ORIGINAL ARTICLE

Prehospital and hospital shock indices as predictors of massive blood transfusion during the initial treatment of polytrauma patients

Laura Pariente Juste, Maylin Koo Gómez, Antonia Bonet Burguera, Raquel Reyes García, Lourdes Pérez García, Irene Macía Tejada

Objectives. To explore a possible association between the shock index and a need for massive blood transfusion, duration of hospital stay in the critical care unit, and mortality.

Methods. Observational study of data for all patients over the age of 18 years with multiple high-energy injuries included in the TraumCat Registry who were treated in Hospital Universitario de Bellvitge between 2012 and 2016. We calculated shock index values before hospital emergency department arrival, on arrival at the hospital, and on admission to the critical care unit for resuscitation. The amount of blood transfused in the first 24 hours was also obtained from the registry.

Results. Of 184 polytrauma patients, 75 (41%) received blood transfusions. Median (interquartile range) shock indices were as follows: prehospital, 0.77 (0.61–1.01); on hospital arrival, 0.78 (0.64–1); and on critical care admission, 0.92 (0.76–1.13). Forty-six patients (25%) died. A prehospital shock index of 0.9 was significant, differentiating the amount of blood transfused. The specificity and sensitivity of the cutoff were 73% and 66%, respectively, at the prehospital recording and 74% and 80% on hospital arrival. The areas under the receiver operating characteristic curve and 95% CIs were as follows for prehospital and on-arrival shock indices: 68% (61%–75%) and 72% (65%–79%). Mortality and hospital stay were not significantly associated with shock indices.

Conclusions: The shock index is a useful, easy-to-obtain predictor to identify polytrauma patients who need early blood transfusion for optimal treatment. Hospital stay and mortality might be better predicted by other indicators.

Keywords: Shock index. Hypovolemia. Massive blood transfusion. Massive hemorrhage. Multiple trauma. Mortality. Hospital length of stay.

Índices de shock prehospitalario y hospitalario como predictores de transfusión masiva en la atención inicial del paciente politraumático

Objetivos. Establecer la posible relación entre el Índice de *Shock* (IS) con los requerimientos de transfusión masiva, estancia hospitalaria y en unidad de críticos, y mortalidad.

Método. Estudio observacional de los pacientes mayores de 18 años con traumatismos de alta energía del registro TraumCat atendidos en el Hospital Universitario de Bellvitge entre 2012 y 2016. Se recogió el IS prehospitalario (PH), a la llegada al hospital (H) y en la unidad de reanimación (IS-C), y la cantidad de transfusión las primeras 24 horas.

Resultados. Se recogieron 184 pacientes y 75 (41%) recibieron transfusión sanguínea. Las medianas de los IS para todos los pacientes del estudio fueron: IS-PH 0,77 (Q1-Q3; 0,61-1,01), IS-H 0,78 (Q1-Q3; 0,64-1), IS-C 0,92 (Q1-Q3; 0,76-1,13). Fallecieron 46 pacientes (25%). El IS-PH y el IS-H fueron los que diferenciaron de manera significativa la cantidad de transfusión. El valor 0,9 mostró una especificidad/sensibilidad del 73%/66% para el IS-PH y del 74%/80% para el IS-H. El área bajo la curva ROC para el IS-PH y el IS-H fue del 68% (IC 95% 61-75) y del 72% (IC 95% 65-79) respectivamente. No hubo relación significativa de los IS con la mortalidad y la estancia hospitalaria.

Conclusión. El IS es una herramienta útil y accesible para identificar pacientes politraumatizados con requerimientos transfusionales de manera temprana y optimizar el tratamiento. Para evaluar estancias hospitalarias o mortalidad, podrían ser más útiles otros índices.

Palabras clave: Índice de *Shock*. Hipovolemia. Transfusión masiva. Hemorragia masiva. Politrauma. Mortalidad. Estancia hospitalaria.

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Introduction

Polytrauma and mainly traffic accidents are the leading cause of death among young people in Europe. It is estimated that for each death, 20 patients require hospitalization and another 70 require outpatient medical treatment[1], with hemorrhagic shock being the main cause of preventable death[2]. It is therefore necessary to early identify the state of shock in order to provide adequate initial care to reduce morbidity and mortality.

