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Research Article

The Potential Use of the Respiratory Rate in Predicting Outcomes in Trauma Patients in a Low-Middle Income Country

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Abstract

Background: Trauma is an insult which triggers a cascade of deleterious pathophysiological responses. The respiratory rate has been suggested as the most accurate physiologic measurement of this process. This study proposes the respiratory rate to be better than gestalt clinical assessment in the triage of trauma patients and considers its use in a low-middle income country.

Methods: Data was extracted from the patient notes at the Lagos State Accident and Emergency Centre (LASAEC). Exclusions included patients less than 18 years old. The area under receiver operator characteristic curve (AUROC) was determined for the need for higher level facility care (HLFC) for all variables and age.

Results: Respiratory rate (RR) had an area under the curve 0.5288 with CI 0.4656 - 0.5336, in predicting the need for higher level facility. This was similar to the AUROC for other vital signs, systolic blood pressure (sbp) 005396, diastolic blood pressure (DBP) 0.5389, oxygen saturation (SPO_2) 0.4859.

Thresholds were set for the prevalence of the respiratory rate at 72%, 70% and 74.1% to produce a sensitivity of 61.7%, 59.4% and 64%. The likelihood of requiring HLFC was 1 at a prevalence of 74%.

In comparison low blood pressure (BP) had a sensitivity of 65.6%, 46.8% and 81.4% with prevalence of 1.6%, 1.1%and 2.2%. The likelihood of requiring HLFC was 1 with a prevalence of 2.2%.

In the multivariable analysis, the logistic regression also showed correlation between low systolic blood pressure (SBP) and the need for HLFC with an OR 1.0, AUROC 0.6378. Thus, being statistically significant but not of high significance.

Conclusion: As the statistical evidence is unavailable, RR is unable to serve as an independent tool to predict the need for HLFC in these patients. This is in agreement with multiple studies performed in High Income Countries. However, low SBP appears to offer some prediction on the outcome of these patients, although it is also unable to do entirely independently. The use of new markers like the Shock Index (SI) which incorporate the SBP might hold significant benefit in predicting patients who will require HLFC, especially in LMIC.

Keywords: *Respiratory Rate; Trauma Patients; Low-Middle Income Country*

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Abbreviations

LASAEC: Lagos State Accident and Emergency Centre; AUROC: Area Under Receiver Operator Curve; RR: Respiratory Rate; SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; SpO_2: Oxygen Saturation; LMIC: Low-Middle-Income Country; HIV: Human Immunodeficiency Virus; T.B: Tuberculosis; HIC: High Income Country; SI: Shock Index; SD: Standard Deviation; IQR: Interquartile Range

Introduction

Trauma remains a major cause of disability and death worldwide [1]. In managing trauma, the early identification and management of patients at risk of deterioration and significant morbidity and mortality is critical in improving survival. The assignment of degrees of urgency to prioritize the order of treatment of trauma (Triage) has been documented as a useful tool in achieving this. The role of triage is further highlighted by evidence that shows how under-triaging of patients influences mortality and morbidity due to delays in commencing appropriate treatment [2,3]. It is reported that there are three obvious death peaks in trauma patients; they occur within 1 hour (about 50%), 3 hours (about 30%), and 1 - 4 weeks (about 15%) after injury [4].

The early prediction of mortality from trauma requires that doctors identify and manage these patients accordingly, as the activation of teams, resources, and communication is time-critical [4].

There is clear evidence that inaccurate assessment of patients in early trauma management leads to underestimation of the severity of the injury, subsequently impacting appropriate management.

In evaluating patients, the vital signs of: BP, heart rate (HR), and RR have been used to aid patient management from the decision on arrival by the trauma team to further management, although the value of these signs has been disputed [5].

There is also literature that suggests that the respiratory rate may be an important predictor of cardiac arrest in hospitals [6]. The respiratory rate has been shown to be superior to other vital signs in discriminating between stable patients and patients at risk of mortality.

