Safety Considerations for Medical Staff and Patients Who Fly Over Water in a Helicopter for Work or Recreation

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BACKGROUND: Around 25% of people involved in a helicopter accident in water do not survive. From time to time, physicians and their medical staff are required to fly over water in a helicopter to attend one or more seriously ill patients. Many will have had little or no experience of the issues involved if the helicopter has an accident in the water. Also as Family Practitioners, Aeromedical Examiners, and Flight Surgeons, they are asked to provide advice to patients, travel agents, and airline booking agents about whether an overwater helicopter flight is advisable or not.

METHOD: From 50 yr of helicopter accident evidence in the scientific literature, government agency reports, and statistics from the military safety centers and the offshore oil industry, the critical hazards involved and risks to medical staff and their patients have been identified.

RESULTS: Patients most at risk are those who suffer from cardiovascular or respiratory disease, have physical disabilities, have a very large body size, and anyone who is a non-swimmer. Medical staff are at risk if they are not familiar with the procedure for escape from a flooded inverted cabin and difficulties after escape from the fuselage with life jackets, life rafts, and sometimes the necessity to swim ashore.

CONCLUSIONS: With 50 yr of hindsight, many of the deaths were preventable, and many lives can be saved if a series of very simple mental and physical preventive actions are taken by anyone stepping on to a helicopter that flies over water.

KEYWORDS: marine, survival, helicopter, accident, water.

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From time to time, physicians and their medical staff are required to fly over water in a helicopter to attend one or more seriously ill patients. Many will have had little or no experience of the issues involved if the helicopter has an accident in the water. Also as family practitioners, aeromedical examiners, and flight surgeons, they are asked to provide advice to patients and their travel and airline booking agents when a vacation involves an overwater helicopter flight and whether it is safe to proceed.[24] From 50 yr of scientific evidence, we have identified the hazards involved.[1] The patients most at risk are those who suffer from cardiovascular or respiratory disease, have physical disabilities, have a very large body size, and anyone who is a nonswimmer. The reasons for this become obvious once one follows the four phases of the event tree: preimpact, impact, escape from the helicopter, and post-accident survival. Because there are preventive measures to be taken in each one of these phases that may save a life, each phase has been discussed individually under its own heading.

To put the whole issue in context, this is one survivor's terrible ordeal. It covers virtually every aspect of the human factors of escape and survival from a helicopter accident into water, a lake, a river, or the sea. This story is not uncommon:

> "*The weather was clear, sunny and warm. Our seat belts were fastened and the crew boarded the helicopter. The engines started at the same time as the safety tape was being played. I could not make much of it out. We taxied into position and lifted off. We did not get far. The crash was so unexpected; there was a loud 'Pop', and down we went.*

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Immediately upon impact the cabin filled with water, we landed on our left side and when I looked over, the passenger by the left window was gone under water, my husband was next to me and I was in the right rear window seat.

I only had one thought—get out of here. I was mad because nothing worked as it should. Mad because we had no instructions and there were no flotation devices. Terrified because my husband was trapped and then concerned because we had a good distance to cover and he cannot swim well. The water was like ice and I was shaking uncontrollably. Terrified, because I was certain that the man next to us had drowned.

I was trying to get my seat belt unfastened, my belt was jammed, and so I tried to open the door. It wouldn't open. My husband's seat belt was jammed also, but he was leaning over me trying to help with the door. The water was filling the cabin fast. A crewmember had gotten outside and was on top helping with the door. This is very fuzzy to me. How I finally got my seat belt undone and got out, I don't recall. Then I realized my husband had not got out. The helicopter seemed to have capsized and he was covered in debris struggling to get out. He was straining to keep his head above water. Finally, he was able to get his belt undone and swim free."

METHOD

We consulted a wide range of worldwide accident data from the scientific literature of the past 50 yr, from government agency reports such as the NTSB, FAA, CAA, AAIB, BASI (Aus), TSB (Cdn), statistics from the safety centers of the U.S. Army, Navy, Air Force, and Coastguard, the RAF and RN, and reports from NATO (AGARD), and research establishments such as RAF IAM, Pensacola, and the former DCIEM, Toronto, and reports from the offshore oil industry.

