Docket No. SA-530

Exhibit No. 5-I

NATIONAL TRANSPORTATION SAFETY BOARD

Washington, D.C.

Helicopter Scene Transport of Trauma Patients with Nonlife-Threatening Injuries: A Meta-Analysis

(10 Pages)

Helicopter Scene Transport of Trauma Patients with Nonlife-Threatening Injuries: A Meta-Analysis

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Background: Helicopters have become a major part of the modern trauma care system and are frequently used to transport patients from the scene of their injury to a trauma center. While early studies reported decreased mortality for trauma patients transported by helicopters when compared with those transported by ground ambulances, more recent research has questioned the benefit of helicopter transport of trauma patients. The purpose of this study was to determine the percentage of patients transported by helicopter who have nonlife-threatening injuries.

Methods: A meta-analysis was performed on peer-review research on helicopter utilization. The inclusion criteria were all studies that evaluated trauma patients transported by helicopter from the scene of their injury to a trauma center with baseline parameters defined by Injury Severity Score (ISS), Trauma Score (TS), Revised Trauma Score (RTS), and the likelihood of survival as determined via Trauma Score-Injury Severity Score (TRISS) methodology.

Results: There were 22 studies comprising 37,350 patients that met the inclusion criteria. According to the ISS, 60.0% [99% confidence interval (CI): 54.5–64.8] of patients had minor injuries, According to the TS, 61.4% (99% CI: 60.8–62.0) of patients had minor injuries. According to TRISS methodology, 69.3% (99% CI: 58.5–80.2) of patients had a greater than 90% chance of survival and thus nonlife-threatening injuries. There were 25.8% (99% CI: −1.0–52.6) of patients discharged within 24 hours after arrival at the trauma center.

Conclusions: The majority of trauma patients transported from the scene by helicopter have nonlife-threatening injuries. Efforts to more accurately identify those patients who would benefit most from helicopter transport from the accident scene to the trauma center are needed to reduce helicopter overutilization.

Key Words: Helicopter, Trauma, Prehospital, Overtriage, Overutilization.

J Trauma. 2006;60:1257–1266.

The use of helicopters to transport patients from the scene of their injury to a trauma center has become a major part of the modern trauma care system. Early studies reported decreased mortality for trauma patients transported by helicopters when compared with those transported by ground ambulances.[1–4] However, more recent research has questioned the benefit of helicopter transport of trauma patients.[5–7] Helicopter utilization criteria have been established by leading industry and professional organizations to aid prehospital personnel in determining when to summon a medical helicopter to a trauma scene.[8–10] These criteria utilize both mechanism of injury (MOI) information and physiologic parameters to determine which patients may benefit from helicopter transport. Underutilzation of helicopter transport can result in some patients being denied the benefit of the speed and care helicopter transport affords while overutilization results in inappropriate use of this relatively expensive and potentially dangerous modality.[11]

Prehospital triage of trauma patients is an inexact science and some degree of overtriage (patients transported by helicopter who are later determined to have nonlife-threatening injuries) is generally accepted.[12] This is to assure that the majority of trauma patients who are likely to benefit from helicopter transport have it available. Several studies have demonstrated that most helicopter transports adhere to established utilization criteria.[13–16] However, utilization describes frequency of use rather than need. Need, when applied to health care technology, implies that the proposed technology provides a demonstrated patient benefit. Thus, to be considered beneficial, helicopter transport of trauma patients must show improved outcome, enhanced safety, and/or reduced overall health care cost when compared with ground transport.[17]

The purpose of this study was to determine the percentage of trauma patients transported from the scene by medical helicopter who have nonlife-threatening injuries.

METHODS

This study was an observational meta-analysis of peer-reviewed articles in the English language literature regarding helicopter transport of trauma patients.[18] Each of the authors was independently polled to establish inclusion criteria for the study. The inclusion criteria called for studies that used validated and recognized trauma scoring systems to allow for comparison of outcomes and injury severity across different patient populations.

Submittted for publication October 12, 2004.

Accepted for publication May 18, 2005.

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DOI: 10.1097/01.ta.0000196489.19928.c0

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Studies were also limited to helicopter transports where trauma patients were retrieved from the scene of the injury and transported to a trauma center/hospital. Interfacility helicopter transport of trauma patients were excluded as these patients often received stabilization and definitive care at the referral hospital before transfer and thus their values on standardized trauma scoring systems might be artificially skewed because of the care provided.

After determination of selection criteria, an on-line search of Pub Med was carried out using the following keywords: "helicopter", "helicopter + trauma" "helicopter + utilization criteria." The keyword "helicopter" returned 5836 citations, "helicopter + trauma" revealed 977 citations, and "helicopter + utilization criteria" revealed 77 citations. These citations were independently reviewed by the authors. Forty-eight articles were identified as possibly relevant for inclusion. These were retrieved and evaluated independently by three of authors (BEB, AKW, ME) and 22 articles were determined to meet one or more of the inclusion criteria.

Standard scoring systems that quantify the severity of trauma include the Injury Severity Score (ISS), Trauma Score (TS), Revised Trauma Score (RTS), and Trauma Score-Injury Severity Score (TRISS). The ISS is an anatomic scoring system for patients with multiple injuries and does not include physiologic variables. The ISS ranges from 0 to 75 with the severity of injury and mortality increasing with the score. Patients with an ISS >15 are deemed to require specialized trauma care while patients with an ISS of 15 or less are considered to have nonlife-threatening injuries.[19–21] The original TS included four physiologic parameters (respiratory rate, respiratory expansion, systolic blood pressure, capillary refill) and the Glasgow Coma Scale (GCS). It had a range from 1 to 16 points. Patients with a score of 12 or less were deemed to be seriously injured and required specialized trauma care.[22] The TS was revised in 1989 and became the RTS. Two of the physiologic parameters (respiratory expansion and capillary refill) were dropped. The range of the RTS is 0 to 12. Patients with a score of 11 or less are deemed to require specialized trauma care. While the RTS is most commonly used in the prehospital setting, a weighted form of the scale is used to predict patient outcomes following trauma. With the weighted RTS, greater emphasis is placed on the GCS. The range for the weighted RTS is 0 to 7.8408. Higher scores are associated with a better prognosis.[23] Patients with a weighted RTS score of <4 are felt to benefit from specialized trauma care while patients with a score of ≥ 4 are generally considered to have minor injuries. The TRISS system combines the RTS, the ISS, the patient's age, and the type of trauma sustained (blunt or penetrating) to determine a probability of survival (P_s).[24]

