Lives saved by Helicopter Emergency Medical Services

An Overview of Literature

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Abstract

Objective The objective of this review is to give an overview of literature on the survival benefits of Helicopter Emergency Medical Services (HEMS). The included studies were assessed by study design and statistical methodology.

Methods A literature search was performed in the National Library of Medicine's Medline database, extending from 1985 until April 2007. Manuscripts had to be written in English and describe effects of HEMS on survival expressed in number of lives saved. Moreover, analysis had to be performed using adequate adjustment for differences in case-mix.

Results Sixteen publications met the inclusion criteria. All indicated that HEMS assistance contributed to increased survival: Between 1.1 and 12.1 additional survivors were recorded for every 100 HEMS uses. A combination of the four reliable studies shows overall mortality reduction of 2.7 additional lives saved per 100 HEMS deployments.

Conclusion Literature shows a clear positive effect on survival associated with HEMS assistance. Efforts should be made to promote consistent methodology, including uniform outcome parameters, in order to provide sufficient scientific evidence to conclude the ongoing debate about the beneficial effects of HEMS.

Introduction

Worldwide, Helicopter Emergency Medical Services (HEMS) provide prehospital care for severely injured patients in order to improve outcome and increase chances of survival. The effectiveness of HEMS in general is often debated, and results from existing studies are mixed[1-3]. Since HEMS is a limited and expensive resource with safety risks involved, it is important to quantify any HEMS-associated value, in order to facilitate cost-benefit analysis. Therefore, an objectifiable outcome parameter should be defined. Descriptions of HEMS' impact on "chance of survival" (*e.g.* "20% mortality reduction") have some utility but are somewhat abstract and difficult to apply elsewhere. Survival is the most substantial, the most transferable and least ambiguous variable used to express outcome in HEMS studies. Because of case mix and acuity differences between air and ground-transported trauma patients, multivariate techniques (usually logistic regression models) should be used to evaluate the impact of HEMS on survival.

The objective of this review was to summarize literature on the survival effects of Helicopter Emergency Medical Services. Furthermore, the included studies were assessed by study design and methodology.

Methods

A computerized literature search was performed in the National Library of Medicine's Medline database, extending from 1985 until April 2007.

The following search terms were used in all possible combinations: Helicopter Emergency Medical Services (HEMS), Emergency Medical Services (EMS), Trauma Injury Severity Score (TRISS), Survival, Trauma Helicopter, Air Ambulances and Outcome.

To be included in our review, studies must have evaluated the effect on survival by HEMS, calculated with a model (*e.g.* TRISS) that included calculation of a "predicted mortality."[4] Only manuscripts written in English and published in peer-reviewed, indexed journals were considered eligible. While this approach may have excluded some worthy studies, the use of indexed journals constituted a well-defined, objective threshold for study inclusion that was tied to scientific quality. In addition, all references in the eligible papers and background papers were checked to ensure no papers had been missed with the search terms chosen.

The quality of the studies we analyzed was rated by two observers (AR and EvL) for their level of evidence as described by Mahid and Sackett [5, 6]. A systematic review of randomized controlled trials (RCTs) with or without meta-analysis was considered level I, single RCTs were level II, cohort studies level III, case-control studies level IV, case series level V, case reports level VI and opinion papers as level VII.

The included manuscripts were then judged by study design and statistical methodology. Multivariate analysis should be used to calculate expected survival, in order to correct for possible confounding variables. The TRISS (logistic regression-based) method is usually the multivariate approach of choice [7]. The coefficients used in the TRISS model are derived from the Major Trauma Outcome Study (MTOS). Many studies did not have a patient population similar to the MTOS population, so to ensure an equivalent case mix between the MTOS and a study population a M-statistic should be calculated. Although M does not follow a specific distribution, it is generally considered acceptable to apply uncorrected TRISS when M is 0.88

or higher. In such case, a W-statistic should be calculated to estimate the number of lives saved for every 100 HEMS cases (Table 1). If M is smaller than 0.88 a standardized (adjusted) W, denoted "Ws", should be calculated in order to correct for case-mix.[8, 9] Ultimately, a Z statistic can be calculated to evaluate whether the difference between the observed and predicted mortality is statistically significant (Table 1). For an optimal measurement of HEMS' mortality effects, ground EMS-assisted patient outcome should be used as the control group. A meta-analysis was not performed since the primary data of all studies included could not be obtained.

