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TITLE

OPTIONS FOR LIFERAFT ENTRY AFTER HELICOPTER DITCHING

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ORIGINAL RESEARCH

Options for Liferaft Entry After Helicopter Ditching

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Method: Dry and wet evacuations were conducted by 24 male and 19 female subjects from the Nutec Super Puma Simulator into two different types of aviation liferaft. *Results:* Dry evacuation on the windward side is the method of choice. The non-canopy raft is subjectively and objectively easier to enter both from the helicopter and the sea. *Conclusions:* The non-canopy raft is the raft of choice, the canopy raft needs a redesign to ensure that it always inflates the correct way and both rafts need a redesign of the painter anchor point. Aircrew should have special training in open water after traditional pool training. A helicopter ditching survival compass has been developed for training all who fly over water for a living.

In July 1995, the CORD Group of Nova Scotia (1,4) conducted a ditched helicopter evacuation trial in calm water in the Bergen Fjord. The objective was to advise the National Energy Board of Canada of the preferred method of evacuation: dry vs. wet, and whether evacuation should be conducted on the windward or the leeward side of the helicopter.

The CORD Group (4) literature search associated with this work noted that the inflatable aviation liferaft has not performed well in the helicopter environment. These findings have been reinforced by the recent Super Puma LN-ODP ditching off Stavanger in January 1996 (Hognestad B. Personal communication. 1996). In 4 m seas, the crew first deployed the starboard liferaft on the windward side where it was blown on its side up against the fuselage and then decided to deploy the second liferaft on the port side. This liferaft was launched on the leeward side and a dry evacuation was attempted. It was impossible to paddle the liferaft clear of the fuselage because the helicopter drifted faster than the survivors could paddle. As a result, the liferaft was struck by the tail rotor, was punctured and sank. Then they swam back to the still floating helicopter along the painter, which fortunately had not been cut or damaged. Once back in the fuselage and after much effort, they forced the original starboard liferaft down onto the water, but in the process of cutting the entangled sea anchor, they inadvertently cut the painter. As a result, the survivors closest to the door did not have the strength to hold it close to the fuselage because the helicopter was drifting faster than the liferaft; only three survivors were able to get into it before it drifted clear on the windward side. They were hoisted by a rescue helicopter directly from the raft before the remainder of the survivors were hoisted from the floating fuselage later.

In 1996, Kinker et al. (2) added further weight to these findings. For the period 1977 to 1995, they reported that the liferaft was successfully deployed in only one-quarter of 67 U.S. Navy survivable helicopter ditchings. The problems were similar to those noted in the CORD report, i.e., loss of the liferaft because the helicopter rolled on top of it; raft puncture due to friction against the fuselage, or from a tail rotor strike; the raft being blown onto its side up against the fuselage, impossible to right; survivor difficulty with boarding; the line or painter securing it to the helicopter being cut by a sharp edge; and, difficulty or impossibility to launch the raft with the helicopter heaving and rolling precariously on the water or in the process of capsizing and/or sinking.

The basic conclusions from the Nutec (1) trial were: first, that the dry method is the evacuation of choice; second, that even though there are many problems with the wet method, it still should be taught as an alternative method because in a rapidly capsizing helicopter, there may be no choice but to throw the uninflated liferaft into the water and swim it away; and third, that evacuation, wherever possible, should be conducted on the windward side.

Three questions remained unanswered. What happens to degree of difficulty and escape times in more turbulent water? Should Canada retain the traditional liferaft in which the canopy and liferaft are integral and inflate together, or replace it with a liferaft where the canopy is independently erected later? And are there other significant problems that may arise in more turbulent water that have not been noted in previous evacuations carried out to date in calm open water?