To determine which patients were unlikely to benefit from helicopter transport, we used the standard trauma scoring systems described above. Based upon validated criteria, patients having a TS ≥ 13, a RTS >11, a weighted RTS ≥ 4, and/or an ISS ≤ 15 were deemed to have sustained nonlife-threatening injuries and therefore did not require helicopter transport. Likewise, a TRISS-derived probability of survival (P_s) of greater than 0.90 (a 90% or better chance of survival) also represents nonlife-threatening injuries and was included as one of the inclusion criteria.[25] Finally, patients who were discharged from the emergency department or hospital within 24 hours of admission for trauma are generally considered to have nonlife-threatening injuries and were included in the inclusion selection criteria.[26]

Statistical analysis was completed by two of the authors (TMD and MFO). Ultimately, this study had four different variables (ISS, TS, TRISS, and Discharge within 24 hours of admission). A meta-analysis was conducted for each of the four variables by entering the percentages of patients with scores indicative of nonlife-threatening injuries into a statistical software package (Statistical Package for the Social Sciences, Version10.0, SPSS, Inc., Chicago, Ill.). The total number of patients was also entered to weight each percentage. A mean percentage was calculated and a confidence level around each mean was also computed.

RESULTS

There were 22 articles spanning 21 years (1983–2004) that met the inclusion criteria providing a study cohort of 37,350 patients (Table 1).[2,3,5–7,26–42] Table 2 details the 26 studies excluded from the study group and the reason(s) for exclusion.[16, 43–67]

Analysis

Thirteen of the 22 studies meeting inclusion criteria utilized the ISS and provided score stratification sufficient to determine the number of patients who had an ISS ≤ 15. There were a total of 31,244 patients in this subgroup of which 18,629 (60.0%) [99% confidence interval (CI): 54.5–64.8] had an ISS ≤ 15 and thus nonlife-threatening injuries. This subgroup is detailed in Table 3.

Two of the 22 studies utilized the TS and provided score stratification sufficient to determine the number of patients who had a TS ≥ 13. There were a total of 2,110 patients in this subgroup of which 1296 (61.4%) (99%CI: 60.8–62.0) had a TS ≥ 13 and thus nonlife-threatening injuries. This subgroup is detailed in Table 4.

Only 1 of the 22 studies (Eckstein[7]) utilized the RTS. However, this study also utilized the ISS system. Because of this, the RTS scores were not included in the meta-analysis. Eleven of the 22 studies utilized TRISS methodology and provided a stratified listing of P_s values. There were a total of 6,328 patients in this subgroup of which 4,414 (69.3%) (99% CI: 58.5–80.2) had a TRISS $P_s \geq 0.90$ and thus nonlife-threatening injuries. This subgroup is detailed in Table 5.

Five of the 22 studies provided data detailing the number of patients discharged from the hospital within 24 hours of admission after helicopter transport from the

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Table 1 Descriptions of Studies Included in Final Meta-Analysis Sample

Study	Year	Population	Patients	Description
Amatangelo[26]	1997	Mixed	450	1 yr retrospective review of patients transported in Boston, Massachusetts
Bartolacci[27]	1998	Mixed	157	8 yr retrospective study of ground and helicopter transport of blunt trauma patients in Australia
Baxt(a)[3]	1985	Mixed	1,273	2 yr multi-center prospective study of trauma mortality following helicopter transport
Baxt(b)[2]	1983	Mixed	150	Comparison study of 150 blunt trauma patients transported by air to 150 transported by ground
Braithwaite[28]	1998	Mixed	15,938	8 yr retrospective study of ground and helicopter transport of trauma patients (trauma registry study)
Cameron[29]	1983	Adult	254	2.5 yr retrospective study of helicopter transport of trauma patients in Victoria, Australia
Cunningham[5]	1997	Mixed	1,856	Retrospective study of ground and helicopter transport of trauma patients (trauma registry study)
Eckstein[7]	2002	Pediatric	189	3 yr retrospective study of helicopter transport of trauma patients in Los Angeles, California
Garner[30]	1999	Mixed	207	2 yr retrospective study of helicopter transport of blunt trauma patients in Australia
Kerr[31]	1999	Mixed	11,623	7.5 yr retrospective study of ground and helicopter transport of trauma patients in Maryland
Larson[32]	2004	Pediatric	379	8.5 yr retrospective study of trauma patients transported by helicopter (trauma registry study)
Moront[33]	1996	Pediatric	1,100	4 yr retrospective study of ground and helicopter transport of trauma patients
Norton[34]	1996	Mixed	172	2.5 yr retrospective study of helicopter transport of urban trauma patients in Oregon
Phillips[35]	1999	Mixed	105	1 yr retrospective study of ground and helicopter transport of trauma patients in San Antonio, Texas
Rhodes[36]	1986	Mixed	130	7 mo prospective study of helicopter transport of trauma patients in Pennsylvania
Schmidt[37]	1992	Mixed	408	1 yr retrospective comparative study of helicopter transport of blunt trauma patients in the US and Germany
Shatney[6]	2002	Adult	947	10 yr retrospective study of helicopter transport trauma patients in Santa Clara County, California
Snooks[38]	1996	Mixed	570	1–2 yr prospective study of ground and helicopter transport of patients in the United Kingdom
Wills[39]	2000	Mixed	179	1 yr retrospective study of helicopter transport of trauma patients in New South Wales, Australia
Wong[40]	2000	Mixed	85	7 mo prospective study of trauma patients transported in Hong Kong
Wuerz[41]	1996	Mixed	333	2 yr retrospective study of helicopter transport of trauma patients in Pennsylvania
Younge[42]	1997	Mixed	845	4 yr prospective study of trauma patients transported by helicopter in London, UK

scene of their injury. There were a total of 1,850 patients in this subgroup of which 446 (25.82%) (99% CI: −0.90–52.63) were discharged from the emergency department and not admitted to hospital. Thus, one out of every four trauma patients transported by helicopters in this subgroup had injuries so minor that they did not require admission to hospital. This subgroup is detailed in Table 6.

