Use of helicopters for retrieval of trauma patients: A geospatial analysis

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BACKGROUND: Helicopters are widely used to facilitate the transport of trauma patients, from the scene of an incident to the hospital. However, the use of helicopters may not always be appropriate. The aim of this project was to conduct a geospatial analysis of helicopter transport to a Level I trauma center.

METHODS: Retrospective geospatial analysis of trauma registry data, 2013 to 2018. We included all adult (≥16) trauma patients brought to the trauma center directly from the scene. Data were geocoded and analyzed using arcGIS. Drive times and flight times were calculated using Google Maps. Flight times included the time required to reach the incident location.

RESULTS: Two thousand eight hundred ninety-three patients were identified, and 1,911 had incident locations recorded and were therefore included in the analysis. The median age was 41 years (interquartile range [IQR], 27–58 years). Twenty-four percent of the patients had suffered severe injuries (Injury Severity Score [ISS], 16–25), 17% very severe injuries (ISS > 25), 24% moderately severe injuries, and 36% minor injuries (ISS, 1–8). The overall geographical distribution was centroidal, although with a concentration of case volume in the vicinity, and to the northeast, of the trauma center. Median flight time was 60 minutes (IQR, 52–69 minutes), and median drive time 65 minutes (IQR, 54–86 minutes). In 33% of the patients, the calculated drive time to the trauma center was shorter than the calculated flight time when considering the time for the helicopter to reach the scene.

CONCLUSION: The majority of patients taken to our level I trauma center by helicopter are injured in relatively close proximity. One in four patients is severely or very severely injured, but one third of the patients have only minor injuries. Over a quarter of trauma patients might have reached hospital more quickly if they had been taken by road, rather than helicopter. (*J Trauma Acute Care Surg.* 2019;87: 168–172. Copyright © 2019 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Epidemiological/geographical study, level V.

KEY WORDS: Trauma; trauma systems; helicopters; geospatial analysis.

Trauma is the leading cause of death for those younger than 45 years.[1] Trauma systems—managed clinical networks of trauma centers and prehospital care providers—have been shown to reduce mortality and improve functional outcomes,[2,3] but access to such specialist care is a concern. Trauma centers require a certain volume of severely injured patients to ensure that individual and institutional expertise is maintained. The precise position of the inflection point on the volume/outcome curve is not known, but estimated to be between 240[4] and 650[5] severely injured patients per year. Such case volumes, as well as a number of other criteria required to be designated as a trauma center, demand that these units are usually located in areas of high population density and are associated with academic institutions.[4] Specialist trauma care cannot be provided in all locations, and geographical access to these services may be limited and inherently inequitable.

Helicopters are a means of reducing this inequity. Introduced in the Korean War, they were quickly recognized as an effective method of transporting patients.[6] Today, helicopter transport is widely used and is an integral part of emergency care systems across the United States and worldwide, particularly in rural and inaccessible areas. The Association of Air Medical Services estimates that there are 400,000 medical helicopter flights annually in the United States.[7] These aircraft travel two to three times faster than an emergency vehicle, but at a price. The average cost of a scene retrieval is US $6,800 which translates into US $2.72 billion in health care costs per year.[8] In addition to the expense, helicopter flights are inherently dangerous. The National Transportation Safety Board report on emergency medical service helicopter crashes noted 55 fatalities from 1990 to 2005.[9] Ground transport costs, on average, US $1,100 per journey, and the risks of injury and fatality are lower.[8,10]

Making appropriate use of helicopter transport is therefore essential. Previous studies and case reports have examined overuse primarily with regards to injury severity and other measures of clinical appropriateness,[11–14] rather than geography. Even when clinically indicated, helicopter transport is usually only appropriate if the predicted flight time is less than the predicted drive time to the trauma center. This calculation also needs to take into consideration that, in most cases, helicopters are called

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by a ground crew at the scene, rather than dispatched primarily. The flight time calculation, therefore, needs to consider both the outbound flight and the inbound flight, as well as the wind-up time, finding a suitable landing zone, loading of the casualty, and unloading at the trauma center. In addition, helicopters are often based at locations other than hospitals, which means that inbound and outbound flights differ in duration.

