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Association Between PPI and SI Measurement in Need of the Ventilation and 48 Hours Hospital Outcome

[1]H. Prathibha, [2]Sunil Kumar Mooknoor, [3]M. Gayatri and [4]J. Udaykumar khasage

[1]*Department of Anesthesia, Shri Sugurseshwar Ortho care Hospital workanalli Road Near Gunj Circle Yadgir 585202 Karnataka, India*
[2]*Department of Orthopeadics, Shri Sugurseshwar Ortho care Hospital workanalli Road Near Gunj Circle Yadgir 585202 Karnataka, India*
[3]*Department of Pathology YIMS YADGIR, India*
[4]*Department Of Emergency Medicine, BLDE Bijapur Karnataka, India*

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Corresponding Author
J. Udaykumar Khasage,
Department Of Emergency Medicine
BLDE Bijapur Karnataka, India
drudayjk@gmail.com

Author Designation
[1]Consulting Anaesthetist
[2]Consulting Orthopaedician
[3]Assistant Professor
[4]Associate Professor

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ABSTRACT
The admissions in the Emergency Department are increasing day by day in recent years requiring the strong and effective triage systems. The goals of these triage systems are to differentiate the patients as high to low-risk patients and immediate attention to the high-risk patients. Objective. Determine the association between PPI and SI measurement in need of the ventilation and 48 hours hospital outcome. This Prospective observational study, designed to investigate the prognostic performance of the PPI, SI, with Emergency Severity Index (ESI) in predicting hospital outcomes such as ventilator need and clinical improvement or deterioration of the patient. Conducted in the Emergency Medicine Department of BLDE, Shri B M Patil Medical College Hospital and Research Centre, Vijayapura, this study planned from August 2022 till April 2024. Among the 610 participants, Emergency Severity Index (ESI) score of less than 3, The PPI at admission shows a strong predictive accuracy with an AUC of 0.89 and a standard error of 0.01. At 12 hours, the PPI's AUC slightly decreased to 0.86 and at 24 hours, it modestly increased to 0.87, indicating consistent predictive performance over time. The SI at admission had an AUC of 0.82, with a standard error of 0.02, reflecting moderate predictive accuracy. The SI's predictive power improved significantly, with an AUC of 0.93 at 12 hours and 0.95 at 48 hours, demonstrating high predictive accuracy. Integrating PPI and SI with ESI can enhance triage effectiveness, ensuring better patient outcomes and more efficient emergency department operations.

INTRODUCTION

The Emergency Severity Index is a five-level triage tool that not only evaluates patients' vital signs but also considers their current resources and symptoms[1]. This comprehensive approach aims to provide a more nuanced assessment of patient severity. Despite its widespread use, the ESI has certain limitations. It involves subjective judgment, which can lead to variability in triage decisions[2]. Though, vital signs may remain within normal limits until physiologic compensatory mechanisms are overwhelmed, potentially leading to the misclassification of high- risk patients. So, there is a need of additional objective measurements to supplement the ESI, enhancing the accuracy of patient risk assessment and improving outcomes.

One such objective measurement is the PPI-Peripheral Perfusion Index, [a non-invasive numerical value reflecting real-time changes in peripheral blood flow]. Obtained from the photoelectric plethysmographic signal of pulse oximetry, PPI is recorded on the pulse-oximeter monitor and is fluctuating by the amount of blood flow at the monitoring site[3]. An increase in pulsatile flow, indicated by greater pulsation intensity, results in a higher PPI value. PPI serves as an at time recording of local blood flow changes, indicating tissue perfusion. Recent trails have demonstrated significant correlation between PPI with patient outcomes, suggesting its potential as a valuable prognostic tool in the ED setting[4].

Another important measure of hemodynamic stability is the SI i.e, Shock Index, defined as the components like heart rate divided by systolic blood pressure. SI being useful outcome variable with various clinical conditions and is a key indicator of hemodynamic instability[5-6]. An elevated SI often signals reduced contractility and left ventricular output and acute circulatory damage, with a persistent increase indicates worsening with increased morbidity and mortality[7]. Despite its clinical utility, SI has been studied in critically ill patients within intensive care settings, with limited research on its application in the ED[8].

