Annals of Medical Research
DOI: 10.5455/annalsmedres.2019.06.329 2019;26(9):1885-9

Original Article

# Clinical benefits of shock index and modified shock index in pulmonary embolism for 30-day mortality prognosis

Umut Payza[1], Zeynep Karakaya[1], Fatih Esad Topal[1], Pinar Yesim Akyol[1], Rezan Tahtaci[1], Ahmet Kayali[1], Serkan Bilgin[2]

[1]Izmir Katip Celebi University, Ataturk Training and Teaching Hospital, Emergency Department, Izmir, Turkey
[2]Batman Regional State Hospital, Emergency Department, Batman, Turkey



**Abstract**

**Aim:** It was evaluating the shock index and the modified shock index, which are strongly correlated with the severity of the shock. Determining the risk analysis in terms of early mortality of patients diagnosed with pulmonary thromboembolism (PE) in order to specify treatment options and prognosis. Therefore, it is important to determine the severity of pulmonary embolism correctly. The available algorithms, such as the pulmonary embolism severity index, provide a prediction of the patients according to clinical findings. These algorithms score abnormal vital signs, medical findings, age, and comorbid diseases. However, vital signs in normal physiological limits cause errors in determining the severity of the disease. In this case, the problem is a lack of correlation between the severity of the disease and vital signs. Consequently, we need a more reliable parameter. In our study, we searched for a parameter that can be calculated easily in a dynamic manner, and which is not affected by normalized vital signs. We attempted to find a parameter that could indicate the severity of the disease. Therefore, we evaluated the shock index and the modified shock index, which are strongly correlated with the severity of the shock.

**Material and Methods:** Patients diagnosed with pulmonary embolism were screened retrospectively between January 2012 and December 2017. A total of 99 patients whose pulmonary embolism was confirmed by angio-thoracic tomography were included in the study. Heart rate, systolic and diastolic blood pressure were measured in these patients. Mean arterial pressure, shock index and the modified shock index were also calculated. The values showing the severity of the disease were evaluated.

**Result** When all the parameters were examined, the predictive power of deaths within 30 days was significant at differing degrees ($p<0.05$). In ROC analysis, shock index was the most prominent parameter with its clinical utility and sensitivity. This was followed by pulse count and modified shock index, which are other valuable parameters.

**Conclusion:** At the time of admission to the emergency department, we found that the shock index could be easily calculated with vital signs and display a better correlation with the severity of the disease. Although systolic-diastolic blood pressure, pulse rate and mean arterial pressures calculated in pulmonary embolism are within physiological limits, the shock index shows particularly better correlation and sensitivity of the severity of the disease.

**Keywords:** Pulmonary embolism; shock index; modified shock index.

## INTRODUCTION

Pulmonary thromboembolism (PE) is a disease which is recurrent and difficult to diagnose, and continues to have high mortality and morbidity rates. Diagnosis is delayed due to clinical symptoms, concomitant diseases and atypical presentations, especially in patients admitted to emergency departments. Consequently, diagnostic and treatment guidelines are frequently updated. However, high mortality rates are still being observed, especially in the first 30 days (1). Early mortality is associated with the delay in diagnosis and underlying diseases (2,3).

The emergency department is an important step to reduce the mortality of pulmonary embolism. Specifically, identifying patients at risk is important to reduce mortality. Various warning systems are used for risk classification in emergency services. The National Early Warning Score (NEWS) and the Pediatric Early Warning System Scores (PEWS), which have international validity, are applicable. The WELLS score is used for patients with suspected pulmonary embolism and the Pulmonary Embolism Severity Index (PESI) is also used to predict the severity of the disease. In all of these guidelines, vital

**Received:** 17.06.2019 **Accepted:** 17.09.2019 **Available online:** 30.09.2019
**Corresponding Author:** Umut Payza, Katip Celebi University, Ataturk Training and Research Hospital, Department of Emergency Medicine, Izmir, Turkey, E-mail: umutpayza@hotmail.com

signs are scored. However, vital values may not always show a correlation with the severity of the disease (4, 5). Therefore, there is a need for indicators that will identify patients with high risk in emergency services.

In our study, we searched for a parameter that can be calculated using a patient's vital signs, but which is more reliable than those vital signs. We considered the 30-day mortality rate, and assessed the clinical benefit of the shock index and modified shock index, in identifying patients with high risk.

