate and effective treatment on time. In triage systems, the patient's history, vital signs, and resource requirements take an important place in scoring. Vital signs are the most crucial markers in identifying critically ill patients. However, vital signs begin to change whenever the compensation mechanisms are insufficient. Studies have been performed that aim to test the state of tissue perfusion in a non-invasive, rapid way, such as perfusion index (PI), brachial index, and thoracic impedance, to establish tissue perfusion state before the compensation mechanisms occur. Therefore, rapid assessment of tissue perfusion status guides the clinician in identifying critically ill patients.

Recently, the shock index (SI) has been used to predict the prognosis of high-energy trauma, shock, sepsis, and pneumonia with high mortality. Many studies have demonstrated that SI is superior to only systolic blood pressure (SBP) or only pulse measurement in predicting the prognosis [1,2]. Failure to take into account the patient's diastolic blood pressure (DBP) in the calculation of SI was considered a deficiency; as a result, a modified SI (MSI) was developed [3]. Later, age SI (ASI) was

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defined because comorbidities and medications used in elderly patients affect the pulse and blood pressure values [4].

This study aimed to obtain information about the clinical significance of SI, MSI, ASI, and PI values in addition to standard vital parameters and to determine their role in predicting mortality in patients admitted to ED.

Materials and Methods

After the approval of the University of Health Sciences Turkey, Kanuni Sultan Süleyman Training and Research Hospital Ethics Committee no: 2022.02.37, subject no: KAEK/2022.02.37, a prospective cross-sectional study was performed in the ED of University of Health Sciences Turkey, Kanuni Sultan Süleyman Training and Research Hospital between 10/02/2022 and 30/10/2022. Patients who were admitted outpatient or by ambulance were evaluated by triage nurses and doctors who had more than 10 h of practical and theoretical training, and patients at the age of 18 and above who gave consent were included in the study. Patients were accepted consecutively, and participants in each ESI category were aimed to be in similar numbers. Thirty-seven patients with uncertain clinical outcomes (19 patients who left without permission and 18 patients who refused treatment) were excluded from the study (Figure 1).

Heart rate, SpO_2, and blood pressure were measured after 5 min of resting in the sitting position and avoiding patients' speech. PI was measured non-invasively from the distal phalanx of the second finger of the right hand until the value on the display stabilized or by waiting for at least 10 s via Lifescope, BSM-3562 device; by Nihon Koden, Tokyo, Japan. The respiratory rate (RR) was measured by visual inspection of the patient's chest wall motion for 1 min. The patients were divided into five groups based on their vital signs according to the ESI classification. PI data, patient's age, gender, consciousness status, comorbidities, Glasgow Coma score (GCS) value, and vital signs (blood pressure, body temperature, pulse, SpO_2, RR) were recorded in the study form. Then, with these obtained values, SI, MSI, and ASI were calculated. The patients' hospitalization status, emergency operation requirement, discharge status, and in-patient and 1-month mortality were

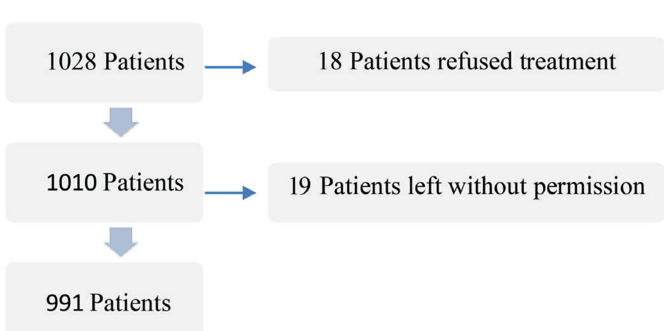

Figure 1. Patient flow chart

followed. Hospitalization was defined as the admission of patients either to the inpatient service or to the intensive care unit (ICU) after evaluation in the ED. The outcome measure for mortality was defined as death from any cause within 30 days of hospital admission and was determined based on hospital records or, in some cases, telephone interviews.