The aim of this study was to conduct a comprehensive examination of the logistical/geographical appropriateness of helicopter transport of trauma patients in a mixed urban/rural population served by a Level I trauma center. We hypothesized that a proportion of patients taken to University of Alabama at Birmingham (UAB) by helicopter could have reached hospital more quickly if they had been taken by road.

METHODS

Design and Participants

This is a retrospective, geospatial analysis of adult (≥16 years) trauma patients injured in the State of Alabama, and taken to UAB Hospital, by helicopter, between December 2013 and February of 2018. We excluded patients who were transferred from other hospitals. Data were obtained from the UAB trauma registry. We analyzed multiple patient variables including demographics, injury characteristics, admission physiological parameters, incident location, and outcomes. The study was approved by the institutional review board.

Setting

The state of Alabama has a land area of 135,765 km^2 and a population of 4,863,300. Birmingham is the largest city and is centrally located. The UAB Hospital is an American College of Surgeons-verified Level I trauma center, which admits approximately 4,500 trauma patients per year and acts as the tertiary referral center for the state. There are also state-designated Level I trauma in the cities of Huntsville, to the north, and Mobile, on the Gulf Coast. In addition, there is a state-designated Level II trauma center in Montgomery and 54 Level III trauma centers.

Geocoding

Incident locations were recorded with variable accuracy, ranging from complete addresses, to cities, ZIP code areas, and counties only. We excluded incidents which had no recorded incident location. All remaining locations were geocoded into latitude and longitude. Where precise addresses were not available, we used the centroid (geographical center) of the city, ZIP code area, or county as a surrogate. We attributed a confidence level, indicating the certitude of each pair of coordinates to all records. Addresses were geocoded using Google maps/Google sheets (Google Inc, Mountain View, CA).

Calculation of Travel Times

Drive times were calculated using the Google Maps Distance Matrix application programming interface (Google Inc), accessed using the statistical programming language "R." The application programming interface permits the selection of "normal," "pessimistic," or "optimistic" drive time assumptions. We chose the "optimistic" setting to account for the effect of travel under "lights and sirens" conditions. Flight times were calculated by determining the geodesic distance from the nearest helicopter base to the incident location and from the incident location to the trauma center. This methodology reflects the fact that, in Alabama, helicopters are usually only called once a ground-based emergency medical service has attended. We calculated flight times using published cruising speeds for each type of helicopter. We added a total of 30 minutes to account for mission ground time. This allows time for start-up, slower speeds on take-off/landing, time spent at incident locations and loading of casualties, and landing at the trauma center.

Analysis and Presentation of Results

The results are presented as tables and choropleth maps, showing the number of incidents per county. Nonnormally distributed data were summarized using medians and interquartile ranges (IQRs). We compared calculated drive times and calculated flight times to determine which patients were appropriately transported by helicopter. We did not consider differences in the clinical capabilities of airborne and ground-based units.

RESULTS

Study Population

We identified 2893 patients who had been taken to UAB by helicopter between December 2013 and February 2018. Of these, 1,911 (66%) had an incident location recorded. Twenty-five percent of these incidents could be geocoded with a very high degree of confidence using an exact address, 8% with a high degree of confidence using a postal code with incomplete address, 58% with a moderate degree of confidence using a postal code, 6% with low confidence recorded by city, and 3% with minimal confidence defined by county. The baseline characteristics of these patients are shown in Table 1. Seventy-one percent of the patients were male, 80% were white, and 18% African American. The median age was 41 years (IQR, 27–57.5 years). The characteristics of the geocodable incidents did not differ markedly from those without incident location information.

The median Injury Severity Score (ISS) was 12 (IQR, 5–22). Seventeen percent of the patients had suffered very severe injury (ISS, >25), 24% severe injury (ISS, 16–25), 24% moderate injury (ISS, 9–15), and 36% mild injury (ISS, 1–8). On arrival at the trauma center, 9% of patients had a systolic blood pressure less than 90 mm Hg. Seventy-five percent had a Glasgow Coma Scale (GCS) score of 13 to 15, 2% had a GCS score of 9 to 12, and 23% had a GCS score of 8 or lower. Two percent of the patients were pronounced dead in the emergency department. Sixteen percent were taken to an operating room, 34% directly to an intensive care unit, 6% to a step-down unit, and 22% admitted directly to a floor bed. Twenty percent of patients who were brought to the trauma center by helicopter were discharged home from the emergency department.

