Retrospective review of injury severity, interventions and outcomes among helicopter and nonhelicopter transport patients at a Level 1 urban trauma centre

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Background: Air ambulance transport for injured patients is vitally important given increasing patient volumes, the limited number of trauma centres and inadequate subspecialty coverage in nontrauma hospitals. Air ambulance services have been shown to improve patient outcomes compared with ground transport in select circumstances. Our primary goal was to compare injuries, interventions and outcomes in patients transported by helicopter versus nonhelicopter transport.

Methods: We performed a retrospective 10-year review of 14 440 patients transported to an urban Level 1 trauma centre by helicopter or by other means. We compared injury severity, interventions and mortality between the groups.

Results: Patients transported by helicopter had higher median injury severity scores (ISS), regardless of penetrating or blunt injury, and were more likely to have Glasgow Coma Scale scores less than 8, require airway control, receive blood transfusions and require admission to the intensive care unit or operating room than patients transported by other means. Helicopter transport was associated with reduced overall mortality (odds ratio 0.41, 95% confidence interval 0.33–0.39). Patients transported by other methods were more likely to die in the emergency department. The mean ISS, regardless of transport method, rose from 12.3 to 15.1 ($p = 0.011$) during our study period.

Conclusion: Patients transported by helicopter to an urban trauma centre were more severely injured, required more interventions and had improved survival than those arriving by other means of transport.

Contexte : Le transport par ambulance aérienne pour les polytraumatisés est d'une importance vitale compte tenu du volume croissant de patients, du nombre limité de centres de traumatologie et des effectifs insuffisants en médecine de spécialité dans les hôpitaux dépourvus d'unités de traumatologie. Les services de transport ambulanciers aériens ont la capacité d'améliorer les résultats chez les patients, comparativement au transport terrestre dans certaines situations. Notre objectif principal était de comparer les traumatismes, les interventions et les résultats chez les patients transportés par hélicoptère ou autrement.

Méthodes : Nous avons procédé à une revue rétrospective sur 10 ans du transport de 14 440 patients vers un centre urbain de traumatologie de niveau 1 par hélicoptère ou autrement. Nous avons comparé la gravité des blessures, les interventions et la mortalité entre les groupes.

Résultats : Les patients transportés par hélicoptère présentaient des indices médians de gravité des blessures plus élevés, indépendamment de la nature ouverte ou fermée des blessures, et ils étaient plus susceptibles de présenter un score inférieur à 8 sur l'échelle de Glasgow, de nécessiter une intubation, de recevoir des transfusions sanguines et d'être admis aux soins intensifs ou au bloc opératoire, comparativement aux patients transportés autrement. Le transport par hélicoptère a été associé à une mortalité globale moins élevée (rapport des cotes 0,41; intervalle de confiance de 95 % 0,33–0,39). Les patients transportés autrement étaient plus susceptibles de mourir à l'urgence. Le score moyen de gravité des blessures, indépendamment du moyen de transport, est passé de 12,3 à 15,1 ($p = 0,011$) durant la période de l'étude.

Conclusion : Les patients transportés par hélicoptère vers un centre de traumatologie urbain étaient plus grièvement blessés, nécessitaient plus d'interventions et leur survie a été meilleure que celle des patients transportés autrement.

Air ambulance transport for injured patients is vitally important given increasing patient volumes, a limited number of trauma centres and inadequate subspecialty coverage in nontrauma hospitals. Despite a paucity of reported objective data, air ambulance services in numerous countries have been shown to improve patient outcomes when compared with ground transport in select circumstances.[1–3] These benefits have not, however, been noted in all studies, and the value of air ambulance transport continues to be debated.

Given the debate regarding the role and potential benefit of prehospital helicopter transport, the objective of this study was to compare injuries, interventions and outcomes in patients transported by helicopter versus nonhelicopter transport. We also reviewed the cost and safety of air transport.

Methods

We reviewed trauma registry data for all patients evaluated by the Emory University Trauma Service at Grady Memorial Hospital, a Level 1 trauma centre in Atlanta, GA, from Jan. 1, 1998, to Apr. 30, 2008. Data collected included injury severity score (ISS), Abbreviated Injury Scale score (AIS), Glasgow Coma Scale (GCS) score at admission, need for airway control, emergency department disposition (e.g., operating room, intensive care unit, or floor), emergency department mortality and overall hospital mortality. We compared patients transported by helicopter (HTPs) with those transported by other means (NHTPs) based on the data collected.

