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Complete Title: Helicopters and injured kids: Improved survival with scene air medical transport in the pediatric trauma population

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Abstract

Background—Helicopter emergency medical services (HEMS) are frequently used to transport injured children, despite unclear evidence of benefit. The study objective was to evaluate the association of HEMS compared to ground emergency medical services (GEMS) transport with outcomes in a national sample of pediatric trauma patients.

Methods—Patients age ≤15 undergoing scene transport by HEMS or GEMS in the NTDB 2007-2012 were included. Propensity score matching was used to match HEMS and GEMS patients for likelihood of HEMS transport based on demographics, prehospital physiology and time, injury severity, and geographic region. Absolute standardized differences <0.1 indicated adequate covariate balance between groups after matching. The primary outcome was in-hospital survival, while the secondary outcome was discharge disposition in survivors. Conditional logistic regression determined the association between HEMS versus GEMS transport with outcomes while controlling for demographics, admission physiology, injury severity, non-accidental trauma, and in-hospital complications not accounted for in the propensity score. Subgroup analysis was

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There are no conflicts of interest for the current study

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performed in patients with transport time >15 min to capture patients with the potential for HEMS transport.

Results—A total of 25,700 HEMS/GEMS pairs were matched from 166,594 patients. Groups were well matched with all propensity score variables having absolute standardized differences <0.1. In matched patients, HEMS was associated with a 72% increase in odds of survival compared to GEMS (AOR 1.72; 95%CI 1.26—2.36, p<0.01). Transport mode was not associated with discharge disposition (p=0.47). Subgroup analysis included 17,657 HEMS/GEMS pairs. HEMS was again associated with a significant increase in odds of survival (AOR 1.81; 95%CI 1.24—2.65, p<0.01), while transport mode was not associated with discharge disposition (p=0.58).

Conclusions—Scene transport by HEMS was associated with improved odds of survival compared with GEMS in pediatric trauma patients. Further study is warranted to understand the underlying mechanisms and develop specific triage criteria for HEMS transport in this population.

Level of Evidence—III, therapeutic study

Keywords

Helicopter; Children; Outcomes; Prehospital; Emergency medical services

Background

Helicopter emergency medical services (HEMS) have become an integral component of modern trauma systems. HEMS has been shown to improve trauma center access for a substantial proportion of the United States (US) population.[1] Trauma is well known as a time-sensitive disease.[2] HEMS can offer a significant benefit by reducing time to definitive care for the patient injured remotely from a trauma center when compared with ground emergency medical service (GEMS) transport, due to higher speed and straight line flight irrespective of traffic and weather impediments.[3] Further, HEMS crews may offer advanced interventions not available from GEMS providers, which can improve survival in severely injured patients.[4, 5]

To this end, HEMS is often used to transport injured children to a trauma center. However, this intervention carries additional risks and costs that may or may not be outweighed by the benefits.[6, 7] While several studies have established a benefit of HEMS compared to GEMS in the adult population,[8-13] the evidence is less clear to support use of HEMS transport in pediatric trauma patients.[14, 15] As injury remains the leading cause of death and productive life-years lost among children, interventions to reduce these potentially have a significant public health impact.[16]

The objective of this study was to evaluate the association of HEMS compared to GEMS transport with outcomes in a national sample of pediatric trauma patients. We hypothesized that HEMS transport would be associated with improved survival and increased likelihood of discharge to home when compared with GEMS transport.

Methods

Study Population

Patients aged ≤15 years old who underwent transport from the scene of injury to a definitive care hospital by either HEMS or GEMS in the National Trauma Databank (NTDB) between 2007 and 2012 were included. Patients transferred from a referring hospital, those with burn injury, or that were dead on arrival to the emergency department (ED) were excluded. Demographics, injury characteristics, *International Classification of Diseases, Ninth Revision* (ICD-9) diagnosis codes, and hospital disposition were collected for each subject. All prehospital and admission vital signs were age-adjusted and binary variables created to indicate whether each vital sign was abnormal for the child's age.[17-19] Patients undergoing GEMS transport were considered the control group, while patients undergoing HEMS transport were considered the treatment group.

Missing Data

Multiple imputation was performed for analysis variables missing <35% of observations. Imputed variables included race, insurance status, mechanism of injury, prehospital systolic blood pressure (SBP), prehospital heart rate (HR), prehospital respiratory rate (RR), and prehospital Glasgow Coma Scale (GCS), prehospital time, admission SBP, admission HR, admission RR, and admission GCS. Multiple imputation using iterative fully conditional specification chained models was performed to develop five imputed datasets. Outcome models were performed using estimation techniques that combine model coefficients and standard errors from each imputed dataset while adjusting for the variability between imputed datasets.[20] Missing data for imputed variables ranged from 2% (admission HR) to 32% (prehospital SBP). The analysis was repeated using complete cases only, and no significant differences were seen between the imputed and complete case results. Thus, imputed results are presented below.

