

Acute Risk in Helicopter Emergency Medical Service Transport Operations

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Abstract

Objective: The highest safety risk for helicopter emergency medical service (HEMS) operations in the United States is during night-time operations. Although guidelines recommend physicians consider the risk to the patient and flight crew when triaging a patient for flight, no objective measure of risk between day and night-time HEMS flights exist. The purpose of this study was to measure the acute risk of HEMS transport within a spectrum of aviation and medical procedure risk.

Methods: The number of fatal HEMS accidents, fatal patient injuries and patients transported by day and night between 1995 to 2015 were classified as events and measure of activities, respectively. Acute risk was measured using the MicroMort (mM) which represents a one in a million chance of dying from an accident. Comparisons with other activities were used to contextualize aviation and medical procedure risk.

Results: Each daytime HEMS task (7.55 mM) was similar to one parachute jump (7.96 mM). One night-time HEMS task in hazardous operational conditions (18.75 mM) was over ten-times greater than one scuba dive (1.84 mM). Patient night-time mortality (6.43 mM) was similar to one general anaesthetic (8.2 mM).

Conclusion: Daytime HEMS accident risk is of similar risk to one parachute jump, and at night-time in hazardous operational conditions over ten-times greater than one scuba dive. Where a patient's risk of death from their injury or illness is not greater than that of a general anaesthetic, triage for a night HEMS transport may introduce greater risk than the patient's medical condition itself.

Keywords: Patient; Micromort; Risk; Fatalities; HEMS; Accident

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Citation: Aherne B, Newman D, Chen WS (2021) Acute Risk in Helicopter Emergency Medical Service Transport Operations. Health Sci J. 15 No. 1: 788.

Received with Revision January 11, 2021, **Accepted:** January 25, 2021, **Published:** January 29, 2021

Introduction

Helicopter emergency medical service (HEMS) operations in the United States (U.S.) have historically had higher fatal accident rates compared to other aviation domains [1-9].

A systems safety risk analysis found night-time visual flight rules (VFR) HEMS accidents made a significantly greater contribution to the overall HEMS fatal accident rate compared to daytime [5]. The majority (69%) of night-time accidents in that study were caused by the pilot's entering hazardous operational conditions [4] and losing visual orientation cues which are required under VFR. This resulted in the pilots suffering sustained spatial disorientation, resulting in the helicopter's high-energy impact with terrain [5]. As such, night VFR HEMS operations present the highest safety risk for the U.S. HEMS industry [6].

When considering the need for HEMS transport, physicians should carefully balance the risk to the patient and helicopter flight crew [10-12]. However, not all patients transported by HEMS flights have been found to be suffering a life-threatening injury. Analysis

of U.S. patient trauma injury retrieved by HEMS between 1983 and 2004 found the majority of patients had non-life threatening injuries: over 25% were discharged within 24 hours following arrival at hospital [8,9-21]. Similar results were seen with children flown to trauma centres: 36% with low Injury Severity Scores (ISS) were discharged within 24 hours of helicopter transport [22,23-27]. Another study of 5,202 patients triaged with trauma injury between 2007 and 2013 found over 27% of the 981 (N=264) transported by HEMS were not seriously injured [28]. Therefore, the transport of such patients at night potentially exposes a HEMS flight to unnecessary risk.

Guidelines for the appropriate use of HEMS as the mode of patient transport have been developed by the American College of Surgeons Committee on Trauma (ACSCOT) [12]. These call for communication between referring and receiving physicians

to determine the most appropriate mode of transport for the patient and their anticipated en-route care, noting that HEMS may not be the most rapid or safest mode in every situation [12].

HEMS transport has been described as the only medical procedure that poses a greater risk for the medical providers compared with the patient [1]. A patient's shared fate with the flight crew in a catastrophic night-time operational HEMS accident [6] is not shared between a medical team and a patient who dies undergoing other medical procedures [1]. Even though comparisons of HEMS patient mortality to medical procedures were highlighted in 2001 [19], that data did not calculate mortality risk in the night-time HEMS environment and no further studies have been reported.

In order to improve the ACSCOT guidelines and reduce the likelihood of over-triage, an objective measure to contextualise the high-risk presented during night-time VFR HEMS flights should consider mortality from both an aviation and medical aspect. Acute risk, where the outcome (i.e. death) is apparent during the activity, becomes redundant after completion of the activity [15]. In contrast, the chronic risk (of death), e.g., the patient's underlying medical condition, remains relevant after completion of the activity [15]. Therefore, as HEMS patient transport represents both an aviation activity [3-5] and a medical intervention en-route [1,12], either activity can be measured using acute risk.