Geospatial Analysis

The geographical distribution of the incidents is shown in Figure 1. The majority of the incidents originated from the central and northern parts of the state, with a greater concentration in Etowah, Calhoun, and Talladega counties to the northeast of Birmingham.

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TABLE 1. Baseline Characteristics of Study Population, and Included (Geocodable) Incidents

	All Incidents	Geocodable (Included) Incidents	Nongeocodable (Excluded) Incidents
No. patients, n (%)	**2,893**	**1,911 (66.1)**	**982 (33.9)**
Demographics			
Sex			
Male, n (%)	2,039 (70.5)	1,347 (70.5)	692 (70.5)
Female, n (%)	854 (29.5)	564 (29.5)	290 (29.5)
Age: median (IQR), years	41 (27–57)	41 (27–57.5)	39 (26–56.75)
Race			
White, n (%)	2,249 (77.7)	1,529 (80.0)	720 (73.3)
African American, n (%)	587 (20.3)	349 (18.3)	283 (24.2)
Other, n (%)	56 (1.9)	32 (1.7)	24 (2.4)
Missing, n (%)	1 (0.03)	1 (0.05)	0 (0)
Admission vital signs			
Systolic blood pressure, mm Hg			
Median (IQR)	136 (114–153)	137 (117–153)	134 (111–151)
<90 mm Hg, n (%)	282 (9.7)	164 (8.6)	98 (10.0)
≥90 mm Hg, n (%)	2,611 (90.3)	1,733 (90.7)	878 (89.4)
Missing, n (%)	20 (0.7)	14 (0.7)	6 (0.6)
GCS score			
Median (IQR)	15 (11–15)	15 (13–15)	15 (8–15)
13–15, n (%)	2,136 (73.8)	1,429 (74.8)	707 (72.0)
9–12, n (%)	61 (2.1)	39 (2.0)	22 (2.2)
3–8, n (%)	676 (23.4)	430 (22.5)	246 (25.0)
Missing, n (%)	20 (0.7)	13 (0.6)	7 (0.7)
Mechanism of injury			
Blunt, n (%)	2,303 (79.6)	1,491 (78.0)	812 (82.7)
Penetrating, n (%)	316 (10.9)	224 (11.7)	92 (9.4)
Burn, n (%)	254 (8.8)	185 (9.7)	69 (7.0)
Other, n (%)	20 (0.7)	11 (0.6)	9 (0.9)
ISS			
Median (IQR)	13 (5–22)	12 (5–22)	14 (8–22)
Mild (1–8), n (%)	927 (32.0)	678 (35.5)	249 (25.4)
Moderate (9–15), n (%)	712 (24.6)	465 (24.3)	247 (25.2)
Severe (16–25), n (%)	747 (25.8)	450 (23.5)	297 (30.2)
Very severe (≥26), n (%)	505 (17.5)	318 (16.6)	187 (19.0)
Missing, n (%)	2 (0.1)	0 (0.0)	2 (0.2)
Emergency department discharge			
Operating room, n (%)	491 (7.0)	310 (16.2)	181 (18.4)
ICU, n (%)	1,040 (36.0)	652 (34.1)	388 (39.5)
Step-down unit, n (%)	165 (5.7)	114 (6.0)	51 (5.2)
Floor/other, n (%)	714 (24.7)	422 (22.1)	292 (29.7)
Home, n (%)	426 (14.7)	378 (19.8)	48 (4.89)
Geocoding confidence			
Very high, n (%)	468 (16.2)	468 (24.5)	0 (0.0)
High, n (%)	151 (5.2)	151 (7.9)	0 (0.0)
Moderate, n (%)	1,110 (38.4)	1,110 (58.1)	0 (0.0)
Low, n (%)	119 (4.1)	119 (6.2)	0 (0.0)
Minimal, n (%)	63 (2.2)	63 (3.3)	0 (0.0)
Missing, n (%)	982 (33.9)	0 (0.0)	982 (100.0)

