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# Association of mechanism of injury with overtriage of injured youth patients as trauma alerts

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## ABSTRACT

**Background** Trauma alert criteria include physiologic and anatomic criteria, although field triage based on injury mechanism is common. This analysis evaluates injury mechanisms associated with pediatric trauma alert overtriage and estimates the effect of overtriage on patient care costs.

**Methods** Florida's Agency for Health Care Administration inpatient and financial data for 2012–2014 were used. The study population included mildly and moderately injured patients aged 5–15 years brought to a trauma center and had an International Classification of Diseases-based Injury Severity Score survival probability ≥0.90, a recorded mechanism of injury, no surgery, a hospital stay less than 24 hours, and discharged to home. Overtriaged patients were those who had a trauma alert. Logistic regression was used to analyze the odds of overtriage relative to mechanism of injury and multivariable linear regression was used to analyze cost of overtriage.

**Results** Twenty percent of patients were overtriaged; yet these patients accounted for 37.2% of total costs. The mechanisms of injury related to firearms (OR 11.99) and motor vehicle traffic (2.25) were positively associated with overtriage as a trauma alert. Inpatient costs were 131.8% higher for overtriaged patients.

**Discussion** Firearm injuries and motor vehicle injuries can be associated with severe injuries. However, in this sample, a proportion of patients with this mechanism suffered minimal injuries. It is possible that further identifying relevant anatomic and physiologic criteria in youth may help decrease overtriage without compromising outcomes.

**Level of evidence** Economic, level IV.

## INTRODUCTION

Emergency medical services (EMS) personnel assess injury severity at the scene; stabilize the patient to the extent possible; and decide if the patient meets trauma alert criteria to help determine the appropriate receiving hospital. The last task is done through triage.[1] Severely injured patients and trauma alert patients are transported to a trauma center (TC), with patients aged 0–15 years transported to the nearest pediatric TC when available. Paramedics have limited time to make a trauma alert decision. Reliable triage guidelines specifically designed for children are lacking.[2 3] In Florida, paramedics use the Pediatric Trauma Scorecard Methodology to assess whether a patient meets trauma alert criteria based on factors such as: airway patency, level of consciousness, hypotension, obvious fractures, cutaneous injuries, and patient size. If patients do not meet any of the trauma conditions, EMS responders are allowed to use their judgement in issuing a trauma alert, and document it in the patient's record.[4] Nationally, 40% of triage cases are based on paramedic judgement.[5] Qualitative analysis involving EMS responders suggests personal judgement is heavily guided by visual cues of the trauma scene and injury mechanism.[6]

Engum *et al* found that paramedics cannot evaluate youth as well as adults when triaging patients.[7] Overtriage occurs when patients are brought in as a trauma activation but are not ultimately found to have serious injuries.[8] Lin *et al* reported that paramedic judgement was one of the most common causes of overtriage.[8] However, Lowe *et al* found that relying on trauma scores alone would miss 8%–36% of significant injury in trauma patients and encouraged use of mechanism of injury in triage especially with high energy transfer injuries.[9]

Research shows conflicting evidence for using mechanism of injury to determine trauma alert status and subsequent trauma care. Engum *et al* and Santaniello *et al* found mechanism of injury to be a good indicator of trauma and, therefore, reasonable to use in triaging.[7 10] Newgard *et al* concluded pediatric patients from motor vehicle crashes (MVC) needed more reliable triage guidelines and suggested additional physiological parameters would help.[11] However, McSwain *et al* did not find mechanism of injury to be a reliable predictor.[12] Lerner *et al* found mechanism of injury reduced undertriage rates but significantly raised overtriage rates, and that some mechanisms of injury from the Field Triage Decision Scheme were more appropriate for use in triage than others.[13] Ciesla *et al* found high energy transfer transportation-related injury mechanisms to be associated with overtriage.[14]

Overtriage is an economic issue that can create problems such as longer distance transports that are inconvenient for the patient and family, unnecessary use of land and air EMS vehicles, greater demands of EMS personnel, loss of revenue for the bypassed hospitals, potential overburdening of urban TCs, and a waste of valuable resources if the trauma team is unnecessarily activated.[12 14] It is, therefore, important to correctly identify trauma patients to ensure an appropriate balance of overtriage and undertriage rates. Research has estimated the overtriage rate of youth is as high as 71%.[7] Acceptable rates of overtriage are as high as 50% to keep undertriage below 5%.[15] However, Newgard *et al* argued that this high overtriage rate has been accepted and perpetuated by current trauma system culture and may not need to be so high to keep undertriage low.[6] There is an acceptable overtriage