Mortality from trauma is high in low- and middle-income countries (LMIC), with 90% of the deaths worldwide occurring in these countries (Figure 1). The noticeable improvement in mortality in high-income countries in the last few decades is due to the recognition accorded to functional trauma health systems. There is an acknowledgment that the application of a trauma health system could result in a reduction of mortality for up to 30% in LMIC [7].

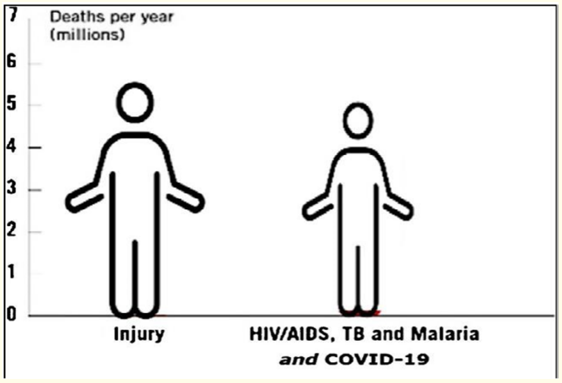
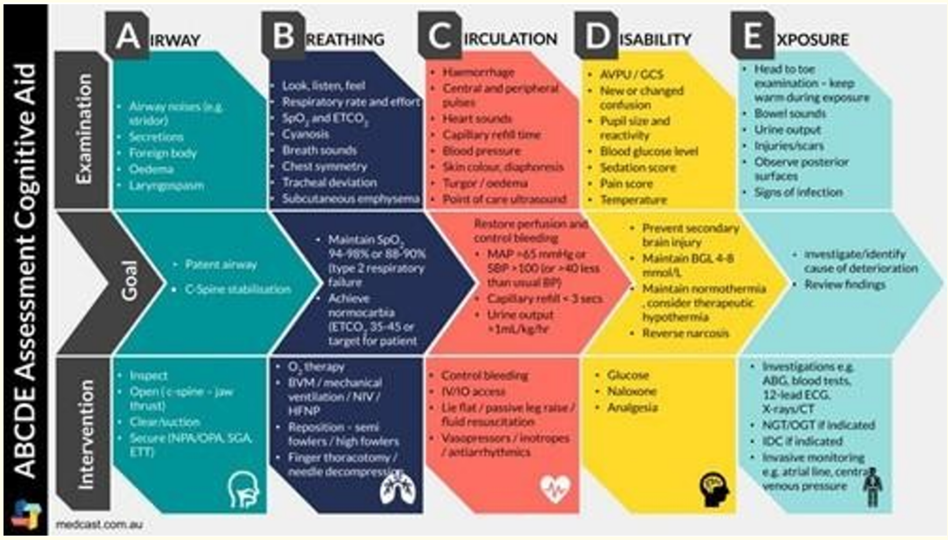


Figure 1: *Adapted from Rossiter ND. "Trauma-the forgotten pandemic?". Int Orthop. 2022 J [18].*

In addition, the key to improving emergency care is the early recognition of severe injury/illness and subsequent timely intervention.

In light of this, the clinical assessment of all patients proceeds in the sequence of A to E (Figure 2), with the respiratory rate a key part of the B: breathing assessment. An increased respiratory rate at the presentation of an unwell patient is associated with a higher mortality rate, as a correlation with the compromise or failure of respiratory function.