Propensity Score Matching

Since transport mode was not randomly assigned, a selection bias exists with HEMS subjects more likely to be severely injured. To mitigate this, propensity score matching was performed. Propensity score matching produces more accurate treatment effect estimates when comparing HEMS and GEMS patients, reducing selection bias by matching treated and control subjects based on their likelihood of being exposed to the treatment of interest using observed variables that influence treatment assignment.[10, 21] The propensity score model was developed to predict the likelihood of undergoing HEMS transport based on variables that would be directly available to prehospital providers or as a proxy for information and factors that would reasonably influence the decision to assign a patient to either HEMS or GEMS transport at the scene of injury.

Covariates in the propensity score model included age, gender, mechanism of injury, prehospital hypotension, prehospital tachycardia or bradycardia, prehospital tachypnea or apnea, prehospital GCS, total prehospital time, injury severity score (ISS), the presence of any one of the eight anatomic triage criteria from the Centers for Disease Control national field triage guidelines,[22] availability of a level I pediatric trauma center, and United States

(US) geographic census region. Propensity scores were estimated using a probit model. Propensity scores for each patient were averaged across the imputed datasets and the average propensity score used for matching.[23]

Since important differences may exist across specific ages within the pediatric population, the study population was categorized into infant/toddler (age <2years), children (age 2-12 years), and adolescents (age >12) age subgroups based on established standards.[24] Matching was performed within each age subgroup using a 1:1 ratio nearest neighbor algorithm without replacement or caliper. This ensured that only patients within each age subgroup could be matched. Matched pairs from each age subgroup were then re-combined to give the final matched cohort.

Standardized differences were used to assess the balance of covariates used in propensity score estimation after matching. The percent reduction in mean bias after matching was also assessed.[25] An absolute value for the standardized difference <0.1 for a given variable was considered to indicate good balance between treatment groups.[26]

Statistical Analysis

The primary outcome was in-hospital survival. The secondary outcome examined was discharge disposition in survivors, categorized as discharge home with no services versus discharge needing additional services, including discharge to a rehabilitation center, skilled nursing facility, or with home care. Conditional logistic regression models were used to determine the association of outcomes with HEMS compared to GEMS transport, while accounting for the matched pair design. Model covariates were selected *a priori* for known prognostic significance in each outcome after injury which were not accounted for in the propensity score matching procedure. Covariates included race, insurance status, Trauma Mortality Prediction Model (TMPM) predicted mortality,[27] admission hypotension, abnormal admission HR, abnormal admission RR, admission GCS, ICU admission, need for mechanical ventilation, urgent operation, occurrence of in-hospital complications, non-accidental trauma, and trauma center type (adult only level I/II, pediatric only level I/II, mixed adult/pediatric level I/II, non-level I/II center). Given recent evidence that trauma center type influences mortality in children,[28] interactions were tested between transport mode and trauma center type as well as trauma center level to determine if the effect of transport mode on survival differs across these factors. Discharge disposition models were also adjusted for presence of an extremity injury with abbreviated injury scale (AIS)>2 and presence of a spinal cord injury. Model standard errors were calculated using a robust variance estimator to account for clustering at the center level. Adjusted odds ratios (AOR) and 95% confidence intervals (95%CI) of HEMS compared to GEMS transport were determined for each outcome. Numbers needed to treat (NNT) were calculated from AORs and expressed as number of patients required to undergo HEMS to save one additional life or to result in one additional discharge home.[29] The distribution of deaths over time was evaluated between groups to assess differences in timing of death across transport mode.

Collinearity was assessed using variance inflation factors and any covariate with a value >10 was removed from final models. Since typical measures of logistic regression discrimination cannot be calculated for conditional logistic regression models, the model above was applied as a simple logistic regression model to the study population prior to matching and the c-statistic determined to ensure adequate discrimination of the covariates for each outcome. To evaluate the conditional model as applied to the matched cohort, lack-of-fit and delta-β influence statistics were evaluated to identify potential outlier pairs. These outlier pairs were then deleted and the conditional regression model re-run to evaluate the change in coefficient for treatment effect.[30]

A formal sensitivity analysis for hidden bias was also performed.[31] The goal of this analysis was to determine the magnitude of unaccounted bias that would be necessary to explain the association between transport mode and mortality, potentially changing the inference of the results. Matched pairs were analyzed based on outcome concordance and transport mode using McNemar's test to evaluate a confidence interval for significance across a range of sensitivity parameter (Γ) values representing uncertainty in treatment assignment due to unobserved confounding. The Γ value at which the confidence interval is no longer significant represents the magnitude of unobserved confounding that would be needed to potentially change the association observed between transport mode and survival. Higher values of Γ indicate greater robustness to hidden bias.

