Spectrum of Trauma Care in the State of Ohio: Assessment and Improvement of Quality of Care

ANNUAL PROJECT REPORT

Submitted to

Division of Emergency Medical Services (EMS)
Ohio Department of Public Safety (ODPS)

Submitted by

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Original: December 31, 2015
Revised: January 5, 2017

A manuscript with the most recent analysis can be requested from the PI.
Executive Summary

The trauma triage system in the state of Ohio has not quite achieved their objectives of care access and delivery. This has prevented the growth and improvement of the current system beyond its present status. The primary objective of this research was to contribute to the state of Ohio’s goals of improving trauma system by focusing on two key aims: (i) identifying over- and under-triage percentages and study both clinical and system factors that may be affecting these percentages, and (ii) deriving a statistical model and compare it with the current system and that of the National Field Triage Decision Scheme.

Our multidisciplinary team of medical and engineering researchers analyzed nearly 35,631 patient records from the 2008-12 data available from the ODPS that comprised of both EMSIRS and Trauma Registry data elements for each patient record. Over- and under-triage errors were calculated using the Injury Severity Score (ISS) method where over-triage (OT) was defined as the proportion of patients with ISS ≤15 and were transported to a Level I/II trauma center. Similarly, under-triage (UT) was defined as the proportion of patients with ISS >15 and were transported to a Level 3/Non-trauma center (NTC).

Key findings from our study included the following. First, the mean over-triage (OT) and under-triage (UT) percentages across all 5 years were 43.03% and 3.06%; these percentages were stable year-to-year. It is essential to note that according to national trauma guidelines, the accepted range for over-triage is from 25-35%. The average over-triage percentage observed for the state of Ohio for 5-year period, however, was significantly higher than that. Second, the over- and under-triage errors showed specific patterns per regions. For instance, regions 7 and 8 experienced the highest percentages of UT and nearly zero OT. This might be due to the placement of trauma centers. If there are no L1/L2 trauma centers nearby these regions, then all trauma patients would have to be sent to the nearest non-trauma facilities. Similarly, regions 2 and 5 experienced the least UT errors and the highest OT errors probably due to the availability of large number of trauma centers. Thus,
placement of trauma centers could potentially affect quality, care access, and resource utilization in any trauma system. Third, the average mortality percentage for 5-year period was 5.1%; nearly 0.52% of under-triaged and 0.81% of over-triaged patients died. Fourth, system level factors such as patient/family preference, proximity of hospital, and protocol were the top three reasons for triage decisions. Fifth, while blunt injury type was associated with higher triage errors (both OT and UT), an increase in patient’s age appeared highly correlated with the patient’s preference for a hospital type. Finally, the statistical model derived from EMSIRS 2, protocol only, dataset of 817 patients revealed significant factors that may be affecting triage decisions. Although it achieved nearly same levels of UT and OT percentages, it can be viewed as a standardized approach compared to the current decentralized, non-standardized, approach adopted by EMS providers in the state; the model.

In summary, our study addresses several concerns related to on-field trauma triage currently under review within the state of Ohio. Our findings suggest that trauma care in the state of Ohio could be improved further by reducing the triage errors and resource utilization. Further, the study also proposed a statistical model to help standardize the trauma triage in the state. We strongly believe that our findings would help the state of Ohio in achieving their goal of providing a “Framework for Improving Ohio’s Trauma System” that was included in the Ohio EMS 2015 Strategic Plan.
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1. **Investigators**

**Priti Parikh, PhD (Role PI):** Priti Parikh serves as a Research Director and faculty in the Department of Surgery at WSU. She has significant experience in healthcare systems and informatics areas where she has worked on predicting discharge disposition at a point of admission of trauma patients, system analysis of surgical operations, and developing ontologies to answer critical questions. She has over 15 peer-reviewed articles with many presentations and talks at national and international conferences.

**Melissa Whitmill, MD (Role, co-PI):** Melissa Whitmill has been a trauma and critical care surgeon for the past 6 years. Additionally she is currently a Medical Director of the Surgical Intensive Care Unit at Miami Valley Hospital. In these roles, she has been involved in the entire spectrum of patient care, including pre-hospital care, hospital care, and rehabilitation.

**Randy Woods, MD (Role, co-PI):** Randy Woods is a trauma surgeon and researcher for more than 15 years. As a trauma surgeon, he has expertise about the prehospital setting, to include inpatient care through rehabilitation. He is a fellow of the American College of Surgeons (ACS), and served as President of the Ohio Chapter of the ACS and also elected as a Governor to the ACS. He is an active researcher and has many peer-reviewed papers and publications.

**Kimberly Hendershot, MD (Role, co-PI):** Kimberly Hendershot has an active practice in the fields of trauma surgery, emergency general surgery, and surgical intensive care for the past 7 years. During that time, she has been involved in the entire spectrum of care for the injured patient, from injury prevention to pre-hospital care to hospital care to rehabilitation.

**Pratik J. Parikh, PhD (Role, co-PI):** For over 6 years, Pratik Parikh and his team have focused on exploring the interdependencies between various healthcare subsystems and identifying alternate methods to improve the system performance. He has been PI and/or Co-PI on federal and industry grants and has over 25 peer-reviewed journal and conference articles.
2. **Study Rationale and Objectives**

The primary objective of this research is to contribute to the state of Ohio’s goals of improving the trauma system. Specifically, we plan to focus on the entire spectrum of trauma care through the study of care access, quality, and safety experienced by a trauma patient. The optimal triage of trauma patients has been the source of vigorous debate over the years. In the state of Ohio, the trauma system has experienced less-than-desirable goals towards improving trauma patient care and there has been no apparent decrease in potentially preventable deaths since 1999. These issues may likely be due to inefficient and/or poorly-defined triage regulations [6].

‘Over-triage’ (i.e., transporting less injured patients to major trauma centers, such as a Level I or II center) and ‘under-triage’ (i.e., transporting severely injured patients to a Level III or non-trauma center (NTC)) errors pose significant problems to any trauma system. As per Ohio’s 2013 Trauma System Consultation Report “no knowledge exists regarding over- and under-triage percentages and issues” for the state [1]. While clinical factors (e.g., patient’s physiologic factors on scene, type of injuries) should determine the triage decision, often system-level factors (e.g., patient’s choice, proximity to a trauma center) and non-physiologic factors (e.g., mechanism of injury alone) affect the EMS decision to transfer a patient from the scene to a hospital. Such limitations within the current system have significantly affected performance and statewide resource utilization. In response, the state of Ohio included “Framework for Improving Ohio’s Trauma System” as one of the goals of the Ohio *EMS 2015 Strategic Plan* [1]. Our research agenda was to contribute to these goals.

3. **Specific Aims**

Following are the specific aims that we identified and planned in the original proposal:

- **Aim 1: Study over- and under-triage percentages.** Using the state level trauma and emergency medical services (EMS) data from Ohio Department of Public Safety (ODPS), we will study pre-hospital over- and under-triage percentages for the state of Ohio and also reveal a trend over the last 5 years. This will enable us to identify both clinical- and system-level factors
contributing to over- and under-triage in the state of Ohio.

- **Aim 2: Develop and validate a new triage model.** We plan to utilize the information that is readily available to EMS providers in the field (such as Glasgow Coma Scale, blood pressure, respiratory percentage, mechanism of injury, and/or anatomical factors) to develop a novel statistical model to accurately triage a trauma patient in the field.

4. **Significance**

The question regarding trauma triage and system utilization is a complex problem that the current literature does not address effectively [8]. Trauma care is the second highest contributor to total U.S. health care spending with an estimated cost of more than $163 billion (in 2008 dollars), which represents approximately 10% of the total US medical expenditures [5, 11]. The over- and under-triage percentages play a significant role in trauma care costs. Therefore, more efficiently matching patients’ needs to hospitals’ resources and capabilities is vital if the value of a trauma system is to be improved. Recently, Newgard and others observed a 34.4% over-triage percentage across 7 regions (94 EMS, 122 hospitals, and 301,214 patients) and suggested that improved triage methods could save up to $136.7 million annually [5]. Furthermore, researchers have also studied secondary over-triage; i.e., the phenomenon where a patient is discharged home shortly after transfer from another hospital. The secondary over-triage percentages also help assess the quality and efficiency of trauma care and resource utilization [7].

Development of triage methods in the trauma system, however, remains a difficult problem for most states. The trauma system in the state of Ohio was created following an exclusive design where trauma centers could provide access within one hour for 99% of the population and 98% of the state’s geographic area. However, it has not achieved the desired goals of care, likely due to inefficient pre-hospital triage guidelines. The annual case-fatality percentage, since 1999, has been 4.2% with no decrease in potentially preventable deaths [6]. The state law requires that all severely injured patients be transported to a designated trauma center. Since the term ‘severely injured’ is not
defined uniformly by trauma centers, a significant number of injured patients are actually transported to Level III or non-trauma centers. No knowledge, however, exists about pre-hospital over- and under-triage percentages, issues, and resource utilization for the state of Ohio [1]. Such limitations within the current trauma system in the state of Ohio have prevented it from growing and improving beyond its present status.

