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A REVIEW OF THE COSTS AND BENEFITS OF HELICOPTER EMERGENCY AMBULANCE SERVICES IN ENGLAND AND WALES

Final Report to the Department of Health

An independent study carried out by the Medical Care Research Unit of the University of Sheffield on behalf of the Department of Health. The views expressed are those of the authors and not necessarily those of the Department of Health.

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SUMMARY

We have conducted a survey of current helicopter emergency ambulance service (HEAS) provision in the UK, and a review of the published evidence on the costs and benefits of HEAS in order to identify what further research is needed to inform decisions about the involvement of the NHS. The main findings are:

- Currently there are 16 HEAS covering the whole country with reported average response times of 17 minutes, and transfer times of 10 minutes.
- About half the receiving hospitals used by HEAS require a ground ambulance (G/A) transfer rather than trolley transfer, so that times into the ED will often be greater than these reported times.
- No randomised studies comparing outcomes in HEAS and G/A patients have been found. In nine studies from which outcomes in HEAS can be compared to contemporary G/A patients managed by the same system, the estimated odds ratio for death following trauma managed by HEAS adjusted for injury severity casemix was 0.86 (95% confidence interval 0.70, 1.06).
- Assuming there is a benefit, the estimated number of lives saves by HEAS is approximately 2-3 patients per 100 patients transported. The studies examined suggest that the main benefit arises in blunt trauma patients, particularly those injured in Road Traffic Accidents (RTAs), with severe injuries.
- Targeting helicopters to these patients is very poor. A wide variety of criteria are used for tasking HEAS which are based on scant evidence. Most studies report that a large proportion of patients attended are not severely injured and unlikely to benefit from HEAS.
- One estimate of the appropriate size of population to be covered by a HEAS which was correctly targeted to serious blunt trauma is 3 - 5 million - indicating a network of 10 - 16 HEAS for England and Wales.
- There is very little reliable evidence, relevant to the environment in England and Wales, to judge whether there is any benefit in any other groups of patients.
- Three studies of reasonable quality, all from the US, have compared survival in patients transferred between hospitals by HEAS or G/A. Overall, the results of these studies were inconclusive.
- It is possible that the main benefit from using HEAS for inter-hospital transfers or primary missions in remote areas is in improving the effectiveness of Ambulance Services to deploy their ground ambulances. Two studies in the same service have examined this question, but neither found conclusive results.

- Helicopter safety has been a major issue in the US, and national studies have identified several risk factors. These point to the risks involved in using HEAS at night and/or in poor weather conditions.

- Overall, the average additional (incremental) cost of operating and using a HEAS rather than ground ambulances in England and Wales is £858,000 p.a. We have not attempted to measure the cost consequences for hospitals and other services.

- There are two studies of the effect of HEAS on the quality of life of survivors. Neither found any benefit compared to G/A.

- Assuming 2-3 lives can be saved per 100 serious blunt trauma patients transported by HEAS, we have estimated that HEAS in England and Wales may generate 43-136 QALYs per year. An estimate of 157 QALYs has been reported in a Norwegian study.

- Ignoring any cost consequences, and any benefits from activities other than responding to the scene for patients with serious blunt trauma, we estimate, therefore, that the incremental cost per QALY resulting from HEAS is £6310 - £19,950. Because of assumptions we have had to make, this estimate of the cost per QALY of HEAS should only be taken as indicative.

- Whatever the true cost per QALY, if a HEAS can save 4 or more blunt trauma patient lives each year the cost per QALY is likely to be acceptable acceptable at a threshold of £30,000 per QALY, which is approximately the threshold used implicitly by the National Institute for Clinical Excellence. The evidence, though not conclusive, suggests that HEAS, appropriately targeted, can achieve this.

- The continuing uncertainty about the cost-effectiveness of helicopters points to two main research issues. Firstly, how to target HEAS to serious blunt trauma patients for whom the evidence of benefit is good, and secondly to quantify the benefits associated with other types of mission.

1. INTRODUCTION

Background

Helicopter emergency ambulance services (HEAS) started operations in England in 1987, and by 2002 there were 14 dedicated air ambulance services in England operating as independent charitable trusts. A further two helicopters in Scotland are funded by the NHS. Each of the trusts flies one helicopter, apart from County air ambulance in the West Midlands which has three. In addition, there are four Police authorities operating helicopters which can carry medical equipment and crew to respond to medical emergencies. There are also helicopter services operated by the armed forces that are used in medical emergencies and for inter-hospital transfer as well as in their usual role in air-sea rescue operations.

During the 1990s in the middle of these developments the Department of Health commissioned studies of three UK HEAS[1-5], and a review of evidence on costs, effectiveness, and operational issues[6,7] to inform decisions about possible NHS support. The 1995 review uncovered a large, but poorly focussed, low quality literature on HEAS which suggested that they could have an important role in the management of serious trauma in some circumstances. However, there was little solid evidence that they enhanced overall performance or outcomes to an extent which would justify their costs. It was noted that a major issue was the difficulty of targeting HEAS at appropriate emergencies, and it was suggested that HEAS should only be operated in conjunction with systems capable of improving targeting whose performance should be audited. A later review[8] concluded that the best way of over-coming the difficulty of targeting HEAS to incidents where their benefits could be maximised was to use them in a secondary responder role. In this role, instead of responding directly to 999 calls from the public (primary response), they are called out by other emergency services at the scene which have assessed the need for an air ambulance.

Since these studies were carried out there have been a number of important developments. Firstly, the number of HEAS operating in the UK continued to increase. These services have almost all been funded by Charitable Trusts, some with support from the AA Foundation, and hence have bypassed questions about the opportunity costs of using NHS funds for air ambulance operations. Indeed, the public willingness to give money to support HEAS suggests that their perceived value may go beyond the benefits measured in the literature, and a study to begin to examine this issue was commissioned alongside this review.

A second development has been the widespread introduction of computer-aided dispatch systems, and the development of many alternative primary response services, and hence a more sophisticated targeting of ambulance resources at appropriate incidents. This could have an important bearing on the ability of HEAS to deliver the benefits they are capable of bringing to patients.

Finally, with the increasing number of HEAS covering much of the country, the air ambulances have begun to be an increasingly organised part of the emergency care system, and the formation of the National Association of Air Ambulance Services (NAAS) and the newly formed Confederation of Helicopter Ambulance Services highlight the increasingly organised role of HEAS in systems of emergency care. However, questions remain about future developments, their appropriate role in emergency care systems, and hence how they should be integrated into national or regional EMS.

As a consequence of these developments, the Department of Health commissioned us to re-assess the literature on the costs and effectiveness of HEAS in order to identify what research was needed to inform decisions about the future involvement of the NHS.

Aims

This review has set out to describe the characteristics of HEAS currently operating in England and Wales and review the published literature relating to the costs and benefits of HEAS in relation to

1. The effectiveness of HEAS in improving the outcomes of trauma patients attended at the scene and other, non-trauma, patients, and to identify any evidence about the aspects of HEAS which produce the benefits.
2. The effectiveness of HEAS in tertiary roles, transferring patients between hospitals.
3. The impact of HEAS on other aspects of emergency system performance, such as Ambulance Service response times, and other 'halo' effects.
4. Their safety, and any lessons which might have an impact on how HEAS could be used in emergency care systems in England and Wales.
5. Operational issues which are important in determining their effectiveness.
6. The direct costs of operating HEAS, and the cost consequences measured from an NHS perspective.
7. The incremental costs and benefits.

Methods

1. Literature search — Since 1990, the Medical Care Research Unit has been compiling a bibliography relating to research on HEAS which contains over 400 references. This bibliography was reviewed to identify all the articles written in English containing primary evidence relating to any of the seven issues, and any further references to articles not already in the bibliography. In addition, another search of electronic databases was undertaken in April 2002 to identify the most recently published literature and any articles that had been previously missed. The databases searched were Medline, CINAHL, and EMBASE using air-, aero-, rotor and helicopter- as the main search terms.
2. Review methods — All the HEAS literature identified in the main search was reviewed for relevance to each of the issues. A systematic review

of outcomes in trauma patients has been undertaken and the methods used for determining study inclusion criteria, quality assessment, and the calculation of synthesised estimates of the effect of HEAS on outcome are given in section 3. For other topics an informal or narrative review approach has been taken.

3. Survey — In addition to the literature review we sent a postal questionnaire to all the dedicated HEAS in England and Wales to gather details about their operations and current role in delivering emergency care. As well as issues about helicopters, equipment, crewing and training, deployment, targeting, and activity, the survey asked about costs of operating the HEAS.

4. Economic analysis — Information on the costs of HEAS, and the results of the reviews of benefits, have been brought together to estimate the additional cost per Quality Adjusted Life Year. The methods used are set out in section 5.

2. HELICOPTER EMERGENCY AMBULANCE SERVICES IN ENGLAND AND WALES

There are currently 16 dedicated helicopter ambulances operating in England and Wales, and to date 14 responses to the survey have been received. One HEAS felt that the survey wasn't relevant to their operation since it was thought to be very different to other services (London); and one service has not responded at all (Dorset and Somerset).

A brief description of these services is shown in Tables 1 and 2. Most services use the small Eurocopter ('Bolkow') 105 crewed by 1 pilot and 2 paramedics, both of whom have flight training and one of whom acts as navigator during flight. The London service (unreported) is the only one with a permanent doctor on the crew, but two others occasionally carry a doctor. The NAAS map shows that virtually the whole country is covered by a 30 min flight time, and the responses to the survey suggests that approximately 47 million people in England and Wales (95%) are within the recognised catchment areas of the responding services.

Nearly all the helicopters operate 7d/wk, but none fly at night-time. On average they are unavailable for 245 hrs/yr (approximately 27 days) or 9% of their normal flying time, mainly due to weather and mechanical failure.

For most services a G/A is usually dispatched as well as the helicopter to respond to incidents at the scene. In this sense the helicopter is operating as a complementary rather than substitute service, so that on many occasions a G/A will attend the scene as well as the helicopter. This is the main reason why services reported that only 44% of primary missions resulted in a patient being transported by helicopter. There was an average of 329 patients transported per year per helicopter in primary missions and a further 51 in inter-hospital transfers.

The reported average call-out time from 999 call to being airborne is 4.5 minutes, and the response time to the scene 12.2 minutes (Table 3). These times are similar to those for locally deployed land ambulances. The average reported scene time was 19.7 minutes and this reflects the slightly longer than average times previously noted for HEAS. However, as expected the main advantage of deploying HEAS to emergencies at the scene was the short transfer times to hospital, reported as taking on average just 9.5 minutes. In some instances this will underestimate the time into hospital because of the need to transfer patients from a landing site at the hospital to A and E by land ambulance. The HEAS reported that about half the receiving hospitals they use require a ground ambulance transfer. Nevertheless, overall, these times demonstrate the ability of just 16 helicopters in England and Wales to respond to incidents throughout the whole country on average in 17 minutes and after delivering care at the scene to transfer them to hospital in 10 minutes.

Table 1 **<u>Dedicated HEAS in England and Wales</u>**

Service	Base	Type of Helicopter	Crew	Patient Capacity	Population Covered
Yorkshire	Leeds/Bradford airport	Eurocopter BO 105	Pilot + 2 paramedics	1	4.7 million
Kent	Marden, Kent	MD 902 Explorer	Pilot + paramedic +paramedics/flight nurse	1	1.6 million
Devon	Exeter airport	Eurocopter BO 105	Pilot + 2 paramedics	1	Approx 1 million
Cornwall	RAF St. Mawgan	Eurocopter BO 105	Pilot + 2 paramedics	2	~ ½ million
Essex	Boreham airfield	Eurocopter BO 105	Pilot + 2 paramedics	2	1.4 million
Thames Valley	White Waltham airbase, Maidenhead	August 109 E Power	Pilot + paramedics + paramedic/doctor	2	2.9 million
Wales	Swansea	Eurocopter BO 105	Pilot + 2 paramedics	2	2.9 million
Lincs and Notts	RAF Waddington, nr. Lincoln	MD 902 Explorer	Pilot + 2 paramedics (doctor occasionally)	1/2	Approx 2.5 million
North East	Blyth, Northumberland	AS 355 F1 Twin Squirrel	Pilot + 2 paramedics	1	2.1 million
North West	Blackpool airport	Eurocopter BO 105	Pilot + 2 paramedics	2	7.5 million
East Anglian	Norwich	Eurocopter BO 105	Pilot + 2 paramedics	1	2.5 million
County -1	RAF Cosford	Eurocopter EC 135	Pilot + 2 paramedics	2	9.0 million
-2	Strawsham (?)	Eurocopter BO 105	Pilot + 2 paramedics	2	
-3	East Midlands airport	Eurocopter BO 105	Pilot + 2 paramedics	2	
London*	Royal London Hospital	MD 902 Explorer	-	-	7.3 million
Dorset and Somerset*	-	Eurocopter BO 105	-	-	0.9 million

* These services did not respond to the questionnaire.

Table 2 **Dedicated HEAS in England and Wales. Operational aspects**

Service	Operational hours		Estimated hours lost/yr			Deployment of G/A	Activity in 2001		IHTs patients transported
	Summer/ winter	Days/wk	Weather	Breakdown	Other		Primary missions	Primary patients transported	
Yorkshire	Daylight hrs	7	234	124	53.5	Always	1082	214	17
Kent	8/8	7	56	40	56	Always	1032	230	24
Devon	Daylight hrs	7	- Not stated -			Usually	754	346	15
Cornwall	8/8	7	160	37	0	Sometimes	1127	552	92
Essex	Daylight hrs	7	80	63	-	Usually	773	392	Very few
Thames Valley	10/8	5	90	54	-	Usually	753	344	65
Wales	8/8	5	352	56	8	Usually	310	174	33
Lincs and Notts	10/8	7	150	120	25	Usually	660	274	132
North East	10/8	7	45	180	315	Sometimes	506	364	110
North West	10/8	7	75	25	-	Not stated	859	138	118
East Anglian	10/9	7	30	5	20	Usually	600	200	6
County -1	10/8	7	Not stated, replacement as part of contract			Usually	1671 (County -1 to -3 combined)	872	56
-2	10/9	7	Not stated, replacement as part of contract			Usually			
-3	8/8	5	Not stated, replacement as part of contract			Usually			
London	-	-	-	-	-	-	1061*	821*	-
Dorset and Somerset	-	-	-	-	-	-	755*	336*	-

* NAAS data Jan-Dec 2001. Primary missions and IHTs combined.

Table 3 <u>**Dedicated HEAS in England and Wales. Performance times (mean, minutes) during 2001**</u>

Service	Call-out time	Helicopter response time	On-scene time	Transfer time
Yorkshire	3	8	15	8
Kent	1	9	25 (median)	10
Devon	6.4	15.8	20.3	9.8
Cornwall	7.9	12.3	17.8	9.8
Essex	?	?	10-15	8-12
Thames Valley	3.5	8	10	10
Wales	6	16.5	23	10
Lincs and Notts	2.4	12.1	24.2	8.2
North East	2*	10.0	15.0	10
North West	Not stated	10(median)	21 (median)	6 (median)
East Anglian	5.0	16.5	28.2	11.6
County -1 -2 -3	5.0	13.6	21.1	10.0
London	-	-	-	-
Dorset and Somerset	-	-	-	-

* Time from call to HEAS Unit to take-off.

3. BENEFITS OF HELICOPTER EMERGENCY AMBULANCE SERVICE

3.1 <u>Introduction</u>

Outcomes for trauma and other patients attended by HEAS compared to G/A reported in the HEAS literature are summarised below. It is worth emphasising at the outset that

i) no study ever conducted comparing HEAS to other pre-hospital care models has been randomised;

ii) only 2 comparative studies have looked at any outcomes other than survival; and

iii) nearly all the papers we have reviewed come from the USA which partly reflects the English language selection.

These limitations inherent in the evidence reviewed below should be borne in mind.

We have also assessed the evidence for benefits from using helicopters for non-trauma patients, for IHT, other benefits for pre-hospital care, and questions about safety.

