

# Dynamic vital signs may predict in-hospital mortality in elderly trauma patients

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## Abstract

Vital signs (VS) are dynamic parameters and understanding the significance of changes in VS in the acute setting may offer clinical meaning. We aimed to measure dynamic changes in vital signs ( $\Delta$ VS) between site of trauma and presentation to hospital and investigate the association between  $\Delta$ VS and in-hospital mortality among elderly with trauma.

We conducted a retrospective cohort study between 2004 and 2015 using data from the nationwide trauma registry. Patients aged  $\geq 75$  years were included. Data were collected at scene of trauma and at arrival of emergency department (ED) in Japan with blunt or penetrating trauma.  $\Delta$ VS scoring was defined based on clinical implications and previous reports. One point was given for each of the following criteria: systolic blood pressure reduction ( $-\Delta$ SBP) of  $\geq 30$  mm Hg, heart rate increase ( $\Delta$ HR) of  $\geq 20$ /minute, and respiratory rate increase ( $\Delta$ RR) of  $\geq 10$ /minute between site of trauma and ED. The primary outcome was in-hospital mortality.

Of 236,698 patients in the registry, data from 28,860 eligible patients (12.2%) were analyzed [mean age (SD), 83.2 (0.3); males, 57%]. Overall in-hospital mortality rate was 10.0%. In-hospital mortality increased from 9.0% to 16.5% for  $-\Delta$ SBP; 9.2% to 22.2% for  $\Delta$ HR; and 9.7% to 15.9% for  $\Delta$ RR.  $\Delta$ VS scores of 0, 1, 2, and 3 points were associated with in-hospital mortality of 8.2%, 14.9%, 30.1%, and 50.0%, respectively.

A score based on the dynamic changes of VS,  $\Delta$ VS score, may be helpful in predicting in-hospital mortality among elderly with trauma.

**Abbreviations:**  $\Delta$ HR = heart rate increase,  $\Delta$ RR = respiratory rate increase,  $-\Delta$ SBP = systolic blood pressure reduction,  $\Delta$ VS = changes in vital signs, AIS = Abbreviated Injury Scale, CI = confidence interval, ED = emergency department, HR = heart rate, ISS = Injury Severity Score, JTDB = Japan Trauma Data Bank, NEWS = National Early Warning Score, RR = respiratory rate, RTS = Revised Trauma Score, SBP = systolic blood pressure, SD = standard deviation, VS = vital signs.

**Keywords:** delta vital signs, dynamic vital signs, elderly, Japan Trauma Data Bank, trauma score, vital signs

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The datasets generated during and/or analyzed during the current study are not publicly available, but are available from the corresponding author on reasonable request.

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## 1. Introduction

Several trauma scores to predict prognosis have been developed over the past several years, such as the Revised Trauma Score (RTS) and the Rapid Emergency Medicine Score.<sup>[1–3]</sup> These scoring systems use easily accessible clinical information including vital signs in pre-hospital and hospital settings. However, the clinical condition of a typical trauma patient may change from moment to moment, and static scoring systems may mislead physicians regarding the clinical prognosis of a patient upon presentation to hospital.<sup>[4]</sup> In particular, this aspect is critical for older patients, since the elderly often require more prompt and appropriate interventions than the young, as they have both higher mortality and higher rates of under-triage compared to younger patients.<sup>[5–7]</sup> Physicians would have indeed experienced that the elderly trauma patient has an underlying cause, such as cranial vascular disease, infection, drug side effects, or cardiac arrhythmias, not only frailty or cognitive impairment, which could have far more serious outcomes.

Japan is a front runner of aging countries in the world. Even among Japanese aged 65 years or older who have been internationally regarded as elderly, mental, and physical health is well maintained, and the majority of them are capable of taking part in active social activities. Taking it into consideration, the Japanese geriatric academic societies redefined the elderly as an aged 75 years and older in 2017.<sup>[8]</sup> This group accounts for 38% of all fatal trauma cases from 2013 to 2017.<sup>[9]</sup> Hence, trauma in the elderly is of great concern in Japan.

