Fatality and Operational Specificity of Helicopter Accidents on the Ground

Alexander J. de Voogt; Caio Hummel Hohl; Hilary Kalagher

INTRODUCTION: Accidents with aircraft standing are more likely with helicopters than fixed-wing aircraft due to the common presence of off-airport landings and the possibility of the rotor system to strike objects in its immediate surroundings.

METHODS: A total of 115 accidents involving helicopters characterized as "standing" as a broad phase of flight were selected from the NTSB online database for the period 1998 until 2018.

RESULTS: Accidents reporting fatal (8.7%) or serious injuries (7.8%) were significantly less likely to occur when the aircraft was substantially damaged (84.3%) or destroyed (5.2%). The majority of the cases occurred after off-airport landings (57.4%), which were reported significantly more often in Alaska (N= 15). A main rotor strike with an individual was at the basis of each of the 10 fatal accidents in the dataset and in 8 of these cases the cause of the accident was attributed to the victim. None of the accidents occurred in instrument meteorological conditions, but, in particular, high winds and gusts proved a main cause of accident (18.3%).

CONCLUSION: Pilot, passengers, and crew endangered themselves when they were outside the aircraft while the rotors were still turning. Helicopter operating manuals should highlight the limitations and dangers for wind and wind gusts not only during takeoff and flight, but specifically when standing.

KEYWORDS: aviation, rotary-wing, rotor strike, off airport, rollover.

de Voogt AJ, Hummel Hohl C, Kalagher H. *Fatality and operational specificity of helicopter accidents on the ground*. Aerosp Med Hum Perform. 2021; 92(7):593–596.

In previous studies on nonmilitary helicopter safety, it was shown that mishaps can not only occur when helicopters are airborne, but also when they are standing.[4] In the latter case they are in operation on the ground with engine(s) running or with the engine(s) shut down but with the rotors still turning. Rollovers may occur when a skid is stuck in uneven terrain or when wind gusts lift the helicopter into unwanted directions. Several helicopter operations, such as aerial application and emergency medical services (EMS), include off-airport landings that may increase the possibility of encountering uneven terrain. In addition, both the tail rotor and the main rotor may strike people or objects on the ground. Unlike propellers on fixed-wing aircraft, which rarely hit the ground or the fuselage of the aircraft, the main rotor system of a helicopter has a wider span and may flex or droop at the far ends. Especially in the case of unfavorable gusts of wind, the rotor blades may strike people standing nearby, the fuselage of the aircraft, or even the ground. These possibilities suggest that accidents of helicopters standing on the ground are more likely than for fixed-wing aircraft.

Helicopter accident analysis has mostly concentrated on EMS, with occasional studies on aerial application and sling loads.[2,4] In the case of EMS, helicopter flights in instrument meteorological conditions (IMC), at night, or both are deemed to be the most dangerous.[1] However, these circumstances are less likely to affect accidents with helicopters on the ground. In EMS, aerial application and sling-load operations off airport are common, which would elevate the risk of rotor strikes when standing.[4,8]

In this study, the characteristics of helicopter accidents when they are standing on the ground are investigated using the National Transportation Safety Board (NTSB) database over a

From Drew University, Madison, NJ, USA.

This manuscript was received for review in October 2020. It was accepted for publication in March 2021.

Address correspondence to: Alexander J. de Voogt, Ph.D., Drew University, 36 Madison Ave., Madison, NJ 07940, USA; adevoogt@drew.edu.

DOI: https://doi.org/10.3357/AMHP.5801.2021

20-yr period.[9] Contrasts between specific operations and the circumstances of fatal accidents are given particular attention.

METHODS

Accidents involving helicopters characterized by "standing" as a broad phase of flight were selected from the NTSB online database for the period 1998 until 2018.[9] The database using these selected parameters afforded 116 accidents as "standing". For each of these reports it was determined if the aircraft was in a standing position at the time of the accident. One accident was removed from the dataset as it involved an autorotation landing on water with no indication of being in a "standing" position. Significant relations between factors of the accidents were determined using Pearson Chi-squared analysis with a *P*-value of 0.05 or lower or using the Fisher Exact Test with a *P*-value of 0.05 or lower when the expected cell frequencies were less than 5.

RESULTS

Out of 3291 helicopter accidents for the 20-yr period from 1998 until 2018, 115 (3.52%) were identified as standing in the broad phase of flight during which the accident occurred. In the same period, 28,386 fixed-wing aircraft accidents were reported with 444 (1.56%) accidents occurring during the standing phase of flight.

Landings were off airport in the majority of cases ($N = 66$) with 6 fatalities, which was not significantly more than the 4 fatal accidents reported on airport grounds ($P > 0.05$). Most of the helicopter accidents occurred in Alaska ($N = 15$), California ($N = 10$), and Florida ($N = 10$). The accidents in Alaska were off airport in 13 out of 15 cases, which is significantly more often than in the other states combined (52 out of 102, Fisher's Exact Test; $P < 0.05$). The accidents in Alaska did not include any fatalities.