The study seeks to determine if any of these indicators play a significant role in predicting clinical results compared to the others. Understanding the relationships between these indices and hospital outcomes could provide valuable insights for enhancing triage accuracy and improving patient care in the ED.

MATERIALS AND METHODS

This Prospective observational study, designed to investigate the prognostic performance of the PPI, SI, with Emergency Severity Index (ESI) in predicting hospital outcomes such as ventilator need and clinical improvement or deterioration of the patient. Conducted in the Emergency Medicine Department of BLDE, Shri B M Patil Medical College Hospital and Research Centre, Vijayapura, this study planned from August 2022 till April 2024. The hospital is a tertiary care-based hospital characterized by high volume in emergency cases, making it an ideal environment for studying the effectiveness and applicability of various triage indices in a real-world clinical context. The hospital's infrastructure and resources provided a robust framework for accurate and systematic data collection and patient assessment.

Inclusion Criteria: The present study included all patients aged 18 years old age and older who presented to the E M Department during the study period. By including all adult patients, the study aimed to capture a representative sample of the ED population.

Exclusion Criteria: Exclusion criteria were established to eliminate potential confounding factors that could bias the study's results. Specifically, patients were excluded if they were pronounced dead on arrival, transferred to another hospital immediately after initial assessment, had consumed alcohol or sedative narcotics prior to measurement, had unobtainable PPI measurements, or were moribund with terminal malignancy. These criteria ensured that the sample consisted of patients whose triage assessments and subsequent outcomes could be reliably compared, thereby enhancing the validity of the study findings.

Sample Size: Sample size for current study was calculated using [G*Power ver. 3.1.9.4 software]. Based on the assumption that the proportion of 30-day mortality is 7.9%, the software calculated that a minimum size with 136 patients, required to achieve the power of 99% for detecting a difference in proportion with a 5% level of significance. However, to enhance the robustness and reliability of the findings, the study aimed to enroll a total of 600 patients. This larger sample size was chosen to ensure that the study would have sufficient power to detect significant associations and to allow for more comprehensive and reliable analysis of the prognostic indicator of PPI, SI, with ESI in predicting outcomes.

Study Variables: Primary variables in this study were the Peripheral Perfusion Index-PPI, Shock Index-SI and Emergency Severity Index-ESI. These indices were selected for their potential to provide critical insights into patient status and prognosis. Additional variables measured included:

Shock Index (SI): Calculated by the ratio of heart rate divided by systolic blood pressure, It is used for an indicator of hemodynamic stability.

All parameters were recorded after the patient had rested for five minutes upon arrival at the Emergency Medicine Department to ensure stable and accurate measurements.

Data Collection Procedure: Upon patient arrival at the Emergency Medicine Department, initial assessments were conducted by trained emergency medical staff. This initial assessment included recording like heart rate, systolic and diastolic blood pressures and calculating SI. The PPI was measured using a pulse oximeter equipped with photoelectric plethysmography capabilities, ensuring a non-invasive and continuous assessment of peripheral perfusion. All measurements were taken after the patient had rested for five minutes to ensure accuracy and consistency. The ESI was assigned based on a detailed assessment of the patient's vital signs, presenting symptoms and overall clinical picture by trained personnel, ensuring uniformity and reliability in triage categorization.

Data collection was systematically performed, with each patient's measurements and ESI score recorded in their medical record. Data entry into a Microsoft Excel sheet was conducted daily by dedicated research staff to ensure accuracy and completeness. The data were then imported into SPSS (Version 20) and JNP-SAS Software for detailed statistical analysis. Efforts to minimize bias included standardized training for all personnel involved in data collection and measurement, adherence to strict inclusion and exclusion criteria and the use of objective measurement tools. Regular audits of data entry and measurement procedures were conducted to maintain data integrity and reliability.

Quantitative Variables: The primary quantitative variables in this study included the PPI, SI along with Emergency Severity Index (ESI). These indices were evaluated to determine their prognostic value in predicting hospital outcomes such as admission rates and mortality. Additional quantitative variables measured included:

Heart Rate (HR): Provides insights into the patient's cardiovascular function and stress response. Systolic Blood Pressure (SBP): Reflects the arterial pressure during the contraction of the heart muscles.