We have deliberately not made any distinction between a crash into water, or a controlled premeditated emergency landing on water, otherwise known as a ditching. As far as the passengers are concerned, one minute they are sitting comfortably strapped in their seats, alive and well. Then seconds later, they find themselves in the water in a life threatening situation, irrespective of the classification of the accident.

If the helicopter lands in water, data show that in daylight about 25% of crew and passengers will not survive the event,[6,15,20,30] and if the accident occurs at night, the risk of fatalities triples.[3,27,31] Are helicopter accidents in water common or rare? In 1984, the Civil Aviation Authority's Helicopter Airworthiness Review Panel (HARP) analysis concluded that helicopter accident rates, either on a per-hour or per-flight basis were significantly worse than those for modern jet transport.[18]

It is not our intention to conduct a review of statistics here, only to say that accidents into water continue to happen regularly, as described in the references, with little sign of improved survival rate. Taber and McCabe[32] summarized all helicopter accidents worldwide between 1971 and 2005 and reported an overall survival rate of 66% among the 1643 crew and passengers (511 accidents). Even for those who survived (477 persons), 30% were injured.[32] In 2014, the Civil Aviation Authority confirmed that the mortality risk, i.e. the possibility of a passenger not surviving a random chosen flight in a helicopter over the North Sea, was ten times higher than for a passenger flying in a commercial jet.[19] Ross and Gibbs presented evidence that between 1990 and 2007 there were disproportionately more night accidents by a factor of five.[31] Most recently, in February 2016 a Bell 206 with four passengers on board crashed into Pearl Harbor, HI.[29] All five occupants survived, but one is critically ill in hospital because he could not undo his seat belt and spent a long time underwater. In April 2016, a Super Puma crashed in the sea off Bergen, Norway, killing all 13 crew and passengers. In September 2016, the pilot and one of two passengers died in a private Bell 206 helicopter that landed in the Restigouche River, New Brunswick, Canada.[25] To summarize, the data clearly show that the survival statistics are not improving. Clifford[20] and Muller et al.[30] concluded that the principal cause of death was drowning.[20] This among other causes of death is preventable, and below we have described several very simple steps that can be taken to save lives.

RESULTS

Pre-Impact

Why are the statistics so gloomy? There are several reasons; the first is that helicopters do not glide well. If there is an inflight problem, and because the flights are generally low level, there is little time to prepare for the ditching. In most events there is less than 15 s of warning time before the crew and passengers find themselves in the water.[9,10,17] This gives the occupants little chance to take a good breath before their heads go underwater.

Impact

The impact will be terrifying, which if the passengers can recall, will include a loud explosion as the red hot exhaust pipes of the engine suddenly disintegrate in the cold water. Coincidental to this, if the windows have been stoved in, there will be a massive inrushing of water. One pilot explained it was like being hit in the chest with a fire hose.

Escape from the Cabin

Because the helicopter has a high center of gravity with all the weight concentrated in the engines and gearbox, and a low center of buoyancy, it is inherently unstable. Unless the pilot is able to land the helicopter on flat calm water, it does not float well, even with buoyancy bags. There is a 50% chance that it will fill up with water and rapidly sink and invert in a high percentage of accidents.[10,15,32] Broadsmith modeled the behavior of helicopters floating in typical conditions in the North Sea. The model rolled over two or three times, and in breaking waves it capsized in 2 s.[5] Even if the helicopter safely lands upright on the water, it is balanced very precariously while the survivors start to make an escape from the cabin. Then what happens? The crew and passengers now find themselves disoriented in the pitch black, underwater with the helicopter still just floating upright, but more likely on one side or inverted.[6,20] At this stage

if they have not taken a deep breath, they are likely to drown. The problem for those who have survived so far is which way is up, which way is down, which way is left, which way is right, and where is the nearest escape exit?

