Aviation Medicine

Special forms of flight

II: Helicopters

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Helicopters first flew in the minds of men, and then as toys, in ancient China and medieval Europe. But the first man-carrying, rotary wing flight occurred in 1907, when Paul Cornu—yet another Frenchman—flew at a height of a few feet for a few seconds, and it was not until 1938 that the first fully controlled helicopter flights were carried out. Since that time there has been, and still is, an enormous expansion in the development, numbers, and use of rotary wing aircraft throughout the world. In terms of capability and adaptability helicopters have become the aerial workhorses of this century. Quite apart from many military applications helicopters are used in such varied civilian activities as commercial and executive transportation, oilrig support and pipe line inspection, agricultural crop spraying, and of course emergency services. Despite this ubiquity helicopters have tended to remain the Cinderellas of aviation medicine. A consideration of the medical aspects of helicopter operations paints a fairly dismal picture with very few bright patches, but there are indications that this attitude is changing.

All the traditional aspects of aviation medicine are relevant to rotary wing flying, but the problems are compounded by movement in a third dimension. Furthermore, helicopters lack the static stability and control damping characteristic of fixed wing aircraft and are inherently more difficult to learn to control.

Comfort and thermal comfort

Flying a helicopter may be uncomfortable and very tiring, especially if no stability augmentation system is fitted. Physical discomfort is largely a result of vibration and more particularly of the operating position needed to fly the craft; both hands are occupied continuously, and because of the location of the control levers the pilot has to lean forward with little support for the upper half of his body. The discomfort to the back muscles is often compounded by poor seat design in relation to the flying controls. Frequently inadequate cushioning causes pelvic rotation and loss of lumbar lordosis, so that postural backache is a common complaint; this is often aggravated by the need to wear heavy and bulky protective clothing. The incidence of backache may, however, be minimised by preventing pelvic tilt through proper design of the seat cushion and providing an adjustable lumbar support pad.¹

Thermal discomfort may cause further stress, particularly in military helicopters. Worldwide operations naturally expose aircrew to extremes of temperature, and designers of military helicopters have usually not regarded cabin conditioning as a high priority. Thus even in a European summer the “greenhouse” effect of the cockpit transparency may produce cabin temperatures of over 40°C during standby.² In Arctic conditions the lack of efficient cabin heating means that the pilot has to wear bulky clothing, which may impair precise operation of the aircraft.

For civilian operators, such as those supporting the North Sea oil industry, different constraints apply. Here the need is for clothing that is effective after ditching in seas at temperatures of 5–12°C or below but ideally does not have to be worn continuously in a heated cabin. The heat load of military type immersion suits was considered unacceptable for civilian flying, but new materials with enhanced ventile properties should improve this. After recent accidents both British Airways and Bristows Helicopters now require their helicopter crews to wear immersion suits when operating over the North Sea. Passengers on these services are also often required by their companies to wear protective clothing, but the search continues for appropriate garments which can be put on quickly and worn continuously. Such clothing must be acceptable to the wearer, durable, and provide protection against drowning, hypothermia, and fire.³

Disorientation

Helicopter pilots and pilots of fixed wing aircraft are subject to the same types of disorientation (see previous article, 28 May, p 1728), and, for both, the “leans” is the most common problem. It has been reported by 96% and 91% respectively of those Royal Navy and United States Navy helicopter pilots questioned.^{4,5} Head movements while in a bank or turn (51%), transition from instrument flight rules to visual flight rules and vice versa (42%), and misperception of the horizon because of a sloping cloudbank (46%) are also common during helicopter flying.⁴ Similar figures for such events have been reported for land based military helicopter operations.⁶

Some phenomena are peculiar to rotary wing flying and are most liable to occur at low altitudes and at slow speeds or in a hover, with consequently very little time to correct mistakes. Thus not only is a helicopter capable of conventional pitch, roll, and yaw movements but in a controlled hover is susceptible to linear accelerations along these three axes. A pilot in the hover experiences a mixture of vestibular and proprioceptive stimuli which may be more difficult to interpret than those experienced in fixed wing aircraft. In general, forward acceleration is less disorientating than backward, lateral, or vertical acceleration.⁶

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There seems to be a particular vestibular insensitivity to vertical acceleration, so the hover is a time of increased risk. In the Royal Navy survey, disorientation frequently occurred in low hover under various conditions: over water by night in 29%, by day in 16%, under instrument flight rules in dust, snow, rain, or over water in 12%, and over land in 3%.⁴ At night or in heavy snow ("white out") it is the loss of visual cues, combined with relatively few vestibular inputs, that predisposes to disorientation, but by day an illusory perception of motion may be generated by the movement of external visual cues. For example, when hovering over water or long grass a pilot may experience a false sensation of forward movement as the rotor downwash creates a rearward moving wave pattern. Similarly, a false sensation of upward motion may be generated by the downward movement of snow, rain, or entrained water through the rotor disc.⁷ Should disorientation develop in this way, the situation is often helped by increasing forward airspeed and by flying straight and level. Other problems include annoyance, confusion, and occasionally epileptiform episodes caused by flicker from the rotor blades or from lights seen through the rotor disc—so called "flicker vertigo"⁶—and the breakoff phenomenon⁸ (see previous article, 28 May, p 1731).

