Characteristics of scene trauma patients discharged within 24-hours of air medical transport

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ABSTRACT

Introduction: Helicopters play an important role in trauma; however, this service comes with safety risks, high transport costs, and downstream care charges.

Objective: Our objective was to determine the characteristics of early discharged trauma patients (<24 h length of stay) in order to reduce overtriage.

Methodology: Data were obtained from the trauma registries at one of two Level 1 trauma centers. Eligible patients included all scene trauma patients transported by helicopter to the Level 1 trauma centers from January 1, 2016, to December 31, 2017, who had a length of stay of 24 h or less. Patient factors such as age, gender, scene location, loaded miles, and transportation costs were collected. Trauma type, mechanism of injury, Abbreviated Injury Scale (AIS), Injury Severity Score, Revised Trauma Score, and prehospital vital signs were documented. Driving distances between the accident scene to local hospital, home of record to local hospital, and home of record to the Level I trauma center were also calculated for patients transported to Level 1 trauma center.

Results: Two hundred and twenty-six of 1042 total patients (21.7%) were discharged within 24 h of helicopter transport from the accident scene to trauma center. Less than 2% of patients were in the age group of 70 years or older. Only 2 (0.88%) patients discharged within 24 h had a prehospital systolic blood pressure <90 mmHg. For patients transported to Level 1 trauma center, the average loaded miles were 50.51 ± 14.99, with average transport charges being $27,921.19 ± $3536.61. Twenty-one percent of Level 1 trauma center patients were self-pay, and families typically drove 71.7 ± 123.23 miles to Level 1 trauma center versus 28.74 ± 40.62 to their local emergency department.

Conclusions: A significant number of patients transported from the scene are discharged within 24 h of admission to a trauma center. These patients rarely have prehospital hypotension, do not receive significant volumes of crystalloid resuscitation, and are infrequently over 70 years of age. One in five patients has no third-party coverage and assumes $27,921.19 in average transport charges.

Key Words: Air medical transport, trauma, triage

INTRODUCTION

Trauma is the leading cause of death for people aged 1–44 years in the United States.[¹] Helicopters play an important role in transporting these critically injured patients and have been shown to reduce mortality[²-⁴] and expand access to Level I trauma centers.[⁵] However, the use of air medical transport comes at a cost – both...
in terms of the safety risks to the patient and crew as well as monetary costs of helicopter transport. Emergency medical services (EMS) providers follow consensus guidelines for field triage promulgated by the centers for disease control when deciding whether to request air medical transport. These guidelines enable EMS providers to make rapid decisions about the seriousness of a patient’s injuries and match the patient’s illness with the level of trauma care needed. Several studies[7–10] have shown that over 60% of patients may be overtriaged to trauma centers by those calling for air medical transport. Previous work from our institution examined the ability of national trauma triage criteria to discriminate between patients who required the resources of a trauma center and those who did not.[11] This evaluation showed that approximately one-third of patients transported directly from a trauma scene are discharged within 24 h of arrival and 83% do not require the specific resources available at a trauma center during their stay. Madiraju et al. examined the impact of patients discharged within 1 day of transport and found that in their trauma center, over $1.3 million dollars could be saved by eliminating overtriage among this group of patients.[12]

The purpose of this study was to determine important characteristics of trauma patients who are delivered to Level I trauma centers and are discharged within 24 h of delivery. By examining such characteristics, it is anticipated that the overtriage of trauma patients can be reduced and that air medical transport can be used more efficiently as an adjunct in trauma care.

**METHODS**

**Study design**

A retrospective chart review of all trauma patients who arrived directly from the scene of an accident via MedFlight from January 1, 2016 to December 31, 2017 to one of two Level 1 trauma centers (Grant Medical Center [GMC] and The Ohio State University Wexner Medical Center [OSUWMC]) were eligible for this study. Triage to a trauma center in state is based on statewide trauma triage guidelines that are directly related to the Centers for Disease Control and Prevention (CDC) field trauma triage guidelines.[6] Inclusion criteria for trauma patients included: (1) age ≥18 years, (2) mode of transport of helicopter, (3) transported directly from an accident scene, and (4) discharged within 1 day or less from arrival to a Level I trauma center. Patients were deemed ineligible if (1) they were in the age group of 17 years or less, (2) transported from another health-care facility, (3) mode of arrival was ground transport, or (4) their length of stay was more than 1 day. Patients whose injury was isolated to major burns were also excluded from the study.