3.2 <u>Benefits for trauma patients</u>

3.2.1 <u>Studies reviewed</u>

A large number of studies have examined the benefits of helicopter transport in trauma patients. The summary review of the impact of HEAS on the survival of trauma patients attended at the scene presented below has excluded studies which

1. Mix results from trauma and non-trauma patients.
2. Mix results for primary or secondary scene transports and tertiary IHTs and do not have a substantial majority of scene transports.
3. Do not present sufficient detail in the results to enable case-mix adjusted estimates of the relative risk or odds ratio of death in HEAS patients compared to G/A patients to be calculated.
4. Do not compare outcomes of HEAS patients with contemporary cohorts of ground ambulance patients. Use of historical controls means that any comparisons are confounded with many other important changes in the development of trauma care.
5. Compare outcomes of a cohort of HEAS patients treated by one emergency care service with ground ambulance patients treated by another service, since this means the effect of the HEAS is confounded with differences in the treatment centres.

Points 4 and 5 mean that evaluations which are based only on the comparison of HEAS patients with norms (or expected outcomes) based on national, historical datasets such as MTOS have been omitted. However, if contemporary HEAS and G/A cohorts treated by the same services were both compared to MTOS norms, these studies have been included. Although this sort of analysis is unnecessary and sub-optimal it may not lead to bias.

Some studies have assessed the outcomes of HEAS patients by expert review to assess whether patients benefited from the helicopter. Uncontrolled or unblinded, these studies are prone to substantial bias and have also been omitted.

HEAS is a pre-hospital intervention and studies of the effect of HEAS on trauma survival which omit pre-hospital deaths should also be excluded. Unfortunately, almost all the studies that have been done have been based on trauma centre registries. These registries only include patients admitted to the trauma centres and hence may exclude some or most pre-hospital deaths, and the extent of this problem is unclear. On balance, we decided to include the trauma registry studies, and hence some studies omitting pre-hospital deaths have been included.

The studies that have been omitted and the reasons for omission are summarised in Tables 4 and 5. The studies that have been included are summarised in Table 6, and their results shown in Table 7.

3.2.2 <u>Analysis</u>

Adjusting for casemix

Comparisons between HEAS and G/A cannot be made directly because in all the studies reviewed the HEAS cohorts include more severely injured patients than the G/A cohorts. Adjusting for differences in casemix is an enduring problem in observational studies. In trauma studies reasonably reliable adjustments can be made using well developed measures of injury severity. Three common approaches are to use the Injury Severity Score (ISS), the Trauma Score (TS) or Revised Trauma Score (RTS), or a combination of these and other factors such as the age of the patient. The quality of the studies and hence the reliability of their results, were judged to be greatest when a combination of several factors were used to adjust for casemix differences using a logistic regression analysis. The next best studies employ the ISS because this is an objective measure of anatomical injury severity which is not affected by the care provided by the HEAS or G/A teams. The least reliable studies employ only the TS or RTS because these scores are based on physiological measures which are time-dependent, and often recorded on arrival at hospital, and which are therefore partly determined by the care which has already been provided. Consequently, for example, good initial care or rapid transfer to hospital can result in Trauma Scores which are better (indicating higher probability of survival) than the scores of patients having poorer initial care. Consequently Trauma Scores recorded on arrival in hospital already partly reflect the quality of HEAS or G/A care and are best not used alone for adjusting for injury severity to compare quality of care.

Note also that one detailed analysis using MTOS norms based on ISS, RTS, and age found that UK MTOS overpredicts survival in more severely injured patients[9]. Consequently, comparison of severely injured HEAS cohorts with MTOS may be unreliable.

Estimation of odds ratios and relative risk

In all the studies examined, the HEAS cohorts were more severely injured than the comparison G/A cohorts. Comparisons have therefore been adjusted for severity and are reported as the estimated odds ratio for death in the HEAS cohort compared to the G/A cohort, and as the relative risk. Most studies have not reported these statistics, and for the purpose of this review they have been estimated as follows.

1. <u>Comparison of HEAS with MTOS</u>. As explained above, studies of a single cohort of HEAS patients which have compared their outcomes with patients in the national MTOS database have been omitted from the main analysis, but when possible odds ratios have been calculated and are shown in the tables.

   These studies usually just report the excess of deaths or survivors in the HEAS group compared to severity matched MTOS patients (assumed to be G/A). The probability of death with G/A care can be estimated as the number of deaths in the HEAS cohort plus the reported excess of survivors associated with HEAS divided by the number of patients in the HEAS cohort. This probability can be combined with the crude probability of death in the HEAS cohort to estimate odds ratios and relative risks.

2. <u>Comparison of HEAS with G/A using MTOS</u>. Studies which have compared a cohort of HEAS patients with MTOS, and a contemporary cohort of G/A patients with MTOS, have usually reported deaths and survivors in probability of survival (Ps) strata derived from MTOS. We have re-analysed these data using a logistic regression to compare HEAS and G/A directly adjusting for the category of Ps. This yields an estimated odds ratio for death with HEAS adjusted for the factors used to calculate Ps. The estimated odds ratio has been combined with the crude probability of death in the HEAS cohort to estimate the relative risk.

3. <u>Direct comparison of HEAS and G/A cohorts</u>. Studies which have directly compared HEAS and G/A have usually estimated a severity adjusted OR using a logistic regression model. As before these ORs have been combined with the crude probability of death in the HEAS cohort to estimate the relative risk. Studies which have not reported the OR, but which have reported deaths and survivors in probability of survival (Ps) strata derived from the study's logistic regression model, have been re-analysed using logistic regression to adjust for Ps and estimate the OR, and hence the relative risk.

Interactions.

Most studies report that any benefit of HEAS is limited to some sub-groups of severely injured patients. We have examined whether there was an interaction between injury severity and the effect of the type of ambulance in each of the 9 studies included in the main analysis of survival benefit.

Where this is reported by the authors, their results are shown. Otherwise, we have attempted to calculate a test-statistic for this interaction from the published data. In all cases where the data have been available we have graphed the relative risk of death with HEAS against an injury severity index. We have used an index defined by the probability of survival wherever possible, and ISS if this was all that was available.

Meta-analysis.

An estimate of the effect of HEAS on death, synthesised from the results of the 9 studies included in the main study, has been obtained by meta-analysis. The meta-analysis was conducted using the random effects option in META in STATA, and effectively calculates a weighted average of the log odds ratios of the studies.

We also carried out a meta-analysis separately for

i) studies based on probabilities of survival derived from MTOS, and studies which calculated their own logistic regression models for the probability of survival.

ii) studies which included blunt and penetrating injuries or just blunt injuries.

3.2.3 Results

We identified 25 peer-reviewed published studies which present data on the estimated benefit of HEAS on survival in trauma patients attended at the scene compared to what would be achieved with conventional ground ambulance (G/A) services. Of these, 7 were rejected because the studies did not give enough detail about their results to enable relative risks of death adjusted for severity to be calculated (Table 4), 9 were rejected because of their focus (Table 5), and 9 were included in the main analysis (Tables 6 and 7). None of the studies was randomised.

Rejected studies

Most of the rejected studies reported some benefit on survival in HEAS. In particular 2 studies which compared HEAS to MTOS norms found estimated relative risks of 0.79 and 0.86, indicating a 14%-21% reduction in risk in blunt trauma[9,15], and adjusting for injury severity two studies of head injured patients found reductions in risk in this group of patients of 35% and 39%[16,17].

Two Scandinavian studies using expert panels judged that some critical interventions which had saved lives had been carried out by HEAS[20,23]. One of these studies estimated that over a period of 2 years one helicopter had generated 24.4 QALYs in trauma patients.

Included studies

Nine studies of the effect of HEAS on the survival of trauma patients were included in the main analysis.

Six are from America. All the American studies are based on trauma centres rather than helicopter systems. Three are retrospective studies based on registers from large multicentre trauma systems served by several HEAS, and three are based on single trauma centres. Of the 6 American studies, only the earliest study, Baxt's single centre study comparing survival in 150 consecutive blunt trauma HEAS patients with 150 similar G/A patients was carried out prospectively. In contrast, the three non-American studies from London, Amsterdam, and Sydney are focussed on a single HEAS delivering patients to multiple centres, and 2/3 were prospective studies.

The three large multicentre trauma registry studies from North Carolina, Pennsylvania, and Boston all compared survival of patients arriving at the trauma centres by helicopter or ground ambulance using logistic regression to adjust for age and ISS, and a variety of other factors. Each study examined over 10,000 patients, and relative risks of death with HEAS of 1.26, 0.96, and 0.66 were estimated. Both the North Carolina and Pennsylvania studies which found no survival benefit with helicopters, observed some benefit in seriously but not critically injured patients, but worse outcomes in patients with relatively minor injuries (see Fig. 1). This is a phenomenon observed in several other studies including Baxt's well-known multicentre study which compared outcomes with MTOS norms[15]. It was also observed in Kerr's single trauma centre study in Maryland included in this review which found evidence of benefits in patients with ISS≥31, but statistically significantly worse outcomes at ISS<31[28].

The three non-American studies all examined the outcomes of doctor crewed HEAS in major urban environments (London, Amsterdam, Sydney). None of these three studies presents clearcut evidence of a survival advantage with HEAS. The casemix adjusted relative risk in Nicholl's London study was 0.99. For Bartolacci's study in Sydney the estimated relative risk in ISS matched groups was 0.70 (0.36, 1.35), although compared to MTOS norms the HEAS mortality rate was half that expected. In Oppe's high quality study in Amsterdam, a marginally significant better survival was reported for all the blunt trauma patients included in the study, but a logistic regression analysis using the Ps strata reported in the paper found a substantial but non-significant benefit (rr=0.64 (0.43, 1.12)) though this could be because of the lack of individual level data.

Survival

A meta-analysis (or synthesis) of the results of these studies together estimated the odds ratio for death with HEAS of 0.86(0.70, 1.06), providing only weak evidence of benefit and suggesting a reduction in risk of about 14%. The generalisability of this conclusion is enhanced by noting that it is based on 9 studies of 31,617 HEAS and 45,617 G/A patients from four countries (USA, UK, Australia, and Holland), using different types of helicopter and crewing configurations.

For the four studies which only included blunt trauma the meta-analysis found an estimated OR=0.51 (0.32, 0.82) compared to 1.04 (0.89, 1.20) for those including penetrating trauma as well. For the most reliable studies which calculated their own logistic regression models for the Ps, the estimated OR=0.90 (0.77, 1.05) compared to an OR=0.60 (0.29, 1.25) for those that compared both cohorts to MTOS norms.

Quality of life

Only two studies examined quality of life in blunt trauma survivors. Oppe[30] reported the mean EQ-5D quality of life score for surviving HEAS and G/A patients combined as 0.67 at 9 months post-injury and 0.71 at 15 months. Overall, he found no difference between HEAS and G/A at 9 or 15 months post-injury, but a worse outcome with HEAS for very severely injured patients. Nicholl[5] found a small but statistically significantly worse outcome overall with HEAS at 6 months. A study by Coats et al of the outcomes of severely head injured patients attended by the London HEMS and treated at the Royal London Hospital found that of those that survived, half made a good recovery, but no comparative G/A data were reported[32].

Interactions

Almost all the papers reviewed comment on the fact that HEAS can provide little benefit (in terms of survival at least) for patients with very minor injuries, nor for patients with the most severe injuries from which death is inevitable or almost inevitable. As reported above, most papers also report some data confirming these assumptions. We have therefore tried to identify and report any evidence of interaction between effect size and injury severity (Table 7). Only 3 studies included in the main analysis of survival report a statistically significant interaction. The estimated relative risk of death within injury severity strata for all the studies giving appropriate data are shown in Figs 1 and 2.

Three different graphs of the Amsterdam data[30] are included, showing the relative risk of death with HEAS against an overall calculated probability of survival, ISS, or RTS. The ISS and RTS data show completely different pictures, and the Ps data a picture which doesn't seem to cohere with either. The ISS data suggest an increased risk at low injury severity, and the RTS data a substantially reduced risk. This probably reflects the inadequacy of the RTS to reflect injury severity, especially when measured in hospital after extensive pre-hospital care.

Lives saved

Several papers have estimated the numbers of lives saved by helicopter operations. Assuming no difference for minor injuries, Nicholl estimated 13/yr with the London HEMS[3], and a later analysis of different data from the same service by Younge estimated 12/yr[9]. Oppe estimated 3.2-5.6 lives were saved per 100 hospitalised patients attended by the Amsterdam HEAS[30]. Baxt's multicentre study of 7 HEAS compared to MTOS estimated 3.9 lives saved per 100 patients transported by the HEAS to trauma centres[15].

In the five studies which reported death rates and numbers of HEAS and G/A patients within each injury severity stratum used to obtain the adjusted relative risks[24,25,28-30] the estimated number of lives saved by HEAS was, on average, 2.8 per 100 HEAS patients included in these studies. Using the calculated relative risks shown in Table 7 for the other four studies[5,26,27,31], the estimated number of lives saved by HEAS was, on average, 2.7 per 100 HEAS patients included in those studies.

Only two of these studies considered all patients attended by the HEAS[3,30], the remainder examining outcomes in patients transported by HEAS. Overall, these studies therefore suggest that 2-3 lives may be saved per 100 patients transported by HEAS, with the main benefit in severely injured blunt trauma patients.

Discussion and conclusions

The quality of the studies examining survival following the use of HEAS is generally poor. There are no RCTs, which may partly be justified by the difficulty in randomising emergency calls for patients often with immediately life threatening injuries. Most of the studies are retrospective, collecting together trauma registry data used for auditing trauma centre performance. This means firstly that the data collected are not targeted at HEAS and therefore miss out on pre-hospital deaths, which would usually be considered important for evaluating a pre-hospital care technology, and also do not include outcome data for survivors. Secondly, by focussing on trauma registries, the studies are focussed on trauma centres, and hence miss one of the potential advantages of HEAS which is to transfer patients directly to the most appropriate (trauma centre) hospital rather than to the nearest. The best designed studies collect outcome data from comparable cohorts of HEAS and G/A patients wherever they were taken for hospital care.

The two strongest prospective, HEAS based studies[3,30] are comparable in many ways but they are both focussed on doctor staffed HEAS operating in densely populated, largely urban environments and generalising to other environments or HEAS configurations would not be sensible.

Finally, the persistence of the observation that HEAS have worse outcomes for minor or moderate injuries, better outcomes for serious injuries and similar outcomes for the most critically injured suggests that the key issue is targeting HEAS to an appropriate caseload. It is also interesting to note that most of the studies reporting benefits focussed only on blunt trauma rather than a mixed caseload. Like many other technologies it is likely that HEAS is beneficial for some sub-groups of patients but not for all.

Table 4 **Studies assessing outcomes in trauma patients following use of HEAS in scene responses omitted because adjusted risks comparing to contemporary G/A cohorts could not be calculated**

Place	Author, yr, (ref no)	Method	Type of patients	Number	Authors Conclusion
Houston Texas	Fischer, 1984 (10)	Survival of patients by trauma score.	One year cohort of trauma scene flights	Blunt = 466 Penetrating=111 100 with TS≤4	Advanced care by helicopter medical crews did not improve survival for patients with very low Trauma Scores, but Dr. staffed HEAS may be valuable.
Arizona	Schiller, 1988 (11)	Retrospective analysis of G/A and HEAS patients	Blunt trauma with 20 ≤ISS≤39 transported from the scene.	HEAS = 347 G/A = 259	No survival advantage with HEAS in an urban area with a sophisticated pre-hospital system. Unadjusted RR = 1.4 with the HEAS.
Connecticut	Schwartz, 1990 (12)	Comparison of survival with MTOS norms for G/A and HEAS patients	Multisystem injured blunt trauma RTA patients transported directly from the scene.	HEAS = 93 G/A = 128	Helicopter patients had survival better than national norms and land ambulance patients worse than national norms. Overall OR could not be calculated from the published data.
Switzerland	Graf, 1983 (13)	Death and complications compared in HEAS and G/A transported patients	Multiple trauma patients	HEAS = 107 G/A = 131	No evidence of better outcomes in HEAS patients
Connecticut	Jacobs, 1999 (14)	Retrospective HEAS registry compared to MTOS norms using the Trauma Score	Air transported trauma patients directly from scene.	HEAS = 3620	Reported 13% reduction in mortality with HEAS but no evidence of any reduction in risk for TS≥12. "While air medical transportation has a definite benefit, reducing mortality by as much as 35%, this benefit applies to a select group of patients".
USA, 7 Centres	Baxt, 1985 (15)	Comparison of survival of HEASpatients meeting MTOS criteria with TRISS predictions.	Blunt trauma contacted at the scene and transported by HEAS to hospital	HEAS = 1273	Estimated relative risk compared to MTOS norms = 0.79. Hospital based HEAS staffed by advanced medical personnel may have the ability to reduce mortality, but only in major blunt trauma.
London	Younge, 1997 (9)	Compared survival in a HEAS trauma registry with UK MTOS norms, using TRISS, and employing a novel statistical approach.	Blunt trauma flown to hospital meeting MTOS criteria	HEAS = 632	Estimated an extra 4% survivors (4.16±2.21/100), most noticeable in a more severely injured sub-group. Overall, estimated RR= 0.86. The novel statistical approach used noted that the (MTOS) TRISS model overpredicts survival in severely injured patients

HEAS = Helicopter Emergency Ambulance Service; G/A = ground ambulance; TRISS = Trauma and injury severity score; ALS = Advanced Life Support; Ps = Probability of survival; TS = Trauma Score; ISS = Injury Severity Score; OR = Odds ratio; RR = relative risk; CI = confidence interval; MTOS = Major Trauma Outcome Study; RTS = Revised Trauma Score; SBP = Systolic blood pressure; GCS = Glasgow Coma Score; GOS = Glasgow Outcome Score.

