# How accurate are vital signs in predicting clinical outcomes in critically ill emergency department patients

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***Objectives*** **We aimed to evaluate the predictive value of pulse rate (PR), systolic blood pressure (SBP), diastolic blood pressure, respiratory rate (RR), oxygen saturation ($SaO_2$), and the Glasgow Coma Scale (GCS) for cardiac arrest and death in critically ill patients.**

***Methods*** **In total, 1025 patients had vital signs recorded at triage at our Emergency Department and were followed up for three clinical outcomes: cardiac arrest in 72 h, admission to ICU, and death within 30 days. Vital signs were used in univariate and multivariate analyses for outcomes. Age was added in multivariate analysis.**

***Results*** **PR, SBP, RR, $SaO_2$, and GCS were significantly associated with cardiac arrest within 72 h, whereas PR, SBP, RR, $SaO_2$, and GCS were associated with death within 30 days. Only PR and GCS were associated with ICU admission. In the multivariate analysis, age, PR (>100) [odds ratio (OR) 1.65; 95% confidence interval (CI) 1.00–2.71], SBP (>140; OR 0.41; 95% CI: 0.21–0.79), RR (>20; OR 2.90; 95% CI: 1.67–5.03), and GCS (<15; OR 5.71; 95% CI: 3.40–9.57) were significantly associated with death. Vital signs with age have low sensitivity (cardiac arrest 11.54%, death 22.73%, ICU 12.50%) and high specificity (cardiac arrest 99.28%, death 97.22%, ICU 93.80%). Age and GCS were found to be independent predictors of all three outcomes.**

***Conclusion*** **Not all vital signs are useful in the prediction of clinical outcomes. Vital signs had high specificity but very low sensitivity as predictors of clinical outcomes. Clinicians should always remember to treat patients and not numbers.** ***European Journal of Emergency Medicine*** **20:27–32 © 2013 Wolters Kluwer Health | Lippincott Williams & Wilkins.**

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**Keywords: blood pressure, cardiac arrest, critically ill, death, Glasgow Coma Scale, ICU, oxygen saturation, pulse rate, respiratory rate, vital signs**

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## Introduction

Monitoring of vital signs is a routine procedure in almost all healthcare systems and departments, especially those dealing with critically ill patients. Vital signs objectively indicate the immediate well-being of patients and have long been considered an imperative component of patient assessment and management. Vital signs may also influence decision-making of healthcare workers, for example, at triage in emergency departments (EDs) for critically ill patients [1]. So much importance has been placed in monitoring vital signs that wearable devices for continuous remote monitoring of vital signs have been developed in order to improve methods of vital sign monitoring [2]. Vital signs are undeniably crucial in the practice of medicine.

Vital signs are physical signs that indicate the physiological status of an individual, such as heart rate, breathing rate, temperature, and blood pressure. These signs may be observed, measured, and monitored to assess the level of physical functioning of an individual. However, any factor that is important in determining the well-being of patients can be considered as a vital sign; for example, pain score has recently been recognized widely as the fifth vital sign. The Glasgow Coma Scale (GCS) and oxygen saturation ($SaO_2$) have also been proposed as vital signs [3,4].

What are considered normal or abnormal vital signs? There have been many debates on this issue. However, no consensus has been achieved as of today [5–7]. Normal vital signs are subjective and vary with age, sex, weight, exercise tolerance, environment, medical conditions, and many other factors.

Although vital signs are highly regarded in the field of medicine, not many studies have been conducted to examine how useful vital signs are in predicting clinical outcomes of patients and which vital signs are the most useful and best at predicting outcomes. Clinical scoring systems that incorporate vital signs and other factors have been proposed to assist in risk assessment of patients and for ED triage [8,9].

We aimed to evaluate whether vital signs are, in practice, good predictors of clinical outcomes such as cardiac arrest and death for critically ill patients presenting at the ED.

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We also aimed to observe which vital signs would be the best at predicting clinical outcomes.