Statistical Analysis

Categorical data will be displayed as number and percentages. The Shapiro-Wilk or Kolmogorov-Smirnov tests will examine the conformity of continuous variables to normal distribution. Normally, distributed data will be shown as mean ± standard deviation, and non-normally distributed data as median (min-max) or (interquartile range). In comparisons between groups with and without in-hospital mortality, vital parameters, perfusion index, SI, MSI, and ASI were calculated using the Student's t-test and ANOVA test for normally distributed parameters and Mann-Whitney U test with Kruskal-Wallis test for non-normally distributed parameters. The cut-off value is determined according to the receiver operating characteristic (ROC) curve for the parameters found to be statistically significant between the groups. The data were analyzed in the SPSS Statistics 24.0 (IBM Inc., New York, USA) program. $P<0.05$ is considered statistically significant in this study.

Results

A total number of 991 patients, 525 (53.0%) female and 466 (47.0%) male, were included in our study. According to the ESI classification, 191 (19.3%) were in the first category, 192 (19.4%) were in the second category, 198 (20.0%) were in the third category, 210 (21.2%) were in the fourth category, and 200 (20.2%) were in the fifth category.

In the clinical follow-ups of the patients, 706 (71.2%) were discharged, 173 (17.5%) were referred to the ICU, 98 (9.9%) were admitted to the inpatient service, and 12 (1.2%) were undergone emergent operation; 2 (0.2%) of them died in the operation room. In-hospital and 30-day mortality rates in patients were 2.4% (24) and 7.2% (71), respectively. The distribution of age, vital parameters, and shock indices of the patients according to the ESI categories are given in Table 1. According to the results of the ANOVA test, which had been performed depending on the ESI categories, statistical significance in age, SBP, and PI values were estimated ($p<0.001$, <0.001, <0.001, respectively). There is no statistically significant difference estimated between the ESI categories and DBP, mean arterial pressure, and pulse ($p=0.190$, 0.079, and 0.065, respectively). In the results of the Kruskal-Wallis test conducted between the ESI categories, there was statistical significance in RR, SpO_2, and ASI values ($p<0.001$, 0.001, 0.001, respectively), while there was no statistical significance in temperature, SI, and MSI values ($p=0.169$, 0.066, 0.333, respectively).

A comparison of the variables according to the in-hospital mortality status is shown in Table 2. Differences in the PI and ASI scores between the mortal and survival groups are statistically significant. Statistically significant lower PI values and statistically significant higher values in the ASI are found in the group with in-hospital mortality compared with the survival group. The age of the patients was higher in the in-hospital mortality group, the RR was statistically significantly higher, and the DBP and SpO_2 values were low in the in-hospital mortality group.

ROC analysis is performed for the statistically significant variables in patients grouped according to in-hospital mortality status. For the perfusion and ASI, we calculated the area under the curve, sensitivity, specificity, and positive and negative predictive values (Table 3, Figures 2 and 3).

Discussion

Our department is one of the most crowded EDs in Turkey, with 535,045 patients admitted between 01/02/2022 and 01/11/2022 and accepting an average of 59,450 patients per month. It is important to recognize quickly critically ill and high-risked patients to provide treatment as soon as possible to reduce mortality rates in busy ER. In this study, which indices may be applicable in predicting in-hospital mortality, statistically significantly higher values were found in ASI, whereas there were statistically significantly lower PI values in the group with mortality compared with the survival group.

Recent studies have showed a significant and positive relationship between in-hospital mortality and ASI in patients with stroke patients [5]. In a study conducted in Korea, ASI had the power to predict in-hospital mortality better than SI or MSI in geriatric trauma patients admitted to ED [6]. In another study, the ASI value in patients over 55 years of age may be useful in predicting early mortality and increasing the need for blood transfusion [7]. In a study by Agerskov et al. [8], which included 1.338 patients who required emergent surgery, found that those with a PI ≤0.5 had a 19% mortality, and those with a PI ≥0.5 had a 10% 30-day mortality.