Evaluation and treatment of patients with severe trauma begins in the prehospital setting, at which time the early activation of massive transfusion protocols could reduce mortality and transfusion requirements, based on the improvement of the acute coagulopathy of the trauma patient[3-5]. On the other hand, the transfer of patients with severe traumatic injuries to specific trauma centers would reduce mortality[6,7].

Clinical signs of shock can be altered by different causes such as age, pain, hypothermia, neurogenic shock, the presence of pacemakers or chronotropic drugs, which make their interpretation difficult. Vital signs may also be initially normal in the presence of hemorrhagic traumatic shock. In this sense, it is essential to have early tools that can guide patient selection and early management in the "golden hour" in an optimal manner, and thus be able to reduce immediate or early traumatic deaths, some of which are potentially avoidable[8].

The Shock Index (SI) is a simple and quick-to-use tool to assist in the evaluation of polytraumatized patients in shock. The SI is defined as the ratio of heart rate (HR) to systolic blood pressure (SBP). SI values > 0.9 generally indicate a state of decompensated shock, and are associated with higher mortality rates[9,10]. This has been considered a good indicator of mortality[11]. The first authors to describe SI were Allgower and Burri, who demonstrated that an SI > 1.0 was associated with a mortality rate of 40%[12]. Subsequently, attempts have been made to further adjust the cut-off point to improve the sensitivity and specificity of the index. One of the latest studies published[11] suggested a cut-off point of SI > 0.8, with which the negative predictive value is higher than that obtained with a cut-off of 0.9, although most of the published studies have done so with a SI > 0.9. Likewise, the SI is dynamically modified according to the time of assessment from the place of initial care of the injured person to his or her reception at the hospital, and the subsequent entry of the patient into the resuscitation unit.

The main objective of this study was to compare the prehospital SI (PH-SI), the in-hospital SI (IN-SI) obtained in immediate hospital care and the critical care SI (CC-SI) obtained immediately after admission to the intensive care unit, with the need for massive transfusion. The secondary objective was to compare the predictive capabilities of the SI compared to other indices in relation to days of hospital stay, stay in the critical care unit and 7-day mortality.

Method

After approval of the study by the Hospital Ethics Committee and with reference number PR335/16, a retrospective observational study was carried out on patients over 18 years of age with high-energy trauma, included in the TraumCat registry[13,14] and attended at the University Hospital of Bellvitge. We included 184 patients, who were activated by polytrauma code at the prehospital level with priority 0 (physiological criteria), priority 1 (anatomical criteria) or any other priority requiring admission to a critical care unit during the period from July 2012 to January 2016. Those in whom there was loss of data, those who did not survive to hospital arrival or died in the ED initial care unit were excluded. The patient registry was carried out in accordance with the Organic Law on Personal Data Protection.

The variables collected were age, sex, injury criteria, respiratory frequency (RF), heart rate (HR), systolic blood pressure (SBP), oxygen saturation, Injury Severity Score (ISS), prehospital/hospital Revised Trauma Score (RTS) and Glasgow Coma Scale (GCS). The SI as HR divided by SBP. The prehospital SI (PH-SI) was calculated on arrival of the patient in the hospital emergency department and on arrival in the intensive care unit.

The initial care of these patients is established by pre-activation of the hospital's trauma team, made up of an anesthesiologist, a surgeon, a traumatologist, 2 nurses and a warden. In addition, in patients with priority 0 and 1 activation, the on-call radiologist is also notified in order to have the tomography room available immediately. The initial care of the polytraumatized patient is performed according to the Advanced Trauma Life Support (ATLS) protocol of the American College of Surgeons. The massive transfusion protocol is activated according to the following criteria: ISS ≥ 15, base excess ≥ -10 or need to transfuse > 4 of red cell concentrates (RCC) in one hour, positive ECO FAST, SBP < 90 mmHg or HR > 120 beats per minute. In these cases, early treatment of the trauma patient's acute coagulopathy is attempted by early intravenous administration of 1 g bolus tranexamic acid followed by 1 g perfusion over 8 hours. In addition, a massive transfusion package consisting of 4 RCCs, 4 units of fresh frozen plasma, 1 apheresis of platelets and 2 g of fibrinogen is ordered. Subsequently, administration is guided by the rotational thromboelastometry (ROTEM) profile and anticoagulation tests, following a fixed transfusion of blood products 1:1:1. The therapeutic objective is to maintain normovolemia with a hemoglobin value of 79 g/dL.