The sub-group findings were consistent across the three trauma scoring systems utilized. Figure 1 details the relationship between the various subgroups described above.

DISCUSSION

Our study demonstrated that the majority of trauma patients transported by medical helicopter from the scene had nonlife-threatening injuries. We believe there are two possible explanations for this phenomenon. First, there may be a significant degree of overutilization of helicopter scene flights for trauma by air-medical services despite quality assurance oversight that reveals these flights to be nonbeneficial. Second, and more probable, the apparent overutilization may be because of a significant degree of overtriage in the field by prehospital providers resulting in inappropriate requests for helicopter scene transport.

Our findings are similar to other studies that have documented that a significant number of trauma patients transported from the scene to a hospital by medical helicopter do not receive any added benefit from helicopter transport. The incidence of non beneficial helicopter transport of trauma patients identified by these authors is similar to what we have identified in our meta-analysis (see Table 7).

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Table 2 Description of Studies Excluded From Final Meta-Analysis Sample

Study	Year	Population	Reason for Exclusion
Barnoski[16]	1998	Mixed	Failed to differentiate scene from interhospital flights
Biewener[43]	2004	Mixed	Failed to differentiate scene from interhospital flights
Brazier[44]	1996	Mixed	ISS not stratified
Buntman[45]	2002	Mixed	TRISS scores not stratified
Burney[46]	1992	Mixed	Failed to differentiate scene from interhospital flights
Cummings[47]	2000	Mixed	Failed to differentiate scene from interhospital flights
Cocanour[48]	1997	Mixed	ISS not stratified
Diller[49]	1999	Pediatric	Failed to differentiate scene from interhospital flights
Falcone[50]	1998	Mixed	Failed to differentiate scene from interhospital flights
Fischer[51]	1984	Mixed	ISS not stratified
Gerhardt[52]	2000	Mixed	Study included both medical and trauma flights
Hamman[53]	1991	Mixed	ISS and TRISS scores not stratified
Jacobs(a)[54]	1989	Mixed	ISS not stratified
Jacobs(b)[55]	1999	Mixed	TS not stratified
Kirk[56]	1993	Mixed	ISS and TRISS scores not stratified
Kotch[57]	2002	Mixed	ISS not stratified
Mackenzie[58]	1979	Mixed	TS not stratified
Nardi[59]	1994	Mixed	ISS not stratified
Rhee[60]	1990	Mixed	Failed to differentiate scene from interhospital flights
Schiller[61]	1988	Mixed	TS and ISS not stratified
Schoettker[62]	2001	Mixed	Study limited to victims ejected from a vehicle
Schwartz[63]	1990	Mixed	TS and ISS not stratified
Stohler[64]	1991	Mixed	ISS not stratified
Thomas[65]	2002	Mixed	Failed to differentiate scene from interhospital flights
Tortella[66]	1996	Mixed	ISS not stratified
Urdaneta[67]	1987	Mixed	ISS not stratified

This meta-analysis suggests that current helicopter utilization criteria may result in a significant degree of overutilization. There are several sets of helicopter usage criteria for trauma patients. The Association of Air Medical Services (AAMS) has published a set of criteria.[8] In addition, the Association of Air Medical Physicians (AAMP) has also published criteria which were subsequently affirmed by the Air Medical Physicians Committee of the National Association of Emergency Medical Services Physicians (NAEMSP).[10] These criteria are quite similar and largely-based on criteria established by the American College of Surgeons.[69] These criteria tend to emphasize MOI and situational conditions.

Many helicopter services publish their own criteria that generally follow the national consensus criteria. However, these criteria tend to be overly broad. For example, based on

Table 3 Patients with ISS of ≤15

Study	Number of Patients Transported by Helicopter	Number of Patients with ISS ≤15	Percentage of Patients with ISS ≤15
Bartolacci	157	80	51.0%
Braithwaite	15,938	8,766	55.0%
Cameron	254	88	34.6%
Eckstein	189	161	85.1%
Kerr	11,623	7,388	63.6%
Larson	379	259	68.3%
Norton	137	72	52.6%
Rhodes	130	59	45.4%
Schmidt	408	225	55.1%
Shatney	947	799	84.4%
Snooks	570	403	70.1%
Wills	179	147	82.1%
Wuerz	333	182	54.7%
Total	31,244	18,629	60.0%

Table 4 Patients with a Trauma Score ≥13

Study	Number of Patients Transported by Helicopter	Number of Patients with TS ≥13	Percentage of Patients with TS ≥13
Cameron	254	154	60.6%
Cunningham	1,856	1,142	61.5%
Total	2,110	1,296	61.4%

Table 5 Patients with a TRISS $p > 0.90$

Study	Number of Patients Transported by Helicopter	Number of Patients with TRISS $p \geq 0.90$	Percentage of Patients with TRISS $p \geq 0.90$
Bartolacci	157	86	54.8%
Baxt(a)	1,273	922	72.4%
Baxt(b)	150	113	75.3%
Cunningham	1,856	1,244	67.0%
Garner	207	134	64.7%
Larson	351	287	81.8%
Moront	1,100	990	90.0%
Norton	161	126	78.3%
Phillips	98	70	71.4%
Rhodes	130	88	67.7%
Younge	845	354	41.9%
Total	6,328	4,414	69.3%

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Table 6 Patients Discharged From Hospital in Less Than 24 h

