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# Shock index as a predictor of mortality among the Covid-19 patients

Fatih Doğanay, M.D. [a,*], Fuat Elkonca, PhD., Dr. [b], Avni Uygar Seyhan, M.D. [c], Erdal Yılmaz, M.D. [c], Ayşe Batırel, M.D., Assoc. Prof. [d], Rohat Ak, M.D. [c]

[a] Specialist of Emergency Medicine, Edremit State Hospital, Department of Emergency Medicine, Balıkesir, Turkey
[b] Muş Alparslan University, Department of Educational Measurement and Evaluation, Muş, Turkey
[c] Specialist of Emergency Medicine, Dr. Lütfi Kırdar Kartal City Hospital, Department of Emergency Medicine, Istanbul, Turkey
[d] Specialist in Infectious Diseases and Clinical Microbiology, Dr. Lütfi Kırdar Kartal City Hospital, Department of Infectious Diseases and Clinical Microbiology, Istanbul, Turkey

## 1. Introduction

In December 2019, several cases of pneumonia of unknown origin were detected in Wuhan, Hubei, China [1,2]. The pathogen was identified as a novel coronavirus (CoV) and renamed as severe acute respiratory syndrome CoV-2 (SARS-CoV-2) [3]. As of September 2020, more than 28 million cases and more than 900 thousand deaths have been reported worldwide [4]. Shock index (SI) is a ratio obtained by dividing heart rate by systolic blood pressure; it is a simple and easy to use formula for detecting changes in cardiovascular performance prior to systemic hypotension. Allgöwer and Buri first introduced this ratio in 1967 as a simple and effective way of measuring the degree of hypovolemia in cases of hemorrhagic and infectious shock [5]. This non-invasive measurement is important because it provides consistent information about hemodynamics. SI is an important marker for understanding the level of tissue perfusion [6].

SI is widely used as a predictor of mortality especially in the intensive care unit and its potential benefits have been evaluated by many other studies, demonstrating superiority over vital sign measurements [7-9]. There are studies in the literature showing that high SI predicts mortality and the need for intensive care in adults [10-12]. King et al. reported that SI can be used as a marker to estimate the severity of injury at initial presentation in trauma patients with hypovolemic shock [10]. SI has been shown to be a good predictor of mortality in many conditions such as sepsis, pulmonary embolism, traumatic injuries and pneumonia [11-15].

Our primary aim is to determine the power of SI at the time of ED presentation as a predictor of mortality in patients with COVID-19. Secondarily, we aimed to determine the relationship between mortality and vital signs and medical history data available at the time of ED triage in this patient population.

## 2. Materials and methods

### 2.1. Study design

This retrospective observational study was conducted with patients who presented to the ED of a tertiary hospital between April 1, 2020 and May 31, 2020 and were hospitalized after diagnosed with COVID-19. The institutional review board approved the analysis and issued a waiver of consent (Ethics Committee Ruling number: 2020/514/186/14).

### 2.2. Selection of patients

All patients who were admitted to the ED with COVID-19 complaints, had an oropharyngeal/nasopharyngeal swab and were hospitalized between April 1 and May 312,020 were included in the study. Patients whose RT-PCR test results were negative and whose ED triage data could not be accessed via Hospital Information Management System (HIMS) were excluded from the study.

### 2.3. Measurements

Age, sex, vital signs and medical history of all patients included in the study were recorded in a digital form.

### 2.4. Outcome measures

Our primary aim in this study is to determine the relationship between SI and 30-day mortality. Our secondary aim is to determine the relationship between mortality and the data (SI, SpO2 and chronic diseases) that can be obtained in ED triage in COVID −19 patients.

### 2.5. Statistical analysis

IBM SPSS Statistics 25 (Chicago, IL) software was used for statistical analysis. CHAID analysis was used in Decision Tree methods. $p < 0.01$ was considered statistically significant. Within the scope of the research, the data obtained in the triage and the literature were taken into consideration while determining the variables related to the regression model

* Corresponding author at: Edremit Devlet Hastanesi, Acil Servis, Edremit, Balıkesir, Turkey.