ABCDE Assessment Cognitive Aid

	AIRWAY	BREATHING	CIRCULATION	DISABILITY	EXPOSURE
Examination	Airway noises (e.g. stridor) Secretions Foreign body Oedema Laryngospasm	Look, listen, feel Respiratory rate and effort SpO_2 and $ETCO_2$ Cyanosis Breath sounds Chest symmetry Tracheal deviation Subcutaneous emphysema	Haemorrhage Central and peripheral pulses Heart sounds Capillary refill time Blood pressure Skin colour, diaphoresis Turgor / oedema Point of care ultrasound	AVPU / GCS New or changed confusion Pupil size and reactivity Blood glucose level Sedation score Pain score Temperature	Head to toe examination - keep warm during exposure Bowel sounds Urine output Injuries/scars Observe posterior surfaces Signs of infection
Goal	Patent airway C-Spine stabilisation	Maintain SpO_2 94-98% or 88-90% (type 2 respiratory failure Achieve normocarbia ($ETCO_2$ 35-45 or target for patient	Restore perfusion and control bleeding MAP >65 mmHg or SBP >100 (or >40 less than usual BP) Capillary refill < 3 secs Urine output >1mL/kg/hr	Prevent secondary brain injury Maintain BGL 4-8 mmol/L Maintain normothermia , consider therapeutic hypothermia Reverse narcosis	investigate/identify cause of deterioration Review findings
Intervention	Inspect Open (c-spine - jaw thrust) Clear/suction Secure (NPA/OPA, SGA, ETT)	O_2 therapy BVM / mechanical ventilation / NIV / HFNP Reposition - semi fowlers / high fowlers Finger thoracotomy / needle decompression	Control bleeding IV/IO access Lie flat / passive leg raise / fluid resuscitation Vasopressors / inotropes / antiarrhythmics	Glucose Naloxone Analgesia	Investigations e.g. ABG, blood tests, 12-lead ECG, X-rays/CT NGT/OGT if indicated IDC if indicated Invasive monitoring e.g. atrial line, central venous pressure

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Figure 2: *Adapted from Peran, D., Kodet, J., Pekara, J. et al. ABCDE cognitive aid tool in patient assessment - development and validation in a multicenter pilot simulation study [19].*

A possible complication of a traumatic injury is haemorrhagic shock, which is a leading cause of mortality in traumatic injury with evidence showing that a greater than 30% blood volume loss, leads to reduced oxygen delivery and consequently intracellular acidaemia. Acidaemia has been shown to result in organ dysfunction and increased pulmonary resistance [9,10].

There is evidence that in trauma prolonged periods of metabolic acidosis correlates with increased mortality rates. Ideally metabolic acidosis should result in a compensatory respiratory alkalosis which can take 12 - 24 hours to fully manifest, however this hyper- ventilatory response is hastened and exaggerated following a traumatic injury [11].

It is important to note that the pulmonary system is also an independent cardiovascular stressor which is known to fail early in multi-organ-failure.

This study was based on the hypothesis that following a traumatic insult the respiratory rate is directly indicative of an underlying injury and would be a useful tool to triage patients following a traumatic insult, especially in communities with limited expertise and equipment such as are found LMIC.

Aims/Objectives

This paper intends to answer the question: Is there a relationship between the measured respiratory rate and severity of physiological decompensation in patients following a traumatic insult?

The paper aims to:

- Determine if the initial RR can aid in stratifying trauma patients.
- If the RR proves to be useful, it further aims to equip clinicians with information to avoid under-triaging of patients, using a single vital sign; the measurement of the respiratory rate, which requires no equipment and is a basic clinical skill [3].
- Suggest that the measured respiratory rate on its own will aid clinicians in reducing delay in accessing the required level of care with a higher sensitivity than the clinical gestalt of an experienced clinician.
- Identify if other vital signs perform better than the Respiratory rate in stratifying trauma patients.

Methods

A retrospective observational study was performed using data obtained from the Lagos State Accident and Emergency Centre (LASAEC), Lagos, Nigeria.

Nigeria sits on a 923,786 km^2 landmass off the gulf of Guinea in West Africa and with over 200 million people, it is the most populous African nation and currently 7th on the global population list.

It is a lower-middle-income country with 55% of its population living in urban centres, while the remaining 45% live in rural areas with poor access to roads, inadequate telephone coverage and minimal resuscitation facilities [13].