Study	Number of Patients Transported by Helicopter	Patients Discharged <24 h of Admission	Percentage of Patients Discharged <24 h of Admission
Amatangelo	450	18	4.0%
Eckstein	189	57	30.2%
Shatney	947	312	32.9%
Wills	179	12	6.7%
Wong	85	47	55.3%
Total	1,850	446	24.1%

Table 7 Incidence of Nonbeneficial Helicopter Transports for Trauma Patients

Study	Year	% Patients Not Benefited*
Shatney[6]	2002	82.6
Wills[39]	2000	82.7
Cocanour[48]	1997	95.1
Cunningham[5]	1997	67.2
Norton[34]	1996	64.0
Nicholl[68]	1995	91.5
Urdanetta[67]	1987	73.1

* Patients determined by a review panel to be inappropriate or not helped by helicopter transport.

commonly used criteria, two or more long bone fractures meets criteria for helicopter transport. However, such injuries are often minor such as an uncomplicated fracture of the tibia and fibula or an uncomplicated fracture of the radius and ulna. Table 8 is an example of current helicopter utilization criteria provided to prehospital personnel by medical helicopter programs.[70]

Several researchers have recently questioned the ability of current trauma triage criteria to identify which patients might benefit from specialized trauma care. The MOI has been found to correlate poorly with injury severity. In one study, the MOI criteria alone only identified 73% of patients with an ISS >15.[71] Wuerz and colleagues compared physiologic criteria with MOI criteria in 333 trauma patients and found that physiologic criteria, when used alone, had a high specificity (85.7%) but low sensitivity (55.6%). MOI criteria alone had a high sensitivity (86.6%) yet low specificity (19.9%). In their study, use of physiologic criteria alone would miss 44% of patients with an ISS >15 and 16% of the fatalities. The MOI criteria would capture 87% of major trauma patients missed by the physiologic criteria but would also capture an additional 25 patients with minor injuries representing an overtriage rate of 37.5%.[40] Cook and colleagues have suggested that eliminating MOI as a triage criterion will result in reduction of trauma patient overtriage, which improves resource allocation.[72] Black and colleagues introduced an algorithm that emphasized simple physiologic variables to determine which trauma patients should be transported from the scene by helicopter in the United Kingdom. A fundamental component of their algorithm is the dictum that patients should always be transported by ground ambulance if the transport time is less than 45 minutes.[73] Diaz and colleagues found that, unless the helicopter is dispatched simultaneously with the ground ambulance, helicopter transport times are slower when the distance is less than 45 miles from the hospital.[74] Future studies should critically evaluate each MOI and physiologic criteria to determine the best predictors of helicopter usage.

Schiller et al. was among the first to recognize that helicopter transport of urban trauma patients may be nonbeneficial. In a retrospective study of patients in the Phoenix, AZ

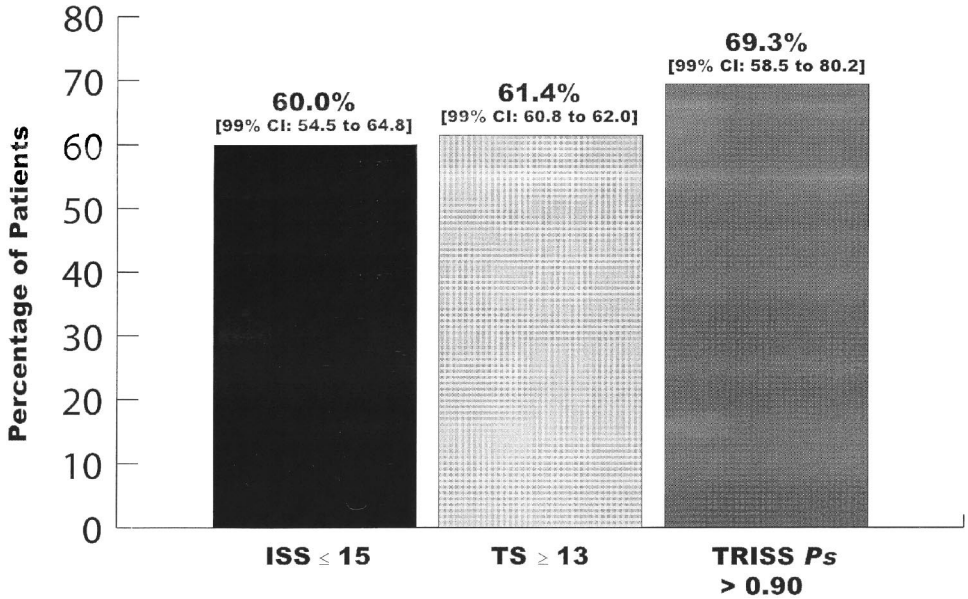

Fig. 1. *Percentage of patients with minor injuries by scoring system.*

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Table 8 Typical Criteria for Air Medical Dispatch for Trauma Scene Responses

Mechanism of Injury Criteria
Vehicle roll over
Victim ejected from vehicle
Pedestrian hit by vehicle at speed >10 MPH
Fall >15 feet
Extrication time >20 minutes
Motorcycle accident >20 MPH
Death within the same vehicle
Amputation of a limb proximal to the wrist or ankle
Significant steering wheel deformity
Physiological and hemodynamic criteria
Patient is unconscious
Respiratory or airway difficulty
Massive head or facial trauma
Decreased level of consciousness (GCS <13)
Low blood pressure (SBP <90 mm Hg)
Unexplained tachycardia
Pelvic instability
Flail chest or chest wall instability
Two or more long bone fractures
Paralysis or suspected spinal cord injury
Miscellaneous Indications
Multiple victims
Difficult ground access
Farm accident
Aircraft mishap
Major burns
Near drowning