Statistical analysis

We performed statistical analyses using Stata software version 9.0 (Stata Corp.). Normally or near-normally distributed variables are reported as means and non-normally distributed variables are reported as medians with interquartile ranges (IQR). We compared means using the Student *t* test or 1-way analysis of variance, and we compared medians using the Mann–Whitney *U* test for 2 groups or the median test for 2 or more groups. Differences in proportions among categorical data were assessed using the Fisher exact test or the χ^2 test for multiple groups. A multivariable logistic regression model was developed to assess factors associated with mortality. Variables significant at $p < 0.1$ in univariate analyses were included in the initial model. We then performed backward stepwise variable elimination to develop the final model. Unless otherwise specified, we considered results to be significant at $p < 0.05$.

Results

During the study period 14 440 patients who had 14 465 episodes of trauma were transported to Grady Memorial Hospital and evaluated by the Emory University Trauma Service. Patient transport was by ambulance in 79% (11 408 of 14 440) of patients, by helicopter in 17% (2394 of 14 440) and by private vehicle in 3% (434 of 14 440). Mode of prehospital transport was not documented in 1% (204 of 14 440) of the patients.

A number of changes in both mechanism and severity of injury occurred during the study period. The first was a significant increase in the volume of nonpenetrating trauma treated at Grady Memorial Hospital. The percentage of patients with penetrating injury decreased from 38% in

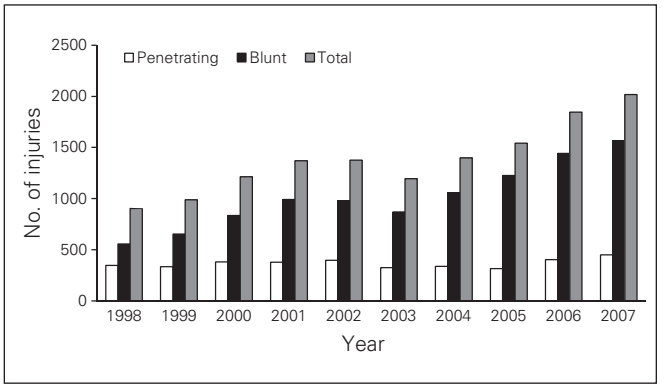

Fig. 1. Blunt and penetrating injury by year.

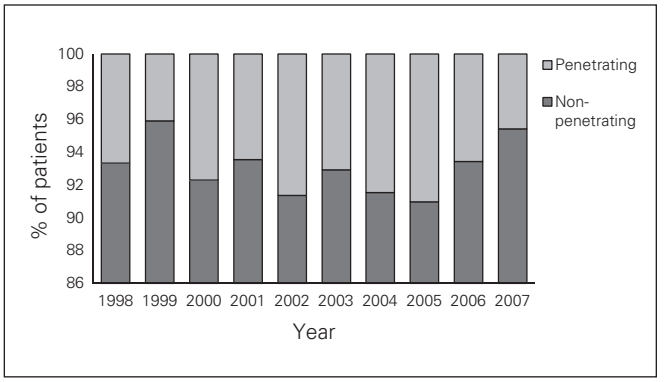

Fig. 2. Mechanism of injury in patients transported by helicopter.

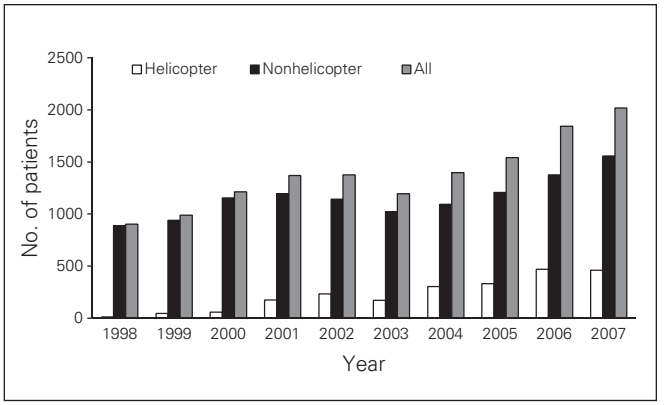

Fig. 3. All patients by method of transportation to hospital.