## Methods

We conducted a prospective observational cohort study on 1025 patients between November 2006 and December 2007 presenting at the ED of a tertiary hospital in Singapore. The Institutional Review Board at the Singapore General Hospital granted approval for this research project with a waiver of patient consent.

The Department of Emergency Medicine, Singapore General Hospital, sees between 300 and 500 emergency patients daily. All patients are initially triaged by a nurse, and those with airway, breathing, and circulation problems, or thought to be possibly unstable and needing close monitoring, are routinely put on vital signs monitoring.

We recorded the vital signs of these 1025 patients taken at triage in the ED on arrival. These patients were then followed up on three clinical outcomes: cardiac arrest in 72 h, admission to ICU, and death within 30 days. This data collection was part of an ongoing study of critically ill patients in the ED [10].

The 1025 patients were priority 1 (PACS 1 and 2) patients as determined by the Singapore Patient Acuity Category Scale (PACS) (Table 1). The Singapore PACS is a nationally accepted triage scale that is used by all public EDs in Singapore. Categorization of patients is according to mechanism of injury, physiological status (vital signs) at triage, anatomical site of injury, and chief complaints. These patients were deemed by the triage nurse to be at risk for adverse clinical outcomes.

Exclusion criteria were as follows: age less than 18 years, pregnancy, and those who presented at the ED with cardiac arrest. Only one set of initial vital signs taken at triage in the ED was used in this study and included pulse rate (PR), systolic blood pressure (SBP), diastolic blood pressure (DBP), respiratory rate (RR), $SaO_2$, and the GCS. We excluded PACS 3 and 4 patients as we wanted to focus on critically ill patients presenting at the ED. The event rate (cardiac arrest and death) would likely be very low in PACS 3 and 4 patients.

**Table 1 Singapore Patient Acuity Category Scale**

| | |
|---|---|
| PAC Scale 1 | These patients are either in a state of cardiovascular collapse or in imminent danger of collapse and would therefore be required to be attended to without delay. They would most likely require maximum allocation of staff and equipment resources for initial management. |
| PAC Scale 2 | These patients are ill, nonambulant, and in various forms of severe distress. They would appear to be in a stable state on initial cardiovascular examination and are not in danger of imminent collapse. The severity of their symptoms requires very early attention, failing which early deterioration of their medical status is likely. They would be trolley based. |
| PAC Scale 3 | These patients have acute symptoms but are ambulant and have mild-to-moderate symptoms and require acute treatment, which will result in resolution of symptoms over time. |
| PAC Scale 4 | These are nonemergency patients. They should not be presented at the emergency department and should be managed in a primary healthcare setting such as by general practitioners or in polyclinics. They may have an old injury or condition that has been present for a long time. They do not require immediate treatment. There is no immediate threat to their life or limb. |

PAC, Patient Acuity Category.

The above-mentioned vital signs were used as predictor variables and classified into 'normal' and 'abnormal' using standardized adult parameters [6,11]. The normal values for each vital sign were arbitrarily regarded as follows for data analysis: PR, 60–100 beats/min; SBP, 90–140 mmHg; DBP, 60–95 mmHg; RR, 12–20/min; $SaO_2$ 95% or more; and GCS, 15 (Table 2). Clinical outcomes such as death, hospital admission, ICU admission, and length of hospital stay were subsequently obtained from review of hospital charts.

Data entry was carried out using a spreadsheet application (Excel 2000, Microsoft Corp., Redmond, Washington, USA) and data analysis using SPSS (SPSS Inc., Chicago, Illinois, USA). Descriptive statistics (mean, SD, or median as appropriate) are primarily presented. Receiver operating characteristic analyses were carried out for each parameter for the outcomes of ICU admission, hospital admission, and death. Vital signs were used as predictor variables in univariate and multivariate analyses for the three clinical outcomes of interest. A multivariate analysis was also carried out using the vital signs. Age was added in the multivariate analysis of data to improve the predictive value of the model. Colinearity between the variables of vital signs was assessed by examining the SEs for inflation. Statistical significance was set at $P < 0.05$.