**Data collection**

The trauma databases at the Level 1 trauma centers (GMC and OSUWMC) were queried to determine all eligible patients. Data integrity for each database was maintained in accordance with the American College of Surgeons (ACS) Committee on Trauma Level 1 trauma center verification process and is routinely assessed for data quality. Final Injury Severity Score (ISS) as well as a categorization of injuries sustained as denoted by their discharge ICD-9 (or ICD-10) codes in the ranges of 800–939.9, 987.9, 991.0–991.6, 992.0–992.9, 994.0, 994.1, 994.7, 994.8, and 995.50–995.59 were included. Injuries were also grouped by body systems according to the Abbreviated Injury Severity classification.[13]

Data points collected included patient age, gender, scene location, loaded miles, and transportation costs. Traditional triage factors including physiologic metrics, anatomic injuries, and mechanisms of injury as identified in the 2011 CDC guidelines for field triage of injured patients[14] were collected and categorized by one of the authors (CG) who was trained for this analysis. Trauma type was characterized as either blunt or penetrating. The mechanism of injury was categorized as fall, bicycle crash, gunshot wound, motorcycle collision, motor vehicle accident, pedestrian versus car, and stab wound. Anatomic injuries included penetrating injuries of the head, neck, torso, or extremities proximal to the elbow or knee; chest deformity; crush injury; suspected pelvic fracture; amputation; skull fracture; or injury associated with paralysis. Special considerations for triage to a trauma center included geriatric falls, patients on anticoagulants, operative procedures other than laceration repair, and pregnancy >20 weeks. Other factors analyzed included patients who were intubated in the field, the volume of prehospital fluids administered, and the patient’s Revised Trauma Score (RTS).[15] The RTS is a physiologic scoring system yielding values between 0 and 12 with lower scores indicating higher mortality risk. The RTS is made up of three parameters – Glasgow Coma Scale (GCS), systolic blood pressure (SBP), and respiratory rate. The GCS is weighted more heavily than the other two parameters to account for serious head injuries. All data were reviewed for accuracy by a second author (HW).

Electronic medical charts from MedFlight, the primary air medical transport agency in central Ohio were queried. MedFlight operates nine air medical bases throughout its service region and completes approximately 3200 air transport missions annually. Data were abstracted from MedFlight’s privately maintained data to determine the location of the accident, prehospital vital signs, initial GCS and RTS, interventions performed during transport including endotracheal intubation, loaded patient miles, and air medical transport cost. These data were assessed for accuracy via 100% peer-review of transport records.
Air medical transport costs were calculated by the sum of MedFlight’s base rate and cost per loaded mile. Using the location of the accident and the county of origin, the authors used the “nearby” function within Google Maps to determine the closest available hospital (in miles) with an emergency department (ED). Google Maps was then used to determine the shortest driving distance (in miles) between the patient’s home of record to the closest available hospital and the patient’s home of record to the Level I trauma center to which they were transported.

Of note factors such as average loaded miles, transport charges, driving distances, and patient payment source were limited to only transported to OSUWMC patients due to information sharing limitations outlined in the institutional review board approvals at each medical center.

This study protocol was approved by the institutional review boards at both GMC and OSUWMC (2018H0024). The methods used in this retrospective medical record review were compliant with the procedures outlined by Worster et al. [16]

**Data analysis**

Data were entered into an Excel spreadsheet (Microsoft Corporation, Seattle, WA, USA) and analyzed using the data analysis ToolPak to calculate descriptive statistics. Continuous numerical data were reported in tables as means + standard deviations. ISS, GCS, and RTS values were assumed to lack a normal distribution, and thus, median values and the interquartile range were calculated. Categorical data were reported as absolute numbers and percentages. Patients with a home of record outside of state and its contiguous states (surrounding states) were excluded when calculating distances between home of record to local hospital and home of record to Level I trauma center in order to reduce the effects of outliers on the mean.