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rate as the trauma system errs on the side of patient safety. However, it is possible to reduce overtriage rates and associated costs while maintaining patient safety.[16] Cook *et al* found one way to do this was to identify trauma alert patients by physiologic and anatomic criteria and not by injury mechanism.[17]

Thorpe *et al* found trauma care to be the second largest contributor condition in healthcare spending in the USA among the five most expensive conditions.[18] Healthcare costs are higher at TCs, meaning resources are wasted when patients are overtriaged.[19] Also, patients who are trauma alerts are charged a trauma alert response charge, which is a fee for activating of the trauma team. Trauma alert charges vary greatly between and across TC levels and regions.[20 21] From 2012 to 2014, per admission trauma charges for inpatient youth patients in Florida ranged from $429 to $46 890.[21] Our study goals were to determine mechanisms of injury commonly associated with overtriage, and the cost of overtriage.

## METHODS

The 2012–2014 Florida's Agency for Health Care Administration (AHCA) inpatient and financial data were used in this retrospective cohort analysis. The data sets are publicly available and deidentified making this research exempt from Institutional Review Board review. The inpatient data include demographic variables, up to 30 diagnoses, charges, and external cause of injury codes (E-code) for patients admitted to an acute care hospital. The financial data include hospital ownership type, location, and financial information. The study population includes patients aged 5–15 who were hospitalized; had an admission priority of either trauma or emergency; were not transferred from another hospital; had a recorded mechanism of injury; received no surgery as implied by the absence of operating room charges; had a length of stay of less than 24 hours; had a routine discharge to home or self-care; had an injury identified in the Barell Injury Diagnosis Matrix; and had mild to moderate injuries, meaning an International Classification of Diseases-9th Revision-Clinical Modification (ICD-9-CM) Injury Severity Score (ICISS) of 0.90 or higher. Major trauma was defined as having an ICISS <0.85 by the Florida Department of Health.[22] ICISS is a product of a patient's survival risk ratios based on their ICD-9-CM codes.[23] For example, an ICISS of 0.85 means 85% of previous patients with that combination of traumatic injuries in the last 20 years survived their injuries. The higher the ICISS, the more likely a patient is to survive. In an effort to be conservative in the identification of overtriage, this study used a threshold of 0.90 or higher for ICISS scores and pediatric patients 5 years and older. These criteria were based on the commonalities in the definitions of pediatric overtriage in the research of Osen *et al*, Ciesla *et al*, and Goldstein *et al*.[24–26]

Patients meeting the inclusion criteria who also had a trauma alert charge were deemed overtriaged. A trauma alert charge indicates that EMS identified the patient as a trauma alert in the field. Of the 609 observations in the study population, 122 patients were overtriaged as trauma alerts. The ICISS means of each group were assessed to confirm that the overtriaged and non-trauma alert groups were comparable.

Two regression models were used. The first used overtriaged youth as the dependent variable and was dichotomous with a value of 1 if the patient was overtriaged as a trauma alert and a value of 0 if not. Given the dichotomous nature of the dependent variable, a logistic regression was used to analyze the influence of the independent variables in the model. The likelihood ratio and Wald test statistics were both statistically significant ($p<0.0001$). The independent variables were not highly correlated, indicating multicollinearity was not a problem in the analysis. The second model used cost of patient care as the dependent variable and multiple linear regression. Cost was calculated from each patient's total charges for the admission. The total charges were multiplied by each hospital's annual weighted cost-to-charge ratio to estimate patient care cost. These costs were then adjusted for inflation to 2014 dollars using the producer price indices for hospital inpatient care. The distribution of the costs was skewed to the right, therefore, the cost dependent variable was log transformed, indicating a log-linear specification for the final model. The adjusted $R^2$ of the second model was 0.44.

Independent variables used in each model included demographics such as age, gender, race, ethnicity, payer, and ICISS. The Barell Injury Diagnosis Matrix was used to create nature of injury categories: internal, open, burns, fractures of the skull/neck/trunk, and other fractures (not associated with skull/neck/trunk), and other injuries (defined below). Following Ciesla *et al*, the 'other fractures' category was used as the control group for injury type.[14] Categories of blood vessels, dislocation, amputations, crush, and nerves accounted for less than 1% of the observations and were grouped with the 'other' category along with unspecified injuries. Finally, sprains and strains and contusion/superficial injuries did not have any observations in the study population.