The RCC transfused during the first 24 hours were collected, establishing, according to the number of RCC received, 3 intervals: < 5 RCC (low transfusion group); between 59 RCC (medium transfusion group) and ≥ 10 RCC (massive transfusion group). The different SI were compared with the number of RCC received. Subsequently, the relationship of SIPH with regard to ISS, RTS and GCS was analyzed regarding mortality 7 days after admission, stay in the critical care unit and hospital stay.

After ruling out a normal distribution of the continuous variables using the Shapiro-Wilk test, the ANOVA test was used for the analysis of transfusion, non-parametric tests for the rest of the comparisons and Spearman's correlation between the different indices and the consumption of red blood cell concentrates. Receiver operating characteristic (ROC) curves were obtained and the area under the curve (AUC) was calculated for the SIs in relation to transfusion. Statistical significance was set at a probability level < 0.05. For

Table 1. Demographic data according to transfusion among different groups

	Low transfusion group N = 41 n (%)	Medium transfusion group N = 21 n (%)	Massive transfusion group N = 13 n (%)	p
Men	28 (68%)	19 (90%)	12 (92%)	0.07
Age	43 (19-89)	46 (26-83)	43 (18-84)	0.9
ISS	30 (19-75)	34 (18-75)	57 (29-75)	0.001
PH-RTS	12 (6-12)	11 (5-12)	12 (4-12)	0.7

ISS: Injury Severity Score; PH-RTS: Pre-hospital Revised Trauma Score.

analysis, the statistical package R version 3.4 and Windows SPSS version 15 were used.

Continuous variables are described using median and interquartile range (IQR, Q1Q3). Categorical variables are expressed as absolute and relative frequencies.

Results

A total of 184 patients enrolled, of whom 75 (41%) received blood transfusion. Forty-six patients (25%) died. Eighty-one percent were male with a median age of 43 years (31-59). The median ISS was 29 (22-36). The ISS value was significantly higher in the massive transfusion group (Table 1). Of the hemodynamic values collected, in-hospital SBP was significantly lower in the massive transfusion group (Table 2).

SI values were: PH-SI 0.77 (0.61-1.01), IN-SI 0.78 (0.641), CC-SI 0.92 (0.76-1.13). The PH-SI and IN-SI were the ones that significantly differentiated the amount of transfusion (Table 3). SI increased progressively according to a higher number of bags transfused. Spearman's correlation index regarding transfusion was 0.45 ($p < 0.001$), 0.66 ($p < 0.001$) and 0.29 ($p = 0.02$) for PH-SI, IN-SI and CC-SI respectively. ISS with regard to transfusion showed a correlation coefficient of 0.45 ($p < 0.001$).

The value of 0.9 showed a specificity of 73% with a sensitivity of 66% for PH-SI and a specificity of 74% with a sensitivity of 80% for IN-SI (Table 4). Figures 1 and 2 show the ROC curves for PH-SI (AUC 68% 95% CI 61-75) and IN-SI (AUC 72%; 95% CI 65-79). However, the cut-off point of 0.9 showed no difference between transfusion groups (Table 5).

Of those patients who died, 31 (17%) died within the first week of admission. Of the 3 SI, only the IN-SI showed differences. In contrast, the PH-RTS indices, the ISS and a GCS < 8 were clearly significant for patients who died in the first week of admission (Table 6).

The severity indices all showed low correlation values compared to hospital stay and stay in the intensive care unit (Table 7).