Results

Sixteen publications met the criteria for inclusion in this review (Table 2). In these manuscripts survival by HEMS was described and calculated using logistic regression analysis. One of these studies was a level II (randomized trial) study [10], the other fifteen were level III (cohort study) studies [9, 11-24].

The level II study of Baxt et al [10] randomized between a 'physician/ flight nurse'-staffed HEMS and a 'paramedic/ flight nurse'-staffed HEMS. They did not randomize between HEMS or no HEMS (*i.e.* ground EMS control group). The study results showed that the 'physician/flight nurse'-staffed HEMS group (n=316) achieved outcomes better than predicted by the TRISS methodology (1.9 additional lives saved per 100 dispatches, Z 2.28, $p<0.05$). The 'paramedic/ flight nurse'-staffed group performed slightly better than predicted by TRISS, although the difference did not reach significance. Fifteen of manuscripts retrieved consisted of level III (cohort) studies (Table 2). The majority of these manuscripts were performed in the USA, with a sample size ranging from 77 up to 1460. Only 5 studies used a ground EMS control group ranging from 110 up to 2896 patients. Four of these 5 studies used the TRISS methodology but did not describe M-statistics[12, 20-22]. The fifth study by Oppe et al. used another logistic regression method (CANALS analysis) and showed the appropriateness of the regression model[16].

All 16 papers found that HEMS assistance resulted in mortality reduction. The extent of mortality reduction by HEMS ranged from 1.1 to 12.1 additional lives saved per 100 dispatches. The mean of the 16 papers' W estimates was 4.0 lives saved for every 100 uses.

Of all 16 publications only six studies included all of the components we defined *a priori* as constituting "adequate" statistical methodology. Five studies used the TRISS method with appropriate calculation of M, W (or Ws), and Z-statistics [9, 15, 18, 19, 23]. The other study used a custom fitted regression method [16].

Only one study, by Oppe in 2001[16], incorporated all elements of statistical methodology defined as adequate, and also utilized a ground EMS control group.

Discussion

This study provides an overview of literature on the mortality reduction by Helicopter Emergency Medical Services. All papers that met the inclusion criteria showed mortality reduction by HEMS, varying between 1.1 and 12.1 additional lives saved per 100 uses. Differences in study design (e.g. inclusion criteria, manner of obtaining data) and statistical analysis may have contributed to the considerable variance in results. Besides geographical distinctions (e.g. urban versus rural) and the organization of trauma systems (e.g. autolaunch versus secondary dispatches), the differences in composition of the population (e.g. ratio of blunt versus penetrating trauma) also influence survival. Also, the differences in the composition of the HEMS crew may be of significant influence on outcome. If a physician is a part of a HEMS team, the scope of diagnostic and therapeutic options and experience at the scene of an accident will usually be more extensive. In a randomized study Baxt et al. [10] demonstrated the beneficial effect of a physician-staffed, as compared to non physician-staffed, HEMS.

Appropriate adjustment for case-mix is important in HEMS outcome studies, in order to make groups comparable. Use of statistical methods such as logistic regression models may enable valid conclusions for clinical strategies. If an existing regression model is used, TRISS is still the method of choice [7]. The TRISS coefficients are based on the MTOS population.

