International comparison of prehospital trauma care systems

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Introduction

Prehospital care at the scene of injury and during transportation to a medical care facility is often provided by emergency medical service (EMS) systems and is the first step in managing the injured patient. Currently there are four different types of prehospital trauma care systems worldwide. In some environments, there is no organisation responsible for providing prehospital care to trauma patients. This is the pattern in most developing countries.39 Basic life support (BLS) EMS systems provide non-invasive supportive care to trauma patients. The major role of emergency medical technicians (EMTs) in these systems is to transport trauma patients rapidly to a medical care facility and to keep them alive during transport. Some developing countries and many small cities and rural areas in developed countries are served by this type of EMS system.39 Advanced life support (ALS) EMS systems provide more sophisticated care. In these systems, paramedics have intensive training programs for performing invasive procedures such as intubation and intravenous fluid therapy. In the most advanced form of prehospital trauma care (Doc-ALS EMS systems), physicians are responsible for providing prehospital care to trauma patients at the scene of injury and during transport. The primary goal of ALS and Doc-ALS EMS systems is to initiate the highest level of care at scene and during transport.

The gold standard for the evaluation of the effectiveness of different levels of prehospital trauma care is a randomised trial. These randomised trials would almost certainly have to be group-randomised, since the exposure of interest, i.e. types of EMS system, varies at the population level and not at the individual level.33 However, ethical concerns and resource and infrastructure limitations preclude such trials. Therefore, observational studies have primarily been used to compare patients’ outcome across different systems of prehospital trauma care. However, these studies often suffer from a number of limitations. First, patients within the catchment area of a particular trauma centre often receive prehospital care from a single EMS system. Therefore for an evaluation of the association between type of EMS and patients’ outcome, other settings/areas with different types of EMS systems should be used as controls.33 This issue requires researchers to design and conduct multicentre studies, taking into consideration the correlation of the observations within centres or systems.1,9–11,14,15,26,33 Second, multicentre studies that evaluate different aspects of trauma care often use the in-hospital trauma fatality rate as...
the main outcome of interest. However, this outcome may be heavily influenced by the quality of hospital care rather than prehospital interventions. Considering these limitations, and given the recent emphasis on developing prehospital trauma care globally, we embarked upon a multicentre study to compare trauma patients’ outcome across different countries. We sought to test the null hypothesis that patient outcomes do not differ materially between EMS systems. Any superiority of patient outcomes under Doc-ALS compared to ALS EMS systems might be expected to be more prominent for patients with more serious injuries that require higher level of care and more advanced procedures. Due to limited access to the information from countries with BLS EMS system, the focus of this study was on the comparison of the patients’ outcome between ALS and Doc-ALS EMS systems.

Methods

Source of data

De-identified patient-level data were obtained from regions in five countries with ALS EMS system and four countries with DOC-ALS EMS system. In order to protect countries’ identity, we refer to these countries as ALS1 to ALS5 and Doc-ALS1 to DOC-ALS4. The trauma registries within different regions had dissimilar inclusion criteria. Therefore, to render the mix of studied patients more comparable across regions, we restricted our analysis to criteria common to all registries. Thus the analyses were limited to patients 15—55 years old, with severe injuries (defined as injury severity score (ISS) > 15) and directly transported from the scene of injury to a definitive trauma care facility. This study was approved by the institutional review board or other relevant authorities from each participating country and of the University of Washington.

Patient descriptors

Baseline characteristics of subjects across the nine regions were age, gender, mechanism of injury, mode of transportation (ground ambulance, air ambulance, etc.), and whether the patient was transported directly from the scene to a centre providing definitive care or was transferred by means of another health care facility. Injury severity was evaluated using the injury severity score (ISS), Glasgow coma scale (GCS), and the presence of shock at the scene of injury (systolic blood pressure (SBP) < 90 mmHg). Prehospital information included vital signs at scene, prehospital time intervals and prehospital interventions (intravenous access and endotracheal intubation).