## PATIENTS AND METHODS

### Study setting and population

The study was performed in the emergency department of Izmir Katip Çelebi University, Atatürk Training and Research Hospital. Patients who were admitted to the emergency department in a 5-year period, between January 2012 and December 2017, were retrospectively evaluated. Patients diagnosed with pulmonary embolism were scanned from the hospital database. Computerized thoracic angiographies, which were reported by a radiologist for diagnosis, were accepted as the gold standard diagnostic method. Patients diagnosed or treated in the outpatient center, patients who underwent cardiopulmonary resuscitation, pregnant women and patients under the age of 18 were not included in the study. Pulmonary embolism patients were screened with an ICD code. 236 patient data were obtained. 155 of these patients had pulmonary embolism confirmed by tomography. Patients who met the inclusion criteria and whose survival / mortality information were available were included. Secondary pathologies preventing P.E diagnosis were excluded. The data of 99 patients who met all these criteria were analyzed. The vital parameters of the patients recorded at the time of admission to the emergency department were taken as the basis. Shock Index (SI), Modified Shock Index (MSI) and Mean Arterial Pressure (MAP) were calculated by these parameters. Thirty-day mortality rates of the patients were also evaluated.

We searched, 'İs shock index and modified shock index a more reliable parameter which is not affected by normalized vital signs'.We accepted the 30-day mortality as the primary outcome.

The ethics committee approval required for the study was obtained from our hospital.

### Measurements

Recorded systolic blood pressure, diastolic blood pressure and pulse values, and the shock index were calculated according to the formula (SI) = HR / SBP; while modified the shock index was calculated by (MSI) = HR / MAP. The mean arterial pressure was calculated as (MAP)= [(DBP × 2) + SBP] / 3.

### Statistical analysis

The statistical analysis of the data was performed in the IBM SPSS Statistics Version 22 package program. The Pearson Chi-Square and Fisher's Exact test were used for the comparison of categorical data between the groups, and the Mann Whitney U statistical analysis was used in the comparisons between the groups since the continuous data were not in the normal distribution (Kolmogorov, Smirnov and Shapiro, Wilks; $p<0.05$). The interaction between demographic and clinical features and death status within 30 days was evaluated by single logistic regression analysis. In addition, optimal cut-off values were calculated by using ROC analysis for age, pulse, shock index, modified shock index, systolic BP, diastolic BP and MAP values for the death prediction powers within 30 days. $P<0.05$ was accepted as statistically significant.

## RESULTS

In our study, 37 (37.4%) of the patients were male, and 62 (62.6%) were female. No significant difference was observed between the mortality rates according to gender in our study. The age distributions of both genders were found to be similar (M: 68.57±13.66, F: 68.29±17.87).

Out of the 74 (74.7%) patients with comorbid diseases, 30 (30.6%) had congestive heart failure (CHF), 26 (26.3%) had hypertension (HT) and 18 (18.2%) had malignancy history. The number of patients with diabetes history (DM) who were operated in the last three months was 16 (16.2%). When the patients were examined according to their 30-day mortality, the mortality rate in patients with CHF was 42.4%; in patients with hypertension, it was 33.3%; and in patients with malignancy, it was 21.2%. Patients with diabetes and patients with a history of an operation in the last three months were found to have an equal mortality rate (18.2%) (Table 1).

The data were analyzed for pulse, systolic BP, diastolic BP and MAP. Shock index came into prominence as the highest parameter of clinical correlation. When the cutoff value in the shock index was considered as >0.735, the predictive power of mortality was 79.7%. Again, the

**Table 1. Comorbid Diseases and Mortality**

| | Comorbid Diseases (n) (%) | | Death within 30 days (n) (%) | | P |
|---|---|---|---|---|---|
| CHF | 30 | 30.3 | 14 | 42.4 | >0.05 |
| COPD | 8 | 8.1 | 3 | 9.1 | |
| HT | 26 | 26.3 | 11 | 33.3 | |
| STROKE | 10 | 10.1 | 5 | 15.2 | |
| DVT | 11 | 11.1 | 2 | 6.1 | |
| Malignancy | 18 | 18.2 | 7 | 21.2 | |
| DM | 16 | 16.2 | 6 | 18.2 | |
| MI | 6 | 6.1 | 2 | 6.1 | |
| PTE | 3 | 3 | 2 | 6.1 | |
| CRF/ARF | 4 | 4 | 2 | 6.1 | |
| MJ | 16 | 16.2 | 6 | 18.2 | |
| Total | 74 | 74.7 | 27 | 81.8 | |