The median calculated drive time was 65 minutes (IQR, 54–86 minutes; range, 3–267 minutes). The median calculated flight time was 60 minutes (IQR, 52–69 minutes; range, 30–180 minutes). These results are shown in Figure 2, demonstrating the relationship between pairs of flight times and drive times. Markers below the red line indicate incidents where the predicted drive time was shorter than the predicted flight time. The distribution is partly explained by the fact that we assumed a total of 30 minutes for stand-to, scene activity, and landing at the trauma center. On comparing calculated

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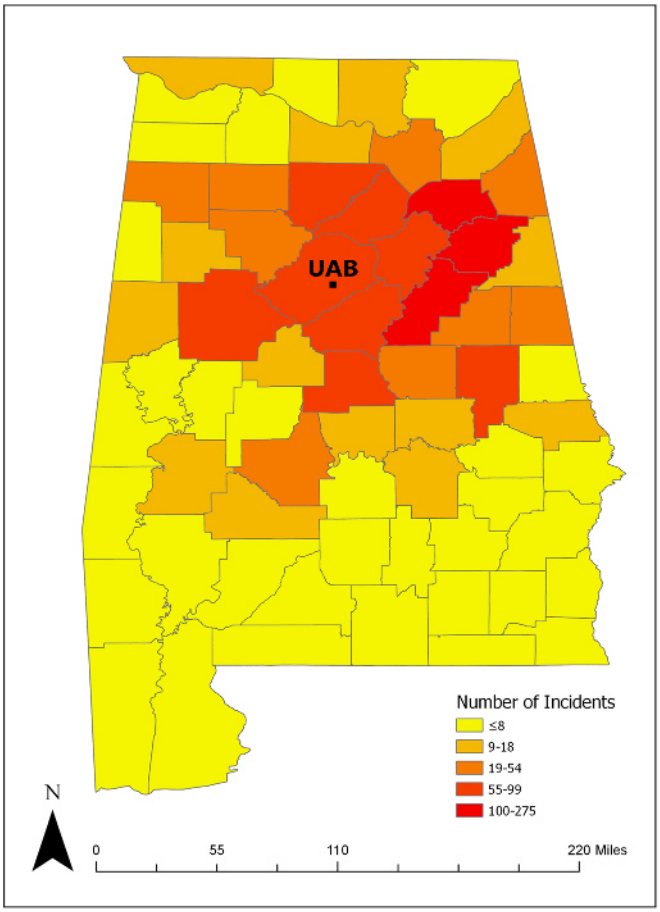

Figure 1. Geographical distribution of incidents, by county.

drive times and flight times, 33% of patients taken to UAB by helicopter might have reached more quickly if they had been taken by road.

DISCUSSION

This study has examined the use of helicopters for transport from the scene to a Level I trauma center, in terms of the clinical indications and the geography of the incident location. The triage of patients for aeromedical evacuation has been extensively studied, and there is broad agreement that there is frequent overutilization of helicopter transport.[11–14] Our results confirm this finding: more than half of patients had suffered only mild or moderate injury, although one quarter had a GCS score of 8 or less, and 8.6% were hypotensive. Twenty percent of the patients were discharged home from the emergency department. These results indicate that the prehospital triage of patients for transfer by helicopter could be improved. However, it should be borne in mind that the physiological criteria listed above were recorded on admission to the trauma center, rather than at the scene, and that injury severity score and discharge destination are determined following a full diagnostic work-up and not available for triage.

However, while clinical decision making is important, many studies fail to address the geographical issues associated with helicopter transport. In terms of the logistic analysis, our results indicate that one third of incidents had a longer predicted flight time than drive time. Given the risks and costs of aeromedical transport, this is also concerning. Assuming an estimated cost of US $6,800 per flight,[8] this amounts to US $4.3 million in health care expenditure that could have been avoided in central Alabama alone—while also getting patients to specialist care more expeditiously. Unnecessary flights may also impact on those patients who do need them: over the duration of this study, an average of two patients was flown to UAB by helicopter per day, although the numbers ranged from zero to eight. With only six helicopters in Alabama, it is possible that some patients requiring helicopter transport were retrieved using a helicopter from a location other than the nearest base. If the number of flights could be reduced, patients who are appropriately triaged for helicopter transport will have an increased chance of access to the nearest helicopter.

