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# Massive transfusion prediction with inclusion of the pre-hospital Shock Index

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ABSTRACT

*Background:* Detecting occult bleeding can be challenging and may delay resuscitation. The Shock Index (SI) defined as heart rate divided by systolic blood pressure has attracted attention. Prediction models using combinations of pre-hospital SI (phSI) and the trauma centre SI (tcSI) values may be effective in identifying patients requiring massive blood transfusions (MT).
*Aim:* To explore whether combinations of the phSI and the tcSI augment MT prediction.
*Methods:* The scores were retrospectively developed using all major trauma patients that presented to The Alfred Hospital between 2006 and 2012. The first PH and TC observations were used. To avoid exclusion of the 'sickest' patients, the SI was imputed to 2 where SBP was missing, but HR was present. We developed 4 models. (i) 'Dichotomised', defined as positive when both phSI and tcSI were $\geq$1. (ii) 'Formulaic', defined by logistic regression analysis. (iii) 'Combination', defined pragmatically based on the logistic regression. (iv) 'Trending', defined as: tcSI minus phSI.
*Results:* There were 6990 major trauma patients and 360 (5.2%) received MT. There were 1371 cases with either phSI or tcSI missing and were thus excluded from the analysis. The 'Dichotomised' had higher positive predictive value than the tcSI with a further 5 per 100 patients identified. The 'Formulaic' model, defined as: log Odds (MT) = 2.16 × tcSI + 0.89 × phSI − 5.42, and the 'Combination' model, defined as: phSI × 0.5 + tcSI, performed equally (AUROC 0.83 versus 0.83, $\chi^2 = 0.86$, $p = 0.35$). The 'Formulaic' performed marginally, but statistically significantly, more accurate than the tcSI alone (AUROC 0.83 versus 0.82, $\chi^2 = 6.89$, $p < 0.01$). An 'Upward Trending' SI was observed in 1758 patients, revealing a 4.6-fold univariate association with MT (OR 4.55; 95%CI 2.64–7.83), and an AUROC of 0.79 (95%CI 0.74–0.83). The 'Downward Trending' SI was protective against MT (OR 0.44; 95%CI 0.34–0.57).
*Conclusion:* The initial pre-hospital SI is associated with MT. However, this relationship did not clinically augment MT decision when combined with the in-hospital SI. The simplicity of the SI makes it a favourable option to explore further. Computer-assisted technology in data capturing, analysis and prognostication presents avenues for further research.



## Background

Haemorrhagic shock (HS) is responsible for a third of all trauma deaths [1]. Timely diagnosis is therefore crucial, but remains challenging [2]. Diagnosis of HS relies primarily on the clinician's gestalt as traditional vital signs are commonly insufficient to diagnose HS [3]. The time-critical nature of the initial trauma resuscitation has necessitated reliance on single time-point

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measurements – rather than trends – that may add to delays in diagnosis and treatment of HS [4].

A key component of HS treatment is the transfusion of blood or blood products. In a small proportion of patients, extraordinary amounts of blood and blood products may be required for resuscitation, a process termed 'massive transfusion' (MT) [5]. This requires extensive resources to co-ordinate care and ensure accurate and timely delivery of blood and blood products. Early and accurate prediction of MT serves to streamline time-consuming processes of preparation of theatres and blood products, including thawing of frozen products.

Several authors have reported predictive models for massive transfusion [6], with the majority including imaging or pathology. The most accurate model in the literature is the Trauma Associated Severe Haemorrhage (TASH) score [2]. However, not even this complex formula with its seven clinical parameters is accurate enough to mandate MT protocols. In addition, due to time constraints, such models are limited in the prompt prediction of MT following arrival to hospital. The clinical utility of these models therefore lies in augmenting clinical decisions [2].

Pre-hospital vital signs are frequently relayed to the receiving hospital prior to arrival. Estimated, expected and/or ongoing bleeding pre-hospital is a variable that is considered by hospital clinicians to assist in decisions to initiate transfusions [7]. Combination of pre- and in-hospital data to risk stratify patients has successfully been implemented in other areas of emergency medicine such as acute myocardial infarction [8] and stroke [9]. However, it remains unknown whether pre-hospital vital signs objectively adds any value to those measured in-hospital improves MT predictability.

