Analysis of Grade Classification for Prehospital Injury Severity Scores Applied in Shonan-area Medical Control Council

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Objective: To clarify the usefulness of grade classification for injury severity scores applied in Shonan-area Medical Control Council.

Methods: The participants included 11,668 injury cases that occurred in this jurisdiction from April to September 2016. Multivariate analysis was performed using "severity at the time of the disease" as the response variable. The AUC-ROC was also compared with and without Grade classification, and potential improvements in discrimination ability were examined.

Results: There were 11,271 subjects in the "mild/moderate" group and 397 subjects in the "severe/dead" group. Almost all explanatory variables were significant and independent risk factors in the multivariate analysis, and the "Load & Go adaptation" had a particularly high odds ratio of 20.2. Discrimination ability improved (AUC-ROC: 0.773 VS. 0.787) when Grade classification was added to the conventional pre-hospitalization evaluation items.

Conclusion: Load & Go adaptation has a great influence on severity, and discrimination ability is improved through Grade classification.

Key words: Load and Go, JPTEC, medical control, prehospital

INTRODUCTION

The Japan Prehospital Trauma Evaluation and Care (JPTEC) [1] program is a guideline of the knowledge and skills that should be mastered by all personnel involved in prehospital care to avoid preventable trauma death (PTD). The Shonan Area Medical Control Council (Shonan MC) developed its trauma protocol in 2004 based on the JPTEC as well as its Trauma Emergency Care Guidelines [2]. In the JPTEC guidelines, load and go (L&G) is applicable if physiological or anatomical abnormalities are present or if circumstances of the injury are judged to be severe [1]. In addition, these guidelines include pointers such as "Grade classifications for severity (hereafter, Grade classifications)" to assist emergency personnel in providing appropriate and rapid emergency trauma care at the site of injury or during transport. Fig. 1 and 2 describe the grades in detail. For Grade 2, L&G is applicable if circumstances of the injury apply and is not applicable if the injured person is vulnerable or has had an underlying disease. However, whether these unique Grades are useful as an actual severity scale for prehospital injuries has yet to be investigated. Thus, the objective of this study was to elucidate the usefulness of the Grades as a prehospital care injury severity scale for all the trauma cases in the Shonan MC jurisdiction.

MATERIALS AND METHODS

All trauma cases that occurred within the Shonan MC jurisdiction (which includes 14 fire departments, 22 municipalities, and a population of approximately 2,040,000) between April 1 and September 30, 2016, where the patient was transported to medical facilities were included in this study. The total number of cases was 11,757. We excluded 12 cases due to unclear data and 77 more due to cardiopulmonary arrest at the time that the ambulance crew arrived on the scene. The remaining 11,668 cases were retrospectively analyzed. The following data were gathered: age, sex, Glasgow Coma Scale (GCS) at ambulance crew arrival, systolic blood pressure (BP) at ambulance crew arrival, respiratory rate at ambulance crew arrival, load and go (L&G) applicability, Grade, and severity at hospital arrival. Of these, GCS, systolic BP, and respiratory rate have been widely used as elements of the revised trauma score (RTS) [3, 4]. Severity at hospital arrival was determined by the physician of first contact based on the definitions of injury/disease severity (Table 1) used in statistics compiled by the Fire and Disaster Management Agency [5].