## Results

The mean age of the study population was 62 years, and there was an approximate 1 : 1 ratio of women and men in this study. The proportion of patients of different ethnicities in our study reflects the current ethnic distribution in Singapore well. Most of the cases were nontrauma cases and a large percentage of them were PACS 1 patients. Table 3 presents the characteristics of the study population.

Results from the univariate analysis (Table 2) showed that five of the six vital signs, namely, PR [> 100/min; odds ratio (OR) 1.93; 95% confidence interval (CI) 1.08–3.44], SBP (> 140 mmHg; OR 0.35; 95% CI: 0.18–0.70), RR (< 12/min; OR 27.50; 95% CI: 1.68–450.26), RR (> 20/min; OR 3.93; 95% CI: 2.19–7.05), $SaO_2$ (< 95%; OR 2.28; 95% CI: 1.22–4.26), and GCS (< 15; OR 2.96; 95% CI: 1.60–5.49), were significantly associated with cardiac arrest within 72 h. In addition, five of six vital signs, namely, PR (> 100/min; OR 1.80; 95% CI: 1.15–2.81), SBP (> 140 mmHg; OR 0.60; 95% CI: 0.36–0.98), RR (> 20/min; OR 3.56; 95% CI: 2.23–5.68),

**Table 2 Odds ratios and 95% confidence intervals of various vital sign parameters and three hospital outcomes in univariate analysis**

| | Clinical outcomes | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Cardiac arrest within 72 h | | | Death within 30 days | | | ICU admission | | |
| Vital Signs | OR | 95% CI | *P*-value | OR | 95% CI | *P*-value | OR | 95% CI | *P*-value |
| PR/min | | | | | | | | | |
| *N*: 60–100 (reference) | 1 | – | – | 1 | – | – | 1 | – | – |
| <60 | 0.71 | 0.16–3.07 | 0.642 | 0.78 | 0.27–2.24 | 0.640 | 2.25 | 1.32–3.81 | 0.003 |
| >100 | 1.93 | 1.08–3.44 | 0.025 | 1.80 | 1.15–2.81 | 0.010 | 0.95 | 0.68–1.32 | 0.752 |
| SBP/mmHg | | | | | | | | | |
| *N*: 90–140 (reference) | 1 | – | – | 1 | – | – | 1 | – | – |
| <90 | 0.71 | 0.29–1.73 | 0.449 | 1.34 | 0.72–2.48 | 0.357 | 0.95 | 0.57–1.56 | 0.824 |
| >140 | 0.35 | 0.18–0.70 | 0.003 | 0.60 | 0.36–0.98 | 0.040 | 0.74 | 0.53–1.03 | 0.076 |
| DBP/mmHg | | | | | | | | | |
| *N*: 60–95 (reference) | 1 | – | – | 1 | – | – | 1 | – | – |
| <60 | 1.61 | 0.84–3.06 | 0.148 | 1.65 | 1.00–2.73 | 0.050 | 1.00 | 0.67–1.49 | 0.998 |
| >95 | 0.92 | 0.41–2.05 | 0.837 | 0.93 | 0.50–1.73 | 0.822 | 1.13 | 0.76–1.70 | 0.537 |
| RR/min | | | | | | | | | |
| *N*: 12–20 (reference) | 1 | – | – | 1 | – | – | 1 | – | – |
| <12 | 27.50 | 1.68–450.26 | 0.020 | NC | – | – | NC | – | – |
| >20 | 3.93 | 2.19–7.05 | <0.001 | 3.56 | 2.23–5.68 | <0.001 | 1.06 | 0.70–1.60 | 0.778 |
| $SaO_2$/% | | | | | | | | | |
| *N*: ≥ 95 (reference) | 1 | – | – | 1 | – | – | 1 | – | – |
| <95 | 2.28 | 1.22–4.26 | 0.010 | 2.39 | 1.46–3.90 | 0.001 | 1.32 | 0.88–1.97 | 0.180 |
| GCS | | | | | | | | | |
| *N*: 15 (reference) | 1 | – | – | 1 | – | – | 1 | – | – |
| <15 | 2.96 | 1.60–5.49 | 0.001 | 5.16 | 3.23–8.23 | <0.001 | 2.41 | 1.63–3.55 | <0.001 |

CI, confidence interval; DBP, diastolic blood pressure; GCS, Glasgow Coma Scale; *N*, normal; NC, not computable because of small cell count; OR, odds ratio; PR, pulse rate; RR, respiratory rate; SBP, systolic blood pressure; $SaO_2$, oxygen saturation.