metropolitan area, they compared ground versus air transport of trauma patients and found that helicopter transport did not improve survival.[61] Norton et al. found a high proportion of inappropriate scene flights in the Portland (Oregon) area. They suggested that utilization could be improved by using physiologic markers to determine which patients might benefit from helicopter transport.[34] Cunningham et al. found that outcomes were not uniformly better among trauma patients transported by helicopter in North Carolina.[5] Braithwaite et al. retrospectively evaluated 8 years of data in the Pennsylvania trauma registry and found that helicopter transport of trauma patients did not affect the estimated odds of survival.[28] Kerr et al. was able to document improved survival in trauma patients transported by helicopter in Maryland when the patient had an ISS >31.[31] Wills et al. had an independent panel retrospectively evaluate 179 trauma scene flights in northern New South Wales, Australia. The panel found that helicopter transport only benefited 17.3% of patients and possibly was harmful to 1.7%.[39] Shatney et al. retrospectively studied all trauma patients transported to the Santa Clara Valley (California) trauma center by helicopter for a 10 year period (1990–2001) and found that only 22.8% of the study population possibly benefited from helicopter transport.[6]

Several studies have demonstrated a significant overutilization of helicopter transport for pediatric trauma patients. Moront et al. performed a retrospective assessment of triage criteria and utilization patterns for helicopter patients transported to the Children's National Medical Center in Washington, DC. They were able to demonstrate that helicopter transport was associated with better survival rates among urban injured children. However, they found an overtriage rate of 85% and, based upon this, recommended that the use of physiologic criteria (GCS and heart rate) would improve helicopter resource utilization without compromising care.[33] Eckstein et al. reported that 83% of urban injured children transported by helicopter in Los Angeles (California) had minor injuries. They found that pediatric trauma patients with a GCS <10 and/or RTS ≤6.5 are those most likely to benefit from helicopter transport.[7] Larson et al. compared outcomes of injured children transported by helicopter to those transported by ground ambulance in central Ohio. They found that 68% of children had minor injuries and, overall, were not able to verify any benefit for pediatric trauma patients transported by helicopter directly from the injury scene to a pediatric trauma center.[32]

Additionally, beyond the issue of overutilization, helicopters are costly to operate. The average helicopter charge is typically 10 to 15 times that of ground ambulance transportation. Hourly operational costs can exceed $5,000.00 per hour.[28,38,75,76]

Despite the cost, many operators enjoy significant downstream revenues from air medical operations. In FY 2001, the University of Michigan Health System's Survival Flight program had operating costs of approximately $6.0 million but generated inpatient revenues of $62.0 million (excluding professional fees).[77]

There has been a marked increase in the number of medical helicopter accidents in the United States.[78] In fact, half of all accidents in one 10-year study (1993–2002) occurred during the last 3 years of the study period.[79] Because of the lack of a centralized database, it is impossible to determine whether this increase in accidents reflects a decline in operational safety or merely reflects the fact that there are more aircraft flying more missions. In January of 2005, in response to a sharp increase in fatal medical helicopter accidents, the NTSB and the Federal Aviation Administration (FAA) launched safety reviews of medical helicopters.[80]

It is curious that early studies demonstrated that helicopter transport decreased mortality from trauma while more recent studies have indicated little or no benefit from helicopter transport. The authors believe this reflects the tremendous improvements in ground prehospital care observed over the last 20 years including more widespread advanced life support units and markedly enhanced EMT and paramedic education. Other factors that may explain this difference include improved categorization of hospitals, the organization and implementation of regional trauma systems, trauma centers, and postgraduate educational programs that specialize in trauma care.

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There are several limitations in this study. First, all of the studies included in our meta-analysis were uncontrolled. Second, the majority of the included studies were of a retrospective design and are thus at risk for selection bias. However, prospective studies of medical helicopter utilization are difficult as medical helicopters are widely perceived as beneficial and it would be difficult to secure IRB approval to conduct a randomized clinical trial where one subset of patients would not receive this modality. Also, as with all observational studies, there exists the possibility of publication bias.

Third, it is assumed that helicopter utilization is based on scientific criteria that accurately predict the likelihood of the presence of major trauma. Our meta-analysis did not undertake an evaluation of each specific criterion as the included studies did not stratify the specific criteria used to justify helicopter utilization.

Fourth, current helicopter utilization criteria are applied at the scene of trauma while the ISS is calculated retrospectively once the patient has received definitive care. The use of the ISS has been reported to not identify a subset of trauma patients who may benefit from definitive trauma care. However, the ISS is usually applied retrospectively following hospital admission and is not routinely used for prehospital trauma triage decision making. The ISS is the scoring system most commonly used in the studies referenced in this article.

The use of the TRISS system has both benefits and limitations. TRISS is widely used and validated. However, it is applied retrospectively and does not aid prehospital personnel in determining which patients may actually benefit from helicopter transport Furthermore, the TRISS has been reported to overestimate survival in patients who are severely injured.[42] However, in our cohort we were interested in patient with minor injuries.

Finally, there are those patients who might benefit from the assessment and monitoring provided in a tertiary care trauma center based upon their MOI or field vital signs, even though they ultimately did not require surgical intervention. One example is a pediatric patient with a splenic hematoma who is closely monitored in an ICU setting, but ultimately does well with conservative management.

The incidence of patients transported from trauma scenes by helicopter and subsequently discharged from the emergency department or hospital in less than 24 hours has not been widely studied. However, review of the recent literature demonstrates a significant percentage of trauma patients transported by helicopter were discharged. The percentage of patients discharged from the hospital in less than 24 hours in our meta-analysis had a large CI and thus does not have the power to make any conclusions. Additional studies and a larger sample size are necessary to further define the significance of this finding. The data on discharges in less than 24 hours was presented as an incidental finding but worthy of further investigation.