Er et al.'s [9] research studied the 60-day mortality of patients receiving mechanical ventilation and found the mortality of patients with a low PI value at the 12^{th} h to be high. Savastano et al. [10] calculated the mean PI value of 346 patients who had spontaneous respiratory return after cardiopulmonary resuscitation. The mean PI value was found to be high in

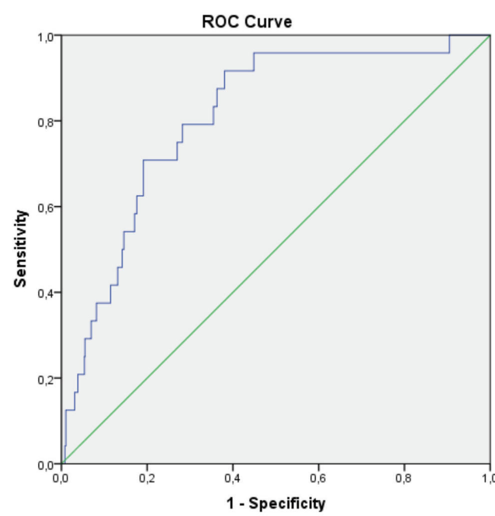

Figure 2. ROC curve of age shock index

ROC: Receiver operating characteristic

Table 1. Analysis of age, vital parameters, and shock indices according to ESI

Parameters	ESI categories					p values
	1 (191)	2 (192)	3 (198)	4 (210)	5 (200)	
Age	60.48±19.83	56.27±21.57	52.84±21.27	37.98±14.67	36.31±13.98	**<0.001**
SBP	133.19±36.62	139.68±33.43	132.42±24.41	128.33±20.19	129.29±16.86	**<0.001**
DBP	75.53±19.67	78.68±16.12	76.65±13.31	77.52±12.87	78.58±11.86	0.190
MAP	94.75±24.28	99.01±20.67	95.24±15.60	94.46±13.95	95.48±12.20	0.079
Pulse	93.14±24.13	89.23±17.50	88.80±17.78	89.02±10.86	89.71±10.04	0.065
Temperature	36.5 (36.0-39.2)	36.5 (36.0-39.4)	36.5 (35.0-40.0)	36.5 (34.5-38.4)	36.6 (35.7-38.8)	0.169
Respiratory rate	20 (10-40)	18 (12-34)	16 (12-30)	14 (11-25)	14 (12-20)	**<0.001**
SpO_2	92 (53-100)	97 (83-100)	98 (85-100)	98 (92-100)	98 (92-100)	**<0.001**
GCS	15 (3-15)	15 (10-15)	15 (11-15)	15 (14-15)	15 (15-15)	**<0.001**
Perfusion index	1.38±1.00	1.76±1.52	1.99±1.33	2.39±1.11	2.37±1.06	**<0.001**
Shock index	0.68 (0.22-2.39)	0.66 (0.29-1.26)	0.68 (0.29-1.29)	0.70 (0.33-1.15)	0.70 (0.42-1.14)	0.066
Modified shock index	0.93 (0.32-3.35)	0.91 (0.45-1.89)	0.93 (0.43-1.85)	0.95 (0.52-1.52)	0.95 (0.60-1.53)	0.333
Age shock index	39.68 (12.18-165.97)	34.30 (9.50-104.21)	32.39 (8.67-78.10)	24.39 (9.80-56.37)	23.69 (8.40-63.39)	**<0.001**

ANOVA test, Kruskal-Wallis test, parametric values shown as mean ± SD; non-parametric data shown as median (min-max) (interquartile range). SD: Standard deviation, ESI: Emergency severity index, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, MAP: Mean arterial pressure, GCS: Glasgow Coma score those who survived 30 days. Recent studies have shown that PI is a significant marker for mortality in trauma patients [11]. The findings of this study were found to be compatible the literature. Although there is systemic vasodilation secondary to sympathetic nervous system hyperstimulation in septic patients, this is not the case for peripheral vessels. Thus, we believe that the peripheral PI value is estimated to be low [12].