Several factors, both specific to aircraft and general, compound the risk to the pilot of becoming disorientated. In the aircraft internal reflections on the cockpit transparency, the reflection of anticollision lights on cloud or fog, and most importantly the inability to read instruments because of vibration are the most frequent predisposing factors. Fatigue, discomfort, upper respiratory tract infection, self medication, lack of recent instrument flying, insufficient flight planning, and inexperience all add to the risk.^{4 5}

Fortunately, most episodes of disorientation do not progress to accidents. Nevertheless, in military flying from 3.4% of helicopter accidents in the United States Army⁹ to 15% in the British Army¹⁰ were considered to have disorientation as the major cause and in both cases accounted for nearly one third of all fatalities. Improvements in these figures, which have remained remarkably constant over the past decade,⁷ will depend on modified and vibration damped instrumentation, additional cockpit aids (such as cathode ray tube displays and simple, peripheral vision horizon devices), and realistic training schemes both in the air and on the ground.^{4 5 10 11}

Vision

A true visual horizon is essential for maintaining a selected attitude in helicopters because of their inherent instability. Most helicopter flying is, therefore, carried out while the pilot is in visual contact with the ground or surface of the sea, although flight in bad weather and at night is now becoming normal practice by using instruments. Landing, however, still requires good external visual cues. These cues are modified in flight by many factors (see previous article, 28 May, p 1728) including motion perspective—that is, the apparent flow of stationary objects, or the surface, relative to the pilot's eyes.¹² This apparent flow indicates to the pilot the velocity, direction of movement, and approach path of his aircraft with respect to other objects or surfaces. In helicopters flow perspective can be appreciated in all three planes of movement and provides one of the more important cues for aircraft control. In some circumstances, however, problems may arise. In the hover it is motion perspective which, combined with absence of texture, produces the illusions of movement and consequent disorientation described above. Similar visual illusions of motion can occur at night when ground lights are reflected in cockpit transparencies, and this effect is a cause of serious incidents during flight.¹³

Approach and landing are also influenced visually by other distance cues such as size, density, and parallax. For this reason suitably textured landing sites in daylight—preferably with some indication of scale—and appropriately dispersed landing light

patterns at night are needed. The hazard presented by wires is another visual problem. The distance at which they are detected depends on their size, the background against which they are located, and the ambient visual conditions. Wirestrikes are a major cause of military and agricultural helicopter accidents, and active research into providing warning systems to help pilot visual acuity is being undertaken.

Noise and communication

Many helicopters are very noisy indeed; internal levels above 100 db may occur in military helicopters during flight.¹⁴ Together with discomfort, noise is the major complaint of helicopter occupants. Such high noise levels reduce communication efficiency, increase workload and fatigue, and if sufficiently high and prolonged can produce temporary and even permanent hearing loss. Predictably, the noise in helicopters derives from the transmission, which produces a broad band spectrum of noise with additional large spikes produced by the main and tail rotor blades. The gearbox contributes to the broad band noise and produces smaller spikes. Aerodynamic noise from poorly streamlined surfaces adds to the load, particularly since many helicopters are inadequately sealed and are often flown with the windows and doors open or removed.

Communication input takes place for about 40% of the time during an average sortie and is a major part of the total noise dose.¹⁵ In addition, audio signals may be distorted during reception and amplification before they reach the recipient and are further degraded by extraneous cabin noise. Cabin noise should, therefore, be reduced to improve the signal to noise ratio and decrease the total noise dose; ideally, speech signals should also be reduced both in magnitude and quantity.

The problems of noise reduction and improvement in communication should be tackled during the design stage of a helicopter's development—for example, by carefully siting engines and gearboxes, isolating the cabin from noise and vibration sources so far as possible, and selecting a communication system with frequencies that do not conflict with noise peaks of other equipment. Since many helicopters have not been designed with such forethought, secondary measures need to be adopted to counter the problems. A modern protective helmet or headset with efficient noise dampening properties helps reduce the effects of cabin noise, but the low frequencies commonly encountered in helicopters are more difficult to attenuate, and audio signals at such frequencies may either be lost or need to be so high as to be hazardous themselves. The size of the audio work load may also be a problem with the operator having to monitor several radio frequencies simultaneously. Clearly, a wide range of possible signals makes learning, recognition, and response in emergencies more difficult. When these problems are added to the already sizeable normal audio input, the capacity of the operator may easily be exceeded. Verbal warning systems are now being considered, as load sharing in multicrew helicopters can provide only a partial solution. The amount of noise impinging on the ears is also reduced by effective noise cancelling microphones and voice operated switches.

