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The use of the reverse shock index to identify high-risk trauma patients in addition to the criteria for trauma team activation: a cross-sectional study based on a trauma registry system

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ABSTRACT

Objectives: The presentation of decrease blood pressure with tachycardia is usually an indicator of significant blood loss. In this study, we used the reverse shock index (RSI), a ratio of systolic blood pressure (SBP) to heart rate (HR), to evaluate the haemodynamic status of trauma patients. As an SBP lower than the HR (RSI<1) may indicate haemodynamic instability, the objective of this study was to assess whether RSI<1 can help to identify high-risk patients with potential shock and poor outcome, even though these patients do not yet meet the criteria for multidisciplinary trauma team activation (TTA).

Design: Cross-sectional study.

Setting: Taiwan.

Participants: We retrospectively reviewed the data of 20 106 patients obtained from the trauma registry system of a level I trauma centre for trauma admissions from January 2009 through December 2014. Patients for whom a trauma team was not activated (regular patients) and who had RSI<1 were compared with regular patients with RSI≥1. The ORs of the associated conditions and injuries were calculated with 95% CIs.

Main outcome measures: In-hospital mortality.

Results: Among regular patients with RSI<1, significantly more patients had an Injury Severity Score (ISS) ≥25 (OR 2.4, 95% CI 1.58 to 3.62; p<0.001) and the mortality rate was also higher (2.1% vs 0.5%; OR 3.9, 95% CI 2.10 to 7.08; p<0.001) than in regular patients with RSI≥1. The intensive care unit length of stay was longer in regular patients with RSI<1 than in regular patients with RSI≥1.

Conclusions: Among patients who did not reach the criteria for TTA, RSI<1 indicates a potentially worse outcome and a requirement for more attention and aggressive care in the emergency department.

Strengths and limitations of this study

- This study proposes that systolic blood pressure (SBP) lower than heart rate (HR) (ie, reverse shock index (RSI)<1) in trauma patients suggests an unstable haemodynamic status and a poor outcome.
- The addition of RSI<1 to the criteria for trauma team activation may be justified but would result in overtriage and longer hospital stay.
- Injured patients who died before arrival at hospital or who were discharged against advice from the emergency department were excluded, which may have been a source of bias.
- Lack of data on the circumstances of injury, factors influencing decision making, patients' underlying diseases and medication use may have also been sources of bias.

INTRODUCTION

Trauma patients present to the emergency department (ED) with a great variety of injuries and diseases. As the most important task is to quickly and accurately identify those patients at greatest risk, triage is employed in order to improve patient outcome and minimise wastage of ED resources.[1–3] In addition, activation of a multidisciplinary trauma team (trauma team activation, TTA) to assess and treat seriously injured patients has been shown to improve health outcomes.[4–7] The trauma team usually comprises members of different specialties, including an emergency physician, a surgeon, an anaesthesiologist, a radiologist, a nurse and support staff, all of whom help assess and manage the trauma patient. A single team trauma response or a tiered-response TTA is used depending on policy and requirements.

Significant bleeding is a major cause of morbidity and mortality in seriously injured patients,[8] so the vital signs of the patient, including heart rate (HR) and blood pressure, are usually monitored. Moreover, tachycardia together with hypotension is usually an indication of blood loss and identifies haemorrhagic shock. However, tachycardia does not always accompany haemorrhagic shock in trauma patients, and the correlation between tachycardia and hypotension maybe poor and misleading according to previous studies.[9–13]