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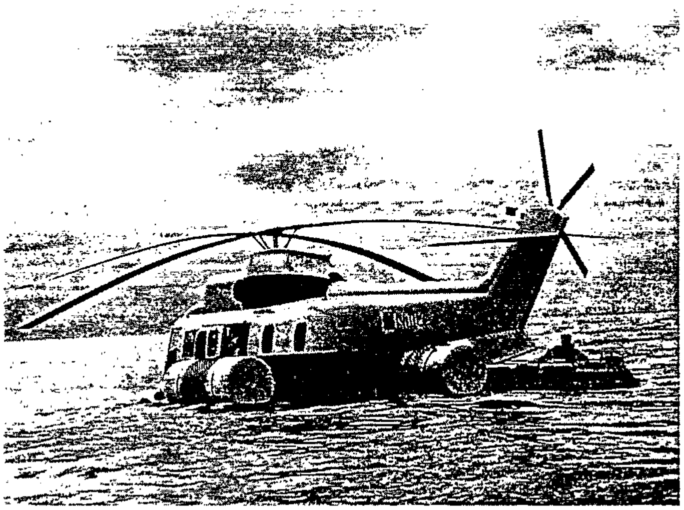

Fig. 1. Nutec Super Puma helicopter simulator. Note the large styrofoam bag mounted on the sponson to represent the inflatable flotation bag.

METHODS

The experiment was conducted in the Nutec facility off Norsik in Sund at the end of the Bergen Fjord in Norway using their Super Puma simulator. It was approved by their Human Ethics Committee. For additional safety, flotation bags similar to those on the actual helicopter were added (Fig. 1). Two fundamentally different life rafts were compared: a liferaft (Fig. 2) in which the canopy was erected after boarding the entire complement of survivors and clearing the strike envelope of the helicopter (non-canopy); and a conventional aviation type liferaft (Fig. 3) in which the canopy inflated as an integral part of inflation of the entire raft (canopy). For all evacuations, the helicopter was positioned crosswind, the worst case scenario.

After completing a health questionnaire and signing an informed consent form, a total of 24 male and 19 female subjects aged 18–48 yr were recruited through a newspaper advertisement, chosen on a first come, first served basis. All subjects could swim and had no physical impairments. They were advised that they could withdraw from the experiment at any time if they wished.

They were randomly assigned to four groups (A, B, C and D), each representing a full passenger load in the helicopter simulator. They underwent the Nutec 1-d classroom and pool training and underwater escape training required for offshore workers in case of a ditched helicopter evacuation.

Fig. 2. A non-canopy type aviation liferaft. The canopy is erected after paddling out of the strike envelope.

Fig. 3. A traditional canopy type aviation liferaft. The canopy is inflated integral with the entire liferaft.

For the evacuations and the training, subjects were dressed in a cotton T-shirt, cotton shorts and underwear, and a Helly Hansen 352 survival suit, each suit was clearly numbered to track the order of evacuation and entry into the liferaft. Because the survival suit is highly buoyant, a lifejacket was not required. Seat assignment for each evacuation was randomized from front to back into 1 of 12 seats in the simulator, but the order of seat evacuation was always the same. Each group conducted four dry and four wet evacuations. Half the dry and wet evacuations were executed from the windward side, the remaining half were executed from the leeward side. Half were done using the canopy liferaft and the other half using the non-canopy liferaft. For the eight experimental days, environmental conditions ranged from: wind 1–3.5 $km \cdot h^{-1}$; sea state up to 1.5 m and helicopter drift rate 1.25–3.50 kt. During calm conditions, a small boat pushed or pulled the helicopter at a rate of 2.25 kt to simulate actual drift.

A total of 32 evacuations were completed. Common to all evacuations was the presence of two Nutec instructors in the fuselage to act as the pilot and safety swimmer, but not as subjects. The pilot jettisoned the port emergency door and directed orderly evacuation of personnel. For safety purposes, a fast rescue craft with medical services was positioned close by. For recording data, one investigator was positioned inside the helicopter and two others in a stand-by vessel close by. Evacuation times were measured with a stop watch. The complete evacuation, including any difficulties, was recorded on video. The completion of each test evacuation was indicated by blowing the horn in the stand-by vessel when the investigators determined that each group had reached the safe zone.

The dry and wet evacuation procedures were identical to those reported in 1997 (1). Times were recorded for each individual to exit the helicopter and enter the water, for the total time to evacuate the fuselage, for the entire group to swim clear to the safe zone before inflation of the liferaft, and for the individual from evacuating the helicopter to entering into the liferaft.