**Table 3 Characteristics of patients**

| Characteristics | (*N*=1025) |
|---|---|
| Mean age (SD) | 62.0 (16.3) |
| Female (%) | 403 (39.3) |
| Ethnicity (%) | |
| Chinese | 689 (67.2) |
| Malay | 153 (14.9) |
| Indian | 126 (12.3) |
| Others | 57 (5.6) |
| Priority class (%) | |
| P1 | 901 (87.9) |
| P2 | 124 (12.1) |
| Type of incidence (%) | |
| Trauma | 43 (4.2) |
| Nontrauma | 982 (95.8) |
| Pre-existing medical history (%) | |
| None | 83 (8.1) |
| Diabetes mellitus | 338 (33.0) |
| Hypertension | 558 (54.4) |
| Heart disease | 362 (35.3) |
| Respiratory disease | 123 (12.0) |
| Renal disease | 138 (13.5) |
| Stroke | 72 (7.0) |
| Others | 623 (60.8) |
| Unknown | 68 (6.6) |
| Vital signs: median (IQR) | |
| Pulse rate (per min) | 93 (75–113) |
| Systolic BP (mmHg) | 132 (107–157) |
| Diastolic BP (mmHg) | 76 (62–90) |
| Respiratory rate (per min) | 18 (16–20) |
| Oxygen saturation (%) | 98 (96–99) |
| GCS | 15 (15–15) |
| Hospital outcome (%) | |
| Cardiac arrest within 72 h | 52 (5.1) |
| ICU admission | 201 (19.6) |
| Died within 30 days | 90 (8.8) |

BP, blood pressure; GCS, Glasgow Coma Scale; IQR, interquartile range.

$SaO_2$ (< 95%; OR 2.39; 95% CI: 1.46–3.90), and GCS (< 15; OR 5.16; 95% CI: 3.23–8.23), were associated with death within 30 days. Only PR (< 60/min; OR 2.25; 95% CI: 1.32–3.81) and GCS (< 15; OR 2.41; 95% CI: 1.63–3.55) were associated with ICU admission. RR, $SaO_2$, and GCS were consistent in predicting both cardiac arrest within 72 h and death within 30 days. Among the three, GCS was also found to be consistent in predicting ICU admission (Table 2). Surprisingly, DBP was found to have no significant association in predicting any of the three clinical outcomes of our study.

In the multivariate analysis component of our study, vital signs were analyzed together with age (Table 4). The results revealed that age had a significant effect on cardiac arrest, death, and ICU admission, although effect sizes were small. PR (> 100; OR 1.65; 95% CI: 1.00–2.71), SBP (> 140; OR 0.41; 95% CI: 0.21–0.79), RR (> 20; OR 2.90; 95% CI: 1.67–5.03), and GCS (< 15; OR 5.71; 95% CI: 3.40–9.57) were significantly associated with death within 30 days. Age, together with three other vital signs, namely, SBP, RR, and GCS, were found to be independent predictors of cardiac arrest within 72 h. For ICU admission, age and GCS were found to be independent predictors, with inverse association.