Previous studies have shown that improved triage methods are required to enhance trauma patient care and resource utilization. A variety of methods and scores exist in the current literature for triaging trauma patients, such as Trauma Score (TS), Revised Trauma Score (rTS), Baxt Trauma Triage Rule (TTR), CRAMS (Circulation, Respiration, Abdomen, Motor, Speech) scale, and Glasgow Coma Score (GCS) [8]. Moreover, many studies have also focused on using various physiologic, anatomic, mechanistic, and/or demographic factors for triaging trauma patients. However, they all suggest that for field triage a combination of different factors and scores should be used to achieve the highest sensitivity (i.e., proportion of high severity trauma patients identified as such) and specificity (i.e., proportion of low severity trauma patients identified as such) [2-4]. Some ‘mistriage’ is, nevertheless, unavoidable as it depends not only on clinical factors, but also on system-level factors (e.g., patient’s choice, proximity to a trauma center). The latter sometimes plays a key role in triaging patients on the field. Thus, there is clearly a gap in the current literature on an optimal solution to this very complex problem.

5. Approach

As a part of the proposal, we received 2008-2012 data (both EMSIRS 1 and 2 merged with Trauma Registry) from ODPS, which accounted to 40,819 patient records. Figure 1 shows the collaborative approach and responsibilities of each investigator for the project. The WSU investigators had several teleconferences with ODPS personnel (Mr. Tim Erskine and Mr. Schuyler Schmidt) to understand the data collection/extraction process. Based on these discussions, we excluded some of the patient records that did not have values of Injury Severity Scores (ISS). Table
1 shows the number of records removed per year. The total number of patient records finally included in our analysis of the 2008-2012 dataset was 35,631 for EMSIRS 1 and 2. We estimated % under-triage as the percentage of patients under-triaged out of the total number of patients evaluated at the scene. Similarly, % over-triage was estimated as the percentage of patients over-triaged out of the total number of patients.

Table 1. Number of patients removed per year (removal criteria: ISS=99)

<table>
<thead>
<tr>
<th>Year</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total  (EMSIRS 1 + 2)</td>
<td>8881</td>
<td>8293</td>
<td>8065</td>
<td>7405</td>
<td>8175</td>
</tr>
<tr>
<td># removed</td>
<td>1305</td>
<td>1152</td>
<td>851</td>
<td>854</td>
<td>1026</td>
</tr>
<tr>
<td>Final  (EMSIRS 1 + 2)</td>
<td>7576</td>
<td>7141</td>
<td>7214</td>
<td>6551</td>
<td>7149</td>
</tr>
</tbody>
</table>

6. Results

We organize the key findings from our analysis of this data corresponding to each aim. Additional findings can be found in the appendix at the end of this report.
6.1 Aim 1a: Study the trauma triage and other trends

We studied the trauma triage trend by years and by county. We observed that the total triage numbers (Y-axis on the right) decreased from 2008 to 2012 (Figure 2). The percentages of over- and under-triage (Y-axis on the left), however, appeared fairly stable over the years. We also studied the mortality and found that average mortality percentage for 5-year period was 5.1% (Figure 3). As shown in Figure 4, in 2012 overall 4.8% patients died. Moreover, 0.52% of under-triaged and 0.81% of over-triaged patients died. Trauma triage trend by county showed that the top three counties that had the highest total triages were (i) Montgomery, (ii) Hamilton, and (iii) Summit (Figure 4).

![Figure 2: Annual trend of the number of total and Over/Under triages (EMSIRS 1+2)](image-url)
Figure 3: Annual trend of % mortality of trauma patients (EMSIRS 1+2)

N=35182

Figure 4: Total triages by county

Note: County names and exact values associated with the X-axis in the graph are below.
6.2 Aim 1b: Study pre-hospital over- and under-triage percentages

For the datasets, we studied over- and under-triage percentages for 2008-2012. We used the ISS method to calculate over- and under-triage. For example, patients who had ISS<16, but taken to Trauma Level 1/2 Center were considered as over-triage patients. On the other hand, patients who had ISS≥16, but were taken to Trauma Level 3/NTC were considered as under-triage patients.

**Table 2: Triage of all patients (EMSIRS 1+2, N=35,631)**

*Ideal hospital-type from scene*

<table>
<thead>
<tr>
<th>Actual hospital-type from scene</th>
<th>L1/L2</th>
<th>L3/NTC</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1/L2</td>
<td>Correct (4501) 12.63%</td>
<td>Over-Triage (15331) 43.03%</td>
</tr>
<tr>
<td>L3/NTC</td>
<td>Under-Triage (1092) 3.06%</td>
<td>Correct (14707) 41.28%</td>
</tr>
</tbody>
</table>
Our analysis of the 2008-2012 dataset indicates the following:

- The over- and under-triage percentages in the EMSIRS 1 and 2 dataset for all the patients were 43.03% \( (15,331/35,631) \) and 3.06% \( (1,092/35,631) \), respectively (Table 2).
- The homeland security regions with high %-UT seem to have low %-OT, and vice versa (Figure 5).
- The top three counties with the highest under-triage percentages are: (i) Wyandot (31.9%), (ii) Guernsey (22.1%), and (iii) Holmes (19.9%) (Figure 6).
- There were several counties, such as Hancock, Madison, Mahoning, Richland, and Tuscarawas that had 100% over-triage percentages (Figure 7). Other counties with high OT included: (i) Coshocton (89.3%), (ii) Allen (83.5%), and (iii) Portage (83.3%).
- OT and UT percentages are not related to patient’s age. The percentage remains stable when stratified through patient’s age (Figure 7).

![Figure 5: Under- and Over-Triage numbers and percentages for each of the 8 homeland security regions](image-url)
Number of UT by Region

<table>
<thead>
<tr>
<th>Year</th>
<th>Region 1</th>
<th>Region 2</th>
<th>Region 3</th>
<th>Region 4</th>
<th>Region 5</th>
<th>Region 6</th>
<th>Region 7</th>
<th>Region 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>42</td>
<td>12</td>
<td>26</td>
<td>37</td>
<td>34</td>
<td>56</td>
<td>1</td>
<td>23</td>
</tr>
<tr>
<td>2009</td>
<td>20</td>
<td>17</td>
<td>15</td>
<td>42</td>
<td>34</td>
<td>39</td>
<td>4</td>
<td>32</td>
</tr>
<tr>
<td>2010</td>
<td>22</td>
<td>15</td>
<td>35</td>
<td>28</td>
<td>23</td>
<td>50</td>
<td>4</td>
<td>37</td>
</tr>
<tr>
<td>2011</td>
<td>29</td>
<td>12</td>
<td>39</td>
<td>39</td>
<td>16</td>
<td>35</td>
<td>4</td>
<td>54</td>
</tr>
<tr>
<td>2012</td>
<td>29</td>
<td>5</td>
<td>50</td>
<td>32</td>
<td>25</td>
<td>49</td>
<td>7</td>
<td>19</td>
</tr>
</tbody>
</table>

Percentage of UT by Region

<table>
<thead>
<tr>
<th>Year</th>
<th>Region 1</th>
<th>Region 2</th>
<th>Region 3</th>
<th>Region 4</th>
<th>Region 5</th>
<th>Region 6</th>
<th>Region 7</th>
<th>Region 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>4.92</td>
<td>1.45</td>
<td>2.13</td>
<td>3.27</td>
<td>1.87</td>
<td>4.06</td>
<td>1.20</td>
<td>8.75</td>
</tr>
<tr>
<td>2009</td>
<td>2.40</td>
<td>2.05</td>
<td>1.39</td>
<td>4.15</td>
<td>1.75</td>
<td>3.46</td>
<td>5.71</td>
<td>12.80</td>
</tr>
<tr>
<td>2010</td>
<td>2.50</td>
<td>1.58</td>
<td>2.81</td>
<td>3.06</td>
<td>1.31</td>
<td>4.58</td>
<td>4.21</td>
<td>12.98</td>
</tr>
<tr>
<td>2011</td>
<td>3.73</td>
<td>1.29</td>
<td>3.36</td>
<td>4.85</td>
<td>1.13</td>
<td>3.26</td>
<td>4.26</td>
<td>17.94</td>
</tr>
<tr>
<td>2012</td>
<td>3.91</td>
<td>0.73</td>
<td>3.72</td>
<td>2.76</td>
<td>1.47</td>
<td>4.00</td>
<td>7.53</td>
<td>9.55</td>
</tr>
</tbody>
</table>