Finally, we conducted an analysis of specific factors (age and payer source) and compared these parameters to the distribution of adult patients in the 2010 State of Ohio census data and with patients with a hospital length of stay >24 h. A Chi-square test was applied using STATA (Version 10, StataCorp LP, College Station, TX, USA) to determine if there were specific differences among early discharge patients and 2010 state census data as well as patients with a length of stay >24 h. Statistical significance was assumed for \( P < 0.05 \).

**RESULTS**

There were 1042 adult nonburn scene trauma patients who were transported by helicopter to either GMC or OSUWMC between January 1, 2016, and December 31, 2017. Of these patients, 226 were discharged within 24 h of arrival. Therefore, the calculated early discharge rate for the study population was 21.7%. Patient demographics, trauma type, mechanism of injury, and patient status for intubation, anticoagulant therapy, and pregnancy for patients with a length of stay of 1 day or less are shown in Table 1. Of note, the majority (93.8%) of patients were Caucasian, 71.7% were male, and 96.9% were victims of blunt trauma. Motor vehicle accidents (44.7%) and falls (20.4%) comprised the most common mechanisms of injury. Figure 1 shows the distribution of mechanisms of injury for the study cohort.

| Table 1: Patient demographics, trauma type, mechanism of injury, intubation status, anticoagulant therapy, pregnancy status and operative procedure |
|---|
| Race | \( N (\%) \) |
| Asian | 1 (0.4) |
| African-American | 7 (3.1) |
| Indian | 2 (0.9) |
| Other | 1 (0.4) |
| Caucasian | 212 (93.8) |
| Unknown | 2 (0.9) |
| Sex | \( N (\%) \) |
| Male | 162 (71.7) |
| Female | 64 (28.3) |
| Trauma type | \( N (\%) \) |
| Blunt | 219 (96.9) |
| Penetrating | 7 (3.1) |
| Intubation performed at the scene | \( N (\%) \) |
| Yes | 2 (0.9) |
| No | 224 (99.1) |
| Anticoagulant | \( N (\%) \) |
| Yes | 8 (3.5) |
| No | 218 (96.5) |
| Pregnancy >20 weeks | \( N (\%) \) |
| Yes | 2 (3.1) |
| No | 62 (96.9) |
| Operative procedure (other than laceration repair) | \( N (\%) \) |
| Yes | 5 (2.2) |
| No | 221 (97.8) |

**Figure 1:** Mechanism of injury for early discharged patients. AS: Asphyxiation, BIKE: Bicycle, FALL: Fall, GSW: Gunshot wound, MCC: Motorcycle crash, MVA: Motor vehicle accident, OTHER: Other injury not classified, OV: Overexertion, PED: Pedestrian, SPORT: Sports-related injury, STAB: Stab wound, ATV: All-terrain vehicle, CRUSH: Crush injury.
Table 2: Patient characteristics for early discharged patients

| Characteristic                        | Mean ± Standard Deviation |
|--------------------------------------|---------------------------|
| Age, mean ± SD                       | 39.12 ± 15.22             |
| ED length of stay (h:min), mean ± SD | 8.48 ± 6.55               |
| ISS, median (IQR)                    | 5 (2-6)                   |
| ED GCS, median (IQR)                 | 15 (15-15)                |
| Driving distance (scene to local hospital) (miles), mean ± SD | 10.33 ± 8.36             |
| Distance driving (HOR to local hospital) (miles), mean ± SD | 28.74 ± 40.62            |
| Driving distance (HOR to Level I trauma center) (miles), mean ± SD | 71.70 ± 123.23           |
| Prehospital GCS, median (IQR)        | 15 (15-15)                |
| Prehospital SBP, mean ± SD           | 137.99 ± 20.91            |
| Prehospital respiratory rate, mean ± SD | 17.95 ± 4.79             |
| RTS, median (IQR)                    | 7.841 (7.840-7.841)       |
| Prehospital heart rate, mean ± SD    | 92.82 ± 15.45             |
| Volume of fluids administered (mL), mean ± SD | 334.64 ± 299.69         |
| Loaded Miles (no parentheses), mean ± SD | 50.51 ± 14.99            |
| Transportation cost ($), mean ± SD   | 27,921.19 ± 3536.61       |