After each run, the subjects were asked to rate the evacuation on a scale of 1 (very easy) to 20 (impossible), and to identify what problems he/she incurred. In addition, at the end of the eight runs, the subjects were asked specifically to rate the ease or difficulty in entering the liferaft from the helicopter and the liferaft from the sea for both the canopy liferaft and the non-canopy liferaft. All results were analyzed using a 2 (Liferaft Type; Canopy vs. Non-canopy) × 2 (Direction; Leeward vs. Windward) × 2 (Method; Dry vs. Wet evacuation) fully within-conditions analysis of variance (ANOVA). The ANOVAs for the performance times involved groups ($n = 4$) as replicates, whereas the ANOVAs for the subjective questionnaires involved subjects ($n = 43$) as replicates. As an exploratory study involving a relatively small number of groups, we report both statistically significant results as well as trends. Finally, due to technical difficulties, Group A could not complete two of the eight conditions. Throughout, these missing data points were estimated using the procedure recommended by Myers and Well (3).

RESULTS

Time for first person out: The analyses revealed two main effects. First, as expected, dry evacuations (70 s ± 10.14) took longer than wet evacuations (20.1 s ± 1.1) because of the waiting time to inflate the raft ($F(1,3) = 27.99$, $p \leq 0.013$). Second, evacuations into the canopy liferaft (56.6 s ± 12.4) took longer than evacuations into the non-canopy liferaft (33.5 s ± 3.9), with this effect being marginally reliable ($F(1,3) = 7.27$, $p = 0.074$). Finally, there was a marginal interaction between the two main effects ($F(1,3) = 7.03$, $p = 0.077$). Wet evacuations did not depend on liferaft type (20.6 s vs. 19.5 s), but dry evacuations took much longer with a canopy liferaft (92.5 s ± 16.9) than with a non-canopy liferaft (47.5 s ± 2.7). No other main effects or interactions approached statistical significance.

Time to evacuate helicopter: An analysis of the time to evacuate the helicopter revealed significant main effects for each of the three independent variables. As is evident in Panel A of Fig. 4, canopy evacuations took longer than non-canopy evacuations ($F(1,3) = 23.49$, $p < 0.017$), leeward evacuations took longer than windward ($F(1,3) = 13.36$, $p < 0.036$), and dry evacuations took longer than the wet ones ($F(1,3) = 15.41$, $p < 0.029$). The latter two results replicating the findings previously reported by Brooks et al. (1). The only interaction to approach statistical reliability was a marginal interaction between liferaft type and evacuation method. Specifically, evacuation times for the dry method and a canopy liferaft (154.0 s ± 20.8) were more than twice those for the other conditions (Canopy–wet = 69.9 s ± 8.8, non-canopy–wet = 67.0 s ± 8.6, and non-canopy–dry = 77.8 s ± 2.2).

Time to reach "safe zone": Panel B of Fig. 4 provides the results of the time to reach the safe zone. Overall, the results parallel closely those reported in the previous analysis. Leeward took longer than windward evacuations ($F(1,3) = 11.64$, $p < 0.042$), the dry evacuation took longer than the wet one ($F(1,3) = 14.87$, $p < 0.031$); and