Lagos state is located in the south west of Nigeria and is the economic and financial capital; it is densely populated with about 21 million inhabitants on a land mass of 385.9 sq miles resulting in a population density of 17,800/sq miles compared to a city like London which has a population density of 14,670/sq miles.

Emergency medicine is not a medical specialty with an established training programme in Nigeria and consequently neither is pre-hospital emergency medicine [12].

Pre-hospital care is provided in Lagos state by the Lagos State Ambulance Service (LASAMBUS), which was established in 2001 to provide pre-hospital care for trauma victims.

These ambulances are manned by healthcare workers trained in basic life support and placed at specific points on the highway [13].

The Lagos State Accident and Emergency Centre (LASAEC) is an emergency unit based at the Toll-Gate on the main highway in and out Lagos state. It is a 22-bed emergency facility, accepting patients from Lagos State Ambulance Service (LASMABUS), walk-ins, and private ambulances.

The data is from medical records collected as part of routine patient care, and as is standard practice, patient consent is not required for retrospective analysis of anonymised data.

The data was obtained from January to December 2019 at LASAEC, and was retrieved from hospital records with the assistance of the hospital management and approval of the Lagos State Health Service Commission.

The exclusion criteria was patients less than 18 years old.

The main goal was the prediction of the need for high-level facility care, while the secondary goal was to ascertain if other traditional vital signs would predict outcomes for higher-level facility care.

The power of the study was calculated using the final sample size following the exclusion of those with missing variables as it is a retrospective study.

As a superiority study, the absolute difference with type 1 error of 5%, sample size 2361, minimum detectable effect of 0.5% would be required to obtain a Power of 0.87.

Data analysis was performed using Stata (version 17MP, StataCorp, College Station, Texas).

Descriptive statistics for continuous data were executed after using quantile-normal plotting to assess normality.

Normal data were reported with Mean +/- Standard Deviation (SD), while non-normal data were reported with median and Interquartile range (IQR).

Univariable analysis was executed in order to identify co-variates for inclusion in multivariable modelling. To achieve univariable testing, the following steps were taken:

- Categorical variable had most analyses executed using Pearson X2 test. However, when any cell value fell below five, Fisher's exact test was used, except where computing power limitations precluded this.
- Ordinal or continuous variables were analysed using the Non-parametric Kruskal-Wallis testing.

Thus, the analysis of the RR as with the other traditional vital signs was with non-parametric Kruskal- Wallis testing initially to identify those which would be suitable for multivariable analysis.

In order to demonstrate non-normality Shapiro-Wilk testing was conducted, with variables excluded if they were missing more than 10% of observations: PR on discharge and RR on discharge. Variables also varied in Paediatrics, and the data of patients older than 17 years old were included.

To further predict the need for HLFC, the area under the curve was calculated for each of the vital signs: HR, SBP, DBP, RR, and SPO_2. For each of the vital signs, 95% CI for the AUROC included the null value of 50%.

Multivariable analysis was also performed to identify associations that might have been missed by the univariable assessments.

Multivariable logistic regression modelling was executed using a stepwise and purposeful selection process. All variables that were discarded were assessed for the presence of confounding factors. This was done by reintroducing them in the final model to assess for a greater than 10% change in the magnitude of the effect estimate of the main independent variable.

Variable	P value	OR (95% CI)
Month	(9 months only) p < .25	N/A
Day of the week	(3 days only) p < .25	N/A
Male sex	.032	1.02 - 1.52
Age	<.001	1.00 - 1.02
Blunt mechanism	.06	.22 - 1.04

Table 1: *Univariable prediction of HLF.*

Logistic regression analysis was clustered on each variable and it was recognized that clustering based on an individual hospital could result in overly broad Cis, thus a type II error. The decision was taken to reduce the chance of a type I error since unmeasured factors at the hospital level were likely to influence outcomes.

Once the model was reduced to only those co-variates with statistical significance, post- estimation analytics were executed.

Logistic regression model evaluation included assessment of both discrimination and calibration.