Analysis of the risk factors for the degree of trauma severity was performed using multivariate analysis. The response variable used in the generalized linear model was "severity by the physician at hospital arrival" (0: Mild/Moderate, 1: Severe/Death) and the predictor
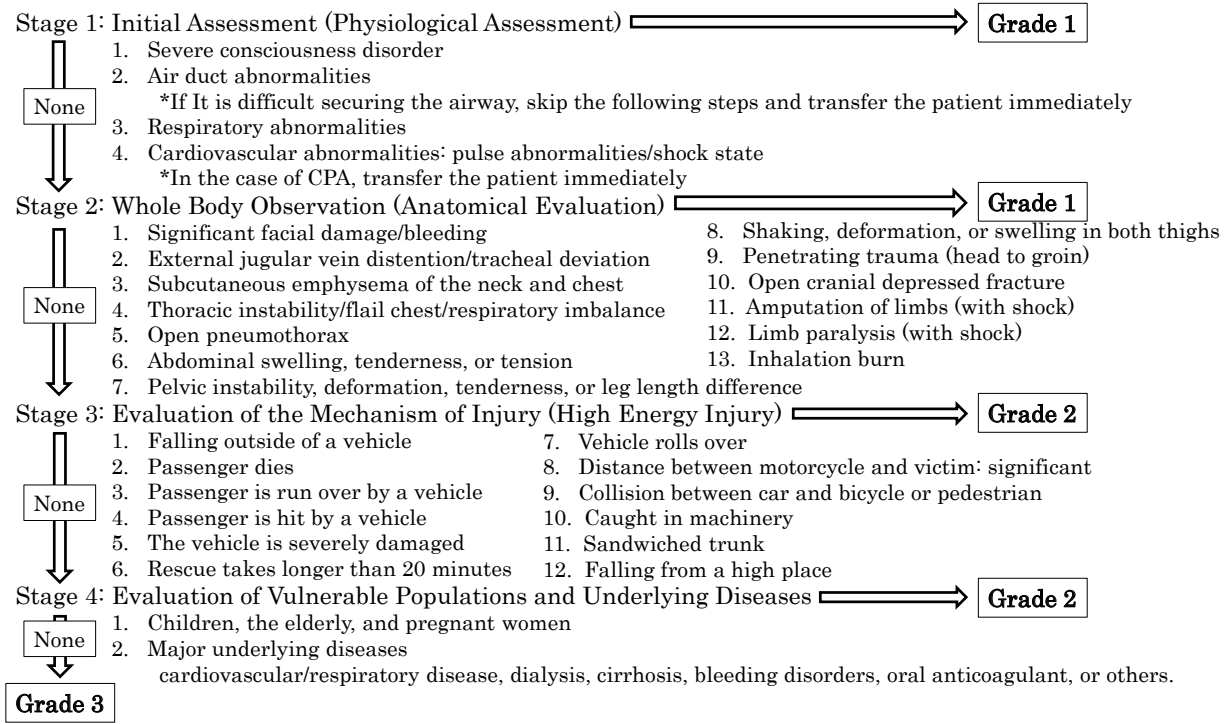
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Stage 1: Initial Assessment (Physiological Assessment) ⟹ **Grade 1**
    1. Severe consciousness disorder
    2. Air duct abnormalities
       *If It is difficult securing the airway, skip the following steps and transfer the patient immediately
None   3. Respiratory abnormalities
    4. Cardiovascular abnormalities: pulse abnormalities/shock state
       *In the case of CPA, transfer the patient immediately

Stage 2: Whole Body Observation (Anatomical Evaluation) ⟹ **Grade 1**
    1. Significant facial damage/bleeding   8. Shaking, deformation, or swelling in both thighs
    2. External jugular vein distention/tracheal deviation   9. Penetrating trauma (head to groin)
    3. Subcutaneous emphysema of the neck and chest   10. Open cranial depressed fracture
None   4. Thoracic instability/flail chest/respiratory imbalance 11. Amputation of limbs (with shock)
    5. Open pneumothorax   12. Limb paralysis (with shock)
    6. Abdominal swelling, tenderness, or tension   13. Inhalation burn
    7. Pelvic instability, deformation, tenderness, or leg length difference

Stage 3: Evaluation of the Mechanism of Injury (High Energy Injury) ⟹ **Grade 2**
    1. Falling outside of a vehicle   7. Vehicle rolls over
    2. Passenger dies   8. Distance between motorcycle and victim: significant
    3. Passenger is run over by a vehicle   9. Collision between car and bicycle or pedestrian
None   4. Passenger is hit by a vehicle   10. Caught in machinery
    5. The vehicle is severely damaged   11. Sandwiched trunk
    6. Rescue takes longer than 20 minutes   12. Falling from a high place

Stage 4: Evaluation of Vulnerable Populations and Underlying Diseases ⟹ **Grade 2**
None   1. Children, the elderly, and pregnant women
    2. Major underlying diseases
       cardiovascular/respiratory disease, dialysis, cirrhosis, bleeding disorders, oral anticoagulant, or others.