Table 5 **Other studies assessing outcomes in HEAS patients omitted because of other reasons**

Place	Author, yr, (ref no)	Method	Type of patients	Number	Conclusion	Reason for omission from main analysis
San Diego California	Baxt, 1987 (16)	Comparison of survival and Glasgow Outcome Scores of urban G/A and rural HEAS patients. Mortality adjusted for GCS (for this review).	Severely brain injured (GCS≤8) blunt trauma patients transported directly from the scene.	HEAS = 104 G/A = 128	Significant 9% reduction in mortality associated with HEAS and improvement in GOS scores. Adjusted for GCS using logistic regression, estimated OR for death with HEAS = 0.65 (0.34, 1.25).	Head injuries only
San Diego California	Abbott, 1998 (17)	Retrospective trauma registry comparison of G/A and HEAS	Blunt closed head injuries with GCS≤8 and treated with RSI and mannitol (HEAS) or not (ALS G/A) and transported directly from the scene.	HEAS = 196 G/A = 1090	A large and significant reduction in risk with HEAS was found. This was not quite significant adjusting for GCS, because there was a small increase in risk in the less severely injured patients (GCS 6-8). Overall OR, adjusted for GCS=0.69(0.47,1.03).	Head injuries only
Washington USA	Moront, 1996 (18)	Retrospective trauma registry study of all <u>children</u> <15 transported by EMS to ED, comparing HEAS vs G/A using TRISS, over 4 years.	All children <15, 76% were primary (scene) transports.	HEAS = 1460 G/A = 2896	Estimated 1.1 lives/100 savedwith HEAS, but G/A not given, and marginal benefit can't be calculated. Nevertheless, the authors conclude that HEAS was "associated with better survival rates among urban injured children".	Children only
Iowa	Urdaneta, 1987 (19)	Retrospective review of HEAS patients	Trauma patients; 18.8% directly from scene.	HEAS = 916	14% of HEAS transports were judged 'essential' to survival.	Majority were IHTs.
Norway	Hotvedt, 1996 (20)	Unblinded, retrospective. Expert panel review of life-years gained.	All patients transported from rural areas over 2 years.	HEAS = 370 71 Trauma patients, 299 other.	7/71 trauma patients were judged to have benefited, gaining 24.4 QALYs. But fatal HEAS accidents and costs meant that, overall, routine use of helicopters was questionable.	Trauma and non-trauma.

HEAS = Helicopter Emergency Ambulance Service; G/A = ground ambulance; TRISS = Trauma and injury severity score; ALS = Advanced Life Support; Ps = Probability of survival; TS = Trauma Score; ISS = Injury Severity Score; OR = Odds ratio; RR = relative risk; CI = confidence interval; MTOS = Major Trauma Outcome Study; RTS = Revised Trauma Score; SBP = Systolic blood pressure; GCS = Glasgow Coma Score; GOS = Glasgow Outcome Score.

Table 5 **Other studies assessing outcomes in HEAS patients omitted because of mixed data (Cont'd)**

Place	**Author, yr, (ref no)**	**Method**	**Type of patients**	**Number**	**Conclusion**	**Reason for omission from main analysis**
Kentucky	Koury, 1998 (21)	Retrospective trauma registry comparison.	ED stay < 60 mins and transferred directly to OR for surgical treatment of trauma. IHTs were included	HEAS = 168 G/A = 104 Scene transports: HEAS = 37 G/A = 61	Odds ratio for mortality with HEAS =0.74 (p=0.44). For penetrating trauma with ISS≥25, RR-0.63; for other trauma RR=3.0. Conclusion: Not sufficient power to reach definitive answers.	Majority were IHTs
Texas	Chappell, 2002 (22)	Before and after discontinuation of HEAS study of trauma registry data	All patients in the trauma registry	1 yr before: HEAS = 366 (14% of all trauma cases, 49% of ISS>15); 2 yrs after: HEAS=285 (5%, 29%)	Mortality before cessation = 2.4%. After = 2.3%. For ISS>15 mortality = 25% before, 22.1% after. Total times to hospital reduced. Termination of HEAS had no impact on trauma outcomes.	Too many non-HEAS patients in the before group.
Finland	Kurola, 2002 (23)	Expert review of HEAS patients	All HEAS patients given ALS at the scene in one year. Only 42 (20%) were trauma patients	HEAS = 206 But only 26 transported by HEAS.	3 lives saved. 42 patients benefited. Estimated cost per beneficial mission =E28444	Trauma and non-trauma.
Cornwall	Nicholl, 1994 (1)	Comparison of survival and outcome for survivors at 6 months in HEAS and G/A cohorts managed by the same paramedics	Patients with severe injuries (similar to MTOS criteria)	HEAS = 265 G/A = 217	There was no difference in survival, but some evidence of reduced disabilities at 6 months in the HEAS cohort.	Not published.

HEAS = Helicopter Emergency Ambulance Service; G/A = ground ambulance; TRISS = Trauma and injury severity score; ALS = Advanced Life Support; Ps = Probability of survival; TS = Trauma Score; ISS = Injury Severity Score; OR = Odds ratio; RR = relative risk; CI = confidence interval; MTOS = Major Trauma Outcome Study; RTS = Revised Trauma Score; SBP = Systolic blood pressure; GCS = Glasgow Coma Score; GOS = Glasgow Outcome Score.

Table 6 **Comparative studies assessing mortality in trauma patients following use of HEAS in scene responses**

Place	Author, yr, (ref no)	Method	Type of patients	Number	Authors' Conclusion
San Diego California	Baxt, 1983 (24)	Comparison of survival of G/A and HEAS patients compared to TRISS predictions	Blunt trauma patients surviving to hospital	HEAS = 150 G/A = 150	Physician staffed HEAS improve patient mortality.
London	Nicholl, 1995 (3)	Comparison of survival and outcome for survivors at 6 months in doctor crewed HEAS and paramedic staffed G/As.	Patients with severe injuries meeting MTOS criteria <u>attended</u> by HEAS (whether flown to hospital or not).	HEAS = 337 G/A = 466	Overall, no survival or outcome advantage with HEAS; but some evidence that very severely injured patients did better with HEAS and less severely injured worse. Estimated up to 13 extra survivors per year.
North Carolina	Cunningham, 1997 (25)	Retrospective trauma registry study 1987 - 1993	All trauma patients with blunt or penetrating injuries transported directly to a trauma centre	HEAS = 1856 G/A = 11765	Analysis by ISS, Trauma Score, ICD-9 group, travel time no difference to times HEAS and G/A was reported. Patients with 5<TS <12 and 21 ,ISS <30 had significant benefit. Need further study to identify who benefits from this "expensive and risky mode of transport".
Pennsylvania	Braithwaite, 1998 (26)	Retrospective trauma registry study for 28 trauma centres.	All scene transports to the trauma centres by HEAS or ALS G/A	HEAS = 14967 G/A = 6148	"Transportation by helicopter did not improve overall survival . . . patients with 16< ISS<60 may have improved survival".
Sydney Australia	Bartolacci, 1998 (27)	Retrospective trauma registry comparison of Dr HEAS vs. ISS matched G/A paramedic cases for survival up to 48 hrs, and comparison of HEAS with MTOS norms using TRISS and Younge's method.	Major (ISS ≥15) blunt trauma transported to hospital	HEAS = 77 G/A = 308	Compared for MTOS, HEAS increased survival by 12% (12.2/100; 5.3-19.1) for major blunt trauma. "Air medical transport is currently relevant only to those patients who have significant injuries."

HEAS = Helicopter Emergency Ambulance Service; G/A = ground ambulance; TRISS = Trauma and injury severity score; ALS = Advanced Life Support; Ps = Probability of survival; TS = Trauma Score; ISS = Injury Severity Score; OR = Odds ratio; RR = relative risk; CI = confidence interval; MTOS = Major Trauma Outcome Study; RTS = Revised Trauma Score; SBP = Systolic blood pressure; GCS = Glasgow Coma Score; GOS = Glasgow Outcome Score.

Table 6 Comparative studies assessing mortality in trauma patients following use of HEAS in scene responses (Cont'd)

Place	Author, yr, (ref no)	Method	Type of patients	Number	Authors' Conclusion
Maryland	Kerr, 1999 (28)	Retrospective trauma registry study. HEAS staffed by trained and certified Maryland State Police personnel	All trauma patients taken to the trauma centre. 83% were transported directly from the scene.	HEAS = 11623 G/A = 11379	There were significant differences in mortality in favour of G/A below ISS=31 (RR=1.32, p<0.001), and in favour of HEAS above ISS=31 (RR0.82 p<0.001). Authors conclude that "rapid air transport of severely injured trauma patients by specialised personnel to a trauma centre decreases mortality rates".
San Antonio	Owen, 1999 (29)	Retrospective trauma registry study using TRISS to adjust for severity	All scene transports to the trauma centre for injured patients	HEAS = 105 G/A = 687	For HEAS there were 15 deaths vs 16.3 predicted. For G/A 41 vs 39.1. "Aeromedical transportation can be an integral part of the system".
Amsterdam, Holland	Oppe, 2001 (30)	Prospective evaluation of hospitalised polytrauma patients comparing G/A and HEAS cohorts, adjusted for ISS, RTS (and other factors considered). Death and QoL (at9m and 15m) was measured.	Polytrauma patients not dead at scene, taken to hospital.	HEAS = 210 G/A = 307	Estimated 7-12 extra survivors per year. There were no differences in QoL, but those with "very severe" injuries had lower QoL with HEAS. "HEAS was effective in saving lives of seriously injured victims".
Massachusetts	Thomas, 2002 (31)	Retrospective 5 hospital trauma registry study. Several HEAS staffed by nurse/para + nurse/dr.	Blunt trauma, scene (67%) and IHTs (33%) both included	HEAS = 2292 G/A = 14407	Estimated 24% reduction in mortality with HEAS, and 38% for primary scene transports only. No analysis of interaction with ISS/severity. Concludes that there is an association between transport mode and survival.

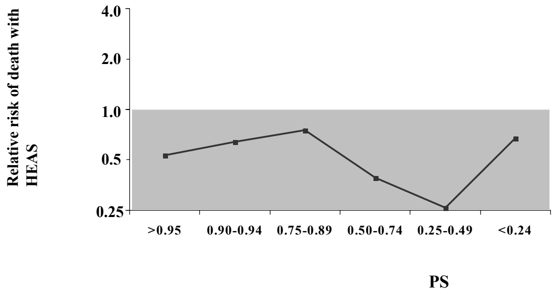
HEAS = Helicopter Emergency Ambulance Service; G/A = ground ambulance; TRISS = Trauma and injury severity score; ALS = Advanced Life Support; Ps = Probability of survival; TS = Trauma Score; ISS = Injury Severity Score; OR = Odds ratio; RR = relative risk; CI = confidence interval; MTOS = Major Trauma Outcome Study; RTS = Revised Trauma Score; SBP = Systolic blood pressure; GCS = Glasgow Coma Score; GOS = Glasgow Outcome Score.

Table 7 <u>**Estimated effect of HEAS on mortality in scene responses**</u>

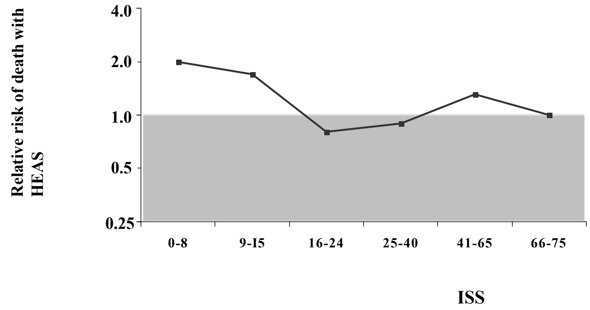
Author (ref)	**Year**	**Type of trauma**	**Risk adjustment method**	**Risk factors**	**Estimated OR for death with HEAS (95% CI)**	**Estimated RR for death with HEAS (95% CI)**	**p-value for interaction of effect and severity**	**Estimated lives saved per 100 HEAS patients**
Baxt (24)	1983	Blunt trauma	Logit regression using 5 Ps strata derived from MTOS to compare study HEAS and G/A patients.	TS, ISS, age	0.14 (0.04, 0.50)	0.20 (0.10, 0.53)	0.55	9.8
Nicholl (3)	1995	Blunt and penetrating	Logistic regression using risk factors to compare study HEAS and G/A patients	RTS, ISS, age	0.99 (0.69, 1.40)	0.99	0.13	0.3
Cunningham (25)	1997	Blunt and penetrating	Logistic regression using 5 Ps strata derived from logistic regression to compare HEAS vs G/A.	Scene TS, ICD-derived ISS, age	1.34 (1.08, 1.67)	1.26 (1.06, 1.52)	0.02	-1.3
Braithwaite (26)	1998	Blunt and penetrating	Logistic regression using risk factors to compared study HEAS and G/A patients	RTS, categorised ISS, age, SBP, sex, geographical area	0.95 (0.81, 1.12)	0.96 (0.83, 1.10)	"significant" (data not given)	0.5
Bartolacci (27)	1998	Blunt trauma	i) Direct comparison of ISS-matched HEAS and G/A cohorts ii) Comparison of HEAS to outcomes in MTOS database	ISS RTS, ISS, age	0.66 (0.28, 1.40) 0.42	0.70 (0.36, 1.35) 0.49	Can't be calculated	5.0
Kerr (28)	1999	Blunt and penetrating	Logistic regression using risk factors to compare study HEAS and G/A patients	ISS	0.95 (0.84, 1.08)	0.96 (0.85, 1.07)	0.005	0.2
Owen (29)	1999	Blunt and penetrating	Logistic regression using 6 Ps strata derived from MTOS to compare HEAS and G/A patients	RTS, ISS, age	0.69 (0.21, 2,20)	0.74 (0.33, 2.02)	>0.5	1.8
Oppe (30)	2001	Blunt trauma	Logistic regression using 5Ps strata derived from study data to compare HEAS vs G/As.	ISS, GCS, age, sex, accident type	0.50 (0.22, 1.16)	0.64 (0.43, 1.12)	0.02	3.7
Thomas (31)	2002	Blunt trauma	Logistic regression using risk factors to directly compare HEAS and G/A patients	ISS, age	0.62 (0.45, 0.86)	0.66	Can't be calculated	4.8

HEAS = Helicopter Emergency Ambulance Service; G/A = ground ambulance; TRISS = Trauma and injury severity score; ALS = Advanced Life Support; Ps = Probability of survival; TS = Trauma Score; ISS = Injury Severity Score; OR = Odds ratio; RR = relative risk; CI = confidence interval; MTOS = Major Trauma Outcome Study; RTS = Revised Trauma Score; SBP = Systolic blood pressure; GCS = Glasgow Coma Score; GOS = Glasgow Outcome Score; Ps = Probability of survival.