Table 2. Hemodynamic values between different groups according to transfusion

	Low transfusion group N = 41 Median (IQR)	Medium transfusion group N = 21 Median (IQR)	Massive transfusion group N = 13 Median (IQR)	p
Prehospital				
SBP	110 (99-122)	90 (70-120)	94 (76-136)	0.06
HR	94 (82-107)	103 (90-134)	110 (84-140)	0.07
Hospital				
SBP	105 (90-127)	85 (70-103)	78 (57-114)	0.01
HR	92 (78-118)	109 (95-123)	104 (89-132)	0.28
Critical				
SBP	99 (80-106)	90 (79-98)	88 (76-98)	0.27
HR	93 (81-106)	112 (84-134)	126 (96-139)	0.12

SBP: systolic blood pressure; HR: heart rate. Kruskall-Wallis test.

Table 3. Shock Index values between different groups according to transfusion

	Low transfusion group N = 41 Median (IQR)	Medium transfusion group N = 21 Median (IQR)	Massive transfusion group N = 13 Median (IQR)	p
PH-SI	0.86 (0.69-1.10)	1.20 (0.78-1.32)	1.33 (0.61-1.76)	0.013
IN-SI	0.91 (0.74-1.22)	1.16 (0.94-1.57)	1.32 (0.94-1.81)	0.009
CC-SI	0.97 (0.83-1.27)	1.24 (1.00-1.48)	1.63 (1.08-1.64)	0.187

PH-SI: Pre-hospital Shock Index; HSI: Hospital Shock Index; CC-SI: Critical Care Shock Index.

Discussion

This study demonstrated that SI is a useful tool to determine hypovolemic shock in the polytraumatic patient, and it correlated well with transfusion requirements. However, while SBP was significantly lower in the massive transfusion group, HR did not show these differences. According to the ATLS classification[15], the mid-transfusion and massive transfusion groups would be grade II and III hemorrhages assessed by their decreased SBP, although not by their HR. This classification would theoretically place blood loss between 750-1,500 ml and 1,500-2,000 ml, respectively. However, several studies consider this classification insufficient to assess blood loss in trauma patients with hemorrhagic shock[16,17].

Comparing the three SIs, we observed that they increased progressively in relation to the greater number of bags transfused. However, only the PH-SI and INIS significantly differentiated the amount of blood products administered. The CC-SI could probably be interfered by treatment with vasoactive drugs and fluid therapy. Other authors found that SI offered a good prediction of massive hemorrhage in trauma patients,

Table 4. Sensitivity, specificity, PPV and NPV for the 0.9 cut-off point of the prehospital and hospital shock indexes

	PH-SI		H-SI	
	%	95% CI	%	95% CI
Sensitivity	66%	54-78	74	63-85
Specificity	73%	65-82	80	72-87
PPV	55%	43-67	67	56-78
NPV	81%	74-89	84	77-91

PPV: positive predictive value; NPV: negative predictive value; PH-SI: prehospital shock index; IN-SI: in-hospital shock index.

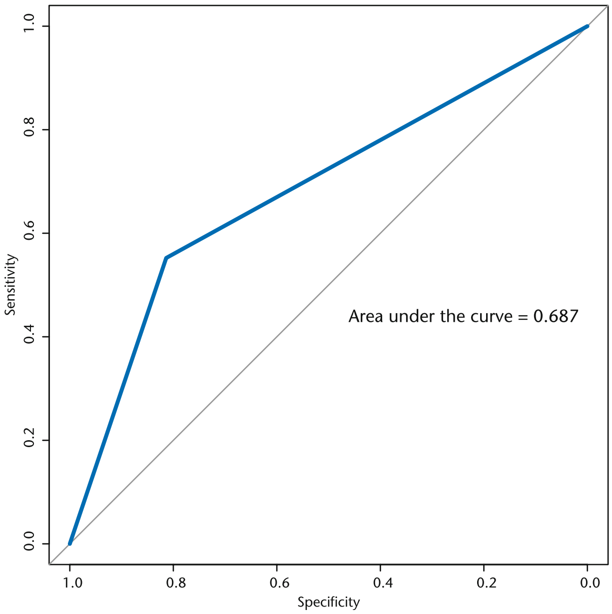

Figure 1. Receiver operating characteristic curve for the prehospital shock index to diagnose transfusion. Cut-off point 0.9.

with a sensitivity of 91.3% and specificity of 79.7%[18]. The predictive value of SI for the need for transfusion has also been found to be useful in patients with severe head injury (AIS head ≥ 3)[19].

