Air medical service: a review on its cost-effectiveness, the role of in-flight physician and safety

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A literature review of recent articles on helicopter aeromedical services (HEMS) was carried out.The methods used included a Medline search using the key words 'air ambulance' and 'helicopter EMS'. Other sources of information were also obtained from internet web-sites such as www.aams.org, www.info.gov.hk/gfs/performctx.htm and eMedicine.com free online textbook.The results show that HEMS is cost-effective with a good safety record, and it is also evident that in-flight physicians are particularly useful in improving the survival of severely injured patients. Strict criteria to select patients for HEMS operations must be publicised and followed by both callers and the HEMS dispatcher. (*Hong Kong j.emerg.med.* 2001;8:27-33)

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Introduction

The first hospital-based helicopter medical service in the USA was established in Denver in 1972, while similar systems had been in place in Germany since the 1960s.[1] The Denver scheme which was built on military-based experience after war data highlighted the importance of early rapid access to trauma patient, with subsequent lowering of mortality. Some of the figures showing the relationship of mortality and the time to definitive care in the wars are shown below:

Wars	Time from injury to definitive care	Mortality
World war II	6 to 12 hours	5.8%
Korea war	2 to 4 hours	2.4%
Vietnam war	65 min	<1%

Today, air medical services exist in different forms: Hospital-based services, Private services, Public agency services or combination of these. The transportation may consist of rotary-wing aircraft or fixed-wing aircraft. In future, services may be able to use tilt-rotor, vertical, fixed-wing aircraft to combine the advantages of helicopter and fixed-wing aircraft.

The number of engines categorises helicopters. Early air transport programs typically utilised single-engined helicopters, but in the past decade, twin-engined helicopters have largely replaced these relatively small, light, and economical aircraft. While generally more expensive to purchase and operate, twin-engined helicopters have the advantages of providing larger carrying capacity, larger cabin spaces with improved patient access, potential for 2-patient transport, faster transport speed and improved safety. In addition, "Hot-loading" while the rotor blades are turning is more easily accomplished with the rear clamshell doors or side-loading schemes available in larger helicopters.[2] The usual operating range is of the order of 100 to 500 km.

Fixed-wing aircraft generally provide an increased range (greater than 500 km), greater speed, and increased patient, crew and equipment capacity than helicopters. Helicopters cannot tolerate ice on the rotors, and are less tolerant of bad weather, whereas fixed-wing aircraft may have de-icing equipment over the engine and are capable of flying in poorer

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conditions. However, airports or broad expanses of water or snow (for those aircraft featuring skis or floats) are required. Transport time must take into account the ground transfer of members and patient to and from the base airport and at the destination.

HEMS personnel include a pilot, with or without co-pilot, flight nurse, and a paramedic and/or physician. The optimal crew configuration for any aeromedical system must reflect the mission of the program, the acuity of its patients, the type of work performed, and the capabilities of both the aircraft and flight personnel.

Physicians are routinely present in only a minority of programmes in USA. The use of physicians as flight members may be indicated in special circumstances, for instance when field amputation may be required. Flight nurses should have extensive experience in intensive care or emergency departments. The effectiveness of flight nurses in the pre-hospital setting is also markedly enhanced if they are also certified as Emergency Medical Technicians or as Paramedics.

Pilots must be skilled in Visual Flight Rules (VFR) and Instrument Flight Rules (IFR), navigational techniques, aviation communications and have a working knowledge of the geographical area in which flight operations are to be conducted. The pilot must make operational assessments of weather conditions and the capabilities of the aircraft, and should not be placed under pressure by being told of the condition or acuity of the patient. The pilot should only be asked: "We have a flight to a certain location; may we go?". The addition of a second pilot or the use of infrared visual aids may help to ensure the safety of poor weather and night operations.

Providing for the safety of member crew includes instruction for all members in aviation physiology, the recognition and treatment of in-flight medical emergencies, and the effects of spatial or visual disorientation. Highlights of this instruction include the use of Valsalva manoeuvre to pressure effects on the ear and facial sinuses, and prohibitions on diving 24 hours before involvement in flight operations. Landing zones are inherently dangerous places, and Pre-hospital care providers may approach the aircraft only at the direction of the flight crew and never by the rear, as the tail-rotor is extremely dangerous. A sudden gush of wind can dip the rotor blade down to 4 feet height. The helicopter should always be approached in a crouch and from the downhill side when a helicopter is parked on a hillside.