Number of OT by Region

<table>
<thead>
<tr>
<th>Year</th>
<th>Region 1</th>
<th>Region 2</th>
<th>Region 3</th>
<th>Region 4</th>
<th>Region 5</th>
<th>Region 6</th>
<th>Region 7</th>
<th>Region 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>288</td>
<td>437</td>
<td>484</td>
<td>504</td>
<td>1133</td>
<td>386</td>
<td>22</td>
<td>21</td>
</tr>
<tr>
<td>2009</td>
<td>302</td>
<td>463</td>
<td>498</td>
<td>360</td>
<td>1207</td>
<td>285</td>
<td>20</td>
<td>7</td>
</tr>
<tr>
<td>2010</td>
<td>335</td>
<td>572</td>
<td>494</td>
<td>359</td>
<td>1102</td>
<td>191</td>
<td>23</td>
<td>6</td>
</tr>
<tr>
<td>2011</td>
<td>296</td>
<td>495</td>
<td>467</td>
<td>294</td>
<td>860</td>
<td>247</td>
<td>22</td>
<td>6</td>
</tr>
<tr>
<td>2012</td>
<td>215</td>
<td>364</td>
<td>590</td>
<td>569</td>
<td>1005</td>
<td>382</td>
<td>19</td>
<td>1</td>
</tr>
</tbody>
</table>

Percentage of OT by Region

<table>
<thead>
<tr>
<th>Year</th>
<th>Region 1</th>
<th>Region 2</th>
<th>Region 3</th>
<th>Region 4</th>
<th>Region 5</th>
<th>Region 6</th>
<th>Region 7</th>
<th>Region 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>33.72</td>
<td>52.65</td>
<td>39.70</td>
<td>44.48</td>
<td>62.39</td>
<td>28.01</td>
<td>26.51</td>
<td>7.98</td>
</tr>
<tr>
<td>2009</td>
<td>36.30</td>
<td>55.78</td>
<td>46.20</td>
<td>35.61</td>
<td>62.12</td>
<td>25.29</td>
<td>28.57</td>
<td>2.80</td>
</tr>
<tr>
<td>2010</td>
<td>38.11</td>
<td>60.27</td>
<td>39.65</td>
<td>39.23</td>
<td>62.83</td>
<td>17.51</td>
<td>24.21</td>
<td>2.11</td>
</tr>
<tr>
<td>2011</td>
<td>38.05</td>
<td>53.28</td>
<td>40.29</td>
<td>36.57</td>
<td>60.82</td>
<td>23.04</td>
<td>23.40</td>
<td>1.99</td>
</tr>
<tr>
<td>2012</td>
<td>29.01</td>
<td>52.98</td>
<td>43.93</td>
<td>49.01</td>
<td>59.12</td>
<td>31.18</td>
<td>20.43</td>
<td>0.50</td>
</tr>
</tbody>
</table>
Figure 6: Under-Triage percentages by county and year (see Appendix A)

Figure 7: Over-Triage percentages by county and year (see Appendix A)
Factors affecting triage decisions: We found that the top three reasons for high over-triage percentage were (i) patient’s preference, (ii) proximity, and (iii) triage protocol (Figure 9). Patient’s or family preference accounted for approximately 45% of over-triages. Similarly, for under-triage errors, the top reasons were (i) proximity, (ii) patient’s preference, and (iii) triage protocol (Figure 10). When we analyzed the data based on injury type, we observed that blunt injuries are primarily associated with triage errors (Figure 11). Moreover, when stratified through age, we observed that patient’s preference percentage increases with age (Figure 8).
6.3 Aim 2: Investigate the development of a new trauma triage model

As mentioned above, the primary reason for triage errors was either patient/family choice or proximity to the accident site. Since these reasons were at the system level and so could not be controlled in developing new models, we extracted data of patients who were triaged based on protocol and used those for modeling. Specifically, we used EMSIRS2, 2008-12, “protocol-only” records. A final set of 817 patient records were obtained after excluding records with missing values and 2nd transfers. Using this dataset, we accomplished this aim in the following way:

- **Step 1:** Identify the UT and OT percentages based on these data; we refer to them as “Actual.”
- **Step 2:** We then used the Field Triage Decision Scheme – The National Trauma Triage Protocol
(proposed in 2006 by the American College of Surgeons-Committee on Trauma and the National Highway Traffic Safety Administration) [9,10] to evaluate its applicability to this dataset. The idea was to judge whether or not the “NFTDS” would have yielded better outcomes (UT and OT percentages) if it were used since 2008.

- **Step 3:** Finally, we built a new logistic regression based model using the train-test methodology, and compared the outcomes from this model with the “Actual” and “NFTDS” approaches.

Below we describe each of these steps in appropriate detail.

### 6.3.1. UT and OT percentages based on “Actual”

While we were told that there is no standardized protocol that EMS providers follow in the State of Ohio, each region seems to have their own version for triaging trauma patients on the scene. After correspondence with the ODPS-EMS personnel, we realized that it would be nearly impossible for us to decipher the actual decision making process even for the 817 records that indicated “protocol” as the criterion. With that understanding, we went ahead and used the process of identifying the UT and OT in the manner consistent with the previous sections. That is, we used the ISS score of $\geq 16$ to indicate severe injuries and destined to L1/L2 versus $\leq 15$ as more appropriate for L3/NTC. The following table indicates the UT and OT percentages.

<table>
<thead>
<tr>
<th></th>
<th>% UT</th>
<th>% OT</th>
<th>% Correct (L1/L2)</th>
<th>% Correct (L3/NTC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual</td>
<td>4.04</td>
<td>38.31</td>
<td>22.15</td>
<td>35.5</td>
</tr>
</tbody>
</table>

### 6.3.2. Evaluating the National Field Triage Decision Scheme (NFTDS)

One of the agendas for the NFTDS was to be the foundation for the development, implementation, and evaluation of local and regional field triage protocols. While not knowing whether or not the EMS providers in the State of Ohio used NFTDS to develop and implement their specific trauma triage decision making process, we wanted to evaluate the basic version of NFTDS on this data. *Could this standardized protocol have provided improved outcomes if it were being used by the EMS providers on this 817 patient records since 2008?*
To answer this question, we first had to understand how the NFTDS works and then map the factors stated therein with the factors available in our dataset. From what we know, the NFTDS is a hierarchical decision making process involving four steps, with each step either indicating the patient must be taken to a trauma center (L1/L2 in our case) or further evaluation may be required. When in doubt, the EMS providers are recommended to take the patient to a trauma center.

During the mapping of factors in the NFTDS and those available to us, we realized that either some factors were missing from our dataset or they had to be mapped using indirect measures. Appendix B summarizes our attempt to perform this mapping. Based on the directly available or indirect derivation of applicable factors, we found the UT and OT percentages to be 2.82% and 64.02%, respectively. These are fairly different from the “Actual” – we discuss this a bit more in detail in Section 6.3.4.

6.3.3. A new, statistical, trauma triage model

Our final step as part of Aim 2 was to investigate if we could derive a new trauma triage model based on statistically significant factors. The idea was to that if such a model could be developed, then it can then be converted into a score which then can be tested in the field as an alternate, better, and standardized protocol throughout the state of Ohio. While there are several ways in which a prediction model can be developed, we opted for the standard logistic regression approach as it does not assume a linear relationship between the outcome and predictors, can handle nonlinear effects, and the predictors themselves need not be normally distributed. While we did not have a very large dataset, 817 records were good enough for us to split it into a 70-30 train-test approach; i.e., about 70% of the data (570 records) were used for training the model and the rest for testing the model. We ensured that the train and test datasets were reasonably balanced. The outcome was dichotomous; 1, if L1/L2 was appropriate, and 0, if L3/NTC was appropriate. This was determined using the ISS score for each record.

In consultation with our surgery and EMS colleagues, we determined that some of these
factors are typically measured immediately upon EMS arrival and prompt the trauma triage decision, while the others are measured subsequently (and do not necessarily affect or alter this decision). The following factors (Table 3) were deemed to be vital and worth inclusion as potential predictors; total GCS score and IRR were derived per the NFTDS protocol.