Vibration

Vibration—defined as any sustained, mechanical, oscillatory disturbance perceived by senses other than hearing¹⁶—may be a source of annoyance and even a hazard during helicopter operations. Helicopters vibrate in all major axes and at frequencies related to both rotor speeds and flight conditions, while further vibrations are produced by the engines, gearboxes, and tail rotors. The effect of these vibrations, usually of low frequency (1-50 Hz) but sometimes of considerable energy, is exacerbated in certain flight conditions. The greatest body resonance occurs at 4-5 Hz and is related to the dynamics of the

thorax and abdomen, but energy at these frequencies is usually low. Of greater concern is the effect on visual performance. Interpretation of instruments, target tracking through sights, and even the view of the outside world may be impaired if vibration levels are excessive. Vibration may also be a factor in the development of backache in helicopter crews.¹⁷ The effects of vibration depend not only on body build, weight, and posture but also on the direction, area, intensity, and duration of application. Such equipment as seat cushions and harnesses also influence its effects.

Vibration in helicopters may be reduced externally by careful design of engines and rotors and internally by instruments which are spring mounted or damped in some other way. Transmission of vibration to the occupants should be minimised as far as possible. A seat, separated mechanically from the airframe by springs, is one effective method of achieving this, especially when used with a five point harness and a cushion made of energy absorbing material.¹⁸

Fatigue

Fatigue may be taken to denote those changes in bodily physiology, decrease in work output (either in quantity or in quality), and characteristic subjective feelings of tiredness or disinclination to work which are associated with a continuous activity. It affects the efficiency and accuracy of aircraft operations and is an important cause of helicopter accidents. Of 120 peacetime military helicopter accidents, fatigue was a major contributory cause in 15%,¹⁹ while in a United States Army series covering seven years and 1270 accidents fatigue related accidents (4% of the total) were four times more common in helicopters than in fixed wing aircraft.²⁰ In a detailed analysis of the factors believed to promote fatigue, three main areas were important: long term workload, duty day workload, and short term workload.¹⁹ When long term workload is assessed scheduling of work and rest cycles, social and emotional factors, and morale have to be considered. Duty day workload covers the duration of work and rest periods throughout a given period of duty, while immediate or short term workload involves such factors as vibration, aircraft noise, limited visibility, instrument flying, and seat comfort.

Acute fatigue is produced by excessive mental or physical activity or both and is often related to specific work situations: it is usually relieved by a period of sleep or rest. Operationally, the acutely fatigued pilot shows a fall in the level of skill while accepting, without being aware of it, a lower standard of accuracy and performance. Coning of attention is also likely. Chronic fatigue develops if the acute phase is not alleviated. It does not respond to simple rest or a period of sleep, and those afflicted often have feelings of intense fatigue even before beginning work. In addition to the features of acute fatigue there is a decline in motivation, morale, and the quality of decision making.

Despite these apparently clear cut descriptions, a high index of suspicion is needed to detect victims of either acute or chronic fatigue. Clinically, features may include irritability with associated anxiety and depression, insomnia, social and vocational withdrawal, and excessive use of tobacco, drugs, or alcohol. There may also be a pronounced decline in attention span, recent memory, and cooperation, while physically there may be a loss of appetite, weight, and libido, and gastrointestinal problems may arise. The differential diagnoses include neurosis and physical disease, but there are no confirmatory behavioural or biochemical tests.

The causal factors indicate the preventive measures that should be considered: most—such as physical fitness, adequate recreational facilities, and sleep—are obvious. Less so, perhaps, is the need to adhere to the concept of a duty day whereby time on duty, whether flying or not, is strictly regulated. In addition, the scope of expected tasks should be carefully and fully briefed, although this may be difficult to achieve without restricting the

versatility of the helicopter. In the long term the effects of many of the adverse immediate workload factors could be minimised in the design phase by careful instrument and cockpit layout, more efficient control of the environment, and consideration of the ergonomics of seat and harness design.²¹ Where prevention fails, however, the treatment is complete rest.