Discrimination was assessed by calculation of the AUROC area (c statistic). Calibration was assessed using Stata's implementation of the Cox plotting approach of probability deciles' predictions vs. outcomes: perfect predictions lie on the 45-degree line, and intercept at 0 is consistent with acceptable "calibration in the large" (i.e. lack of systemic over or under prediction).

Stata's predictive marginal probability suite, including the contrast command, was used to assess individual variables' significance as well as the significance of higher-order polynomials.

Results

The initial data available provided 2,626 samples, however those with more than 10% of their observations missing were excluded resulting in final sample size of 2,361 (Table 2).

	n	Percentage
Initial Sample	2,626	100
Missing Variable	265	9.7
Final Sample	2361	90.26

Table 2: *Variable sample size.*

77% of the sample was male, with a very low prevalence of penetrating injury 1%, and corresponding mortality of only 1% .62% of the sample ended up requiring a higher level of facility care.

Variable	Frequency	Percentage
Male	1,781	77.1
Female	529	22.9
Blunt Trauma	2072	98.25
Penetrating Trauma	37	1.7
Need HLF	1453	62.36
No Need for HLF	877	37.6
Survived	2289	98.16
Died	43	1.84

Table 3: *Distribution of variables.*

With a mean AUROC of 0.522(0.46 - 0.533) the RR with a performance similar to the other vital signs shows that on its own, would be an inadequate tool by which to triage patients for HLFC.

Variable	Cv Mean AUC	Boot Strap Corrected CI
RR	0.5288	0.4656 - 0.5336
SBP	0.5396	0.5035 - 0.5592
DBP	0.5389	0.5036 - 0.5591
SPO_2	0.4859	0.4276 - 0.4833

Table 4: *Vital signs predicting HLFC.*

A subsequent analysis of vital signs as categories to ascertain if this would improve diagnostic performance involved a selection of cut-offs a priori.

The cross-validated mean AUC was the following Abnormal RR -0.5101, Bootstrap Bias Corrected CI 0.4249-0.4758.

However once again, based on the AUROC analysis, none of the predefined categories of abnormal vital signs are likely to be useful predictors of the need for HLFC.

Variable	Cv Mean AUC	Boot Strap Bias CI
Abnormal HR	0.5108	0.4329 - 0.4822
Abnormal RR	0.5101	0.4249 - -0.4758
Low SBP	0.4940	0.3769 - 0.4328
Abnormal SpO_2	0.5.49	0.3927 - 0.4471

Table 5: *Vital sign categories predicting HLFC.*

Diagnostic classification tables were then generated for categorical predictors, HR, RR, SBP, and hypoxaemia in predicting HLF.

The sensitivity of the vital signs, RR 61% (59.4 - 64), further highlights that vital signs are not useful independently for the clinical triage of patients needing HLFC, as this sensitivity is quite low.

Variable	Sensitivity	Confidence Interval
Abnormal HR	61	57.6 - 64.3
Abnormal RR	61.7	59.4 - 64
Low SBP	65.6	46.8 - 81.4
Abnormal SpO_2	57.6	44.8 - 69.7

Table 6: *Sensitivity of vital signs predicting HLFC.*

Prevalence	73%	71%	74.3%
Sensitivity	61.7%	59.4%	64%
Specificity	35.9%	32.2%	39.8%
ROC area	.488	.466	.51
Likelihood ratio (+)	.963	.899	1.03
Likelihood ratio (-)	1.07	.945	1.2
Odds ratio	.904	.749	1.09
Positive predictive value	71.8%	69.4%	74.1%
Negative predictive value	26.2%	23.3%	29.3%