**Table 3. Factors deemed appropriate for inclusion as possible predictors**

<table>
<thead>
<tr>
<th>Field</th>
<th>Entries in the Field</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient Age</td>
<td>Continuous</td>
</tr>
<tr>
<td>Patient Gender</td>
<td>650=Male, 655=Female, -10=Unknown</td>
</tr>
<tr>
<td>Condition Code</td>
<td>8001=Severe Abdominal Pain, 8010=Difficulty Breathing, 8012=Chest Pain, 8029=Neurologic Distress, etc.</td>
</tr>
<tr>
<td>Complaint Anatomic Location</td>
<td>1305=Abdomen, 1310=Back, 1315=Chest, 1320=Extremity-Lower, etc.</td>
</tr>
<tr>
<td>Patient’s Primary Symptom</td>
<td>1405=Bleeding, 1410=Breathing Problem, 1415=Change in Responsiveness, 1420=Choking, etc.</td>
</tr>
<tr>
<td>Provider’s Primary Impression</td>
<td>1615=Abdominal Pain/Problems, 1620=Airway Obstruction, 1625=Allergic Reaction, etc.</td>
</tr>
<tr>
<td>Cause of Patient’s Injury</td>
<td>1885=Bites, 9500=Aircraft Related Accident, 9505=Bicycle Accident, 9515=Chemical Poisoning, etc.</td>
</tr>
<tr>
<td>Injury Type</td>
<td>2035=Blunt, 2050=Penetrating, 2040=Burns, 2045=Other, -25=No Injury Present</td>
</tr>
<tr>
<td>Initial Systolic Blood Pressure</td>
<td>Continuous</td>
</tr>
<tr>
<td>Initial Pulse Rate</td>
<td>Continuous</td>
</tr>
<tr>
<td>Total GCS Score</td>
<td>Derived per NFTDS, converted to binary (1, if &lt;14)</td>
</tr>
<tr>
<td>Initial Respiratory Rate</td>
<td>Derived per NFTDS, converted to binary (1, if &lt;10 or &gt;29)</td>
</tr>
</tbody>
</table>

Table 4 lists factors that were statistically significant (at $\alpha=0.05$) in the final model. The odds ratios indicate the odds of a patient exhibiting that factor to be taken to L1/L2 versus L3/NTC. For instance, if a patient’s combined GCS score was <14, then that patient is >2.8 times (odds ratio = 2.82) more likely to go to an L1/L2 than L3/NTC.
### Table 4. Significant factors from the Logistic Regression model (N=817)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Specific Field in the Dataset</th>
<th>In NFTDS?</th>
<th>Estimate</th>
<th>(p)-Value</th>
<th>Odds Ratio</th>
<th>95% Conf Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severe Pain</td>
<td>Code_8030</td>
<td>No</td>
<td>0.5334</td>
<td>0.0243</td>
<td>2.907</td>
<td>1.105 – 7.207</td>
</tr>
<tr>
<td>Facture or Dislocation</td>
<td>Code_8046</td>
<td>Yes*</td>
<td>0.4946</td>
<td>0.0038</td>
<td>2.690</td>
<td>1.384 – 5.301</td>
</tr>
<tr>
<td>Complaint in Abdomen</td>
<td>Complaint_A_Location_1305</td>
<td>No</td>
<td>0.6659</td>
<td>0.0438</td>
<td>3.788</td>
<td>0.975 – 13.518</td>
</tr>
<tr>
<td>Change in Responsiveness</td>
<td>Complaint_A_Location_1310</td>
<td>No</td>
<td>0.7295</td>
<td>0.0025</td>
<td>4.302</td>
<td>1.662 – 11.143</td>
</tr>
<tr>
<td>Complaint in Chest</td>
<td>Complaint_A_Location_1315</td>
<td>No</td>
<td>1.0262</td>
<td>&lt;.0001</td>
<td>7.787</td>
<td>2.939 – 20.882</td>
</tr>
<tr>
<td>Complaint in Back</td>
<td>Complaint_A_Location_1330</td>
<td>No</td>
<td>0.5187</td>
<td>0.0033</td>
<td>2.822</td>
<td>1.436 – 5.756</td>
</tr>
<tr>
<td>Complaint in Whole Body/General</td>
<td>Complaint_A_Location_1340</td>
<td>No</td>
<td>0.6389</td>
<td>0.0027</td>
<td>3.589</td>
<td>1.569 – 8.397</td>
</tr>
<tr>
<td>Complaint in Head</td>
<td>P_Symptom_1415</td>
<td>No</td>
<td>0.3562</td>
<td>0.0372</td>
<td>2.039</td>
<td>1.040 – 3.988</td>
</tr>
<tr>
<td>Falls</td>
<td>Cause_Injury_9550</td>
<td>Yes**</td>
<td>-0.4293</td>
<td>0.0037</td>
<td>0.424</td>
<td>0.233 - 0.746</td>
</tr>
<tr>
<td>Blunt Injury Type</td>
<td>Injury_Type_2035</td>
<td>No</td>
<td>0.4586</td>
<td>0.0049</td>
<td>2.502</td>
<td>1.340 – 4.825</td>
</tr>
<tr>
<td>Penetrating Injury Type</td>
<td>Injury_Type_2050</td>
<td>Yes</td>
<td>0.5750</td>
<td>0.0308</td>
<td>3.158</td>
<td>1.090 – 8.895</td>
</tr>
<tr>
<td>Initial Pulse Rate</td>
<td>IPR</td>
<td>No</td>
<td>-0.0085</td>
<td>0.0603</td>
<td>0.992</td>
<td>0.983 – 1.000</td>
</tr>
<tr>
<td>Initial Respiratory Rate</td>
<td>IRR</td>
<td>Yes</td>
<td>0.5455</td>
<td>0.0017</td>
<td>2.977</td>
<td>1.509 – 5.925</td>
</tr>
<tr>
<td>Combined Glasgow Coma Score</td>
<td>GCS (verbal, motor, and eye)</td>
<td>Yes</td>
<td>0.5204</td>
<td>0.0003</td>
<td>2.832</td>
<td>1.608 – 5.018</td>
</tr>
</tbody>
</table>

* NFTDS indicates “two or more proximal long-bone fractures” and “pelvic fractures”

** NFTDS indicates “>20 ft are considered to be severe” and so to be taken to L1/L2.

The following things must be noted though. First, note that there are 5 factors that appear to be common between our model and the NFTDS. For the other factors which we found significant, we could not identify a direct or indirect factor in NFTDS. Second, we retained “IPR” even though its \(p\)-value was slightly higher than 0.05 owing to its medical significance. Finally, although “Falls” was
identified as significant, the interpretation of it is a little intriguing in our model compared to NFTDS. In the NFTDS, if a fall was recorded to be >20ft, then the patient would be taken to L1/L2. However, in our dataset the height of a fall was not available. In that case, the model seems to indicate that a fall suggested a decision in favor of L3/NTC. This finding must be considered carefully in the current model and is worth further investigation. The area under receiver operating curve (AUC or ROC) was found to be 0.76, which indicates a very good model. The AUC corresponding to the test dataset (247 records) was comparable (0.72) suggesting model’s generalizability.

7. Discussion

Below we provide summary of findings and discuss our results for both Aim 1 and 2.

7.1 Findings from Aim 1

Analysis of 2008-2012 data showed that several factors affect trauma triage decisions. These include system level factors, such as patient/family preference and proximity of location, along with patient level factors, such as triage protocol and mechanism of injury. It is interesting to note that in the state of Ohio, only about 50% of the time trauma patients are triaged appropriately. According to national trauma guidelines [9], the accepted range for over-triage is from 25-35%. The average over-triage percentage observed for the state of Ohio for 5-year period, however, was significantly higher than that (~43%). Since patient/family preference is the number one reason for high over-triage percentages in the state of Ohio, steps need to be taken to educate patients/families and EMS providers. A score based system might be able to help the EMS providers and might give some insights and objectivity in discussion with patients to help them select the appropriate facility for their optimum care.

The detailed analysis of over- and under-triage errors based on regions and/or counties suggest that regions with highest under-triage had the lowest over-triage errors and vice versa. This suggests that the placement and location of trauma centers in the state of Ohio is probably not adequate. There are some regions where no trauma center is available, and so have the highest
percentage of under-triage. On the other hand, some regions have more trauma centers than needed so very high percentage of over-triage. A systematic analysis of placement of trauma centers, therefore, would certainly help overcome such errors and resource utilization in the future.

7.2 Findings from Aim 2

We now summarize the findings based on our research as part of Aim 2. Recall, we used 817 patient records obtained from EMSIRS2 “protocol” only data for the period 2008-12. We analyzed three approaches, “Actual,” “NFTDS,” and our proposed statistical model, and summarize the resulting UT and OT percentages in the table below.