A useful method of quantifying acute risk is the MicroMort (mM). One mM represents a one in a million chance of dying from an accident [7,14,25]. The mM can provide a comparison of acute risk between various activities, such as medical procedures, sky diving and rock climbing [13] and extreme activities such as base-jumping [25]. Its use can improve the accuracy of everyday risk perception [15].

Objectives of investigation

Therefore, this study sought to determine:

What is the acute risk of the HEMS mission task as an aviation activity during daytime and night-time operations?

What is the acute risk to a HEMS patient during daytime transport and at night in hazardous operational conditions as a medical procedure?

Compare these results with the acute risk of other medical procedures and activities common in the U.S.

Methods

Study design

Retrospective U.S. accident data was used for the study. No experiments comprising human participants were conducted. HEMS fatal accidents between 1995 to 2015 identified from previous research were identified and stratified by night and day [5,6]. A HEMS mission task comprises any flight to/or with a patient or flights positioning from the patient receiving facility to home-base without a patient. HEMS accidents on any of those sectors are included. Patients transported by HEMS were used as the measure of activity [9,10,23]. Thirty-eight percent (38%)

of patient transports occurred at night and 62% during the day of [5,9].

Events were classified as follows:

- A. The number of fatal HEMS accident's stratified by day and night-time during 1995 to 2015,
- B. The number of patients with fatal injury,
- C. The number of fatal night-time HEMS accident's caused by pilot spatial disorientation resulting in loss of control (LCTRL) and controlled flight into terrain (CFIT), and,
- D. The number of patients with fatal injury for the accidents listed at C.

MicroMort (mM) was calculated to represent the chance of:

- A fatal HEMS accident by day and night.
- Fatal patient injury in a HEMS accident, by day.
- Fatal spatial disorientation HEMS accident at night.
- Fatal patient injury in a spatial disorientation HEMS at night.
- Fatal HEMS accident at night from other causes (other causes).

Measurement of acute risk

The mM calculation [29] is expressed in this study as:

$$\text{mM} = (\text{Events (classified above as A through D)} / \text{Total Patients Flown, Patients Flown by Day and Patients Flown by Night}) \times 1,000,000$$

Medical procedures used for comparison were:

1. Patient fatal injury in road ambulance accidents (Smith 2015) and number of ambulance admissions to emergency departments for 2003 [16].
 2. Anaesthesia-related mortality and number of hospital surgical discharges in the U.S. between 1999 to 2005 [17].
- A comparison table of mM during other activities common in U.S. society is presented to contextualize day and night HEMS aviation operations. Activities included in the analysis were:
3. Skiing fatalities and number of skier visits in the U.S. 2018/19 season.
 4. Diving fatalities and number of dives in the U.S. between 2006-2015.
 5. Parachuting fatalities and number of jumps in the U.S. between 2000-2019.
 6. Rock climbing fatalities and number of climbing attempts at 'The Devils Tower' National Monument in Wyoming U.S. between 2003-2020.

The calculation for comparative activities is:

$$\text{mM} = (\text{Event (comparisons classified above as 1 through 6)} / \text{Number of Activities (of activities of 1 through 6)}) \times 1,000,000$$

Results

Table 1 shows just under 5 million HEMS patients transported

Table 1 United States Helicopter Emergency Medical Service (HEMS) MicroMorts (mM) 1995 to 2015; Accidents (Accid) Day, Night and Night Spatial Disorientation (SD), Patient Day, Night and Night SD.

