Factors predicting the early mortality of trauma patients

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ABSTRACT

BACKGROUND: The aim of this study was to identify factors predicting early mortality in trauma patients.

METHODS: This was a study of 6288 trauma patients admitted to the hospital between July 2011 and June 2016. Among the variables recorded for a prospective trauma registry, the following were selected for analysis: sex; age; a combination of the Glasgow Coma Scale score, age, and systolic blood pressure (SBP) (GAP); a combination of the mechanism of injury, the Glasgow Coma Scale score, age, and SBP (MGAP); SBP; respiratory rate; peripheral oxygen saturation (SpO2 value); the Glasgow Coma Scale score; laboratory variables; and presentation time. Logistic regression analysis was used to explore associations between these variables and early mortality.

RESULTS: In total, 296 (4.6%) patients died within 24 hours. Univariate regression analysis indicated that age, the GAP, the MGAP, SBP, SpO2, the Glasgow Coma Scale score, base excess, hemoglobin level, platelet count, INR, and presentation time predicted early mortality. Multivariate regression showed that the GAP, the MGAP, SpO2, base excess, platelet count, and INR were independently predictive. The areas under the receiver operator curve comparisons for the GAP and MGAP models revealed the superiority of the GAP-based model.

CONCLUSION: The GAP model, SpO2, base excess, platelet count, and INR predicted the early mortality of trauma patients.

Keywords: Acute traumatic coagulopathy; base excess; mortality; peripheral oxygen saturation; trauma; trauma scoring system.

INTRODUCTION

Trauma is a serious global medical and economic issue, accounting for 10% of all mortality worldwide.1,2 Many studies of trauma-related death have been performed, including the establishment of trauma scoring systems (TSSs) and the evaluation of coagulopathy associated with bleeding and non-trauma-related factors, such as the time of presentation to emergency departments (EDs).3-5

Over the past 40 years, TSSs have been developed to rate trauma severity and predict mortality. These include the Injury Severity Score (ISS); the Trauma-related Injury Severity Score (TRISS); the Revised Trauma Score (RTS); the Mechanism, Glasgow Coma Scale, Age, and Systolic Blood Pressure (MGAP) Score; and the Glasgow Coma Scale, Age, and Systolic Blood Pressure (GAP) Score. Of these, the MGAP and GAP systems are more recent additions. They are simple, rapid scoring systems that are more accurate than other TSSs in the prediction of trauma-associated mortality.3,6-9

Bleeding and coagulation disorders cause most preventable trauma-related mortality. Over the last 10 years, the number of studies of acute traumatic coagulopathy (ATC) has...
increased significantly. ATC independently predicts mortality and is commonly encountered during the treatment of trauma patients.\(^{[6,15,11]}\)

Recently, ED presentation time, which is an indicator of treatment quality, has become a topic of interest.\(^{[12]}\) A study has explored whether presentation time was associated with prognosis.\(^{[13]}\) Several studies have explored whether trauma-associated in-hospital mortality differed in those admitted during business and non-business hours. Although the results varied somewhat, no remarkable difference was noted.\(^{[5,14]}\)

However, these studies related to TSSs, ATC, and ED presentation time evaluated only in-hospital or 30-day mortality, not early mortality. The major causes of early and late mortality caused by trauma are different. Most early mortality is caused by bleeding and brain injuries, whereas most late mortality is attributable to complications developing in the hospital, such as infection and multiple organ failure (MOF).\(^{[15]}\) The associated factors may differ. Predictive factors are needed, since most deaths from trauma are cases of early mortality.\(^{[16,17]}\) These factors should be readily identifiable in the early phase of management. Indeed, if such factors could be promptly identified, trauma patients could receive more aggressive treatment. Thus, factors that could rapidly predict early mortality were the subject of this study.

**MATERIALS AND METHODS**

**Study Design**

Data in a prospectively recorded trauma registry were retrospectively reviewed to identify 24-hour mortality and early predictors thereof. Professional health information managers, closely supervised by emergency physicians, maintain the ED trauma registry of our 900-bed tertiary care university hospital. All ED patients are managed by board-certified emergency physicians. This study was approved by the Gyeongsang National University Hospital Institutional Review Board.

**Patient Information**

Patients aged ≥16 years with blunt or penetrating trauma admitted to the ED of a single hospital between July 2011 and June 2016 were evaluated. The exclusion criteria were other forms of trauma, trauma of unknown type, and dead-on-arrival status (whether or not cardiopulmonary resuscitation was attempted). Patients who were discharged or transferred to another hospital within 24 hours of arrival were also excluded.