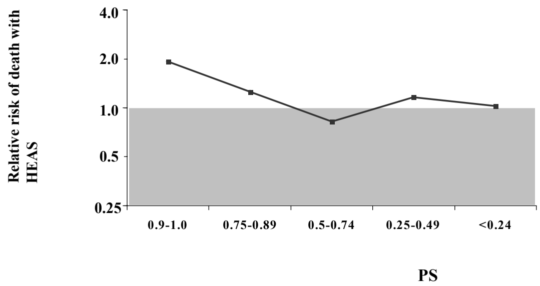
Evaluation of San Diego HEAS, Baxt 1983



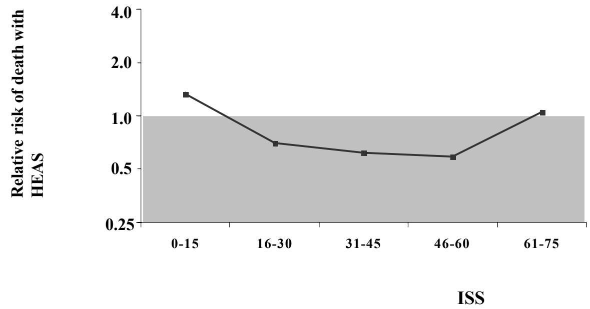
Evaluation of London HEMS, Nicholl 1995



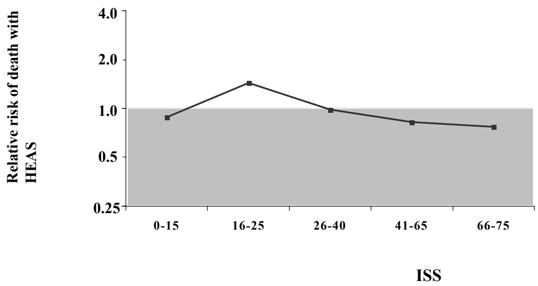
Evaluation of North Carolina HEAS, Cunningham 1997



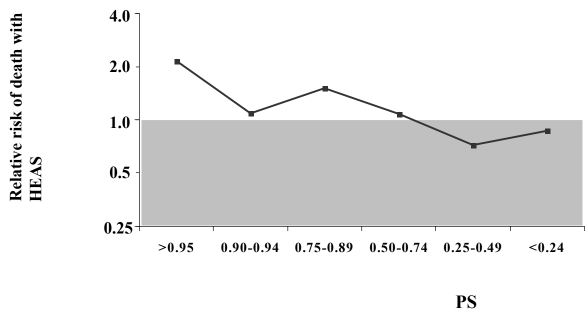
Evaluation of Pennsylvania HEAS, Braithwaite 1998



Evaluation of Maryland HEAS, Kerr 1999

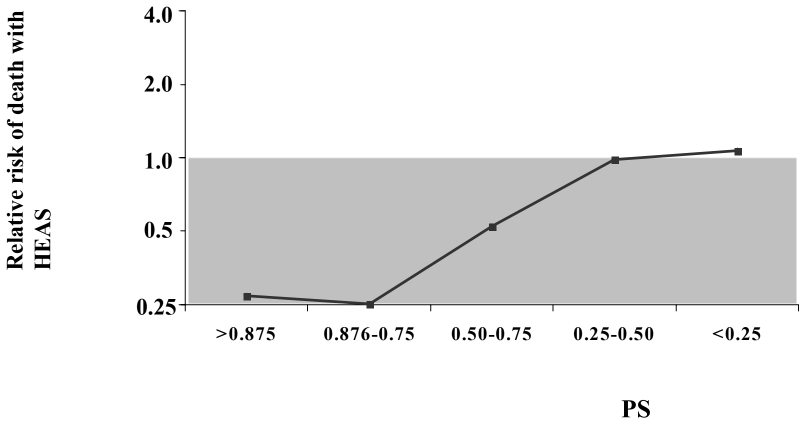


Evaluation of San Antonio HEAS, Owen 1999



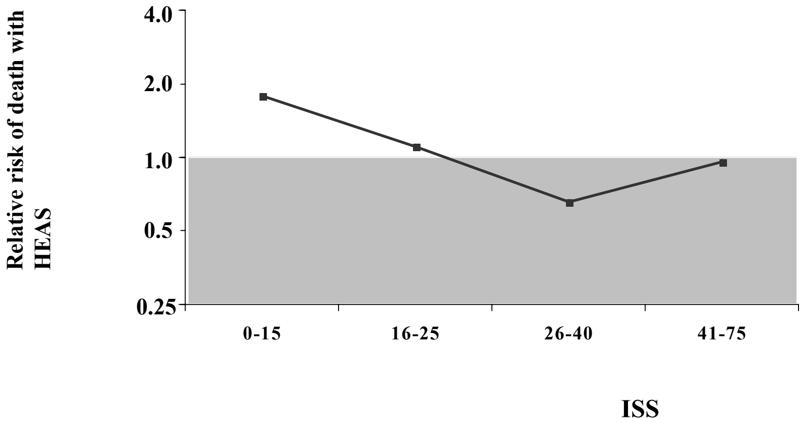
Evaluation of Amsterdam HEAS, Oppe 2001

1) Probability of survival



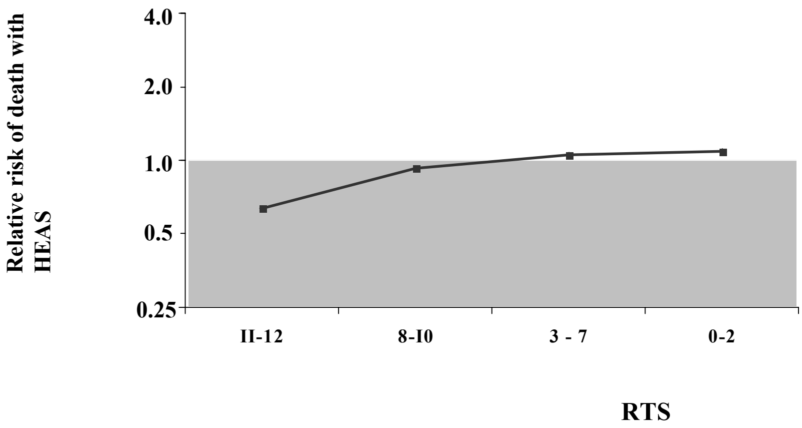
Evaluation of Amsterdam HEAS, Oppe 2001

2) Injury severity score



Evaluation of Amsterdam HEAS, Oppe 2001

3) Revised trauma score



3.3 Helicopter Emergency Ambulance Services For Non-Trauma

Helicopter emergency ambulance services (HEAS) have been used for a variety of non-traumatic conditions, principally acute myocardial infarction (AMI),[33-37] cerebrovascular accident (CVA),[38] cardiac arrest,[39,40] obstetric[41-43] and neonatal emergencies,[44] burns,[45-48] hypothermia[49] and poisoning.[20,51] The rationale for using HEAS, and the potential benefit, depends upon the patient group.

Acute Myocardial Infarction

The development of effective, but time-sensitive, interventions for AMI, such as intravenous thrombolysis or percutaneous coronary interventions, has led to interest in the use of HEAS to reduce response times, provide prehospital thrombolysis and provide direct transfer to specialist centres. Data from phases I and II of the Thrombolysis in Myocardial Infarction (TIMI) trials[34,35] have been published to support the use of HEAS in delivering thrombolysis.

Patients with AMI are at high risk of in-flight adverse events, but concerns regarding the safety of aeromedical transport do not appear to be borne out by published studies. Gore[34] reported transport of 57 patients enrolled in the TIMI I trial, 34 of whom were transported by HEAS and 23 by ground ambulance. Although 26 HEAS patients suffered chest pain en route, only 6 suffered minor arrhythmias and 2 suffered hypotension. The risk of complication was unrelated to the mode of transport and the distance travelled. Fromm et al35[35] reported data from 95 patients enrolled in the TIMI II trial who were transported by HEAS. Although 18 (19%) suffered an episode of hypotension, there were no cardiac arrests or cardioversions during transport, the incidence of bleeding problems was similar to a ground-transported control group, and in-hospital mortality was as expected for this population (6.3%). Low rates of in-flight complications were also reported among 104 patients transported by HEAS in Michigan,[36] and among 250 patients with AMI in North Carolina,[37] of whom 72% received thrombolysis before or during the flight.

HEAS transport of patients with AMI therefore appears to be relatively safe, but there is little data available to determine whether it can save time and reduce mortality, or whether it is cost-effective. The efficacy of thrombolytic therapy is clearly related to the time from symptom onset to administration of thrombolysis,[51] so reduced transport times should result in reduced mortality. However, reduced transport times, compared to a control group, have yet to be demonstrated specifically for HEAS-transported AMI victims. Hotvedt et al,[20] in a descriptive study of the role of HEAS for a mixed group of patients in Tromso, Norway estimated that HEAS resulted in patients arriving at hospital 69 minutes earlier than would have been the case with ground ambulance. Despite this impressive time-saving, a Delphi-technique consensus estimated that patients transported with cardiovascular diseases only gained an average of 0.54 years of life as a result of receiving HEAS transport. It is also unlikely that time-savings of 69 minutes could be achieved by HEAS in the United Kingdom.

Cerebrovascular accident

Early administration of thrombolytic therapy is also the rationale behind using HEAS for CVA victims, although the evidence of benefit from thrombolysis in CVA is much weaker and the time-frame for effective administration is smaller. Conroy et al[38] reported descriptive data from 73 CVA victims transported by HEAS, of whom 8 (11%) received thrombolysis prior to transport. The rest were transported to hospital where 52% were enrolled into studies of stroke therapy and 48% received neither thrombolytic nor experimental therapy. Although it was estimated that HEAS reduced transport times, it is clear that further evidence of treatment effectiveness is required before a strong rationale for HEAS transport of CVA victims exists.

Cardiac arrest

Early defibrillation improves the chances of survival after cardiac arrest due to ventricular fibrillation. Concerns that defibrillation might interfere with the safety of HEAS appear to be unfounded,[52,53] so HEAS may have a role in reducing the time to critical interventions.

Two studies have reported cohorts of victims of non-traumatic cardiac arrest treated by HEAS providers. Skogvoll et al[39] reported data from 541 calls to an HEAS in Trondheim, of whom 36 (6.6%) survived to hospital discharge. Lindbeck et al[40] reported data from 84 victims of cardiac arrest attended in Virginia, of whom 29 were transported to the emergency department and one (1%) survived to hospital discharge.

These data produce estimates of the incidence of HEAS-assisted survival of 0.46 and 0.1 per 100,000 population per year. Both systems operated in regions with a sparsely dispersed population, so it may be reasonable to assume that these survivors would have died without HEAS intervention. No such assumption can be made in the United Kingdom, where rapid ground ambulance responses can be expected for out-of-hospital cardiac arrest. Hence there is no reliable evidence that HEAS will provide effective, or cost-effective, care for cardiac arrest victims in the United Kingdom.

Obstetric and neonatal emergencies

HEAS offer a potentially rapid means of transporting obstetric or neonatal expertise to women with obstetric emergencies, or to transport women and neonates to specialist facilities. However, there are substantial concerns about the safety of in-flight delivery.

A survey of air medical programmes in the United States found that 5% of air medical transports involved obstetric patients,[41] but the services were often poorly prepared for their needs. An earlier survey by Low et al[42] found that there were no in-flight deliveries among 357 reported transfers. There was some evidence in this survey that women were selected for transport, with HEAS transport being avoided for those in late labour.

A descriptive study from Texas[43] reported no in-flight deliveries among 22 women transported by HEAS whilst in labour. This study estimated that the costs of air transport were substantially higher than those of ground transport ($4226 versus $742) and concluded that aeromedical transfer had only a limited role in the management of preterm labour.

Holt and Fagerli[44] reported 267 transports of 275 sick newborn infants over a ten-year period in Norway. Most were by fixed-wing transport, with only 34 transported by HEAS. They concluded that transport of very immature infants (<26 weeks gestation) should be avoided and, if possible, very low birth weight infants should be transferred in utero, due to the risk of in-flight complications, hypothermia and associated mortality.

All these studies report services operating in regions with widely dispersed populations and provide no comparison to a ground-ambulance control group. Thus there is no evidence that HEAS provides any advantage over ground-based obstetric or neonatal services in the United Kingdom. HEAS is likely to be substantially more costly, however.

Burns

Although patients with severe burns or airway burns may require emergency treatment, the principal rationale for using HEAS to transport burns patients is to provide rapid transport to specialist burns care.

A number of studies have reported data from burns patients transported by HEAS. Treat et al[46] described 148 aeromedically transported burns patients. No patients died in-flight and the authors concluded that aeromedical transfer did not affect overall mortality, although no comparison was made to a control group.

Baack et al[47] compared 81 HEAS transported burns patients to 81 randomly selected, ground-transported controls. They found no difference in transport times and identified that 56% of the HEAS transported patients required no acute treatments. De Wing et al[48] compared 47 HEAS transported burns victims to 47 matched, ground transported controls and found no difference in outcomes. Although HEAS transport for significantly quicker than ground transport it was 7 to 8 times more expensive.

Although HEAS transport for significantly quicker than ground transport it was 7 to 8 times more expensive.

Hence, although HEAS transport for burns patients appears to be safe and may be quicker than ground transport, there is no evidence that it improves outcomes and it is much more costly.

Other non-traumatic conditions

HEAS transport of other non-traumatic conditions is unusual, although transport of victims of hypothermia and poisoning have been reported. In both cases HEAS transport may be justified by rapid transport to definitive care.

Fox et al[49] reported 17 patients with hypothermia who were transported by HEAS, of whom one died, and concluded that there were no long-term adverse consequences of HEAS transport. Hodvedt et al[20] reported a mixed group of patients, including patients with infections and poisoning, for whom they estimated, using expert opinion by a Delphi approach, that HEAS transport provided a small benefit in terms of life-years gained. Jones et al[50] also reported a mixed cohort of patients, a quarter of whom had suffered poisoning. A small number of patients with carbon monoxide poisoning may have benefited from early evacuation to a hyperbaric chamber.

The small number of cases reported and absence of any control group mean that no firm conclusions can be drawn regarding the benefits of using HEAS to transport these patients.

Summary

HEAS may have a role to play in providing rapid access to definitive care for patients requiring specialist treatment, such as women in preterm labour or burns victims, or reduced response times for those with conditions amenable to effective, but time-dependent treatment, such as AMI and cardiac arrest. HEAS appears to be a safe means of transport for victims of AMI, CVA, and burns, but concerns remain about the risk transporting very low birth weight infants.

Most studies do not report comparison to a control group and have been undertaken in regions with a widely dispersed population, so there is very little evidence that the theoretical advantages of HEAS transport will produce benefits for patients in the United Kingdom. Where comparison to a control group has been undertaken, time-savings associated with HEAS transport have not resulted in improved outcomes.

3.4 Potential benefits of HEAS in transfer of patients between hospitals

3.4.1 Introduction

Most people in need of hospital care can be cared for adequately at their local district general hospital. However, a small proportion of critically ill patients may need to be transferred from a hospital to a unit which can provide more specialist care and which will increase their chance of survival. This role has traditionally been carried out by ground ambulance services although the introduction of Helicopter Emergency Ambulance Services (HEAS) in the 1980s and 1990s has seen some of this load taken on by helicopters[54,55]. All HEAS in the UK carry out inter-hospital transfers to a greater or lesser extent. (See section 2).

This review looks at the evidence to support the use of HEAS in the transfer of patients from hospitals to facilities were they will receive definitive care. Where possible we have tried to compare the relative effectiveness for patients of air versus ground inter-hospital transfer, and considered any wider implications for services and their organisation.

3.4.2 Evidence

There are very few prospective studies comparing groups of patients transported by helicopter and land transport. No randomised controlled trials have been carried out, which would provide the best evidence to compare the relative effectiveness of helicopter and ground ambulances in the inter-hospital transfer of patients.

A key comparative outcome for any study of air versus ground inter-hospital transfer is mortality. A few non- randomised prospective studies have compared mortality rates in patients that were transferred by either land ambulance or helicopter. We have found three prospective evaluations which have adjusted comparisons for severity of condition or have presented data from which direct comparisons adjusted for severity could be made (Table 8). The strongest of these studies compared HEAS patients with other patients for which HEAS was also selected but which were transferred by G/A because the HEAS was not available[57]. This study found a non-significant 30% increase in the odds of death with HEAS. The other two studies estimated a substantial reduction in chance of death with HEAS[56,58].