The cut-off point for this prediction is a matter of discussion. In our study, the transfused patients had a median SI value above 0.8, and a value of 0.9 was the cut-off point with the best sensitivity and specificity. Mitra et al.[20] found that a prehospital SI value > 1 predicted with a specificity of 93.5% and a sensitivity of

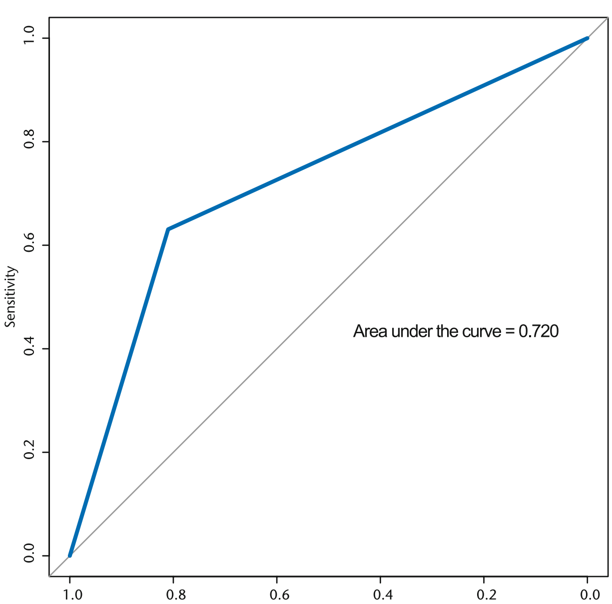

Figure 2. Receiver operating characteristic curve for the prehospital shock index to diagnose transfusion. Cut-off point 0.9.

Table 5. Comparison of the 0.9 cut-off point for shock index vs. transfusion groups

	Low transfusion group N = 41 n (%)	Medium transfusion group N = 21 n (%)	Massive transfusion group N = 13 n (%)	p
PH-SI ≥ 0.9	19 (46)	12 (57)	6 (46)	0.4
IN-SI ≥ 0.9	22 (54)	15 (71)	8 (61)	0.2

PH-SI: prehospital SI; IN-SI: in-hospital SI. Chi-square test.

43.4% any need for transfusion in the first hours of resuscitation. This is a simple value to use as a prehospital triage to alert of a shock situation. Haider et al. also include in their discussion a cut-off point of SI > 1.0, arguing that it is associated with higher mortality and blood transfusion, and that it decreases the number of underestimated patients[7]. Schroll et al. also do so, defending its greater sensitivity despite its lower specificity compared to other cut-off points. This group found that an IS ≥ 1 had a sensitivity of 67.7% and a specificity of 81.3% and offered advantages over other predictive tests of massive transfusion[21]. Terceros-Almanza et al.[18] set the cut-off point at 1.11 while Campos et al. found that a value of 0.8 had a higher sensitivity than a value of 0.9[11]. No study compared the calculation of SI in the different scenarios of polytrauma patient care. In our study, we observed that the cut-off point of 0.9 offered greater sensitivity and specificity at the hospital level than at the prehospital level, but this value was not able to differentiate the volume of red blood cells transfused (low transfusion vs massive transfusion) in either of the 2 situations.

IN-SI was significantly higher in the group of patients who died 7 days after admission, but not for the other SI calculated. McNab et al.[10] determined that a prehospital SI ≥ 0.9 was associated with a relative risk of overall mortality of 1.466 and hospital mortality of 1.721. Other authors obtained no differences in SI between the group of surviving and non-surviving patients in the univariate analysis; however, an SI < 0.3 had an odds ratio (OR) of 2.2 (95% CI 2.1-2.4) for mortality and an SI > 1.3 an OR of 3.1 (95% CI 1.6-5.9)[22]. In contrast to these studies, in our study only early mortality was assessed. On the other hand, the