For baseline subject-level comparisons, standardized differences were used with an absolute value >0.1 considered to indicate residual imbalance between treatment groups. Standardized differences have been proposed as a superior method of comparing baseline characteristics in matched samples.[32] Standardized differences are not influenced by large samples sizes as t-tests or Chi-square tests are, which can result in statistically significantly differences when no clinically meaningful difference exists. Data analysis was conducted using Stata v13MP (College Station, TX).

Subgroup Analysis

HEMS transport is also subject to logistical considerations within trauma systems. Some children are injured close enough to a trauma center that it would be impractical to transport them by HEMS. In these cases, activation and response of HEMS to the scene would actually significantly prolong prehospital time. This group would not have the potential to undergo HEMS transport and it may be less useful to evaluate the effect of HEMS comparted to GEMS on outcome in these patients. Thus, to capture patients with the potential to undergo HEMS transport, a subgroup analysis was performed on patients with a transport time >15 minutes. This cut off was selected as it represents the 25th percentile of HEMS transport time in the matched cohort. The conditional logistic models described above were repeated in matched pairs of HEMS and GEMS patients with a transport time >15 minutes.

Results

A total of 166,594 patients were included in the study population, with 25,837 (16%) undergoing HEMS transport (Fig. 1). Overall, 58% of patients had an ISS<9 and 47% of patients had a hospital length of stay ≤1 day. Among HEMS patients, 41% of patients had an ISS<9 and 30% of patients had a hospital length of stay ≤1 day. Prior to matching, HEMS patients were slightly older, had longer prehospital time, more abnormal prehospital vital signs, higher injury severity, and more often were treated at a level I pediatric trauma center (Table 1). Unadjusted survival was lower among HEMS patients.

From the initial study population, 25,700 pairs were matched from each transport group giving a final matched cohort of 51,400 patients for analysis. The matching procedure produced well balanced groups, with all absolute standardized differences <0.1 for each variable used in the propensity score (Fig. 2). This resulted in an 85% reduction in mean bias after matching.

Table 2 summarizes and compares patient characteristics for the matched groups. After matching, HEMS patients were more likely to be Caucasian, require ICU admission and mechanical ventilation, and less likely to be transported to a non-level I/II trauma center.

When evaluating outcomes in the matched cohort, HEMS transport was independently associated with a 72% increase in the odds of in-hospital survival after controlling for in-hospital confounders (AOR 1.72; 95%CI 1.26—2.36, p<0.01). This translates into a NNT of 41 (95%CI 29–84). Transport mode was not associated with discharge disposition in survivors (AOR 1.10; 95%CI 0.84—1.43, p=0.49).

Trauma center type was not associated with survival in the matched cohort (p>0.05). Further, the interaction between trauma center type and transport mode was not significant, and not included in the final models (p>0.05). Similar results were seen when evaluated by pediatric age subgroups. When comparing level I to level II designation, there was no association with survival (p=0.55) and there was no interaction between trauma center level and transport mode (p=0.50). When comparing level I to level II designation among only pediatric trauma centers, level I designation was associated with a more than two-fold increase in survival (AOR 2.71; 95%CI 1.10—6.69, p=0.03), although there was no interaction between pediatric trauma level and transport mode (p=0.37).

Most deaths occurred within 48 hours in both groups (Fig. 3). The overall distribution in timing of deaths was significantly different between groups (p<0.01). A greater proportion of deaths in the GEMS group occurred in the ED (p<0.01) and first 24 hours (p<0.01); however, by 48 hours the cumulative proportion of deaths catches up in the HEMS group and remains similar over time (p>0.05).

The survival model demonstrated excellent discrimination in the initial study population prior to matching, with a c-statistic of 0.95. Conditional logistic regression diagnostics identified three clear outlier pairs. Deletion of these resulted in a 6% change in the model coefficient for HEMS compared to GEMS transport, giving a similar result as the primary analysis (AOR 1.78; 95%CI 1.27—2.49, p<0.01). Similarly, the discharge disposition model had excellent discrimination, with a c-statistic of 0.88. Only one clear outlier pair was identified and deletion resulted in a similar 6% change in the model coefficient for transport mode, again giving a comparable result as the primary analysis (AOR 1.11; 95%CI 0.85—1.44, p=0.47). Sensitivity analysis for hidden bias revealed a sensitivity parameter Γ=2.6. This indicates if unobserved confounding exists which perfectly predicted survival, it would have to be >2.6 times more common in the HEMS group to potentially change the association observed between HEMS and survival. This suggests a fair robustness to potential hidden bias.