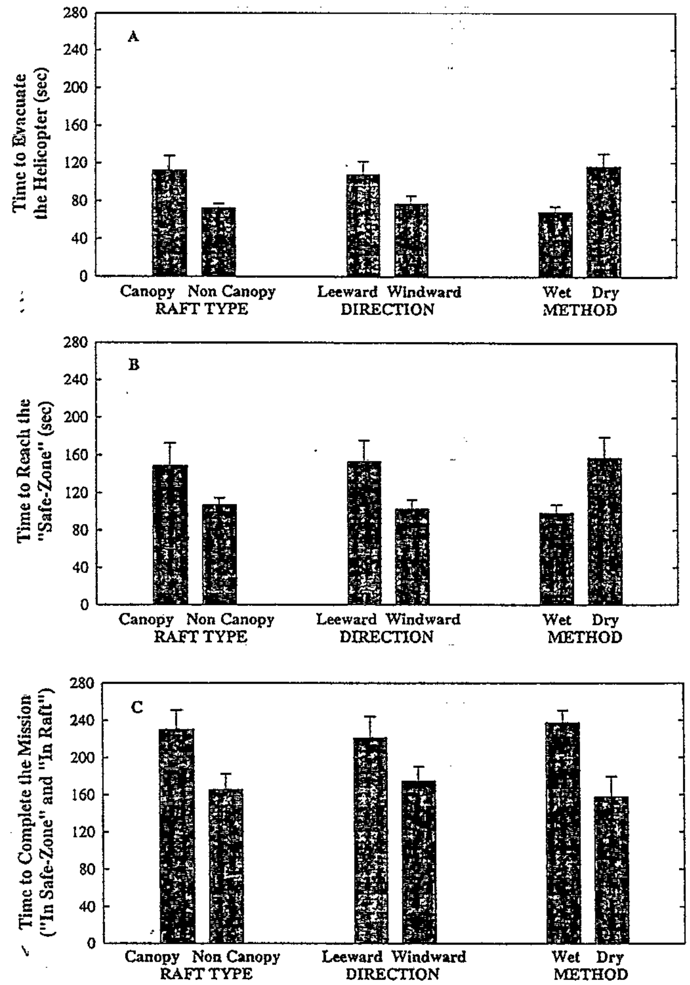

Fig. 4. A comparison of times to evacuate the helicopter (A); to reach the "Safe Zone" (B); and to complete the mission (C).

canopy liferaft evacuations took longer than non-canopy liferaft evacuations, although only marginally significant ($F(1,3) = 5.41$, $p = 0.10$). No interactions approached significance.

Time to complete the mission ("in safe zone" and "in liferaft"): Panel C of Fig. 4 provides the data concerning the time to complete the mission. The data are similar to those reported above, with one notable exception. Specifically, canopy evacuations were slightly slower than non-canopy ($F(1,3) = 6.82$, $p = 0.079$) and leeward evacuations took slightly longer than windward ($F(1,3) = 7.55$, $p = 0.071$). On the other hand, the time to complete the mission using the wet evacuation took significantly longer that the dry evacuation ($F(1,3) = 103.65$, $p < 0.002$). Hence, noted by Brooks et al. (1), the Swim Away or wet method has the advantage of getting people out of the helicopter sooner, but is slower overall because of the time to swim to the safe zone and then enter the liferaft. No other main effects or interactions were reliable.

Subjective ease or difficulty with evacuations: Panel A of Fig. 5 provides subjective ratings concerning the relative ease or difficulty of the various evacuations. Importantly, the subjective measures precisely parallel the objective measures concerning the time to complete the mission