*E-mail addresses:* drdoganay@gmail.com (F. Doğanay), f.elkonca@alparslan.edu.tr (F. Elkonca), ayse.batirel@sbu.edu.tr (A. Batırel).

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to be established to determine the variables that affect the mortality. For this purpose, sex, age, comorbidities such as Chronic Obstructive Pulmonary Disease (COPD), Asthma, Diabetes Mellitus (DM), Hypertension (HT), Congestive Heart Failure (CHF), Coronary Artery Disease (CAD), Atrial Fibrillation (AF), Chronic Renal Failure (CRF), Blood Oxygen Saturation (SpO2) and Shock Index (SI) variables were taken into the model.

### *2.6. CHAID analysis*

CHAID analysis has advantages such as being able to model categorical and continuous variables at the same time, provide reliable estimates in large samples, and can be used as an alternative non-parametric tree diagram to binary and multi nominal logistic regression models since it does not take into account the assumptions that should be provided in parametric models. In addition to these advantages, it can detail the relationships between independent variables and provide easy-to-understand outputs in the form of trees even in the most complex models. Because of these advantages, CHAID analysis has a wide usage area in the literature [16-18].

## 3. Result

The remainder of the study was conducted with 489 patients after using the inclusion and exclusion criteria. The demographic and comorbidity data of the study population are summarized in Table 1**.** It is observed that 253 (51.7%) of the patients included in the study were male and 236 (48.3%) were female. The average age was 59.33 ± 19.42 for all patients (range 10–101), 53.44 ± 18.60 for survivors and 72.15 ± 14.38 for non-survivor**s (**Table 1).

The tree diagram of the CHAID model established to determine the variables that affect the mortality status of COVID-19 patients within the scope of the research is given in Fig. 1.

When the tree structure in Fig. 1 is examined, 335 (68.5%) of the patients within the scope of the study were survivors, while 154 (**31.5%)** were non-survivors.

Fig. 1 shows that the variable that has a dominant effect on mortality is "age" ($\chi2 = 116.67$; $p < 0.01$). The age variable is divided into three different groups according to mortality. According to these findings, as the age of the patients increases, the rate of mortality also increases.

**Table 1**
Demographic and comorbidity data of the study population.

| Variables | Category | Survivors | | Non-Survivors | | Total | |
|---|---|---|---|---|---|---|---|
| | | n | % | n | % | n | % |
| Sex | Male | 163 | 48.7 | 90 | 58.4 | 253 | 51.7 |
| | Female | 172 | 51.3 | 64 | 41.6 | 236 | 48.3 |
| COPD | No | 324 | 96.7 | 134 | 87.0 | 458 | 93.7 |
| | Yes | 11 | 3.3 | 20 | 13.0 | 31 | 6.3 |
| Astma | No | 311 | 92.8 | 147 | 95.5 | 458 | 93.7 |
| | Yes | 24 | 7.2 | 7 | 4.5 | 31 | 6.3 |
| DM | No | 250 | 74.6 | 112 | 72.7 | 362 | 74.0 |
| | Yes | 85 | 25.4 | 42 | 27.3 | 127 | 26.0 |
| HT | No | 221 | 66.0 | 89 | 57.8 | 310 | 63.4 |
| | Yes | 114 | 34.0 | 65 | 42.2 | 179 | 36.6 |
| CHF | No | 325 | 97.0 | 122 | 79.2 | 447 | 91.4 |
| | Yes | 10 | 3.0 | 32 | 20.8 | 42 | 8.6 |
| CAD | No | 312 | 93.1 | 123 | 79.9 | 435 | 89.0 |
| | Yes | 23 | 6.9 | 31 | 20.1 | 54 | 11.0 |
| AF | No | 327 | 97.6 | 143 | 92.9 | 470 | 96.1 |
| | Yes | 8 | 2.4 | 11 | 7.1 | 19 | 3.9 |
| CRF | No | 320 | 95.5 | 134 | 87.0 | 454 | 92,8 |
| | Yes | 15 | 4.5 | 20 | 13.0 | 35 | 7,2 |
| **Total** | | 335 | 100.0 | 154 | 100.0 | 489 | 100.0 |
| | | **Survivors** | | **Non-Survivors** | | **Total** | |
| Age | | $\bar{X}$ | **S.D** | $\bar{X}$ | **S.D** | $\bar{X}$ | **S.D** |
| | | 53.44 | 18.60 | 72.15 | 14.38 | 59.33 | 19.42 |