The ratio of HR to systolic blood pressure (SBP), the shock index (SI), has been shown to be useful in predicting mortality rates in trauma patients,[14 15] and may be useful in detecting early acute hypovolemia.[16] Cannon *et al*[17] reported that trauma patients with SI>0.9 have higher mortality rates, and that an increase in the SI from the field to the ED may predict higher mortality. Mitra *et al*[18] found that patients with SI≥1.0 have significantly higher transfusion requirements and higher mortality rates than major trauma patients in general, despite prehospital crystalloid resuscitation. A retrospective study using multiple logistic regression demonstrated that SI>1 is an independent predictor of death.[19] Previous studies have also shown that SI is correlated with duration of hospital stay, duration of stay in the intensive care unit (ICU), number of ventilator days, and blood product use.[15 20] However, evaluation of haemodynamic instability is based on the presence of hypotension, which may cause concern if SBP is lower than HR, instead of HR being higher than SBP (ie, SI>1).[21] Therefore, calculation of SI as the ratio of HR to SBP seems to conflict with the basic concept of shock. In our opinion, checking if SBP is lower than HR may help identify patients with potential shock and a poor outcome. Consequently, we introduce the ratio of SBP to HR as the reverse SI (RSI) to be used with TTA criteria to identify high-risk trauma patients with haemodynamic instability and a poor outcome.

METHODS

This study was approved by the institutional review board (IRB) of Kaohsiung Chang Gung Memorial Hospital, a 2400-bed facility and level I trauma centre that provides care to trauma patients primarily from South Taiwan. Informed consent was not required under IRB regulations. A retrospective study was designed to review all patients (n=20 106) whose data were entered into the trauma registry system between 1 January 2009 and 31 December 2014. Detailed patient information was retrieved from the trauma registry system of our institution including data on age, sex, vital signs and RSI on arrival, procedures performed in the ED, presence or absence of TTA, injury mechanism, blood alcohol concentration (BAC) on arrival, Injury Severity Score (ISS), hospital length of stay (LOS), ICU LOS, in-hospital mortality, and associated trauma in each body region.

In our hospital the trauma team is activated when the patient meets one of the following established criteria: (i) Glasgow Coma Scale score ≤10; (ii) SBP ≤90 mm Hg; (iii) respiratory rate ≥30/min or <10/min; (iv) fall from a height of ≥6 m or from two stories up; or (v) severe multiple injuries requiring TTA as decided by on-site physicians. To evaluate the need to add RSI<1 to the TTA criteria, patients for whom a trauma team was not activated (ie, regular patients) but who had RSI<1 (n=585, 2.9%) were compared with regular patients with RSI≥1 (n=17 407, 86.6%), and with those for whom a trauma team was activated (n=2114, 10.5%). SPSS V.20 statistical software (IBM, Armonk, New York, USA) was used. The main outcome measure was in-hospital mortality. For categorical variables, χ^2 tests were used to determine the significance of associations between the predictor and outcome variables. For continuous variables, Student's t-tests were applied to evaluate the significance of associations between the predictor and outcome variables. Univariate logistic regression analyses were initially performed to identify the significant predictor variables of the injury or mortality risk. The corresponding unadjusted ORs with 95% CIs for each variable were obtained. We also estimated the adjusted ORs (aORs) and 95% CIs for mortality through stepwise model selection of a multiple regression model that was adjusted by controlling for the confounding variables age and ISS. All results are presented as the mean±SE. A p value <0.05 was considered statistically significant.

RESULTS

The demographic data and clinical features of the patients enrolled in this study are summarised in table 1. The mean RSIs were 0.8±0.1, 1.8±0.5 and 1.5±0.7 in regular patients with RSI<1, regular patients with RSI≥1 and TTA patients, respectively. Overall, 348 (59.5%) of the regular patients with RSI<1 were aged 0–9 years, while most of the regular patients with RSI≥1 and the TTA patients were aged 20–79 years (79.4% and 83.5%, respectively). As regards mechanism of injury, motorcycle accidents, falls and being struck by/striking an object accounted for most cases in all three groups of patients. Among regular patients with RSI<1, 241 (41.2%) were struck by/struck an object, 173 (29.6%) experienced a fall, and 92 (15.7%) had motorcycle accidents. However, among regular patients with RSI≥1 and TTA patients, 6759 (38.8%) and 1014 (48.0%), respectively, had motorcycle accidents, while 5409 (31.1%) and 476 (22.5%), respectively, experienced a fall. The mean BAC levels were 138.1±84.7, 155.1±94.6 and 165.4 ±98.5 mg/dL for patients in the three groups, respectively. More regular patients with RSI<1 than regular patients with RSI≥1 had a BAC level ≥50 mg/dL (OR 1.5, 95% CI 1.05 to 2.16; p=0.025), but fewer regular patients with RSI<1 than TTA patients had a BAC level ≥50 mg/dL (OR 0.3, 95% CI 0.19 to 0.39; p<0.001). Most regular patients with RSI<1 and regular patients with RSI≥1 were moderately injured (ISS<15). However, significantly more patients were very severely injured