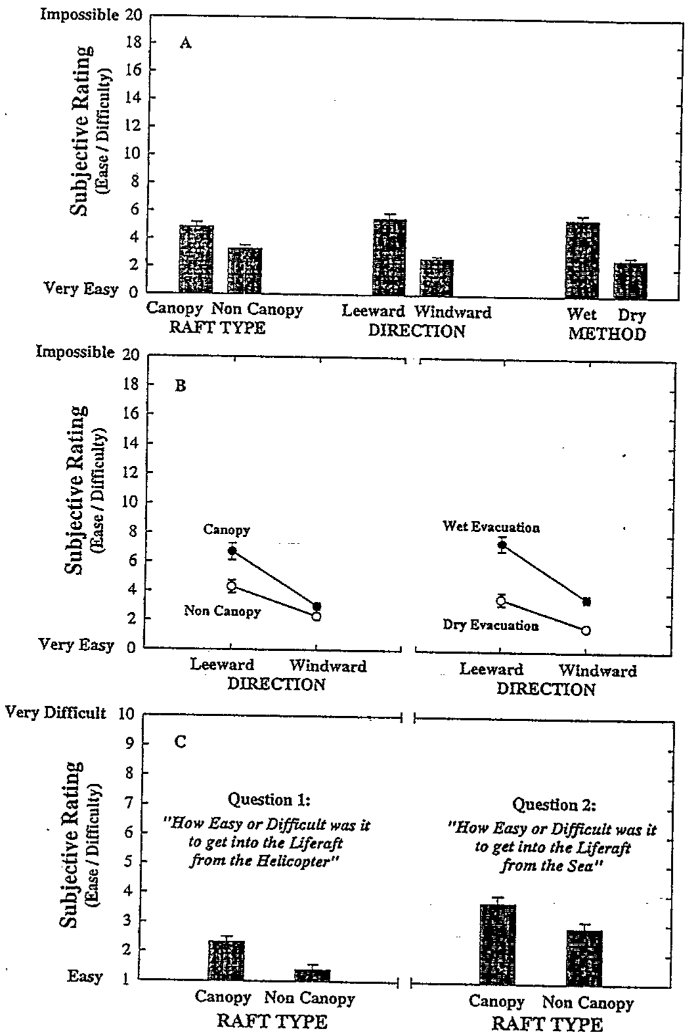

Fig. 5. A comparison of subjective ratings for raft type, direction and method of evacuation (A & B) and ability to get into the liferaft from the helicopter and the sea (C).

(Fig. 4 Panel C); i.e., canopy evacuations were judged more difficult than non-canopy ($F(1,42) = 29.52$, $p < 0.0001$), leeward evacuations were more difficult than windward ($F(1,42) = 55.17$, $p < 0.0001$), and dry evacuation was judged easier than the wet ($F(1,42) = 67.32$, $p < 0.0001$). In addition, increased power in the analysis permitted the detection of two interactions. As illustrated in Fig. 5 Panel B, canopy evacuations were judged significantly more difficult than non-canopy only when the evacuation was on the leeward side ($F(1,42) = 7.95$, $p < 0.007$), and not when on the windward side. In addition, the right side of Fig. 5 shows a comparable result concerning the wet evacuation technique as opposed to the dry evacuation.

Finally, panel C of Fig. 5 presents subjective ratings of liferaft entry from the helicopter and from the sea. In both cases, subjects rated the canopy liferaft significantly more difficult than the non-canopy liferaft [$t(42) = 4.24$, $p < 0.0001$); and $t(42) = 3.31$, $p < 0.002$, respectively].

Our own observations of this experiment confirmed that a dry evacuation was easier than a wet evacuation and the windward side was easier than the leeward side. The majority of problems (Table I) came with the wet evacuations, i.e., communication in the water, judging the helicopter exit prior to jumping into the sea, holding the painter, swimming away from the fuselage, and entering the raft from the sea. The use of the canopy liferaft resulted in four new problems. First, the painter securing the liferaft to the helicopter is attached at a position at right angles to each entry port (Fig. 6), so the door of the liferaft does not line up with the door of the helicopter. Thus evacuees must scramble around one-quarter of the periphery of the top inflated tube of the liferaft while leaning against the inflated canopy to gain access to the raft entrance, thus making each evacuation more difficult and slow. A different problem arose for the non-canopy raft, although again attributed to the painter anchor point, which caused, in this case, the long boarding ramp to be awkwardly and unevenly approximated to the side of the fuselage. Consequently, the liferaft cannot be held closely and securely to the fuselage, and the benefit of open design enabling boarding by simply jumping straight into the liferaft is reduced. These boarding ramps interfere with the process. These boarding ramps are designed to assist boarding from the sea, but are a detriment to boarding from the helicopter.

The second and more serious problem is that the canopy liferaft inflated upside down in 6 of the 16 evacuations. A typical example occurred during a dry evacuation and the liferaft half in the sea got hung up on the inflation bag, all made worse by gusty winds and because the liferaft was on the leeward side of the helicopter. Only with an enormous effort by the instructor, who assisted the crew, was it possible to get the inverted liferaft into the sea. In this particular case, the crew then conducted a wet evacuation and forced the liferaft around the nose of the helicopter onto the windward side. By the time they had got their strength back to attempt to right it, it was very close to the tail rotor (Fig. 7). After an enormous amount of effort to right the liferaft, which kept swinging in and out of the wind, they finally entered the liferaft absolutely exhausted, after a very hard wet evacuation which started off as a dry evacuation.

Third, it was much easier to lie back in the non-canopy liferaft and to use the feet to fend off the helicopter. Four or five people could do this as the liferaft swung around, whereas the design of the canopy liferaft did not allow for this.

