Journal of Pediatric Surgery xxx (2018) xxx–xxx

Contents lists available at ScienceDirect

Journal of Pediatric Surgery

journal homepage: www.elsevier.com/locate/jpedsurg

Resource utilization and indications for helicopter transport of head-injured children☆,☆☆

Clay M. Elswick [a], Deidre Wyrick [b], Lori A. Gurien [c], Malik Rettiganti [d], Marie Gowen [d], Ambre' Pownall [e], Diaa Bahgat [f], R. Todd Maxson [b], Eylem Öcal [e], Gregory W. Albert [e],*

[a] Department of Neurosurgery, Wayne State University, Detroit, MI
[b] Division of Surgery, Arkansas Children's Hospital and Department of Surgery, University of Arkansas for Medical Sciences, Little Rock, AR
[c] Department of Surgery, University of Florida College of Medicine–Jacksonville, Jacksonville, FL
[d] Biostatics Program, Department of Pediatrics, University of Arkansas for Medical Sciences, Little Rock, AR
[e] Division of Neurosurgery, Arkansas Children's Hospital and Department of Neurosurgery, University of Arkansas for Medical Sciences, Little Rock, AR
[f] Division of Neurosurgery, John L. McClellan Memorial Veterans' Hospital and Department of Neurosurgery, University of Arkansas for Medical Sciences, Little Rock, AR

ARTICLE INFO

Article history:
Received 31 July 2017
Received in revised form 22 April 2018
Accepted 23 April 2018
Available online xxxx

Key words:
Helicopter transport
Traumatic brain injury
Pediatric trauma

ABSTRACT

Introduction: Helicopter emergency medical services (HEMS) have provided benefit for severely injured patients. However, HEMS are likely overused for the transportation of both adult and pediatric trauma patients. In this study, we aim to evaluate the degree of overuse of helicopter as a mode of transport for head-injured children. In addition, we propose criteria that can be used to determine if a particular patient is suitable for air versus ground transport.
Materials and methods: We identified patients who were transported to our facility for head injuries. We included only those patients who were transported from another facility and who were seen by the neurosurgical service. We recorded a number of data points including age, gender, race, Glasgow Coma Score (GCS), and intubation status. We also collected data on a number of imaging findings such as mass effect, edema, intracranial hemorrhage, and skull fractures. Patients undergoing emergent nonneurosurgical intervention were excluded.
Results: Of the 373 patients meeting inclusion criteria, 116 (31.1%) underwent a neurosurgical procedure or died and were deemed appropriate for helicopter transport. The remaining 68.9% of patients survived their injuries without neurosurgical intervention and were deemed nonappropriate for helicopter transport. Multivariable logistic regression identified GCS 3–8 and/or presence of mass effect, edema, epidural hematoma (EDH), and open-depressed skull fracture as appropriate indications for helicopter transport.
Conclusions: The majority of patients transported to our facility by helicopter survived their head injury without need for neurosurgical intervention. Only those patients meeting clinical (GCS 3–8) or radiographic (mass effect, edema, EDH, open-depressed skull fracture) criteria should be transported by air.
Level of Evidence: Level III (Diagnostic Study).

Helicopter emergency medical services (HEMS) are widely used throughout the United States and other countries for the transport of critically ill patients, both from the scene to the hospital and for interfacility transfers. Medical helicopter transports were initially utilized by the military during the Korean War. Following that conflict, helicopters were brought into the civilian realm for the expeditious transport of trauma victims. However, it was not until 1972 that HEMS crews had medical training [1].

National Trauma Databank (NTDB) studies have shown improvements in survival of adult general trauma patients [2] and adult traumatic brain injury (TBI) patients [3] transported by helicopter compared to those transported by ground. Other NTDB studies demonstrated improved survival in pediatric general trauma patients [4] and pediatric TBI patients [5] transported by helicopter as opposed to by ground.

Despite these benefits of helicopter transport, there is concern that helicopters are overused in the transport of patients. Vercruysse, et al. reviewed 6-years of data on transports to their facility. They found that 27.5% of these patients were minimally injured and did not benefit from helicopter transport. The estimated cost to the system for transporting these minimally injured patients by air was $4.8 million

☆ This work has been previously presented at the American College of Surgeons Region VI Resident Trauma Papers Competition (November 2015, Dallas, TX) and the 44th Annual Meeting of the International Society for Pediatric Neurosurgery (October 2016, Kobe, Japan).
☆☆ The authors have no conflicts of interest to report.

* Corresponding author at: Division of Neurosurgery, Arkansas Children's Hospital, 1 Children's Way, Slot 838, Little Rock, AR 72202. Tel.: +1 501 364 1448; fax: +1 501 364 3621.
E-mail address: galbert2@uams.edu. (G.W. Albert).

https://doi.org/10.1016/j.jpedsurg.2018.04.032
0022-3468/© 2018 Elsevier Inc. All rights reserved.

[6]. Polites, et al. reviewed the NTDB for children transported by helicopter versus by ground ambulance. They found that while severely injured children did have a lower mortality when transported by helicopter, no such benefit was identified for children with minor injuries [7]. Knofsky, et al. reviewed their own experience and found that 22% of pediatric patients transported by HEMS were discharged from the emergency department [8]. These previously published articles do not identify specific criteria which may help inform the decision as to air versus ground transport.

