UK Military Rotary-Wing Accidents: 2000–2015

Alaistair J. R. Bushby; Nicole Powell-Dunford; William D. Porter

BACKGROUND: Analysis of mishap data is an obvious measure of performance for those who wish to improve flight safety and affect aviation capability development within military forces.

METHODS: This study examined rotary-wing accident information held by UK Ministry of Defence authorities for the 16-yr (inclusive) period from January 2000 through December 2015 in order to ascertain incidence patterns. Serious accidents of military registered aircraft operated by Joint Helicopter Command, the Royal Navy, the Search and Rescue Force, and the Defence Helicopter Flying School were included in the analysis. A secondary intent of the review was to examine the influence of broad-based organizational changes on the overall incidence of rotary-wing accidents across the U.K. Ministry of Defence that grew out of the report published by Charles Haddon-Cave, QC, following his wide-ranging investigation into the catastrophic crash of Royal Air Force Nimrod XV230 that occurred during a routine mission in Southern Afghanistan.

RESULTS: During the 16-yr period between January 2000 and December 2015, 53 rotary-wing accidents occurred. The overall accident rate was 2.32 accident events per 100,000 flight hours. Spatial disorientation accidents remain a prevalent risk in this study, being acknowledged in 43% of accidents. Prior to the Haddon-Cave report, the accident rate was 2.81 events per 100,000 flight hours. Following the report, the accident rate decreased to 1.24 events per 100,000 flight hours.

DISCUSSION: The decrease in the accident rate between 2000 and 2015 shares a temporal association with the adoption and operationalization of the recommendations found in Haddon-Cave's report.

KEYWORDS: aviation, spatial disorientation, military.

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Analysis of mishap data provides an effective means to improve flight safety and enhance the development of aviation capabilities within military forces. The most recent aeromedical review of UK military helicopter accident data studied the period from 1991 to 2010 and primarily focused on the impact of changes in the overarching operational environment confronting the British Army Air Corps.[1] Specifically, events occurring from 1991–2000 were compared with those occurring from 2001–2010. While the first period was primarily impacted by peace enforcement and peace-keeping operations in Northern Ireland and the Balkans, counter insurgency operations, primarily in Iraq (Operation Telic) and Afghanistan (Operation Herrick), dominated the period from 2001–2010. The overall accident rate was determined to be 2.5 events per 100,000 flight hours, with 84% of all events being attributed to errors in the human factors domain. Spatial disorientation, a particularly critical risk for rotary-wing aviation, was implicated in 43% of all events.

Given the elapsed time since this most recent review, rotary wing accident information was once again gathered from UK Ministry of Defence authorities for the 16-yr (inclusive) period from January 2000 through December 2015. The primary intent of examining this data was to look for any concerning patterns or trends across aircraft types that might drive changes in current aeromedical practices, with a specific focus on the continued impact of spatial disorientation on the rotary-wing community. Ultimately, the overall accident rate would appear to be the most tangible measure of effectiveness for the United Kingdom's military rotary-wing aviation medicine program, and changes in this rate over time should provide valuable feedback to those individuals who are directly involved in aeromedical aspects in pursuit of safety.

Additionally, a secondary intent of this review was to examine the influence of more recent and broad-based

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organizational changes on the overall incidence of rotary-wing accidents across the UK Ministry of Defence. On 13 December 2007, The Secretary of State for Defence appointed Charles Haddon-Cave, QC, to spearhead an investigation into the catastrophic crash of Royal Air Force Nimrod XV230 during a routine mission in Southern Afghanistan [as part of ongoing North Atlantic Treaty Organization (NATO) operations].[9] The aircraft experienced a midair fire and was rendered a total loss. Tragically, 14 crewmembers perished in the event.

Although not directly focused on aeromedical issues, the results of Haddon-Cave's independent investigation of higher risk activities (published in October 2009) proposed wide-ranging and transformative contextual changes in the aviation safety culture across the Ministry of Defence. Haddon-Cave stated that the ultimate aim of his report was to "improve Safety and Airworthiness for the Future. The duty of those in authority reading this Report is to bring about, as quickly as possible, the much-needed and fundamental improvements for the Future which I have identified." Haddon-Cave's recommendations were rooted in the concept of the "Military Covenant," which "embraces the whole panoply of measures which it is appropriate the Nation should put in place and sustain for Service personnel, including adequate training, suitable and properly maintained equipment, sufficient provisions in theatre, and proper support and conditions for Service personnel and their families at home."