Finally, it became apparent that the evacuees should not be advised to take a specific route, e.g., swim/paddle at 45° to the tail, or to swim/paddle around the nose. Rather, because of the unpredictable dynamics of a swinging helicopter and variable wind and wave conditions, they should be instructed to use their common sense and judgment at the time of the accident and to take the path of least resistance, whichever route that may be.

DISCUSSION

A total of 48 helicopter evacuations involving 47 male and 40 female subjects have now been conducted from the Nutec Super Puma simulator in two experiments. In the first experiment, only the non-canopy liferaft was

TABLE I. TYPE AND FREQUENCY OF PROBLEMS REPORTED IN EACH OF THE EVACUATIONS.

	DRY WINDWARD						DRY LEEWARD					
	Non-Canopy			Canopy			Non-Canopy			Canopy		
Problems	S	A	C	S	A	C	S	A	C	S	A	C
Secure Suit	1	0	0	0	0	0	1	0	0	1	0	0
Unbuckle	1	0	0	0	0	0	0	0	0	0	0	0
Judging Exit	0	0	0	1	0	0	0	0	0	1	0	0
Paddle Raft	3	1	0	0	0	0	7	2	0	11	0	0
Landing in Raft	0	0	0	1	0	0	0	0	0	1	0	0
Total	5	1	0	2	0	0	8	2	0	14	0	0
	WET WINDWARD						WET LEEWARD					
	Non-Canopy			Canopy			Non-Canopy			Canopy		
Problems	S	A	C	S	A	C	S	A	C	S	A	C
Secure Suit	0	0	0	1	0	0	0	0	0	0	0	0
Unbuckle	1	0	0	1	0	0	1	0	0	1	0	0
Commun	0	0	0	2	1	1	3	1	0	2	0	0
Judging Exit	0	0	0	0	0	0	0	0	0	2	0	0
Holding Painter	0	0	0	11	0	0	6	1	0	5	2	0
Swim Away	1	0	0	8	3	0	15	9	1	13	13	4
Entry into Raft	7	0	0	20	1	0	12	2	0	6	0	0
Righting Raft	0	0	0	1	0	0	0	0	0	0	0	0
Jump in Water	0	0	0	1	0	0	0	0	0	0	0	0
Total	9	0	0	45	5	1	37	13	1	29	15	4

S = some difficulty; A = a lot of difficulty; C = couldn't do it.

used and both non-canopy and canopy types were used in this one. The current results confirm that dry is the evacuation of choice and windward is the direction of choice, followed by dry–leeward. A wet evacuation should be avoided if possible, but if inevitable, the windward side is again preferable. A wet evacuation presents a number of problems made worse by a high sea state and darkness. These include difficulties in gripping the painter, swimming away on the leeward side, navigating to the safe zone, communication in the water and, after an exhausting swim, climbing into the liferaft. It was observed that for navigating to the safe zone, the route is dependent on the position of the escape exit in relation to the sponson, the position of the flotation bag and the shape of the fuselage. Fighting the helicopter swinging in the wind is a futile effort. Therefore, the easiest way to do either a dry or wet evacuation is to take the path of least resistance, whether it be around the nose or under the tail.

By design, the canopy liferaft is more stable in the water than the non-canopy. However, the great disadvantage is that it does not always inflate the correct side up. This might be acceptable for ship abandonment, but is not acceptable for helicopter evacuation. As we noted in the dry evacuation, a liferaft which inflates inverted