Table 1 Demographic data of the hospitalised trauma patients

Variable	Regular patients with RSI<1 n=585	Regular patients with RSI≥1 n=17 407	TTA patients n=2114	Regular patients with RSI <1 vs regular patients with RSI≥1		Regular patients with RSI <1 vs TTA patients	
				OR (95% CI)	p Value	OR (95% CI)	p Value
RSI							
Mean	0.8±0.1	1.8±0.5	1.5±0.7	–	<0.001	–	<0.001
Range	0.0–0.9	1.0–9.5	0.08.5	–	–	–	–
Gender							
Male	340 (58.1)	9905 (56.9)	1424 (67.4)	1.1 (0.89 to 1.24)	0.581	0.7 (0.56 to 0.81)	<0.001
Female	245 (41.9)	7502 (43.1)	690 (32.6)	1.0 (0.81 to 1.12)	0.581	1.5 (1.23 to 1.79)	<0.001
Age (years)	18.5±23.7	47.8±22.3	46.0±21.0	–	<0.001	–	<0.001
0–9	348 (59.5)	576 (3.3)	64 (3.0)	42.9 (35.67 to 51.61)	<0.001	47.0 (34.89 to 63.40)	<0.001
10–19	41 (7.0)	1579 (9.1)	158 (7.5)	0.8 (0.55 to 1.04)	0.095	0.9 (0.65 to 1.33)	0.789
20–29	50 (8.5)	2376 (13.6)	343 (16.2)	0.6 (0.44 to 0.79)	<0.001	0.5 (0.35 to 0.66)	<0.001
30–39	41 (7.0)	2004 (11.5)	293 (13.9)	0.6 (0.42 to 0.80)	0.001	0.5 (0.33 to 0.66)	<0.001
40–49	24 (4.1)	2174 (12.5)	325 (15.4)	0.3 (0.20 to 0.45)	<0.001	0.2 (0.15 to 0.36)	<0.001
50–59	28 (4.8)	2832 (16.3)	340 (16.1)	0.3 (0.18 to 0.38)	<0.001	0.3 (0.18 to 0.39)	<0.001
60–69	14 (2.4)	2438 (14.0)	249 (11.8)	0.2 (0.09 to 0.26)	<0.001	0.2 (0.11 to 0.32)	<0.001
70–79	21 (3.6)	2006 (11.5)	214 (10.1)	0.3 (0.18 to 0.44)	<0.001	0.3 (0.21 to 0.52)	<0.001
80–89	17 (2.9)	1240 (7.1)	107 (5.1)	0.4 (0.24 to 0.63)	<0.001	0.6 (0.33 to 0.94)	0.026
≥90	1 (0.2)	182 (1.0)	21 (1.0)	0.2 (0.02 to 1.16)	0.054	0.2 (0.02 to 1.27)	0.065
Mechanism							
Driver of MV	9 (1.5)	207 (1.2)	67 (3.2)	1.3 (0.66 to 2.54)	0.436	0.5 (0.24 to 0.96)	0.034
Passenger of MV	6 (1.0)	121 (0.7)	41 (1.9)	1.5 (0.65 to 3.37)	0.311	0.5 (0.22 to 1.24)	0.155
Motorcycle driver	92 (15.7)	6759 (38.8)	1014 (48.0)	0.3 (0.24 to 0.37)	<0.001	0.2 (0.16 to 0.26)	<0.001
Motorcycle pillion passenger	29 (5.0)	483 (2.8)	85 (4.0)	1.8 (1.25 to 2.68)	0.002	1.2 (0.81 to 1.92)	0.352
Bicycle	22 (3.8)	710 (4.1)	76 (3.6)	0.9 (0.60 to 1.42)	0.820	1.0 (0.65 to 1.70)	0.804
Pedestrian	13 (2.2)	299 (1.7)	68 (3.2)	1.3 (0.74 to 2.28)	0.333	0.7 (0.38 to 1.25)	0.272
Fall	173 (29.6)	5409 (31.1)	476 (22.5)	0.9 (0.78 to 1.12)	0.467	1.4 (1.18 to 1.77)	0.001
Unspecified	241 (41.2)	3419 (19.6)	287 (13.6)	2.9 (2.42 to 3.39)	<0.001	4.5 (3.63 to 5.48)	<0.001
BAC ≥50 mg/dL	33 (5.6)	664 (3.8)	387 (18.3)	1.5 (1.05 to 2.16)	0.025	0.3 (0.19 to 0.39)	<0.001
BAC (mg/dL)							
Mean	138.1±84.7	155.1±94.6	165.4±98.5	–	0.255	–	0.054
Range	1.0–290.3	0.2–414.6	0.5–443.1	–	–	–	–
ISS	7.1±7.3	7.3±5.4	16.7±12.1	–	0.340	–	<0.001
1–8	370 (63.2)	9587 (55.1)	444 (21.0)	1.4 (1.18 to 1.67)	<0.001	6.5 (5.31 to 7.89)	<0.001
9–15	136 (23.2)	6203 (35.6)	568 (26.9)	0.5 (0.45 to 0.66)	<0.001	0.8 (0.67 to 1.02)	0.079
16–24	54 (9.2)	1298 (7.5)	589 (27.9)	1.3 (0.95 to 1.68)	0.108	0.3 (0.20 to 0.35)	<0.001
≥25	25 (4.3)	319 (1.8)	513 (24.3)	2.4 (1.58 to 3.62)	<0.001	0.1 (0.09 to 0.21)	<0.001
Mortality	12 (2.1)	94 (0.5)	257 (12.2)	3.9 (2.10 to 7.08)	<0.001	0.2 (0.08 to 0.27)	<0.001
ISS (aOR)	–	–	–	3.1 (1.62 to 6.11)	0.001	0.4 (0.22 to 0.79)	0.007
ISS+age (aOR)	–	–	–	8.1 (3.99 to 16.43)	<0.001	0.8 (0.40 to 1.47)	0.431
Hospital LOS (days)	9.2±10.1	8.5±8.8	15.6±15.9	–	0.093	–	<0.001
ICU stay	214 (36.6)	2360 (13.6)	1178 (55.7)	3.7 (3.09 to 4.38)	<0.001	0.5 (0.38 to 0.55)	<0.001
ICU LOS (days)	10.1±10.2	8.4±10.6	10.6±13.0	–	0.024	–	0.502