**Variables**

Among the many possible variables, those that have usefully predicted trauma mortality in previous studies and could be quickly scored (within 30 minutes) were selected for analysis. Variables exhibiting significant correlations (multicollinearity) were excluded. Sex, age, the GAP, the MGAP, systolic blood pressure (SBP), respiratory rate (RR), peripheral oxygen saturation (SpO\(_2\)) level, the Glasgow Coma Scale (GCS) score, base excess, hemoglobin (Hb) level, platelet count, international normalized ratio (INR), and presentation time were evaluated. The first measurement taken after ED presentation was used in this study. The GAP and MGAP reliably predict trauma-related mortality and can be readily calculated even in busy EDs (Table 1).\(^{[16,17]}\) Presentation time was classified as a weekday or not a weekday. Weekdays were defined as Monday to Friday from 09:00 to 17:59. Early mortality was defined as mortality within 24 hours of presentation. The primary outcomes were early mortality and factors predicting such mortality.

**Statistical Analysis**

Multivariate imputation by chained equation was used to impute missing values.\(^{[18]}\) Sex, age, the GAP, the MGAP, SBP, RR, SpO\(_2\), the GCS, Hb level, platelet count, INR, and presentation time were subjected to univariate analysis, and factors identified as significant were then subjected to multivariate analysis (with the exceptions of age and SBP because both feature in the GAP and MGAP). Multivariate logistic regression was performed twice, including either the GAP or the MGAP and other variables identified as significant by the univariate analysis. The equation used to calculate predicted survival (Ps) was: Ps = 1/(1 + e\(^{-b}\)), b = b\(_0\) + b\(_1\) x GAP + b\(_2\) x sex + b\(_3\) x INR… (thus including coefficients b\(_0\), b\(_1\), b\(_2\), b\(_3\)…). The coefficients were derived during multivariate regression analysis. The discriminatory ability of the final models was evaluated by drawing receiver operator characteristic curves and a comparison of the curves using the method of DeLong et al.\(^{[19]}\)

The ease of deriving the variables of the final model was also assessed. The cutoffs were the 3 GAP groups (mild, moderate, and severe), INR 1.5, platelet count <100,000/µL, base excess –6, and the 6 saturation groups (>91%, 90–81%, >81–76%, 75–71%, 70–61%, <60%).

**Table 1. GAP and MGAP scoring systems**

<table>
<thead>
<tr>
<th>GAP</th>
<th>Points</th>
<th>MGAP</th>
<th>Points</th>
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<tbody>
<tr>
<td>GCS</td>
<td>3–15</td>
<td>GCS</td>
<td>3–15</td>
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<tr>
<td>Age (years)</td>
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<td>Age (years)</td>
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<tr>
<td>&lt;60</td>
<td>3</td>
<td>&lt;60</td>
<td>5</td>
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<td>&gt;60</td>
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<td>&gt;60</td>
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<tr>
<td>SBP (mmHg)</td>
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<td>SBP (mmHg)</td>
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<tr>
<td>&gt;120</td>
<td>6</td>
<td>&gt;120</td>
<td>5</td>
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<tr>
<td>60–120</td>
<td>4</td>
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GAP: Glasgow Coma Scale, Age, and Systolic Blood Pressure; GCS: Glasgow Coma Scale; MGAP: Mechanism, Glasgow Coma Scale, Age, and Systolic Blood Pressure.
80–71%, 70–61%, 60–51%, <50%) derived in previous studies. A p value <0.05 was considered statistically significant. MedCalc 17 (MedCalc BVBA, Ostend, Belgium) and Stata version 13 (StataCorp LP, College Station, TX, USA) software were used for the analysis.

**RESULTS**

**Baseline Characteristics**

In total, 45,589 trauma patients were admitted to the ED during the study period, and 26,202 patients ≥16 years of age with blunt/penetrating trauma were included. After excluding those who had experienced cardiac arrest prior to presentation and those discharged or transferred within 24 hours, a total of 6288 patients remained (Fig. 1). The mean patient age was 57.3±18.6 years, and 67.1% were male. Baseline data (and the percentages of missing data) are shown in Table 2.

**Univariate and Multivariate Logistic Regression**

The 24-hour mortality rate of the study patients was 4.6%. No significant between-group difference in sex was noted (males 67.0% vs. females 68.9%; p=0.49). However, a significant difference was observed in terms of age (56.90 vs. 64.56 years, p<0.001). Univariate logistic regression showed that age, the GAP, the MGAP, SBP, SpO2, the GCS, base excess, Hb level, platelet count, INR, and presentation time predicted 24-hour mortality (Table 3).

The results of the two multivariate logistic regression analyses are shown in Table 4. Both the GAP and the MGAP were significant, whereas neither Hb level nor presentation time was significant. Two GAP and MGAP models were created using SpO2, base excess, platelet count, and INR values. The GAP-based model afforded good discrimination (area under the receiver operator characteristic curve (AUROC): 0.962; p<0.001; 95% confidence interval (CI): 0.94–0.973). The MGAP-based model also afforded good discrimination (AUROC 0.958; p<0.001; 95% CI: 0.946–0.970). AUROC comparisons revealed the superiority of the GAP-based model (p<0.001; 95% CI: 0.003–0.005; absolute difference: 0.00383).

