5_MackenzieRoss 11/12/06 4:12 PM Page 521

Ill health following exposure to contaminated aircraft air: psychosomatic disorder or neurological injury?

S MACKENZIE ROSS, A HARPER, J BURDON

Sarah Mackenzie Ross, MPhil, is a Clinical Psychologist in the Sub-department of Clinical Health Psychology, University College London. Andrew Harper, MBBS, is an Occupational and Public Health Physician in Western Australia. Jonathan Burdon, MD, is a Respiratory Physician in Melbourne.

Address for correspondence: Dr S Mackenzie Ross, Sub-department of Clinical Health Psychology, University College London, Gower Street, London WC1E 6BT, United Kingdom.

Cabin air on commercial aircraft is sometimes contaminated with hydraulic fluids, synthetic jet engine oils and combusted or pyrolised materials, and aircrew have been reporting ill health following fume events for many years. The purpose of this article is to raise awareness among physicians of the short- and long-term health effects that may develop after exposure to pyrolised engine oil, and to discuss issues regarding causation and diagnosis. Symptoms reported by aircrew are often referred to as "non-specific", and some physicians reject the concept of chemical poisoning and attribute symptoms to other factors, such as psychosomatic disorder. A single case study is presented to highlight the issues of differential diagnosis, and published reports regarding the nature of ill health reported by aircrew following contaminated air events are reviewed. Scientific uncertainty regarding the potential hazards of inhalation of pyrolised engine oil is not evidence for psychological causation.

KEYWORDS

- AIRBORNE CONTAMINANTS
- AVIATION INDUSTRY
- ORGANOPHOSPHATE COMPOUNDS
- OCCUPATIONAL EXPOSURE
- HEALTH SYSTEMS

5_MackenzieRoss 11/12/06 4:12 PM Page 522

Introduction

Cabin air on commercial aircraft is supplied from the engines or auxiliary power unit. The air, which is unfiltered and known as "bleed air", is sometimes contaminated with hydraulic fluids, synthetic jet engine oils and combusted or pyrolised materials (for example, carbon monoxide, phosphorus oxides, aldehydes). These oils contain a large number of chemicals (for example, the organophosphate tricresyl phosphate (TCP)) which can cause irritation, skin sensitisation and neurotoxicity.[1-3] Indeed, the material safety data sheet for the engine oil BP 2380 states that toxic fumes may develop following burning or exposure to heat, and the MSDS for Exxon Mobil Jet Oil II states that repeated inhalation or skin contact with oil mist can cause nervous system disorders.

For many years, flight attendants, flight crew and passengers around the world have reported ill health following contaminated air events, but it is only recently that this issue has received attention in the United Kingdom.[3-7] There is an urgent need to increase awareness of this problem among medical practitioners in order to improve the recognition, diagnosis and development of treatment protocols for individuals who suffer ill health following these events.

Evidence of exposure

Commercial aircraft do not have air quality monitoring systems on board and no monitoring has ever been successfully undertaken during a contaminated air event. Therefore, the nature of the contaminants in the cabin air and the levels of exposure to passengers and aircrews during a contaminated air event are unknown. A recent study which investigated the nature of contaminants present in the cabin air of commercial aircraft during routine flights found TCP, and other chemicals which can act as potential synergists of TCP (fire retardants, plasticisers, and so on), in cabin air filters, coalescer bags and even on a pilot's uniform.[8] The synergistic effects of chemical combinations may increase the toxicity of pyrolised engine oil. Animal studies have demonstrated that chemical cocktails can be more toxic than what would be predicted from the known properties of each chemical making up the mixture, and this effect may be due to particular chemicals knocking out the enzymes needed to detoxify others in the mixture.[9,10]

Inhalation is the most likely route of exposure and it is important to note that contamination is occurring in a hypoxic environment where individuals may have higher respiratory rates and increased inhalation. Chemical absorption through the skin may also occur if particulates settle on exposed areas, and particulate matter can carry absorbed gases deep into the respiratory tract where they may provoke a local reaction or be absorbed to produce systemic effects. The respiratory abnormalities which have been described in aircrew after exposure to contaminated air are consistent with lung injury as a result of hydrocarbon inhalation.[11]

Incidence of contaminated air events

The incidence of contaminated air events on commercial and military aircraft is difficult to quantify due to a lack of monitoring systems. Underreporting of contaminated air events is common among aircrew due to a lack of awareness, commercial pressure, and fears over job security if crew members complain about working conditions.[6,12,13] A recent survey by the British Airline Pilots Association (BALPA) found that only 61 out of 1,667 contaminated air events were recorded on the UK Civil Aviation Authority (CAA) database.[14]

Despite underreporting by aircrew, many contaminated air events are recorded.[6] It is recognised that all aircraft are subject to engine oil leaks occasionally but certain types of aircraft record statistically more events than others. These include the BAe 146 and the Boeing 757.[13] The BALPA survey found that only 3.66% of contaminated air events experienced by pilots were subsequently reported to the CAA.* The CAA database for 2004

* 3.66% is close to the accepted defect product liability complaint rate of 3%.