This review found that only a few studies described M-statistics. M-statistics is useful to describe (injury severity) case-mix variety. It is difficult finding studies that are comparable with the MTOS population. Without using the M-statistic comparisons with MTOS would be inaccurate and of questionable usefulness. Especially in non-USA countries M-statistics should be described. Literature demonstrates that M-statistics are significantly lower (e.g. different distribution of injury severity) in non-USA countries than the accepted threshold for the uncorrected use of TRISS [25]. If the study groups are not comparable with the MTOS population from which the TRISS coefficients are derived, Ws-statistics should be calculated [8, 9].

Another alternative to using the TRISS method would be a custom fitted regression model with own coefficients or modification of TRISS coefficients based on a local dataset. This alternative would probably give the most reliable information [25].

In most of the reviewed studies the MTOS population has been used as the control group. By not using a ground EMS control group, these studies only demonstrate that their HEMS population survived better than the MTOS population, as predicted by TRISS. Using the MTOS population as control group risks confounding (*e.g.* by level of trauma center care) and does not reflect upon the specific effects of HEMS. If a proper ground EMS control group is used, and all patients are treated at the same trauma centre, the confounding effects based on selection bias and the quality of the in-hospital care are removed.

The study of Oppe et al.[16] was performed according to the most rigorous methodological practice, and may therefore give the most reliable view on the effect of HEMS on survival. Though the three studies from the USA that incorporated a ground EMS control group did not describe M-statistics, they may also give an adequate reflection of reality [12, 20, 22]. Since the MTOS data are drawn from a U.S. population, the injury severity distributions of these three studies are likely to be comparable with the MTOS population[25]. If the data of these 4 most methodologically rigorous HEMS outcomes manuscripts are considered, there is an average mortality reduction of 2.7 additional lives saved per 100 HEMS interventions.

In the Netherlands, HEMS provide prehospital care in addition to ambulance services. The HEMS crew, consisting of a physician, a nurse and a pilot, provides Basic Life Support, Advanced Trauma Life Support (ATLS) [26], and an expansion of diagnostic, (invasive) therapeutic, and logistics options at the accident scene [27].

Due to topographical and logistical reasons only 5-20% of the HEMS-assisted patients are transported by helicopter in the Netherlands. During transport to the hospital by ambulance the HEMS physician still assists the patient. Frankema et al [28] showed that the Dutch HEMS improves chances of survival, especially for severely injured blunt force trauma patients.

For example the effects of HEMS in the South West Netherlands were calculated as a supplementary analysis, performed on a previously documented patient cohort [28]. We analyzed a total of 346 poly-trauma patients (ISS >15), presented to a Level 1 trauma center's emergency department. Ground EMS personnel treated 239 of these patients; the remaining 107 patients received additional HEMS assistance. A custom fitted regression model, as described previously [28], was used to compensate for possible confounding variables. A predicted mortality was calculated and compared to the observed mortality for both groups.

The custom fitted regression model was found to be sufficiently calibrated (Hosmer Lemeshow =11.8: p=0.16) and of good discriminative value (area under the ROC curve: 0.911). Analysis ofthe HEMS-assisted trauma population in South West Netherlands showed that 8.4 lives were saved for each 100 instances of HEMS assistance. The main weakness of this study is the potential for overestimation of HEMS effect due to the fact that patients with ISS <16 were not included in the dataset used for our calculations. [28] In fact, over the study period in South West Netherlands, the total proportion of HEMS dispatches for patients who are later calculated to have ISS >16 is only 12%. If a similar rate of low-ISS patients would be added to the dataset used for the current study, the impact on survival estimates decreases to 1.0 life saved for every 100 dispatches.

Only studies that included "predicted mortality", calculated with a logistic regression model, were included in this review. This causes that valuable studies using Odds Ratios as outcome measure were excluded from this review [29-37]. The results of these studies were ambiguous. Two cohort studies of which one had a study population of 16.999 patients [31, 37] and three expert panel studies [32, 33, 36] described positive effects of HEMS on outcome. Furthermore there was an American study that could not demonstrate any positive effects of HEMS though the included population had a very low average Injury Severity Score [38] suggesting overtriage [29]. Three English studies also failed to demonstrate an added value of HEMS assistance [30, 34, 35]. Major comment on these studies was that patients were transported to 20 different hospitals and not to a single level one trauma centre. Younge et al [9] demonstrated that if these patients were transported to a level one trauma centre, HEMS assistance would save 4.2 additional lives per 100 uses.