Vital signs, though typically reported as static parameters, are in reality, dynamic, reflecting the real-time condition of the body's

functions. Changes in physiological variables, reflected in changes in vital signs ( $\Delta$ VS), may function as early alarms and thus better predict prognosis after trauma. Nonetheless, there is scant data in the literature focusing on these potentially important features.<sup>[5,10–13]</sup> Thus, the aim of our current study was to develop a  $\Delta$ VS score for elderly with trauma based on vital sign changes between the site of trauma and presentation to hospital, as well as to analyze the association between the  $\Delta$ VS score and in-hospital mortality.

## 2. Methods

### 2.1. Data collection

We conducted a retrospective cohort study using registered data from the Japan Trauma Data Bank (JTDB) to analyze the association between a score based on changes in vital signs ( $\Delta$ VS score) and in-hospital mortality among trauma patients. Data were obtained from the JTDB, a nationwide trauma registry established in 2003 and authorized and maintained by the Japanese Association for the Surgery of Trauma and the Japanese Association for Acute Medicine to improve and assure the quality of trauma care in Japan. In Japan, there is no centre which specializes in treatment of only trauma patients, and tertiary emergency medical centers are mainly responsible for treating trauma patients. A total of 260 hospitals, including 95% of certified tertiary emergency medical centers in Japan, contributed to the JTDB in 2015. The JTDB collected data regarding patient demographics, trauma cause, Injury Severity Score (ISS),<sup>[14]</sup> and vital signs at pre-hospital and at hospital. It also collected data regarding ED mortality and in-hospital mortality.<sup>[15]</sup> The primary outcome of this study was in-hospital mortality.

### 2.2. Patient selection

The JTDB enrolled a total of 236,698 patients between January 2004 and December 2015. Exclusion criteria were: patients who were 74 years of age and younger, or those with missing age data; those who had trauma mechanisms other than blunt or penetrating trauma, or those with missing mechanism data; patients with cardiorespiratory arrest at either the trauma scene or at ED; or those with an Abbreviated Injury Scale (AIS) score of 6 (i.e., non-survivable injury) for any reason. We also excluded patients with vital sign data at the extremes of normally reported distributions: systolic blood pressure (SBP)  $>300$  or  $<40$  mm Hg; heart rate (HR)  $>220$  or  $<20$  per minute; and respiratory rate (RR)  $>60$  or  $<4$  per minute. Data included in analysis were those representing complete datasets for score predictors of patient age, SBP, HR, RR at both the trauma scene and ED, and in-hospital mortality.

### 2.3. Statistical analyses

Data were described as mean  $\pm$  standard deviation (SD) or raw number with percentage. The  $\Delta$ VS score was developed using the dynamic change in vital signs. Selection of included parameters was based on previous literature<sup>[5]</sup> and ease of use in the clinical settings (Table 1). One point was given for each of the following criteria: systolic blood pressure reduction ( $-\Delta$ SBP) of  $\geq 30$  mm Hg, heart rate increase ( $\Delta$ HR) of  $\geq 20$ /minute, and respiratory rate increase ( $\Delta$ RR) of  $\geq 10$ /minute between site of trauma and presentation to hospital. Scoring items were assessed using

**Table 1**

#### Delta vital sign score ( $\Delta$ VS).

Score Item	Scoring*
$-\Delta$ SBP (SBP at ED – SBP at the trauma scene)	
Decrease of 30 or more than 30 mmHg	1
Not applicable to above	0
$\Delta$ HR (HR at ED – HR at the trauma scene)	
Increase of 20 or more than 20/min	1
Not applicable to above	0
$\Delta$ RR (RR at ED – RR at the trauma scene)	
Increase of 10 or more than 10/min	1
Not applicable to above	0

\*  $\Delta$ VS score calculated by adding scores of all predictors; score range, 0–3.

$\Delta$  = delta (changes between at-scene and at-arrival), ED = emergency department, HR = heart rate (per minute), RR = respiratory rate (per minute), SBP = systolic blood pressure (mm Hg).

c-statistic with 95% confidence interval (CI) and characteristics were evaluated using sensitivity, specificity, and positive and negative predictive values for score cutoff values of 1, 2, and 3. All analyses were performed with IBM SPSS statistics version 25 (IBM Corporation, Armonk, NY, USA).