AOR, adjusted OR; BAC, blood alcohol concentration; ICU, intensive care unit; ISS, Injury Severity Score; LOS, length of stay; MV, motor vehicle; RSI, reverse shock index; TTA, trauma team activation.

(ISS≥25) among regular patients with RSI<1 than among regular patients with RSI≥1 (OR 2.4, 95% CI 1.58 to 3.62; p<0.001). Notably, among 585 regular patients with RSI<1, 76 (13%) had SBP ≤90 mm Hg and 509 (87%) had SBP >90 mm Hg, so some of the latter group of patients may not have met the criteria for TTA.

The mortality rates were 2.1%, 0.5% and 12.2% in regular patients with RSI<1, regular patients with RSI≥1 and TTA patients, respectively. A higher mortality rate was noted in regular patients with RSI<1 than in regular patients with RSI≥1 (OR 3.9, 95% CI 2.10 to 7.08; p<0.001). After adjustment of the OR of mortality for ISS, the mortality rate in regular patients with RSI<1 was 3.1-fold higher (p=0.001) than that in regular patients with RSI≥1, and it was up to 8.1-fold higher (p<0.001) when the OR was further adjusted for ISS and age. Moreover, the mortality rates in TTA patients were not significantly higher than those in regular patients with RSI<1 after the adjustment for ISS and age (aOR 0.8, 95% CI 0.40 to 1.47; p=0.431). Further analysis of adult patients (18–65 years of age) (see online supplementary table S1) revealed that the mortality rate in regular patients with RSI<1 was still 4.3-fold higher (p=0.024) than that in regular patients with RSI≥1, after adjustment of the OR of mortality for ISS and age. The hospital LOS of regular patients with RSI<1 and regular patients with RSI≥1 were similar; however, more regular patients with RSI<1 than regular patients with RSI≥1 were cared for in the ICU (36.6% vs 13.6%; OR 3.7, 95% CI 3.09 to 4.38; p<0.001). Furthermore, the ICU LOS in regular patients with RSI<1 was also longer (10.1 vs 8.4 days, p=0.024) than that in regular patients with RSI≥1, and was similar to that in TTA patients (10.1 vs 10.6 days, p=0.502).

The life-saving procedures, including cardiopulmonary resuscitation, intubation, chest tube insertion and blood transfusion, carried out in the ED are summarised in table 2. No regular patients with RSI<1 underwent cardiopulmonary resuscitation. However, 14 (2.4%), 19 (3.2%) and 26 (4.4%) patients received intubation, chest tube insertion and blood transfusion, respectively. In comparison with regular patients with RSI≥1, significantly higher rates of intubation, chest tube insertion and blood transfusion were identified in regular patients with RSI<1, although fewer patients received the procedures among regular patients with RSI<1 than among TTA patients. This suggested that patients with RSI<1 may have a greater need for these live-saving procedures despite not meeting the criteria for TTA.

Concerning associated injuries in these trauma patients (table 3), significantly fewer patients had head trauma and maxillofacial trauma among regular patients with RSI<1 than among TTA patients, which may be attributed to a close relationship between intracranial haemorrhage and worsening consciousness, thus leading to a greater possibility of TTA. Regular patients with RSI<1 were also at a greater risk of having a pneumothorax (OR 2.1, 95% CI 1.21 to 3.63; p=0.017) and haemopneumothorax (OR 3.0, 95% CI 1.71 to 5.20; p=0.001) than those with RSI≥1. This may explain the higher chest tube insertion rate in regular patients with RSI<1 than in regular patients with RSI≥1. Similarly, more regular patients with RSI<1 had intra-abdominal, hepatic, splenic, retroperitoneal and renal injuries than did regular patients with RSI≥1. Therefore, regular patients with RSI<1 were more likely to have intra-thoracic or intra-abdominal injuries than regular patients with RSI≥1. In addition, there was a higher rate of humeral fracture in regular patients with RSI<1 than in regular patients with RSI≥1 (OR 2.6, 95% CI 2.05 to 3.35; p<0.001), whereas the rates of radial and femoral fractures were lower (OR 0.4, 95% CI 0.28 to 0.59; p<0.001, and OR 0.6, 95% CI 0.50 to 0.841; p=0.001, respectively).

DISCUSSION

The correlation between a high SI and poor outcome has been demonstrated in many previous studies.[15 17–20] In this study, RSI was defined as the ratio of SBP to HR, and therefore, theoretically, a lower RSI should correlate with a worse haemodynamic status and a worse outcome. Unsurprisingly, more regular patients with RSI<1 than regular patients with RSI≥1 had severe injury. Furthermore, these patients also had a higher mortality rate. After adjusting the OR by controlling for the confounding variables age and ISS, the mortality