Outcomes of interest

We defined the emergency department (ED) shock rate (proportion of patients with SBP < 90 mmHg in the ED) and early trauma fatality rate (i.e. death during the first 24 h after hospital arrival) as the outcomes of interest, since they may be mainly influenced by the severity of injury and quality of prehospital care rather than the quality of hospital interventions.

Power calculation

For the calculation of power, we used a formula for clustered studies (Appendix A). It is comprised of two factors, the standard sample size calculation and a “design effect” or “variance inflation factor”. The design effect depends on the average number of subjects per cluster and the intracluster correlation coefficient (ICC) for the outcomes of interest. An estimate of the ICC came from a separate analysis of patient outcome data from trauma systems in the US. Considering an estimated frequency of ED shock in ALS EMS systems of 20%, an ICC of shock 0.0098 and an average of 1000 subjects per cluster, we estimated that our study had approximately 90% power for detecting an 8% absolute difference in the rate of shock between ALS and Doc-ALS EMS systems.

Data analysis

We used generalised linear latent and mixed models (GLLAMM) to estimate the odds ratios for the outcomes of interest comparing ALS EMS (reference group) with Doc-ALS EMS system, adjusting for age, sex, type and mechanism of injury, ISS and SBP at scene. Since the exposure of interest (i.e. type of EMS system) varied only at the country level and not at the individual level, we only included random intercept and not random slope to the GLLAMM model. To evaluate the hypothesis that any superiority of Doc-ALS over ALS would be most prominent for more severely injured patients, we conducted a sub-analysis that evaluated the association between type of
EMS and patients’ outcome among patients with ISS > 25 using the GLLAMM model. Due to the differences in registry protocols, patients who were dead-on-arrival (DOA) might be under-represented in a particular database. In order to evaluate the potential influence that this difference in inclusion criteria might have had on our estimates, we conducted two other sub-analyses. First, we limited analyses to patients with a detectable blood pressure at the scene of injury. Later, we implemented the same approach focusing on subjects with a detectable blood pressure at the time of ED arrival.

For the second approach, we compared ED shock and early trauma fatality among different countries, using logistic regression analysis. In this approach we treated "country" as a fixed effect variable and evaluated the heterogeneity in outcomes of interest within the countries with similar type of EMS system. We adjusted the results for patient age, sex, mechanism and type of injury, injury severity score and SBP at scene as potential confounding or precision variables. Doc-ALS3 had the largest sample size in our study. Therefore, we used this country as the baseline for calculation of odds ratios for ED shock and early trauma fatality in logistic regression models. This approach allowed us to estimate the ORs more precisely (i.e. with the narrowest possible confidence intervals). Finally, in order to quantify within and between region variability in the outcomes of interest, we estimated the intracluster correlation coefficient (ICC) of ED shock and early trauma fatality rate for ALS and Doc-ALS EMS systems.

One of the obstacles in using trauma registries is the issue of missing data. Table 1 reflects the proportion of missing values for the main variables. Our evaluations showed that missing pattern was not completely at random (data not presented). It has been shown that when missingness is not completely at random, using complete case analysis could lead to biased estimates. Therefore, we used multiple imputation (MI) using predictive mean matching in order to deal with these missing data. Special emphasis was placed on the imputation of systolic blood pressure at the scene and at ED. The proportion of missing SBP at scene varied from 0% in ALS5 database to 58% in Doc-ALS2. We conducted 10 imputations. Since different datasets had different characteristics that could qualify for inclusion in the MI model by the above criteria, each dataset was imputed separately and then the datasets were combined.