The potential difference in prehospital care provided by helicopter transport is a potentially confounding variable. In some of the systems that were studied, helicopters were staffed with flight nurses, flight paramedics, or flight surgeons who may have a greatly expanded scope of practice compared to the ground-based EMS providers in their respective jurisdictions. Prehospital interventions such as definitive airway control with the use of paralytic induction agents (rapid sequence induction [RSI]) may be permitted by flight paramedics but not ground-based paramedics in the same system. It is possible that patients with closed head injury and a low GCS might have had airway compromise that was controlled via the use of RSI, even though the patient was ultimately determined to have a minor head injury or was intoxicated. But, despite low ISS values (reflecting nonlife-threatening injuries), such prehospital intervention may have been life-saving.[81] Without prospective cohort-controlled studies, it is difficult to draw definitive conclusions.

Additional comparative studies are needed to determine the benefits of the various modes of transport (ground, helicopter, and fixed-wing). In addition, the implementation of statewide and national registries of helicopter utilization would provide an unbiased centralized repository of data that will help answer some of the questions raised in this study. Finally, given the costs and risks associated with their use, further research must refine the utilization criteria to better define and predict those patients who would benefit most from helicopter transport.

CONCLUSIONS

The majority of trauma patients transported from the scene by helicopter have nonlife-threatening injuries. Additional studies are required to clearly identify the subset of trauma patients who would benefit most from helicopter transport and revise utilization criteria to reflect these studies.

REFERENCES

1. Cowley RA, Hudson F, Scala E, et al. An economical and proved helicopter program for transporting the emergency critically-ill and injured patient in Maryland. *J Trauma.* 1973;13:1029–1038.
2. Baxt WG, Moody P. The impact of rotorcraft aeromedical emergency care service on trauma mortality. *JAMA* 1983;249:3047– 3051.
3. Baxt WG, Moody P, Cleveland HC, et al. Hospital-based rotorcraft aeromedical emergency care services and trauma mortality: a multicenter study. *Ann Emerg Med.* 1985;14:859–864.
4. Baxt WG, Moody P. The impact of advanced prehospital emergency care on the mortality of severely brain-injured patients. *J Trauma.* 1987;27:365–369.
5. Cunningham P, Rutledge R, Baker CC, et al. A comparison of the association of helicopter and ground ambulance transport with the outcome of injury in trauma patients transported from the scene. *J Trauma.* 1997;43:940–946.
6. Shatney CH, Homan SJ, Sherck JP, Ho CC. The utility of helicopter transport of trauma patients from the injury scene in an urban trauma system. *J Trauma.* 2002;53:817–822.