Almost twenty-nine percent of the cases were hospitalized, 11.1% were admitted to inpatient service, and 17.5% were admitted to the ICU. In the study of Rivers et al. [13], it has been reported that 100 million ED admissions annually constitute 40% of hospitalizations, and 25% of these patients are critically ill. In this study, in-hospital mortality was estimated at 2.4%, and 30-day mortality was 7.2%; the rate of 30-day mortality and hospitalization were low compared to other studies. This is considered because this study is single-centered with a limited number of patients.

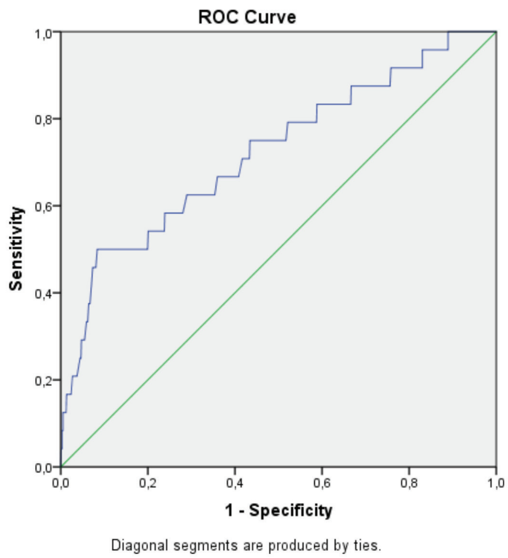

Figure 3. ROC Curve of perfusion index

ROC: Receiver operating characteristic

Table 2. Analysis of variables with in-hospital mortality

Parameters	In-hospital mortality		p values
	Yes (24)	No (967)	
Perfusion index	1.13±1.03	2.01±1.27	**0.001**
Shock index	0.68 [0.30]	0.69 [0.22]	0.386
Modified shock index	0.93 [0.45]	0.94 [0.28]	0.318
Age shock index	48.56 [24.53]	29.68 [18.98]	**<0.001**
Age	67.67±15.45	48.02±20.80	**<0.001**
SBP	123.13±42.32	132.71±26.92	0.281
DBP	71.33±20.16	77.55±14.81	**0.044**
MAP	88.60±27.14	95.94±17.51	0.200
Pulse	89.75±22.38	89.96±16.63	0.965
Fever	36.4 [0.48]	36.5 [0.40]	**0.026**
RR	20 [2]	16 [5]	**<0.001**
SpO_2	92 [9]	97 [3]	**<0.001**

Independent sample t-test, Mann-Whitney U test, parametric values shown as mean ± SD; non-parametric data shown as median [interquartile range]. SD: Standard deviation, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, MAP: Mean arterial pressure, RR: Respiratory rate

In this study, PI, temperature, RR, DBP, SpO_2 value, and ASI were found to be statistically significant variables for in-hospital mortality. Studies showed a significant correlation between PI and the core-to-toe temperature difference [14]. Torabi et al. [15] also examined patients in the ESI category three and found that SBP and ASI values were better in determining mortality than SI and MSI. In another study, a non-linear correlation between baseline DBP and in-hospital mortality in patients with acute myocardial infarction was found, and a decrease in DBP within the first three days in patients who had a mortal course [16]. Lee et al. [17] determined that the SpO_2/RR ratio is an independent prognostic factor for 28-day mortality in patients with sepsis or septic shock. Another study found that nocturnal RR measures in patients aged 65 and over may be a risk marker for mortality [18]. Daş et al. [19] demonstrated that the SI value had a clear advantage over some vital measures for estimating 30-day mortality but was not useful in estimating hospitalization and showed that a lower PI value was associated with both hospitalization and 30-day mortality. In another study, conventional vital signs and SI values were compared to determine acute critical illnesses in ED, and they concluded that a more than 0.9 unit abnormal increase in SI values of 36 patients was closely associated with hospitalization and intensive treatment after hospitalization [20]. SI and MSI values are found to be potentially useful for predicting in-hospital and out-of-hospital massive bleeding and defining hemorrhagic shock [21]. Laaksonen et al. [22] showed that it could be used to predict 30-day mortality by dividing the ASI value by the GCS in seriously injured patients in the pre-hospital setting. ASI and SI are found to be valuable in predicting mortality in acute heart failure [23]. The ASI value is calculated to be high due to the decrease in physiological reserve, metabolic and hormonal response with advanced age, and the decrease in the body's response to trauma [4,6]. In another study, they found that SpO_2 <90 in coronavirus disease-2019 patients was a strong indicator of in-hospital mortality [24]. Studies are conducted in variable patient groups of different populations that explain the discrepancy of findings.