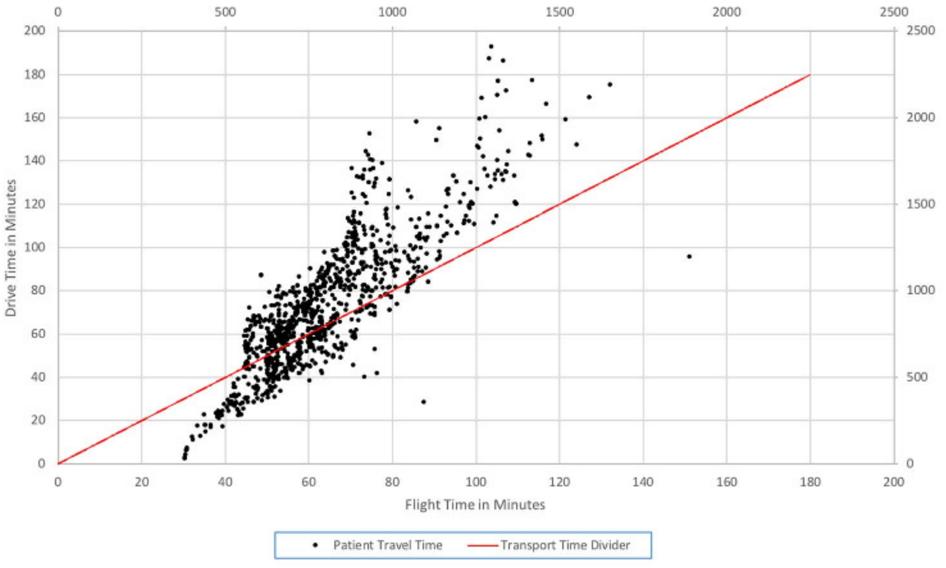

Figure 2. Comparison of calculated drive times and flight time.

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Incident location is still a frequently neglected aspect of trauma system evaluation and trauma systems research. Many registries do not routinely record incident location, or record it inconsistently, or inaccurately. However, there is increasing interest in the subject. A recent study by the Pittsburgh group, which examined the distance at which aeromedical transport is quicker than ground transport, under different conditions, showed that the threshold varied from 5.4 miles to 35.3 miles, depending on traffic, weather, and geographic location.[15] The authors concluded that these factors must be considered when making triage decisions. Limitations of the study included the use of ZIP code centroids, rather than precise incident locations. Our study goes some way to addressing these issues, by considering actual incident locations, where possible, and using realistic flight times. The latter may also explain our more conservative estimate of the number of incidents which might benefit from aeromedical retrieval. A further study, from Oklahoma, found that "flights that were potentially inappropriate by logistics factors alone were rare."[16] However, this study simply dichotomized flights from incidents less than 30 miles from the trauma as inappropriate, rather than considering individual drive and flight times and is, therefore, less robust than our analysis.

Our study does, however, also have limitations. The most significant of these is that the appropriateness of helicopter transport was determined by comparing *calculated* flight and drive times. These calculated times may not reflect the incident date's weather conditions, traffic, or availability of the closest helicopter. Furthermore, we allowed 30 minutes for launch, landing, and loading of casualties, which can vary for each incident and responding flight crew. A prospective study to properly evaluate these timings would be helpful, and to consider the effects of weather, traffic, and aircraft availability/location would be helpful. Similar, such a study should ideally record prehospital triage decisions (and associated physiological parameters), rather than relying on admission vital signs. Furthermore, when a precise address was not available, incident location was calculated using the geographic center of the zip code, city, or county. Thus, if the centroid was located in a rural area, this could inflate the predicted drive time.

CONCLUSION

In conclusion, this study demonstrates that scene aeromedical retrieval in our service area may be overutilized, both in terms of clinical triage and logistical considerations. A prospective study is warranted to overcome the limitations of registry data, the assumptions underlying flight time analysis, and incomplete incident location data.