There were 17,657 (69%) HEMS/GEMS matched pairs with a transport time >15 minutes included in the subgroup analysis. HEMS transport remained significantly associated with survival, with an 81% increase in the odds of in-hospital survival compared to GEMS transport (AOR 1.81; 95%CI 1.24—2.65, p<0.01). Again, transport mode was not associated with discharge disposition in survivors (AOR 1.07; 95%CI 0.84—1.38, p=0.58).

Discussion

This is the largest and most robust study to date to examine prehospital transport mode in the pediatric trauma population. Our findings demonstrate a significant survival advantage for HEMS transport from the scene of injury when compared to GEMS transport in a well-matched cohort of pediatric trauma patients. One life may be saved for every additional 41 children undergoing HEMS instead of GEMS transport based on these results. HEMS appears to impact very early mortality which may represent salvageable patients with correctable problems, such as airway issues and hemorrhagic shock. The higher proportion of deaths between 24 and 48 hours for the HEMS group may represent non-salvageable patients with moribund central nervous system injuries. However, cause of death is not available in the current data and requires additional study. Further, death timing after 48 hours is similar between groups and it does not appear that HEMS transport simply shifts death until later in the hospital stay. Further, it does not appear that the association between HEMS transport and survival is significantly altered by trauma center type or level in this matched cohort. Transport mode was not, however, associated with discharge disposition among survivors.

Similar large studies in the adult trauma population have demonstrated benefits ranging from a 16% to 64% increase in the odds of survival for HEMS compared to GEMS transport.[8, 10, 12, 15] However, prior studies investigating this issue in the pediatric trauma population are few and present conflicting results. Moront and colleagues reported improved survival associated with HEMS transport in a cohort of nearly 4,000 injured children using TRISS methodology.[33] Missios and Bekelis more recently examined a propensity matched cohort of pediatric patients with traumatic brain injury from the NTDB, demonstrating a 77% increase in the odds of survival for children transported by HEMS to a level I trauma center.[34] This effect size is similar to the survival benefit seen in the current study.

Conversely, some groups have not shown a benefit of HEMS transport among injured children. Larson et al evaluated pediatric patients undergoing scene HEMS transport compared to inter-facility referrals.[35] The scene group had higher unadjusted mortality, although this study likely suffers from survivor bias without further risk adjustment and does not compare a control GEMS group. Recently Stewart and colleagues investigated outcomes for HEMS compared to GEMS transport in nearly 15,000 injured children.[15] They evaluated several scenarios, making adjustments for transport time and distance. The authors did not find an association with transport mode and survival, and in some analyses GEMS was associated with reduced length of stay compared with HEMS transport. The authors included a propensity matched analysis; however, this was limited by the use of only GCS and ISS in the propensity score which resulted in matching only 20% of their HEMS patients.

The mechanism underlying the benefit seen in this study is likely multifactorial.[5] HEMS offers a potential speed benefit over GEMS, depending on distances between the scene, trauma center, and HEMS base, as well as HEMS activation timing, traffic, and weather conditions. This may reduce out of hospital time which would affect children with time sensitive injuries. Further, the additional capabilities and experience of HEMS crews likely provides benefit in severely injured patients over GEMS. Our group has shown that a survival benefit for HEMS exists in adult patients, even in the absence of a time-saving advantage.[36] Specific advanced prehospital interventions such as blood transfusion may be available from HEMS and can reduce mortality.[4, 37] These differences may be even more pronounced in children, as severe pediatric trauma is a relatively rare call for GEMS providers.[38] One group found GEMS had unacceptably high complication and failure rates for pediatric intubation, while HEMS crews provided safe and effective intubation.[39] Finally, trauma center access may also play a role in the benefit of HEMS transport. HEMS may reduce time to definitive care by transporting a patient to a trauma center capable of definitively managing all injuries rather than initial evaluation at a non-trauma center and subsequent transfer. This may also be even more relevant in the pediatric population. Emerging evidence demonstrates superior outcomes for injured children treated at pediatric trauma centers compared with adult or mixed trauma centers.[28] Our data also suggest a higher pediatric trauma center level may be associated with improved survival. Thus, HEMS may afford an opportunity to transport injured children to a pediatric designated trauma center, particularly as fewer pediatric trauma centers exist and are more geographically distributed. The survival benefit seen in this study is likely due to one or more of these factors; however, the current data cannot determine which specific factors are responsible.