### 2.4. Ethical approval

We received permission to use the data from the steering committee of the JTDB. This study was approved by the ethics committee of Tsukuba Medical Center Hospital. The ethics committee at our institution does not require informed consent from patients for observational studies using anonymous data previously collected for routine clinical standard of care.

### 2.5. Patient and public involvement

Patients (and/or the public) were not involved in the development of the research question (s), the design of the study, recruitment, and conduct of the study.

## 3. Results

Of 236,698 patients registered in the JTDB, data from 28,860 eligible patients (12.2%) were analyzed. Table 2 shows the clinical characteristics of these patients (mean age, 83.2 years ( $\pm 0.3$ ); 57% male). The majority of patients had blunt trauma (98.7%). Mortality in the ED was 0.8% (222 of 28,707 patients) and in-hospital mortality was 10.0% (2878 patients). Table 3 shows distribution of patients by score items. A  $-\Delta$ SBP of  $\geq 30$  mm Hg between trauma scene and ED was seen in 12.4% patients. A  $\Delta$ HR of  $\geq 20$ /minute was observed in 6.1% patients, while 5.2% patients had a  $\Delta$ RR of  $\geq 10$ . When  $-\Delta$ SBP  $\geq 30$  mm Hg, the in-hospital mortality rate increased from 9.0% to 16.5%. Similarly, mortality increased from 9.2% to 22.2% for  $\Delta$ HR  $\geq 20$ /minute. Mortality increased from 9.7% to 15.9% for  $\Delta$ RR  $\geq 10$ /minute.

In-hospital mortality according to  $\Delta$ VS score is shown in Table 4. While patients with a score of zero had a mortality of only 8.2%, 50.0% of those with a maximum score of 3 died during the hospitalization. Score characteristics for in-hospital mortality according to different cutoffs are shown in Table 5. For patients with a score of 1, 2, and 3, specificity was 80.0%, 98.4%, and 99.9%, respectively. Positive likelihood ratio for mortality was 5.0 for patients with score 3 and negative likelihood ratio

**Table 2**  
**Characteristics of patients (N = 28860).**

Characteristic	Measurement	Value	Unit
Age	Mean ± SD	83.2 ± 0.3	
Male gender	n (%)	16332 (57)	
Trauma mechanism			
Blunt	n (%)	28498 (98.7)	
Penetrating	n (%)	362 (1.3)	
Causes of Trauma			
Traffic Accident	n (%)	6827 (23.7)	
Fall	n (%)	20878 (72.3)	
Other blunt trauma	n (%)	793 (2.7)	
Penetrating trauma	n (%)	362	
Transportation			
Ambulance	n (%)	26777 (92.8)	
Ambulance with physician	n (%)	443 (1.5)	
Helicopter with physician	n (%)	1369 (4.7)	
Prehospital Treatment			
Oxygen administration	n (%)	10094 (35.0)	
Intravenous fluids	n (%)	744 (2.6)	
AIS			
Head (n = 11,305)	Median (IQR)	4 (3–4)	
Face (n = 3126)	Median (IQR)	1 (1–2)	
Neck (n = 189)	Median (IQR)	1 (1–3)	
Thorax (n = 5135)	Median (IQR)	3 (3–4)	
Abdomen and Pelvis (n = 1458)	Median (IQR)	3 (2–3)	
Cervical Spine (n = 4076)	Median (IQR)	3 (2–4)	
Upper extremity (n = 4571)	Median (IQR)	2 (1–2)	
Lower extremity (n = 15181)	Median (IQR)	3 (3–3)	
Others (n = 627)	Median (IQR)	1 (1–1)	
ISS			
Severe (ISS > 15)	n (%)	2888 (10.0)	
Moderate (ISS 9–15)	n (%)	14967 (52.7)	
Mild (ISS < 9)	n (%)	10537 (36.5)	
Vital sign at scene			
SBP	Mean ± SD	147.5 ± 0.2	mm Hg
DBP	Mean ± SD	78.5 ± 0.1	mm Hg
HR	Mean ± SD	83.2 ± 0.1	Per minute
RR	Mean ± SD	21.0 ± 0.0	Per minute
Vital sign at ED			
SBP	Mean ± SD	147.7 ± 0.2	mm Hg
DBP	Mean ± SD	78.7 ± 0.1	mm Hg
HR	Mean ± SD	83.2 ± 0.1	Per minute
RR	Mean ± SD	20.5 ± 0.0	Per minute
Δ vital sign*			
–ΔSBP	Mean ± SD	0.2 ± 0.2	mm Hg
ΔHR	Mean ± SD	0.0 ± 0.1	Per minute
ΔRR	Mean ± SD	–0.5 ± 0.0	Per minute
Treatment			
Craniotomy	n (%)	878 (3.0)	
Thoracotomy	n (%)	139 (0.5)	
Celiotomy	n (%)	424 (1.5)	
TAE	n (%)	863 (3.0)	