Table 2 includes the descriptive statistics for patient age, ED length of stay, ISS, ED GCS, and driving distances from scene to local hospital, home of record to local hospital, and home of record to Level 1 trauma center. Factors such as average loaded miles, transport charges, driving distances, and patient payment source were limited to only Level 1 trauma center patients due to information sharing limitations outlined in the institutional review board approvals at each trauma center. Table 2 also includes the prehospital values of GCS, SBP, respiratory rate, RTS, heart rate, and volume of fluids administered. For patients transported by MedFlight, loaded miles and transportation costs are included in Table 2. About 20.92% of patients had no third-party coverage and assumed on average $27,921.19 in transportation charges.

Patient age stratification is shown in Table 3. A comparison with the 2010 State of Ohio census data is depicted in Figure 2. Of note, only 1.8% of patients were in the age group of 70 years or older and only 2 (0.9%) of patients discharged within 24 h of arrival had a prehospital SBP <90 mmHg. In addition, the minority of patients (2.7%) received >1000 mL of prehospital crystalloid. The prehospital volume of fluid administered is shown in Figure 3.

The payment source is shown in Figure 4 which also compares the distribution for early discharged patients to those who had a length of stay >24 h. There was a trend (P = 0.055) toward a higher representation of self-pay in the early discharge group although this did not achieve statistical significance.

**DISCUSSION**

Helicopters serve an important role in transporting trauma patients from the accident scene to trauma centers. Studies have shown that air medical transport provides a survival advantage when compared to ground transport in major trauma. Air medical services extend the benefits of access to high-level trauma care to an additional 81.4 million U.S. citizens. However, the overtriage of scene trauma patients leads to inappropriate use of helicopter transport, increasing costs to the patient, and increasing safety risk. Air medical transport of less severely injured patients also leads to higher downstream costs. Newgard et al. reported that trauma patients accrued on average $5590 (2008 dollars) in additional costs for medical workup at a Level I trauma center compared to a lower acuity facility. In addition, during a trauma activation, hospital trauma teams are removed from other priorities, leaving care of surgical patients on hold. Similarly, Madiraju et al. noted in their study entitled “In by helicopter out by cab: The financial cost of aeromedical overtriage of trauma patients” that savings of over $1.3 million could be realized by simply eliminating those patients transported by air who were discharged within 24 h.

Previous work found that approximately one of three scene trauma patients are overtriaged as defined by discharge within 24 h of arrival. This indicates an opportunity for improvement when triaging a helicopter transport request for traumatic injuries. The challenge is to determine factors predictive of a trauma patient’s future medical needs at the time of injury. Cudnik et al. found that only a few factors identified the majority of trauma patients transported by helicopter with serious injuries requiring resources immediately available at a Level I trauma center. These included age >44 years, GCS <14, SBP <90 mmHg, and flail chest.

Our study focused specifically on a cohort of early discharged patients (within 24 h of arrival) to better investigate factors shared among specific overtriaged...
Patients aged 70 years or older were significantly ($P < 0.01$) under-represented in our study cohort as compared to that same age group from the 2010 United States Census Bureau report for the state. This result suggests that geriatric patients may continue to be undertriaged within state trauma system as well as nationally. The state of Ohio has geriatric-specific trauma triage criteria and currently uses a SBP <100 mmHg as criteria for transport of patients aged 70 or older. Our study found only 4 (1.8%) patients, aged 70 or older, who were discharged early. These four patients had prehospital SBP recorded as 131 mmHg or greater. Brown et al. found that among geriatric patients, defined as age > 65 years, triaged with a SBP between 90 and 109 mmHg, there was an odds ratio for mortality similar to younger adult trauma victims with a SBP <90 mmHg. Our study found 2 (0.9%) patients aged 65 years or older whose prehospital SBP fell within or below the 90–109 mmHg range described by Brown et al. There is current evidence that CDC Field Trauma Triage Criteria, validated criteria promulgated by the ACS and the CDC, has low predictive power in identifying seriously injured older adults based on physiologic criteria. One proposed explanation is that a SBP <90 mmHg may underestimate the need for geriatric patients to receive trauma resources. The National Trauma Triage Protocol suggests that increasing the SBP threshold to <110 mmHg (rather than 90 mmHg) in triage of patients older than 65 years increased the sensitivity from 5% to 13% and the specificity from 93% to 99%.