As with any complex organization, sufficient time must elapse before changes to processes and systems can be assessed for realization of their desired objectives. Changes in outcome measures may also be confounded by the maturation effect over lengthy periods of observation. In light of the Haddon-Cave report, we acknowledge from the outset that any retrospective review of accident data relies on ecological principles to compare changes in rates over time. Additionally, the recommendations from Haddon-Cave's report were imposed on wide-ranging organizations that must operate aircraft fleets of varying technological sophistication on a daily basis across a full spectrum of mission sets, in various climates, locations, and levels of hostility across the globe, and his recommendations touched upon processes related to personnel management, the relationships between the military and the industrial base, the complexity of military hardware procurement, and the prioritization of issues related to the conduct of military operations in a safe manner. Given the sheer magnitude and scope of these processes at the strategic level, it is beyond the ability of this simple ecological review to assign causality (or the lack thereof) between Haddon-Cave's report and the overall accident rate.

This study is also limited by several other important factors. Overall, the number of observed events collected during this study is small; this limits the statistical power for comparisons of rates and specific subcategories of events over time. However, we feel the broad patterns are informative. Additionally, the UK Ministry of Defence operates fleets of niche aircraft that face dissimilar challenges from their forward-deployed counterparts in the conduct of their daily missions. These differences may translate to varying levels of risk across the entire rotary-wing aircraft fleet and could almost certainly impact the observed accident rates.

Finally, this study relies on rates of accidents that are calculated by using flight hours as the denominator. These values were collected by the investigators across disparate organizations, aircraft types, and locations for the purposes of this study. When faced with discrepancies across time or organizations, conservative estimates were chosen with the intent of decreasing the likelihood of Type I errors. Future analyses would certainly benefit from centralized collections of flight hour data from within a single-source tracking system.

METHODS

In line with the previous study by Adams et al.[1], the authors examined rotary wing accident information held by UK Ministry of Defence authorities for the 16-yr (inclusive) period from January 2000 through December 2015. Accidents, as defined by a person being killed or suffering major injury, or an aircraft sustaining serious damage (category 4 or 5), were selected for analysis from records held by the Military Aircraft Accident Investigation Branch, Joint Helicopter Command or Service Safety Centres.[11] **Table I** describes the current aircraft repair categorization scheme used by the Ministry of Defence to delineate accidents and incidents.

Accident occurrences in military registered aircraft operated by Joint Helicopter Command, the Royal Navy, the Search and Rescue Force, and the Defence Helicopter Flying School were included in the analysis. January 2000 was chosen as the start point for data collection as it aligned with the formation of Joint Helicopter Command and follows the formation of the Defence Helicopter Flying School, providing a continuous period of basic organizational structures within the UK rotary-wing flying community.

Table I. Abridged UK Ministry of Defence Aircraft Repair Category Definitions.

AIRCRAFT REPAIR CATEGORY	ABRIDGED DEFINITION:
1	The aircraft is repairable within the aircraft custodian's capabilities.
2	The aircraft is repairable within the capabilities of a forward maintenance organization.
3	The aircraft is generally repairable on site, but the required work exceeds the capabilities of the forward maintenance organization.
4	The aircraft is repairable, but it is considered to need special facilities or equipment not available on site.
5	The aircraft is considered beyond economic repair but may be suitable for breakdown into components/parts, or for ground instructional use.

This table features abridged definitions of the comprehensive aircraft repair category definitions currently in use. See the Military Aviation Authority Master Glossary[11] for the complete categorization scheme.

Incidents (defined as an aircraft with category 1, 2, or 3 damage, and/or a person receiving a reportable injury that results in more than 3 d of lost work) were excluded from the analysis as they are not routinely investigated by military authorities, and lack robust data related to etiology or the impact of other factors surrounding the specific event. Other excluded events consisted of transport activities involving the British royal family and government, company-owned/company-operated aircraft operating under contract to the Ministry of Defence, and third-party income generation concerns (e.g., nonmilitary tasks conducted by a Defence contractor using Ministry of Defence assets). Direct Special Forces support was also excluded, as flying hours in support of these missions could not be isolated from other nonmilitary tasks conducted within the same fleet. Fixed-wing aircraft, exclusively ground-based events, those directly caused by hostile fire or attack, and activities generally unrelated to core military tasks were also excluded from the analysis.