From 1972 to 1985, the accident rate in USA aeromedical services was 12 per 100,000 flight hours. In 1986 this rate jumped to 20 per 100,000 hours. 70% of these accidents were felt to be a result of pilot error, and 80% occurred in marginal weather or at night. A renewed emphasis on safety, including avoidance of crew fatigue and the strict enforcement of weather minimums, brought the accident rate down to 5.7 per 100,000 hours in 1987.

The ultimate solution for a smooth operation lies in the prevention of any foreseeable adverse events that may be encountered by the pilot, the physician or other members. Prevention can be best accomplished by a vigorous educational effort directed towards family physicians, other primary care providers, the travel community and the general public concerning the medical contraindications to flight, and the resources available to maximise the chances of safe transport for the passenger who is physically impaired.

Cost-effectiveness

Time and distance factors play a key role in electing to send the helicopter. Effectiveness can be studied by considering the time to first Emergency Medical Service (EMS) arrival, the rate of mortality, and the length of Intensive Care Unit (ICU) stay by comparison with ground EMS. Variables include urban and rural area, injury severity pattern, crew composition and technical procedures.

In a study of 792 trauma patients during the financial year from October 1, 1995 to September 30, 1996 by Phillips et al. 1999,[3] HEMS (105 patients) was associated with higher levels of pre-hospital medical care and faster transportation than ground EMS (687 patients). However the Z test for independent populations demonstrated no statistically significant difference in mortality between the two groups compared with national trauma mortality rates.

In a study by Nardi et al. 1994,[4] 222 severe trauma patients (within 7 months period) with Injury Severity Score (ISS) >15 were included in north-east Italy and divided into 3 groups:

Group A: 82 patients, rescued by EMTs with Basic Life Support (BLS) training, transported to the nearest level 1 hospital for stabilization and subsequently transferred to a trauma centre.

Group B: 98 patients, rescued by EMTs and directly transported to a trauma centre, which was the nearest institution.

Group C: 42 patients, rescued by HEMS, including an anaesthesiologist on board and transported to a trauma centre after full on-the-field stabilisation.

	Mean ISS	Mortality-(%)	Time from 1st call to trauma centre	ICU stay
Group A	35.1±18.2	31-(38%)	162 min (Range 90 to 300 min)	15 days
Group B	33.4±19.6	31-(32%)	27 min	13 days
Group C	36.0±17.8	5-(12%)	55 min	11 days

The mortality rate in Group C was significantly lower than in Group A ($p<0.005$) and Group B ($p<0.05$). None of the 42 patients died before arrival at the trauma centre. Stabilisation included endotracheal intubation in 34 patients (81%) and thoracic drainage in 6 patients (14%). 13 patients with hypotension received an average of 1000 mls colloid and 1200 mls crystalloid via 2 intravenous lines.

In a study by Schwartz et al. in 1990,[5] 126 patients with severe blunt trauma were studied by TRISS methodology:

	No. of patients	Probability of survival vs national norm	Intubated	Use of PASG
HEMS	93 (74%)	2.23 SD better vs norm	42%	56%
Ground EMS	33 (26%)	-2.69 SD below norm	3%	30%

There was no significant difference in the pre-hospital times of either group once help arrived at the scene. Since the scene time of both services was similar, the improved survival in the HEMS group may be due to the technical interventions performed.

In a study by Boyd et al. in 1989,[6] 213 patients from a rural emergency department were transferred to a trauma centre ground or helicopter transport, and the data compared using the TRISS methodology.

	Patients N =	Mean TS	Mean ISS	Mean Ps	Actual death/ Predicted death
HEMS	103	11.4	34.9	0.587	33 vs 46
Ground EMS	110	14.4	25.2	0.867	15 vs 15

In the HEMS group, there was a 25.4% reduction in predicted mortality which was significant ($Z=3.95$; $p<0.001$). The benefit seen with HEMS was directly related to injury severity and was demonstrated only in the patients with a Ps of less than 0.90.

In 1983 Baxt and Moody[7] studied 150 patients who were attended by a HEMS staffed by a physician and nurse, comparing them with 150 patients attended by ground EMS staff. There was a 52% reduction in predicted mortality in the HEMS group that was highly significant.