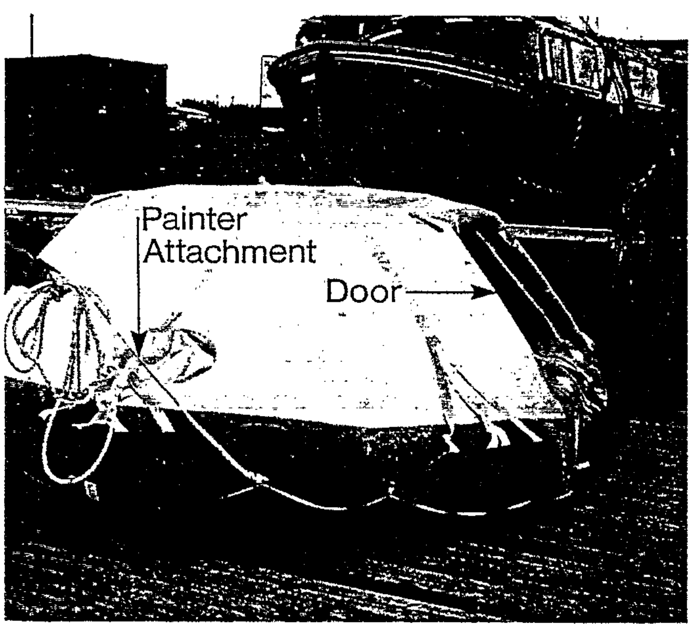

Fig. 6. Painter anchor (arrow) on raft offset 90° from entry port.

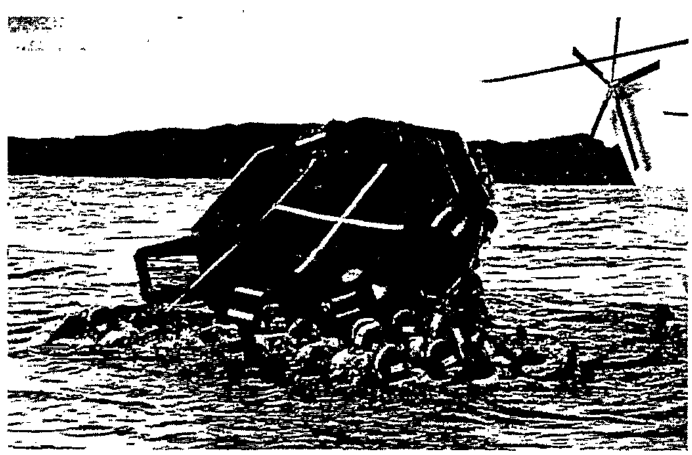

Fig. 7. Canopy raft inflated upside down swings close to the tail rotor with subjects struggling to right it.

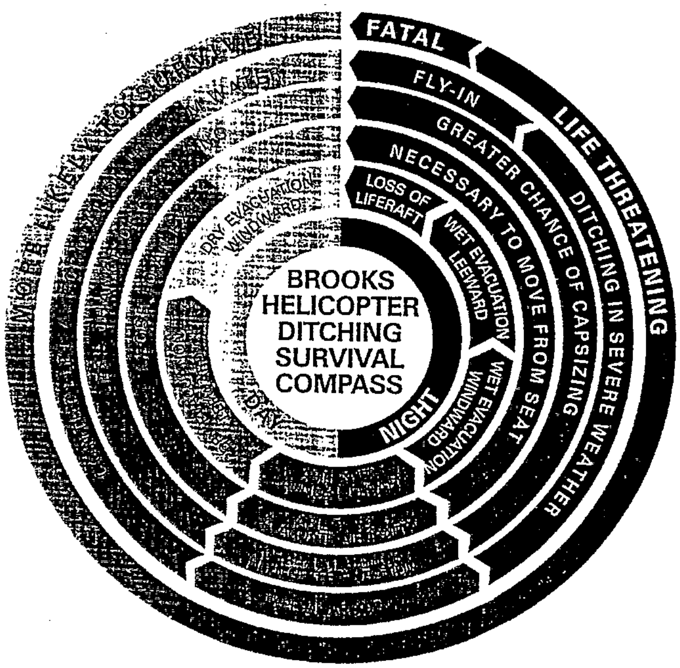

Fig. 8. Brooks Survival Compass.

at the cargo door is a nightmare to right, if at all possible. Also, a liferaft inverted outside the strike envelope is extremely difficult to right and board, particularly since swimming away from the fuselage in a wet evacuation is exhausting. A canopy liferaft should only be accepted for helicopter operation if it can be guaranteed to inflate the correct way up. The non-canopy liferaft has the added advantage that it is much easier to enter both from the helicopter and the sea, and more occupants can fend the liferaft off the fuselage and paddle out of the strike envelope. The painter on both types of liferaft must be repositioned. When the canopy liferaft is secured to the fuselage, the door must be closely opposed to the door of the helicopter; similarly for the non-canopy raft the boarding ramp must not prevent close proximity between the side of the liferaft and the door of the helicopter.