Year	Total Patients Flown	Fatal HEMS Accid	Fatal HEMS Accid mM	Patient Fatalities HEMS Accid	Patient HEMS Accid mM	Day Patients (62% of Total Patients Flown)	Day Fatal HEMS Accid	Day HEMS Accid mM	Patient Day Fatalities HEMS Accid	Day HEMS Accid mM	Night Patients (38% of Total Patients Flown)	Night Fatal HEMS Accid	Night HEMS Accid mM	Night Fatal HEMS Accid (Other Causes)	Night HEMS Accid mM (Other Causes)	Night Fatal HEMS Accid	Night HEMS Accid mM	Night Fatal HEMS Accid	Night HEMS Accid mM	Patient Night Fatalities HEMS Accid	Patient Night HEMS Accid mM
1995	160000	1	6.25	0	0.00	99200	0	0.00	0	0	60800	1	16.45	0	0.00	1	16.45	0	0.00	0	0.00
1996	175000	1	5.71	1	5.71	108500	0	0.00	0	0	66500	1	15.04	0	0.00	1	15.04	1	15.04	1	15.04
1997	175000	2	11.43	1	5.71	108500	0	0.00	1	9.22	66500	2	30.08	1	15.04	1	15.04	0	0.00	0	0.00
1998	170000	3	17.65	2	11.76	105400	1	9.49	1	9.49	64600	3	46.44	1	15.48	2	30.96	1	15.48	1	15.48
1999	203000	4	19.70	0	0.00	125860	1	7.95	0	0	77140	2	25.93	1	12.96	1	12.96	0	0.00	0	0.00
2000	199000	4	20.10	1	5.03	123380	1	8.11	0	0	75620	3	39.67	1	13.22	2	26.45	1	13.22	1	13.22
2001	204000	4	19.61	0	0.00	126480	2	15.81	0	0	77520	2	25.80	2	25.80	0	0.00	0	0.00	0	0.00
2002	212000	5	23.58	1	4.72	131440	2	15.22	0	0	80560	3	37.24	2	24.83	1	12.41	1	12.41	1	12.41
2003	211000	4	18.96	0	0.00	130820	2	15.29	0	0	80180	2	24.94	0	0.00	2	24.94	0	0.00	0	0.00
2004	231000	6	25.97	4	17.32	143220	1	6.98	0	0	87780	5	56.96	0	0.00	5	56.96	4	45.57	0	0.00
2005	262000	6	22.90	1	3.82	162440	4	24.62	1	6.16	99560	2	20.09	0	0.00	2	20.09	0	0.00	0	0.00
2006	270000	3	11.11	1	3.70	167400	2	11.95	1	5.97	102600	1	9.75	0	0.00	1	9.75	0	0.00	0	0.00
2007	280000	2	7.14	1	3.57	173600	1	5.76	0	0	106400	1	9.40	0	0.00	1	9.40	1	9.40	1	9.40
2008	269000	7	26.02	5	18.59	166780	2	11.99	4	23.98	102220	5	48.91	1	9.78	4	39.13	2	9.78	2	9.78
2009	262000	2	7.63	0	0.00	162440	0	0.00	0	0	99560	2	20.09	0	0.00	2	20.09	0	0.00	0	0.00
2010	262000	6	22.90	0	0.00	162440	2	12.31	0	0	99560	4	40.18	2	20.09	2	20.09	0	0.00	0	0.00
2011	262000	1	3.82	1	3.82	162440	0	0.00	1	6.16	99560	1	10.04	1	10.04	0	0.00	0	0.00	0	0.00
2012	263000	1	3.80	0	0.00	163060	0	0.00	0	0	99940	1	10.01	0	0.00	1	10.01	0	0.00	0	0.00
2013	256000	5	19.53	0	0.00	158720	0	0.00	0	0	97280	5	51.40	2	20.56	3	30.84	0	0.00	0	0.00
2014	285500	2	7.01	1	3.50	177010	0	0.00	0	0	108490	2	18.43	1	9.22	1	9.22	0	0.00	0	0.00
2015	300000	5	16.67	1	3.33	186000	2	10.75	0	0	114000	3	26.32	1	8.77	2	17.54	1	8.77	1	8.77
Total	4,911,500	74	15.07	21	4.27	3,045,130	23	7.55	9	2.95	1,866,370	51	27.33	16	8.57	35	18.75	12	6.43	12	6.43

over the study period with 74 fatal HEMS accidents with an overall acute risk at 15mM per mission. Daytime accidents (n=23) had a risk of 7.55 mM whereas night accidents (n=51) had a risk of 27.33 mM. The night-time spatial disorientation operational accident risk of 18.75 mM made up the majority (69%) of night-time accident acute risk. Fatal HEMS accidents from other causes at night (8.57 mM) were similar to daytime acute risk. Patient risk from night-time spatial disorientation accidents was 6.43 mM, over two-fold greater than daytime (2.95 mM).

Comparing HEMS aviation operations with other activities, a single daytime HEMS mission (7.55 mM) (Table 1) carried similar (95%) acute risk to one parachute jump (7.96 mM) (Table 2), over four times greater than one scuba dive (1.84 mM) and seven times greater than skiing (0.82 mM). One night-time HEMS operational transport in hazardous operational conditions (18.75 mM) (Table 1) was over ten-times greater than a single scuba dive (1.84mM) and similar (85%) to a single rock-climb of 'The Devils Tower' (22.00 mM) (Table 2).