Mechanism of injury was categorized according to the recommended framework of E-code groupings for presenting injury mortality and morbidity data from the Centers for Disease Control and Prevention (CDC) National Center for Health Statistics.[27] Drowning, poisoning, and suffocation did not have

**Table 1** Overtriaged counts and costs by demographics

| | | Total | Overtriaged | | Total | Overtriaged | |
|---|---|---|---|---|---|---|---|
| | | Count | Count | Percentage | Cost | Cost | Cost percentage |
| Gender | Female | 204 | 33 | 16.2 | $344 506 | $115 232 | 33.5 |
| | Male | 405 | 89 | 22.0 | $725 346 | $282 280 | 38.9 |
| Race | Black | 142 | 46 | 32.4 | $267 301 | $137 604 | 51.5 |
| | Other race | 79 | 15 | 19.0 | $163 259 | $63 940 | 39.2 |
| | White | 388 | 61 | 15.7 | $639 292 | $195 968 | 30.7 |
| Ethnicity | Hispanic | 116 | 23 | 19.8 | $225 281 | $81 813 | 36.3 |
| | Non-Hispanic | 493 | 99 | 20.1 | $844 571 | $315 699 | 37.3 |
| Insurance | Uninsured | 46 | 6 | 13.0 | $70 101 | $17 261 | 24.6 |
| | Medicaid | 312 | 74 | 23.7 | $543 185 | $230 584 | 42.5 |
| | Commercial | 251 | 42 | 16.7 | $456 566 | $149 667 | 32.8 |
| Total | | 609 | 122 | 20.0 | $1 069 852 | $397 512 | 37.2 |

**Table 2** Overtriage and trauma alert charges by mechanism of injury

| Mechanism of injury | Count | Overtriaged count | Overtriaged percentage | Average trauma alert charge | Total trauma alert charges |
|---|---|---|---|---|---|
| Cut/pierce | 12 | <5 | | $1950 | $23 402 |
| Fire/burn/hot object | 49 | 14 | 28.6 | $2680 | $131 296 |
| Firearm | 14 | 9 | 64.3 | $6705 | $93 872 |
| Motor vehicle traffic | 91 | 26 | 28.6 | $2655 | $241 625 |
| Transport | 134 | 28 | 20.9 | $20 060 | $276 003 |
| Natural/environmental | 24 | <5 | | $57 | $1363 |
| Struck by/against | 122 | 24 | 19.7 | $1956 | $238 685 |
| Other mechanism | 17 | <5 | | $926 | $15 750 |
| Falls | 146 | 16 | 11.0 | $708 | $103 326 |
| Total | 609 | 122 | 20.0 | $1848 | $1 125 322 |

any trauma alerts in the study population and were excluded in the analysis. Machinery and overexertion had observations less than 2% of the study population and were reclassified as 'other mechanism'. Falls was used as the reference group. The following mechanisms were included in the regression models: cutting/piercing, fire/burn/hot object, firearm, motor vehicle traffic, transport, natural/environmental, struck by/against, and other mechanism. Motor vehicle traffic is defined by the CDC as traffic-related injuries that occur on public roadways as opposed to transport injury mechanisms which involve motor vehicle traffic not on public roadways.[27]

Hospital factors were also used as independent variables in both models and included teaching status and ownership type. Teaching status was defined as a hospital officially associated with an accredited medical school with a minimum of seven physician specialty residency programs and at least 100 resident physicians. Hospital TC status or level was not used as an independent variable because of the high correlation with patients who were trauma alerts. Ownership type consisted of for-profit, not-for-profit, and public hospitals.

The second regression model, cost of admission, used two additional independent variables, time and overtriage. The time variable was calculated as the difference in hours between when a patient was admitted and when they were discharged to home. For example, if a patient was admitted anytime between 05:00 and 05:59 hours (coded as 05) and they were released at 22:00 hours (coded as 22), the time variable would be 17. If a patient was kept overnight, they would have a discharge time less than the admission time and so 24 hours was added to the variable to make it accurate. For example, a patient arrived at 21:00 hours and left at 04:00 hours, the variable was calculated as $(4-21)+24=7$.