The vital signs together with age have very low sensitivity and high specificity in predicting the three clinical outcomes of interest (Table 4). The sensitivity for predicting cardiac arrest was 11.54%, that for death was

**Table 4 Multivariate analysis of vital sign parameters with clinical outcomes (model was adjusted for age)**

| | Clinical outcomes | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Cardiac arrest within 72 h | | | Death within 30 days | | | ICU admission | | |
| Vital signs | OR | 95% CI | *P*-value | OR | 95% CI | *P*-value | OR | 95% CI | *P*-value |
| Age | 1.02 | 1–1.04 | 0.022 | 1.04 | 1.02–1.05 | < 0.001 | 0.98 | 0.97–0.99 | < 0.001 |
| PR/min | | | | | | | | | |
| *N*: 60–100 (reference) | 1 | – | – | 1 | – | – | 1 | – | – |
| < 60 | 0.32 | 0.04–2.45 | 0.272 | 0.30 | 0.07–1.32 | 0.110 | 2.22 | 1.27–3.88 | 0.005 |
| > 100 | 1.65 | 0.88–3.06 | 0.116 | 1.65 | 1.00–2.71 | 0.050 | 0.81 | 0.57–1.16 | 0.254 |
| SBP/mmHg | | | | | | | | | |
| *N*: 90–140 (reference) | 1 | – | – | 1 | – | – | 1 | – | – |
| < 90 | 0.54 | 0.18–1.64 | 0.276 | 1.28 | 0.54–3.02 | 0.573 | 1.03 | 0.54–1.98 | 0.921 |
| > 140 | 0.22 | 0.09–0.56 | 0.001 | 0.41 | 0.21–0.79 | 0.008 | 0.64 | 0.42–0.97 | 0.038 |
| DBP/mmHg | | | | | | | | | |
| *N*: 60–95 (reference) | 1 | – | – | 1 | – | – | 1 | – | – |
| < 60 | 1.35 | 0.61–3.01 | 0.457 | 1.08 | 0.54–2.17 | 0.832 | 0.80 | 0.47–1.36 | 0.409 |
| > 95 | 1.82 | 0.64–5.17 | 0.259 | 1.27 | 0.58–2.78 | 0.546 | 1.55 | 0.95–2.53 | 0.081 |
| RR/min | | | | | | | | | |
| *N*: 12–20 (reference) | 1 | – | – | 1 | – | – | 1 | – | – |
| < 12 | 57.42 | 1.49–2207 | 0.030 | NC | – | – | NC | – | – |
| > 20 | 3.04 | 1.57–5.88 | 0.001 | 2.90 | 1.67–5.03 | < 0.001 | 1.19 | 0.75–1.87 | 0.462 |
| $SaO_2$/% | | | | | | | | | |
| *N*: ≥ 95 (reference) | 1 | – | – | 1 | – | – | 1 | – | – |
| < 95 | 1.17 | 0.58–2.37 | 0.665 | 1.18 | 0.67–2.10 | 0.565 | 1.40 | 0.90–2.18 | 0.136 |
| GCS | | | | | | | | | |
| *N*: 15 (reference) | 1 | – | – | 1 | – | – | 1 | – | – |
| < 15 | 2.97 | 1.53–5.77 | 0.001 | 5.71 | 3.40–9.57 | < 0.001 | 2.34 | 1.56–3.50 | < 0.001 |
| Sensitivity | 11.54% | – | – | 22.73% | – | – | 12.50% | – | – |
| Specificity | 99.28% | – | – | 97.22% | – | – | 93.80% | – | – |
| Positive likelihood | 16.04 | – | – | 8.17 | – | – | 2.02 | – | – |
| Negative likelihood | 0.89 | – | – | 0.79 | – | – | 0.93 | – | – |
| Area under curve | 0.76 | – | – | 0.79 | – | – | 0.55 | – | – |

CI, confidence interval; DBP, diastolic blood pressure; GCS, Glasgow Coma Scale; *N*, normal; NC, not computable because of small cell count; OR, odds ratio; PR, pulse rate; RR, respiratory rate; SBP, systolic blood pressure; $SaO_2$, oxygen saturation.

22.73%, and for ICU admission was 12.50%. Similar results were observed for death and ICU admission. The specificity for predicting cardiac arrest was 99.28%, that for death was 97.22%, and for ICU admission was 93.80%.

## Discussion

Our study showed that not all vital signs that we have traditionally regarded as 'vital' predict clinical outcomes of patients. Vital signs had high specificity but low sensitivity for clinical outcomes. Our study shows that vital signs provide limited information about the status of individual patients and may result in impressions that are inconsistent with more global assessment of the patient. Clinicians should always remember to treat patients, not numbers. Patients with apparently 'normal' vital signs may be more ill than they appear.