Table 7: *Abnormal RR prevalence thresholds.*

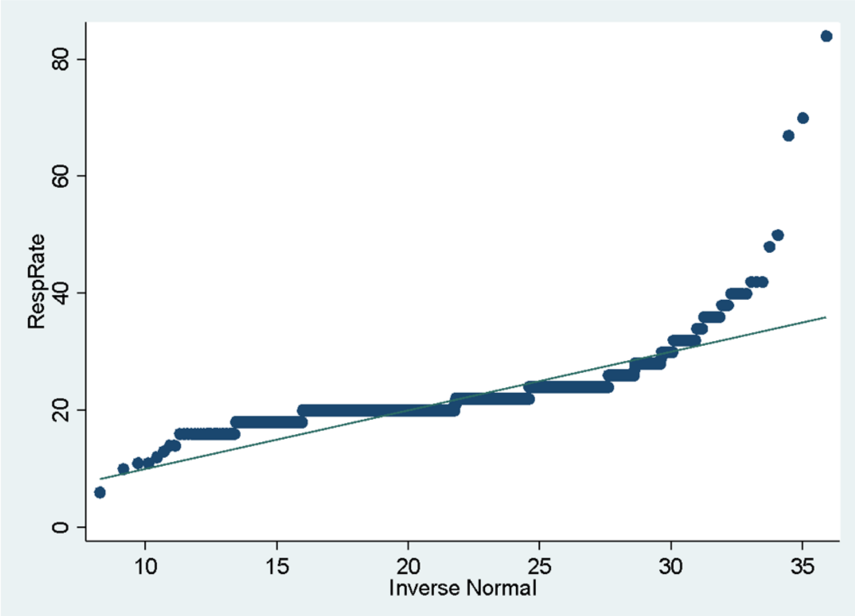

Figure 3: *Respiratory rate.*

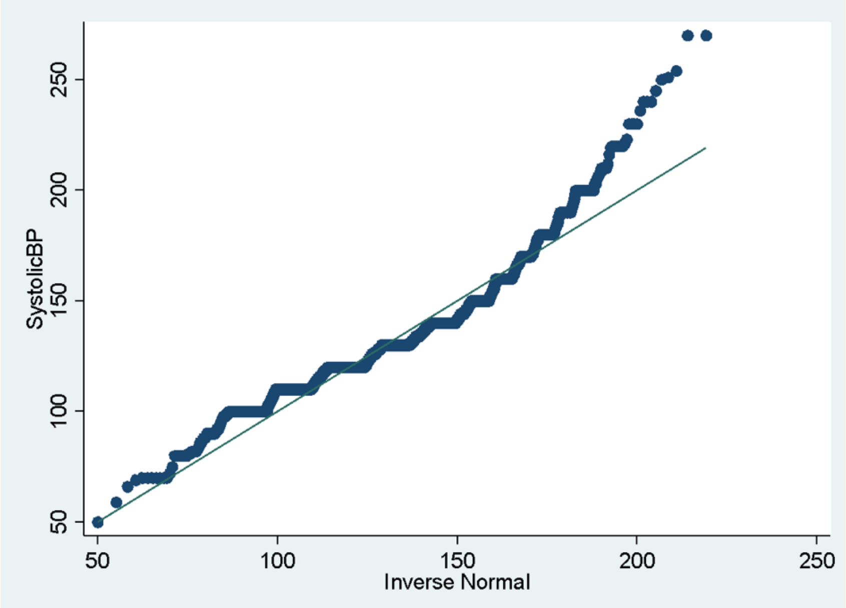

Figure 4: *Systolic BP.*

Prevalence	1.6%	1.1%	2.29%
Sensitivity	65.6%	46.8%	81.4%
Specificity	36.1%	33.9%	35.3%
ROC area	.509	.424	.593
Likelihood ratio (+)	1.03	.797	1.32
Likelihood ratio (-)	.952	.588	1.54
Odds ratio	1.08	.525	1.54
Positive predictive value	1.67%	1.4%	2.54%
Negative predictive value	98.4%	97.2%	99.2%

Table 8: *Low SBP prevalence thresholds.*

Multivariable results

This modelling was executed only on cases at least 18 years old.