In this dataset 10 accidents reported a fatality and only 6 reported a destroyed aircraft. A Fishers Exact Test revealed a significant inverse relationship between the damage to the aircraft and the injury severity of the people involved in the accident ($P < 0.05$). In other words, accidents reporting fatal or serious injuries were significantly less likely to occur when the aircraft was substantially damaged or destroyed (see **Table I**). None of the rollovers in this study resulted in a destroyed aircraft; however, all 29 helicopters involved in rollovers were substantially damaged. Two rollovers caused a fatality, while in 27 other cases the rollover was not fatal, but the difference with all other causes combined was not significant ($P > 0.05$).

Table I. Injury Severity and Damage to the Helicopter.

	INJURY SEVERITY			
DAMAGE TO AIRCRAFT	**NONE**	**MINOR**	**SERIOUS**	**FATAL**
None	0	0	2	5
Minor	0	0	2	3
Substantial	74	17	4	2
Destroyed	3	2	1	0

In all cases in this dataset the engine was either running or had just shut down while the rotor blades were still turning. In the latter case ($N = 6$), all accidents involved a rotor strike. There was a total of 48 main rotor strikes and 20 tail rotor strikes with 3 cases that included both tail and main rotor. The main rotor struck a person in 11 cases, of which 3 were pilots and the tail rotor struck a person in 2 other cases. In all fatal accidents in this dataset, the main rotor blades struck a person, which led to the fatality. In four additional cases a person was also struck by a main rotor or tail rotor blade, but in all these instances the person was seriously injured and survived. In most cases (80%), the victim of the fatal rotor strike was also attributed with the cause of the accident. The people that were struck fatally included a flight engineer, ground crew, paramedic, passengers ($N = 3$), and pilots ($N = 4$). Inattention on the part of the victims ($N = 8$) was the main cause, while in two other cases it was either the pilot who was violating procedures, which led to a passenger being struck by a blade, or it was the unexpected gust of wind that was the considered the main cause.

Helicopters were operating under different Federal Aviation Regulations (FAR). The different proportions of fatal accidents between these operations was not significant. Among the different operations, five were conducting emergency helicopters services (EMS) and one flight was conducting a search and rescue that was fatal. Out of the 67 accidents in Part 91, there were 17 conducting instructional flights, none of which were fatal. The differences between the types of operations did not show significant differences in the proportion of fatal accidents or the numbers were too low for a statistical analysis (see **Table II**).

There were 45 helicopters with a reciprocating engine reporting 2 fatalities. The remaining 70 had turbo jet/shaft engines with 8 fatalities. A Fisher exact test revealed that the proportion of fatalities in reciprocating engines was not significantly different from the proportion of fatalities in turbo jet/shaft engines ($P > 0.05$). There were 11 twin-engine helicopters in this dataset with 2 fatalities and no destroyed aircraft. There were three twin-engine helicopters operating under Part 135 and the rest under Part 91. It is noted that all accidents reporting mechanical failures as part of the accident were not fatal.

Pilots had an average of 5927 flight hours with a high of 28,710 and a low of 12 with only 8 pilots with less than 100 total flight hours while there were 24 with more than 10,000 total flight hours. Two cases did not report the total number of flight hours. The average age of the pilots involved was 43 yr with a low of 22 and a high of 78 and four cases in which pilot age was not reported.

The cause of accident was attributed to the flight crew ($N = 3$, of which 2 were fatal), ground/service crew ($N = 10$, none fatal), once to an engineer and fatal, maintenance personnel ($N = 8$, none fatal), manufacturer ($N = 2$, none fatal), passengers ($N = 2$, of which 1 was fatal), pilot and passenger ($N = 1$ and fatal), pilot (58 of which 4 were fatal), pilot of another aircraft ($N = 2$, none fatal), undetermined or unknown ($N = 5$, none fatal), and mechanical failures and weather issues that were not attributed to a

Table II. FAR Operations in Relation to Fatality, Wind, and Number of Engines.

	PART 91	PART 133	PART 135	PART 137	PUBLIC USE
Total	67 (4 fatal)	7	20 (3 fatal)	9 (1 fatal)	12 (1 fatal)
EMS	4	0	1	0	1* (fatal)
Instruction	17	0	0	0	0
Off airport	34 (2 fatal)	5 (1 fatal)	16 (2 fatal)	6	5 (1 fatal)
Twin-engine	8	0	3 (2 fatal)	0	0
Wind-related	13 (1 fatal)	3	5 (2 fatal)	0	0

FAR: Federal Aviation Regulations; EMS: Emergency Medical Services.
*Search and Rescue.

specific individual or group. It is noted that in half the fatal cases ($N = 5$), the cause of a fatality was attributed to someone other than the pilot, namely a crewmember or engineer ($N = 3$), a passenger ($N = 1$), and in one case a crosswind gust that was not attributed to a specific individual or group.