**Table 5. Comparison of three approaches on 2008-12 EMSIRS 2 “protocol” dataset**

<table>
<thead>
<tr>
<th>Approach</th>
<th>% UT</th>
<th>% OT</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual</td>
<td>4.04</td>
<td>38.31</td>
<td>As realized during 2008-12</td>
</tr>
<tr>
<td>NFTDS</td>
<td>2.82</td>
<td>64.02</td>
<td>If NFTDS were used</td>
</tr>
<tr>
<td>Statistical Model</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>vs. Actual</td>
<td>--</td>
<td>40.18</td>
<td>For similar % UT</td>
</tr>
<tr>
<td>vs. Actual</td>
<td>4.74</td>
<td>--</td>
<td>For similar % OT</td>
</tr>
<tr>
<td>vs. NFTDS</td>
<td>--</td>
<td>43.68</td>
<td>For similar % UT</td>
</tr>
<tr>
<td>vs. NFTDS</td>
<td>0.18</td>
<td>--</td>
<td>For similar % OT</td>
</tr>
</tbody>
</table>

It is worth noting that while the NFTDS is a standardized protocol that is relatively easy to understand and implement, it would have resulted in a much lower UT percentage (2.82%) compared to the “Actual” values; however, that could have been at the cost of a much higher OT percentage (64.02%). So there is no conclusive evidence that the NFTDS would have been a better or worse model compared to the current, non-standardized, protocol used by EMS providers in the State of Ohio.

Comparing the findings from the statistical model, the story is much different. First, when comparing the model to the “Actual” values, we see that it is comparable for similar UT or OT percentages. That is, the model tends to perform very similar to the “Actual” system. On one hand, this means that now there is a standardized approach to achieve nearly identical system performance
compared to the current one. However, this also means that the statistical model could not improve upon the current performance either. We avoided exploring more advanced models as they tend to behave like a black-box model; possibly higher prediction quality, but poor interpretability. Second, the statistical model clearly surpassed the UT and OT measures that would have been achieved had NFTDS been used. This means that if a standardized model were to be used for the State of Ohio, then a model proposed by our research would yield better outcomes.

8. Summary and Recommendations

The optimal triage of trauma patients has been a source of vigorous debate over the years. While clinical factors should determine the triage decision, often system-level factors and non-physiologic factors affect the EMS decision to transfer a patient from the scene to a hospital. It is, therefore, essential to study the state’s trauma system to identify any such limitations that could significantly affect performance and statewide resource utilization.

While the trauma triage system in the state of Ohio was created for increased accessibility of trauma care to severely injured patients, it has not quite achieved these objectives. This has prevented the growth and improvement of the current system beyond its present status. The primary objective of this research was to focus on two key aims: (i) identify over- and under-triage percentages and study both clinical and system factors that may be affecting these percentages, and (ii) derive a statistical model and compare it with the current system and that of the Field Triage Decision Scheme. Our multidisciplinary team of medical and engineering researchers analyzed nearly 35,631 patient records from the 2008-12 data available from the ODPS that comprised of both EMSIRS and Trauma Registry data elements for each patient record. The following are the key findings:

- The mean over- and under-triage percentages across all 5 years were 43.03% and 3.06%; these percentages were stable year-to-year.
- The average mortality percentage for 5-year period was 5.1%; nearly 0.52% of under-
triaged and 0.81% of over-triaged patients died.

- System level factors such as patient preference, proximity of hospital, and protocol were the top three reasons for triage decisions.
- While blunt injury type was associated with higher triage errors (both OT and UT), an increase in patient's age appeared highly correlated with the patient's preference for a hospital type.
- On the EMSIRS 2, protocol only, dataset of 817 patients, the statistical model revealed significant factors that may be affecting triage decisions. Although it achieved nearly same levels of UT and OT percentages, it can be viewed as a standardized approach compared to the current decentralized, non-standardized, approach adopted by EMS providers in the state; the model.

Further analysis of the data revealed several important aspects of the trauma system. For instance, nearly 15.45% patients out of 7576 trauma patients in 2008 were transferred during their care. Additionally, nearly 85.82% of patients that were correctly triaged (according to their ISS) were also transferred to another hospital. While there may be medical reasons necessitating transfer, patients may also be transferred to Level I trauma centers for nonmedical reasons. Unnecessary inter-facility transfer of patients, including secondary over-triage, presents a resource-sensitive challenge to the state’s trauma system and trauma centers. Moreover, it also delays definitive care and can be costly and inconvenient for patients and their families.

Analyzing data for counties and regions showed that there are specific patterns of OT and UT errors in the counties and regions. For instance, regions 7 and 8 have highest UT and nearly zero OT. This might be due to the placement of trauma centers. There may not be any L1/L2 trauma centers nearby these regions, resulting in all trauma patients being transferred from seen to the nearest available non-trauma facilities. Similarly, regions 2 and 5 have the least UT errors and the highest OT errors probably due to availability of large number of trauma centers. Clearly, the location of trauma centers in the region can directly affect quality care access and resource utilization in any trauma
In summary, our study findings suggest that trauma care in the state of Ohio could further be improved by reducing the triage errors and resource utilization. Based on our discussion with regional EMS providers, triage protocol is not standardized in the state and so it varies by the regions and/or EMS providers on scene. Therefore, a score-based system for triaging patients (such as one derived from the statistical model) could be very valuable and might help standardize the triage process in the state. Furthermore, studying transfer percentages and reasons, and possible secondary triages — aims of our ongoing grant with the ODPS — would shed further light on the inherent dynamics of trauma triages and their impact. Leveraging these findings to develop a system-wide model that would correlate the regional and county statistics (UT, OT, transfer, and secondary OT) to the proportion of triage centers in that region (L1/L2 vs. L3/NTC) can provide quantitative evidence to reallocate specific services between the hospital and the opening/closure of future trauma centers.

9. Dissemination Plan

Part of the work presented in this report has been accepted and will be presented as an oral presentation at the Academic Surgical Congress Annual Meeting (February 2016). A manuscript is planned based on this work and will be submitted either to Journal of Trauma and Acute Care Surgery or Journal of Surgical Research. We also plan to disseminate the results to trauma surgeons and staff through Surgery grand rounds at Miami Valley Hospital (a Level 1 trauma center) in 2016.
10. References


1. Triage Trends (Figure 2 in the report)

N = 35,631

<table>
<thead>
<tr>
<th>Triage Trends</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total triages</td>
<td>7576</td>
<td>7141</td>
<td>7214</td>
<td>6551</td>
<td>7149</td>
</tr>
<tr>
<td>Under-triage (#/%)</td>
<td>231/3.1%</td>
<td>203/2.8%</td>
<td>214/2.9%</td>
<td>228/3.5%</td>
<td>216/3%</td>
</tr>
<tr>
<td>Over-triage (#/%)</td>
<td>2175/43.2%</td>
<td>3142/44%</td>
<td>3082/42.7%</td>
<td>2687/41%</td>
<td>3145/44%</td>
</tr>
</tbody>
</table>
2. Mortality Trends (Figure 3 in the report)

This trend chart should be read as:
- “In 2008, 5.21% of patients died.”
- “In 2008, 0.67% of all patients were under triaged patients who died.”
- “In 2011, 1.01% of all patients were over triaged patients who died.”

N = 35,631

<table>
<thead>
<tr>
<th>Mortality Trends</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total triages</td>
<td>7576</td>
<td>7141</td>
<td>7214</td>
<td>6551</td>
<td>7149</td>
</tr>
<tr>
<td>Mortality (#/%)</td>
<td>395/5.2%</td>
<td>338/4.7%</td>
<td>347/4.8%</td>
<td>377/5.7%</td>
<td>340/4.7%</td>
</tr>
<tr>
<td>via UT (#/%)</td>
<td>51/0.67%</td>
<td>32/0.45%</td>
<td>54/0.75%</td>
<td>52/0.79%</td>
<td>37/0.52%</td>
</tr>
<tr>
<td>via OT (#/%)</td>
<td>73/0.96%</td>
<td>63/0.88%</td>
<td>63/0.87%</td>
<td>66/1.01%</td>
<td>58/0.81%</td>
</tr>
</tbody>
</table>
3. Under-Triage % by County and Year (Figure 6 in the report)

County Names (some counties did not experience any UT, so excluded):

[1] "Adams"  "Ashland"  "Ashtabula"  "Auglaize"  "Belmont"
[6] "Brown"  "Butler"  "Champaign"  "Clark"  "Claymont"
[11] "Clinton"  "Columbiana"  "Coshocton"  "Cuyahoga"  "Darke"
[16] "Defiance"  "Delaware"  "Erie"  "Fairfield"  "Fayette"
[21] "Franklin"  "Fulton"  "Geauga"  "Greene"  "Guernsey"
[26] "Hamilton"  "Hancock"  "Hardin"  "Henry"  "Highland"
[31] "Hocking"  "Holmes"  "Huron"  "Jefferson"  "Knox"
[36] "Licking"  "Logan"  "Lorain"  "Lucas"  "Madison"
[41] "Mahoning"  "Marion"  "Medina"  "Miami"  "Monroe"
[46] "Montgomery"  "Morgan"  "Morrow"  "Muskingum"  "Noble"
[51] "Other"  "Ottawa"  "Perry"  " Pickaway"  "Portage"
[56] "Preble"  "Putnam"  "Richland"  "Ross"  "Sandusky"
[61] "Seneca"  "Shelby"  " Stark"  "Summit"  "Trumbull"
[66] "Tuscarawas"  "Union"  "Unknown"  "Warren"  "Washington"
[71] "Vinton"  "Voyahot"
4. Over-Triage % by County for 2008 to 2012 (Figure 7 in the report)