1998 to 22% in 2007 (Fig. 1). Very few victims of assault (19 of 879; 2.16%), gunshot wounds (152 of 2793; 5.44%) or stab wounds (34 of 1009; 3.37%) were transported by helicopter (Table 1). The percentage of patients with penetrating injuries transported by helicopter was consistently lower than 10% per year (Fig. 2). The second was that the number of patients transported by helicopter steadily increased over time and approached 25% of all arrivals at the end of the study period (Fig. 3). The mean ISS of patients in both groups increased steadily through the study period from 12.24 in 1998 to 15.09 in 2007 ($p = 0.011$ for HTP and $p < 0.001$ for NHTP).

The HTP group had a higher median ISS than the NHTP group (median 17, IQR 9–25 v. median 9, IQR 5–18, $p < 0.001$) and was more likely than the NHTP group to have an ISS above 15 (1281 of 2347 [55%] v. 1842 of 11 549 [16%], $p = 0.001$). In addition, the HTP group was more likely than the NHTP group to have an ISS above 25 (714 of 2347 [30%] v. 1842 of 11 549 [16%], $p < 0.001$); to have a head, face chest, extremity, and soft tissue AIS score of 3 or more; and to have a GCS score less than 8 (Table 2). The differences in both AIS and GCS were significant ($p < 0.001$).

Interventions were significantly more likely to be performed in the HTP than the NHTP group. For example, the HTP group was more likely than the NHTP group to require insertion of a formal airway (826 of 2394 [35%] v. 1929 of 12 071 [16%], $p < 0.001$), to require any transfusion of packed red blood cells (730 of 2251 [32%] v. 2418 of 10 930 [22%], $p < 0.001$) and to receive a transfusion of more than 6 units of packed red blood cells (Table 3). In addition, admission to the operating room (826 of 2394 [35%] v. 3830 of 12 071 [32%], $p = 0.008$) and the intensive care unit (1107 of 2394 [46%] v. 3711 of 12 071 [31%], $p < 0.001$) was more likely in the HTP group than the NHTP group. One patient in the HTP group was discharged from the emergency department during the study period.

Table 1. Mechanism of injury among patients transported by helicopter or other modes of transportation ($p < 0.001$)

	Group; no. (%)	
Mechanism of injury	Nonhelicopter	Helicopter
All-terrain vehicle	52 (48.6)	55 (51.4)
Accident	371 (78.94)	99 (21.06)
Aircraft	0 (0)	6 (100)
Animal	9 (56.25)	7 (43.75)
Assault	859 (97.84)	19 (2.16)
Bicycle	96 (84.21)	18 (15.79)
Electrical	2 (100)	0 (0)
Fall	1253 (86.35)	198 (13.65)
Gunshot wound	2641 (94.56)	152 (5.44)
Hanging	6 (100)	0 (0)
Motor vehicle crash	4070 (74.26)	1411 (25.74)
Machine	20 (52.63)	18 (47.37)
Motorcycle crash	525 (67.48)	253 (32.52)
Not available	13 (92.86)	1 (7.14)
Pedestrian	1121 (90.99)	111 (9.01)
Sports	10 (76.92)	3 (23.08)
Stab wound	975 (96.63)	34 (3.37)
Struck	48 (84.21)	9 (16.79)
Total injuries	12 071 (83.46)	2394 (16.56)

The overall inhospital mortality was 12% (1749 of 14 465) and varied significantly ($p < 0.001$) by mode of transport; mortality was 12% (1345 of 11 408) for patients transported by ground ambulance, 15% (357 of 2394) for patients transported by helicopter and 3% (15 of 459) for those transported by private vehicle. Mortality was 16% (32 of 204) for those whose mode of transport was unknown. Patients in the NHTP group were more likely to die in the emergency department than those in the HTP group (585 of 12 071 [5%] v. 43 of 2394 [2%], $p < 0.001$). In a multivariate logistic regression analysis, the HTP group was associated with reduced hospital mortality (OR 0.41; Table 4). The need for secured airway, an ISS above 15, transfusion of 6 or more units of packed red blood cells and a GCS score less than 8 were associated with increased mortality.