\* –ΔSBP = SBP at ED – SBP at the trauma scene; ΔHR = HR at ED – HR at the trauma scene; ΔRR = RR at ED – RR at the trauma scene.  
DBP = diastolic blood pressure (mm Hg), ED = emergency department, HR = heart rate (per minute), RR = respiratory rate (per minute), SBP = systolic blood pressure (mm Hg), SD = standard deviation.

was 0.8 for those with score zero. C-statistic of the score was 0.581 (95% CI, 0.570–0.593).

#### 4. Discussion

The current study investigated the association between changes in vital signs (ΔVS) and in-hospital mortality among elderly with

**Table 3**  
**Mortality and distribution of patients according to score item (N = 28860).**

Score item	n (%)	Mortality (%)
Mortality in ED		222 (0.8)
Mortality in hospital		2878 (10.0)
–ΔSBP (SBP at ED – SBP at the trauma scene)		
30 or lower	3581 (12.4)	591 (16.5)
Higher than 30	25279 (87.6)	2287 (9.0)
ΔHR (HR at ED – HR at the trauma scene)		
20 or greater	1760 (6.1)	390 (22.2)
Less than 20	27100 (93.9)	2488 (9.2)
ΔRR (RR at ED – RR at the trauma scene)		
10 or greater	1494 (5.2)	237 (15.9)
Less than 10	27366 (94.8)	2641 (9.7)

DBP = diastolic blood pressure (mmHg), ED = emergency department, HR = heart rate (per minute), RR = respiratory rate (per minute), SBP = systolic blood pressure (mmHg), SD = standard deviation.

**Table 4**  
**In-hospital mortality of patients according to delta vital sign score (N = 28860).**

Score	n (%)	Mortality by score, n (%)	Cumulative mortality, n (%)
0	22635 (78.4)	1854 (8.2)	1854 (6.4)
1	5641 (19.5)	843 (14.9)	2697 (9.3)
2	558 (1.9)	168 (30.1)	2865 (9.9)
3	26 (0.1)	13 (50.0)	2878 (10.0)

**Table 5**  
**Score characteristics for in-hospital mortality according to different cutoffs for delta vital sign score. (N = 28860).**

Cutoff of score	Sensitivity, %	Specificity, %
≥1	35.6	80.0
≥2	6.3	98.4
≥3	0.5	99.9

trauma, mainly blunt trauma, using data obtained from a nationwide trauma database in Japan. A novel prediction rule, the ΔVS score, was developed to predict in-hospital mortality. The score was developed using the following 3 items with 1 point added for each positive criterion: –ΔSBP ≥ 30 mm Hg, ΔHR ≥ 20/minute, and ΔRR ≥ 10/minute. In-hospital mortality was positively correlated with an increasing ΔVS score, and patients with 3 points had a 50% in-hospital mortality.