Grade 3

Fig. 1 The Grade Classification Evaluation Method
       CPA: Cardiopulmonary arrest. As defined by Shonan-area Medical Control Council
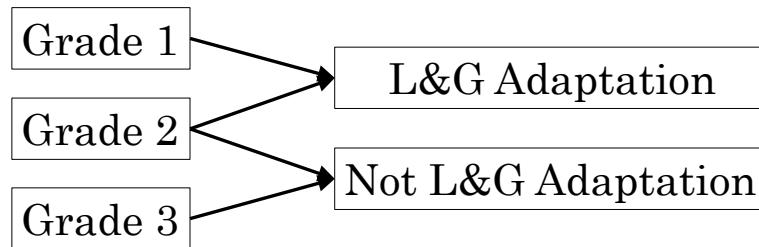

Fig. 2 The Grade Classification and Load and Go adaptation
       L&G: Load & Go. As defined by Shonan-area Medical Control Council

variables were age, sex, GCS at ambulance crew arrival (3–8, 9–14, 15), systolic BP upon ambulance crew arrival (mmHg: under 90, 90 to under 180, ≥ 180), respiratory rate at ambulance crew arrival (breaths/minute: under 12, 12-under 30, ≥ 30), L&G applicability, and Grade (severe Grade group = Grades 1 & 2, mild Grade group = Grade 3).

We then created a logistic regression model (= Base model) with "severity by the physician at hospital arrival" as the response variable and age, sex, GCS at ambulance crew arrival, systolic BP at ambulance crew arrival, respiratory rate at ambulance crew arrival, and L&G applicability as the predictor variables. We further created a model (= Grade model) that included "Grade" along with the abovementioned predictor variables to compare the discriminatory ability of the models.

Statistical analysis was performed using IBM SPSS Statistics-Ver.26 and R-Ver. 3.3.2. The results of the multivariate analysis are indicated as odds ratios and 95% confidence intervals (CIs) for all parameters. The parameters where p < 0.01, and p < 0.05 are indicated with an asterisk (*).

Data collection and analysis for this study were conducted after receiving the approval of the Tokai University Institutional Review Board (no. 16R146). All data were carefully stored after being anonymized. And the investigation conforms with the principles outlined in the Declaration of Helsinki.

RESULTS

An overview of the participants is presented in Table 2. The level of severity classifications determined 11,271 subjects to be in the mild/moderate group and 397 in the severe/death group. We found that 158 (1.4%) subjects in the mild/moderate group, and 146 (36.8%) in the severe/death group fulfilled the requirements of L&G applicability. When classified by severity Grade, 4,476 (39.7%) subjects were in the mild/moderate Grade group and 274 (69.0%) in the severe/death Grade group.

The results of the multivariate analysis are presented in Table 3. The significant independent risk factors for severe disease/death were age, sex (male), poor vital signs on ambulance crew arrival (low GCS, low systolic BP, elevated or reduced respiratory rate), L&G applicability, and severe Grade group. Notably, it was found that L&G applicability had a particularly high odds

Table 1 Severity of Injury and Disease Defined by the Physician at Hospital Arrival.

Death	Confirmed death at first visit
Severe	Patients who require hospitalization for at least 3 weeks
Moderate	Patients whose severity of injury or disease is not severe or mild
Mild	Patients with injury or sickness who do not require hospitalization

Table 2 Overview of Participants

		Mild/Moderate n = 11,271	Severe/Dead n = 397
Age, median (IQR)		54 (25-77)	63 (42-80)
Sex, n (%)	Male	6,362 (56.4)	247 (62.2)
	Female	4,909 (43.6)	150 (37.8)
GCS, n (%)	15	10,149 (90.1)	234 (58.9)
	9-14	1,055 (9.4)	97 (24.4)
	3-8	57 (0.5)	66 (16.6)
sBP, n (%)	90-179	9,612 (88.6)	319 (82.4)
	-89	162 (1.5)	23 (5.9)
	180-	1,073 (9.9)	45 (11.6)
RR, n (%)	12-29	10,543 (93.8)	343 (86.6)
	-11	56 (0.5)	8 (2.0)
	30-	638 (5.7)	45 (11.4)
L&G adaptation, n (%)	Not L&G	11,113 (98.6)	251 (63.2)
	L&G	158 (1.4)	146 (36.8)
Grade classification, n (%)	Mild Grade	6,795 (60.3)	123 (31.0)
	Severe Grade	4,476 (39.7)	274 (69.0)