Although PR and blood pressure have been shown to be indicators of cardiovascular function [12,13], blood pressure was not a reliable predictor of clinical outcomes in our study. This can be explained by the fact that blood pressure is dynamic and can be affected by many environmental or internal factors such as anxiety, noise, stress, and emotions. In addition, studies have demonstrated many factors that can possibly contribute to inaccurate measurements, such as inappropriate cuff size [14], site of measurement [15], position of arm [16], and position of person during measurement [17].

RR was found to be a strong predictor of clinical outcomes in our study. This finding is similar to many other studies conducted to evaluate RR and its usefulness [18–21]. However, several other studies have highlighted limitations of usage of RR associated with inaccurate measurements [22–24].

$SaO_2$ was found to be the strongest predictor of clinical outcomes in our study. This is also similar to many other studies conducted [25,26]. Studies have shown that use of pulse oximetry in the ED significantly changed medical treatment and has been recommended for all acutely ill patients presenting at the ED [27]. However, there are also a number of studies that have demonstrated that pulse oximetry lacks specificity and is not a specific indicator for serious illness [28,29]. Pulse oximetry may also be inaccurate because of factors such as reduced perfusion at site of measurement [30] or reduced blood hemoglobin concentration [31]. In addition, healthcare workers must be clear that pulse oximetry is not an indicator of adequate ventilation and does not reflect hypercarbia. Arterial blood gas is still necessary for identifying hypercarbia. Therefore, pulse oximetry will definitely not replace any other vital signs like RR but will merely complement the interpretation of other vital signs.

GCS was found to have modest predictive value for clinical outcomes. Not many studies have been conducted to evaluate GCS in outcome prediction. However, GCS was the only vital sign found to be a significant predictor of all three clinical outcomes evaluated in our study, and only GCS among all the other vital signs was associated with predicting ICU admission. This is a finding that is interesting and requires more evaluation and validation, especially in the ED setting. A possible explanation can be one of the limitations of our study, as only one set of vital signs was used. The subsequent progression of the patients' condition and vital signs were not taken into account. A previous study showed that, although average vital signs measured over 21 min showed higher discriminatory value than initial vital signs, vital sign temporal trends were still diagnostically weak and did not discriminate between sicker patients and controls [32].

Our study has some limitations. The sample size of 1025 patients is not a large number compared with other studies. Vital signs taken only at triage may not be equally reflective for all patients. We did not track changes in vital signs over time. Recording of vital signs was based on routine clinical practice, and we did not assess inter-rater reliability. Also, some patients arriving by ambulance were given prehospital treatment such as oxygen supplementation or intravenous drip, which can significantly alter their vital signs. In our data, we did not distinguish between those with and without oxygen. The cutoff point of normal and abnormal values for vital signs may not be appropriate for all patients as normal values of vital signs can differ among individuals. We also did not have control over the accuracy of measurement of all vital signs taken by healthcare workers. We assume that all healthcare workers at our hospital are well trained in taking accurate vital signs. We do note that in the ED there are always a number of patients who change triage status during their stay in the ED, and this is a limitation we recognize in our study. Finally, we only observed critically ill patients in this study and assume that our conclusions can be extrapolated to stable patients (e.g. PACS 3, 4).

Further studies need to be conducted to find a better risk assessment method for patients and better prediction of clinical outcomes to allow more effective triaging and improved patient care. We intend to investigate the use of heart rate variability at triage to improve prediction of clinical outcomes [33].

### Conclusion

Not all vital signs are useful in the prediction of clinical outcomes. Vital signs had high specificity but very low sensitivity as predictors of clinical outcomes. Clinicians should always remember to treat patients and not numbers. Patients with apparently 'normal' vital signs may be more ill than they appear. Other factors need to be considered in the initial evaluation of critically ill patients.

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### Conflicts of interest

All authors have neither commercial, personal associations nor any sources of support that might pose a conflict of interest in the subject matter or materials discussed in this manuscript.

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