Diastolic Blood Pressure (DBP): Reflects the arterial pressure when the heart is at rest between beats.

Shock Index (SI): Calculated as ratio of heart rate divided by systolic blood pressure, serving as a quick indicator of circulatory health.

These variables were essential for a comprehensive assessment of the patient's clinical condition and for evaluating effectiveness in the triage indices.

Statistical Methods

Statistical analyses: Done using SPSS (Version 20). Descriptive statistics were employed to summarize the data, presenting means, medians, standard deviations (SD), counts and percentages to provide a clear overview of the patient demographics and clinical characteristics. For comparing groups, 'an independent sample t-test' was used for normally distributed continuous variables, ensuring accurate comparison of means between two groups. The Mann-Whitney U test was selected for non-normally distributed variables to compare medians. Categorical variables were calculated using the Chi-square test or Fisher's exact test to determine associations between different categorical outcomes and groups. For comparisons involving more than two groups, ANOVA test was utilized for normal variables and the Kruskal-Wallis H test for non-normally variables, ensuring appropriate analysis based on data distribution.

The correlation between PPI, SI, and ESI was assessed using Pearson or Spearman correlation coefficients, depending on the normality of the data distribution. Logistic regression analysis was conducted to evaluate the association of PPI and SI measurements with hospital admission and mortality outcomes, providing insights into the predictive value of these indices. The prognostic value of PPI, SI and ESI in predicting adverse outcomes was further assessed using receiver operating characteristic (ROC) curve analysis and the area under the curve (AUC).

A p-value of less than 0.05 was considered statistically significant, ensuring rigorous evaluation of the results. All statistical tests were performed two-tailed to ensure comprehensive analysis and robust conclusions.

RESULTS AND DISCUSSIONS

The characteristics of the study population reveal that a majority of participants were aged between 31-45 years (26.7%), followed closely by those over 60 years (29.2%). Subjects aged 15-30 years consist of 24.8% of the sample, while those aged 46 to 60 years made up 19.3%. In terms of gender distribution, males represented a significant majority at 66.9%, with females accounting for 33.1%. The study population was predominantly Hindu (92.5%), with Muslims constituting 6.7% of the participants.

Table1: Basic Characteristics of Study Participants (n=610)

Variables	Number	Percentage
Age(in years)		
15-30	151	24.8
31-45	163	26.7
46-60	118	19.3
>60	178	29.2
Sex		
Female	202	33.1
Male	408	66.9
Religion		
Hindu	564	92.5
Muslim	41	6.7
Missing	5	0.8

This demographic distribution provides a comprehensive overview of the population involved in the study, highlighting a diverse age range and a significant male predominance.

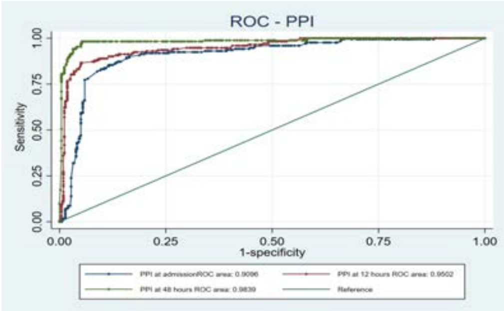

Fig.1: Indicates ROC PPI with sensitivity on X axis and (1-specificity) on Y axis.

Table2: ROC Analysis Summary for PPI (Outcome: Clinical deterioration)

Outcome	Area	Std. Err.	95% Confidence Interval
PPI at admission	0.91	0.01	0.88- 0.94
PPIat12hours	0.95	0.01	0.93- 0.97
PPIat24hours	0.98	0.01	0.97- 1.00

The PPI at admission demonstrated a high area under the curve (AUC) of 0.91 with a standard error of 0.01, indicating good predictive accuracy. At 12 hours, the PPI's AUC further increased to 0.95, reflecting enhanced predictive capability, and reached an AUC of 0.98 at 24 hours, signifying excellent prediction with a narrow confidence interval of 0.97-1.00.