In 21 cases, of which 3 were fatal, wind gusts or unfavorable winds were a cause or contributing factor to the accident; of these, 3 were in Part 133, 5 were in Part 135, 0 were in Part 137, 13 were in Part 91, and 0 were in Public Use (see Table II). The difference between the number of wind-related accidents in Part 91 and 135 versus all other operations was not significant ($P > 0.05$).

A Fisher's Exact Test revealed that pilots with 5000 or less flight hours ($N = 68$) included 7 cases in which wind was a contributing factor or cause while those pilots with more than 5000 h included 13 cases, which is significantly more ($P < 0.05$). There were 4 cases out of 11 in which twin-engine helicopter accidents reported wind as a factor or cause, but this was not significantly different from single-engine helicopters ($P > 0.05$).

None of the accidents occurred in IMC. Light conditions were reported as dusk ($N = 1$), night ($N = 8$), and day ($N = 106$), but all fatal accidents occurred in daylight conditions.

DISCUSSION

Accidents with aircraft standing are more common with helicopters than fixed-wing aircraft. The characteristics of these helicopter accidents are distinct from those found in most other helicopter accident studies. The severity of the injuries and the damage to the aircraft are inversely related, a situation so far only found with balloon accidents.[5] This may be partly explained by the presence of rollovers, which substantially damage the aircraft but rarely lead to serious injury, as well as rotor strikes that are often fatal when it involves a person, in which case the strikes rarely sustain damage to the aircraft.

The accidents occurred with both twin- and single-engine helicopters and under different FAR. Recent research on twin-engine helicopters found that twin-engine helicopters have fewer accidents and that flights under FAR Part 135 are likely to limit accidents in general due to additional training and weather restrictions.[3] The preponderance of fatal accidents occurring under Part 135 in this dataset did not show a significant difference with those under Part 91. In the case of twin-engine helicopters, fatal accidents only occurred under Part 135. This suggests that these regulations do not effectively mitigate the accidents of helicopters when they are standing. However, added pilot training requirements, which are mandatory under Part 135, could include recommendations concerning helicopters standing.

The majority of the cases occurred after off-airport landings, which occurred significantly more often in Alaska. This state has been mentioned in the literature as having a challenging environment for aviation and its off-airport operations may explain its prominence in this dataset as well.[7] The presence of specialized FAR operations, such as aerial application and sling loads, as well as EMS operations, was not related to a higher presence of fatalities or wind-related accidents, but the nature of their operations, in particular the presence of off-airport landings, likely explains their presence.

A rotor strike with an individual was at the basis of each fatal accident in the dataset. In 80% of the fatal accidents, the cause was attributed to the victim of the accident, suggesting that pilots, crew, and passengers endangered themselves when they were outside the aircraft while the rotors were still turning. Even if some procedures may allow pilots to leave their aircraft while the rotor system is still running, the general danger of allowing people near the main rotor system is highlighted by this study.

One particular description of an accident involving a rotor strike illustrates the point made about rotor strikes. In this case from 2013, a pilot/owner had just taken control of a helicopter from another pilot. As the relieved pilot was walking away from the helicopter and between the 10 and 11 o'clock position forward of the helicopter, he was struck by a rotating main rotor blade. "The pilot/owner stated that, when exiting the helicopter, it was the company's practice to disengage the rotor drive system and secure the collective control. In this condition, the rotor blades droop below the normal height, and the drooping is most pronounced in the 9 to 12 o'clock position of the rotor disk." The manufacturer representative added that the main rotor height can vary depending on how the helicopter landing gear was serviced. Also, depending on the position of the cyclic, the main rotor can descend lower than 6 ft when the main rotor is operating.[9] This description highlights several factors that may affect the drooping of a main rotor blade and may inform the content of operating manuals.

Although IMC conditions played no role in this accident set, weather conditions, in particular high winds and gusts, proved a main cause of accident. In several cases, such winds led to rotor strikes and mechanical failures that substantially damaged or even destroyed the aircraft. This element appeared significantly more likely to occur with more experienced pilots. One may argue that more experienced pilots find themselves off airport more often or underestimate the risk of drooping blades. While regular helicopter training is unlikely to mitigate the occurrence of such accidents for experienced pilots, the dangers of drooping rotor blades, especially in gusty conditions, could be explained not only in aircraft manuals but also in operating manuals and training materials.[6] Depending on the helicopter and the type of rotor system, helicopter manuals may highlight the limitations and dangers for wind and wind gusts not only during takeoff and flight, but specifically when standing, for instance when (un)loading passengers, and during start-up and shut-down procedures.

ACKNOWLEDGMENTS

Financial Disclosure Statement: The authors have no competing interests to declare.

Authors and Affiliations: Alexander J. de Voogt, Ph.D., Caio Hummel Hohl, B.A. Candidate, and Hilary Kalagher, Ph.D., Drew University, Madison, NJ, USA.

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