We also found that high-impact motor vehicle accidents and falls were commonly represented in the early discharge population. It has been suggested that mechanism of injury is overemphasized as a triage factor in determining the need for helicopter transport to a Level I trauma center. Mechanism of injury is often the primary reported reason for requesting helicopter transport despite the fact that these criteria have been shown to have low positive predictive value in identifying major trauma victims.

Our study showed that patients discharged within 24 h rarely receive more than 1000 mL of prehospital crystalloid. The volume of crystalloid fluid administered prehospital can be a surrogate measure of the hemodynamic status of a patient before arrival to a Level I trauma center. This suggests that the majority of early discharged trauma patients are hemodynamically stable and fail to meet physiologic criteria prior to arrival at the Level I trauma center.
An interesting observation was that 20.92% of the patients in our study lacked any public or private insurance. This implies that approximately one in five of early discharged patients may be accruing a significant debt as the result of their care, including transport costs. When our study population was compared to helicopter transported scene trauma patients with a length of stay >24 h, we found that self-pay was still over-represented (20.92% compared to 14.40%), although this did not achieve statistical significance \((P = 0.055)\). This finding deserves further investigation.

Our study further suggests that the current CDC Field Triage guidelines may be an inefficient tool for appropriately triaging patients for direct transport via helicopter to a trauma center. Others have investigated the potential for a more efficient triage tool, including work from Brown et al.\(^{[26,27]}\). These investigators have developed the Air Medical Prehospital Triage (AMPT) score for determining the need for helicopter transport of trauma patients from the accident scene.\(^{[28]}\) This tool has been validated externally using the Pennsylvania Trauma Outcomes Study registry.\(^{[28]}\) The AMPT score uses factors such as GCS, respiratory rate, unstable chest wall fractures, suspected hemothorax/pneumothorax, paralysis, multisystem trauma, and physiologic/anatomic criteria present in the National Field Triage guidelines to select patients for direct helicopter scene response. Further prospective validation as well as face validation by end users is warranted before the AMPT score can be fully endorsed as an effective mean of trauma triage. One important limitation cited in the use of any triage tool that seeks to determine patient destination is the role of patient autonomy in choosing the health-care facility in which they will receive medical care.\(^{[17]}\)

One final factor to consider in improving prehospital triage may be the use of point-of-care lactate measurement which has been shown to reclassify patients to a more appropriate level of trauma activation when compared to the ACS recommendation.\(^{[29]}\) Prehospital lactates have already been shown to be feasible in the assessment of prehospital patients with suspected sepsis.\(^{[29,30]}\) Brown et al. found that the benefit of using the ACS recommendations for triage in addition to a prehospital lactate measurement provided a significant reduction in overtriage relative to a small increase in undertriage.\(^{[28]}\) Currently, however, point-of-care lactate measurement is limited in the prehospital environment.

**Limitations**

The major limitation of this study is its retrospective investigation of a cohort of scene trauma patients discharged within 24 h of trauma center arrival. It is possible that some additional factors other than those studied may better assist in identifying patients who would likely be discharged within 24 h of arrival by helicopter. Charts reviewed were also subject to potential documentation errors by EMS providers. Specifically, items such as prehospital vital signs may not be uniform in their collection and thus alter calculated values such as GCS and RTS.