The four most frequently obtained and pre-notified vital signs are heart rate (HR), systolic blood pressure (SBP), respiratory rate (RR), and Glasgow Coma Score (GCS). A recent systematic review of 30 studies assessing the relationship between vital signs and blood loss concluded there was no association between bleeding and either RR or GCS [10]. However, HR and SBP were associated with bleeding in 92% and 74% of patients, respectively. Further, when combining HR and SBP together into the Shock Index (SI) (defined as HR divided by SBP), the association with blood loss was present in 10 out of 10 papers reviewed [10]. The ability of the SI to distinguish between those patients who received MT and those who did not has also been demonstrated [11,12]. The SI is simple and easy to calculate, as well as being repeatable and deployable in the pre-hospital setting.

The aim of this study was to explore whether combinations of the first pre-hospital SI (phSI) and the first trauma centre SI (tcSI) can augment MT prediction.

## Methods

### *Setting*

The state of Victoria in Australia has three Major Trauma Services (MTS) within metropolitan Melbourne, of which The Alfred Hospital is the largest. In 2008 a massive transfusion protocol (MTP) was introduced. This guideline recommended a 2:1 units ratio of Red Blood Cells (RBC) to Fresh Frozen Plasma (FFP), and 4:1 units of RBCs and leucocyte depleted platelets. Each unit of RBC has an average volume of 260 (SD 19) mL, each unit of FFP has an average volume of 280 (14) mL, and each unit of platelets had a volume of 326 (14) mL with a platelet count of $284 \times 10^9$ (40) per pool. The use of cryoprecipitate was recommended for fibrinogen levels below 1.0 g/L and each unit of cryoprecipitate had a volume of 61 (3) mL and contained Factor VIII at 290 (60) IU/unit, fibrinogen at 874 (244) mg/unit and Von Willebrand factor at 534 (69) IU/unit. Ambulance Victoria is the only emergency pre-hospital service covering the state of Victoria.

### *Research design*

This was a single-centre retrospective, comparative study. Data were extracted from The Alfred Trauma registry. This registry is a trauma epidemiology, injury surveillance and performance-monitoring program that prospectively collects data on all patients presenting to the hospital after major trauma, all trauma ICU admissions, all trauma transfers, all deaths after injury and patients who are admitted for $\geq$72 h after trauma. Patients aged $\geq$16 years old with major trauma (ISS > 15) were included. In order to avoid exclusion of the 'sickest' patients, a missing SBP, but present HR, was treated as a positive SI. For these cases the SI was imputed to be equal to 2; a number chosen to represent a clearly shocked patient, without exaggerating the SI beyond reasonable levels. Otherwise, complete case analysis was used.

We defined MT as $\geq$5 units in the first 4 h post hospital arrival [13,14]. This differs from the more traditional definition of $\geq$10 units in the first 24 h. This was done in order to include patients actively bleeding during trauma resuscitation, while excluding patients who may not require transfusion during the initial resuscitation phase [13,14]. The acute definition is also more inclusive than the traditional definition, capturing more patients with 'critical' bleeding, as well as accounting for survival bias to some extent [13].

### *Derivation*

The records of all trauma patients transported from scene to The Alfred Hospital in the study period from January 2006 to December 2012 were evaluated. The authors used the first recorded vital signs from the pre-hospital setting and the first recorded vital signs from the in-hospital setting to generate the combination scores.

We explored the phSI and the tcSI together in 4 different ways: (Table 1)

1. 'Dichotomised', defined as positive when both the phSI and the tcSI were $\geq$1. This cut-off was chosen for practical purposes, and its association with 'moderate or severe' shock [11,15].
2. 'Formulaic', defined by logistic regression analysis. We assessed the goodness of fit by using Hosmer–Lemeshow test, and grouped the predictors into groups of 10 [16].
3. 'Combination', defined more pragmatically based on coefficients from the logistic regression. For practical purposes, in order to calculate a pre-arrival value, the coefficient was placed on the phSI.
4. 'Trending', defined as: tcSI minus phSI. Due to this formula's inevitable distribution across zero, results were split into 'Upward' and 'Downward' trending.

### *Comparison*

We used traditional statistical methods to report as in Tables 3 and 4. We assessed the overall accuracy of the novel predictive

**Table 1**
Combinations of pre-hospital and in-hospital SI explored.

| Name | Formula |
|---|---|
| Dichotomised | phSI $\geq$ 1 AND tcSI $\geq$ 1 |
| Formulaic | log Odds (MT) = $2.16 \times$ tcSI + $0.89 \times$ phSI − 5.42 |
| Combination | $0.5 \times$ phSI + tcSI |
| Upward trending | (tcSI − phSI) if change is positive |
| Downward trending | (tcSI − phSI) if change is negative |

phSI, pre-hospital Shock Index; tcSI, trauma centre Shock Index; MT, massive transfusion.