Other studies have reported positive mortality outcomes when transferring very ill or injured patients by helicopter[59-61]. These studies demonstrate that patients with very serious conditions such as major trauma, and myocardial infarction can be safely transported by air ambulance. They do not however contribute to an argument for the superiority of such a mode of transport over ground services.

A potential advantage in moving patients by helicopter is the possibility of reducing the time spent transferring the patient from a general hospital to a specialist facility, compared to conventional ambulance transfer. Air transfer may reduce the out of hospital phase when very ill or injured patients are most likely to deteriorate. In the comparative studies the time from request of the ambulance to arrival at destination hospital was significantly less for those transported by air compared to those moved by ground[56-58]. However another study reported significant delays on the ground in a group of patients who required interventions by flight crew before they were able to travel[60].

There are no studies that identify which patients would specifically benefit from air as opposed to ground inter-hospital transfer. Studies only identify people who would benefit from inter-hospital transfer per se, such as those who sustain multi-system trauma, head or spinal cord injury and burns where treatment in trauma or burn centres has been shown to improve outcome. Other patients who might benefit from transfer include neonates, paediatric patients, cases requiring specialist surgery, high-risk obstetrical patients and some coronary cases such as aortic aneurysms[54,62].

Studies reporting safe inter-hospital transfer using helicopters for cardiac and trauma patients have mainly been carried out in the North America. In these studies the transfer of patients has been characterised by high levels of medical expertise in the helicopter crew. Staff such as respiratory therapists, anaesthetists, flight nurses specialising in critical care and in some cases hospital physicians have been involved in care of patients transferred by air. In some instances these crew have carried out advanced procedures such as central venous cannulation, chest tube insertion and pericardiocentesis[61]. However in the UK crewing arrangements vary between HEAS, but are often paramedics not specifically trained for IHT (see section 2).

An obvious downside of helicopter transfer by air is the relative cost of this mode of moving patients compared to ground ambulances. Helicopters cost in the region of £1 million pa to run and with numbers of patients who might benefit from such transfer unclear then their cost effectiveness for IHT has been called into question[63]. An additional problem with helicopters in hospital transfers IS the availability of appropriate landing areas on or near both hospital sites, which may necessitate initial transportation by ground ambulance[63].

3.4.3 Conclusion

Inter-hospital transfer of seriously ill or injured patients is risky, particularly for neurosurgical patients. Evidence for the safe transfer of patients has been demonstrated in studies were helicopters have been staffed with hospital physicians, anaesthetists or respiratory clinicians which is not the norm in this country.

However, optimally staffed and equipped helicopters such as those described in the literature seem to offer a safe mode of inter-hospital transfer for a variety of very ill or injured patients. A dedicated, specialist HEAS crew configured to safely transfer patients between hospitals over a wide area could reduce the need for hospital staff to travel with transferred patients and could free up ground ambulance service time for 999 calls. Of course a ground ambulance dedicated to IHT would also leave emergency ambulances in place to respond to 999 calls, and the question is really one of the cost-effectiveness of these options.

Where most of the evidence for inter-hospital transfer by helicopter originates (North America) geography and demographics mean that people in isolated rural areas may be many hundreds of miles from sites of optimum care. It is in such instances that the advantages of time in transfer from hospital to tertiary care facilities will be maximised. If tertiary facilities in the UK were set up to serve large populations over a wide geographical area, then advantages of faster inter-hospital transfer by helicopter would also be realised, particularly for patients living in rural areas.

The use of HEAS covering large areas might also mean fewer specialist and tertiary facilities would be required, potentially leading to cost savings. Overall HEAS may have a valuable role to play in inter-hospital transfers in any future reorganisation of secondary care services.

3.5 Benefits for other emergency patients not attended by HEAS

Aside from the effects on individuals attended by a helicopter ambulance, it has been suggested that helicopter ambulances may bring benefits to health services in other ways, including to patients attended by ground ambulances. However, the research evidence concerning these other types of benefit is sparse.

3.5.1 Performance

Ambulance Services have argued that having a helicopter option brings operational benefits, particularly in services which cover large rural areas. In a rural area, because incidents occur infrequently due to the sparse nature of the population, ambulances are thinly spread over a wide geographical area. Distances between ambulance stations, incidents and receiving hospitals are often long therefore. Dispatch of one or two vehicles to incidents in remote areas can tie up those ambulances for considerable periods of time and can leave large areas without any available nearby cover, affecting response capability significantly. The addition of a helicopter ambulance to the service may provide a back-up for these periods, or indeed, be used as the primary responder to avoid tying up the scarce ground ambulances for prolonged periods. Equally, a helicopter may avoid an emergency ground ambulance being tied up for several hours transferring a patient between hospitals, leaving the AS short of one emergency ambulance for the duration of the IHT[64].

Very little attention has been given to this issue in the research/evaluation literature, which has tended to focus on the issue of whether patients attended by the helicopter benefit directly in terms of processes or outcomes of care. However, two papers have looked at the benefits for other patients [65,8], both papers reporting results of separate studies on the same HEAS. The service studied is based in South West England, by British standards a very rural service with a sparsely populated geographical area.

In Rouse's study, the prehospital intervals for patients with compound fracture of a lower limb were compared for calls that originated during periods when the helicopter was operational with calls that originated during periods when the helicopter was not operational – immaterial of actual mode of transportation to hospital. No difference was found inperformance during periods when the helicopter was operational. In fact, fewer patients arrived at hospital within 1 hour during helicopter augmented ambulance service periods than during basic ground ambulance service periods (31% versus 43%, 95% CI of difference, -17%, 41%). The longer prehospital intervals for the helicopter augmented service group seemed to arise from deployment of the helicopter itself, which was often as a secondary responder. Whether as a primary or secondary responder delays were incurred at the point of deployment and through transfers between helicopter and ground ambulance at scene or from helipad to hospital. It is known also, from other studies[6] that on scene times tend to be longer for helicopter attended patients than those that are attended by ground ambulance only. Although the author states that local views held that the additional 'cover' provided by the helicopter could lead to improved mission times for the entire service, the empirical evidence from this study does not confirm this. However, the response times of patients attended by ground ambulance during periods when the helicopter was available are not presented separately, nor were the intervals within the overall prehospital time in each group. Due to the effect of the longer response and on-scene times for those attended by the helicopter, the question of whether the helicopter can improve response times for other patients during periods of cover is not resolved in this paper.

Nicholl has also looked at this issue in the same service, using a different methodology [8]. In this study, the performance of the whole ambulance service was compared for periods of two hours or more when the helicopter was unexpectedly unavailable for reasons other than bad weather with matched control periods one week before and one week after the period of unavailability. This comparison was made over a 3 year study period. Mean response time was the same in the two matched groups, but non-significant improvements with the helicopter were found in the proportion of calls responded to within 20 minutes; the mean total prehospital time; and the proportion of urgent calls completed to time. If there was any

Table 8 **Studies comparing survival following Inter-hospital transfer in HEAS and G/A adjusted for severity**

Place	Author, yr, (ref no)	Method	Type of patients	Number	Results and Conclusions
North Carolina	Moylan, 1988 (56)	Multisystem trauma patients with TS ≤12 transferred by HEAS or G/A	Direct comparison of HEAS vs G/A (adjusted for TS for this review)	HEAS = 136 G/A = 194	Significant reduction in risk of death with HEAS (OR adjusted for TS = 0.24(0.11, 0.51)). Time from injury to Trauma Centre was similar 182 min vs. 175 min. "An organised systems approach to trauma care improves survival".
St. Louis, Missouri	Arfken, 1998 (57)	Patients aged ≥17 for whom HEAS was requested for an IHT.	Comparison of patients transferred by HEAS with those transferred by G/A because of the unexpected non-availability of HEAS.	HEAS = 1234 G/A = 153	Non-significant increase in the odds of death with HEAS adjusted for age, sex, ethnicity, distance, and physiological severity score (RAPS). OR = 1.30(0.71, 2.37). No difference in QoL outcomes. Time from request to arrival at receiving hospital: HEAS=90mins, G/A=221mins.
Savannah, Georgia	Boyd, 1989 (58)	Major trauma (ISS≥15) or urgent operation required in patients aged ≥14 transferred more than 25 miles.	Direct comparison of survival in HEAS vs G/A (adjusted for TRISS for this review).	HEAS = 103 G/A = 110	The OR for death with HEAS adjusted for injury severity = 0.65(0.23, 1.82). Total time from injury to trauma centre = 174 mins for HEAS, 225 mins for G/A.

service-wide improvement in performance then the effect was small - and the author concludes that there is little evidence that a helicopter can improve overall performance more than a similar investment in land ambulance services.

Despite these two studies reaching similar conclusions concerning the lack of evidence of a service-wide benefit, both studies were carried out in one service at a similar time period. This issue deserves further consideration in other settings, with a robust method for evaluating the impact of the helicopter on service performance, at a micro level for individual patients as well as the macro level described in these two studies. In terms of cost-effectiveness, and as suggested by Nicholl previously, the critical issue is not whether the helicopter ambulance simply improves the performance of the whole system, but whether it improves the system performance as much or more than a similar investment in other modes of response – such as ground ambulances - would. This is a particularly important question with respect to the argument about using a helicopter to carry out IHTs, since investment in a single additional ground ambulance could provide a 24hr specialist transfer service with the same benefit of not tying up front-line emergency ambulances.

Interestingly Thomson's 1999 study[66] shows that, once in place, a helicopter ambulance is difficult to replace with additional ground based resources. In this study, demand for the helicopter ambulance continued to rise despite introduction of a critical care ground ambulance, with the authors concluding that the two services are complementary rather than interchangeable. Other than volume of requests, flights and hospital admissions, no measures of process or outcomes were included in this study and the appropriateness of use of either service is not questioned.

3.5.2 Regionalisation of trauma services

Availability of a helicopter ambulance can help to enable the reorganisation of trauma services into a Trauma Centre model[67]. This arrangement is in place over much of the USA. The geography and population distribution, as well as patterns and types of injury in the UK are, however, very different. Regionalisation of trauma services is not the norm in this country, although examples have been tried, such as in N Staffs. Even where services are regionalised, distances are generally short, and the system may not be dependent on the services of a helicopter. On the other hand, with HEAS coverage over most of the country now, helicopters could play a substantial role if regionalisation were to be planned. Trauma system establishment has, however, been held up in this country due to lack of clear evidence over effectiveness and uncertainty about the impact on local A and E departments and on Ambulance Services. There has been no published work in this country concerning the role of helicopters in trauma systems, although some studies carried out in the States do touch on these issues.

Schwab et al describe the impact of an air ambulance system on an established trauma centre[68]. During a one year period, 192 trauma patients were brought to the Trauma Centre, 140 from local hospitals and 52 from the accident scene. Forty nine percent of the flights occurred at the weekend, and 69% between 19.00 and 03.00. One hundred and twenty six patients were considered to have been new or 'captured' by the air ambulance system. Severity of injury and need for intensive care facilities were high amongst patients brought to the trauma centre by the air ambulance. The authors conclude that the introduction of a HEAS to the trauma service had a considerable impact in terms of volume, need for intensive care, and demand for 'out of hours' services. The relevance of this study, however is questionable to the non-competitive UK environment, where major trauma is a less frequent occurrence and distances are shorter, and HEAS don't operate at night.

An earlier study looked at the other side of the coin - reporting the effects of changes in the trauma system to the helicopter service. A decrease in the number of trauma centres in a county trauma system over a three-year period was shown to be associated with a substantial increase in helicopter missions – from 820 in 1985-6 to 1331 in 1987-8.

Dependence of a trauma system on helicopter services being available may also be affected by periods when aircraft are not operational due to bad weather, flying conditions, mechanical failure or hours of darkness. These periods are not inconsiderable: aside from night time hours during which helicopter services are always unavailable for primary missions in the UK, helicopter services appear to be offline for various reasons for about 5 - 10% of total scheduled flying time (see section 2). The most frequent reasons for being unavailable are related to the weather, although maintenance also accounted for a significant proportion of the downtime. As each HEAS usually has only one operational helicopter, it may often be unavailable due to being committed to other missions, and as the 'abort rate' is quite high the helicopter may often be unavailable when an incident appropriate for HEAS response occurs. In Farnell's study[70] 42% of requests were declined due to prior commitment. Finally, a regionalised trauma system which is dependent on HEAS has to overcome the problems that in the UK night time flying is rare and may bring about increased risk to crew and others as well sometimes incurring delay rather than speeding up evacuation[83]. In none of these areas has the effect of helicopter service unavailability on overall performance of the system been described in the literature in the UK or elsewhere.

3.5.3 <u>Other benefits: disaster management, air rescue</u>

Helicopters have been described as bringing considerable benefits to the management of disasters[71] and it has been suggested that helicopters should be integrated into disaster management plans. Difficulties in communications have frequently been highlighted in disaster response, and helicopters have been said to have a potentially valuable role in contributing communications services, although the same authors point out that helicopter services themselves are not immune to the same communications problems as land based services[71]. Thomas cites the example of a 1989 earthquake response in which conversation between personnel at communications centres, ground units and county disaster centres was enabled by two HEMS aircraft acting as airborne 'repeaters'. In addition to contributing to the triage, treatment and transportation of victims, other ways that helicopters can be of help in responding to disasters are cited by Thomas as: surveillance – providing a birds eye view of the disaster; information dissemination e.g. to forward hazardous material information to receiving hospitals; overcoming traffic disruptions; conveying personnel and equipment to and from incident sites.

The role of helicopters in the management of disasters in the UK has not been investigated or described in the literature.

Helicopter ambulances can also be used to aid rescue of victims in remote or difficult terrain, or from, for instance, water based emergencies. Usually dedicated air/sea rescue craft would be used for this purpose and use of HEAS may carry risk to the pilot, crew and others unless appropriate training and equipment are provided[72].

3.5.4 Other effects: noise, disruption, family dissociation, training opportunities, skilled personnel commitment

Other effects of a helicopter service have been discussed, although empirical findings in the research literature are remarkable by their absence. Helicopter ambulances may clearly cause disturbance to traffic, day-to-day activities in the vicinity of landing sites and to separation of family members by transportation to remote receiving hospitals.

Considerable additional disruption can be caused at the scene of incidents by the need to prepare a landing site for a helicopter, with police generally clearing traffic and sometimes closing entire carriageways of the motorway to allow landing and evacuation of injured patients. Consideration needs also to be given to frequently used landing pads, which may cause concern to the local community.

The need to handle victims relatives appropriately has been tackled in a paper by Fultz. In her 1999 paper[73], Fultz uses a case report involving a fatality and serious injury within one family to illustrate issues which arise. In this paper issues around separation, communication and potential immediate mortality are addressed. Similar issues may arise in the UK, although the longer term consequences of having a family member hospitalised at a hospital that may be far away from home are not acknowledged in this or any other identified paper.

Services that use a helicopter ambulance, particularly for primary trauma missions often express enthusiasm for the training opportunity that is afforded to the service. Paramedics would normally attend a seriously injured patients infrequently – possibly once every month or so, depending on working environment[74]. On board the helicopter, seriously injured patients are attended during most shifts. This gives the opportunity for crew members – both medical and paramedical – to learn new skills and to practise existing skills. Of course, conversely, paramedics throughout the service as a whole will use their skills for trauma patients even less frequently than usual, but the balance of benefits and disbenefits does not appear to have been examined empirically in the literature

A final element, often overlooked, which may help explain the proliferation of helicopter ambulance services despite the lack of clear evidence is the good feeling, or ‘superman’ effect of the helicopter. Although little has been written about this effect, it seems to be powerful, and may be reflected in the ambulance service, accident and emergency receiving units, crews, patients attended, families of patients, local politicians, the press and the general public. Charities have been very successful in supporting local helicopter ambulance services and the public clearly seem to be very willing to believe in the effectiveness of a helicopter ambulance, and to donate funds to keep a helicopter operational.

3.5.5 Summary of findings and discussion

The impact of a helicopter ambulance on the emergency service as a whole, or on other patients that are not themselves attended by the helicopter is not adequately assessed by the current research literature. Attention should be paid to these factors when designing future evaluations, although the issues are complex and appropriate and robust methods would be needed to fully explore these potential benefits and disbenefits.