In this study, we aimed to critically evaluate the pediatric patients transported to our facility with head injuries from other hospitals. We examined the severity of injuries and interventions performed to determine the appropriateness of transport. In addition, we propose criteria that can be used by referring physicians when making triage decisions regarding mode of transport.

1. Materials and methods

1.1. Subject identification

The trauma database at our American College of Surgeons level I pediatric trauma center was queried for patients transported from another facility by helicopter who were evaluated by neurosurgery after arrival. We included patients transported from February 2009 to December 2012. Our facility accepts patients up to 21 years of age. Inclusion criteria were transport from another facility and evaluation by neurosurgery at any time during admission for head injury. At our institution, all patients with an abnormal head CT scan after trauma are seen by the neurosurgery service. Therefore, we are confident that these inclusion criteria allowed us to identify all patients with significant head injury, including those whose head injuries may not have been identified until after transport. Exclusion criteria were neurosurgical evaluation for spine injury absent a head injury, transport directly from the scene of the accident, presence of another nonhead injury which prompted the decision to transport by air. Patients who underwent emergent nonneurosurgical intervention upon arrival to our facility were excluded from this study.

1.2. Data collection

Records were reviewed for age, gender, race, Glasgow Coma Score (GCS), intubation status, Abbreviated Injury Scale-Head (AIS-Head), Injury Severity Score (ISS), and imaging findings. Imaging findings included mass effect as evidenced by midline shift and/or herniation, edema/loss of gray–white differentiation, epidural hematoma (EDH), intracranial hemorrhage other than EDH, and skull fracture. Skull fractures were further classified as open/depressed versus other. Midline shift was defined as present or absent without regard for degree of shift. Images from other institutions were reviewed by radiologists at our institution and imaging findings were recorded from the radiology reports by our pediatric radiologists. Air transport was deemed appropriate if the patient required surgical intervention for head injury (eg craniotomy or craniectomy) at any time during admission, procedure for head injury (eg intracranial pressure monitor insertion) at any time during admission, or if the patient died from his/her injuries.

1.3. Statistical analysis

Demographics and risk factors were summarized using count and percentage for categorical variables and mean and standard deviation for continuous variables. Groups were compared using two-sample t-test for continuous variables and Chi-squared test of association for categorical variables. Logistic regression analysis was performed to identify factors that were associated with appropriate helicopter transport. Factors that were found to be statistically significant in the univariate model as well as those thought to be clinically relevant were included in the multivariate analysis. Penalized maximum likelihood estimation was used to prevent over fitting and the optimum penalty was chosen using the Akaike Information Criteria. Model discrimination was evaluated using the C-statistic and model fit was evaluated using the Hosmer-Lemeshow goodness-of-fit test. Bootstrap validation using 200 resamples with replacement was used to internally validate the final penalized model to check for over fitting. Effects from the final penalized logistic regression model are presented using odds ratios (ORs) and corresponding 95% confident intervals (CIs). All tests were two-sided assuming a significance level of 5%. Statistical analysis was performed using the R software package (R Core Team, 2015) and the rms package (Frank E Harrell Jr., 2015).

This study was approved by the local institutional review board.

2. Results

2.1. Subjects

The trauma database query revealed 452 patients transported to our institution from another facility who received consultation from the neurosurgery service after arrival. Seventy-nine patients were excluded owing to spine injury without head injury or absence of findings of cranial imaging after review by our pediatric radiologists. Two patients with head injury were excluded patients because they underwent emergent nonneurosurgical intervention upon arrival to our facility. One of these patients had limb ischemia and the other underwent exploratory laparotomy and ligation of a splenic artery injury. Two patients underwent delayed exploratory laparotomy (posttrauma day 1 and posttrauma day 5) and were included in this study. Of the remaining 373 patients, 116 (31.1%) underwent a neurosurgical operation or bedside procedure or died, meeting criteria for reasonable transfer. The remaining 257 patients (68.9%) were classified as nonreasonable air transfers and could have been transported by ground. One patient from the nonreasonable transportation group was excluded from further analysis owing to lack of information regarding GCS. AIS-Head and ISS both showed statistically significant differences between the two groups. These factors were not included in our modeling since they are not typically determined by referring hospitals at the time of acute injury and therefore would not be valuable measures by which to make transport decision (Fig. 1).

2.2. Univariate analysis

Age, gender, and presence of an intracranial hemorrhage other than EDH were not associated with classification as appropriate air transport. Regarding epidural hematoma, there was a trend toward association with appropriate air transport, but this was not statistically significant ($p = 0.06$). Being intubated, having mass effect / midline shift / herniation on cranial imaging, presence of edema / loss of gray–white differentiation on head CT, and presence of an open-depressed skull fracture were all statistically significantly associated with appropriate air transport. Presence of another type of skull fracture (not open-depressed, typically linear nondisplaced) was associated with nonappropriate air transport (Table 1). Mechanisms of injury are noted in Table 1.

2.3. Logistic regression

Logistic regression analysis revealed that GCS, presence of mass effect / midline shift / herniation, edema / loss of gray–white differentiation, EDH, and open-depressed skull fracture were predictors of appropriate air transport (Table 2). Discrimination of the final prediction model was very high with a C-statistic of 0.895. Internal bootstrap validation of the penalized logistic regression model resulted in an optimism index for the slope of the calibration equation of 0.0229 suggesting minimal over fit.

Please cite this article as: Elswick CM, et al, Resource utilization and indications for helicopter transport of head-injured children, J Pediatr Surg (2018), https://doi.org/10.1016/j.jpedsurg.2018.04.032