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7. Eckstein M, Jantos T, Kelly N, et al. Helicopter transport of pediatric trauma patients in an urban emergency medical services system: A critical analysis. *J Trauma.* 2002;53:340–344.
8. Association of Air Medical Services. Position paper on the appropriate use of emergency air medical services. Pasadena, CA. Association of Air Medical Services; 1990.
9. Thomson DP, Thomas SH, for the 2002–2003 Air Medical Services Committee of the National Association of EMS Physicians. *Prehosp Emerg Care.* 2003;7:265–271.
10. Air Medical Physicians Association. Medical condition list and appropriate use of air medical transport. *Prehosp Emerg Care.* 2002; 6:464–470.
11. Rhee KJ, Holmes EM, Heinzpeter HP, Thomas FO. A comparison of emergency medical helicopter accident rates in the United States and the Federal Republic of Germany. *Aviat. Space Environ Med.* 1990; 62:750–752.
12. Knopp R, Yanagi A, Kallsen G, Geide E, Doehring L. Mechanism of injury and anatomic injury as criteria for prehospital trauma triage. *Ann Emerg Med.* 1988;17:895–902.
13. Benson NH, Alson RL, Norton EG, Beauchamp AP, Weber R, Carreras JL. Air medical transport utilization review in North Carolina. *Prehospital Disaster Med.* 1993;8:133–137.
14. Stohler SA, Schwartz RJ, Sargent RK, Jacobs LM. Quality assurance in the Connecticut Helicopter Emergency Medical Service. *J Air Med Transp.* 1991;10:7–11.
15. Van Wijngaarden M, Kortbeek J, Lafreniere R, Cunningham R, Joughin E, Yim R. Air ambulance trauma transport: a quality review. *J Trauma.* 1996;41:26–31.
16. Bamoski A, Kovach B, Podmore M, Pastis E, Fulton WF Jr. Trauma triage: do AAMS transport guidelines do it effectively? *Air Med J.* 1998;17:19–23.
17. Thomas F. (Editorial Comment) in Benson NH, Alson RL, Norton EG, Beauchamp AP, Weber R, Carreras JL. Air medical transport utilization review in North Carolina. *Prehospital Disaster Med.* 1993;8:133–137.
18. Stroup DF, Berlin JA, Morton SC, et al. Meta-analysis of observation studies in epidemiology: a proposal for reporting. *JAMA.* 2000;283:2008–2012.
19. Baker SP, O'Neill B, Haddon W Jr, et al. The Injury Severity Score: a method for describing patients with multiple injuries and evaluating emergency care. *J Trauma.* 1974;14:187–196.
20. Baker SP, O'Neill B. The Injury Severity Score: an update. *J Trauma.* 1976;16:882–885.
21. Kane G, Englehardt R, Celentano J, et al. Empirical development and evaluation of pre-hospital trauma triage instruments. *J Trauma.* 1985;25:482–489.
22. Champion HR, Sacco WJ, Carnazzo AJ, et al. Trauma Score. *Crit Care Med.* 1981;9:672–676.
23. Champion HR, Sacco WJ, Copes WS, et al. A revision of the Trauma Score. *J Trauma.* 1989;29:623–629.
24. Champion HR, Sacco WJ, Hunt TK. Trauma severity scoring to predict mortality. *World J Surg.* 1983;7:4–11.
25. Rhodes M, Perline O, Aronson J, et al. Field triage for on-scene helicopter transport. *J Trauma.* 1986;26:963–969.
26. Amatangelo M, Thomas SH, Harrison T, Wedel SK. Analysis of patients discharged from receiving hospitals within 24 hours of air medical transport. *Air Med J.* 1997;16:44–46.
27. Bartolacci RA, Munford BJ, Lee A, McDougall PA. Air medical scene response to blunt trauma: effect on early survival. *Med J Aust.* 1998;169:612–616.
28. Brathwaite CE, Rosko M, McDowell R, et al. A critical analysis of on-scene helicopter transport on survival in a statewide trauma system. *J Trauma.* 1998;45:140–146.
29. Cameron PA, Flett K, Kaan E, et al. Helicopter retrieval of primary trauma victims by a paramedic helicopter service. *Aust N Z J Surg.* 1993;63:790–797.
30. Garner A, Rashford S, Lee A, Bartolacci R. Addition of physician to paramedic helicopter services decreases blunt trauma mortality. *Aust N Z J Surg.* 1999;69:697–701.
31. Kerr WA, Kerns TJ, Bissell RA. Differences in mortality rates among trauma patients transported by helicopter and ambulance in Maryland. *Prehosp Disaster Med.* 1999;14:159–161.
32. Larson JT, Dietricj AM, Abdessalam SF, et al. Effective use of the air ambulance for pediatric trauma. *J Trauma.* 2004;56:89–93.
33. Moront ML, Gotschall CS, Eichelberger MR. Helicopter transport of injured children: system effectiveness and triage criteria. *J Pediatr Surg.* 1996;31:1183–1186.
34. Norton R, Wortman E, Eastes L, et al. Appropriate helicopter transport of urban trauma patients. *J Trauma.* 1996;41:886–891.
35. Phillips RT, Conway C, Mullarkey D, Owen JL. One year's trauma mortality experience at Brooke Army Medical Center: is aeromedical transportation of trauma patients necessary? *Mil Med.* 1999;164: 361–365.
36. Rhodes M, Preline R, Aronson J, Rappe A. Field triage for on-scene helicopter transport. *J Trauma.* 1986;26:963–968.
37. Schmidt U, Frame SB, Nerlich ML, et al. On-scene helicopter transport of patients with multiple injuries: comparison of a German and an American System. *J Trauma.* 1992;33:548–555.
38. Snooks HA, Nicholl JP, Brazier JE, Lees-Mlanga S. The costs and benefits of helicopter emergency ambulance service in England and Wales. *J Public Health Med.* 1996;18:67–77.
39. Wills VL, Eno L, Walker C, et al. Use of an ambulance-based helicopter retrieval service. *Aust N Z J Surg.* 2000;70: 506–510.
40. Wong TW, Lau CC. Profile and outcomes of patients transported to an accident and emergency department by helicopter: prospective case series. *Hong Kong Med J.* 2000;6:249–253.
41. Wuerz R, Taylor J, Smith JS. Accuracy of trauma triage in patients transported by helicopter. *Air Med J.* 1996;15:168–170.
42. Younge PA, Coats TJ, Gurney D, Kirk CJC. Interpretation of the Ws statistic: application to an integrated trauma system. *J. Trauma.* 1997;43:511–515.
43. Biewener A, Aschenbrenner U, Rammelt S, Grass R, Zwipp H. Impact of helicopter transport and hospital level on mortality of polytrauma patients. *J Trauma.* 2004;56:94–98.
44. Brazier J, Nicholl J, Snooks H. The cost and effectiveness of the London helicopter emergency medical service. *J Health Serv Res Policy.* 1996;1:232–237.
45. Buntman AJ, Yeomans KA. The effect of air medical transport on survival after trauma in Johannesburg, South Africa. *S Afr Med J.* 2002;92:807–811.
46. Burney RE, Passini L, Hubert D, Maio R. Comparison of aeromedical crew performance by patient severity and outcome. *Ann Emerg Med.* 1992;21:375–378.
47. Cummings G, O'Keefe G. Scene disposition and mode of transport following rural trauma: a prospective cohort study comparing patient costs. *J Emerg Med.* 2000;18:349–354.
48. Cocanour CS, Fischer RP, Ursie CM. Are scene flights for penetrating trauma justified? *J Trauma.* 1997;43:83–86.
49. Diler E, Vernon D, Dean JM, Suruda A. The epidemiology of pediatric air medical transports in Utah. *Prehosp Emerg Care.* 1999;3:217–224.
50. Falcone RE, Herron H, Werman H, Bonta M. Air medical transport of the injured patient: Scene versus referring hospital. *Air Med J.* 1998;17:161–165.
51. Fischer RP, Flynn TC, Miller PW, Duke JH. Urban helicopter response to the scene of injury. *J Trauma.* 1984;24:946–950.
52. Gerhardt RT, Stewart T, DeLorenzi RA, et al. U.S. Army air