In a study by Cunningham et al. in 1997,[8] a total of 18,490 patients were enrolled from 1987 to 1993 on admission to one of the eight state-designated trauma centres in North Carolina. Study patients included only those who were transported directly from the scene of injury to the trauma centre, and excluded interhospital transfers.

	No. of patients	Mean TS	Mean ISS
HEMS	1,346 (7.3%)	12±3.6	17±11.1
Ground EMS	17,144 (92.7%)	14.3±3.6	10.8±8.4

A trend toward increased survival was observed among HEMS patients with higher ISS. Patients with Trauma Score (TS) between 5 and 12 and ISS between 21 and 30 showed statistical significance in survival. However, the majority of trauma patients in HEMS group had low ISS, and hence outcomes were not uniformly better among patients transported by HEMS compared ground transport.

Similarly, in a study by Dashfield et al. in 1997 in Bosnia,[9] 69 HEMS patients were evaluated over a six-month period in a rural setting. Only 15 out of the 69 patients (22%) had benefited from HEMS. This study again shows low benefit for patients with indiscriminate use of HEMS.

In a 1995 study by Nicholl et al. in London,[10] 337 patients of a HEMS group were compared with 466 patients of a ground EMS group. It was found that the estimated survival rates were the same. An analysis of TRISS methodology found 16% more death than predicted in HEMS but only 2% more in ground EMS. Any benefit in survival was restricted to patients with very severe injuries (ISS > or =16). For the overall helicopter caseload, there was no evidence that HEMS improved the chance of survival in trauma.

In a study by Schiller et al. in 1988 in Phoenix,[11] 606 patients sustaining blunt trauma with ISS from 20 to 39 were studied for the period from 1983 to 1986. A total of 259 patients were in the ground EMS group compared to 347 in the HEMS group. The mean TS was 12.7 for ground EMS and 12.1 for HEMS. Overall, the mortality for ground EMS was 13% compared to 18% for HEMS, showing no survival advantage in HEMS in an urban area with a sophisticated pre-hospital care system.

Concerning the analysis of cost-effectiveness, there are three articles from studies originating from the USA, Germany and UK. Gearhart, Wuerz and Localio (1997),[12] use the service provider's perspective - that is, the cost per year of life saved. The cost estimates comprise direct operating costs and additional survivors' hospital costs. Cost per life saved and Discounted cost per year of life in 1995 US dollars were the main outcome measures.

The average cost per life was calculated by dividing the number of additional survivors per 100 transports into the sum of the cost of 100 transports plus the estimated hospital cost of the additional survivors.

The discounted cost per year of life saved was calculated by dividing the cost of life by the discounted (at 3%) average remaining life expectancy for a trauma survivor.

Transport costs	$2,214 per patient
Average cost of each additional survivor's hospitalization	$15,883
Additional survivors per 100 patients flown (mean value from 11 studies)	5 additional survivors
Cost per life	$60,163
Discounted cost per year of life	$2,454

These results are comparable to a reported median discounted cost per year of life of $19,000 for other commonly used life-saving medical interventions. HEMS was therefore considered a cost-effective option for the treatment of trauma patients.

In another study by Lechleuthner et al in 1994 of Germany,[13] the annual costs incurred by the use of a helicopter was 1,575,000 DM versus a ground-based ambulance of 1,004,000 DM. The effect of varying the ratio of helicopters to ground-based vehicles (ALSC) was considered. In model 1, each region was allocated one additional helicopter and had 6 ALSC removed (daytime only). In model 2, each region had its existing helicopter withdrawn and replaced with 6 ALSC. In model 1, there was improvement in response times and had savings of nearly 1,500,000 DM per year, while model 2 showed longer response time and increased expenditure.

In conclusion, the additional use of rescue helicopters in EMS regions (50 km radius) remains cost-effective up to an ALSC: helicopter cost ratio of 1:6.

In a study by Brazier et al. (1996) of the London HEMS,[14] a prospective comparison of outcomes in terms of disability (an 11-point disability scale) and health status (six dimensions of the 100-point Nottingham Health Profile) in cohorts of seriously injured patients who were attended either by HEMS or paramedically crewed land ambulances was carried out. The result showed no evidence of any improvement in overall outcomes with the extra cost and HEMS was not found to be cost-effective. The incremental costs of HEMS were estimated to be 2.0 million pounds a year.