Furthermore it should be noted that some of the studies described in this review might not be ideally applicable today, since these studies were performed more then 15 years ago. More studies are needed to assess the present state of prehospital Helicopter Emergency Medical

Services.

To render HEMS studies internationally comparable in the future, there should be uniformity in statistics. Uniformity can be achieved by correcting for differences in injury severity (case-mix). Correcting for these differences can be performed by using Ws-statistics [8, 9]. Since the Ws approach corrects for differences in distributions of probability of survival, Ws-results would be very useful as an additional standard outcome parameter for HEMS studies.

Conclusion

Sixteen studies, with varying methodological rigour, have assessed the effects of HEMS on trauma survival and reported estimates of lives saved per 100 missions. Evaluation of the four most statistically rigorous studies reveals an average estimated mortality reduction of 2.7 additional (*i.e.* over ground EMS) lives saved per 100 HEMS patient interactions. Overall the literature provides mixed conclusions on the effect of HEMS. However as this paper shows, when rigorous statistical methodology is applied to the literature, those studies that remain show a clear positive effect. Efforts should be made to use uniform statistics and comparable outcome parameters in order to provide sufficient scientific evidence to conclude the ongoing debate about the beneficial effects of HEMS, and acknowledge HEMS as a valuable addition to the EMS systems in the treatment of the severely injured trauma patients. HEMS have a considerable impact on the survival of the more severely injured patient, but does not demonstrate significant effects on the less injured. These findings stress the importance of dispatch triage criteria for prehospital providers that accurately differentiate the more severely injured from the less injured.

References

1. Thomas SH. Helicopter emergency medical services transport outcomes literature: annotated review of articles published 2000-2003. Prehosp Emerg Care 2004;8(3): 322-333.
2. Thomas SH. Helicopter EMS transport outcomes literature: annotated review of articles published 2004-2006. Prehosp Emerg Care 2007;11(4): 477-488.
3. Thomas SH, Cheema F, Wedel SK, Thomson D. Trauma helicopter emergency medical services transport: annotated review of selected outcomes-related literature. Prehosp Emerg Care 2002;6(3): 359-371.
4. Boyd CR, Tolson MA, Copes WS. Evaluating trauma care: the TRISS method. Trauma Score and the Injury Severity Score. J Trauma 1987;27(4): 370-378.
5. Mahid SS, Hornung CA, Minor KS, Turina M, Galandiuk S. Systematic reviews and meta-analysis for the surgeon scientist. Br J Surg 2006;93(11): 1315-1324.
6. Sackett DL, Rosenberg WM, Gray JA, Haynes RB, Richardson WS. Evidence based medicine: what it is and what it isn't. Bmj 1996;312(7023): 71-72.
7. Glance LG, Osler TM, Dick AW. Evaluating trauma center quality: does the choice of the severity-adjustment model make a difference? J Trauma 2005;58(6): 1265-1271.
8. Hollis S, Yates DW, Woodford M, Foster P. Standardized comparison of performance indicators in trauma: a new approach to case-mix variation. J Trauma 1995;38(5): 763-766.
9. Younge PA, Coats TJ, Gurney D, Kirk CJ. Interpretation of the Ws statistic: application to an integrated trauma system. J Trauma 1997;43(3): 511-515.
10. Baxt WG, Moody P. The impact of a physician as part of the aeromedical prehospital team in patients with blunt trauma. Jama 1987;257(23): 3246-3250.
11. Baxt WG, Moody P, Cleveland HC, Fischer RP, Kyes FN, Leicht MJ, Rouch F, Wiest P. Hospital-based rotorcraft aeromedical emergency care services and trauma mortality: a multicenter study. Ann Emerg Med 1985;14(9): 859-864.
12. Boyd CR, Corse KM, Campbell RC. Emergency interhospital transport of the major trauma patient: air versus ground. J Trauma 1989;29(6): 789-793; discussion 793-784.
13. Cameron PA, Flett K, Kaan E, Atkin C, Dziukas L. Helicopter retrieval of primary trauma patients by a paramedic helicopter service. Aust N Z J Surg 1993;63(10): 790-797.
14. Gearhart PA, Wuerz R, Localio AR. Cost-effectiveness analysis of helicopter EMS for trauma patients. Ann Emerg Med 1997;30(4): 500-506.
15. Hamman BL, Cue JI, Miller FB, O'Brien DA, House T, Polk HC, Jr., Richardson JD. Helicopter transport of trauma victims: does a physician make a difference? J Trauma 1991;31(4): 490-494.
16. Oppe S, De Charro FT. The effect of medical care by a helicopter trauma team on the probability of survival and the quality of life of hospitalised victims. Accid Anal Prev 2001;33(1): 129-138.
17. Rhodes M, Perline R, Aronson J, Rappe A. Field triage for on-scene helicopter transport. J Trauma 1986;26(11): 963-969.
18. Schmidt U, Frame SB, Nerlich ML, Rowe DW, Enderson BL, Maull KI, Tscherne H. On-scene helicopter transport of patients with multiple injuries--comparison of a German and an American system. J Trauma 1992;33(4): 548-553; discussion 553-545.
19. Bartolacci RA, Munford BJ, Lee A, McDougall PA. Air medical scene response to blunt trauma: effect on early survival. Med J Aust 1998;169(11-12): 612-616.
20. Schwartz RJ, Jacobs LM, Yaezel D. Impact of pre-trauma center care on length of stay and hospital charges. J Trauma 1989;29(12): 1611-1615.