In addition, it should be noted that we could not consider the potential impact of undertriage in our cohort. Specifically, we only had access to data from our Level 1 trauma centers and did not have access to a regional trauma database for this study; therefore, our analysis was limited to the significant number of patients who were discharged in the first 24 h. Furthermore, we did not include a control group to compare our cohort of air medical scene transports to those transported by ground. Our intent was to focus specifically at the air transport group in a manner similar to Madiraju et al.\(^{[12]}\) as these patients typically incur a much greater expense in terms of transport charges and experience significant travel from their home communities. The study was also conducted at two institutions with a primary reliance on a single air medical program and functioning within one statewide trauma system. As such, these results may not necessarily be generalizable to other trauma systems. Finally, a convenience sample was chosen over a 2-year period. This may have led to Type II errors in the assessment of mechanism of injury or payer source in patients discharged within 24 h compared to those whose length of stay was longer.

**CONCLUSIONS**

A significant number of patients transported from the scene are discharged within 24 h of admission to a trauma center. These patients rarely have a prehospital SBP < 90 mmHg, receive more than 1000 mL of crystalloid, or are over 70 years of age. One of five patients has no third-party coverage and assumes $27,921.19 in average transport charges. Future research should validate prehospital triage factors in a prospective manner to reduce overtriage to an “acceptable” level, ideally without increasing undertriage.

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**Conflicts of interest**

There are no conflicts of interest.

**Ethical conduct of research**

This study was approved by the Institutional Review Board / Ethics Committee. The authors followed applicable EQUATOR Network (http://www.equator-network.org/) guidelines during the conduct of this research project.
REFERENCES

1. Centers for Disease Control and Prevention. Key Data and Statistics | WISQARS | Injury. Centers for Disease Control and Prevention; 2017.

2. Galvagno SM Jr., Haut ER, Zafar SN, Millin MG, Efron DT, Koenig GJ Jr., et al. Association between helicopter vs. ground emergency medical services and survival for adults with major trauma. JAMA 2012;307:1602-10.

3. Hannay RS, Wyzykowski AD, Ball CG, Laupland K, Feliciano DV. Retrospective review of injury severity, interventions and outcomes among helicopter and nonhelicopter transport patients at a Level I urban trauma centre. Can J Surg 2014;57:49-54.

4. Stewart KE, Cowan LD, Thompson DM, Spears T, Steele SR, Martin MJ. A simplified trauma triage system safely reduces overtriage and improves provider satisfaction: A prospective study. Am J Surg 2015;209:856-62.

5. Uleberg O, Vinjevoll OP, Eriksson U, Aadahl P, Skogvoll E. Overtriage in trauma patients: a propensity score analysis. Acad Emerg Med 2011;18:1208-16.

6. Delgado MK, Staudenmayer KL, Wang NE, Spain DA, Weir S, Owens DK, et al. Cost-effectiveness of helicopter versus ground emergency medical services for trauma scene transport in the United States. Ann Emerg Med 2013;62:351-64.e19.

7. Flanagan ME. A revision of the trauma score. J Trauma 1989;29:623-9.

8. Shawhan RR, McVay DP, Casey L, Spears T, Steele SR, Martin MJ. Physiologic field triage criteria for identifying seriously injured older adults. Prehosp Emerg Care 2017;21:138.

9. Branas CC, MacKenzie EJ, Williams JC, Schwab CW, Teter HM, Owens DK, et al. Association between helicopter vs. ground emergency medical services and survival for adults with major trauma. JAMA 2012;307:1602-10.

10. Bledsoe BE, Wesley AK, Eckstein M, Dunn TM, O’Keefe MF. Helicopter scene transport of trauma patients with nonlife-threatening injuries: A meta-analysis. J Trauma 2006;60:1257-65.

11. Woraster A, Bledsoe RD, Cleve P, Farnsede CM, Upadhye S, Eva K. Reassessing the methods of medical record review studies in emergency medicine research. Ann Emerg Med 2005;45:448-51.

12. Galvagno SM Jr., Haut ER, Zafar SN, Millin MG, Efron DT, Koenig GJ Jr., et al. Association between helicopter vs. ground emergency medical services and survival for adults with major trauma. JAMA 2012;307:1602-10.