**CHF:** Congestive Heart Failure, **COPD:** Chronic Obstructive Pulmonary Disease, **HT:** Hypertension, **DVT:** Deep Vein Thrombosis, **DM:** Diabetes, **PTE:** Pulmonary Embolism, **MI:** Myocardial Infarction, **CRF:** Chronic Renal Failure, **ARF:** Acute Renal Failure, **MJ:** history of major surgical surgery in the last 3 months highest sensitivity was found in the shock index. In our study, the limit value belonging to the calculated heart rate (HR) was >122 beat/min. The cutoff value of the systolic blood pressure was <119 mmHg, and the diastolic blood pressure cutoff value was <79.5 mmHg. The calculated mean arterial pressure cut-off value was <77.15. Since there was no clear evidence for the modified shock index value, it was calculated based on the modified shock index-death curve in our study. Calculated probability analysis was performed, and the modified shock index cutoff value was determined as >1.085. The predictive power of mortality was 77.5%. Sensitivity was also observed to be quite high (90.9%) (Table 2).

Systolic and diastolic blood pressure and modified shock index values of the patients who died within 30 days were found to be statistically lower than the values of the patients who did not die within 30 days (p<0.05).

In the single logistic regression analysis, it was found that there was a positive interaction among the deaths in 30 days, age and pulse rates; and a negative and statistically significant interaction among systolic blood pressure, diastolic blood pressure and MAP values (P<0.05).

**Table 2. ROC Analysis For Prediction Power Within 30 Days**

| Variables | Cut-Off | Sensitivity | Specificity | AUC | p |
|---|---|---|---|---|---|
| **Pulse** | >122 | 51.5 | 84.8 | 0.697 | 0.001 |
| **Shock index** | >0.735 | 97.0 | 51.5 | 0.797 | 0.000 |
| **Modified shock index** | >1.085 | 90.9 | 62.1 | 0.775 | 0.000 |
| **Systolic BP** | <119 | 87.9 | 68.2 | 0.796 | 0.000 |
| **Diastolic BP** | <79.5 | 87.9 | 51.5 | 0.746 | 0.000 |
| **MAP** | <77.15 | 63.6 | 83.3 | 0.787 | 0.000 |

**BP**: Blood Pressure, **MAP;** Mean arterial pressure

## DISCUSSION

Determining the risk analysis in terms of early mortality in the patients diagnosed with pulmonary thromboembolism (PE) specifies the treatment options (anticoagulant / thrombolytic) and the prognosis. In stable cases, the presence of hemodynamic reserve and additional diseases before the embolism, affects the early prognosis (6).

Prognostic evaluation uses various clinical scoring (7). Prognostic scales such as NEWS or Pulmonary Embolism Index (PESI), the abnormal values of vital parameters such as pulse rate, systolic and diastolic blood pressure values, and respiratory rates are a warning for the diagnosis. They provide prediction using vital parameters. These scorings help to predict a complicated clinical course, particularly early one-month mortality, recurrence, and nonfatal major bleeding. The most common of these is PESI. Class I and II have a high and negative predictive value of 97% in determining the outpatient group who have low risk in terms of 30-day mortality in pulmonary embolism severity index scoring. In the validation study conducted with pulmonary embolism severity index scoring, early mortality in the low-risk group was reported as 0.7% and 1.2%; whereas in the high-risk group, it was reported to be 4.8%, 25%, respectively. The simplified PESI severity index (sPESI), which was less complicated containing fewer parameters, showed similar efficacy with PESI in determining the 30-day mortality compared to the prognostic score of the European Society of Cardiology (ESC) (9). In particular, sPESI recommends a decision based on only the pulse rate, systolic tension, and arterial $O^2$ saturation (Table 3). PE usually has only one abnormal vital finding like tachycardia. Abnormal vital signs were not experienced very often. The examination findings suggest PE, such as dyspnea. Kline et al. stated in his study that normal vital signs do not change mortality (10). Therefore, it becomes more difficult to predict the severity of the disease. In our study, we searched for a parameter, which would not be affected by the normalization of vital signs and indicate the severity of the disease.