21. 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(2): 129-133.
22. Moront ML, Gotschall CS, Eichelberger MR. Helicopter transport of injured children: system effectiveness and triage criteria. J Pediatr Surg 1996;31(8): 1183-1186; discussion 1187-1188.
23. Larson JT, Dietrich AM, Abdessalam SF, Werman HA. Effective use of the air ambulance for pediatric trauma. J Trauma 2004;56(1): 89-93.
24. Campbell RC, Corse KM, Boyd CR. Impact of interhospital air transport on mortality in a rural trauma system [abstract]. Ann Emerg Med 1989;18: 474.
25. Joosse P, Goslings JC, Luitse JS, Ponsen KJ. M-study; arguments for regional trauma databases. J Trauma 2005;58(6): 1272-1276; discussion 1277.
26. Advanced Trauma Life Support ® for student course manual. The American College of Surgeons, 2004.
27. De Charro FT, Oppe S. Het effect van de inzet van helikopter- trauma team bij ongevallen: Leidschendam, 1998.
28. Frankema SP, Ringburg AN, Steyerberg EW, Edwards MJ, Schipper IB, van Vugt AB. Beneficial effect of helicopter emergency medical services on survival of severely injured patients. Br J Surg 2004;91(11): 1520-1526.
29. Brathwaite CE, Rosko M, McDowell R, Gallagher J, Proenca J, Spott MA. A critical analysis of on-scene helicopter transport on survival in a statewide trauma system. J Trauma 1998;45(1): 140-144; discussion 144-146.
30. Brazier J, Nicholl J, Snooks H. The cost and effectiveness of the London Helicopter Emergency Medical Service. J Health Serv Res Policy 1996;1(4): 232-237.
31. Cunningham P, Rutledge R, Baker CC, Clancy TV. 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(6): 940-946.
32. Kurola J, Wangel M, Uusaro A, Ruokonen E. Paramedic helicopter emergency service in rural Finland - do benefits justify the cost? Acta Anaesthesiol Scand 2002;46(7): 779-784.
33. Lossius HM, Soreide E, Hotvedt R, Hapnes SA, Eielsen OV, Forde OH, Steen PA. Prehospital advanced life support provided by specially trained physicians: is there a benefit in terms of life years gained? Acta Anaesthesiol Scand 2002;46(7): 771-778.
34. Nicholl JP, Brazier JE, Snooks HA. Effects of London helicopter emergency medical service on survival after trauma. Bmj 1995;311(6999): 217-222.
35. Snooks HA, Nicholl JP, Brazier JE, Lees-Mlanga S. The costs and benefits of helicopter emergency ambulance services in England and Wales. J Public Health Med 1996;18(1): 67-77.
36. Wills VL, Eno L, Walker C, Gani JS. Use of an ambulance-based helicopter retrieval service. Aust N Z J Surg 2000;70(7): 506-510.
37. 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(1): 136-145.
38. Baker SP, O'Neill B, Haddon W, Jr., Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma 1974;14(3): 187-196.