Given the variable nature of helicopter ditching accidents, the pilot and crew may have very little choice concerning which method to use. Their training must present the options along with their advantages and disadvantages and include practice of each. Then the crew will be adequately trained to make the split-second decision as to which method to adopt and from which side to evacuate. After 48 evacuations into the Bergen Fjord, it is our opinion that it is not possible to simulate sufficiently realistic evacuation conditions in a swimming pool such as an exhausting wet evacuation on the leeward side around the nose or tail of the helicopter, and then, a difficult climb into a pitching liferaft. Dry and wet evacuations must be first taught in the pool for basic training, and then in open water. The Brooks helicopter ditching survival compass (Fig. 8) has been created as an aid for showing students what options may be available when conducting dry or wet evacuations in relationship to the nature of the accident and the potential life threatening situation.

Three conditions must be considered pro-actively during pre-flight strap-in. The first is the helicopter flotation characteristics and whether or not it has flotation bags. Good characteristics as seen in recent history for the Super Puma give more confidence that the helicopter may remain afloat, in up to 3- or 4-m waves, whereas a small helicopter with no flotation aid will not. The second condition is the closeness of the survivor to an escape door/hatch/window, particularly the survivor who may have to deploy the liferaft in the event that the two pilots are injured or killed. The third condition relates to the liferafts that are available in the specific helicopter; i.e., number of liferafts, internally or externally jettisoned, helicopter side of deployment, and fixation to or mobility around the fuselage. If the pilots and passengers mentally paint a picture of their options before each flight, then they will, of course, be better prepared before the ditching.

After a ditching, four conditions must be taken into account before the decision to launch the liferaft is made. The first condition is the type of accident. If it is a fly in, which is immediately life threatening, a rapid underwater escape without liferaft is likely the only option. For a ditching in severe weather, there may not be the option to wait 30 s for the liferaft to inflate, as the helicopter could capsize, so a wet evacuation will be the only choice. A controlled ditching into calm water may allow a short time to consider the best way to launch the liferaft and from which side. It may well be better to stay inside the helicopter and await rescue, although it is prudent to have all the exits jettisoned and to be mentally and physically prepared to escape in the event of a sudden unexpected capsizing. The final condition is the dynamic situation on landing in the water, where the best option is to conduct a dry evacuation from the windward side, the worst option is to conduct a wet evacuation on the leeward side.

Conclusions and Recommendations

The dry evacuation on the windward side is the method of choice. The findings confirm those in our original trials (1). The wet evacuation should be used only if the helicopter is about to capsize. Problems that will be encountered with this method should be described in the classroom, and wet evacuations must be practiced. For aircrew, training in the pool is not adequate; rather open ocean conditions must be used. Additionally, the non-canopy raft is both subjectively and objectively easier to enter, both from the helicopter and from the sea. Because it does not matter which way it inflates in the water, it has an advantage over the traditional canopy liferaft. The traditional canopy liferaft has a good chance of not inflating the correct way up and this should be corrected. The placement of the painter anchor point should be reconfigured for both types of liferafts. Helicopter manufacturers should provide emergency exit doors on both port and starboard sides to jettison the liferaft(s) as well as for escape routes. Finally, a Brooks Helicopter Ditching Survival Compass has been created as an aid for showing students what options may be available when conducting wet and dry evacuations in relationship to the nature of the accident and the potential life threatening situation.

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REFERENCES

1. Brooks CJ, Potter PL, Hognestad B, Baranski JV. Liferaft evacuation from a ditched helicopter: Dry shod vs. swim away method. Aviat Space Environ Med 1997; 68:35–40.
2. Kinker, LE , Loeslein, GF , O'Rourke, C. US Naval and Marine Corps helicopter over-water mishaps: stowage and deployment of liferafts. SAFE Symposium, Reno, Nevada October 1996.
3. Myers, JL , Well, AD. Research design and statistical analysis. New York: Harper Collins, 1991.
4. Programme of Energy Research Development, Canada. Report on the evaluation of surface evacuation procedures for a ditched helicopter. Dartmouth, N.S., Canada: The CORD Group, July 1995.

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