County Names (some counties did not experience any OT, so excluded):

[7] "Brown"  "Butler"  "Carroll"  "Champaign"  "Clark"  "Clermont"
[13] "Clinton"  "Columbiana"  "Coshocton"  "Crawford"  "Cuyahoga"  "Darke"
[19] "Defiance"  "Delaware"  "Erie"  "Fairfield"  "Fayette"  "Franklin"
[25] "Fulton"  "Geauga"  "Greene"  "Guernsey"  "Hamilton"  "Hancock"
[31] "Hardin"  "Harrison"  "Henry"  "Highland"  "Hocking"  "Holmes"
[37] "Huron"  "Jackson"  "Knox"  "Lake"  "Licking"  "Logan"
[43] "Lorain"  "Lucas"  "Madison"  "Mahoning"  "Marion"  "Medina"
[49] "Meigs"  "Mercer"  "Miami"  "Monroe"  "Montgomery"  "Morgan"
[55] "Morrow"  "Muskingum"  "Not Applicable"  "Other"  "Ottawa"  "Paulding"
[61] "Perry"  "Pickaway"  "Pike"  "Portage"  "Preble"  "Putnam"
[67] "Richland"  "Ross"  "Sandusky"  "Scioto"  "Seneca"  "Shelby"
[73] "Stark"  "Summit"  "Trumbull"  "Tuscarawas"  "Union"  "Unknown"
[79] "Van Wert"  "Vinton"  "Warren"  "Wayne"  "Williams"  "Wood"
5. System Level Factors

(i) Reason for choosing destination

Over-Triage (Figure 9 in the report)

Under-Triage (Figure 10 in the report)
(ii) First Unit Level of Service

Over-Triage

Under-Triage
(iii) Transport Vehicle Type

**Over-Triage**

![Over-Triage Chart]

N=13142
***Factors not included: Fixed Wing (n=5)

<table>
<thead>
<tr>
<th>Year</th>
<th>Ground</th>
<th>Rotor Craft</th>
<th>Other</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>2650</td>
<td>85</td>
<td>4</td>
<td>43</td>
</tr>
<tr>
<td>2009</td>
<td>2614</td>
<td>158</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>2010</td>
<td>2583</td>
<td>164</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>2011</td>
<td>2149</td>
<td>96</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>2012</td>
<td>2094</td>
<td>82</td>
<td>0</td>
<td>13</td>
</tr>
</tbody>
</table>

**Under-Triage**

![Under-Triage Chart]

N=943
***Factors not included: Rotor Craft (n=0), Fixed Wing (n=0)

<table>
<thead>
<tr>
<th>Year</th>
<th>Ground</th>
<th>Rotor Craft</th>
<th>Fixed Wing</th>
<th>Other</th>
<th>None</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>287</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>2009</td>
<td>171</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>2010</td>
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6. Clinical Factors

(i) Drug Alcohol Status

Over-Triage

Under-Triage

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(ii) Injury Type

Over-Triage

- No.Injury.Present is from EMSIRS 2 only (EMSIRS 2 contributed 2,170 patients to this plot)

Under-Triage

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(iii) Complaint Anatomic Location

Over-Triage

Under-Triage

Complaint Anatomic Location Key:
-25...Not Applicable
1305...Abdomen
1310...Back
1315...Chest
1320...Extremity-lower
1325...Extremity-upper
1330...General/ global/ whole body
1335...Genitalia
1340...Head
1345...Neck

***Factors not included: 1305 (n=4), 1345 (n=3)
(iv) Primary Symptom

Over-Triage

N=2164
***Factors not included: 1420 (n=2), 1425 (n=2), 1440 (n=1), 1485 (n=1)

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Primary Symptom Key
-25...Not Applicable
1405...Bleeding
1410...Breathing Problem
1415...Change in responsiveness
1420...Choking
1425...Death
1430...Device/Equipment Problem
1435...Diarrhea
1440...Drainage/discharge
1445...Fever
1450...Malaise (general, non-specific feeling of illness)
1455...Mass/lesion
1460...Mental/psychiatric
1465...Nausea/vomiting
1470...None
1475...Pain
1480...Palpitations
1485...Rash/itching
1490...Swelling
1500...Weakness
1505...Wound
Under-Triage

N=138
***Factors not included: 1425 (n=4), 1460 (n=1), 1465 (n=3), 1490 (n=2), 1500 (n=1)

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(v) Complaint Organ System

Over-Triage

Complaint Organ Symptom Key:
-25...Not Applicable
1350...Cardiovascular
1355...CNS/ Neurologic
1360...Endocrine/ Metabolic
1365...Gastrointestinal
1370...Global/ Whole body
1375...Musculoskeletal
1380...Obstetric/ Gynecologic
1385...Psychiatric
1390...Pulmonary
1395...Renal
1400...Skin

N=2164
***Factors not included: 1360 (n=2), 1380 (n=1), 1395 (n=3)

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Under-Triage

![Bar Chart]

- N=143
- ***Factors not included: 1365 (n=3), 1390 (n=2), 1395 (n=1)

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(vi) Provider's Primary Impression

Over-Triage

N=2156

***Factors not included: 1640 (n=3), 1645 (n=1), 1655 (n=2), 1665 (n=1), 1670 (n=3), 1675 (n=1), 1705 (n=1), 1725 (n=2)
**Under-Triage**

Provider's Primary Impression key:
- 25...Not Applicable
- 1615...Abdominal pain/ problems
- 1620...Airway obstruction
- 1625...Allergic reaction
- 1630...Altered level of consciousness
- 1635...Behavioral/ psychiatric disorder
- 1640...Cardiac arrest
- 1645...Cardiac rhythm disturbance
- 1650...Chest pain/ discomfort
- 1655...Diabetic symptoms
- 1660...Electrocution
- 1665...Hyperthermia
- 1670...Hypothermia
- 1675...Hypovolemia/ shock
- 1680...Inhalation injury (toxic gas)
- 1685...Obvious death
- 1690...Poisoning/ drug ingestion
- 1695...Pregnancy/ OB delivery
- 1700...Respiratory distress
- 1705...Respiratory arrest
- 1710...Seizure
- 1715...Sexual assault/ rape
- 1720...Smoke inhalation
- 1725...Stings/ venomous bites
- 1730...Stroke/ CVA
- 1735...Syncope/ fainting
- 1740...Traumatic injury
- 1744...Non-traumatic injury
- 1745...Vaginal hemorrhage

N=141

***Factors not included: 1615 (n=2), 1650 (n=1), 1670 (n=1), 1705 (n=1), 1710 (n=1), 1720 (n=1), 1730 (n=1)***

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15
(vii) Injury Cause

**Over-Triage**

![Chart showing percentage of over-trauma cases by year.](chart)

N=2154

Factors not included: 1885 (n=3), 9530 (n=1), 9540 (n=1), 9575 (n=1), 9585 (n=3), 9607 (n=3), 9625 (n=2), 9650 (n=2)

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</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>9595</th>
<th>9600</th>
<th>9605</th>
<th>9607</th>
<th>9610</th>
<th>9625</th>
<th>9630</th>
<th>9635</th>
<th>9640</th>
<th>9650</th>
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<tr>
<td>2008</td>
<td>114</td>
<td>30</td>
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<td>11</td>
<td>0</td>
</tr>
<tr>
<td>2009</td>
<td>70</td>
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<td>0</td>
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<td>0</td>
<td>0</td>
<td>4</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>2010</td>
<td>60</td>
<td>30</td>
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<td>1</td>
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<td>8</td>
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</tr>
<tr>
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<td>75</td>
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<td>0</td>
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<td>4</td>
<td>8</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>2012</td>
<td>200</td>
<td>24</td>
<td>2</td>
<td>0</td>
<td>9</td>
<td>0</td>
<td>22</td>
<td>3</td>
<td>32</td>
<td>2</td>
</tr>
</tbody>
</table>
Under-Triage

Injury Cause Key:
-10...Unknown
-25...Not Applicable
1885....Bites
9500....Aircraft related accident
9505....Bicycle accident
9515....Chemical poisoning
9520....Child battering
9525....Drowning
9530....Drug poisoning
9535....Electrocution
9540....Excessive cold
9545....Excessive heat
9550....Falls
9555....Fire and flames
9560....Firearm (assault)
9565....Firearm injury (accidental)
9570....Firearm(self-inflicted)
9575....Lightning
9590....Motor vehicle non-traffic accident
9595....Motor vehicle traffic accident
9600....Motorcycle crash
9605....Non-motorized vehicle crash
9607....Overexertion/ strenuous movements
9610....Pedestrian traffic accident
9615....Radiation exposure
9620....Rape
9625....Smoke inhalation
9630....Stabbing/ cutting unintentional
9635....Stabbing/ cutting assault
9640....Struck by blunt/ thrown object
9645....Venomous stings (plants, animals)
9650....Water transport accident
9580....Machinery accidents
9585....Mechanical suffocation
(viii) GCS Eye