In-flight physician role

In a study by Baxt and Moody in 1987,[15] it was shown that the mortality rate was 35% lower than predicted in those patients who were treated by the flight nurse/flight physician. However, the flight nurses and paramedics in USA are now routinely performing many advanced procedures formerly performed by physicians. Hence, in a study by Burney et al. in 1992,[16] there was no objective difference in the outcome of patients between physician/nurse and nurse/nurse teams.

In another study by Schmidt et al. in 1992,[17] a German university-affiliated hospital-based helicopter service (GER-HEMS) was compared to an American university-affiliated hospital-based helicopter service (AMR-HEMS). GER-HEMS is directed on scene by a trauma surgeon who is a member of the flight crew, in contrast with the remote medical control of the nurse/paramedic team in the AMR-HEMS.

	GER-HEMS	AMR-HEMS
Overall mortality	21 of 221 (9.5%)	21 of 186 (11.3%)
Survivor-based TRISS methodology:		
Z-statistics	+2.459 ($p<0.025$)	+1.049
M-statistics	0.89	0.874
W-statistics	+1.35	
Unexpected survivors	nine	six
Early death (less than 6 hours)	four; ISS=64	12; ISS=56 ($p<0.01$)
Mean volume of IV fluids infused	1800 ml	825 ml ($p<0.05$)
Intubation ($p<0.001$)	82 of 221 (37%)	24 of 186 (13.4%)
Thoracic decompressions ($p<0.001$)	20 of 221 (9.1%)	1 of 186 (0.5%)

This showed that with the presence of a surgeon, more advanced procedures were performed and there was significantly higher number of early death in AMR-HEMS.

Safety record

The safety record has been improved during the past 10 years. In a study by Rhee et al.,[18] the safety record of HEMS in USA and Germany and the domestic air taxi service in USA were compared.

	USA-HEMS	USA-Taxi	FRG-HEMS
Period studied	1982-1987	1980-1985	1982-1987
Overall accident rate	11.7/100,000 hr	6.7/100,000 hr	10.9/100,000 hr
Fatal accident rate	4.7/100,000 hr	1.6/100,000 hr	4.1/100,000 hr

In another study by De Lorenzo et al.,[19] a retrospective review of safety data of USA Army HEMS and Army general aviation from 1987 to 1995 was studied.

	Army HEMS	Army general aviation
Class A (loss of life or aircraft destruction)	2.02/100,000 hr	1.86/100,000 hr
Mean overall crash rate (Class A to C)	7.44/100,000 hr	7.37/100,000 hr

Between 1992 and 1995, there were 3 years when the Army HEMS suffered no class A mishaps. Both rates are comparable with published civilian mishap rates. There was a very low overall incidence of crashes in both groups.

In a study by Wuerz and O'Neal in 1997,[20] it was suggested that instrument-proficient pilots were better able to manage unexpected encounters with various meteorologic conditions in a safer manner. HEMS should strongly consider maintaining instrument proficiency to enhance safety.

Carter and O'Brien (1986)[21] showed that flight safety equipment including helmets, shoulder-harness restraints and fire-retardant suits are under-utilised in all HEMS programs surveyed. In a study by Dodd (1994),[22] an energy-absorbing seat (EAS) was suggested in addition to Nomex uniforms and helmets.

In another study by Low et al. in 1991,[23] the single most important factor identified for safety was the number of flights: busy programs had an eightfold lower accident rate and a three-fold lower total mishap rate (accidents and incidents). Programs with the ability to fly under IFR at the pilot's discretion had no mishaps during the study period.

Conclusion

Ground EMS and HEMS have their own advantages and disadvantages. An efficient, well-trained ground EMS remains the backbone of pre-hospital and interhospital transport systems. For the delivery of early advanced life support resuscitation and rapid transfer of severely injured patients, HEMS must be integrated into the EMS system. There must be strict criteria for HEMS dispatchers to follow so as to prevent inappropriate use. HEMS improves survival statistics for rural patients with ISS >16. In contrast to USA, registered nurses and pre-hospital personnel in Hong Kong are not trained to perform advanced procedures normally performed by physician. The flight physician is potentially useful in lowering mortality when dealing with severely injured patients.

The safety record of HEMS is good. Pilots with both VFR and IFR are preferred. The existence of HEMS should not rely solely on cost-effectiveness analysis.

A highway accident in USA and the arrival of the helicopter to the scene.

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After all, our primary goal is to get the right patient, with right personnel, to the right place in the right amount of time.

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