Following the case-collection process, each accident was thoroughly reviewed by a minimum of two specialist physicians in aviation medicine, acting jointly. This review included data from Defence Air Safety Occurrence Reports (DASORs), Board of Inquiry and Service Inquiry files, and other supporting documentation. The specialists in aviation medicine then completed accident summaries and tabulations of the collected data. Variations in categorization were reviewed and discussed until a mutually consistent assessment could be reached.

Accidents were categorized by:

- Aircraft type (attack, transport, multirole, training, other).
- Severity of injury or death to the aircraft occupants as part of the accident sequence.
- Pursuit of an operational task at the time of the accident (operational tasks require the crew to be operating in an operational theater and undertaking an operational mission; currency training in an operational theater was not counted as an operational task for the purposes of this categorization).
- Local environmental conditions (temperate, desert, maritime, tropical, and arctic).
- Contribution of spatial disorientation (SD) in the accident sequence.
- Contribution of brown-out conditions in the accident sequence.

Due to flying hour totals being calculated on an annual basis, we chose 1 January 2010 as the demarcation point between the two principal time periods in the study and classified those mishaps that occurred prior to this date as being in the pre-Haddon-Cave era, and those occurring after this date as being in the post-Haddon-Cave era.

Table II. UK Ministry of Defence Rotary Wing Accidents, 2000–2015.

	OPERATIONAL ROLE/AIRCRAFT TYPE									
	ATTACK	TRANSPORT				MULTI-ROLE		TRAINING		
	APACHE	CHINOOK	MERLIN	PUMA	SEA KING	LYNX	GAZELLE	SQUIRREL	OTHER	TOTAL
All Accidents										
# of accidents per aircraft type	1	4	4	12	5	14	6	6	1	53
% of total accidents	1.9	7.5	7.5	22.6	9.4	26.4	11.3	11.3	1.9	100.0
Rate per 100k flight hours	0.67	1.91	2.64	8.16	1.13	3.35	2.52	1.65	0.58	2.32
Accident severity										
Fatality occurred (#)	0	1	0	6	2	4	2	2	0	17
% of total accidents	0.0	1.9	0.0	11.3	3.8	7.5	3.8	3.8	0.0	32.1
Rate per 100k flight hours	0.00	0.48	0.00	4.08	0.45	0.96	0.84	0.55	0.00	0.74
Major injury occurred but no fatality (#)	0	1	3	5	1	2	1	1	0	14
% of total accidents	0.0	1.9	5.7	9.4	1.9	3.8	1.9	1.9	0.0	26.4
Rate per 100k flight hours	0.00	0.48	1.98	3.40	0.23	0.48	0.42	0.28	0.00	0.61
Accident occurred while executing an operational task										
# of accidents per aircraft type	1	3	2	9	3	3	0	0	0	21
% of total accidents	1.9	5.7	3.8	17.0	5.7	5.7	0.0	0.0	0.0	39.6
Rate per 100k flight hours	0.67	1.43	1.32	6.12	0.68	0.72	0.00	0.00	0.00	0.92
Local environment of accident										
Temperate (# of accidents)	0	0	2	6	2	8	5	6	0	29
Desert (# of accidents)	1	4	2	6	1	2	0	0	0	16
Maritime (# of accidents)	0	0	0	0	2	3	0	0	0	5
Tropical (# of accidents)	0	0	0	0	0	0	1	0	1	2
Arctic (# of accidents)	0	0	0	0	0	1	0	0	0	1
Spatial Disorientation Accidents										
# of accidents per aircraft type	1	3	2	4	2	6	3	2	0	23
% of aircraft type accidents	100	75.0	40.0	36.4	40.0	42.9	50.0	33.3	0	43.4
Rate per 100k flight hours	0.67	1.43	1.32	2.72	0.45	1.44	1.26	0.55	0	1
Brownout Condition Accidents										
# of accidents per aircraft type	1	3	2	4	1	1	1	0	0	13
% of aircraft type accidents	100	75.0	40.0	36.4	20.0	7.1	16.7	0	0	24.5
Rate per 100k flight hours	0.67	1.43	1.32	2.72	0.23	0.24	0.42	0	0	0.57

Annual flying hours were gathered and corroborated from a variety of sources, including the Military Aviation Authority, Joint Helicopter Command, the military Service Safety Centres, engineering authorities, project teams, contractors, and individual units. Flying hour totals were pooled across commands, units, and other organizations responsible for the operation of similar aircraft types. Accident rates were calculated by dividing the number of accidents by the total flying hours during each period. Using techniques described by Rosner, accident rates in the two time periods of interest were compared via the normal-theory method, and a rate ratio (along with a 95% confidence interval) was obtained.[14] Microsoft Excel 2010 was used for all tabulations, statistical calculations, and quantitative analyses.