Table 2 Life-saving procedures performed in the emergency department

Variable	Regular patients with RSI<1 n=585	Regular patients with RSI≥1 n=17 407	TTA patients n=2114	Regular patients with RSI<1 vs regular patients with RSI≥1 OR (95%CI)	p Value	Regular patients with RSI<1 vs TTA patients OR (95%CI)	p Value
Procedures in the ED, n (%)							
CPR	0 (0.0)	4 (0.0)	24 (1.1)	–	1.000	–	0.005
Intubation	14 (2.4)	101 (0.6)	333 (15.8)	4.2 (2.39 to 7.39)	<0.001	0.1 (0.08 to 0.23)	<0.001
Chest tube insertion	19 (3.2)	140 (0.8)	95 (4.5)	4.1 (2.55 to 6.73)	<0.001	0.7 (0.43 to 1.18)	0.203
Blood transfusion	26 (4.4)	257 (1.5)	292 (13.8)	3.1 (2.06 to 4.69)	<0.001	0.3 (0.19 to 0.44)	<0.001

CPR, cardiopulmonary resuscitation; ED, emergency department; RSI, reverse shock index; TTA, trauma team activation.

Table 3 Injuries in hospitalised trauma patients

Variable	Regular patients with RSI<1 n=585	Regular patients with RSI≥1 n=17 407	TTA patients n=2114	Regular patients with RSI<1 vs regular patients with RSI≥1 OR (95% CI)	p Value	Regular patients with RSI<1 vs TTA patients OR (95% CI)	p Value
Head trauma, n (%)							
Neurological deficit	0 (0.0)	72 (0.4)	46 (2.2)	–	0.177	–	<0.001
Cranial fracture	31 (5.3)	599 (3.4)	440 (20.8)	1.6 (1.08 to 2.28)	0.018	0.2 (0.15 to 0.31)	<0.001
Epidural haematoma (EDH)	16 (2.7)	381 (2.2)	323 (15.3)	1.3 (0.78 to 2.09)	0.388	0.2 (0.10 to 0.26)	<0.001
Subdural haematoma (SDH)	28 (4.8)	1015 (5.8)	664 (31.4)	0.8 (0.55 to 1.19)	0.322	0.1 (0.07 to 0.16)	<0.001
Subarachnoid haemorrhage (SAH)	29 (5.0)	965 (5.5)	617 (29.2)	0.9 (0.61 to 1.30)	0.638	0.1 (0.09 to 0.19)	<0.001
Intracerebral haematoma (ICH)	4 (0.7)	193 (1.1)	181 (8.6)	0.6 (0.23 to 1.66)	0.421	0.1 (0.03 to 0.20)	<0.001
Cerebral contusion	16 (2.7)	503 (2.9)	369 (17.5)	0.9 (0.57 to 1.57)	0.985	0.1 (0.08 to 0.22)	<0.001
Cervical vertebral fracture	3 (0.5)	116 (0.7)	40 (1.9)	0.8 (0.24 to 2.42)	1.000	0.3 (0.08 to 0.87)	0.015
Maxillofacial trauma, n (%)							