Table 1. Formula of W- and Z-statistic

W - statistic	(Number of observed deaths – Number of predicted deaths/ N) x 100
Z - statistic	$\dfrac{\text{Number of observed deaths} - \text{Number of predicted deaths}}{\sqrt{\sum (Ps\,(1 - Ps))}}$

N, total number of dispatches; Ps, probability of survival of an Individual.
When Z-statistic > 1.96, then the survival rate in the HEMS assisted group is superior to the reference database.
A Z-statistic < -1.96 implies a worse overall performance.

Table 2. Overview of manuscripts describing mortality reduction by HEMS, sorted by year

Author (year)	Country	Type of Care	Sample size	Control group	Described Statistics	Observed mortality	Expected mortality	Mortality reduction per 100 assistances (calculated W-statistic)	Level of evidence
Baxt (1985) [11§]	USA	Ph / N	1273	MTOS	Z	191	240.7	3.9	III
Rhodes (1986) [17]	USA	Ph	130	MTOS	Z	22	28.6	5.1	III
Baxt (1987)[10§]	USA	Ph / N	574	MTOS	Z	30	36.4	1.1	II
Campbell (1989) [24†]	USA		168	MTOS	Z	31	50.0	11.3	III
Boyd (1989)[12†]	USA	P/N	103	110	Z	33	45.5	12.1	III
Schwartz (1989)[20]	USA		168	709	Z	25	36.7	7.0	III
Hamman (1991)[15]	USA	Ph	259	MTOS	M/W/Z	20	32.0	4.6	III
Schmidt (1992)[18§]	Germany / USA	Ph	407	MTOS	M/W/Z	42	57.0	3.7	III
Cameron (1993)[13]	Australia	P	242	MTOS	Zns	34	41.8	3.2	III
Moront (1996)[22#]	USA	P/N	1460	2896	W/Z	77	93	1.1	III
Gearhart (1997)[14]	USA	P/N	604	MTOS	W/Z	50	90.3	6.7	III
Younge (1997)[9]	UK	Ph	632	MTOS UK	M/W/Ws/Z	161	168.6	1.2	III
Bartolacci (1998)[19]*	Australia	Ph	77	MTOS	M/W/Ws/Z	9	18.0	11.7	III
Oppe (2001)[16]*	Netherlands	Ph	210	307	CANALS	132	143.7	5.1	III
Larson (2004)[23]	USA		1087	MTOS	M/W/Z	59	111.4	4.8	III
Mitchell (2007)[21]	Canada	P/N	225	545	W/Z	40	53.6	6.4	III
Total			7619			956	1247.3	3.8	

N, nurse; P, paramedic; Ph, Physician; †, interfacility transport; §, report two separate cohort, combined in this table *, most methodologically rigorous analysis; CANALS, CANALS-analysis with appropriate statistics; #, pediatric patients; M, M-statistics described; W, W-statistics described; Ws, Ws-statistics described; Z, Z-statistics described; Zns, Z-statistics not significant. Ws-statistics were calculated if M statistics was below 0.8