IQR: Interquartile range, GCS: Glasgow coma scale, sBP: Systolic blood pressure, RR: respiratory rate, L&G: Load & Go, Severe Grade: Grade1&2, Mild Grade: Grade 3.

Table 3 Multivariate analysis of the Risk Factors for "Severe/Death"

		Odds ratio (95% CI)	
		Base model	Grade model
Age		1.02**(1.01-1.02)	1.01**(1.01-1.02)
Sex	Male (REF)		
	Female	0.77*(0.60-0.97)	0.77*(0.60-0.97)
GCS	15 (REF)		
	9-14	2.21**(1.67-2.93)	2.16**(1.63-2.86)
	3-8	5.97**(3.54-10.06)	5.90**(3.51-9.92)
sBP	90-179 (REF)		
	-89	2.03*(1.11-3.69)	2.04*(1.12-3.71)
	180-	0.94 (0.65-1.35)	0.93 (0.65-1.35)
RR	12-29 (REF)		
	-11	2.90*(1.08-7.81)	2.98*(1.11-8.04)
	30-	1.64*(1.04-2.59)	1.61*(1.02-2.53)
L&G adaptation	Not L&G (REF)		
	L&G	23.9**(17.41-32.84)	20.2**(14.29-28.64)
Grade classification	Mild Grade (REF)	-	
	Severe Grade	-	1.34*(1.03-1.74)

REF: Reference, GCS: Glasgow coma scale, sBP: Systolic blood pressure, RR: respiratory rate, L&G: Load & Go, Severe Grade: Grade1&2, Mild Grade: Grade 3.
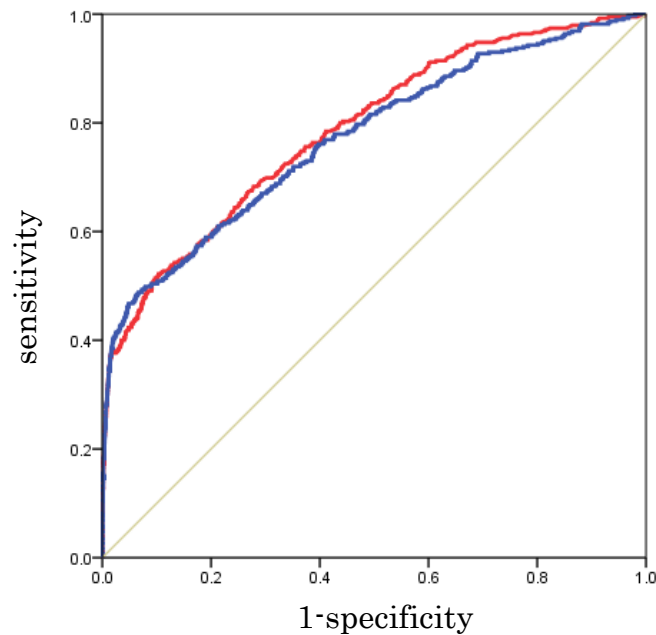*: p < 0.05, **: p < 0.01

Fig. 3 ROC curves of the Base model and Grade model
Blue line = Base model： AUC-ROC = 0.773 (95%CI 0.745-0.800),
Red line = Grade model： AUC-ROC = 0.787 (95%CI 0.762-0.812).

ratio of 20.2 (Grade model). When the base and grade models were compared, the significant independent risk factors were the same and the odds ratios were not significantly different.