Study Limitations

A limited number of patients were included, as it was a single-centered, cross-sectional study conducted in a limited time frame with a limited number of patients. These are considered to be the limitations of our study.

Table 3. ROC analysis of the perfusion index and age shock index

	AUC	p values	95% CI		Sensitivity	Specificity	PPV	NPV	Accuracy
			Lower bond	Upper bond					
Perfusion index <0.505	0.723	0.000	0.608	0.838	50%	91.62%	12.9%	98.66%	90.62%
Age shock index >34.21	0.807	0.000	0.728	0.887	91.67%	61.94%	5.64%	99.67%	62.66%

ROC: Receiver operating characteristic, AUC: Area under curve score, CI: Confidence interval, PPV: Positive predictive value, NPV: Negative predictive value

Conclusion

We recommend using PI and ASI with existing triage category systems for easier recognition and early treatment of critically ill patients in busy EDs.

Ethics

Ethics Committee Approval: After the approval of the University of Health Sciences Turkey, Kanuni Sultan Süleyman Training and Research Hospital Ethics Committee no: 2022.02.37, subject no: KAEK/2022.02.37.

Informed Consent: Patients at the age of 18 and above who gave consent were included in the study.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Concept: B.S.K., S.D., Design: B.S.K., S.D., A.F.B.K., V.A., Data Collection or Processing: B.S.K., A.F.B.K., M.G., M.U., Analysis or Interpretation: B.S.K., S.D., S.F., V.A., Literature Search: B.S.K., A.F.B.K., M.G., Writing: B.S.K., V.A.

Conflict of Interest: No conflict of interest was declared by the authors.