Orbital fracture	1 (0.2)	272 (1.6)	53 (2.5)	0.1 (0.02 to 0.77)	0.003	0.1 (0.01 to 0.48)	<0.001
Nasal fracture	3 (0.5)	149 (0.9)	38 (1.8)	0.6 (0.19 to 1.88)	0.494	0.3 (0.09 to 0.92)	0.021
Maxillary fracture	8 (1.4)	775 (4.5)	242 (11.4)	0.3 (0.15 to 0.60)	<0.001	0.1 (0.05 to 0.22)	<0.001
Mandibular fracture	8 (1.4)	314 (1.8)	85 (4.0)	0.8 (0.37 to 1.53)	0.527	0.3 (0.16 to 0.69)	0.001
Thoracic trauma, n (%)							
Rib fracture	26 (4.4)	1193 (6.9)	252 (11.9)	0.6 (0.43 to 0.94)	0.027	0.3 (0.23 to 0.52)	<0.001
Sternal fracture	0 (0.0)	19 (0.1)	7 (0.7)	–	1.000	–	0.358
Haemothorax	7 (1.2)	169 (1.0)	87 (4.1)	1.2 (0.58 to 2.64)	0.520	0.3 (0.13 to 0.61)	<0.001
Pneumothorax	14 (2.4)	201 (1.2)	81 (3.8)	2.1 (1.21 to 3.63)	0.017	0.6 (0.35 to 1.09)	0.100
Haemopneumothorax	14 (2.4)	142 (0.8)	81 (3.8)	3.0 (1.71 to 5.20)	0.001	0.6 (0.35 to 1.09)	0.100
Lung contusion	8 (1.4)	111 (0.6)	80 (3.8)	2.2 (1.05 to 4.45)	0.060	0.4 (0.17 to 0.73)	0.002
Thoracic vertebral fracture	4 (0.7)	150 (0.9)	42 (2.0)	0.8 (0.29 to 2.15)	0.821	0.3 (0.12 to 0.95)	0.030
Abdominal trauma, n (%)							
Intra-abdominal injury	16 (2.7)	197 (1.1)	101 (4.8)	2.5 (1.47 to 4.12)	0.003	0.6 (0.33 to 0.96)	0.030
Hepatic injury	26 (4.4)	187 (1.1)	113 (5.3)	4.3 (2.82 to 6.51)	<0.001	0.8 (0.53 to 1.27)	0.459
Splenic injury	12 (2.1)	106 (0.6)	64 (3.0)	3.4 (1.87 to 6.25)	<0.001	0.7 (0.36 to 1.25)	0.258
Retroperitoneal injury	3 (0.5)	14 (0.1)	12 (0.6)	6.4 (1.84 to 22.35)	0.017	0.9 (0.25 to 3.21)	1.000
Renal injury	6 (1.0)	60 (0.3)	25 (1.2)	3.0 (1.29 to 6.96)	0.020	0.9 (0.35 to 2.12)	1.000
Urinary bladder injury	0 (0.0)	24 (0.1)	7 (0.3)	–	1.000	–	0.358
Lumbar vertebral fracture	7 (1.2)	297 (1.7)	44 (2.1)	0.7 (0.33 to 1.48)	0.417	0.6 (0.26 to 1.27)	0.228
Sacral vertebral fracture	3 (0.5)	79 (0.5)	20 (0.9)	1.1 (0.36 to 3.59)	0.750	0.5 (0.16 to 1.82)	0.447
Extremity trauma, n (%)							
Scapular fracture	6 (1.0)	229 (1.3)	42 (2.0)	0.8 (0.34 to 1.76)	0.710	0.5 (0.22 to 1.21)	0.156
Clavicle fracture	18 (3.1)	1141 (6.6)	185 (8.8)	0.5 (0.28 to 0.73)	0.001	0.3 (0.20 to 0.54)	<0.001