AUTHORSHIP

W.A.S. and J.O.J. conceived the idea for this study and designed it. W.A.S., K.L.S., A.B., P.F., and R.L.G. contributed to the data collection. W.A.S., R.L.G., and J.O.J. analyzed the data. D.B.C. and J.D.K. assisted with the interpretation of the data. All authors contributed to the writing of the article, and approved the final version.

DISCLOSURE

J.D.K. and J.O.J. are medical directors for EMS agencies in Alabama.

REFERENCES

1. Pigneri DA, Beldowicz B, Jurkovich GJ. Trauma systems: origins, evolution, and current challenges. *Surg Clin North Am*. 2017;97(5):947–959.
2. MacKenzie EJ, Rivara FP, Jurkovich GJ, Nathens AB, Frey KP, Egleston BL, Salkever DS, Scharfstein DO. A national evaluation of the effect of trauma-center care on mortality. *N Engl J Med*. 2006;354(4):366–378.
3. Gabbe BJ, Simpson PM, Sutherland AM, Wolfe R, Fitzgerald MC, Judson R, Cameron PA. Improved functional outcomes for major trauma patients in a regionalized, inclusive trauma system. *Ann Surg*. 2012;255(6):1009–1015.
4. American College of Surgeons. *Resources for the Optimal Care of the Injured Patient*. Chicago: American College of Surgeons; 2014.
5. Nathens AB, Jurkovich GJ, Maier RV, Grossman DC, MacKenzie EJ, Moore M, Rivara FP. Relationship between trauma center volume and outcomes. *JAMA*. 2001;285(9):1164–1171.
6. McGinnis KK, Judge T, Nemitz B, et al. Air medical services: future development as an integrated component of the emergency medical services (EMS) system: a guidance document by the Air Medical Task Force of the National Association of State EMS Officials, National Association of EMS Physicians, Association of Air Medical Services. *Prehosp Emerg Care*. 2007;11(4):353–368.
7. The Association of Air Medical Services. Available from: http://aams.org/wp-content/uploads/2014/01/AIRMED101.pdf.pdf. Accessed 20 December 2018.
8. Delgado MK, Staudenmayer KL, Wang NE, Spain DA, Weir S, Owens DK, Goldhaber-Fiebert JD. Cost-effectiveness of helicopter versus ground emergency medical services for trauma scene transport in the United States. *Ann Emerg Med*. 2013;62(4):351–64 e19.
9. Aviation Special Investigation Report, Board NTS, ed. In: *Special Investigation Report on Emergency Medical Services Operations*. Washington, DC; 2005.
10. Becker LR, Zaloshnja E, Levick N, Li G, Miller TR. Relative risk of injury and death in ambulances and other emergency vehicles. *Accid Anal Prev*. 2003;35(6):941–948.
11. Michael Abernethy BB, Carrison D. Reduce inappropriate helicopter utilization in EMS. *J Emerg Med*. 2010;35(3).
12. Vercruysse GA, Friese RS, Khalil M, et al. Overuse of helicopter transport in the minimally injured: a health care system problem that should be corrected. *J Trauma Acute Care Surg*. 2015;78(3):510–515.
13. Meyer MT, Gourlay DM, Weitze KC, Ship MD, Drayna PC, Werner C, Lerner EB. Helicopter interfacility transport of pediatric trauma patients: are we overusing a costly resource? *J Trauma Acute Care Surg*. 2016;80(2):313–317.
14. Saffle JR, Edelman L, Morris SE. Regional air transport of burn patients: a case for telemedicine? *J Trauma*. 2004;57(1):57–64.
15. Chen X, Rosengart MR, Peitzman AB, Billiar TR, Sperry JL, Brown JB. Logistics of air medical transport: when and where does helicopter transport reduce prehospital time for trauma? *J Trauma*. 2018;85(1):174–181.
16. Soulek JJ, Arthur AO, Williams E, Scheiche C, Banister N, Thomas SH. Logistics and helicopter use appropriateness in a large rural state. *Air Med J*. 2014;33(4):143.

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