COPD: Chronic Obstructive Pulmonary Disease, DM: Diabetes Mellitus, HT: Hypertension, CHF: Congestive Heart Failure, CAD: Coronary Artery Disease, AF: Atrial Fibrillation, CRF: Chronic Renal Failure.

The lowest mortality rate was in the group 56 years and younger (8.6%). While the mortality rate of patients between the ages of 56 and 77 is 35.6%, the mortality rate of patients older than 77 is 70.1%.

Within the scope of the study, the most effective variable on the mortality status of the participants within the three different age groups was found to be the SI. According to the findings, those who were 56 years old ($\chi2 = 12.82$; $p < 0.01$), those between 56 and 77 years old ($\chi2 = 39.03$; $p < 0.01$) and those over 77 years old ($\chi2 = 11.88$; $p < 0.01$), the mortality rate of patients with a SI value above 0.93 was significantly higher than that of participants with a SI value of 0.93 and below. In addition to these findings, it is noticed that the effect of SI on mortality increases with increasing age (26.9%, 80.5%, 91.4%, respectively). SpO2 is the most influential variable on the mortality of patients under the age of 56 and with a SI value of 0.93 and below ($\chi2 = 18.37$; $p < 0.01$). According to the findings, while the mortality rate of patients with SpO2 value of 95.0 and below was 15.9%, none of the patients with SpO2 values above 95.0 died.

The classification accuracy rates of the CHAID model established within the scope of the study are calculated and the findings are given in Table 2. As seen in Table 2**,** the total correct classification rate for the CHAID model, which is established with only three variables that are statistically significant, is 81.0%. In addition, the established model correctly classified 63.0% of non-survivors, while correctly classifying 89.3% of survivors.

## 4. Discussion

Various publications have reported that older age predicts higher mortality in patients with COVID-19 pneumonia [19-21]. In our study, the first classification by CHAID analysis was made by age, and in our sample, it was divided into 3 groups, ages 56 and 77 stand out as critical limits. The mortality rate was found to be the lowest in those younger than 56 years old, and those over 77 years old constitute the group with the highest mortality rate. In our study, advanced age was found to be directly related to mortality, and this is consistent with the literature.

As can be seen in Fig. 1, by CHAID analysis, the most significant classifying variable for mortality in all three age groups was determined as SI. The most frequently recommended cut-off values for SI in the literature are 0.7, 0.9, and 1.

In a study where the cut-off value was taken as 1 for SI, it was reported that SI values greater than 1 in patients with a diagnosis of Pulmonary Embolism were associated with hospital mortality [22]. Kristensen et al. reported that in patients who presented to the ED, those with SI values greater than 1 were higher with 30-day mortality risk [23]. In a study conducted in geriatric ED patients with influenza, it was determined that a SI value greater than 1.0 was associated with high mortality [24].

Rady et al. reported that SI values greater than 0.9 were associated with critical illness and the need for intensive treatment [25]. In a study conducted in 2007, it was reported that the use of SI with a cut-off value of 0.9 is more effective than the SIRS criteria for early detection of sepsis patients in ED settings [26]. Another study advocating the use of 0.9 as a cut-off for SI, argued that a SI value greater than 0.9 measured before hospitalization in patients with sepsis has a strong relationship with mortality [27]. Birkhahn et al. reported that in patients diagnosed with ectopic pregnancy, a SI value greater than 0.7 is a better predictor of intraperitoneal bleeding than vital values [28]. Berger et al. argued that a SI value greater than 0.7 performed as well as the SIRS criteria in defining sepsis [29].