Several trauma scores have been developed to predict severity and prognosis of trauma patients. Some of these are anatomical scoring systems such as the AIS and the ISS, while others, like the RTS, employ physiological scoring systems. Among these, the anatomical scoring systems have shown better predictive performance compared with the physiological scoring systems for trauma patients.<sup>[16]</sup> Combinations of anatomical and physiological scores have been proposed to increase accuracy.<sup>[17]</sup> However, the calculation of these scores is often cumbersome and time-consuming. Anatomical scoring also requires a great deal of experience, as well as advanced examination such as the addition of computed tomography imaging. Meanwhile, present static physiological trauma scores may fit less well with elderly patients compared to non-elderly adults. Some studies suggest that

geriatric patients may appear to have normal adult vital signs, despite the presence of life-threatening injuries.<sup>[18,19]</sup>

In order to further explore this, we developed a method to predict prognosis for elderly with trauma using a dynamic index.  $\Delta$ VS is an objective and convenient dynamic indicator readily available to clinicians and paramedical providers. To our knowledge, there are few studies that have evaluated the differences between prehospital and ED vital signs and its association with mortality.<sup>[15,20]</sup> One report concluded that  $-\Delta$ SBP and  $\Delta$ RR was associated with 48 hour-mortality for trauma patients,<sup>[15]</sup> while another study suggested that  $\Delta$ HR may be useful for identification of severely injured patients.<sup>[20]</sup> In addition, a study has recently reported that a change in the National Early Warning Score (NEWS) 12 hours after admission has far more prognostic value for patients with a high NEWS on admission, and very little value for those with a normal NEWS on admission. However, there is no previous study about combination of changes in classical vital signs including blood pressure, heart rate, and respiratory rate.

In the actual clinical settings, medical professionals are likely to be able to easily identify patients with scores of 2 or 3 points, and who are at high risk of death, even without use of a scoring system. However, the prognosis of patients with only 1 point might be underestimated by medical professionals, especially those who initially present without acute distress; although, transient vital signs changes such as a vasovagal response, anxious mood, or hyperventilation were included for patients who scored 1 point. In the current study, 1 out of 5 patients (19.5%) scored 1 point and 15% of these subsequently died in hospital, resulting in an 80% specificity. To identify patients in this “grey zone” of mortality risk, the  $\Delta$ VS score might be helpful. Finally, this score can be used in any setting as assessment requires neither special experience nor expensive instrumentation. It may be useful not only in developed countries, but also in resource-limited environments such as rural areas or developing countries.

Potential limitations of this study should be acknowledged. First, this research is based on Japanese data. In Japan, it is hard for emergency medical technicians to intervene actively at the trauma scene outside of the hospital, except when they are associated with the small number of helicopter ambulances and ambulances with doctors.<sup>[21,22]</sup> Thus, this scoring system may not apply to other countries, which are associated with extensive intervention at the site. Second, patients with missing data were excluded, possibly introducing selection bias. Third, we did not have data of patients daily activity, underlying diseases, and medications. Due to their underlying illnesses, most elderly usually take some medications, which could influence their VS. Fourth, it is not clear whether patients received appropriate treatment either at the site, the ED, or the ward after hospital admission. Fifth, this current study did not design to add different points to each  $\Delta$ VS, since we focused on simple use on the site for anyone, rather than for accuracy.<sup>[23,24]</sup> Finally, our study was retrospective and the results should be validated in a prospective study. A reduction of under-triage rates may be achieved using our  $\Delta$ VS score; this also warrants evaluation. An optimal trauma score ideally provides higher predictive performance with simpler design.

## 5. Conclusions

Our novel trauma scoring system, the  $\Delta$ VS score, focuses on changes in vital signs and predicts in-hospital mortality. It may be

useful in improving an emergency physicians decision-making process regarding identification of patients needing close monitoring for critical care services. Validation studies are required.

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## Author contributions

KK conceived and designed this study, interpreted the data, drafted the manuscript, and revised the manuscript for important intellectual content. TA contributed to the acquisition of data, conceived and designed this study, interpreted the data, drafted the manuscript, and revised the manuscript for important intellectual content. MA contributed to the acquisition of data, conducted data cleaning, interpreted the data, and revised the manuscript for important intellectual content. GD interpreted the data and revised the manuscript for important intellectual content. SD conceived and designed this study, interpreted the data, and revised the manuscript for important intellectual content. YT interpreted the data and revised the manuscript for important intellectual content. All of the authors approved the final manuscript.

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