Discussion

According to the Association of Air Medical Services, an estimated 400 000 air ambulance flights occur each year within the United States.[4] The number of helicopters dedicated to emergency medical services doubled from 400 to 800 between 2002 and 2008. In the state of Georgia, there are 19 aircraft located at 16 bases, most of them residing in the northern part of the state.[5] While the debate over outcome differences between patients transported by helicopter versus ground transport has continued for 25 years, the general consensus indicates that severely injured patients transported by air ambulance have better survival.[6–14] Controversy remains, however, regarding the injury severity and necessity of helicopter transport for particular cohorts of patients.[15–21] A study from a single institution in Great Britain of 156 injured patients with a mean ISS of 12 transported by helicopter reported that 45 patients were discharged within 24 hours.[22] This ISS was much lower than the mean ISS for the patients transported by helicopter in the present study and was more comparable to that of the patients transported by ground ambulance. A large meta-analysis of 22 studies with 37 350 patients by Bledsoe and colleagues[23] noted that 60% of patients had an ISS of 15 or less and that 24% were discharged within 24 hours. As a result, 73% of aeromedical transports in the meta-analysis were described as "nonbeneficial." In contrast, 55% of patients transported by helicopters in the present study had an ISS of 15 or more. In addition, the ISS of the HTPs in the study by Bledsoe and colleagues correlates well with the ISS of the NHTP severity in the

present study. This probably represents poor selection of patients for helicopter transport in the reports reviewed in the meta-analysis. Over a 5-year period, 29% of patients evaluated and discharged from the emergency department by the trauma service at the University of Pennsylvania were transported by helicopter.[24] When the University of Texas Medical Branch in Galveston, Texas, discontinued their air ambulance service, they observed no subsequent increase in mortality of injured patients, but they did find a significant decrease in the volume of both total and severely injured patients.[25] A study by Talving and colleagues[3] from the University of Southern California/Los Angeles County Hospital failed to document a survival benefit when comparing HTPs to those transported by ground with transport times longer than 30 minutes. The HTPs in their report had a lower mean ISS and there were fewer patients with an ISS of 15 or more as compared with the present study. Also, penetrating injury occurred in 19% of the HTPs in the study by Talving and colleagues[3] compared with less than 10% among the HTPs in the present study. The differences in mechanism of injury coupled with their mean transport time of 46 minutes may have contributed to the higher mortality among the HTPs in the study by Talving and colleagues.[3] These reports and others continue to demand an improvement in triage to avoid the unnecessary transport of minimally injured patients. Based on injury severity, the scene triage in the present study may have been more accurate than in prior ones.

Safety is an important factor that must be taken into account when discussing the utility of helicopter transport.[26] According to the Federal Aviation Administration, 85 helicopter emergency medical services (HEMS) accidents occurred between 1998 and 2004. Deaths occurred in 27 of those accidencts; the majority (21 deaths) occurred at night.[27] Baker and colleagues[28] analyzed 182 helicopter crashes that occurred between January 1983 and May 2005. Fatal crashes were 33% more common among HEMS providers than in general aviation. Helicopter EMS providers were also found to have a 16-fold increased risk of death on the job than all workers. This exceeded the on-the-job mortality of such well-known dangerous occupations as logging or deep-sea fishing. Darkness, bad weather and postcrash fires were associated with an increased risk of death in HEMS crashes, as expected. There was also an increase in crashes noted from 2000 to 2004.[30] From May 1, 2005, to Mar. 1, 2010, there were 19 HEMS crashes resulting in 25 deaths in the United

Table 2. Injury characteristics associated with mode of transport

Characteristic	Group; no. (%)* Unknown, *n* = 204*	Ambulance, *n* = 11 408*	Helicopter, *n* = 2394*	Private vehicle, *n* = 459*	*p* value
Median ISS (IQR)	10 (5–18)	10 (5–18)	17 (9–25)	9 (4–13)	< 0.001
AIS abdomen ≥ 3	33 (16)	1489 (13)	347 (14)	58 (13)	0.16
AIS chest ≥ 3	53 (26)	2547 (22)	779 (33)	109 (24)	< 0.001
AIS extremity ≥ 3	39 (19)	2385 (21)	745 (31)	49 (11)	< 0.001
AIS face ≥ 3	1 (0 < 1)	125 (1)	50 (2)	3 (1)	< 0.001
AIS head ≥ 3	40 (20)	2751 (24)	933 (39)	66 (14)	< 0.001
AIS soft tissue ≥ 3	2 (1)	24 (< 1)	20 (1)	0	< 0.001
GCS < 8	28 (16), *n* = 180	1362 (12), *n* = 11015	799 (35), *n* = 2300	12 (3), *n* = 450	< 0.001

AIS = Abbreviated Injury Scale; GCS = Glasgow Coma Scale; IQR = interquartile range; ISS = injury severity score.
*Unless otherwise indicated.