3.6 **Safety**

3.6.1 HEAS accident rates

The accident rate for US helicopter emergency ambulance services (HEAS) is approximately twice that of commercial helicopter operations[75] and the fatal accident rate about 3.5 times greater[76]. Rhee et al[77], in their comparison of US HEAS accident rates to US domestic air taxi service and HEAS in the Federal Republic of Germany (FRG), found that emergency air transport is inherently more risky than routine air taxi services.

In relation to US HEAS a total of 122 accidents occurred between 1978 and 1998 during patient-related missions only. These numbers only related to dedicated HEAS and do not include accidents to private or public aircraft that may also perform occasional medical transport. Regarding fatalities, in the 1980s, 42% of all accidents resulted in at least one fatal injury. In the 1990s this rose to 56%[78].

During the early 1980s the number of flight programmes in the US more than tripled and there was a significant rise in the number of accidents. The National Transportation Safety Board (NTSB) studied 59 HEAS accidents that occurred between 1978 and 1986, reporting in 1988[76]. Forty-seven (80%) of these accidents were on patient mission flights.

Blumen et al[79] studied HEAS accidents in the three year period during 1998 to 2000. They found a further increase in the number of HEAS accidents in the US: 30 accidents in three years. Since 1986, dedicated HEAS have averaged 5.6 accidents per year; during 1998 to 2000 this averaged ten per year. Of the 30 accidents during this three year period, 11 (37%) resulted in at least one fatality.

Despite the increase in accidents during 1998 to 2000 there has been a substantial improvement in the fatal accident rate per 100,000 flight hours. The current rate, although showing an increase in the past few years, is approximately 75% less than during the worst years in the 80s (approximately 8 per 100,000 in 1985, compared to approximately 2 per 100,000 in 2000). Calculating the percentage of helicopters that were involved in HEAS accidents each year, Blumen et al found a high of 14.5% in 1982 (9 accidents, 62 helicopters). In comparison, in 1996, when an estimated 309 dedicated medical helicopters were in operation, there was one HEAS accident, a total percentage for that year of 0.3%.

In relation to other countries, the overall accident rates for the US HEAS (11.7/100,000 hours) and the fatal accident rates (4.7/100,000) did not significantly differ from the Federal Republic of Germany (FRG) HEAS overall rates (10.9/100,000 hours) and fatal accident rates (4.1/100,000 hours) compared during 1982-87[77].

The US HEAS and the FRG HEAS systems differ in terms of flight times, time of day flown, and types of craft flown. However, despite these differences the accident rates are very similar, illustrating a common, shared experience thought to be inherent in HEAS operations[77].

In the UK, there has been one fatal accident involving a pilot and two paramedics from Kent Air Ambulance, in 1998.

3.6.2 Factors associated with US HEAS accidents

Night flying. Since 1988 an average of only 38% of all HEAS flights have been at night but 49% of the HEAS accidents occurred during night operations (53 of 107)[78]. Since 1998, an even higher percentage of HEAS accidents have occurred at night (62%)[79].

Cause of HEAS accidents. During 1978-98 Frazer[78] reported a total of 68 (65%) accidents were due to pilot error, and 26 (25%) were mechanical. Three were unknown and nine were still to be determined. The identified causes of these accidents are detailed in Table 9.

A study of 87 accidents from 1987 to 2000 found that human error was the primary causal factor in 66 accidents (76%) and 27 fatal accidents (84%)[80]. The NTSB identified four major factors in the 59 HEAS accidents studied during 1978-86: pilot error (68%); weather (30%); mechanical failure (25%); and obstacle strikes (20%)[76].

The NASA-Ames Research Center looked at reports of helicopter incidents that did not result in accidents from 1986 to 1991[81]. The NASA report compared their findings with the 1988 NTSB report and found several similarities in relation to operational factors. Similarities involved phase of flight, airspace, weather conditions, and pilot experience.

Weather conditions. The quality and interpretation of weather information was highlighted as a concern in all studies. The NASA report found that pre-flight weather briefings had been obtained in 80% of the incidents, but 75% of the briefings did not match the actual weather conditions the pilots encountered in flight.

During the 20 year period studied by Frazer[78], 23 (22%) accidents were weather related; 17 (16%) of which were fatal, during the 80s. The of weather-related accidents in the 90s rose to 32%. The weather related accidents reported by the NTSB for 1978 to 1986 accounted for 61% of the fatalities. The NTSB concluded that poor weather posed the greatest single hazard to HEAS operations[76]. The NTSB reported that pilot training was often lacking in interpretation of weather conditions and in instrument flight procedures. However, during the three year period for 1998 to 2000 reviewed by Blumen and the University of Chicago Hospitals Safety Committee there appeared to be six weather–related accidents, reducing the percentage of weather-related accidents to 20%[79].

Table 9 US HEAS accidents by cause (1978-98)

Cause	Total number of Non-Fatal Accidents	Total number of Fatal Accidents
To be determined	4	5
Unknown	3	-
Improper Maintenance	4	-
Flight Controls	5	3
Engine	12	2
IFR: Failure to Follow	-	1
Engine: Wrong Shutdown	-	2
Foreign Object into a/c	3	-
Other	2	-
Fuel Starvation	-	2
Loss of Control	9	3
Hit Obstacle	15	3
Spatial Disturbance	1	4
Weather	6	17

Source: Blumen (2001)

(light shading) = Mechanical error

(dark shading) = Pilot error

Nearly half of all HEAS accidents studied by Frazer occurred at night[78], and his review also found that 88% of weather-related HEAS accidents occurred at night, suggesting a strong interaction between these factors.

Pilot experience. Does experience and 'high' flying time prevent accidents happening? Of the pilots involved in HEAS accidents during 1978-98, the lowest total hours of flying time was 1,432 and the highest was 14,000. More significantly perhaps, in 27 of the accidents the pilot had less than 200 hours of flight time in the make and model of the aircraft they were flying at the time of the accident. Eighteen had less than 100 hours and one had only three hours[79].

Engines. Are two engines better than one? Of the 14 accidents attributed to engine problems during 1978-98, 10 were single engine and 4 were twin engine. However, lighter, less expensive, single-engine helicopters were used exclusively until 1980, when a larger twin-engine helicopter was introduced for EMS use[82]. Therefore, in the early years of HEAS, more of the accidents were in single-engine aircraft.

Human error. In relation to human factors, concerns involved communications (78% reported), time pressures (64%), and distractions (60% reported). Workload (12%) and flight/duty conditions (4%) were also identified[79].

Sixty per cent of the communication incidents involved pilot-air traffic control, and 13% were communications problems between pilots and weather services (i.e. poor or inaccurate weather information). Other reported problems involved communication difficulties between pilots, HEAS dispatchers and ground personnel.

In relation to time pressure, patient condition was reported 44% of the time and was the most important contribution to time pressure as 'the critical condition of a patient could create a sense of maximum urgency'79. Other problems involved not stopping for refuelling, failure to obtain or review correct charts, over-flying scheduled aircraft maintenance, and inadequate or 'less-than thorough' weather briefings.

Distraction from flying the aircraft included in-flight aircraft equipment problems, interruptions, radio frequency congestion, marginal weather, noise from on-board medical equipment and impending low-fuel situations.

The NASA study concluded that workload and flight/duty considerations were not a significant contributor to any HEAS incident. However, these factors can influence judgement, error recognition, concentration, and fatigue and ultimately lead to aviation incidents[79].

3.6.3. Conclusions

Since 1972, it is estimated that in the US HEAS has flown an estimated 2.78 million hours, transporting approximately 2.54 million patients. In 29 years there have been 154 accidents involving dedicated medical helicopters and four accidents involving dual-purpose helicopters in the US. In 60 fatal accidents, 159 people have lost their lives, including 139 crew members. Although there has been a decrease in the accident rate since the mid-80s, since

1990, there has been an average of 2.4 fatal accidents annually, involving the lives of approximately 6 crew members per year.

It is important to note that the US HEAS accident rates and fatality rates are based on several industry wide surveys and various calculations. The number of HEAS programmes and dedicated helicopters may have been underestimated by ten percent or more. Therefore, the calculated accident and fatality rates could be overestimated by approximately ten percent. However, this difference should not affect the overall trends identified nor bias the study of the factors involved in the accidents.

A disproportionate number of accidents occurred during night flights. Since 1998 a higher percentage of HEAS accidents have occurred at night (62%) and more accidents have occurred during the cruise phase of flight, but there was also an increase in the number of accidents occurring on landing. Pilot error was attributed as the direct or indirect cause of HEAS accidents nearly three times more often than mechanical failure. Pilot fatigue and total hours of flight do not appear to be significant factors in HEAS accidents. However, communications problems, time pressures and distractions are frequently identified as contributing risk factors in HEAS incidents (Blumen, 2001).

In relation to pilot errors, one in three are weather-related. Although there may have been a decrease in the percentage of weather-related accidents during the 80s and 90s, from 32% to 20%, deteriorating weather conditions still represent a significant risk – weather is the second most common factor or cause of HEAS accidents. The cause of weather-related accidents generally relates to the pilots' encounter with poor weather en route rather than a pilot's disregard for reported weather conditions. This raises concerns regarding the quality and interpretation of weather information. Of the weather-related HEAS accidents, over 85% occurred at night and approximately 75% of all weather–related HEAS accidents resulted in fatalities.

In summary:

- There has been a decrease in accident rates since the 1980s, but HEAS accidents are still more likely to result in fatalities or serious accidents than other helicopter accidents.
- Pilot error is three times more likely to be attributed to cause than mechanical error, often due to weather-related factors.
- There is a correlation between accidents occurring at night, during the cruise phase of flight and weather-related causes.
- The high accident rates and some of the causes of error, suggests that there may be a conflict between safety and medical needs which sometimes leads to high risk-taking behaviour.

4. OPERATIONAL ISSUES

4.1 Call out procedures

In general, air ambulances are called out for 3 types of mission:

- Primary scene responses – where the helicopter is dispatched directly to an incident scene as a response resource to a 999 call
- Secondary scene responses – where the helicopter is dispatched following a request from others already at the scene
- Tertiary responses – planned missions, for example inter hospital transfers (IHTs)

There are two main issues related to call out procedures, these are:

1. Tasking – the process of dispatching the helicopter when it is required

2. Call selection – the decision making process that guides which calls require a helicopter response

4.2 Tasking for primary and secondary emergency responses

There are a number of mechanisms for activating helicopter ambulance services. Tasking can be direct – that is a request for activation to the helicopter service itself, or indirect via a second agency such as ambulance service control.

In the UK, activation is principally via an ambulance service control. All primary responses are via this route and the helicopter is dispatched following a 999 call. The decision to activate the helicopter is made by the ambulance service dispatcher in response to the information received by the 999 caller who may be a member of the public. Secondary responses are also activated via ambulance service control following a request from an ambulance crew or doctor on scene. Direct requests can also be made from other emergency services (e.g. mountain rescue, coastguard) and, in some remote areas, by GPs. In Australia primary and secondary HEAS dispatch is also mediated by the ambulance service but there is a separate retrieval service for inter-hospital transfers[85]. France[86] and Germany[87] operate similar systems in which helicopter ambulance services are dispatched as both primary and secondary responses from EMS control. In France this is a physician led service.

In Switzerland, a national network of helicopter ambulances is controlled by a dedicated central dispatch centre accessed by a single telephone number. Both primary and secondary responses are made following a direct request to this control including those made by members of the public[88]. A similar system operates in Norway but there is no single access telephone number. Instead each individual helicopter service is accessed by its own telephone number.

In contrast, in the USA, all responses are secondary responses following a request from the EMS or other public safety agency at the scene of an incident[89]. HEMS cannot be directly accessed by the public.

Helicopter ambulances are an expensive resource and their use is not without risk, so, whichever system is in operation some decision has to be made, either in the control room for primary responses or at the scene for secondary responses, about which incidents HEAS should be dispatched to. This requires some form of call selection to identify calls that may benefit from a HEAS response and therefore appropriate deployment.

4.3 Call selection criteria in England & Wales

A variety of criteria have been proposed and used to try and identify calls suitable for a HEAS response. These criteria fall into 3 main categories:

- Patient characteristics
- Incident characteristics
- Geographical/time characteristics

Our survey of UK air ambulance services has revealed that within each category a large number of indicators are used, some of which are general and others very specific. These are discussed in more detail below.

Patient characteristics

Patient characteristics range from broad condition types (major trauma, medical emergencies) more specific condition types through to detailed physiological parameters. The combined full range of patient characteristics used by UK services is given below

General condition types

- Major or multi-system trauma
- Time critical medical emergencies

Specific condition types

Trauma

- Major abdominal/head/chest/pelvic injuries
- High velocity/penetrating injuries
- Two or more long bone fractures
- Limb paralysis/amputations
- Spinal injuries
- Burns - adult >15% total body surface, children >10% TBS

Medical

- Anaphylaxis
- Severe chest pain
- Carbon monoxide poisoning
- Cardiac arrest

Physiological

- Respiratory obstruction/airway compromise
- Unconscious/decreasing loss of consciousness
- Systolic BP <90mmHg
- Pulse rate <50 or >140bpm
- Respiratory rate <10 or >30/minute

Incident characteristics

Incident characteristics are used as indicators for general events or more detailed descriptors of incident types or mechanisms. The rational for using these types of indicators in the absence of any specific patient information is that they are often indicative of potential serious injury or life-threatening conditions.

General incident characteristics

- Serious Road Traffic Accident (RTA)
- Motorway incidents
- Aviation/rail incidents
- Explosions
- Agricultural/industrial incidents involving heavy machinery
- Large/untoward incidents
- High profile/major incidents
- Fires with the likelihood of burns/inhalation injuries

Specific incident characteristics

RTA

- Impact speed > 30mph
- Head on collision
- Roll over of vehicle
- Death of vehicle occupant
- Motorcycle impact >20mph
- Pedestrian struck by vehicle travelling >20mph
- Entrapment

Other

- Fall from height >15 feet (6 feet in children under 3)
- Drowning/near drowning

Geographical/time characteristics

These characteristics are related to access and distances or road travel difficulties which may result in long response or transport times. They also include ambulance service operational considerations related to response time performance.

Geographical characteristics

- Isolated locations
- Locations with difficult access for land vehicles

Time characteristics

- Land journeys to scene >20 minutes
- Land journeys from scene to hospital > 30 minutes
- Delay in response time due to heavy traffic
- Conditions requiring direct transfer to specialist facilities

Operational characteristics

- Land ambulance cannot meet category A response time target
- Use of air ambulance will leave a ground ambulance in a rural community
- No land ambulance available

With the exception of response time performance criteria different combinations of all these indicators or variations of them are used internationally.

4.4 Assessment of call selection criteria

In general, indicators and guidelines for the deployment of helicopter ambulances have been developed by expert opinion and consensus methods[90] or extrapolated from criteria used in related areas. For example, many of the indicators are those that have been suggested as useful to identify individuals with major trauma and an assumption made that these patients will benefit from a HEAS response. A few descriptive studies have discussed the advantages of helicopter rescue in difficult access locations such as mountain rescue[91-93] in terms of both reduced response and transport times and the ability to deliver advanced life support. However, very few indicators have been properly investigated for their ability to accurately identify appropriate cases for helicopter deployment.

One Swiss study has assessed the injury profile of occupants ejected from vehicles[88]. They found that these patients were more severely injured and required more ALS interventions than non-ejected occupants of vehicles and concluded that, based on mechanism of injury alone, ejection was a sufficiently robust indicator for automatic dispatch of a physician staffed helicopter. Similarly, another descriptive study in Italy identified entrapped patients as seriously injured and requiring ALS interventions and therefore suitable for helicopter response. However, in this setting land services only provide BLS care and the helicopter is used to deliver ALS care. Only helicopter attended patients were included so it cannot be determined whether this provides any advantage over a ground ALS service.

An observational study of helicopter transported trauma patients in Australia[85] found no benefit for cases that occurred within 35km of a major trauma centre and concluded that HEAS should not be tasked as a primary response to these cases.

Another study in the USA evaluated the efficacy of helicopter attendance for patients with noncranial penetrating injuries[94]. Helicopter transport did not result in faster arrival at a trauma centre for any patient and only 5% of patients required medical interventions by the flight crew that could not have been provided by the first responding ground crew. The study recommended that in a metropolitan area HEAS should only be deployed where it is likely to significantly reduce time to arrival at hospital or where medical care beyond the capabilities of the ground crew is required.