Continued

Table 3 Continued

Variable	Regular patients with RSI<1 n=585	Regular patients with RSI≥1 n=17 407	TTA patients n=2114	Regular patients with RSI<1 vs regular patients with RSI≥1 OR (95% CI)	p Value	Regular patients with RSI<1 vs TTA patients OR (95% CI)	p Value
Humeral fracture	79 (13.5)	979 (5.6)	68 (3.2)	2.6 (2.05 to 3.35)	<0.001	4.7 (3.35 to 6.59)	<0.001
Radial fracture	29 (5.0)	1982 (11.4)	112 (5.3)	0.4 (0.28 to 0.59)	<0.001	0.9 (0.61 to 1.42)	0.834
Ulnar fracture	22 (3.8)	962 (5.5)	79 (3.7)	0.7 (0.43 to 1.03)	0.070	1.0 (0.62 to 1.63)	1.000
Pelvic fracture	18 (3.1)	374 (2.1)	101 (4.8)	1.4 (0.89 to 2.34)	0.147	0.6 (0.38 to 1.05)	0.087
Femoral fracture	65 (11.1)	2814 (16.2)	200 (9.5)	0.6 (0.50 to 0.84)	0.001	1.2 (0.89 to 1.61)	0.239
Tibia fracture	35 (6.0)	1188 (6.8)	113 (5.3)	0.9 (0.61 to 1.23)	0.500	1.1 (0.76 to 1.67)	0.539
Fibular fracture	15 (2.6)	631 (3.6)	90 (4.3)	0.7 (0.42 to 1.78)	0.217	0.6 (0.34 to 1.03)	0.069

RSI, reverse shock index; TTA, trauma team activation.

rate rose even higher for regular patients with RSI<1, which was the same as that for TTA patients. A higher rate of ICU stay, a longer ICU LOS, and more life-saving procedures were also seen in this population than in regular patients with RSI≥1. This result suggested that a decreasing RSI indicates an unstable haemodynamic status and an injury that can be life threatening.