There is not always an emergency exit by each seat, and for those sitting in an aisle seat, some passengers will have to queue.[12] Matters can be worse because the person next to them in a seat with an escape exit may have died. In the process of figuring out what to do next, the survivor may run out of breath (see below) and drown;[2,16,26] others who are not as agile, or not comfortable underwater, may have a considerable struggle to make their escape. Unfortunately, the exits are quite small, so any very large person may not be able to fit through the aperture. An additional problem is that there is no standardization of the mechanisms in helicopters to jettison the emergency windows and doors, so precious breath-holding time can be used up trying to jettison them.[4,7,8] This is particularly an issue for recreational travelers who have just taken a sight-seeing trip, or a physician responding to a medical emergency who may never have flown in a helicopter, or that type of helicopter, before.

If the flight has been taken over cold water, especially below 15°C (60°F), then the crew and passengers face the immediate problems of cold shock. The powerful stimulus from rapid skin cooling immediately upon immersion causes a deep inspiratory gasp, severe hyperventilation, and a massive increase in blood pressure and heart rate.[23] Most people do not realize that a person's breath-holding ability is greatly reduced in cold water, and for those who are not cold acclimatized, it may be as little as 15 s in 5°C water.[26] Thus death from drowning may occur before escape from the helicopter has been completed, or within a minute of escaping.

Post-Accident Survival

Even if a successful escape from the helicopter is achieved, the survivor is still not safely out of danger yet.[9,17,30] The person has to know how locate and don the life jacket if not worn in the cabin, then inflate it outside the fuselage and board the life raft. Unfortunately, the history of life raft performance in helicopter accidents is not good.[2,13,14] The life raft may not be deployed and sink with the helicopter, it may have been damaged in the accident and rendered useless, it may be inflated inverted and no one has the physical strength to right it, or it can be simply blown up against the side of the fuselage and it may not be possible to board it. Even if the life raft inflates successfully, it takes extreme effort for those not trained to get into it from the water. Under such circumstances, the crew and passengers may have to abandon the life raft option and swim to shore or other rescue vessel.

The following anecdote illustrates some of these problems:

> *"Following an S61 helicopter ditching in the North Sea off Halifax, Nova Scotia, the pilot in command had shut down the helicopter engines and stopped the rotor, he moved aft to the passenger cabin to the passengers, the life raft was pushed away from the helicopter. As the raft moved into the outer limit of the rotor arc, the rotor blades were striking dangerously close to the raft and the passengers had difficulty keeping the raft from being struck. After launching the No. 1 life raft, the pilot, co-pilot, and remaining passengers inflated the No. 2 life raft beside the aircraft and stepped directly into it. The raft was then pushed away from the helicopter and it drifted under the tail pylon. The occupants had difficulty keeping the raft clear of the stationary rotor blades as the helicopter was pitching and rolling in the water. The No. 1 raft has a four inch tear from rubbing against the helicopter and as a result, the lower buoyancy chamber deflated. By the time the rescue helicopter arrived, the occupants were sitting in 18 inches of water."*

If the crew and passengers survive this event and safely make it out of the helicopter, if there is no life raft available, and they are not wearing a lifejacket (not all helicopter operators insist on the passengers wearing the lifejacket in flight), the next problem is swimming failure caused by rapid cooling of the nerves and muscles.[33] A fact not appreciated is that the distance a person can swim in cold water is reduced by about two-thirds of the distance compared to that person's ability in warm water. Even the best swimmers can only swim in cold water for about 45 min before swimming failure. With a lifejacket it is only possible for most people to swim approximately 800 meters in very cold water before drowning.[22]

Passengers who have serious cardiac risk factors may not survive the cold shock if the flight is over cold water; those with respiratory problems may not have enough breath-holding ability to make their underwater escape; those with serious physical disabilities or very large body size may not be able to navigate underwater through the cabin and squeeze out of the small escape exits; and none may have the strength to climb into the life raft or swim very far.

The medical advice? Perhaps postpone the trip or make alternate travel arrangements. Remember that if one of these patients becomes incapacitated on board and is occupying a seat next to an exit, he/she puts the life of other passengers in jeopardy by blocking that exit.