CHAID analysis was performed in our study. The cut-off values used for the groupings specified in Fig. 1 were determined by CHAID analysis by making the most significant divisions. In our study, SI being the most effective classifier variable in all 3 age groups, is an important data emphasizing the determinacy of SI on mortality. The SI cut-off value determined by CHAID analysis is 0.93 and it is compatible with the literature.

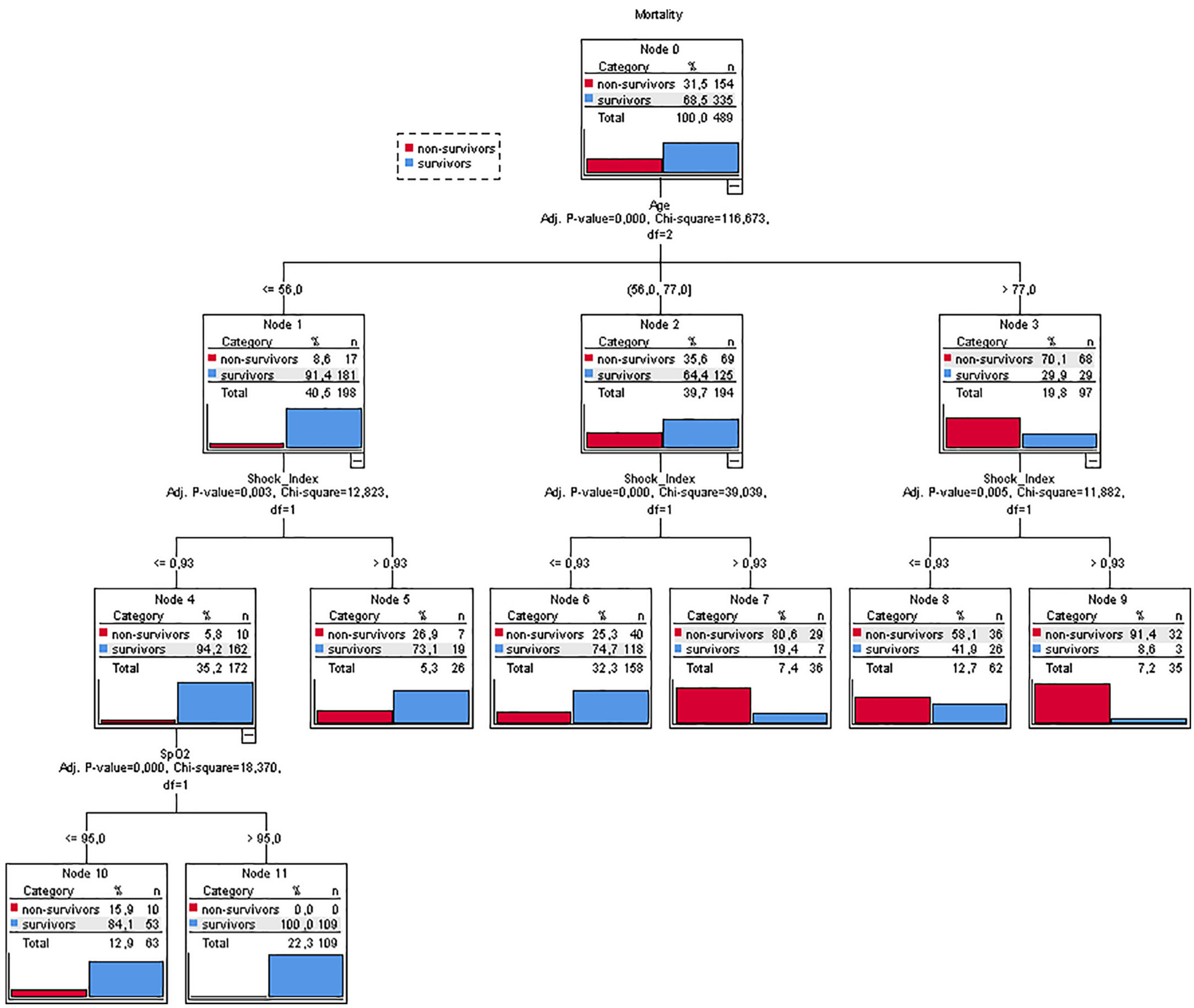


**Fig. 1.** Tree structure of predictor variables affecting mortality.

**Table 2**
Survival estimation accuracy with age, shock index and SpO2 parameters by using CHAID analysis among COVID-19 patients.