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ambulance operations in El Paso, Texas: a descriptive study and system review. *Prehosp Emerg Care.* 2000;4:136–243.
53. Hamman BL, Cué JI, Miller FB, et al. Helicopter transport of trauma victims: does a physician make a difference? *J Trauma.* 1991; 31:490–494.
54. Jacobs LM, Schwartz RJ, Jacobs BB, Gonsalves D, Gabram SGA. A three-year report of the medical helicopter transportation system of Connecticut. *Conn Med.* 1989;53:703–710.
55. Jacobs LM, Gabram SGA, Sztajnkrycer MD, Robinson KJ, Libby MCN. Helicopter air medical transport: ten-year outcomes for trauma patients in a New England program. *Conn Med.* 1999; 63:677–682.
56. Kirk CJ, Earlam RJ, Wilson AW, Watkins ES. Helicopter emergency medical service operating from the Royal London Hospital: the first year. *Br J Surg.* 1993;80:218–221.
57. Kotch SJ, Burgess BE. Helicopter transport of pediatric versus adult trauma patients. *Prehosp Emerg Care.* 2002;6:306–308.
58. Mackenzie CF, Shin B, Fisher R, Cowley RA. Two-year mortality in 760 patients transported by helicopter directly from the road accident scene. *Am Surg.* 1979;45:101–108.
59. Nardi G, Massarutti D, Muzzie R, et al. Impact of emergency medical helicopter service on mortality in north-east Italy: a regional prospective audit. *Eur J Emerg Med.* 1994;1:69–70.
60. Rhee KJ, Baxt WG, Mackenzie JR, et al. Differences in air ambulance patient mix demonstrated by physiologic scoring. *Ann Emerg Med.* 1990;19:552–556.
61. Schiller WR, Knox R, Zinnecker H, et al. Effect of helicopter transport of trauma victims on survival in an urban trauma center. *J Trauma.* 1988;28:1127–1134.
62. Schoettker P, Ravussin P, Moeschler O. Ejection as a key word for the dispatch of a physician staffed helicopter: the Swiss experience. *Resuscitation.* 2001;49:169–173.
63. Schwartz RJ, Jacobs LM, Juda RJ. A comparison of ground paramedics and aeromedical treatment of severe blunt trauma patients. *Conn Med.* 1990;54:660–662.
64. Stohler SA, Schwartz RJ, Sargent RK, Jacobs LM. Quality assurance in the Connecticut helicopter emergency medical service. *J Air Med Transp.* 1991;10:7–11.
65. Thomas SH, Harrison TH, Buras WR, Ahmed W, Cheema F, Wedel SK. Helicopter transport and blunt trauma mortality: a multicenter trial. *J Trauma.* 2002;52:136–145.
66. Tortella BJ, Sambol J, Lavery RF, Cudihy K, Nadzam G. A comparison of pediatric and adult trauma patients transported by helicopter and ground EMS: managed care considerations. *Air Med J.* 1996;15:24–28.
67. Urdaneta LF, Miller BK, Ringenberg BJ, Cram AE, Scott DH. Role of an emergency helicopter transport service in rural trauma. *Arch Surg.* 1987;122:992–996.
68. Nicholl JP, Brazier JE, Snooks HA. Effects of London helicopter emergency services on survival after trauma. *BMJ.* 1995;311:217–222.
69. Committee on Trauma, American College of Surgeons: *Resources for Optimal Care of the Injured Patient.* 1992, American College of Surgeons.
70. Theda Clark Medical Center, ThedaStar. *Air Medical Dispatch for Trauma Scene Responses.* Neena, WI, 2003.
71. Esposito TJ, Offner PJ, Jurkovich GJ, Griffith J, Maier RV. Do prehospital TC triage criteria identify major trauma victims? *Arch Surg.* 1995;130:171–176.
72. Cook CH, Muscarella P, Praba AC, Melvin WS, Martic LC. Reducing overtriage without compromising outcomes in trauma patients. *Arch Surg.* 2001;136:752–756.
73. Black JJM, Ward ME, Lackey DJ. Appropriate use of helicopters to transport trauma patients from incident scene to hospital in the United Kingdom: an algorithm. *Emerg Med J.* 2004;21:355–361.
74. Diaz MA, Hendey GW, Bivens HG. When is Helicopter Faster? A Comparison of Helicopter and Ground Ambulance Transport Times. *J Trauma.* 2005;58:148–153.
75. Nicholl JP, Beeby NR, Brazier JE. A comparison of the costs and performance of an emergency helicopter and land ambulance in a rural area. *Injury.* 119;28:145–153.
76. Kurola J, Wangel M, Uusaro A, Ruoken E. Paramedic helicopter service in rural Finland: do benefits justify the cost? *Acta Anaesthesiol Scand.* 2002;46:779–784.
77. Rosenberg BL, Butz DA, Comstock MC, Taheri PA. Aeromedical service: how does it actually contribute to the mission? *J Trauma.* 2003;54:681–688.
78. Bledsoe BE. Air-medical helicopter accidents in the United States: a five-year review. *Prehosp Emerg Care.* 2003;7:94–98.
79. Bledsoe BE, Smith MG. Medical helicopter accidents in the United States: a ten-year review. *J Trauma.* 2004;56:1325–1329.
80. Levin A. Johnson K. Air Ambulance Crashes Spurs Reviews. *USA Today.* January 14, 2005 [available online at http://www.usatoday.com/news/washington/2005-01-13-medivacs-usat_x.htm]
81. Davis DP, Ochs M, Hoyt DB, Bailey D, Marshall LK, Rosen P. Paramedic-administered neuromuscular blockade improves prehospital intubation in severely head-injured patients. *J Trauma.* 2003;55:713–719.

EDITORIAL COMMENT

The authors of this manuscript are to be commended for addressing an extraordinarily difficult topic: the provision of clinically optimal and responsible emergency transport. It is noteworthy to mention that this analysis reveals, the majority of scene call patients transported by helicopter did not have life-threatening injuries necessitating aeromedical care (ISS $\leq$15). This manuscript provides a summary of the complexities surrounding prehospital triage and an examination of two substantive issues: the validity of the field triage criteria in determining need for aeromedical intervention and the growing use of commercial transport services.

Most trauma physicians are sympathetic to the difficulties inherent in obtaining reliable field information. Current nonanatomic and nonphysiologic field triage criteria are largely based upon indicators such as mechanism of injury, amount of vehicle deformation, initial vehicle speed, and extrication time. There are few or no data supporting the validity of the current criteria in determining need for aeromedical intervention. Empirically based criteria would improve the triage process; further analysis of currently accepted criteria is indicated.

Regions with multiple aeromedical services typically have excess flight capacity. The authors examined the disturbingly common incidence of multiple helicopter services vying for a single patient at a given scene. While market regulation is often unpopular, most would agree that the convergence of competing aeromedical services at a given location is irresponsible for clinical, economic and safety reasons. Likewise, launching an aircraft with little clinical data (often referred to as auto-launch) is excessive, expensive, and a poor use of resources. If allowed to continue, inefficient practices such as these will jeopardize the economic health of the entire EMS system.

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As in any industry, aeromedical service providers must generate an acceptable rate of return to maintain their operation. To maximize efficiency and strengthen the response system, aeromedical coverage should be based upon geographic reach and clinical volume instead of predicted per flight reimbursement. Continued analysis of both clinical demand and the aeromedical triage process will improve industry efficiency and insure long term viability.

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