The lack of association between transport mode and discharge disposition was contrary to our original hypothesis. HEMS transport has been associated with increased odds of discharged to home among injured adults.[8, 40] The inability to demonstrate this result may be due to several factors in the current study. Variations in care and events during hospitalization represent a set of competing risks and thus make it difficult to establish an association with prehospital transport mode, particularly in a retrospective study. While we did control for in-hospital care and complications, the NTDB only collects a limited pre-defined set of variables and other unobserved factors may play an important role. Discharge disposition may also be influenced by socioeconomic factors that are unrelated to transport mode. This may be further complicated by the fact that more HEMS patients will have come from farther away and this may alter discharge options and planning.[11] Finally, it may be that that transport mode does not substantially influence this outcome in children after injury. A more optimistic alternative interpretation of this finding is possible, particularly in the context of improved survival. While HEMS transport did not increase the likelihood of discharge to home, it also was not associated with need for greater services or discharge to skilled nursing facilities after discharge. This may indicate that HEMS transport contributes to meaningful survival, rather than just saving additional children that are neurologically devastated or otherwise live with severe disability after injury. A more rigorous evaluation of disability and long-term outcomes is necessary to confirm this possibility.

While we did demonstrate a survival benefit for HEMS transport, clearly not every child undergoing HEMS transport is benefiting. In fact, several studies document high overtriage rates for HEMS transport in pediatric trauma patients, ranging from 17% to 57% depending on the definition of overtriage.[11, 14, 41-43]Our study demonstrated comparable proportions of HEMS patients had an ISS<9 or length of stay ≤1 day. Knofsky et al demonstrated that injured pediatric HEMS patients were both less severely injured and more likely to be discharged from the ED when compared to their adult counterparts.[42]

These findings are troubling when considering the aviation risks and costs of HEMS transport. While both GEMS and HEMS transport have increased risk of injury from crashes in the line of duty, HEMS accidents are more deadly, with a rate up to 0.02 fatal crashes per 100,000 miles flown and 0.86 fatalities per accident.[6, 44] HEMS providers had the deadliest job in the US with 113 fatalities per 100,000 employees in 2007. Further, each unnecessary transport can carry a charge between $6,500 and $13,000 with hourly operating costs as high as $1,500.[7]

Thus, patient selection becomes paramount. Although the high overtriage rate has been well documented in pediatric HEMS transport after injury, few studies have examined specific triage criteria to reduce this. Moront and colleagues reported that using a GCS<12 and HR>160 for HEMS triage provided a 99% sensitivity and 90% specificity for identifying pediatric trauma patients with <95% predicted probability of survival.[33] The American College of Surgeons Committee on Trauma has made development of standardized evidence-based HEMS triage criteria a national priority;[45] however these efforts remain limited, even among adult trauma patients.[46-49] As this study demonstrates a survival benefit at the population-level, the next step would be to concentrate on developing triage criteria for HEMS scene transport in pediatric trauma patients that can prospectively identify patients in the field most likely to benefit from this intervention, and avoid the safety risks and unnecessary costs to the health care system.

This study does have several limitations for consideration. First are those of any retrospective design. Second are those of the NTDB dataset. While NTDB data quality has improved over time, high levels of missing data exist, particularly among prehospital data. Multiple imputation was used to mitigate this, and this method has been validated in the NTDB previously.[50] No significant differences in the direction and magnitude of associations between transport mode and outcomes were found when using complete cases only. We were limited in outcomes available for study; however, outcomes such as longer-term disability and level of functioning are important to evaluate in severely injured children, particularly given the possibility of significant productivity loss over a lifetime. Further, the NTDB does not indicate the level of prehospital care provided during transport. As noted above, the mechanisms driving the survival benefit found cannot be elucidated using this dataset. While we used propensity score matching to mitigate the selection bias in transport mode allocation, only observed variables can be included in the propensity score and unmeasured confounding may remain. While our sensitivity analysis suggests a fair robustness to hidden bias, nevertheless such bias may exist. Our subgroup analysis was based on the recognition that not all patients are candidates for HEMS transport based on distance; however, the cut off used for transport time was selected arbitrarily as the 25th percentile of HEMS transport time. This transport time also represents different distances in a helicopter and ground ambulance. Some patients may not have had the potential to undergo HEMS transport due to weather conditions at the time of injury, while others may have only been able to be transported by HEMS due to inaccessible terrain for ground ambulances. Finally, the dataset represents a heterogeneous national population, while individual trauma system characteristics will likely influence outcomes and applicability of these findings.

Conclusion

In the largest and most robust evaluation of outcomes related to prehospital transport mode in pediatric trauma patients, scene transport by HEMS was associated with improved odds of survival compared with GEMS nationally. Further study is warranted to understand the underlying mechanisms that drive this benefit and to develop specific triage criteria for HEMS transport in this population.