13. Madiraju SK, Catino J, Kokaram C, Albrecht R. helicopter versus ground transport and in-hospital mortality in trauma patients: a propensity score analysis. Acad Emerg Med 2011;18:1208-16.

14. Sasser SM, Hunt RC, Faul M, Sugerman D, Pearson WS, Dulski T, et al. Guidelines for field triage of injured patients: Recommendations of the National Expert Panel on Field Triage, 2011. MMWR Recomm Rep 2012;61:1-20.

15. Champion HR, Sacco WJ, Copes WS, Gann DS, Gennarelli TA, Flanagan ME. A revision of the trauma score. J Trauma 1989;29:623-9.

16. Woraster A, Bledsoe RD, Cleve P, Farnsede CM, Upadhye S, Eva K. Reassessing the methods of medical record review studies in emergency medicine research. Ann Emerg Med 2005;45:448-51.

17. Newgard CD, Staudenmayer K, Hsia RY, Mann NC, Bulger EM, Holmes JF, et al. The cost of overtriage: More than one-third of low-risk injured patients were taken to major trauma centers. Health Aff (Millwood) 2013;32:1591-9.

18. Cook CH, Muscarella P, Praba AC, Melvin WS, Martin LC. Reducing overtriage without compromising outcomes in trauma patients. Arch Surg 2001;136:752-6.

19. Cudnik MT, Werman HA, White LJ, Opake JLM. Prehospital factors associated with mortality in injured air medical patients. Prehosp Emerg Care 2012;16:121-7.

20. Newgard CD, Richardson D, Holmes JF, Rea TD, Hsia RY, Mann NC, et al. Physiologic field triage criteria for identifying seriously injured older adults. Prehosp Emerg Care 2014;18:461-70.

21. Caterino JM, Raubenoth A, Cudnik MT. Modification of glasgow coma scale criteria for injured elders. Acad Emerg Med 2011;18:1014-21.

22. Esposito TJ, Offner PJ, Joravich GJ, Graftith J, Maier RV. Do prehospital trauma triage criteria identify major trauma victims? Arch Surg 1995;130:171-6.

23. Brown JB, Gestring ML, Forsythe RM, Stassen NA, Billiar TR, Peitzman AB, et al. Systolic blood pressure criteria in the National Trauma Triage Protocol for geriatric trauma: 110 is the new 90. J Trauma Acute Care Surg 2015;78:352-9.

24. Newgard CD, Richardson D, Holmes JF, Rea TD, Hsia RY, Mann NC, et al. Physiologic field triage criteria for identifying seriously injured older adults. Prehosp Emerg Care 2014;18:461-70.

25. Caterino JM, Raubenoth A, Cudnik MT. Modification of glasgow coma scale criteria for injured elders. Acad Emerg Med 2011;18:1014-21.

26. Brown JB, Gestring ML, Guyette FX, Rosengart MR, Stassen NA, Forsythe RM, et al. Development and validation of the Air Medical Prehospital Triage score for helicopter transport of trauma patients. Ann Surg 2016;264:378-85.

27. Brown JB, Gestring ML, Guyette FX, Rosengart MR, Stassen NA, Forsythe RM, et al. External validation of the Air Medical Prehospital Triage score for identifying trauma patients likely to benefit from scene helicopter transport. J Trauma Acute Care Surg 2017;82:270-9.

28. Brown JB, Lerner EB, Sperry JL, Billiar TR, Peitzman AB, Guyette FX. Prehospital lactate improves accuracy of prehospital criteria for designating trauma activation level. J Trauma Acute Care Surg 2016;81:445-52.

29. Guerra WF, Mayfield TR, Meyers MS, Clouatre AE, Riccio JC. Early detection and treatment of patients with severe sepsis by prehospital personnel. J Emerg Med 2013;44:1116-25.

30. Boland LL, Hokanson JS, Fernstrom KM, Kinzy TG, Lick CJ, Satterlee PA, et al. Prehospital lactate measurement by emergency medical services in patients meeting sepsis criteria. West J Emerg Med 2016;17:648-55.