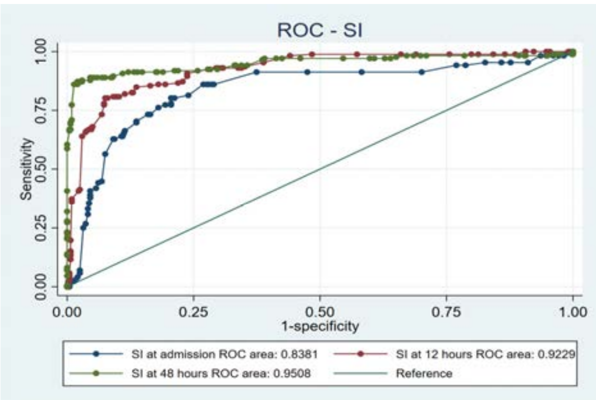

Fig.2: Indicates ROC-SI with sensitivity on X axis and (1-specificity) on Y axis.

Table3: ROC Analysis Summary for S I(Outcome: Clinical deterioration)

Outcome	Area	Std. Err.	95% Confidence Interval
Si at admission	0.84	0.02	0.80- 0.88
SIat12hours	0.92	0.01	0.90- 0.95
SIat48hours	0.95	0.01	0.93- 0.98

The SI at admission had a lower AUC of 0.84, with a standard error of 0.02, suggesting moderate accuracy. The predictive power of the SI improved over time, with an AUC of 0.92 at 12 hours and 0.95 at 48 hours, both showing strong predictive performance.

These results highlight the increasing accuracy of both PPI and SI over time in predicting clinical deterioration. The PPI at admission shows a strong predictive

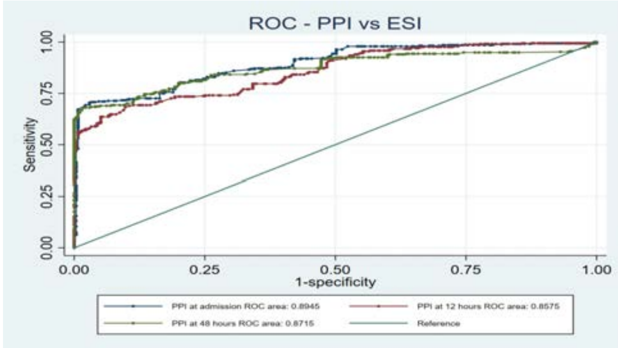

Fig.3: ROC- PPI vs ESI (ESI<3) On X axis sensitivity with Y axis (1-specificity)

Table4: ROC Analysis Summary for PPI (Outcome: ESI Score<3)

ESI category <3	Area	Std. Err.	95% Confidence Interval
PPI at admission	0.89	0.01	0.87- 0.92
PPIat12hours	0.86	0.01	0.83- 0.89
PPIat24hours	0.87	0.01	0.84- 0.90

accuracy with an AUC of 0.89 and a standard error of 0.01. At 12 hours, the PPI's AUC slightly decreased to 0.86, and at 24 hours, it modestly increased to 0.87, indicating consistent predictive performance over time

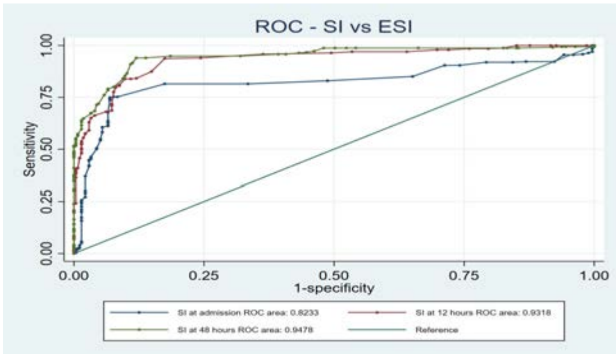

Fig.4: ROC SI vs ESI (ESI<3), [X axis sensitivity with Y axis (1-specificity)]

Table5: ROC Analysis Summary for SI (Outcome: ESI score<3)

ESI category <3	Area	Std. Err.	95% Confidence Intervals
SI at admission	0.82	0.02	0.79-0.86
SIat12hours	0.93	0.01	0.91-0.95
SIat48hours	0.95	0.01	0.93-0.97

The SI at admission had an AUC of 0.82, with a standard error of 0.02, reflecting moderate predictive accuracy. The SI's predictive power improved significantly, with an AUC of 0.93 at 12 hours and 0.95 at 48 hours, demonstrating high predictive accuracy.