We included the following variables in the MI model: (a) variables that were used in the final analysis that compared patients’ outcome across ALS and Doc-ALS EMS systems: age, sex, mechanism and type of injury, injury severity score, type of EMS, SBP at scene and at ED and death during the first 24 h of hospital arrival; (b) variables that potentially influenced the occurrence of missing data: mode of transportation (i.e. ground ambulance, air ambulance, etc.) and prehospital time intervals; and (c) variables that were correlated with SBP: length of hospital stay, ICU admission and prehospital and hospital interventions. We used the ICE command written by Royston for STATA (STATA Corporation, College Station, Texas) in order to implement the multiple imputation process. Each imputed dataset was analysed separately. The results were averaged and calculation of the standard errors was based on Rubin’s formula.

**Results**

The mean age of the patients varied from 30 years in ALS2 to 35 years in Doc-ALS1. Men comprised 75% (Doc-ALS1) to 82% (Doc-ALS4) of the patients.

### Table 1 Proportion of missing data for the main variables

<table>
<thead>
<tr>
<th>Country</th>
<th>Age</th>
<th>Sex</th>
<th>Type of injury</th>
<th>Mechanism</th>
<th>ISS</th>
<th>SBP (scene)</th>
<th>SBP (ED)</th>
<th>Outcome</th>
<th>LOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALS1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>16</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>ALS2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>18</td>
<td>4</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>ALS3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>52</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>ALS4</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>52</td>
<td>26</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>ALS5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Doc-ALS1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>25</td>
<td>10</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Doc-ALS2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>58</td>
<td>7</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Doc-ALS3</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>15</td>
<td>22</td>
<td>8</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>Doc-ALS4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>29</td>
<td>6</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

* Injury severity score.
  * Systolic blood pressure.
  * Emergency department.
  * Length of stay.
Shock at the scene was more common in Doc-ALS2 (27%), Doc-ALS1 (21%) and ALS3 (21%). DOC-ALS3 (32/C6), DOC-ALS2 (30/C6) and Doc-ALS3 (30/C6) reported the highest mean ISS (Table 2).

The results of the GLLAMM model showed that after adjustment for patient age, sex, type and mechanism of injury, ISS and SBP at scene, the observed difference in ED shock rate (OR: 1.16, 95% CI: 0.73—1.91) did not reach a statistically significant level. However, early trauma fatality was less common in Doc-ALS EMS systems compared with ALS EMS systems (OR: 0.70, 95% CI: 0.54—0.91).

Changes in the ORs after restricting the analyses to patients with more severe injuries (ISS > 25) and detectable SBP at scene or at ED have been summarised in Table 3. This shows that the OR for mortality decreased even further with Doc-ALS compared with ALS for more severe injuries. This pattern pertained whether or not analysis was restricted to detectable SBP.

Fig. 1a and b demonstrate the adjusted results of between-countries comparison of outcomes, modeling "country" as a fixed-effect variable in the logistic regression model. As presented, there is a considerable heterogeneity in outcomes of interest even among countries with similar type of EMS system. In order to quantify the heterogeneity in outcomes of interest within and between countries with similar type of EMS system, we calculated the ICC of ED shock and early trauma fatality rate. The ICCs of ED shock for ALS and Doc-ALS EMS systems were 0.007 (95% CI: 0.000—0.018) and 0.013 (0.000—0.038), respectively. The ICCs for early trauma fatality rate were 0.019 (95% CI: 0.000—0.049) for ALS and 0.036 (95% CI: 0.000—0.101) for Doc-ALS EMS systems.

### Discussion

Our report is the first study that aims at a comparison of patients’ outcome within and between ALS and Doc-ALS EMS systems using a broad sample of such systems. The following characteristics differentiate this study from prior related reports. First, we used ED shock and early trauma fatality rate, and not in-hospital trauma fatality rate, as the outcomes of interest. As previously mentioned, the rationale behind this decision was the potential dependency of late hospital trauma fatality on the quality of hospital care rather than prehospital care. Ideally, even earlier assessment of mortality status (within the first hour of ED arrival) would provide greater insight into prehospital care. Unfortunately, trauma registries do not record the time of death with this degree of resolution. Second, when an EMS system adopts a particular model of care (i.e. ALS or Doc-ALS) almost all of the patients within the jurisdiction of that EMS receive that level of care if required. For example, in 1990, 98.5% of the 200 largest cities in the US had ALS EMS system. In 82% of these cities, ALS units were present at all dispatches. To address the possible consequences of this policy decision, we considered type of EMS as a system-level varying exposure of interest. Accordingly, we designed a clustered study, taking into consideration the correlation of observations within each cluster.