A categorical model using the GAP was created because it is easy to apply (Table 5). GAP <19 points, INR >1.5, platelets count <100,000/µL, base excess <-6, and saturation <90% mortality was significant (males 67.0% vs. females 68.9%; p=0.49). However, a significant difference was observed in terms of age (56.90 vs. 64.56 years, p<0.001). Univariate logistic regression showed that age, the GAP, the MGAP, SBP, SpO2, the GCS, base excess, Hb level, platelet count, INR, and presentation time predicted 24-hour mortality (Table 3). The results of the two multivariate logistic regression analyses are shown in Table 4. Both the GAP and the MGAP were significant, whereas neither Hb level nor presentation time was significant. Two GAP and MGAP models were created using SpO2, base excess, platelet count, and INR values. The GAP-based model afforded good discrimination (area under the receiver operator characteristic curve (AUROC): 0.962; p<0.001; 95% confidence interval (CI): 0.94–0.973). The MGAP-based model also afforded good discrimination (AUROC 0.958; p<0.001; 95% CI: 0.946–0.970). AUROC comparisons revealed the superiority of the GAP-based model (p<0.001; 95% CI: 0.003–0.005; absolute difference: 0.00383).

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showed a significant association for predicting early mortality. The odds ratios became greater as the conditions measured indicated greater seriousness.

**DISCUSSION**

The aim of this research was to identify factors that can rapidly predict early mortality in trauma patients. The GAP, the MGAP, SpO₂, base excess, platelet count, and INR were determined to be useful in this context. Of the 2 models using these parameters, the GAP was better than the MGAP.

Trauma-related mortality can be classified into 3 categories based on time; the causes of mortality differ between categories. The categories are immediate death (within minutes after injury), death within 24 hours, and in-hospital death after 24 hours. Most in-hospital mortality occurs during the second and third periods. Although factors directly related to trauma often cause mortality during the second period, the immediate effects of the accident decrease in the third period, during which death is caused by complications, such as sepsis and MOF.[15] Thus, as early and late trauma mortality differ in their etiologies, only 24-hour mortality was assessed in this study.

Most trauma-related mortality occurs within the first 24 to 48 hours.[16,17] The survival of patients admitted to EDs is determined by the severity of the condition at the time of presentation and the promptness of treatment. Therefore, patients must be rapidly triaged, and the worst-affected treated quickly. Several studies have identified predictors of early mortality. However, these studies involved hospitalized patients or those with specific diseases, or employed tests that are not readily available.[17,23–25] One recent study proposed an early mortality prediction model for trauma patients based on clinical and laboratory values, as in the present study.[26] This model was simple and included some variables that were similar to those used in our study for trauma mortality prediction. However, that study evaluated the 28-day mortality, not
24-hour mortality. Furthermore, they used traumatic brain injury as a factor, which required image scan-taking times. In contrast, we evaluated only variables that can be rapidly measured, in order to facilitate rapid triage and thereby aid in initial management. Based on the categorical model outcomes using the GAP, we identified that a GAP <19 points, INR >1.5, platelet count <100,000/µL, base excess <-6, and saturation <90% could be used as cutoff values for predicting early mortality. A previous study showed that these factors proved to be significant factors for in-hospital or 30-day mortality.[9,20–22] In addition, the results indicated that they can also be used as the factors for early mortality.

Of the various TSSs, the RTS has been widely used since 1989. Although the RTS is simple to use, its predictive power is less than that of other recent TSSs. The ISS (developed in 1974) and the TRISS (developed in 1987) have found widespread use. Although the TRISS is more accurate, patients must be examined, and the required measurements are usually available only after several hours, rendering the system unsuitable as a predictor of early mortality.[6] The ISS also requires that patients be examined.[3] The GAP and MGAP are recent systems that do not require examination.[8,9] Both systems are rapid and more predictive than the RTS.[9,27,28] Thus, we chose the GAP and MGAP to predict early mortality. Previous studies on TSSs focused principally on in-hospital mortality. The GAP was studied in this context and, although short-term mortality was mentioned, this did not meet our definition of early mortality, as it was defined in terms of mortality in the ED or the operating room rather than in terms of time.[9] One GAP validation study examined 24-hour mortality. However, the study included only patients with severe trauma; thus, not all trauma patients were included, and only 100 patients were evaluated.[27] We found that when the GAP was used to evaluate all trauma patients admitted to the ED, the GAP predicted 24-hour mortality.