**Table 3. Original and Simplified Pulmonary Embolism Severity Index (PESI/sPESI)**

| Variables | PESI | sPESI |
|---|---|---|
| Age | Age / year | 1 (Age>80) |
| Male Gender | +10 | |
| Cancer History | +30 | 1 |
| History of Heart Failure | +10 | 1* |
| History of Chronic Lung Disease | +10 | |
| Pulse ≥110 / minute | +20 | 1 |
| Systolic Blood Pressure <100 mmhg | +30 | 1 |
| Respiration Rate ≥30 / min | +20 | |
| Body Temperature <36 ° C | +20 | |
| Mental State Change | +60 | |
| Saturation of Arterial 02 <90% | +20 | 1 |

***Choronic Cardiopulmonary disease;** Combined variable of history of heart failure and chronic lung disease

| PESI | | sPESI |
|---|---|---|
| **Low Risk**<br>Class I: ≤65<br>Class II: 66-85 | **High Risk**<br>Class III: 86-105<br>Class IV: 106-125<br>Class V: >125 | **Low Risk:** 0<br>**High Risk:** ≥1 |

When we examined the results of our study, no significant difference was observed in the mortality rates according to sex. In their study, Horlander et al. found that the mortality rate of males is 20-30% higher than females (11). In the study conducted by Wells et al., it was stated that there was no difference in mortality rates between sexes (12). The age distribution of both sexes was close in our study. Kline et al. reported that the mortality rates of patients over 60 years of age are high (13). In our study, the age limit was 73 years. The PESI score showed an increase in the risk rate in terms of age / year. sPESI shows that being over 80 years of age poses a risk. Our age score is a value close to sPESI

Goldhaber et al. showed comorbid diseases as one of the primary causes of early mortality (14). However, the history of PESI and sPESI, cancer, heart failure and chronic lung diseases increase the likelihood of mortality in patients within 30 days (14). In our study, the probability of death within 30 days in patients with congestive heart failure takes the first place. It is followed by hypertension and malignancy.

In our study, we examined the parameters that were obtained, calculated and correlated easily with the severity of the disease. The vital signs consistent with both prognostic scales and sPESI were evaluated. The first of the vital signs is the pulse rate. Tachycardia is usually observed in PE. Tachycardia is one of the major determinants in other studies. In our study, the calculated limit value is >122 beats/minute. In patients with tachycardia, the difference between the patients who died within 30 days and those who did not die, was significant ($p<0.05$). When the clinical benefit is assessed, however, in the ROC analysis to calculate the predictive power of death within 30 days, AUC has a low power (69.7%). Tachycardia is a stimulant, but is relatively weak in determining mortality. This limit value was determined as >110 beats/minute in the study of Kilic and Sam et al. (15). In the study of Liu and Singh et al, this value was >120 beats/minute (16, 5). Similar results were obtained in the studies that were similar to our study.

In the study of McNab et al., Systolic Blood Pressure (SBP) was accepted as <90mmHg. It is estimated that mortality is higher in cases where SBP is below this value (17). In our study, the cutoff value of systolic blood pressure was <119 mmHg. The interaction between the systolic blood pressure and the presence of death was found to be statistically significant ($p<0.05$). The predictive power of 30-day mortality was 79.6%, which indicates a high correlation for mortality. However, when we consider the current limit value, we see that it is within the normal vital limit.

Diastolic Blood Pressure (DBP) is not involved in many prognostic scales. There are few studies examining this vital sign. Liu et al. showed in their study that mortality increases with values that are lower than 60 mmHg (16). In our study, the cutoff value for this vital sign was calculated as <79.5 mmHg. DBP, which is close to normal limits, is noteworthy. The AUC calculated for DBP was 74.6%.

Mean Arterial Pressure (MAP) is an indicator of perfusion. The normal values are 70-100 mmHg. It is recommended to evaluate MAP, especially when tissue perfusion is inadequate. The mortality rate is higher in 65 mmHg (18). In our study, the cutoff value for MAP was <77.15; and the predictive power of mortality was 78.7%. Although our value was in the physiological range, it predicted mortality.