In this study, regular patients with RSI<1 were not associated with a higher percentage of head trauma or maxillofacial trauma than were regular patients with RSI≥1. There is a lack of information on the relationship between head injuries and unstable haemodynamic status; however, head injury as a cause of shock in paediatric patients has been reported previously.[22] Another study stated that the relationship between SI and haemorrhage is altered after an acute traumatic brain injury, and that the use of SI in the assessment of blood volume loss could be unreliable in these patients.[23] Thoracic and abdominal traumas, on the other hand, often result in massive haemorrhage, which subsequently leads to haemodynamic instability. Therefore, more regular patients with RSI<1 and TTA patients have thoracic trauma and abdominal trauma than do regular patients with RSI≥1. Notably, in addition to SI, a paediatric specific SI has also been reported in the literature.[24] In our study, patients <9 years of age account for 59.5% of the total population of regular patients with RSI<1. This makes sense because, physiologically, children have higher HRs than adults. A systematic review by Fleming *et al*[25] demonstrated a decline in HR with age, and that the median HR decreases to 100 bpm between 4 and 6 years of age. Therefore, an even worse outcome for patients with RSI<1 can be expected if children, the so-called normal variants in this study, were excluded. In this study, the mortality rate in regular adult patients with RSI<1 was still 4.3-fold higher than that in regular adult patients with RSI≥1, after adjustment of the OR of mortality for ISS and age.

Should RSI<1 be added as a criterion for TTA? TTA is used to identify and provide rapid treatment for the most severely injured trauma patients, and there is a tendency to overtriage to prevent mortality or morbidity due to delays in definitive care. However, overtriage affects the efficiency of care and can result in increased costs, inappropriate resource use, and frustration for the care provider.[26] In our study, the mortality of regular patients with RSI<1 was significantly higher than that of regular patients with RSI≥1. The rate for very severe injuries (ISS≥25), ICU stay, ICU LOS, rates of life-saving procedures in the ED, and proportions of thoracic/abdominal trauma are also higher or longer, respectively. However, comparison of these variables between regular patients with RSI<1 and TTA patients shows that injury severity, hospital LOS and proportion of patients admitted to the ICU were lower for regular patients with RSI<1; however, the mortality rate was similar after adjustment for ISS and age. Notably, 87% of regular patients with RSI<1 had SBP>90 mm Hg and may not have met the criteria for TTA. Therefore, if RSI<1 were added to the criteria for TTA due to concerns about mortality, it would result in overtriage in the ED in relation to most other outcome measurements.

This study has some limitations. First, the retrospective study design may have given rise to possible bias. Second, the study population was limited to a single urban trauma centre in southern Taiwan. Furthermore, bias may have resulted from the fact that injured patients who died before hospital arrival or who were discharged against advice from the ED were not included in the sample. In addition, there was a lack of available data about the circumstances of injury and the factors influencing decisions concerning patient management. Lastly, other important data such as underlying diseases (eg, hypertension, chronic obstructive pulmonary disease, asthma, etc), medication use (eg, β blockers or β agonists), costs, delays in treatment, and complications were not evaluated in this study.

CONCLUSION

Our examination of data on trauma admissions at a level I trauma centre showed that among patients who did not meet the criteria for TTA, RSI<1 was associated with more life-saving procedures in the ED, a higher ICU admission rate, a longer ICU stay, and a higher mortality rate. Because these patients are potentially at risk of life-threatening problems, they should receive more attention and aggressive care in the ED.

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