The ROC curves for the Base and Grade models are shown in Fig. 3. The Grade model showed slight improvement over the Base model, the AUC-ROC was 0.773 (95%CI 0.745-0.800) for the Base model and 0.787 (95%CI 0.762-0.812) for the Grade model, indicating that the Grade model had significantly better discrimination ability ($p = 0.039$).

DISCUSSION

The local medical control council is responsible for ensuring a system that allows trauma patients to undergo standard care within their area of jurisdiction at any time [6]. In Japan, the JPTEC has been established as the standard prehospital trauma care guideline, and this guideline is widely used by ambulance crews engaged in prehospital care within the Shonan MC jurisdiction. As stipulated in these guidelines, L&G applicability is considered. This is known to be useful in determining the degree of severity and urgency to ensure swift transport to an appropriate medical facility [7, 8]. In addition, a variety of verified methods have been advocated for, both in Japan and overseas, as prehospital trauma triage methods [9-14]. In this study, we conducted a retrospective examination of whether the Grade classifications used as standard policy by the Shonan MC were useful.

A multivariate analysis using "severity by the physician at hospital arrival" as the response variable showed that "severe/death" group was a significant independent risk factor regardless of the predictor variables used. Although advanced age and poor vital signs affected the degree of severity, L&G applicability was found to have a particularly high odds ratio of 20.2 and "degree of severity by the physician at hospital arrival" was found to be a highly influential factor.

This justifies the widespread use of L&G applicability as an indicator of actual severity, and its recommendation for use by the JPTEC. While "Grade classification" is a significant independent risk factor for L&G applicability, its odds ratio was 1.34, which was not particularly high. Based on this result, we concluded that Grade classification does not change L&G applicability. Rather, its usefulness as an index that increases the accuracy of determining L&G applicability should be examined, with consideration given to whether L&G was applicable or not.

Our examination of discriminatory ability showed that the ROC curve of the Grade model was a slight improvement on the Base model, with the AUC-ROC significantly increased from 0.773 (95%CI 0.745-0.800) to 0.787 (95%CI 0.762-0.812) . Based on this result, when a degree of severity assessment is based on L&G applicability, the accuracy of the determination improves when Grade classification is included in the assessment.

However, given the current circumstances, ambulance crews within the Shonan MC jurisdiction will have to have a sufficient comprehension of L&G applicability and will have to study the Grade classifications, which are only used within this region. It will also be necessary to ensure that the physicians and nurses at medical facilities where patients are transported have a sufficient understanding of these factors. However, outside of the medical practitioners who are involved in the MC, the Grade classifications are largely unknown. When one considers the effort required to ensure that both ambulance crews and medical facilities understand the Grade classifications, it becomes clear that further investigation of whether they should be maintained is required.

One of the limitations of this study was the fact that "degree of severity at the time of the disease," which was set as the outcome measure, was determined at arrival at the hospital, and as a result, does not accu-

rately reflect the condition of the patient, including the prognosis at the time of ambulance arrival. It is also currently impossible to obtain detailed information about patients' conditions on arrival from all hospitals where they are transported, including small and mid-sized hospitals. Since the objectives of this study were to examine all trauma cases transported to hospitals, "degree of severity at the time of the disease," was our outcome measure, which was obtained from fire departments. We plan to continue our analysis of this issue evaluating detailed information about trauma victims obtained from a large number of medical facilities, in particular ones where trauma victims are transported. This will include vital prognosis, final diagnosis, and TRISS score [3, 4], among others.

Another limitation is that this study examined only cases in the Shonan region. Nevertheless, since emergency care itself should be organized based on a comprehensive assessment of the medical resources available in each individual region, trauma care is naturally included in this. Similar studies have been conducted both in Japan and throughout the world [8, 15-17], and further study of protocol setting in accordance with the circumstances in each region is required.

CONCLUSION

We examined the usefulness of Grade classifications via a comprehensive regional survey. L&G applicability was found to be a factor that had a major effect on the degree of severity, and it was further found that when Grade classification was considered, discriminatory ability improved. We believe that further research on the usefulness of Grade classifications via the study of detailed patient outcomes is required.