Table 3. Interventions based on transport method

Intervention	Group; no. (%) Unknown, *n* = 183*	Ambulance, *n* = 10 335*	Helicopter, *n* = 2251*	Private vehicle, *n* = 412*	*p* value
Airway status					< 0.001
Other	174 (85)	9534 (84)	1568 (66)	434 (95)	—
Intubated	29 (14)	1839 (16)	816 (34)	24 (5)	—
Surgical	1 (< 1)	35 (< 1)	10 (< 1)	1 (< 1)	—
Transfusion					
Any transfusion	62 (34)	2287 (22)	730 (32)	69 (17)	< 0.001
Transfusion ≥ 6 units	23 (13)	883 (9)	274 (12)	19 (5)	< 0.001

*Unless otherwise indicated.

States.[31] These incidents called attention to the safety of air ambulance transport.[32,33] The Federal Aviation Administration issued guidelines for all flights, including the use of terrain warning equipment, as well as formal flight risk and evaluation procedures for all flights. In February 2009, the National Transportation Safety Board held hearings to discuss the safety of patient transport by air ambulance.[34,35]

The cost of air ambulance services has been increasingly noted by the lay media and this is concerning to both third party payers and patients.[36] One helicopter service in Georgia has an initial charge between $11 000 and $12 000 and then adds a per-mile charge of about $100 (Emory Flight Manager: personal communication, 2009). In Arizona, base rates for helicopter transport vary between $7950 and $14 028 with per-mile rates of $75 to $149.50.[37] In contrast, Virginia Medicaid reimburses $586 for base rate and $13.00 per mile.[38] In Indiana, Medicaid reimbursement is $3127 for the base rate with a $21 mileage rate.[39] With geographic adjustments, the base rate paid by Medicare is $2960 with an additional $17.51–$26.27 paid per mile, depending on location.[40] The dramatic difference between charge and reimbursement is often borne by the patients and their families, creating substantial financial hardship. If, as other studies have indicated, 20%–30% of these patients were discharged within 24 hours and 73% of helicopter transports were not indicated, this represents a substantial unnecessary cost.

Limitations

Limitations of this study are primarily its retrospective nature and single-centre experience. Ultimately, a randomized controlled trial with sufficient power would be required to definitively determine if there was a benefit to helicopter transport of injured patients. It would be practically difficult or even impossible to conduct such a trial. It does seem plausible; however, that helicopter transport should have better outcomes. Our study involved a database analysis, and each patient transport case was not individually assessed for potential added benefit. Also, scene flights were not separated from interfacility transport using air ambulance, nor were the individual quality of the services provided by helicopter or ground ambulance assessed.

Table 4. Multivariate analysis

Variable	OR (95% CI)	*p* value
ISS > 15	8.81 (7.05–11.03)	< 0.001
Helicopter transport	0.41 (0.33–0.49)	< 0.001
Secured airway	3.43 (2.78–4.24)	< 0.001
Transfusion 6 units	3.42 (2.53–3.64)	< 0.001
GCS < 8	7.79 (6.25–9.70)	< 0.001
Mechanism		
Other (reference)	1.0	
Fall	1.52 (1.17–1.99)	0.002
Gunshot wound	2.22 (1.84–2.68)	< 0.001

CI = confidence interval; ISS = Injury Severity Score; GCS = Glasgow Coma Scale; OR = odds ratio.