These findings illustrate that both PPI and SI are reliable indicators for predicting an ESI score of less than 3, with SI showing increasing accuracy over time. Younger participants (15-30 years) demonstrated better ESI outcomes, with a significant majority achieving good ESI scores. In contrast, older age groups (46-60 yrs. and over 60 yrs.) predominantly had poor ESI outcomes, reflecting an age-related disparity[9]. Gender differences were also notable, with males exhibiting a higher proportion of poor ESI outcomes compared to females, suggesting a potential gender influence on emergency care outcomes. Additionally, Muslims had a higher prevalence of poor ESI outcomes compared to Hindus, indicating significant religious disparities. Patients requiring ICU admission and mechanical ventilation had markedly poor ESI outcomes, highlighting the severity of their conditions. Continuous monitoring of PPI and SI scores showed significant correlations with ESI outcomes. Lower PPI and higher SI scores at admission, 12 hours and 48 hours were associated with poor ESI outcomes.

The age-related disparities observed in this study align with previous research indicating that older patients are more vulnerable to poor outcomes because of higher comorbidity along with reduced physiological resilience. Similar findings on gender differences are consistent with existing literature that identifies both biological and behavioral factors contributing to poorer emergency outcomes in males. Biological differences in immune response and cardiovascular function, coupled with behavioral tendencies such as delayed healthcare seeking, are potential explanations. The higher prevalence of poor outcomes among Muslims may reflect underlying sociocultural and healthcare access disparities, as supported by previous studies highlighting the impact of socioeconomic status, cultural stigmas, and linguistic barriers on healthcare access.

The association of ICU admission and mechanical ventilation with poor outcomes is well- documented in the literature. Patients in need of these interventions typically present with severe, life-threatening conditions, which naturally correlate with higher morbidity and mortality. The strong predictive accuracy of PPI and SI scores for clinical deterioration and poor ESI outcomes supports previous findings on the importance of continuous physiological monitoring in emergency care. Studies have shown that early detection of physiological derangements through indices like PPI and SI can significantly improve patient outcomes.

The significant age-related disparities in ESI outcomes can be attributed to several physiological and clinical factors. Older patients generally present with multiple comorbidities, which can complicate their clinical presentation and lead to poorer outcomes. Conditions such as systemic hypertension, thyroid disorders, cardiovascular diseases, diabetes and chronic obstructive pulmonary disease are more prevalent in older populations, increasing their vulnerability to severe complications and mortality. These comorbid conditions can exacerbate the primary illness, making management more challenging and increasing the likelihood of poor outcomes. Furthermore, aging is associated with a decline in physiological reserves and immune function. The diminished capacity for cellular repair, reduced organ function and impaired immune response in older adults make them less resilient to acute stressors, such as infections or trauma.

This physiological decline contributes to their higher susceptibility to severe complications and slower recovery rates, leading to poorer ESI outcomes compared to younger patients.

The observed gender differences in ESI outcomes, with males exhibiting a higher proportion of poor outcomes, can be explained through a combination of biological and behavioral factors. Biologically, males and females have different immune responses and cardiovascular functions. Research has shown that males may have a higher baseline inflammatory response, which can lead to more severe outcomes in the presence of acute infections or injuries. Additionally, males are more prone to cardiovascular conditions, which can complicate their clinical presentations and lead to poorer outcomes in emergency settings. Behaviorally, gender differences in healthcare-seeking behavior also play a crucial role. Studies have indicated that males are less likely to seek timely medical care compared to females, often presenting to the ED at a more advanced stage of illness. This delay in seeking care can result in more severe clinical presentations and subsequently poorer outcomes. Sociocultural factors, such as societal expectations of masculinity and reluctance to report symptoms, further contribute to this delay, exacerbating the gender disparity in ESI outcomes.

CONCLUSION

Age, gender and religious affiliation were also identified as important factors influencing patient outcomes. The study suggests that incorporating these objective indices can optimize resource allocation and improve patient care. Future research should validate these results across multiple centers and explore additional variables. In conclusion, integrating PPI and SI with ESI can enhance triage effectiveness, ensuring better patient outcomes and more efficient emergency department operations.

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