A small number of studies have investigated the used of combined indicators and guidelines for deployment of HEAS. A prospective study of basic vital signs, two mechanisms of injury and time distance factors as a triage tool found that one or more abnormal vital signs accurately identified major trauma patients. When combined with time distance factors this could be helpful in determining when a helicopter should be used as a secondary response[95]. Other studies have attempted to evaluate the effectiveness of transport guidelines. One found AAMS guidelines could identify most patients with serious injury and from this makes the assumption that this justifies helicopter response[96]. However, only helicopter transported patients were included and no comparison was made with ground transportation so the true benefits of a helicopter response were not measured. Another study found that even using deployment criteria 60% of helicopter responses were considered inappropriate[97].

The lack of empirical evidence about robust indicators for HEAS deployment means that deployment guidelines have, in general, developed at local level using different combinations of characteristics and taking into account the geographical operating area. As a result they vary in their complexity. The AAMS guidelines[90] provide a comprehensive set of criteria covering access, time and a variety of trauma, medical and surgical conditions. In Contrast, in Germany, helicopter deployment is purely tactical and is used only where use of HEAS will significantly reduce response or transport times, irrespective of medical condition[87]. In other systems condition type may define the operational scope of a helicopter service, for example some services only deploy helicopters for trauma cases. However, the presence of trauma alone does not justify helicopter use and can result in inappropriate use. This is particularly difficult where HEAS is used as a primary response and deployment is made on limited information available from members of the public making an emergency call. In the UK only the London HEMS specifically targets trauma patients. In this service the difficulties of determining both which patients have major trauma and who require a helicopter response resulted in a substantial proportion of patients receiving an inappropriate response, that is, patients who were not transported by helicopter and who did not require medical assistance from the HEMS doctor. The introduction of a HEMS response desk in ambulance control staffed by a paramedic who reviews calls for potentially serious trauma cases and who further questions the caller for more detailed information has substantially reduced the number of inappropriate HEMS responses[98].

In the rest of the UK, helicopter ambulances are tasked for a range of conditions. Deployment strategies range from simple guidelines based on logistical criteria to more developed protocols that use combinations of access, patient condition and geographical/time indicators.

A few ambulance services have introduced HEAS support desks within their control rooms in order to try and improve call selection and tasking. All UK ambulance services now have Emergency Medical; Dispatch systems to facilitate call prioritisation. However, at present these systems are of limited use in HEAS deployment as the response options only distinguish between type of response – ALS or BLS – and speed. They have not been designed to select calls suitable for HEAS and further research is required to examine if there is any relationship between EMD prioritisation codes and appropriate air ambulance deployment.

There are no definitive guidelines for call selection and HEAS tasking. At present individual services develop their own deployment strategies adapted to local circumstances, for example time/distance factors may be more important in very rural services with remote locations than urban services. However, there are some basic principles that can to be taken into account[89] which are that:

- The purpose of aeromedical emergency transfer is to provide better initial patient care and transport than available alternatives
- Air response is only justified where the speed of transport, skill of the medical team and/or ability of the helicopter to overcome environmental obstacles contribute to improved patient outcome
- In trauma, helicopter deployment is not justified if it does not significantly reduce the time between injury and the patient arriving at an appropriate hospital unless the response delivers additional medical expertise or equipment to the scene

Use of a dedicated air ambulance dispatcher in the ambulance control room may result in more appropriate deployment. There is also a need for further research to explore the possible development of call selection within EMD systems. However, at present, there is no real solution to the problem of appropriately selecting calls for primary response on the basis of information from the public. The best strategy may be to restrict deployment to secondary responses requested using triage guidelines at the scene of an incident.

4.5 Crewing

Internationally there are substantial differences in the crewing profile of air ambulance services. In much of Europe (France, Germany, Norway, Italy) helicopters are staffed by physicians as only this group can provide pre-hospital ALS care. In Australia a variety of combinations are used utilising physicians, flight nurses and paramedics. The predominant model on the USA is paramedic and flight nurse teams, and in the UK, with the exception of London HEMS, all HEAS are usually staffed by paramedic only crews. There are also differences in the range of clinical skills available to different groups, for example, some paramedics in the USA and Australia have a greater scope of practice than their UK counterparts. Consequently the optimum staffing profile for HEAS primary and secondary response remains controversial.

Much of the research in this area has focussed on investigating the possible benefits of providing a physician response. Table 10 provides a summary.

Several studies[99-101] have used opinion based designs to assess the contribution made by physicians to patient care. In two of these studies requirement for a physician was judged to be 22%[100] and 25%[99] and in both cases it was suggested that this was sufficient to justify physician staffed helicopters. The other study[101] found that physician presence was most useful for scene response flights and was not necessary for interhospital transfers where a flight nurse performed just as well.

A number of other studies have attempted to compare physician staffed helicopters with flight nurse and/or paramedic crews for trauma patients. One quasi-randomised study found lower mortality in the physician group[102]. Others have reported similar findings[103,104] and in all of these studies the physician attended patients also received more medical interventions which may have contributed to better survival. In one study[104] the physician attended group were more severely injured suggesting that the groups were not comparable. In all of these studies it is acknowledged that it may be additional treatments that is the key factor rather than who performs them. Several other studies have found no difference in patient outcome between physician and nurse/paramedic crews with additional clinical skills[17,105,106]. These suggest that, given an appropriate range of skills, flight nurses and paramedics can perform as well as physicians. Aggressive airway management in particular has been cited as contributing to improved patient care whether performed by physicians[103,104,107] or Flight nurses/paramedics[17,108].

In the UK helicopter ambulance services are predominantly crewed by paramedics who do not have the additional skills available to flight nurses and paramedics in the USA. As a result patient management is the same as that provided by ground crews and so HEAS cannot usually provide and clinical treatment advantages.

Optimum crew composition for HEAS remains controversial and there is no definitive evidence to suggest which combination is preferable. The evidence that is available suggests that the ability to perform a range of clinical procedures, and in particular advanced airway management is important, but that this skill is not confined to physicians and can be successfully used by nurses and paramedics. Nurses are not part of flight crews in the UK at the moment but the use of nurses and paramedics with additional clinical skills could be explored. The question of whether this combination, the current paramedic crew configuration or a physician staffed model is most clinically and cost effective requires further research.

Table 10 **Studies investigating crewing combinations**

Place	Author Ref	Method	Type of patient	Number	Conclusions
Hannover, Germany Knoxville, USA	Schmidt (103)	Retrospective review of all helicopter transports in each centre in one year. Pre hospital interventions mortality and TRISS outcomes compared between centres	Patients with multiple injuries transported by helicopter to a trauma centre	221 Germany 186 USA	Mortality lower, more unexpected survivors and a higher rate of pre-hospital interventions in the physician attended German group. This group treated more aggressively than nurse paramedic attended USA group
San Diego USA	Baxt & Moody (102)	Randomised trial of flight nurse/paramedic or flight nurse/physician. Groups compared	Blunt trauma transported by helicopter	258 nurse/pmedic 316 nurse/Dr	Predicted mortality of nurse/physician group significantly lower than nurse/paramedic group. More protocol breaches and failed procedures in N/P group
Cleveland USA	Snow (99)	Retrospective review of patients transported by helicopter. Expert judgement of whether physician needed or not needed	Trauma and medical patients 10-15% primary response, 85-90% IHT	395 consecutive cases	39.7% of cases categorised as physician not necessary, 34.7% might be necessary, 25.6% necessary. Concluded physician necessary for skill and clinical judgement
Australia	Garner (104)	Retrospective review of patients transported from the accident scene by physician staffed or paramedic staffed helicopter. Compared TRISS outcomes and interventions	Primary response trauma patients	140 paramedic group 67 physician group	Physician group had more interventions and more unexpected survivors. Reduced mortality results from physician crew

Table 10 <u>**Studies investigating crewing combinations**</u> **Cont'd**

Place	Reference	Method	Type of patient	Number	Conclusions
Michigan USA	Burney, 1992 (108)	Review of all aeromedical transfers over 1 year. Physician/nurse (P/N)and nurse/nurse (N/N) crews compared for mortality, ICU and hospital length of stay	Adult medical and trauma cases transported by helicopter	418 P/N 241 N/N	No difference between the P/N group and N/N group for mortality, Length of ICU stay and length of hospital stay. No objective evidence to prefer one crew composition over the other
Michigan USA	Burney, 1995 (105)	Prospective review of all aeromedical transfers over 2 years. Physician/nurse (P/N)and nurse/nurse (N/N) crews compared for mortality, ICU and hospital length of stay	Adult medical and trauma cases transported by helicopter	255 P/N 914 N/N	No difference between the P/N group and N/N group for mortality, Length of ICU stay and length of hospital stay. Confirmed findings of previous study
Louisville USA	Hamman 1991 (106)	Retrospective review comparing patients attended by physician staffed helicopter in one year and nurse/paramedic staffed helicopter 2 years later	Trauma patients transported by helicopter from the incident scene	145 physician attended 114 nurse attended	No differences in survival or number of procedures performed in the two groups. Nurse/paramedic crews provide care that produces outcomes equal to a physician crew
San Diego USA	Abbott (17)	Retrospective review of air transported head injured patients and ground transported patients. Air crew provided additional interventions. Mortality and discharge to extended care compared	Patients with severe closed head injury	196 air transports 1090 ground transports	Helicopter group had 11% lower mortality and fewer discharges to extended care facilities. Morbidity and mortality improved by aggressive treatment protocols and rapid transfer to hospital

4.6 Operational area

The optimum area for HEAS opeations is difficult to determine. There are two particular issues worth considering

1. the use of helicopters in urban or rural areas.
2. The geogrphical and population size of optimum areas.

4.6.1 Urban and rural areas

The usefulness of helicopters in remote or rural areas where they can reduce response times and times to definitive care is widely recognised. When this is the case there is prima facie evidence that they can improve outcomes in time dependent emergencies such as serious trauma and coronary emergencies. Of course, improved response times could also be achieved by a sufficient increase in G/A resources, and it may seem therefore that the HEAS question is just one of cost-effectiveness. However, when the time to definitive hospital care is also considered, there is no realistic possibility of increasing hospital-based emergency care resources to meet the needs of all emergency patients, and consequently the effectiveness of HEAS in remote rural areas, such as is found in Scotland and some parts of England and Wales, is clear.

There is also an important issue of equity of 'access' to emergency care services, and HEAS enables a similar level of care to be provided for all patients in the population wherever they live.

With regard to the use of helicopters in urban aeas, the arguments revolve around the ability of HEAS to deliver expert and experienced emergency care to the scene, rather than their ability to improve response and transfer times. Bringing the doctor to the patient is one of the main advantages identified for the London HEMS. The advantages are that a single doctor can in effect provide emergency pre-hospital care throughout the whole of London, and that once at the scene the service is able to deliver patients to the most appropriate source of hospital care.

4.6.2 Geographical and population size

The appropriate size of a HEAS catchment population and geographical area depends on the role in which the HEAS is used.

Assuming that helicopters are targeted at serious blunt trauma then it has been calculated that each helicopter should serve 3-5 million people in order to ensure that there is one major trauma patient per day for whom helicopter call out might be beneficial[8]. Table 1 suggests that this might only be achieved by the London, Yorkshire and North-West and one of the West Midlands helicopters. Other helicopter services would therefore need to make up their caseload by responding to other sorts of emergencies, or responding because incidents occurred in remote or inaccessible places, or carrying out inter-hospital transfers.

4.7 Night-flying

The estimate of need for a catchment population of 3-5 million was partly based on the assumption that in England and Wales HEAS would only operate during daylight hours as a result of the Civil Aviation Authority regulations. However, European regulations have removed this restriction and the possibility of night-time scene responses has been raised. Nevertheless, it is unlikely that any UK HEAS operators will start night-time scene-response operations because

i) Costs may increase disproportionately to caseload because on the one hand day-time only operations means only one crew shift per day with maintenance done at night without the need for a second helicopter, and on the other there are fewer serious blunt trauma RTA incidents at night.

ii) Safety. The estimated risk of HEAS accidents at night is approximately twice that during the day.

iii) Noise. At night helicopter noise is unlikely to be acceptable to communities trying to sleep.

4.8 Receiving hospitals

Helicopters have more choice about where to take patients than land ambulances, and that choice leads to more appropriate receiving hospitals for patients attended by the medically crewed HEMS[3]. The choice of appropriate receiving hospitals depends on matching patient needs to hospital resources, and this may require accurate diagnostic assessment as well as accurate information on services available in different sites. Whether transfer to the most appropriate hospitals, which may mean avoiding more local hospitals, can be accurately determined by paramedics does not appear to be been studied.

The capacity to by-pass local hospitals for more appropriate hospital is constrained by transfer time considerations and by the availability of landing sites proximate to the ED. It is known that remote helipads cause delays in access to definitive care and can cancel out any time advantage[84].

In practice, the survey of UK HEAS conducted for this review revealed that nearly all operations in England and Wales use several hospitals frequently, and a large number occasionally. All operators reported that some of the hospitals they use do not have direct landing facilities, and the patients need to transfer to a G/A to be taken to the ED. There is no evidence about whether these hospitals are all being used for appropriate patients.

5. COSTS AND COST-EFFECTIVENESS

5.1 Introduction

This section considers the costs of air ambulances in England and Wales. It is divided into three parts. First, there is a description of the costs of the air ambulance services in England and Wales using data obtained from the services directly. The second part considers the consequences for other services, including the ground ambulance service and the hospital.

The last part considers the cost effectiveness of the air ambulance service and compares this with other health care interventions.

5.2 The cost of air ambulance services in England and Wales

The cost of air ambulance services in England and Wales

There is limited published evidence on the costs and benefits of air ambulance services and much of it is from overseas making it less relevant to the UK.

Estimates of the cost of operating a helicopter vary from $1,686,500 p.a. in 1991[109] to $2,253,952 p.a. in 1994[110] overseas, and between £600,000 p.a. and £1,200,000 p.a. in the UK[7]. These estimates vary considerably, but this is not surprising given that air ambulance services vary in terms of staffing arrangements, geographical area covered and type of helicopter used.

The costs estimated here are the direct pre-hospital costs of operating the air ambulance services and do not include any consequences for use or provision of hospital or community patient services. They have been provided by the local providers/funders of each air ambulance service in response to a postal questionnaire sent to each service, asking them about the costs of operating their helicopter.

The questions asked of the services differed slightly, dependent on whether the helicopter was owned or leased.

The main components of the cost of air ambulances fall into the following categories:

Capital Costs

- Aircraft
- Deployment facilities e.g. landing decks, maintenance sheds

Operating/running costs

- Maintenance
- Fuel
- Insurance
- Fees
- Pilot crew
- Clinical crew
- Control and deployment costs

Hospital costs associated with accommodating a helicopter

- Landing facilities at the hospital
- Other costs due to accommodating the helicopter

Responses were received relating to fourteen helicopters and there were two non-responders. Of the fourteen replies, thirteen helicopters are leased and the other is owned by the Air Ambulance Trust.

Table 1 gives a breakdown of the costs for each of the leased helicopters. All figures are £ per annum (p.a.). The column 'Other costs' (column 7) is not p.a. This represents costs that cannot be expressed as an annual figure due to a lack of information. There are other annual costs that are not detailed separately in the table, but have been included in the total p.a. cost calculation, such as accommodation costs for the helicopter.

County Air Ambulance operates three helicopters and the figures shown in the table are for all three services combined.

Where deployment costs are 0, this is because they are included in the total charge for the helicopter.

The term 'included' means included in the lease (column 3). The final row of the table gives the average cost p.a. of the helicopters.

As the majority of the helicopters are leased, the total cost is mainly made up of charges, which are usually broken down into a standing charge and a variable charge. (column 2)

The charges vary between the services in terms of what they include, however all leased service include maintenance, insurance and pilot crew and approximately two thirds of the services have fuel/oil included in their lease (column 3).

The average cost of the lease itself is £707,261.03 p.a. (column 2). This varies between a minimum of £420,000 p.a. and a maximum of £950,000 p.a. For ten of the twelve leased helicopters, this is broken down into a standing and variable charge. The average standing charge is £529,150.89p.a. and the variable charge is most often calculated per flying hour.

The average cost of a leased air ambulance service is £834,898.57p.a. (column 6). This varies between a minimum of £577,000 p.a. and a maximum of £1,070,600.