Conclusion

We identified an increasing trend in the overall volume of patients transported by helicopter to an urban Level 1 trauma centre. Furthermore, these patients were more severely injured and displayed improved survival over time compared with patients transported by ground ambulance. While there have been some closures of trauma centres in Georgia, 4 Level 2 trauma centres remain in Fulton County and other counties surrounding Atlanta. Paramedics and first responders, who often make the decisions on destination and method of transport at the scene, may triage many of the more severely injured patients in northwest Georgia to Grady Memorial Hospital, the only Level 1 trauma centre in the region during the study period, while transporting a large proportion of the less severely injured patients to the lower level centres. This could explain the increased injury severity in our cohort compared with the studies cited in our discussion. More geographically isolated trauma centres may have HTP cohorts more in line with those involved in other studies. Also, HEMS in nonurban regions of Georgia is useful for transport over large distances and appears to be useful in the metropolitan Atlanta area to avoid traffic delays in patients transported from the surrounding counties. However, the inappropriate use of helicopter transport described in some of the studies cited, may result in delay in treatment as well. Patients transported from outside Fulton County accounted for most of the HTPs in the present study. The difference in injury severity between transport methods observed in the present study may also not be observed in other (less urban) areas of Georgia. Improved survival among patients transported by helicopter may be attributed to more advanced monitoring and equipment, a greater scope of practice, more available medications, and the presence of a flight nurse and paramedic. While more patients transported by helicopter required admission to the operating room, the differences in head/neck AIS and extremity AIS scores indicate that most of the subsequent interventions were likely to be for neurologic or orthopedic injuries. The improved outcomes in our HTP cohort, despite increased injury severity and more interventions required en route and inhospital, indicate that the benefit of appropriate helicopter transport, even with the associated cost and safety risk, is beneficial to severely injured patients.

Competing interests: None declared.

Contributors: R.S. Hannay, A.D. Wyrzykowski, C.G. Ball and D.V. Feliciano designed the study. R.S. Hannay and C.G. Ball acquired

and analyzed the data. A.D. Wyrzykowski, K. Laupland and D.V. Feliciano also analyzed the data. R.S. Hannay, C.G. Ball and D.V. Feliciano wrote the article, which all authors reviewed and approved for publication.