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References

1. Paladino L, Subramanian RA, Nabors S, Sinert R. The utility of shock index in differentiating major from minor injury. Eur J Emerg Med. 2011;18:94-8.
2. Yasaka Y, Khemani RG, Markovitz BP. Is shock index associated with outcome in children with sepsis/septic shock?*. Pediatr Crit Care Med. 2013;14:372-9.
3. Liu YC, Liu JH, Fang ZA, Shan GL, Xu J, Qi ZW, et al. Modified shock index and mortality rate of emergency patients. World J Emerg Med. 2012;3:114-7.
4. Rau CS, Wu SC, Kuo SC, Pao-Jen K, Shiun-Yuan H, Chen YC, 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;13:683.
5. Demir A, Eren F. The relationship between age shock index, and severity of stroke and in-hospital mortality in patients with acute ischemic stroke. J Stroke Cerebrovasc Dis. 2022;31:106569.
6. Kim SY, Hong KJ, Shin SD, Ro YS, Ahn KO, Kim YJ, et al. Validation of the shock index, modified shock index, and age shock index for predicting mortality of geriatric trauma patients in emergency departments. J Korean Med Sci. 2016;31:2026-32.
7. Zarzaur BL, Croce MA, Fischer PE, Magnotti LJ, Fabian TC. New vitals after injury: shock index for the young and age x shock index for the old. J Surg Res. 2008;147:229-36.
8. Agerskov M, Thusholdt ANW, Holm-Sørensen H, Wiberg S, Meyhoff CS, Højlund J, et al. Association of the intraoperative peripheral perfusion index with postoperative morbidity and mortality in acute surgical patients: a retrospective observational multicentre cohort study. Br J Anaesth. 2021;127:396-404.
9. Er MC, Kaya C, Ustun YB, Sahinoglu AH. Predictive value of perfusion index for mortality in mechanically ventilated patients. Aging Male. 2020;23:1251-8.
10. Savastano S, Baldi E, Contri E, De Pirro A, Sciutti F, Compagnoni S, et al. Post-ROSC peripheral perfusion index discriminates 30-day survival after out-of-hospital cardiac arrest. Intern Emerg Med. 2021;16:455-62.
11. Ozakin E, Yazlamaz NO, Kaya FB, Karakilic EM, Bilgin M. Perfusion Index measurement in predicting hypovolemic shock in trauma patients. J Emerg Med. 2020;59:238-45.
12. Elshal MM, Hasanin AM, Mostafa M, Gamal RM. Plethysmographic peripheral perfusion index: could it be a new vital sign? Front Med (Lausanne). 2021;8:651909.
13. Rivers EP, Nguyen HB, Huang DT, Donnino MW. Critical care and emergency medicine. Curr Opin Crit Care. 2002;8:600-6.
14. Lima AP, Beelen P, Bakker J. Use of a peripheral perfusion index derived from the pulse oximetry signal as a noninvasive indicator of perfusion. Crit Care Med. 2002;30:1210-3.
15. Torabi M, Moeinaddini S, Mirafzal A, Rastegari A, Sadeghkhani N. Shock index, modified shock index, and age shock index for prediction of mortality in emergency severity index level 3. Am J Emerg Med. 201634:2079-83.
16. Huang S, Luo Y, Liang L, Guo N, Duan X, Zhou Q, et al. The baseline and repeated measurements of DBP to assess in-hospital mortality risk among critically ill patients with acute myocardial infarction: a retrospective cohort study. Medicine (Baltimore). 2022;101:e30980.
17. Lee CU, Jo YH, Lee JH, Kim J, Park SM, Hwang JE, et al. The index of oxygenation to respiratory rate as a prognostic factor for mortality in sepsis. Am J Emerg Med. 2021;45:426-32.
18. Baumert M, Linz D, Stone K, McEvoy RD, Cummings S, Redline S, et al. Mean nocturnal respiratory rate predicts cardiovascular and all-cause mortality in community-dwelling older men and women. Eur Respir J. 2019;54:1802175.
19. Daş M, Bardakci O, Siddikoglu D, Akdur G, Yilmaz MC, Akdur O, et al. Prognostic performance of peripheral perfusion index and shock index combined with ESI to predict hospital outcome. Am J Emerg Med. 2020;38:2055-9.
20. Rady MY, Nightingale P, Little RA, Edwards JD. Shock index: a re-evaluation in acute circulatory failure. Resuscitation. 1992;23:227-34.
21. Terceros-Almanza LJ, García-Fuentes C, Bermejo-Aznárez S, Prieto-Del Portillo IJ, Mudarra-Reche C, Sáez-de la Fuente I, et al. Prediction of massive bleeding. Shock index and modified shock index. Med Intensiva. 2017;41:532-8.
22. Laaksonen M, Björkman J, Iirola T, Raatiniemi L, Nurmi J. The effect of time of measurement on the discriminant ability for mortality in trauma of a pre-hospital shock index multiplied by age and divided by the Glasgow Coma score: a registry study. BMC Emerg Med. 2022;22:189.

23. Castillo Costa Y, Cáceres L, Mauro V, Fairman E, Fernández A, Soricetti J, et al. Shock index, modified shock index, and age-adjusted shock index as predictors of in-hospital death in acute heart failure. Sub analysis of the ARGEN IC. Curr Probl Cardiol. 2022;47:101309.
24. Mejía F, Medina C, Cornejo E, Morello E, Vásquez S, Alave J, et al. Oxygen saturation as a predictor of mortality in hospitalized adult patients with COVID-19 in a public hospital in Lima, Peru. PLoS One. 2020;15:e0244171.