Impact protection and restraint

Accidents to helicopters may be divided into those that follow autorotation or forced landings, and so are "intentional," and those that are unintentional, such as wirestrikes or catastrophic impacts. (Autorotation is "the process of producing lift with freely rotating aerofoils by means of the aerodynamic forces resulting from an upward flow of air"²²—that is, unpowered flight.) Generally, unintentional accidents are not survivable, but "intentional" accidents, which comprise over 90% of the total,²³ potentially are so. Such potentially survivable accidents in military helicopters, however, account for 30-40% of occupant fatalities, with fire as the single largest cause of death.²³⁻²⁴ A study of civilian helicopter accidents in the United States over 12 years also showed that 10% of 280 deaths resulted from fire after impact.²⁵ A fuel fire after a helicopter crash reaches its maximum intensity—with temperatures of 1093-1149°C—just 15-20 seconds after a single point ignition such as might occur after a controlled impact.²⁶ Thus if the occupants of a helicopter in this sort of accident are prevented from escaping rapidly from the craft and a fire develops there is little chance of survival. The safety aspects of helicopter crash-worthiness are, therefore, largely concerned with ensuring that even mildly incapacitating injuries do not occur and that victims are physically able to escape. Recognised shortcomings in the design of most modern helicopters are common to both civilian and military aircraft and include problems of roll over, intrusion of structures into the cockpit, seat failure, lack of restraint, and restraint failure.

Roll over, with subsequent disintegration of the cabin, may occur if on vertical impact the main rotors flex downwards and sever the tail boom. Similarly, a hard landing with a horizontal component may cause earth scooping and somersaulting of the fuselage. Subsequent intrusion into the cockpit by the engines, rotor blades, or cabin walls has a predictable outcome. The effects of equipment displacement in the passenger compartment may be partly reduced by the "delethalisation" of sharp edges and protuberances and further minimised by the use of an appropriate protective helmet.

Helicopter crew seats often do not match the impact tolerance of their occupants: on vertical impact the seats often collapse completely or break away from their mounts without appreciably reducing the applied force. Alternatively, the cushion alone may compress rapidly but without absorbing energy, so creating a dynamic overshoot and subjecting the victim to an amplified force as he is decelerated on contact with the underlying seat structure. Both mechanisms have resulted in serious injuries or death.²⁵ The problem is even worse for passengers: their seats are often constructed of tubular steel and are often inadequately mounted. The advent of energy absorbing devices, which allow controlled displacement, has enabled improved seating to be introduced in United States military helicopters in accordance with the United States Army's crash survival design guide.²⁷ Such measures are also being considered in the United Kingdom.²⁸

In many civilian helicopters the crew are restrained solely by a lap strap, which produces the inherent danger of jackknifing; even a four point harness, with double lap and shoulder straps, does not prevent submarining. To overcome these risks a five point harness, which includes a "negative G" strap, is now fitted to most military helicopters in the United Kingdom and has the additional advantages of preventing upward movement of the harness during vertical vibration in flight and of

positioning the quick release fitting correctly.¹⁸ Passengers are usually also restrained by a simple lap strap, but to prevent jack knifing and to provide some protection against impact in the longitudinal axis of the aircraft a diagonal strap which passes over the leading shoulder when sitting sideways should also be provided at the very least. The geometry of harnesses is often poor, however, and better restraint is achieved in practice by the adoption of the crash posture, which prevents flail injuries and reduces the impact load on the spine. Harnesses for mobile crewmen must also be considered.²⁸

Although retrospective improvements to seats and restraint systems can only be for the good, it is during the design stage that safety features should be incorporated, not only to improve crashworthiness but also to prevent accidents in the first place. Thus it should be possible to overcome many of the problems known to cause accidents. Twin engines could be provided with duplicated, fracture resistant pipework and self sealing, fire resistant fuel systems. Energy absorbing material could be used not only for seats but also for landing gear, while the crew/passenger compartments could be reinforced to prevent intrusion. Warning systems for detecting cables during flight exist, as do mechanisms for cutting them if hit. Theoretically, even automatic escape in flight is possible using individual rocket ejection/extraction or a passenger capsule escape facility.²⁹ Increased development and production costs, and reduced payload capacity, are usually given as reasons for failing to embody safety features, but a study of the cost effectiveness of many such measures incorporated in the Sikorsky UH-60A (Blackhawk) helicopter³⁰ has shown that a balanced solution in terms of cost, weight, and improved safety—as indicated by lives and aircraft saved—is certainly possible.³¹

Next week's article covers supersonic aircraft.

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A 3 month old infant was given a diphtheria/pertussis/tetanus immunisation and oral polio vaccine. Within five days an indurated, inflamed swelling developed at the injection site that persisted for two weeks. After the second dose of DPT three months later a tender swelling again developed which took several weeks to settle. At his third immunisation he received only diphtheria and tetanus vaccine. Erythema and swelling again developed and lasted for about a week. What is the reason for these reactions and is it wise to continue with the immunisation procedures when such reactions have occurred?

This infant was obviously sensitive to the vehicle with which the immunisation was given, presumably aluminium hydroxide. There is no reason to discontinue the immunisation on account of such a reaction. No local or systemic treatment is likely to be very helpful.—CHARLES G D BROOK, consultant paediatrician, London.