The Shock Index and Modified Shock Index (MSI) show stroke volume and systemic vascular resistance. Both parameters indicate poor perfusion, low systemic vascular resistance, and hypodynamic circulation. It is emphasized that they are good markers for the prediction of mortality (5). In our study, the cutoff value of the Shock Index was calculated as >0.735. When ROC analysis is considered, the clinical benefit is higher than all other parameters, with a sensitivity of 97%, and the calculated AUC is 79.7%. Thus, it becomes a prominent parameter for indicating the shock status the best, being well correlated with the severity of shock, and is the most sensitive indicator in case of shock.

Considering the cutoff value for MSI was 1.085, the predictive power of the 30-day mortality was calculated as 77.5%, and its sensitivity was very strong (90.9%). There was no definite cutoff value for the modified shock index. This value is calculated according to the mortality rates of other studies.

For prognostic scales to be significant, the parameters to be examined at the time of admission should be beyond the physiological limits. However, the previously performed studies, and our study, show that the vital signs in these scales did not change the mortality in normal values. In our study, the tachycardia response was significant, but it would be misleading for the values that are close to normal physiological values. Normal values for systolic and diastolic blood pressure were predicted for mortality. The mean arterial pressure was also above the value that is the accepted as threshold (19). However, mortality did not change and the Shock Index and Modified Shock Index, in particular, provided a more precise prediction for mortality despite the vital values being at the physiological limits. Shock Index is a prominent parameter with high sensitivity value. It is more reliable than systolic and diastolic blood pressure, which is accepted as reliable, or the mean arterial pressure calculated by these parameters. The correlation with the severity of the disease is reliable. It can be easily calculated in the patient's triage and follow-up (20). In our study, the limit value was calculated as 0.735. The predictive power of death was 79.7%. Otero et al. obtained results close to ours in their study.

Kline et al. showed in their study that vital values were normalized and mortality did not change significantly (10). Birkhahn et al. supported this result in their study (21). In the study performed by Kline et al., no statistically significant difference was observed between the mean vital values of patients with and without PTE (13). Our study also has results, which are consistent with these studies. Furthermore, recent studies emphasize the use of Shock Index to predict mortality and shock in both adult and pediatric traumas (22, 23). Masahiro et al. stated in their study that it is a sensitive parameter for sepsis and septic shock (24). In addition, it is reported in the study of Davis et al. that the Shock Index is an important indicator of the shock observed prior to cardiopulmonary resuscitation (25). In our study, we believe that it is a sensitive parameter, and is well-correlated with clinical parameters to determine the severity of pulmonary embolism. We think that it will evaluate the clinical parameters in a more sensitive way in patients with vital signs, especially normal or near-normal patients.

According to the results of our study, we believe that when the shock index is added to vital signs in the triage evaluation, it will better predict the prognosis of patients. In addition, we believe that patients will contribute to the correct planning of treatment.

## CONCLUSION

In recent years, the Shock Index has become prominent as an important indicator of mortality. The important characteristics are that it is easy to be calculated, it can be used in the patient's triage, and it is not affected by normalized vital values.

The results obtained in our study are compatible and supportive with PESI and sPESI.

### Limitations of Study

We believe that performing the study in a larger number of patient groups, and in a multi-centered way, will strengthen our results.

## RECOMMENDATIONS

The shock index and modified shock index with vital signs of patients should be calculated. In particular, the data to be obtained in the shock index should be analyzed well, keeping in mind that vital signs can be misleading.

*Competing interests: The authors declare that they have no competing interest.*

*Financial Disclosure: There are no financial supports*

*Ethical approval: Approval from the ethics committee of the university*

*Umut Payza: ORCID:0000-0002-5297-1066*
*Zeynep Karakaya: ORCID:0000-0003-0562-8297*
*Fatih Esad Topal: ORCID:0000-0002-9941-4224*
*Pinar Yeşim Akyol: ORCID:0000-0003-2477-1443*
*Rezan Karaali: ORCID:0000-0003-1831-2566*
*Ahmet Kayali: ORCID:0000-0003-2557-0600*
*Serkan Bilgin: ORCID:0000-0001-9345-8878*