| Observed | Predicted | | |
|---|---|---|---|
| | Non-survivors | Survivors | Percent Correct |
| Non-survivors | 97 | 57 | 63.0% |
| Survivors | 36 | 299 | 89.3% |
| Overall Percentage | 27.2% | 72.8% | 81.0% |

When evaluated regardless of age, the mortality rate was found to be 70% in patients with SI greater than 0.93, while the same rate was found as 21% in patients with a SI less than 0.93. However, this study revealed that the effect of SI on mortality is higher in advanced ages. In measuring SI in the ED triage of patients with suspected COVID-19, the use of 0.9 SI value for early intervention and hospitalization is an important conclusion to be drawn from the findings of our study and that is valuable for critically ill patients. It is seen in Fig. 1 that the most effective classification variable is SpO2 in patients younger than 56 years with SpO2 value above 95. It has been reported by Xie et al. that SpO2 at the time of admission has an effect on mortality. Xie et al. determined the cut-off value for SpO2 as 90% in their study, and reported that the mortality rate was high in patients with SpO2 below this value [30]. In our study, the SpO2 value was determined as 95% in the grouping determined according to the mortality variable by CHAID analysis, and this value is the limit value that has been proven and generally accepted in the medical literature [31]. Another interesting point in our study is that the mortality rate was found to be “zero” in the group with SpO2 value greater than 95 in patients younger than 56 and with a SI value less than 0.93. The absence of death outcome in patients with age less than 56, SI value less than 0.93 and normal SpO2 values is an important indicator that these 3 parameters should be included in the scoring systems to be planned for mortality.

The coronavirus pandemic has led to a serious public health problem worldwide, especially resulting in serious crowding on emergency departments and intensive care units [32]. Therefore effective early evaluation of patients who need an intensive care unit and high mortality expectation is important for the health system to function as long as possible. In our study, we concluded that an SI value above 0.93 showed a significant correlation with mortality rate. Using a 0.9 value of SI with age and SpO2 value may be helpful for clinicians to early identification of patients with high mortality expectation that it will also be important in terms of protecting the functionality of the health system.

## 5. Limitations

There are some limitations in our study. Firstly, this was a single-center study executed on a relatively small population and needs to be confirmed in a larger, multi-center cohort. Our data were obtained from an electronic registration system, which brings about limitations in respect of providing incomplete or old information. Finally retrospective studies are inherently devoid of the control of variables; therefore, prospective cohorts are needed to confirm our study data.

## 6. Conclusion

Studies conducted to determine various mortality predictors for COVID-19 pneumonia are available in the literature. This study is the first study examining the relationship of SI with mortality in COVID-19 patients. In order to prevent the development of mortality from COVID-19 in patients with advanced age, low SpO2 value and high SI value; physicians should be alert at the time of admission in terms of early intervention and hospitalization. It should be noted that the SI will be a useful parameter in determining both ED triage and the need for hospitalization of patients presenting with the suspicion of COVID-19. There is a need for studies analyzing mortality with subgroups, and it will be enlightening to conduct such studies with larger samples to reveal the pattern of variables affecting mortality in deaths caused by **COVID-19**.

## Ethical approval

This study was approved by the local ethics committee (Ethics Committee Ruling number: 2020/514/186/14).

## Human rights

The principles outlined in the Declaration of Helsinki have been followed.

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## Declaration of Competing Interest

Authors declare that they have no conflicts of interest.

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