Many trauma patients die as a result of bleeding. We found that the percentage of patients who died from uncontrolled bleeding after trauma accounted for 30% to 35% of mortality during the acute stage.[29] ATC develops during bleeding associated with tissue damage and resuscitation, and is caused by the consumption of coagulation factors and platelets, loss of red cells, blood dilution by fluid, hormonal and cytokine-induced changes, hypoxia, acidosis, hypothermia, and immune system activation.[4] Although trauma patients may die from direct bleeding, death is further accelerated by ATC caused by bleeding and other factors. Many studies have been published on ATC,[11,10,11] and have used various definitions of coagulopathy.[9] In the present study, we used INR and platelet count to reflect ATC because these parameters can be easily measured (within 30 minutes at our hospital). Both were risk factors for 24-hour mortality. Prothrombin time-based assays (e.g., INR) and activated partial thromboplastin time (aPTT) are standard laboratory tests for ATC.[6] However, both tests were developed to evaluate clotting factor deficiencies rather than the acquired coagulopathy associated with trauma. Therefore, these tests are inappropriate when measuring ATC. Some studies have used viscoelastic tests (thromboelastography and rotation thromboelastometry) in trauma settings.[20] However, no standard viscoelastic test for ATC is yet available and, unlike INR and aPTT tests, viscoelastic tests are not performed in all hospitals. INR is more sensitive than the aPTT test when used to detect traumatic coagulopathy disorders.[21] Other studies have also used INR to predict ATC.[22] Platelets are responsible for primary hemostasis. A low platelet count is a risk factor for mortality.[13] If ATC is promptly detected and treated, mortality can be reduced; active testing and treatment are needed. Previous research on the effect of ATC on early mortality has indicated that ATC increased such mortality.[20,25] but these studies did not explore whether ATC predicted mortality. We found that ATC predicted early mortality. To the best of our knowledge, this is the first study to use both ATC and TSSs to predict early trauma-related mortality.

The base deficit (BD) is a prognostic marker that has been widely used since the 1960s. Recent studies have confirmed that BD significantly predicts mortality in trauma patients, despite recent advances in such treatment.[21] A higher BD suggests severe traumatic injury[24,33] and is associated with complications, such as MOF, adult respiratory distress syndrome, acute lung injury, and renal failure coagulopathy.[36–38] We also found that BD significantly predicted 24-hour mortality. Automated blood gas analysis yields fast results, particularly on point-of-care testing in EDs, and is simple to perform. Saturation was a useful predictor of trauma mortality in an earlier study.[23] The RTS (a TTS) used respiratory rate (RR) as a predictive variable.[3] In trauma patients, the RR often fails to reflect ventilation or oxygenation status, as it is greatly affected by pain or psychological stress. Also, the normal range of RR is wide (10–29/minutes), and therefore the RTS may not accurately reflect actual ventilation or oxygenation.[39] In contrast, the objective SpO2 accurately reflects the ventilation/oxygenation status of trauma patients. We found that the RR did not predict 24-hour mortality, but saturation did.

Recent studies have evaluated trauma patient prognosis in terms of ED presentation time and found no difference in mortality between those admitted during business and non-business hours[5,14,40] because the medical resources available in hospitals with highly developed trauma systems do not vary significantly by the time of day. Such resources include 24-hour in-house surgeons and anesthesiologists and 24-hour emergency surgery/intervention suites. Our hospital is a tertiary care center for trauma patients, and we have access to such medical resources 24 hours a day. We found that presentation time did not affect mortality. Presentation time can affect ED waiting time or the incidence of adverse events, but in well-run hospitals, presentation time has no significant effect on early mortality after trauma.
In this study, the mortality rate was 4.7%, lower than that of other studies. This may be attributable to the exclusion of patients who were dead-on-arrival with or without attempted cardiopulmonary resuscitation. Also, we included those with mild trauma as well as those with serious trauma.

Our study had several limitations. First, the research was performed in a single center serving a Korean population only. Thus, this study may have a different age distribution and sex ratio than previous studies, and our results may not be completely applicable to all settings. Multicenter studies with different populations are required. Second, we did not include all of the clinical variables that could possibly affect trauma mortality, such as medical history, pre-hospital transfer time, or pre- or intra-hospital interventions. Third, the study was retrospective in nature. Hence, some data were missing, and the results may thus be compromised, despite our use of multiple imputation. Fourth, we enrolled only adults >16 years of age. Pediatric patients were excluded because they have unique physiological characteristics. In future, early mortality in pediatric patients should be studied.

Conclusion
The GAP, MGAP, SpO2, base excess, platelet count, and INR usefully predicted early mortality among trauma patients. The GAP model is simpler and more accurate than the MGAP model. We believe that our GAP-based model will be useful for early triage and appropriate initial management of trauma patients.

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Conflict of interest: None declared.

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