## REFERENCES

1. Janata K, Holzer M, Domanovits H, Met al. Mortality Of Patients With Pulmonary Embolism. Wien Klin Wochenschr 2002;114:766-72
2. Pines JM, Mullins PM, Cooper JK, et al. National Trends in emergency department use, care patterns, and quality of care of older adults in the united states. J Am Geriatr Soc 2013;61:12-7.
3. Platts-Mills TF, Travers D, Biese K, et al. Accuracy of the Emergency Severity Index triage instrument for identifying elder emergency department patients receiving an immediate life-saving intervention. Acad Emerg Med 2010;17:238-43.
4. Liu YC, Liu JH, Fang ZA, et al. World J modified shock index and mortality rate of emergency patients. Emerg Med 2012;3:114-7.
5. Singh A, Ali S, Agarwal A, et al. Correlation of shock index and modified shock index with the outcome of adult trauma patients: a prospective study of 9860 patients. N Am J Med Sci 2014;6:450-2.
6. Konstantinides S, Goldhaber SZ. Pulmonary embolism: risk assessment and management. Eur Heart J 2012;33:3014-22.
7. Bertoletti L, Le Gal G, Aujesky D, et al. Prognostic value of the geneva prediction rule in patients with pulmonary embolism. J Intern Med 2011;269:433-40.
8. Jiménez D, Aujesky D, Moores L, et al. Simplification of the pulmonary embolism severity index for prognostication in patients with acute symptomatic pulmonary embolism. Arch Intern Med 2010;170:1383-9.
9. Righini M, Roy PM, Meyer G, Simplified pulmonary embolism severity index (PESI): validation of a clinical prognostic model for pulmonary embolism. J Thromb Haemost 2011;9:2115-7.
10. Jeffrey A. Kline, MD, Diane M. et al. Normalization of vital signs does not reduce the probability of acute pulmonary embolism in symptomatic emergency department patients. Academıc Emerg Med 2012;19:11-7.
11. Kenneth T. Horlander, David M. et al. Pulmonary embolism mortality in the United States, 1979-1998: an analysis using multiple-cause mortality data. Arch Intern Med 2003;163:1711-7.
12. Wells PS, Anderson DR, Rodger M, et al. Derivation of a simple clinical model to categorize patients probability of pulmonary embolism: increasing the models utility with the simplired D-Dimer. Thromb Haemost 2000;83:416–20.
13. Kline JA, Corredor DM, Hogg MM, et al. Normalization of vital signs does not reduce the probability of acute pulmonary embolism in symptomatic emergency department patients. Acad Emerg Med 2012;19:11-7.
14. Goldhaber SZ, Elliott CG. Acute pulmonary embolism: part i: epidemiology, pathophysiology, and diagnosis. Circulation. 2003;108:2726-9.
15. Kilic T, Ermis H, Gülbas G, et al. Prognostic Role of the simplified pulmonary embolism severity index and shock index in pulmonary embolism. Pol Arch Med Wewn 2014;124:678-87.
16. Liu YC, Liu JH, Fang ZAet al. Modified shock index and mortality rate of emergency patients. World J Emerg Med 2012;3:114-7.
17. Mcnab A, Burns B, Bhullar I, et al. An analysis of shock index as a correlate for outcomes in trauma by age group. Surgery 2013;154:384-7.
18. Smith JB, Pittet J-F, Pierce A. Hypotensive resuscitation. Curr Anesthesiol Rep 2014;4:209-215.
19. Green RS, Butler MB, Erdogan M. Increased mortality in trauma patients who develop post intubation hypotension. J Trauma Acute Care Surg 2017;83:569-74.
20. Day DL, Anzelon KM, Conde FA. Association of prehospital shock index and trauma bay uncrossmatched red blood cell transfusion with multiple transfusion. J Trauma Nurs 2016;23:89-95.
21. Birkhahn RH, Gaeta TJ, Terry D, et al. Shock index in diagnosing early acute hypovolemia. Am J Emerg Med 2005;23:323-6.
22. Petrosoniak A, Hicks C. Resuscitation resequenced: a rational approach to patients with trauma in shock. Emerg Med Clin North Am 2018;36:41-60.
23. Strutt J, Flood A, Kharbanda AB. Shock index as a predictor of morbidity and mortality in pediatric trauma patients. Pediatr Emerg Care 2019;35:132–7.
24. 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;6:131–7.
25. Davis JS, Johns JA, Olvera DJ, et al. Vital sign patterns before shock related cardiopulmonary arrest. Resuscitation 2019;139:337-42.