Microsoft Excel 2016, Microsoft Access 2016, and SAS software V.9.4 were used in this analysis.

**Table 3** Logistic regression model of overtriage of youth with minor Injury

| | | OR estimate | 95% Wald confidence limits | |
|---|---|---|---|---|
| Patient factors | Age* | 1.09 | 1.01 | 1.17 |
| | Female | 0.69 | 0.41 | 1.14 |
| | Black* | 1.95 | 1.11 | 3.42 |
| | Other race | 1.08 | 0.52 | 2.28 |
| | Hispanic | 1.31 | 0.69 | 2.47 |
| | Uninsured | 0.74 | 0.24 | 2.21 |
| | Medicaid* | 1.76 | 1.05 | 2.92 |
| | ICISS | 0.01 | <0.001 | >999.99 |
| Nature of injury | Fractures of the skull, neck, or trunk* | 4.59 | 1.36 | 15.51 |
| (Reference: other fractures) | Internal injury* | 7.78 | 2.52 | 24.00 |
| | Open wound* | 5.26 | 1.40 | 19.78 |
| | Burns | 16.29 | 0.69 | 383.12 |
| | Other injury* | 5.97 | 1.42 | 25.05 |
| Mechanisms of injury | Cut | 1.63 | 0.29 | 9.15 |
| (Reference: falls) | Fire | 0.95 | 0.04 | 21.63 |
| | Firearm* | 11.99 | 2.39 | 60.03 |
| | Motor vehicle traffic* | 2.25 | 1.03 | 4.90 |
| | Transport | 2.08 | 0.98 | 4.44 |
| | Natural/environmental | 0.14 | 0.015 | 1.28 |
| | Struck by/against | 1.06 | 0.48 | 2.36 |
| | Other mechanism | 0.36 | 0.03 | 4.80 |
| Hospital factors | Teaching | 1.79 | 0.96 | 3.36 |
| (Reference: not for profit) | For profit* | 6.70 | 3.42 | 13.15 |
| | Public* | 3.44 | 1.74 | 6.80 |

*Statistically significant at the $\alpha=0.05$ level.
ICISS, ICD-9-CM Injury Severity Score.

## RESULTS

Of the 609 observations, 267 went to a teaching hospital (44%). Private not-for-profit TCs admitted 377 (62%) of the study population whereas 73 went to public TCs (12%) and 159 went to a for-profit TC (26%). Table 1 provides demographics of overtriaged trauma alert. The percent of patients overtriaged was 20%, but accounted for 37.2% of total costs. All overtriaged payer types had a disproportionately high cost percentage. For example, 23.7% of Medicaid patients were overtriaged, yet the healthcare costs of these overtriaged patients accounted for 42.5% of the total costs. Most of the overtriaged demographic groups had costs nearly twice those who were not identified as trauma alerts.

The percentage of overtriaged patients who had trauma alerts was reported by mechanism of injury in table 2. Firearms were associated with the largest percentage of overtriaged patients at 64.3%, followed by motor vehicle traffic collisions and fire/burn/hot object (28.6%). Transport and firearm had the highest average trauma alert charges with $20 060 and $6705, respectively.

Table 3 provides the results of the logistic regression model of overtriaged youth to test for associations of mechanism of injury.

**Table 4** Regression model of cost of youth with minor to moderate injuries

| | | Parameter estimate | P value | Percentage change to cost |
|---|---|---|---|---|
| Patient factors | Age | 0.01 | 0.20 | |
| | Female | 0.08 | 0.86 | |
| | Black | −0.04 | 0.41 | |
| | Other race | 0.06 | 0.36 | |
| | Hispanic* | 0.11 | 0.04 | 11.4 |
| | Uninsured | −0.04 | 0.58 | |
| | Medicaid | −0.03 | 0.45 | |
| | Time* | 0.02 | 0.0002 | 16.1 |
| | ICISS | −2.00 | 0.06 | |
| | Overtriage* | 0.84 | <0.0001 | 131.8 |
| Nature of injury | Fractures of the skull, neck, or trunk | 0.13 | 0.06 | |
| (Reference: other fractures) | Internal injury* | 0.20 | 0.001 | 22.0 |
| | Open wound | 0.09 | 0.36 | |
| | Burns | 0.004 | 0.99 | |
| | Other injury* | 0.22 | 0.02 | 24.4 |
| Mechanisms of injury | Cut | −0.26 | 0.10 | |
| (Reference: falls) | Fire | 0.08 | 0.78 | |
| | Firearm* | 0.33 | 0.03 | 38.4 |
| | Motor vehicle traffic* | 0.30 | <0.0001 | 35.5 |
| | Transport | 0.09 | 0.15 | |
| | Natural/environmental | −0.04 | 0.69 | |
| | Struck by/against | 0.06 | 0.34 | |
| | Other mechanism | −0.09 | 0.50 | |
| Hospital factors | Teaching hospital* | 0.23 | <0.0001 | 25.5 |
| (Reference: not for profit) | For-profit hospital | 0.02 | 0.76 | |
| | Public hospital | −0.05 | 0.43 | |