Acknowledgments

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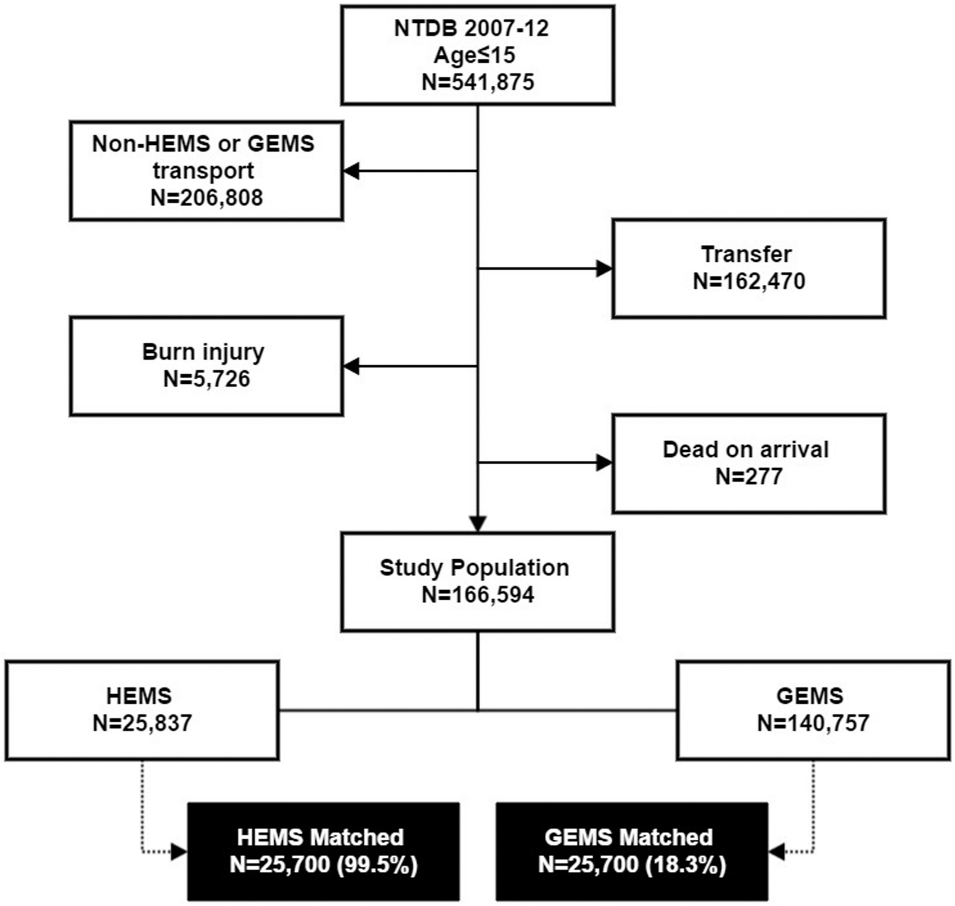

Figure 1.
Study participant selection and propensity score matching of helicopter emergency medical service (HEMS) and ground emergency medical service (GEMS) patients age ≤15 from the National Trauma Databank (NTDB) 2007—2012.

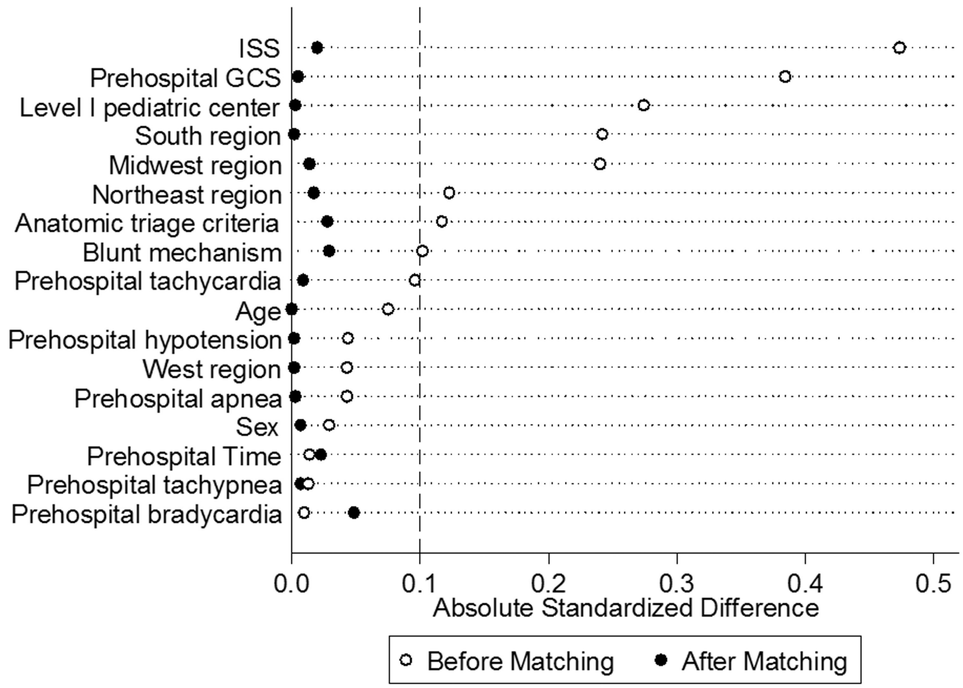

Figure 2.