### Table 2 Measurements of injury severity

<table>
<thead>
<tr>
<th></th>
<th>Shock at scene (%)</th>
<th>ISS&lt;sup&gt;a&lt;/sup&gt; (mean ± S.D.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALS1</td>
<td>18</td>
<td>26 ± 11</td>
</tr>
<tr>
<td>ALS2</td>
<td>17</td>
<td>24 ± 9</td>
</tr>
<tr>
<td>ALS3</td>
<td>21</td>
<td>25 ± 11</td>
</tr>
<tr>
<td>ALS4</td>
<td>10</td>
<td>26 ± 10</td>
</tr>
<tr>
<td>ALS5</td>
<td>17</td>
<td>27 ± 13</td>
</tr>
<tr>
<td>Doc-ALS1</td>
<td>21</td>
<td>26 ± 10</td>
</tr>
<tr>
<td>Doc-ALS2</td>
<td>27</td>
<td>30 ± 13</td>
</tr>
<tr>
<td>Doc-ALS3</td>
<td>17</td>
<td>32 ± 13</td>
</tr>
<tr>
<td>Doc-ALS4</td>
<td>20</td>
<td>30 ± 13</td>
</tr>
</tbody>
</table>

Systolic blood pressure < 90 mmHg.

<sup>a</sup> Injury severity score.

### Table 3 Adjusted<sup>a</sup> odds ratios of ED shock and early trauma fatality rate, comparing Doc-ALS with ALS EMS system (baseline group) for different levels of injury severity and SBP at scene and at ED

<table>
<thead>
<tr>
<th></th>
<th>OR of ED shock&lt;sup&gt;b&lt;/sup&gt;</th>
<th>OR of early trauma fatality&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ISS &gt; 15 ISS &gt; 25</td>
<td>ISS &gt; 15 ISS &gt; 25</td>
</tr>
<tr>
<td>All patients, regardless of their SBP at scene or at ED</td>
<td>1.18 (0.73—1.92) 1.00 (0.72—1.39)</td>
<td>0.70 (0.54—0.91) 0.57 (0.42—0.77)</td>
</tr>
<tr>
<td>Patients with detectable SBP at scene</td>
<td>1.09 (0.82—1.43) 1.00 (0.71—1.41)</td>
<td>0.64 (0.49—0.85) 0.55 (0.40—0.75)</td>
</tr>
<tr>
<td>Patients with detectable SBP at ED</td>
<td>1.03 (0.76—1.46) 1.00 (0.68—1.45)</td>
<td>0.61 (0.46—0.80) 0.53 (0.39—0.73)</td>
</tr>
</tbody>
</table>

<sup>a</sup> Adjusted for age, sex, type and mechanism of injury, injury severity score and SBP at scene.

<sup>b</sup> Comparing Doc-ALS EMS system to ALS (reference group).
To date several studies have evaluated the association between type of prehospital care and patients’ outcome and systematic reviews have nicely summarised the results of those studies.7,23,25 These reports have concluded that the evidence supporting advanced prehospital trauma care is lacking. However, almost all of these studies treated prehospital care (i.e. ALS or BLS) as a patient-level varying exposure and used hospital trauma fatality as the main outcome of interest. Furthermore, with the exception of a single study,24 no comparison between ALS and Doc-ALS EMS systems has been published. Liberman and his colleagues compared Doc-ALS EMS system in Montreal with ALS EMS system in Toronto.24 They reported that after adjustment for age, injured body region, mechanism of injury and ISS, being treated in the Doc-ALS EMS system was not associated with a reduction in risk of in-hospital death (OR: 1.14, 95% CI: 0.97—1.33).24