*Statistically significant at the $\alpha$=0.05 level.
ICISS, ICD-9-CM Injury Severity Score.

Firearm and motor vehicle traffic were significantly more likely to be associated with a trauma alert than patients with a fall. Other mechanisms of injury were not significant in predicting overtriage of trauma alerts. Older youth had an OR of 1.09 compared with younger youth. Patients were more likely to be overtriaged at for-profit (6.70) and public (3.44) hospitals relative to private not-for-profit hospitals.

Table 4 provides the results of the cost of care regression. The independent variable of interest was overtriage of trauma alerts, which was positively associated with cost. If patients were overtriaged, costs increased 131.8%, indicating they more than doubled. The overtriage variable had the largest impact on cost. Other patient factors that increased cost were Hispanic (11.4%) and time (16.1% per hour). Costs increased 16.1% for each additional hour the patient was hospitalized. The mechanisms associated with increasing cost, compared with falls, included firearm (38.4%) and motor vehicle traffic (35.5%). Teaching status of a hospital was also shown to increase costs by 25.5% for patients treated at a teaching hospital.

## DISCUSSION

This study found that some mechanisms were associated with overtriage as Lerner *et al* found.[13] The research found two of the mechanisms, firearms and motor vehicle traffic (both high energy transfer), were highly associated with overtriage, consistent with Ciesla *et al*.[14] Other injury mechanisms were not associated with overtriage. While triage criteria include physiologic and anatomic indicators,[19] we see value in using injury mechanism as well in triage of youth patients. Including mechanism of injury can provide a fuller assessment of traumatic injury during triage. Youth who were older, black, with Medicaid, and went to a for-profit or public TC had higher odds of being overtriaged. The findings such as TC ownership and overtriage warrant further study.

Youths with mild to moderate injuries who were identified as trauma alerts had significantly higher healthcare costs than their counterparts, after controlling for injury severity, demographic characteristics, injury type and mechanism, and hospital characteristics. The trauma alert charge alone can contribute significantly to total charges and may explain at least part of the increase in these patient costs. Overtriage clearly contributes to higher hospital costs.

There are limitations to this study. The ICISS construct used to account for injury severity, and by extension measure overtriage/undertriage, ignores physiology as it is based solely on the mortality history of specific diagnoses. While its nature makes it highly predictive of the probability of mortality, an important trauma outcome of interest, it may not perform as well for the need for hospitalization or trauma alert classification. Because the severity measure used in this retrospective analysis ignores physiologic measures, it is impossible to determine the true extent of mistriage. In the absence of physiologic data, the estimate of overtriage reported in this analysis should be interpreted as an upper limit. The study population was restricted to Florida, which may not be representative of other states. Trauma alert charges were used in many of the descriptive statistics. The exact cost relative to these charges was unknown because the associated cost-to-charge ratio could not be specifically identified in the Florida financial data. AHCA is an administrative data set and does not include clinical findings, which may partly explain why some patients with mild to moderate injuries were identified as trauma alerts.

## CONCLUSION

Pediatric trauma overtriage rates are acceptably low in the state of Florida. However, certain factors were associated with higher overtriage rates, such as MVC and firearm mechanisms of injury and transport to a for-profit TC. While Florida's overtriage rates are acceptable, perhaps achieving a better understanding of the conditions associated with firearm and motor vehicle traffic injuries that do not necessitate a trauma alert could be useful, such as analyzing hospital and police records to gain further insight without compromising quality of care or increasing undertriage. Reducing overtriage will help lower healthcare costs. Finally, the variability between centers deserves further study as well as the association between older age and overtriage.

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