Absolute standardized differences between helicopter emergency medical services group and ground emergency medical services group before and after matching in propensity score variables. Absolute standardized differences <0.1 (vertical dash line) are considered to represent good balance of covariates between groups after matching.

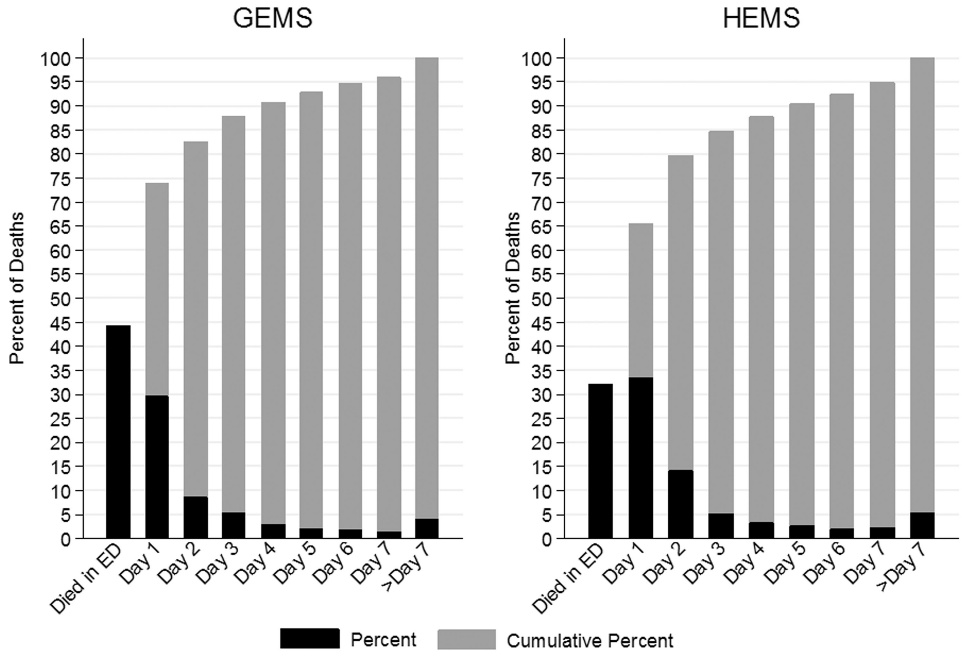

Figure 3.

Categorical percent and cumulative percent of deaths over time for the ground emergency medical services (GEMS) group and helicopter emergency medical services (HEMS) group in the matched cohort. A total of 1,570 (6%) patients died in the GEMS group, while 1,096 (4%) patients died in the HEMS group.Black bars represent the percent of deaths at each time point. Gray bars represent the cumulative percent of deaths at each time point.

Table 1

Comparison of propensity score variables in pediatric trauma patients transported by HEMS or GEMS prior to matching

	HEMS n = 25,837	GEMS n = 140,757	p value
Age [years, med (IQR)]	10 (5, 14)	10 (4, 13)	<0.01
Age group [n (%)]			<0.01
Infant/toddler age	3,346 (13)	22,566 (16)	
Child age	13,495 (52)	71,202 (51)	
Adolescent age	8,996 (35)	46,989 (33)	
Sex [n (%) male]	16,664 (65)	92,638 (66)	<0.01
Mechanism [blunt, n (%)]	23,561 (96)	123,181 (94)	<0.01
Prehospital total time [mins, med (IQR)]	60 (47, 79)	42 (31, 59)	<0.01
Prehospital hypotension [n (%)]	9,561 (37)	49,846 (35)	<0.01
Prehospital tachycardia [n (%)]	4,636 (18)	20,889 (15)	<0.01
Prehospital bradycardia [n (%)]	699 (3)	3,512 (2)	0.04
Prehospital tachypnea [n (%)]	4,670 (18)	26,532 (19)	<0.01
Prehospital apnea [n (%)]	4,158 (16)	20,083 (14)	<0.01
Prehospital GCS [med (IQR)]	15 (12, 15)	15 (15, 15)	<0.01
Anatomic triage criteria [n (%)]	3,844 (15)	15,365 (11)	<0.01
ISS [med (IQR)]	9 (5, 17)	5 (4, 9)	<0.01
ISS category [n (%)]			<0.01
1-8	10,625 (41)	85,010 (61)	
9-15	7,379 (29)	35,642 (26)	
16-24	3,936 (15)	11,364 (8)	
25-75	3,804 (15)	7,255 (5)	
Level I pediatric center [n (%)]	13,000 (50)	51,846 (37)	<0.01
Geographic region [n (%)]			<0.01
Midwest	3,839 (15)	34,454 (25)	
Northeast	2,894 (11)	21,498 (15)	
South	11,728 (45)	47,120 (33)	
West	7,349 (29)	37,301 (27)	
Length of stay [days, med (IQR)]	3 (1, 5)	1 (1, 3)	<0.01
Length of stay ≤1 day [n (%)]	7,796 (30)	70,943 (50)	<0.01
In-hospital Survival [n (%)]	24,726 (96)	137,694 (98)	<0.01
Discharge disposition in survivors [n (%)]			<0.01
Home	21,443 (91)	117,560 (96)	
Need for additional services	2,255 (9)	4,651 (4)	