DISCUSSION

If a decision has been made to make the trip, there are a considerable number of simple positive physical and mental actions that can be taken to save life starting with the minute the person steps on board. As you make your way to your seat, have a look around for obvious obstructions and places where you can get snagged, such as internal fuel tanks. Note the seat arrangement and whether cargo has been stowed in front of a vital escape exit. Always try to sit next to a specific emergency exit or an exit adjacent to a window seat.

Once seated, before you do up your harness, take a look at the window/door and the jettison method (i.e., pull tab, lever, push out). Create a mental and physical schema by feeling for the window sill, the mechanism, or the place where you have to push to jettison the window, and note how far you have to reach. Recycle your harness release mechanism to make sure you can find it in the dark when you are

potentially underwater and drowning. Tuck the tail of your lap strap, if wearing a two-point harness, inside the belt around your waist. Underwater, you will have to make life saving actions as if you were blindfolded. For instance, the tail of the seat belt will float across the release flap of the harness and prevent you locating the flap to release it. Remember, seconds will count.

Where the water is predominantly below 15°C, those who fly over water as part of their profession generally wear survival suits and lifejackets. However, transient passengers and vacationers will only be offered a lifejacket, and it is not always worn during flight. It is usually stowed under the seat. Because of the short warning time of the accident there may not be time enough for it to be located or donned by a passenger before making an escape. To give yourself a better chance, make sure you know exactly where it is when you strap in, and physically feel the entire package and determine how it is released.

If you are sitting in an aisle seat, make a mental and physical schema of which route you are going to take to escape. If the person in the aisle seat has been seriously injured or incapacitated, they will not be able to jettison the exit and may even jam it. So you will have to go cross cabin. You have no time to wait, you must go. People in extreme survival escape situations always go forward, but going forward in a rear facing seat may cause collisions with passengers trying to go in the opposite direction. So it is very important to note which way you are facing and make the decision as to the escape path you will take.

Stow all your gear safely. Anything unsecured will be violently washed around the cabin, and you are the human target of objects flying around the cabin.

If you are in a military helicopter or one operated by the offshore oil companies, before you step on to the helicopter, you may be issued with an Emergency Breathing Apparatus (EBS). Make sure that the mouthpiece is clean and ready to be deployed, make sure the bottle is full and the valve to turn it on is switched to the 'ON' position. There will be a 'Press to test' button on the EBS. Some crew and passengers like to give it a press. This gives them confidence that the system is working. But, if you do this, only give it a very short press; remember this is the precious air that you need if you have to make a complex underwater escape. Don't waste it.

Again, when flying in a military helicopter or one operated by an offshore oil company, once you are strapped in, make sure that if you have been issued with a survival suit, that it is zipped up tight, that your life jacket and EBS are fitted correctly and your personal locator beacon is secure. Again create a mental and physical schema by feeling for the toggles on your life jacket, the mouthpiece on your EBS, and the location of your gloves. Ensure that your mike cord is not jammed behind the head rest when you put your seat back backward and forward, otherwise this may strangulate you as you force your head out of the emergency exit.

Accidents occur during all phases of flight, including takeoff, cruise, and landing. So you must be mentally and physically prepared for a ditching throughout the entire flight.

On the command 'ditching, ditching, ditching', assume the best brace position that you can for whatever type of harness that is fitted (not easy in the bulky survival suits), and try to make your body profile as small as possible so that you are less of a target for the inrushing water and debris flying around the cabin, which reduces the likelihood of you getting disorientated. Even if you are wearing a survival suit, be prepared for cold shock. Very cold water on the face may precipitate the gasp reflex and hyperventilation, so have your EBS ready.

To avoid disorientation, for exit on the right hand side of the helicopter, the right hand does all the initial work; the left hand is the primary reference point from where you started prior to the accident. First, the left hand grips the forward edge of the seat like grim death and does not let go. The crash position is then adopted with the right hand usually folded over the head, or protecting the face. After the accident, as soon as all the bubbles and movement have stopped, the survivor sits up out of the crash position still with the left hand firmly gripping the edge of the seat. Then the right hand feels for the escape exit jettison lever, pull tab, or push out corner of the window, and activates it, pushing out the exit. Then, the right hand transfers to the edge of the open window sill and takes a firm grip on it. That is the direction the survivor is going to take. Immediately, the left hand releases the grip on the seat and undoes the seat belt. Caution, this means the survivor will be free floating if he/she loses a grip on the sill at this time. Then the survivor bends hard over to the right, catches the edge of the sill with the left hand to join the right hand and commences to squeeze through the exit. The whole hand procedure is reversed if escaping through the left hand side exit.