Over-Triage

Under-Triage

N=14361

N=907
(ix)  GCS Verbal

Over-Triage

Under-Triage

GCS Verbal key:
1. None
2. Incomprehensible sounds
3. Inappropriate words
4. Confused
5. Oriented
(x) GCS Motor

Over-Triage

GCS Motor key:
1... None
2... Extensor posturing in response to painful stimulation
3... Flexor posturing in response to painful stimulation
4... Withdrawing from painful stimulation
5... Localizes painful stimulation
6... Obeys commands

Under-Triage

GCS Motor key:
1... None
2... Extensor posturing in response to painful stimulation
3... Flexor posturing in response to painful stimulation
4... Withdrawing from painful stimulation
5... Localizes painful stimulation
6... Obeys commands
(xi)  **Initial Systolic Blood Pressure** (Low = 0-100, High = 101+)

**Over-Triage**

![Bar chart showing percentage of over-triages for initial systolic blood pressure with data for each year from 2008 to 2012.]

<table>
<thead>
<tr>
<th>Year</th>
<th>High</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>327</td>
<td>23</td>
</tr>
<tr>
<td>2009</td>
<td>269</td>
<td>12</td>
</tr>
<tr>
<td>2010</td>
<td>250</td>
<td>23</td>
</tr>
<tr>
<td>2011</td>
<td>299</td>
<td>29</td>
</tr>
<tr>
<td>2012</td>
<td>857</td>
<td>74</td>
</tr>
</tbody>
</table>

**Under-Triage**

![Bar chart showing percentage of under-triages for initial systolic blood pressure with data for each year from 2008 to 2012.]

<table>
<thead>
<tr>
<th>Year</th>
<th>High</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>14</td>
<td>5</td>
</tr>
<tr>
<td>2009</td>
<td>22</td>
<td>6</td>
</tr>
<tr>
<td>2010</td>
<td>23</td>
<td>0</td>
</tr>
<tr>
<td>2011</td>
<td>30</td>
<td>5</td>
</tr>
<tr>
<td>2012</td>
<td>42</td>
<td>2</td>
</tr>
</tbody>
</table>
(xii) Initial Diastolic Blood Pressure

**Over-Triage**

![Over-Triage Chart](image)

<table>
<thead>
<tr>
<th>Year</th>
<th>Zero</th>
<th>Low</th>
<th>Ideal</th>
<th>Pre-High</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>29</td>
<td>0</td>
<td>118</td>
<td>84</td>
<td>118</td>
</tr>
<tr>
<td>2009</td>
<td>32</td>
<td>0</td>
<td>93</td>
<td>52</td>
<td>104</td>
</tr>
<tr>
<td>2010</td>
<td>43</td>
<td>0</td>
<td>88</td>
<td>59</td>
<td>83</td>
</tr>
<tr>
<td>2011</td>
<td>54</td>
<td>0</td>
<td>91</td>
<td>77</td>
<td>106</td>
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<tr>
<td>2012</td>
<td>147</td>
<td>0</td>
<td>235</td>
<td>206</td>
<td>343</td>
</tr>
</tbody>
</table>

N=2162

***Factors not included: Low (n=0)***

**Under-Triage**

![Under-Triage Chart](image)

<table>
<thead>
<tr>
<th>Year</th>
<th>Zero</th>
<th>Low</th>
<th>Ideal</th>
<th>Pre-High</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>6</td>
<td>0</td>
<td>5</td>
<td>3</td>
<td>5</td>
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<td>2009</td>
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<td>0</td>
<td>10</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>2010</td>
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<td>0</td>
<td>5</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>2011</td>
<td>7</td>
<td>0</td>
<td>9</td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>2012</td>
<td>4</td>
<td>0</td>
<td>18</td>
<td>8</td>
<td>14</td>
</tr>
</tbody>
</table>

N=149

***Factors not included: Low (n=0)***
(xiii) Initial Pulse Rate

Over-Triage

![Over-Triage Graph]

Under-Triage

![Under-Triage Graph]

<table>
<thead>
<tr>
<th>Year</th>
<th>Low</th>
<th>Ideal</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>9</td>
<td>263</td>
<td>82</td>
</tr>
<tr>
<td>2009</td>
<td>8</td>
<td>220</td>
<td>53</td>
</tr>
<tr>
<td>2010</td>
<td>8</td>
<td>205</td>
<td>60</td>
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<tr>
<td>2011</td>
<td>16</td>
<td>232</td>
<td>80</td>
</tr>
<tr>
<td>2012</td>
<td>37</td>
<td>675</td>
<td>219</td>
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</table>

N=2167

<table>
<thead>
<tr>
<th>Year</th>
<th>Low</th>
<th>Ideal</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>7</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>2009</td>
<td>2</td>
<td>19</td>
<td>7</td>
</tr>
<tr>
<td>2010</td>
<td>1</td>
<td>16</td>
<td>6</td>
</tr>
<tr>
<td>2011</td>
<td>3</td>
<td>22</td>
<td>10</td>
</tr>
<tr>
<td>2012</td>
<td>3</td>
<td>34</td>
<td>7</td>
</tr>
</tbody>
</table>

N=149
(xiv) Initial Respiratory Rate

**Over-Triage**

![Graph showing percentage of Over-Triage across different years for Low, Normal, and High Initial Respiratory Rates.]

<table>
<thead>
<tr>
<th>Year</th>
<th>Low</th>
<th>Normal</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>4</td>
<td>103</td>
<td>248</td>
</tr>
<tr>
<td>2009</td>
<td>7</td>
<td>100</td>
<td>174</td>
</tr>
<tr>
<td>2010</td>
<td>5</td>
<td>95</td>
<td>173</td>
</tr>
<tr>
<td>2011</td>
<td>11</td>
<td>97</td>
<td>220</td>
</tr>
<tr>
<td>2012</td>
<td>61</td>
<td>361</td>
<td>509</td>
</tr>
</tbody>
</table>

N=2168

**Under-Triage**

![Graph showing percentage of Under-Triage across different years for Low, Normal, and High Initial Respiratory Rates.]

<table>
<thead>
<tr>
<th>Year</th>
<th>Low</th>
<th>Normal</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>5</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>2009</td>
<td>5</td>
<td>5</td>
<td>18</td>
</tr>
<tr>
<td>2010</td>
<td>1</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>2011</td>
<td>5</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>2012</td>
<td>3</td>
<td>22</td>
<td>19</td>
</tr>
</tbody>
</table>

N=149
Age Over-Triage

N=15331

<table>
<thead>
<tr>
<th>Age Group</th>
<th>0-17</th>
<th>18-30</th>
<th>31-40</th>
<th>41-50</th>
<th>51-60</th>
<th>61-70</th>
<th>71-80</th>
<th>81-90</th>
<th>91+</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>106</td>
<td>641</td>
<td>393</td>
<td>484</td>
<td>461</td>
<td>330</td>
<td>333</td>
<td>440</td>
<td>85</td>
</tr>
<tr>
<td>2009</td>
<td>88</td>
<td>550</td>
<td>327</td>
<td>430</td>
<td>461</td>
<td>367</td>
<td>396</td>
<td>425</td>
<td>98</td>
</tr>
<tr>
<td>2010</td>
<td>79</td>
<td>462</td>
<td>289</td>
<td>393</td>
<td>454</td>
<td>390</td>
<td>369</td>
<td>526</td>
<td>120</td>
</tr>
<tr>
<td>2011</td>
<td>64</td>
<td>422</td>
<td>247</td>
<td>311</td>
<td>385</td>
<td>340</td>
<td>347</td>
<td>460</td>
<td>111</td>
</tr>
<tr>
<td>2012</td>
<td>70</td>
<td>506</td>
<td>316</td>
<td>393</td>
<td>424</td>
<td>366</td>
<td>377</td>
<td>524</td>
<td>169</td>
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</table>
Under-Triage

<table>
<thead>
<tr>
<th>Age Group</th>
<th>0-17</th>
<th>18-30</th>
<th>31-40</th>
<th>41-50</th>
<th>51-60</th>
<th>61-70</th>
<th>71-80</th>
<th>81-90</th>
<th>91+</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>2</td>
<td>35</td>
<td>16</td>
<td>33</td>
<td>37</td>
<td>29</td>
<td>28</td>
<td>43</td>
<td>8</td>
</tr>
<tr>
<td>2009</td>
<td>4</td>
<td>26</td>
<td>14</td>
<td>37</td>
<td>24</td>
<td>20</td>
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<td>41</td>
<td>46</td>
<td>6</td>
</tr>
<tr>
<td>2011</td>
<td>3</td>
<td>34</td>
<td>23</td>
<td>19</td>
<td>36</td>
<td>26</td>
<td>33</td>
<td>44</td>
<td>10</td>
</tr>
<tr>
<td>2012</td>
<td>2</td>
<td>26</td>
<td>13</td>
<td>18</td>
<td>29</td>
<td>30</td>
<td>39</td>
<td>47</td>
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</table>

N=1092
(xvi) Gender

**Over-Triage**

![Over-Triage chart](image)

<table>
<thead>
<tr>
<th>Year</th>
<th>Male</th>
<th>Female</th>
<th>Unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Under-Triage**

![Under-Triage chart](image)

<table>
<thead>
<tr>
<th>Year</th>
<th>Male</th>
<th>Female</th>
<th>Unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
7. Trauma Factors

(i) ED Disposition

Over-Triage

![Graph showing the percentage of over-triage by ED disposition from 2008 to 2012.]