HEMS, helicopter emergency medical services; GEMS, ground emergency medical services; med, median; IQR, interquartile range; HR, heart rate; RR, respiratory rate; GCS, Glasgow Coma Scale; ISS, injury severity score

Table 2

Characteristics of matched pediatric trauma patients transported by HEMS or GEMS

	HEMS n = 25,700	GEMS n = 25,700	Standardized difference*
Age [years, med (IQR)]	10 (5, 14)	10 (5, 14)	-0.002
Age group [n (%)]			
Infant/toddler age	3,319 (13)	3,319 (13)	0
Child age	13,426 (52)	13,426 (52)	0
Adolescent age	8,955 (35)	8,955 (35)	0
Sex [n (%) male]	16,579 (65)	16,495 (64)	0.006
Race [n (%)]			0.404
Caucasian	18,939 (74)	14,062 (55)	
Non-Caucasian	6,761 (26)	11,638 (45)	
Insurance Status [n (%)]			0.074
Commercial	13,568 (53)	12,598 (49)	
Subsidized/None	12,132 (47)	13,102 (51)	
Mechanism [blunt, n (%)]	24,690 (96)	24,548 (95)	0.027
Prehospital transport time [mins, med (IQR)]	22 (16, 32)	19 (12, 29)	-0.012
Prehospital total time [mins, med (IQR)]	57 (43, 75)	44 (31, 62)	-0.023
Prehospital hypotension [n (%)]	12,548 (49)	12,581 (49)	-0.006
Prehospital abnormal HR [n (%)]	7,153 (28)	7,285 (28)	-0.011
Prehospital abnormal RR [n (%)]	12,453 (49)	12,531 (49)	-0.007
Prehospital GCS [med (IQR)]	15 (13, 15)	15 (13, 15)	-0.006
Anatomic triage criteria [n (%)]	3,830 (15)	4,071 (16)	-0.027
ISS [med (IQR)]	9 (5, 17)	9 (4, 17)	-0.002
ISS category [n (%)]			
1-8	10,619 (41)	11,144 (43)	-0.041
9-15	7,360 (29)	6,862 (27)	0.043
16-24	3,930 (15)	3,571 (14)	0.040
25-75	3,791 (15)	4,123 (16)	-0.035
TMPM predicted mortality [%, med(IQR)]	1.9 (1.0, 6.2)	1.7 (1.0, 6.0)	-0.015
ICU admission [n (%)]	10,299 (40)	7,941 (31)	0.191
Urgent operation [n (%)]	3,950 (15)	3,350 (13)	0.068
Mechanical ventilation [n (%)]	4,700 (18)	3,528 (14)	0.122
Trauma center type [n (%)]			
Adult	8,504 (33)	7,667 (30)	0.069
Pediatric	3,597 (14)	3,371 (13)	0.028
Mixed	12,231 (48)	11,949 (47)	0.021
Non-trauma center	1,368 (5)	2,713 (10)	-0.193
Geographic region [n (%)]			
Midwest	3,820 (15)	3,649 (14)	0.019
Northeast	2,873 (11)	3,037 (12)	-0.022
South	11,673 (45)	11,659 (45)	0.005

	HEMS n = 25,700	GEMS n = 25,700	Standardized difference*
West	7,335 (29)	7,355 (29)	-0.005
In-hospital Survival [n (%)]	24,604 (96)	24,130 (94)	0.081
Discharge disposition in survivors [n (%)]			-0.038
Home	21,329 (91)	20,062 (92)	
Need for additional services	2,251 (9)	1,851 (8)	

*Represents the standardized difference between groups after matching. Absolute values for the standardized difference >0.1 are considered to indicate imbalance between groups after matching.

HEMS, helicopter emergency medical services; GEMS, ground emergency medical services; med, median; IQR, interquartile range; HR, heart rate; RR, respiratory rate; GCS, Glasgow Coma Scale; ISS, injury severity score; TMPM, trauma mortality prediction model; ICU, intensive care unit