RESULTS

During the 16-yr period between January 2000 and December 2015, 53 rotary-wing accidents met the inclusion criteria. The overall accident rate was 2.32 accident events per 100,000 flight hours. **Table II** summarizes the data, the initial categorizations, and the observed accident rates across categories. Of note, "Other" includes the Bell 212, Griffin, Wildcat, and Wessex platforms.

Accident rates were also compared across aircraft types by calculating rate ratios in order to compare the accident rate observed in each aircraft type against the pooled rate among all other types.[14] These statistical analyses failed to demonstrate significant differences between accident rates across aircraft types. Of all accidents during the study period, 32% included a fatality, while 26% included major injury to at least one aircraft occupant, but no fatalities. Of the accidents, 40% occurred in the operational setting, with the vast majority occurring in temperate ($N = 29$) or desert environments ($N = 16$). Of the events, 43 (83%) included at least some attribution to aircrew human factors, and 23 events (43%) involved some degree of spatial disorientation. There were 13 events (25%) that involved brown-out conditions.

To assess the trend in the accident rate prior to and after the Haddon-Cave report, the data were pooled into two periods, and incidence rates were calculated. From 2000 through 2009, the accident rate was 2.81 events per 100,000 flight hours, and from 2010 to 2015, the accident rate was 1.24 events per 100,000 flight hours.

Comparison of these rates via the normal-theory method resulted in a statistically significant difference ($P = 0.031$). The rate ratio between the pre-Haddon-Cave era and the post-Haddon-Cave era was determined to be 2.27, with a 95% confidence interval ranging from 1.11 to 4.65. **Fig. 1** provides a graphical representation of these annual accident rates over the period of observation.

DISCUSSION

In this study, the observed accident rate from 2000 to 2015 for UK military helicopters was 2.32 per 100,000 flying hours. Two

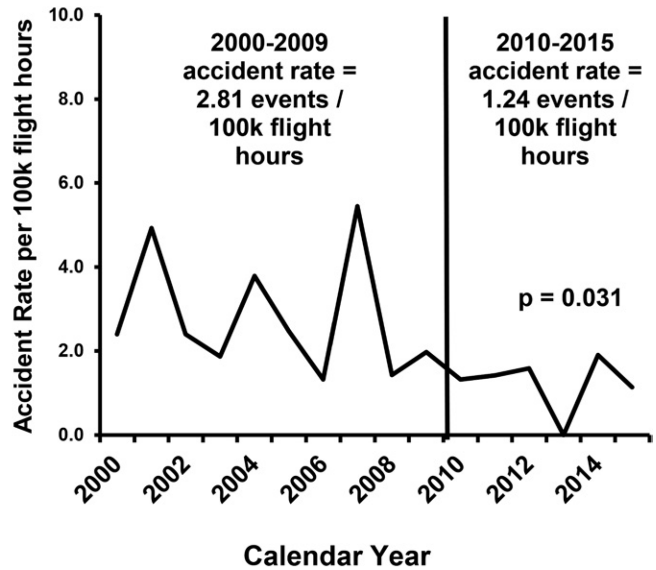

Fig. 1. Annual rotary-wing accident rate per 100k flight hours, UK Ministry of Defence: 2000–2015.

previous studies using similar methodology illustrate comparable but slightly higher rotary-wing accident rates. Bushby et al. reported an accident rate of 3.29 per 100,000 flying hours from 1983–2002 when reviewing U.K. military helicopter accidents.[5] Adams et al. reported an accident rate of 2.5 per 100,000 flying hours from 1991–2010 when reviewing UK Army helicopter accidents.[1] Within the current study, accident rates continued to fall from 2.81 events per 100,000 flying hours between 2000 and the end of 2009, to 1.24 events per 100,000 flying hours between 2010 and 2015. This decrease in the accident rate clearly shares a temporal association with the implementation of Haddon-Cave's recommendations.