<table>
<thead>
<tr>
<th>Year</th>
<th>Admit.Floor</th>
<th>Admit.ICU</th>
<th>Admit.OR</th>
<th>Step.Down</th>
<th>Observation</th>
<th>Transfer.Morgue</th>
<th>Transfer.OH.Hosp</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>1001</td>
<td>514</td>
<td>293</td>
<td>172</td>
<td>35</td>
<td>13</td>
<td>16</td>
<td>1235</td>
</tr>
<tr>
<td>2009</td>
<td>906</td>
<td>550</td>
<td>244</td>
<td>217</td>
<td>62</td>
<td>11</td>
<td>25</td>
<td>1127</td>
</tr>
<tr>
<td>2010</td>
<td>1046</td>
<td>552</td>
<td>213</td>
<td>318</td>
<td>16</td>
<td>18</td>
<td>61</td>
<td>858</td>
</tr>
<tr>
<td>2011</td>
<td>945</td>
<td>464</td>
<td>219</td>
<td>236</td>
<td>7</td>
<td>13</td>
<td>68</td>
<td>758</td>
</tr>
<tr>
<td>2012</td>
<td>1156</td>
<td>505</td>
<td>276</td>
<td>356</td>
<td>18</td>
<td>12</td>
<td>66</td>
<td>732</td>
</tr>
</tbody>
</table>

Under-Triage

![Graph showing the percentage of under-triage by ED disposition from 2008 to 2012.]

<table>
<thead>
<tr>
<th>Year</th>
<th>Admit.Floor</th>
<th>Admit.ICU</th>
<th>Admit.OR</th>
<th>Step.Down</th>
<th>Observation</th>
<th>Transfer.Morgue</th>
<th>Transfer.OH.Hosp</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>13</td>
<td>16</td>
<td>14</td>
<td>2</td>
<td>0</td>
<td>12</td>
<td>136</td>
<td>36</td>
</tr>
<tr>
<td>2009</td>
<td>25</td>
<td>31</td>
<td>14</td>
<td>2</td>
<td>1</td>
<td>10</td>
<td>97</td>
<td>23</td>
</tr>
<tr>
<td>2010</td>
<td>15</td>
<td>31</td>
<td>7</td>
<td>3</td>
<td>0</td>
<td>10</td>
<td>130</td>
<td>18</td>
</tr>
<tr>
<td>2011</td>
<td>20</td>
<td>37</td>
<td>13</td>
<td>3</td>
<td>0</td>
<td>12</td>
<td>122</td>
<td>20</td>
</tr>
<tr>
<td>2012</td>
<td>31</td>
<td>25</td>
<td>7</td>
<td>2</td>
<td>0</td>
<td>15</td>
<td>125</td>
<td>11</td>
</tr>
</tbody>
</table>
(ii) Discharge Disposition

**Over-Triage**

![Over-Triage chart]

<table>
<thead>
<tr>
<th>Discharge Disposition</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home</td>
<td>466</td>
<td>109</td>
<td>74</td>
<td>857</td>
<td>0</td>
</tr>
<tr>
<td>Assisted Home</td>
<td>77</td>
<td>64</td>
<td>62</td>
<td>708</td>
<td>97</td>
</tr>
<tr>
<td>Morgue, Coroner</td>
<td>58</td>
<td>62</td>
<td>570</td>
<td>182</td>
<td>97</td>
</tr>
<tr>
<td>Ext. Nurse, Skilled Care</td>
<td>119</td>
<td>67</td>
<td>742</td>
<td>105</td>
<td>96</td>
</tr>
<tr>
<td>Rehab</td>
<td>173</td>
<td>56</td>
<td>565</td>
<td>213</td>
<td>106</td>
</tr>
<tr>
<td>Transfer Off Hosp</td>
<td>209</td>
<td>1</td>
<td>32</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>Transfer OOS Hosp</td>
<td>137</td>
<td>0</td>
<td>13</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Jail, Prison</td>
<td>17</td>
<td>1</td>
<td>4</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>AMA</td>
<td>22</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
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<td>4</td>
<td>5</td>
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</table>

N=15331

**Under-Triage**

![Under-Triage chart]

<table>
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<tr>
<th>Discharge Disposition</th>
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<th>2011</th>
<th>2012</th>
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<tr>
<td>Home</td>
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<td>23</td>
<td>15</td>
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<td>Assisted Home</td>
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<td>27</td>
<td>16</td>
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<tr>
<td>Morgue, Coroner</td>
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<td>27</td>
<td>17</td>
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<tr>
<td>Ext. Nurse, Skilled Care</td>
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<td>27</td>
<td>17</td>
<td>1</td>
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<tr>
<td>Rehab</td>
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<td>2</td>
<td>27</td>
<td>17</td>
<td>1</td>
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<tr>
<td>Transfer Off Hosp</td>
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<td>2</td>
<td>27</td>
<td>17</td>
<td>1</td>
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<tr>
<td>Transfer OOS Hosp</td>
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<td>17</td>
<td>1</td>
</tr>
<tr>
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<td>2</td>
<td>27</td>
<td>17</td>
<td>1</td>
</tr>
<tr>
<td>AMA</td>
<td>22</td>
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</table>

N=1092
(iii) Hospital Length of Stay (for scene-to-first hospital only)

**Over-Triage**

![Over-Triage Graph]

**Under-Triage**

![Under-Triage Graph]
### Appendix B. An Attempt to Emulate the National Field Triage Decision Scheme (NFTDS) (Used 2008-2012, EMSIRS 2, “Protocol-Only,” Data)

**Step 1:** Used everything as is.

**Step 2:**
1: Injury Type 2050 (penetrating), Complaint Anatomic Location 1305 (abdomen), 1310 (back), 1315 (chest), 1320 (extremity-lower), 1325 (extremity-upper), 1340 (head), 1345 (neck)

2: Flail Chest: not included

3: Two or more proximal long-bone fractures: There was no way to determine if there were multiple long-bone fractures, so we just used one long-bone fracture; Condition Code 8046 (Other Trauma- fracture/dislocation), Complaint Anatomic Location 1320 (extremity-lower), 1325 (extremity-upper).

4: Crush, degloved, mangled extremity: not included

5: Amputation proximal to wrist and ankle: Condition Code 8048 (Other Trauma- amputation digits), Complaint Anatomic Location 1320 (extremity-lower), 1325 (extremity-upper)

6: Pelvic Fractures: not included (none)

7: Open or depressed skull fracture: Condition Code 8046 (Other Trauma- fracture/dislocation), Complaint Anatomic Location 1340 (head)

8: Paralysis: Condition Code 8029 (neurologic distress)

**Step 3:**
1: Falls: Do not have any data based on the heights of falls, so only used Cause of Injury 9550 (Falls)

2: High-risk auto crash: Cause of Injury 9595 (Motor vehicle traffic accident), Airbag Deployment 2225 (Airbag deployed front). We used these because there was no data on mechanism of injury.

3: Auto vs. pedestrian/bicyclist thrown, run over, or with significant (>20 mph) impact: No velocities. Just used Cause of Injury 9610 (Pedestrian Traffic Accident)

4: Motorcycle crash >20 mph: No Velocity. Cause of Injury 9600 (Motorcycle crash)

**Step 4:**
1: Age: Just used age >55 (don’t have data for patients <16 years and don’t have information about pediatric hospitals either)

2: Anticoagulation and bleeding disorders: Condition Code 8045 (Other trauma-major bleeding) or Primary Symptom 1405 (Bleeding)

3: Burns: Injury Type 2040 (Burns)