The model identifies a lower need for HLF in the months of February and August and those patients with blunt trauma. It also identified a higher need for HLF with Low BP.

Variable	OR	Std.Err	z	P> I Z I	(95% CI)	
Feb	.269	.082	-4.26	0.00	.147	.492
Apr	2.07	.567	2.65	0.008	1.20	3.54
Jul	1.67	.445	1.94	0.053	.993	2.82
Aug	.533	.134	-2.48	0.013	.324	.875
Blunt Trauma	.252	.139	-2.49	0.013	.085	.744
SBP	1.00	.002	2.80	0.005	1.00	1.01

Table 9: *Logistic regression of variables.*

Number of observations = 1703 area under ROC curve = 0.6378.

Discussion

Emergency physicians and trauma surgeons place a high value on the use of traditional vital signs: SBP, HP, and RR, during the trauma team activation and resuscitation despite numerous articles questioning the utility thereof. Considering the relative ease with which these markers can be obtained, it is not difficult to see why they are used despite the lack of research evidence that they provide a statistical advantage in clinical decision making [5]. The assessment of conventional vital signs in the context of trauma is a fundamental clinical skill, and while the limitations of using vital signs in the assessment of the unwell patient in trauma exist, a seasoned clinician does not evaluate vital signs as individual variables but uses gestalt. This gestalt, however, does not translate well into research or practice protocols [13].

This study agrees with most of the existing data that states there would be no statistical benefit in using RR or other traditional vital signs in triaging patients. Of note, however, is a study that suggested the RR was a sensitive indicator of trauma deaths in patients in a rural medical facility with protracted evacuations to a higher level facility [14].

This study is able to add to the knowledge base on the vital signs of patients following trauma, and uniquely it presents data from a LMIC which is beneficial as it does not appear to differ much from data from HIC. This suggests that if similar interventions are introduced then similar outcomes can be expected.

There are other markers that combine the vital signs which have been shown to perform better than traditional vital signs, and even in this study, age and blood pressure appear to have some role in helping to predict patients who will require higher-level facilities.

One of these other markers is the Shock Index (SI), which has been mentioned as a sensitive marker and would provide the necessary data to aid in the early triage of patients. The shock index is a useful parameter that is used even in the pre-hospital stage and is useful in predicting the need for major transfusion, hospital resource use, and mortality. It has also been noted to be useful in older trauma patients [15].

There is evidence to confirm that the SI would not be influenced by the diastolic blood pressure, therefore the DBP does not appear as important as the SBP.

However, the main evidence points to the importance of a single episode of hypotension as being predictable of a poor outcome despite subsequent improvements in blood pressure.16 Noting all these, it has been mentioned that the shock index might have the greatest utility in the rural setting, where blood product resources are limited.

Considering this study was set up to look for a ‘vital sign’ which would ideally benefit a LMIC, the shock index appears like that ideal marker.

The study however firmly suggests that none of the vital signs individually have sufficient statistical backing to aid in the triage of patients. This again lends credence to the mantra of treating a patient and not the numbers.

There are, however, quite a few limitations. It is a retrospective study using data from the medical records with unvalidated data collection forms, based at a single center and thus subject to selection bias.

There is also a large percentage of the missing amount of data with the available data is mostly based on blunt trauma. This makes it difficult to extrapolate the evidence of penetrating trauma patients.

Conclusion

This study concludes that the RR is not superior to clinical gestalt in the triage of trauma patients.

This study is in agreement with previous data that states that the RR is not a useful tool in the prediction of outcomes in patients with trauma. It also suggests none of the traditional vital signs is superior in this regard.

However, there was evidence that SBP and age offer some insight into the possible outcomes.

Thus, the SI will in keeping with current studies, be a tool that might offer the benefit of helping to triage patients following a traumatic event. Evidence suggests it is useful in the pre-hospital and low-resource setting and would be ideal for a LMIC setting. To confirm this, a prospective multi-center study based in a LMIC would be ideal.

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