Quantifying cultural change is challenging, but the construct of designated duty holders within the aviation community that arose from Haddon-Cave's recommendations following the Nimrod accident would appear to be the most impactful on the data presented in this study. This duty holder concept identifies specific individuals who are made personally accountable and responsible for potential 'risk to life' decisions within flying organizations.[9] As currently defined by regulation, aviation duty holders have "a personal duty of care for the personnel under their command … and the wider public who may be affected by their operations."[11] Additionally, these duty holders are "legally accountable for the safe operation of systems in their Area of Responsibility and for ensuring that risks to life for 1st, 2nd, and 3rd parties are both ALARP (as low as reasonably practicable) and tolerable."[11] This construct empowers these leaders with the authority to halt or amend activities if specific safety concerns are identified, and firmly places the responsibility (and potential blame) for any untoward events squarely at their feet.

It is also worth noting that Haddon-Cave's recommendations occurred against a maturing backdrop of rotary-wing reorganization related to the delivery of helicopter training and operations. Specifically, the Defence Helicopter Flying School was set up in 1996 to provide a unified ab initio military helicopter training system, and in 1999 the Joint Helicopter Command was established to consolidate the battlefield helicopters of the Royal Navy, British Army, and Royal Air Force under a single command.[10] Although helicopter assets under the Fleet Air Arm and the Search and Rescue Force continued largely unchanged, the formation of Joint Helicopter Command gradually harmonized battlefield helicopter crew training and operating procedures across the UK's Ministry of Defence. However, it is beyond the scope of the current review to quantify the overall impact on the accident rate of these new approaches to rotary-wing organizational structure, training, and operations.

From a materiel standpoint, there has been a significant modernization of the helicopter fleet across the UK Ministry of Defence that may have also impacted the overall accident rate. Some analog aircraft have been replaced with more sophisticated digital platforms that offer enhanced situational awareness. Older platforms such as the Westland Wessex have been retired, while most remaining platforms have been upgraded in some way, and new aircraft such as the Apache, Merlin, Wildcat, Squirrel, and Griffin have been introduced.[2,16] Cockpit workload requirements continue to shift away from the primary tasks of flying (which is increasingly supported by technology and automation) and move toward managing the systems and information sources onboard modernized aircraft, with a direct effect on aircrew problem solving skills and actions during periods of high workload.[6] Although advances in automatic flight control and flight management systems may have reduced the need for pilot control inputs and some system monitoring tasks, multiple information feeds from other battlespace users could potentially escalate the overall operational workload facing aircrew during complex mission sets.[13] In general terms, newer platforms may also provide improved crashworthiness, while the legacy fleet has benefited from upgrade programs intended to reduce the risk of injury or fatality from mishap events.

The shift from complex peace operations to counterinsurgency and hostile operations in the operational context facing the UK military rotary-wing community may have also affected the accident rate, as flying organizations were forced to review and relearn flying techniques and revise standard operating procedures. This shift from temperate to desert operations, with the specific risk of brownout and other forms of degraded visual environments, also forced the evolution of Ministry of Defence predeployment training and capability development programs early in the Southwest Asia experience. The operational imperative to fly in more challenging environmental conditions may have enabled the development of individual skills over time, with greater tolerance and learned ability while flying in degraded visual environments.

SD is a particular risk for military helicopter crews and many previous studies have highlighted the high prevalence of SD as a causative (or contributory) factor in accident sequences, as well as its persistence and association with higher rates of injury and fatality.[3,4,7,8,12] SD accidents remain a prevalent risk in this study, being acknowledged in 43% of accidents. Earlier studies highlighted a fixed SD accident rate against a declining all accident rate.[5] However, Gaydos described a welcome downward trend in the SD accident rate when reviewing U.S. Army helicopter accidents from 2002 to 2011.[8] SD, and in particular brownout, might be viewed as a more likely outcome for transport helicopter crews as they present greater downwash and are more likely to land on unprepared desert surfaces, or surfaces that have not been formally surveyed, for the movement of personnel and materiel and for casualty evacuation.[15] Indeed, in this study, 9 of 13 accidents featuring brownout were found among transport platforms; these typically occurred early in the deployment cycle and before aircrew training, experience, and helicopter landing site improvements were realized. Future research should focus on these interacting variables, as well as others, in order to inform future SD accident mitigation efforts.

In conclusion, rotary-wing aviation remains a risky endeavor for those who choose to participate and accident etiology is complex and varied. Design factors, organizational changes, and training innovations may affect risks and outcomes. The combined influence of all these factors is well beyond the scope of this study, but would be of value for the pursuit of future researchers. However, by examining available accident data and continuing the relentless pursuit of performance improvement initiatives that combine multidisciplinary inputs and participation, enduring risk mitigation is both worthwhile and achievable.

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