Should you jettison the exit just before landing on the water, just after you have landed on the water, or wait for the helicopter to come to a stable floating position? As the majority of accidents occur with little warning this may be an academic question. We cannot give firm advice on this because we just do not have enough evidence to decide upon the best procedure; you will just have to make your own decision.

Cunningham showed that "dunker training" improved U.S. Navy crew survival statistics from 66 to 91%.[21] Travelers who find that there is an increasing demand for them to fly in helicopters over water may wish to consider taking a formal Helicopter Underwater Escape Course. These schools can be found on the International Association of Safety and Survival Training (I.A.S.S.T.) website (http://iasst@iasst.com).[28] A recent study shows that this training is extremely safe.[11]

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REFERENCES

1. Ahmed H, Naik G, Willoughby H, Edwards AG. Communicating risk. BMJ. 2012; 344:e3996.
2. Anton D. A review of UK registered helicopter ditchings in the North Sea. International Journal of Aviation Safety. 1984; 2(1):55–63.
3. Baker SP, Grabowski JG, Dodd RS, Shanahan DF, Lamb MW, Li GH. EMS helicopter crashes: what influences fatal outcomes. Ann Emerg Med. 2006; 47(4):351–356.
4. Barker CO, Bellenkes AH. U.S. Naval helicopter mishaps: cockpit egress problems. Aviat Space Environ Med. 1996; 67(5)480–485.
5. Broadsmith M. Ditching. Helicopter airworthiness, a post HARP review. London (United Kingdom): Royal Aeronautical Society, 1989; ISBN 090340932-1.
6. Brooks C. The human factors relating to escape and survival from helicopters ditching in water. 1989. Loughton, UK: Specialised Printing Services. NATO-AGARDograph No. AG 305 E. ISBN 92-835-0522-0. [Accessed 26 Jan. 2017.] Available from: http://www.dtic.mil/dtic/tr/fulltext/u2/a215755.pdf.
7. Brooks CJ, Bohemier AP. Helicopter door and window jettison mechanisms for underwater escape; ergonomic confusion! Aviat Space Environ Med. 1997; 68:844–857.
8. Brooks CJ, Bohemier AP, Snelling G. The ergonomics of jettisoning escape hatches in a ditched helicopter. Aviat Space Environ Med. 1994; 65:387–395.
9. Brooks CJ, MacDonald CV, Baker SP, et al. Helicopter crashes into water: warning time, final position and other factors affecting Survival. Aviat Space Environ Med. 2014; 85:440–444.
10. Brooks CJ, MacDonald CV, Donati L, Taber MJ. Civilian helicopter accidents in to water: analysis of 46 cases, 1979-2006. Aviat Space Environ Med. 2008; 79:935–940.
11. Brooks CJ, MacDonald CV, Gibbs PN. Injury rate in a Helicopter Underwater Escape Trainer (HUET) from 2005-2012. Aviat Space Environ Med. 2014; 85(8):857–862.
12. Brooks CJ, Muir HC, Gibbs PN. The basis for the development of a fuselage evacuation time for a ditched helicopter. Aviat Space Environ Med. 2001; 72:553–561.
13. Brooks CJ, Potter PL, De Lange D, Baranski JV, Anderson J. Options for liferaft entry after helicopter ditching. Aviat Space Environ Med. 1998; 69(8):743–749.
14. Brooks CJ, Potter PL, Hognestad B, Baranski J. Liferaft evacuation from a ditched helicopter: dry shod vs swim away method. Aviat Space Environ Med. 1997; 68(1):35–40.
15. Chen C, Muller M, Fogarty K. Rotorcraft ditchings and water impacts that occurred from 1982 to 1989-Phase I. U.S. DOT/FAA/CT-92/13. Pleasantville (NJ): Galaxy Scientific Corporation; 1993.