The figure in the other costs column also needs to be taken into account.

The only helicopter that has been purchased is the North East Air Ambulance. In order to make the capital cost of the helicopter comparable with the annual operating costs, the helicopter capital cost needs to be converted to an annual equivalent cost (AEC).

Table 11 <u>**Costs of HEAS in England and wales**</u>

Service	Total Charge (Standing charge and variable charge combined)	Fuel Charge	Staff and training costs	Deployment costs	Total cost p.a.	Other costs	Years
Yorkshire	420,000	15,000	110,000	0	577,000	0	2001
Thames Valley	780,000	4,000	74,632	18,000	876,632	28,000	2001/02
Essex	750,000	Missing	252,000	0	1,002,000	0	2000/01
Lincolnshire and Nottinghamshire	950,000	18,000	95,000	0	1,070,600	22,000	2000/01
East Anglian	502,250	Included	106,260	0	608,510	9,900	2001/02
County Air Ambulance (3 helicopters	2,240,436	Included	302,026	8,960	2,554,422	77,000	2000/01
North West	635,000	Included	100,810	0	741,930	6,120	2001/02
Wales air ambulance	600,000	Included	78,000	11,972	758,972	9,000	2001/02
Cornwall	925,000	Included	112,355	0	1,037,355	31,800	2001/02
Kent	790,000	22,102	105,000	0	917,102	14,200	2001/02
Devon	601,707	Included	107,451	0	709,158	14,000	2001/02
Average	**707,261.03**				**834,898.57**		

Conventionally, assets depreciate over their lifetime. Helicopters are less typical of this as the maintenance work on a helicopter is extremely thorough and components are replaced accordingly. The consequences of this are that the helicopter has considerable resale value, which may not be much less than the original purchase price.

The difficulty in calculating the annual equivalent cost of the helicopter is estimating the resale value. Work by Collet et al[111] and Nicholl et al[6] highlights this problem and discusses the fact that due to an extremely rigorous replacement component system, helicopters can maintain their market value and in some cases even increase it. Brazier et al[4] used an estimate of 50% of the initial purchase price as the resale value and performed sensitivity analysis assuming 0% and 100%. A similar method has been followed here. A discount rate of 6% has been used. The original purchase price of the helicopter was £5,000,000. The helicopter was purchased in 1994 and purchase of a new helicopter is planned in 2002.

Initial training costs have not been annuitised as we have no information on the expected useful life of these items. They have been presented separately and labelled as ‘other costs’.

Listed below are the annual costs of the North East Air Ambulance service.

	Annual Cost (£) 2001	
Helicopter	552,589	(AEC assuming 6% and 8 year life, 50% residual value)
Maintenance	100,000	
Fuel/Oil	27,500	
Insurance	54,283.90	
Staff and training	287,200	
Deployment	190,385	
Accommodation	20,000	
Total cost p.a.	**£1,231,958**	

In addition to these costs, there is a £7,500 initial training cost for the paramedics (other costs).

Assuming a 0% residual value would give a total cost of £1,484,548p.a. and assuming a 100% residual value would give a total cost of £979,369p.a.

The costs of the air ambulance services vary quite considerably. Of the helicopters that are leased, the total cost p.a. ranges from £577,00 p.a. for Yorkshire and £1,070,600 for Lincolnshire and Nottinghamshire. The North East air ambulance service, which owns its helicopter, has the highest total cost overall of £1,231,958 p.a.

There are a number of reasons why the costs vary. These include the use of different helicopters, different populations covered, crewing, accommodation and training arrangements.

5.3 Cost Consequences for other services

The operation of air ambulances could have consequences for hospitals and other services and a full costing would include these cost consequences. For example, if patient outcomes or patient management are changed as a result of the air ambulance, this may have implications for hospital services. Other cost consequences include the cost of a landing site for the helicopter at the hospital and any post discharge costs, for example use of health care services.

These costs were not collected in this research, so we do not know if they have a positive or negative effect and have assumed them to be zero, but work by Brazier et al[4] has shown that they can be significant. They estimated the cost consequences of the London HEMS on hospitals as £826,303. However, London HEMS is atypical of an air ambulance service as it is in the capital and these costs were mainly due to the special trauma unit that was built. In contrast, work in Cornwall found no difference in hospital costs[1].

5.4 Incremental Cost

The incremental cost of the helicopter is the difference in cost between using the air ambulance service and using the ground ambulance service for the same set of patients.

The total cost of the air ambulance service detailed in the previous section includes primary and secondary responses. To estimate the incremental cost, these figures need adjusting to take account of consequences for the land ambulance service in three ways.

1. Costs saved due to land ambulances not being required on primary missions
2. Costs saved due to the helicopter service undertaking inter hospital transfers IHT)
3. Costs incurred due to requiring a separate land ambulance for transferring patients from the helicopter to the hospital, if no landing facilities are available on site.

To estimate the costs saved due to land ambulances not being required on primary missions, an estimate of the cost of a land ambulance call was multiplied by the number of primary missions where a land ambulance was not required, due to the helicopter being deployed.

The average cost of a land ambulance call was taken from the audit commission publication ‘A life in the fast lane’[112]. This gives the cost of a land ambulance call as between a minimum of £50 and a maximum of £125 in 1996/97 prices. Assuming the mean cost is £88 and inflating this cost to 2001/02 prices, give a mean cost of £105, a minimum cost of £60 and a maximum of £149.

The questionnaire included a question asking about whether a land ambulance was deployed as well as an air ambulance. From a response choice of scale of always, usually, sometimes, rarely and never, seven services responded usually, two responded sometimes and two responded always. The majority responded usually, and this was assumed to be approximately 75% of the missions on the five point scale given. The average number of primary missions p.a. flown by the helicopters was therefore multiplied by 0.25 to give the number of missions where a land ambulance was saved. This figure was then multiplied by the cost given above to give an estimate of the total costs saved.

To estimate the costs saved by the helicopter undertaking IHTs, the average number of IHTs undertaken by the helicopter was multiplied by the cost of a land ambulance journey.

The helicopter acts as a substitute service here and so each IHT undertaken by the helicopter means a land ambulance mission is saved.

Not all hospitals have a landing facility for the helicopter, which means that in some cases a land ambulance is required to transport the patient from the helicopter to the hospital. To estimate the cost of this, the average proportion of times a land ambulance is required was estimated using data from the questionnaires and multiplied by the cost of a land ambulance call.

The cost per annum detailed in the first section was then adjusted by the results of the above to produce an estimate of the average incremental cost of a helicopter service.

The mean cost p.a. is £857,865 and the average cost per mission is £1,102.

Varying the proportion of times a land ambulance call is saved for primary missions to 50% and 0% and re-estimating using the minimum and maximum cost of a land ambulance mission gives a range of a minimum annual cost of £817,124.38 and a maximum annual cost of £887,435.53

The average cost per mission is quite substantial although it varies between services. It is worth noting that the marginal cost of undertaking one more missions is likely to be a lot lower than the average cost. This is because the costs contain a relatively large fixed component and increase in activity (missions flown) is unlikely to affect the total cost significantly.

5.5 Cost-effectiveness

In trying to determine whether HEAS represent good value for money it is useful to estimate the incremental cost per quality adjusted life year (QALY). Although numerous, contentious, assumptions are needed for these calculations to be made meaningfully, they do enable rough comparisons across different health care services.

For the purpose of this review we have taken as a central estimate of benefit that HEAS can save 2-3 lives per 100 serious blunt trauma patients transported to hospital. We have not assumed any benefit in other patients, patients transferred between hospital, nor for other patients attended by the AS. In the 9 studies from which the number of lives saved was estimated, the average age of HEAS patients was 32. One HEAS study has measured Quality of Life (QoL) in blunt trauma survivors using the EQ-5D utility scale[30]. The reported mean QoL at 9 months was 0.67, and 0.71 at 15 months. Assuming, therefore, that patients survive an average of 38 years at an average QoL ranging from 0.5-0.7 over the remainder

Table 12. **Costs per mission of HEAS in England and Wales**

Service		Cost p.a.	Cost per mission
Yorkshire		£566,199	£515
Thames Valley		£869,421	£1,063
Essex		£1,001,076	£1,295
Lincolnshire and Nottinghamshire		£1,058,804	£1,337
East Anglian		£611,490	£1,009
County air ambulance	1	£854,183	£1,482
	2	£854,183	£1,482
	3	£854,183	£1,482
North West		£720,519	£698
Wales Air Ambulance		£766,720	£2,235
Cornwall		£1,014,686	£814
North East Air Ambulance		£1,226,502	£1,991
Kent		£905,096	£844
Devon		£707,056	£918
AVERAGE		**£857.866**	**£1,102**

of their lives, each life saved contributes 10.8-15.1 QALYs after discounting at 1.5% in accordance with NICE recommendations.

If we assume that HEAS can save an additional 2-3 lives per 100 blunt trauma patients transported, then for an average of 329 patients scene transports per year, of whom 200-300 are blunt trauma, an average UK HEAS may be saving 4-9 lives per year, which is about half that estimated for the London HEMS[3,9].

We therefore calculate that in England and Wales an additional 43-136 QALYs per year may result from the use of each HEAS. Hotvedt reported that a Norwegian helicopter was producing an extra 157 QALYs per year.

The incremental cost of the air ambulance alone is estimated to be £857,866 pa. The estimated cost per QALY is therefore £6,310-£19,950. This calcualtion has not taken into account any cost consequences of HEAS. However, the same calculations can be used to show that if each HEAS saves only 4 lives/yr, then so long as the costs and cost consequences associated with each HEAS are less than £0.86m (£1.29m) a HEAS will be cost effective at an acceptance threshold of £20,000 (£30,000) per QALY.

6. DISCUSSION

The overall cost and effectiveness of HEAS in the UK remains uncertain. Despite examining over 400 published research reports on HEAS and reviewing in detail over 100 relevant articles we still cannot reach a clear conclusion with much confidence. The main reasons for this are

1. *Study Design*. There have not been any randomised studies of HEAS conducted anywhere in the world. This means that all the comparative observational studies have to adjust for casemix differences between the HEAS and comparator cohorts. Whilst these risk adjustment methods are believed to be relatively well-developed in trauma care, they cannot reliably adjust for selection biases. For non-trauma, casemix adjustment is much less well developed and has rarely been used.

2. *Applicability to the current UK situation*. There is very little directly relevant UK literature. Most of the literature we have reviewed comes from the United States where differences in the geography (size of area covered, terrain, climate, daylight hours, etc.), population density, access to other medical services, incidence of conditions which might benefit from rapid response, and so on, may all affect the relative cost-effectiveness of helicopter and land ambulance services. Thus results from a study in an American state may not be applicable to emergency care services in England. Furthermore, since we are solely interested in the incremental costs and effects - that is those over and above what could be achieved by the existing alternative ground ambulance services - reports on effectiveness from other countries with different ground ambulance services also may not translate to circumstances in England and Wales.

   Indeed, the argument can be extended to the uncertainty of generalising from past studies to future circumstances. If ground ambulance response and transfer times speed up through continuing improvements in deployment and targeting or slow down due to increasing traffic congestion or the re-organisation of hospital A and E departments, or if the type of G/A response changes, for example through an increasingly skilled paramedic workforce, then the size of the marginal benefits associated with HEAS may change.

3. *Targetting*. The observational study data that has been reviewed suggests that within the limitations of study design and applicability to the UK there is evidence of benefit in serious blunt trauma, but that in minor, critical, or penetrating trauma there is evidence pointing to no benefit, and that there is no reliable evidence one way or another in non-trauma.

   However, both in the UK and overseas when helicopters are targeted at trauma they are rarely targeted at serious blunt trauma. All the 9 highest quality most relevant studies of survival in trauma reviewed in section 3 found that the majority of patients attended by helicopter ambulance had minor or moderate severity injuries with ISS<16. This is partly because most HEAS try to maximise their activity to justify their costs, and also because it can be difficult to identify appropriate cases/patients in the emergency, pre-hospital phase, especially if the helicopter is despatched on the basis of emergency telephone calls from the public.

The consequence of this heterogeneous casemix is that any evidence of benefit in trauma is blurred.

4. *Non-trauma*. Most helicopters in the UK also carry out missions which are not aimed at providing direct help to trauma patients. These may be missions for a different casemix such as cardiac or obstetric emergency patients, or inter-hospital transfers, or missions to remote or inaccessible locations which would tie up G/As for considerable periods of time and reduce the response time performance of the ambulance service as a whole. Unfortunately there is very little reliable evidence on the incremental benefits of using helicopters rather than G/As in these roles.

5. *Costs*. There is some remaining uncertainty about the cost consequences of using helicopters rather than G/As in all their roles. Crude assumptions about effects on facilities and their costs, admissions, use of intensive care, etc. have been made, which could be resolved empirically.

6. *Cost-effectiveness*. Finally, for cost-effectiveness, reliable information is not only needed on survival in trauma but on all the benefits of HEAS – on the length and quality of life of survivors, on the benefits of using HEAS in other roles, on any halo effects for other emergency services, and on the values that the public and policy makers put on HEAS and these effects.

   There is no reliable information on any of these effects and consequently in the estimates presented above we have assumed that there are no benefits other than those for serious blunt trauma, and no costs other than the direct incremental costs of operating the HEAS.

   The estimated cost per QALY should therefore be taken only as indicative. Nevertheless, although the estimate of the cost per QALY is shaky, we can reach a slightly more robust answer about whether the cost per QALY is acceptable.

   Roughly speaking if the unknown cost consequences and the unknown benefits of other activities and halo effects are assumed to cancel out then if a HEAS can save 4 or more serious blunt trauma lives per year, the cost per QALY is acceptable at a threshold of £30,000 per QALY.

7. FUTURE RESEARCH

The implications of the discussion of this review are twofold.

1) If HEAS can be targeted at a sufficient caseload of serious blunt trauma to justify the costs of having a helicopter, then this is how the HEAS should be operated.

2) If they cannot, either because cases can't be reliably sorted into those with serious blunt trauma in the pre-hospital emergency phase or because there is not a sufficient volume of identifiable serious blunt trauma cases in the catchment area of the HEAS to generate a full caseload, then HEAS, which have direct costs of about £800,000 pa to run, should also be targeted at other beneficial activities. Three types of 'other' activities that are potentially beneficial can be identified

   - attending different types of primary case, such as cardiac or obstetric cases,
   - carrying out secondary inter-hospital transfers,
   - responding to 999 calls in remote or inaccessible locations which would otherwise tie-up G/As for considerable periods of time.

There are therefore two principal types of research study which need to be undertaken. Firstly, studies to help optimise the targeting of HEAS to serious blunt trauma. The two main options for improving targeting are to respond only indirectly via call-out by emergency or other qualified personnel at the scene of an incident working to agreed guidelines, or to place a helicopter dispatch desk in the AS communications centre so that fuller details about potential incidents can be obtained prior to dispatch.

Secondly, studies of the benefits of using helicopters in other roles need to be undertaken. These studies should only be conducted in areas where there is insufficient serious blunt trauma to generate a full caseload for the helicopter.

As well as these main themes other studies would of course help with refining the cost-effectiveness estimates and the optimal role of UK HEAS. Three potentially important additional studies are

1) to identify any benefits in other trauma patients in terms of immediate relief from pain and distress, improved quality of life in all patients, satisfaction and patient experiences.

2) to resolve the substantial uncertainties around the wider cost implications of using HEAS to respond to emergency calls. We do not know whether hospital and community costs are altered when HEAS is used, and although patients with similar conditions may be assumed to have the same cost consequences this needs to be investigated. The costs of building HEAS facilities, increased use of ICU for survivors, increased use of other inpatient and outpatient services are all possible consequences with substantial cost implications. Only one UK study has attempted

to address any of these issues, and that was based in the London Service which by its own admission is exceptional.

3) to resolve operational issues which need to be addressed. One highlighted by this review is how HEAS should be crewed. We accept that the argument is not really about doctors, flight nurses, or paramedics but about what skills the crew should have. This will, of course, depend on the types of incident to which HEAS are tasked. Secondly, the implications of HEAS for the wider emergency care system are almost entirely unresearched. There is little evidence and many claims for these sorts of ‘halo’ effects and these need to be resolved so that a comprehensive assessment of the effectiveness of HEAS can be made.

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