Patient mortality risk during night-time HEMS transport (6.43 mM) was less than that of one general anaesthetic (8.2 mM), but over six times greater than a single ambulance road trip to an emergency department (0.44 mM). As a medical intervention, the results show the acute risk to a HEMS flight crew was over two-fold greater compared to a patient's during daytime operations (7.55 mM vs. 2.95 mM) and over four-fold greater at night (27.33 mM vs. 6.43 mM).

Discussion

Where a patient's risk of death from their injury or illness is not greater than that of a general anaesthetic, triage for a night HEMS transport may introduce greater risk than the patient's medical condition itself. Additionally, over-triage, especially at night-time, would avoidably subject the HEMS flight crew to greater acute risk than required. The HEMS daytime mission task shared similar comparative acute risk to one parachute jump. The high-risks underlying night-time VFR HEMS transport in hazardous operational conditions are easily contextualized with its similarity to a single climb of the 'Devils Tower' a sheer rock-face 867ft in height. In the case where the patient's medical condition risk of death is not greater than a general anaesthetic, road ambulance transport at night-time reduces the risk of patient fatal injury almost fifteen-fold compared to HEMS transport.

Where the over-triage of patient trauma injury results in a HEMS

transport, as was reported in earlier research [8,22,28], this data indicates an over-triage at night would have exposed those HEMS flights to a statistically greater but preventable risk [5]. While these results reflect mortality from a large population and not an individual patient's medical condition, options other than HEMS transport at night, e.g., daytime transport, should be considered if the patient's expected medical procedure acute risk was not greater than that of a general anaesthetic.

Although the ACSCOT guidelines highlight the generalised increased risk of flights at night [12], this current research provides more objective evidence for physicians to select the best mode of transport for the patient. Risk communicated this way is consistent with calls for shared-care decisions to be based on a more informed choice [25].

Some argue that in order to make the medical air transport resource more available to those who need it, a certain level of over-triage is unavoidable [26]. While an over-triage of 25 to 35% to trauma centres is generally thought acceptable [2], even a conservative 1% over-triage applied to the night patient tasks in this study would have resulted in 18,663 preventable acute risk exposures, an average of 78 transports per month.

There are limitations in this study. Road ambulance admission data was from 2003 only using road ambulance patient mortality averages reported in earlier research [24]. The actual road ambulance mortality in 2003 may vary from the average. The data presented is applicable to a population not to an individual and therefore should not override the circumstances unique to an individual. As the ACSCOT HEMS transport guidelines are based on large population data and provide generalised advice, this research aims to improve that generalised risk advice for HEMS flights at night. The HEMS aviation acute risk should be viewed as being overly conservative. It does not consider the aggregate of HEMS flight crew (pilot, flight-nurse, paramedic/physician) fatalities from each accident, which is beyond the aim of this study.

The study found each daytime mission task had similar risk to one parachute jump and each high-risk night-time VFR task in hazardous operational conditions [6], shared similar risk to one rock climb of 'The Devils Tower'. Importantly, it should be emphasised that the alternative modality of road patient transport reduces the risk of death from a night-time operational HEMS accident almost fifteen-fold if the patient's medical condition risk is not greater than that of a general anaesthetic.

Table 2 Comparative Activity MicroMorts (mM) in the United States.

Comparative Activities	Total Activities	Fatalities Per Activity	mM
1. Skiing 2018/19 [20]	43,882,000 Skier Visits	36	0.82
2. Scuba Diving 2006-2015 [11]	306,174,387 Dives	563	1.84
3. Parachuting 2000-2019 [27]	58,400,000 Jumps	465	7.96
4. Rock Climbing 'The Devils Tower' Wyoming 2003-2020 [21]	90,000 Attempts (Approximately 5000 per year)	2	22.00
5. Patient Mortality Road Ambulance 2003[16]2015** [24]	16,000,000* Ambulance Admissions	7**	0.44
6. Anaesthesia Related Mortality 1999-2005 [17]	105,700,000 Surgical Discharges	867	8.20

This study provides a reference point to understand the acute risk within a spectrum of aviation and medical procedures during a HEMS transport task. Comparing acute risk using the MicroMort permits a participant to easily assess the relative dangers of activities [18]. Such reference provides a starting

point for important conversations about the risks which we experience daily [25]. This will assist emergency physicians, HEMS dispatchers and flight crew, improve their perception of the high-risk night-time VFR HEMS environment.

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