We observed considerable heterogeneity in both outcomes even among countries with similar type of EMS system. Nonetheless, while the observed differences in ED shock rate in our study did not reach a statistically significant level, early trauma fatality was significantly less common in Doc-ALS EMS systems. Unfortunately our current data do not allow us to identify those characteristics of Doc-ALS EMS systems that have been associated with lower early trauma fatality rate. However, the magnitude of difference in trauma fatality rate among different countries even with similar types of EMS system was much higher than that can be explained only by the differences in the quality of prehospital care.

The differences in mortality between EMS systems may represent a real difference in outcome. However, several measurement issues might also account for the perceived differences. For example, there are differences in registry and EMS protocols in dealing with dead at scene, dead-on-arrival (DOA) and death during the first few minutes after hospital arrival.13 Some trauma registries might not record DOA into their databases which can lead to underestimation of the trauma fatality rate. Pronouncement of death at scene or en route might also vary from system to system. For example, while physicians are qualified to announce a patient “dead en route”, EMTs might require a physician’s approval for such a pronouncement. Under these circumstances, “dead en route” subjects might be counted as ED fatalities in an ALS EMS system and as DOA in a Doc-ALS EMS system. Deaths before an adequate survey of injuries might also impact estimation of the ISS, leading to a potential for bias in the types of patients included in the two types of systems’ registries.

By the same token, these differences in inclusion—exclusion criteria might influence ED shock rate estimation. However, since only a fraction of patients with shock at ED die during the first few minutes after ED arrival, the magnitude of bias using ED shock as the outcome might be significantly lower.

There are some potential limitations to this analysis. First, apart from the number of subjects, the
power of a clustered study is highly dependent on the number of regions or clusters. The small number of the regions restricted our ability to detect small but clinically important differences in distribution of ED shock rate between ALS and Doc-ALS EMS systems, if in reality such differences exist. Second, establishment of comprehensive trauma registries requires long term planning and sufficient financial support. This need can explain why all the collaborating countries in this research project are high income countries with more advanced EMS systems, while no countries with BLS EMS system were represented. Third, although multiple imputation is currently a preferred method for dealing with missing information, it cannot remove all of the uncertainty resulting from the missing data. The method thus yields larger standard deviations and wider confidence intervals than would be expected if there were no missing data. Finally, there were potential differences in registry protocol across countries and EMS systems. In spite of these limitations, our study provided a reasonable basis for comparison of patient outcomes within and between EMS systems.

Our findings raise a few important issues. First, there is significant heterogeneity even within a particular type of EMS system. Therefore the ability to generalise across EMS systems is somewhat limited. Second (and closely related), calculation of the ICCs especially for early trauma fatality rate showed a substantial correlation of observations within countries with the same type of EMS system. These large ICCs should be incorporated in sample size calculation of international multicentre studies that use trauma fatality as the main outcome of interest. Third, due to potential differences in registry protocols, study populations should be as comparable as possible. Prospective multicentre studies that follow similar data collection protocols and use uniform inclusion criteria might be the best approach for this purpose.13

Conflicts of interest

None of the authors has any conflict of interest with this research project.

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Appendix A

\[
\begin{align*}
    n &= \frac{(Z_{\alpha/2} + Z_{\beta})^2 [P_1 (1 - P_1) + P_2 (1 - P_2)]}{(P_1 - P_2)^2} \\
    &\times \left[1 + \left(m_0 - 1\right) \times ICC\right] \\
\end{align*}
\]

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3. American College of Surgeons-Committee on Trauma. Resources for optimal care of the injured patients; 1999.