References

1. McVey J, Petrie DA, Tallon JM. Air versus ground transport of the major trauma patient: a natural experiment. *Prehosp Emerg Care* 2010; 14:45-50.
2. Salimi J, Khaji A, Khashayar P, et al. Helicopter emergency medical system in a region lacking trauma coordination (experience in Tehran). *Emerg Med J* 2009;26:361-4.
3. Talving P, Teixeria PG, Barampas G, et al. Helicopter evacuation of trauma victims in los angeles: Does it improve survival? *World J Surg* 2009;33:2469-76.
4. Association of Air Medical Services. AAMS Fact sheet: AIRMED 101. Available: www.aams.org/AAMS/MediaRoom/FactSheetsand FAQs/Air_Med_101.aspx (accessed 2010 Mar 1).
5. Atlas & Database of Air Medical Services. Georgia [report]. Available: http://www.adamsairmed.org/states/Georgia.pdf (accessed 2010 Mar. 1).
6. Baxt WG, Moody P. The impact of a rotocraft aeromedical emergency care service on trauma mortality. *JAMA* 1983;249:3047-51.
7. Baxt WG, Moody P, Cleveland HC, et al. Hospital-based rotocraft aeromedical emergency care services and trauma mortality: a multicenter study. *Ann Emerg Med* 1985;14:859-64.
8. Urdaneta LF, Miller BK, Ringenberg BJ, et al. Role of an emergency helicopter transport in rural trauma. *Arch Surg* 1987;122:992-6.
9. Mitchell AD, Tallon JM, Sealy B. Air versus ground transport of major trauma patients to a tertiary trauma centre: a province-wide comparison using triss analysis. *Can J Surg* 2007;50:129-33.
10. Boyd CR, Corse KM, Campbell RC. Emergency interhospital transport of the major trauma patient: air versus ground. *J Trauma* 1989; 29:789-94.
11. Fischer RP, Flynn TC, Miller PW, et al. Urban helicopter response to the scene of injury. *J Trauma* 1984;24:946-51.
12. Thomas SH, Cheema F, Wedel SK, et al. Trauma helicopter emergency medical services transport: annotated review of selected outcomes-related literature. *Prehosp Emerg Care* 2002;6:359-71.
13. Thomas SH. Helicopter EMS transport outcomes literature: annotated review of articles published 2004-2006. *Prehosp Emerg Care* 2007;11:477-88.
14. Thomas SH, Harrison TH, Buras WR, et al. Helicopter transport and blunt trauma mortality: a multicenter trial. *J Trauma* 2002;52: 136-45.
15. 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;28:1127-34.
16. Cusack SC, Robertson CE. The value of helicopter transportation for trauma patients. *Injury* 1991;22:54-6.
17. Karanicolas PJ, Bhatia P, Williamson J, et al. The fastest route between two points is not always a straight line: an analysis of air and land transfer of nonpenetrating trauma patients. *J Trauma* 2006; 61:396-403.
18. Shatney CH, Homan SJ, Sherck JP, et al. The utility of helicopter of trauma patients from the injury scene in an urban trauma center. *J Trauma* 2002;53:817-22.
19. Diaz MA, Hendley GW, Bivins HG. When is the helicopter faster? A comparison of helicopter and ground ambulance transport time. *J Trauma* 2005;58:148-53.
20. 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;45:140-6.
21. Cunningham P, Rutledge R, Baker C, et al. A comparison of the association of helicopter and ground ambulance transport with the outcome of injury in patients transported from the scene. *J Trauma* 1997;43:940-6.
22. Melton JTK, Jain S, Kendrick B, et al. Helicopter emergency ambulance service (HEAS) Transfer: an analysis of trauma patient case-mix, injury severity, and outcome. *Ann R Coll Surg Engl* 2007;89:513-6.
23. Bledsoe BE, Wesley AK, Eckstein M, et al. Helicopter scene transport of trauma patients with nonlife-threatening injuries: a meta-analysis. *J Trauma* 2006;60:1257-66.
24. Reilly PM, Schwab CW, Kauder DR, et al. The invisible trauma patient: emergency department discharges. *J Trauma* 2005;58:675-85.
25. Chappell VL, Mileski WJ, Wolf SE, et al. Impact of discontinuing a hospital-based air ambulance service on trauma patient outcomes. *J Trauma* 2002;52:486-91.
26. Fallat ME, Overton JW. Air medical transport safety. *Bull Am Coll Surg* 2007;92:19-23.
27. Federal Aviation Administration. *Helicopter Emergency Medical Services Operations*. Washington (DC): FAA; 2006.
28. Baker SP, Grabowski JG, Dodd RS, et al. EMS helicopter crashes: What influences fatal outcomes? *Ann Emerg Med* 2006;47:351-6.
29. Levin A. Expert: Air ambulance crews among most likely to die. *USA Today* 2009 Feb 4. Available: http://usatoday30.usatoday.com/news /nation/2009-02-03-medchopper_N.htm (accessed 2009 Feb. 3).
30. Bledsoe BE, Smith MG. Medical helicopter accidents in the United States: a 10-year review. *J Trauma* 2004;56:1325-9.
31. National Transportation Safety Board. Aviation Accident Reports. Available: www.ntsb.gov/investigations/reports_aviation.html (accessed 2010 Mar. 10).
32. Levin A. Air ambulance crashes trigger FAA's "full attention". *USA Today* 2008 Jun 10. Available: http://usatoday30.usatoday.com/news /nation/2008-06-09-air-med_N.htm (accessed 2010 Mar. 22).
33. Meier B. Crashes start debate on safety of sky ambulances. *The New York Times* 2005 Feb 28. Available: www.nytimes.com/2005/02/28 /national/28copter.html?_r=0 (accessed 2010 Mar. 11).
34. National Transportation Safety Board. *Special Investigation Report on Emergency Medical Services Operations*. Washington : The Board; 2006.
35. National Transportation Safety Board. *Safety Recommendation: February 7, 2006*. Washington: The Board; 2006.
36. Aleccia J. Air ambulances leave some with sky-high bills. 2009 Dec 17. Available: www.msnbc.msn.com/id/34419018 (accessed 2010 Mar. 10).
37. Arizona Department of Health Services, Bureau of Emergency Medical Systems and Trauma. Arizona Air Ambulance Rate Schedule [report]. Pheonix (AZ): ADHS; 2010.
38. Virgina Department of Medical Assistance Services: Emergency Air Ambulance Rates [report]. Richmond (VA): VDMAS, Division of Health Care Services.
39. Indiana Medicaid. Provider Bulletin: Rotary Air Ambulance Transportation Policy and Billing Guidelines [report]. Indianapolis (IN): Indiana Medicaid; 2009 Nov. Bulletin no.: BT200935.
40. 42 CFR Parts 410 and 414 Medicare Program: Medicare Program; Fee Schedule for Payment of Ambulance Services and Revisions to the Physician Certification Requirements for Coverage of Non-emergency Ambulance Services; Final Rule. *Federal Register*. 67:39, February 2002.