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REFERENCES
1) Anzai K, Ishihara S, Ichiyanagi T, Inoue J, Ohtomo Y, Ohnuki T, *et al.* (JPTEC Council): Revised 2nd edition of the JPTEC Guidebook. Tokyo: Health Publishing, 2016: 2-10.
2) Shonan-area Medical Control Council: Trauma Emergency Care Guidelines 2011. https://shonan-mc.org/images/guideline/kguide/trauma_gudeline_2011.pdf (last access: 2021/5/21).
3) Boyd CR, Tolson MA, Copes WS: Evaluating trauma care: the TRISS method. Trauma Score and the Injury Severety Score. J Trauma. 1987; 27(4): 370-8.
4) Champion HR, Copes WS, Sacco WJ, Lawnich MM, Keast SL, Bain Jr LW, *et al.*: The Major Trauma Outcome Study: establishing national norms for trauma care. J Trauma. 1990; 30: 1356-65.
5) Fire and Disaster Management Agency: Number of ambulance dispatches and number of people transported by ambulance 2020 edition. Current state of emergency rescue, 2020: 17-37.
6) Ichikawa T, Inaba H, Inoue K, Imaki S, Iwami T, Ohta S, *et al.* (Japanese Association for Acute Medicine): Medical control for prehospital care. Tokyo: Health Publishing, 2010: 2-11.
7) Norcross ED, Ford DW, Cooper ME, Zone-Smith L, Byrne TK, Yarbrough DR: Application of American College of Surgeons' field triage guidelines by prehospital personnel. J Am Coll Surg. 1995; 181: 539-44.
8) Yamanoue T, Matsunaga M, Morikawa S, Sera A, Naitoh H, Takesaki T, *et al.*: Relationship between the pre-hospital findings and the final outcome in trauma victims: a population-based study in the Hiroshima district. JJAAM. 2010; 21: 63-71.
9) Moore L, Lavoie A, Abdous B, Le Sage N, Liberman M, Bergeron E, *et al.*: Unification of the revised trauma score. J Trauma. 2006; 61: 718-22.
10) Sartorius D, Le Manach Y, David JS, Rancurel E, Smail N, Thicoipe M, *et al.*: Mechanism, Glasgow coma scale, age, and arterial pressure (MGAP): a new simple prehospital triage score to predict mortality in trauma patients. Crit Care Med. 2010; 38: 831-7.
11) Sasser SM, Hunt RC, Sullivent EE, Wald MM, Mitchko J, Jurkovich GJ, *et al.*: Guidelines for field triage of injured patients: recommendations of the National Expert Panel on Field Triage, 2011. MMWR Recomm Rep 2012; 61: 1-20.
12) Newgard CD, Fu R, Zive D, Rea T, Malveau S, Daya M, *et al.*: Prospective Validation of the National Field Triage Guidelines for Identifying Seriously Injured Persons. J Am Coll Surg. 2016; 222: 146-58.
13) Bouzat P, Legrand R, Gillois P, Ageron FX, Brun J, Savary D, *et al.*: Prediction of intra-hospital mortality after severe trauma: which pre-hospital score is the most accurate? Injury. 2016; 47: 14-8.
14) Leichtle S, Poulos N, Whelan J, Aboutanos M: Field triage of motor vehicle crashes: Which factors predict high injury severity? Am Surg. 2019; 85: 764-7.
15) Cassignol A, Marmin J, Cotte J, Cardinale M, Bordes J, Pauly V, *et al.*: Correlation between field triage criteria and the injury severity score of trauma patients in a French inclusive regional trauma system. Scand J Trauma Resusc Emerg Med. 2019; 27(1): 71.
16) Arshad FH, Williams A, Asaeda G, Isaacs D, Kaufman B, Ben-Eli D, *et al.*: A modified simple triage and rapid treatment algorithm from the New York City (USA) Fire Department. Prehosp Disaster Med. 2015; 30: 199-204.
17) Hamada SR, Gauss T, Duchateau FX, Truchot J, Harrois A, Raux M, *et al.*: Evaluation of the performance of French physician-staffed emergency medical service in the triage of major trauma patients. J Trauma Acute Care Surg. 2014; 76: 1476-83.