Table 6. Association of shock, RTS and ISS indices with mortality

	Alive N =138 n (%)	Deaths 7 days N =31 n (%)	p
PH-SI	0.77 (0.63-0.92)	0.78 (0.55-1.31)	0.71
IN-SI	0.76 (0.64-0.96)	1.12 (0.69-1.43)	0.04
CC-SI	0.89 (0.75-1.09)	0.91 (0.67-1.45)	0.19
PH-RTS	12 (11-12)	8 (8-10)	0.00
ISS	25 (20-34)	57 (27-75)	0.00
GCS ≤ 8	25 (18%)	26 (84%)	0.00

PH-SI: Prehospital Shock Index; IN-SI: in-hospital Shock Index; CC-SI: Critical Care Shock Index; PH-RTS: Pre-hospital Revised Prehospital Trauma Score; ISS: Injury Severity Score; GCS: Glasgow Coma Scale. MannWhitney U test. Median (interquartile range).

Table 7. Correlation coefficients of the different severity indexes with the hospital stays

	Days ICU Coeficient (p value)	Days Hospital Coeficient (p value)
PH-SI	0.14 (0.07)	0.09 (0.2)
IN-SI	0.28 (0.00)	0.05 (0.54)
CC-SI	0.13 (0.12)	0.09 (0.27)
PH-RTS	–0.21 (0.01)	0.08 (0.03)
ISS	0.37 (0.00)	0.03 (0.7)

ICU: intensive care unit; PH-SI: Prehospital Shock Index; IN-SI: in-hospital Shock Index; CC-SI: Critical Care Shock Index; PH-RTS: Pre-hospital Revised Trauma Score; ISS: Injury Severity Score. Spearman correlation.

non-inclusion of some patients who died in the initial emergency room could determine the differences in the results.

Other indices such as RTS, ISS and GSC differentiated more decisively the early survival of these patients. Patients with severe TBI are those with a worse prognosis as in other studies[23]. The RTS is an index that includes the GCS within its assessment and has been widely studied and associated as a predictor of mortality and higher ISS values[24,25].

In our study, the 3 shock indices did not show a significant correlation in relation to stay in the critical care unit and overall hospital stay. The ISS was the index that showed the best correlation value, only for stay in the critical care unit, without a Spearman value exceeding 0.5. Low correlation values for these variables are also present in the study by McNab et al.[10] which validates the usefulness of the SI as a quick and simple initial assessment tool to define the initial severity of polytraumatized patients. This usefulness is most apparent during the prehospital assessment of the trauma patient or as the first indicator on arrival at the hospital, using readily available and quickly interpreted vital signs[4]. The American College of Surgeons' Committee's National Trauma Triage Protocol study evaluated the substitution of SBP < 90 mmHg for an SI > 1.0 during prehospital triage and concluded that it improved undertriage, with no significant increase in overtriage[7].

Our study has some limitations, such as its retrospective nature. This limitation is the same as that of most of the studies published in the literature. The fact that the data are from a single center limits the number of patients, and contrasts with the results of other multicenter studies[26]. Another limitation is the non-inclusion of patients who did not survive until arrival at the hospital, and of those who died in the initial emergency department. Retrospective assessment of other transfusion variables, such as platelets, plasma, prothrombin complex or fibrinogen, was excluded from the study so as not to introduce other confounding factors in the analysis of SI in the different care scenarios, since despite the application of transfusion protocols, there is great interindividual variability during the management of these patients. Age, as well as the concomitance of some drugs, could influence the relationship of SI with mortality rate and hospital stay[27,28], factors that have not been taken into account in our study.

In conclusion, SI is an accessible and easy-to-calculate tool for early identification of polytraumatized patients at risk of hypovolemic shock and transfusion requirements. A value of 0.9 seems to offer greater sensitivity and specificity for predicting the need for transfusion, and is more useful when calculated at the hospital level. However, multicenter studies with a larger number of patients would be necessary to corroborate these results. As for the secondary objective of this study, when assessing mortality or stay in the critical care unit, there are other widely validated indexes that are more reliable than SI.

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Addendum

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