16. Cheung SS, d'Eon NJ, Brooks CJ. Breath holding ability of offshore workers inadequate to ensure escape from ditched helicopters. Aviat Space Environ Med. 2001; 72(10):912–918.
17. Civil Aviation Authority. Report of the review of helicopter offshore safety and survival. CAP report 641. Cheltenham (United Kingdom): Documedia Solutions, Ltd.; 1995. [Accessed 26 Jan. 2017] Available from: https://publicapps.caa.co.uk/docs/33/CAP641.PDF.
18. Civil Aviation Authority. Review of helicopter airworthiness (HARP). CAP report 491. London (United Kingdom): CAA; 1984.
19. Civil Aviation Authority. Safety review of offshore public transport helicopter operations in support of the exploitation of oil and gas. London (United Kingdom): CAA; 2014; CAP report 1145.
20. Clifford W. A Review of U.K. military and worldwide civil helicopter water impacts over the period 1971–1992. London (United Kingdom): Civil Aviation Authority; No 96005; 1996.
21. Cunningham W. Helicopter underwater escape trainer (9D5). NATO AGARD conference proceedings, No. 255 (Operational Helicopter Aviation Medicine). Neuilly-sur-Seine (France): NATO AGARD; 1978: 66-1–66-3.
22. Ducharme MB, Lounsbury DS. Self-rescue swimming in cold water: the latest advice. Appl Physiol Nutr Metab. 2007; 32(4):799–807.
23. Golden F, Tipton M. Essentials of Sea Survival. Champaign (IL): Human Kinetics; 2002. ISBN 07360 0215 4.
24. Haaland WL, Shanahan DF, Baker SP. Crashes of sightseeing helicopter tours in Hawaii. Aviat Space Environ Med. 2009; 80:637–642.
25. Hardy G. Investigation into deadly helicopter crash near Campbellton continues. CBC News 2016 Sept 5. [Accessed 26 Jan. 2017] Available from: http://www.cbc.ca/news/canada/new-brunswick/investigation-helicopter-crash-campbellton-continues-1.3748525.
26. Hayward JS, Hay C, Matthews BR, Overweel CH, Radford DD. Temperature effect on the human dive response in relation to cold water near drowning. J Appl Physiol. 1984; 56(1):202–206.
27. Hinkelbein J, Schwalbe M, Wetsch W, Spelten O, Neuhaus C. Helicopter type and accident severity in helicopter emergency medical services missions. Aviat Space Environ Med. 2011; 82:1148–1152.
28. I.A.S.S.T. Website. Southampton (United Kingdom): IASST [Accessed 31 Jan. 2017]. Available from http://iasst@iasst.com.
29. Kelleher J, McAvoy A. Helicopter accident near visitor site at Pearl Harbor. Associated Press. 2016 Feb. 19. [Accessed 26 Jan. 2017] Available from: http://www.marinij.com/article/ZZ/20160219/NEWS/160215202.
30. Muller M, Bark L. Rotorcraft ditchings and water impacts that occurred from 1982-1989. Phase II. U.S. DOT/FAA/CT-92/14. 33. Pleasantville (NJ): Galaxy Scientific Corporation; 1993.
31. Ross C, Gibb G. A risk management approach to helicopter night offshore operations. Presentation to the OGP. 2007 [Accessed 26 Jan. 2017] Available from: http://asasi.org/papers/2008/Risk%20Approach%20to%20Night%20Offshore%20Operations%20Presented%20by%20Gerry%20Gibb%20&%20Cameron%20Ross.pdf.
32. Taber M, McCabe J. An examination of survival trends bases on external flotation devices: a helicopter ditching review from 1971-2005. SAFE J. 2007; 35(1):1–6. ISSN 0191-6319.
33. Tipton M, Eglin C, Gennser M, et al. Immersion deaths and deterioration in swimming performance in cold water. Lancet. 1999; 354:626–629.