5_MackenzieRoss 11/12/06 4:12 PM Page 523

recorded a total of 72 flights experiencing contaminated air. Given the low reporting rate of 3.66%, this could indicate that up to 1,967 flights in the UK may have experienced contaminated air events during 2004. If a modest passenger number of 100 per flight is assumed, over 196,000 passengers could potentially present to general physicians with symptoms of acute toxicity.

Immediate effects of acute exposure

The immediate effects of exposure to contaminated air have been well documented and include eye irritation, respiratory irritation, headaches, skin problems, nausea, vertigo, loss of balance, dizziness, fatigue and cognitive impairment (disorientation, confusion and memory problems). These symptoms show a close temporal relationship with exposure and usually recede after cessation of exposure.[1,3-5,11,14] The term "aerotoxic syndrome" was proposed by Winder and Balouet in 1999 to describe the association of symptoms observed among aircrew exposed to contaminated air and was endorsed by the Australian Senate Inquiry of 2000.[13]

Chronic ill health

A number of individuals report persistent, chronic ill health lasting months or years after exposure, including cognitive impairment (memory, word finding, multi-tasking difficulties), lack of coordination, nausea/vomiting, diarrhoea, respiratory problems, chest pains, severe headaches, lightheadedness, dizziness, weakness and fatigue, parasthesias, tremors, increased heart rate, palpitations, irritation of ear, nose and throat, muscle weakness/pain, joint pain, salivation, skin itching, rashes, blisters, hair loss, signs of immunosuppression and chemical sensitivity.[11,15-19] Work incapacity may be as high as 35%.[16]

Although the aviation industry is aware of the contaminated air problem and accepts that it can cause short-term symptoms of irritation and discomfort, a debate is ongoing in the UK, the United States and Australia about the causation, diagnosis and treatment of long-term effects.[20,21]

Medical evaluations

Aircrew seldom seek medical attention following exposure to contaminated air. The British Airline Pilots Association found that only 10% of the pilots who took part in its survey sought medical advice following exposure.[14] Those who did not seek help cited the following reasons: symptoms often resolve after exposure has ceased; commercial pressure to undertake another flight; pilot advised that fume events don't cause long-term ill health; fear of losing licence to fly; and being in a foreign country where only local doctors were available. The advice given to those who did seek medical attention involved being told: to breathe fresh air and to rest; that the effects are fully reversible; or that symptoms could be attributed to another cause, such as food poisoning. In most cases, no laboratory tests were undertaken.

The symptoms reported by aircrew are often referred to as "non-specific", and routine physical examination and laboratory tests do not usually reveal a specific diagnosis. The response of the medical profession has been inconsistent and probably reflects the lack of scientific knowledge regarding the potential toxicity of pyrolised engine oil. Some physicians accept the presence of disabling symptoms and remain open-minded about the possibility of a toxic cause, while others reject the concept of chemical poisoning and attribute symptoms to other factors (including psychosomatic disorder, industrial hysteria, anxiety and/or stress).[16] Psychological explanations are usually arrived at when routine investigations appear normal rather than there being evidence for psychological factors being involved in the aetiology of an individual's complaints (that is, a history of psychiatric illness, stressful life events, or health concerns).

While the symptoms reported by aircrew do not point towards well-recognised medical diagnoses, there is a pattern. In a survey of 60 commercial aircrew, a close temporal relationship was found

5_MackenzieRoss 11/12/06 4:12 PM Page 524

between exposure to fumes and the onset of ill health.[16] Symptoms occurred during flight and a number of people were usually affected concurrently. Of the symptoms reported, 45% were neurological, 22% respiratory, 14% fatigue-related, 10% gastrointestinal, 5% skin-related and 3% musculoskeletal. Abnormalities detected during medical investigations included a reduction in small airway function, diffusing capacity and gas exchange, nasal and vocal cord polyps, neuropathies, cognitive impairment, abnormal brain scans and evoked potentials. Aircrew were given a range of diagnoses which corresponded, in part, with the nature of the symptoms: 30% of diagnoses were neurological; 25% were respiratory; 21% were in the group of multiple chemical sensitivity, chronic fatigue syndrome and fibromyalgia; 13% were psychiatric (depression or anxiety); and the remaining 11% were viral, gastrointestinal, endocrinal or dermatological. Although these findings do not suggest a psychological or psychiatric condition, opinions to the contrary have often been expressed by physicians who have examined these crew members.

In the present article, the case study of a pilot who presented with chronic ill health following exposure to contaminated air on commercial aircraft is described. Routine investigations failed to reveal a diagnosis and he was referred to clinical psychology, neurophysiology and neurology for further investigations. The purpose of the psychological assessment was two-fold: (1) to assess cognitive functioning; and (2) to determine whether the pilot was suffering from mood disorder, hysteria or psychosomatic disorder.

Case study

A middle-aged commercial pilot presented with a nine-month history of cognitive impairment and a 10-year history of skin ulcerations and gastrointestinal problems (abdominal discomfort and alterations in bowel habit). The pilot had been flying a particular type of jet aircraft for 11 years, during which time his health had deteriorated. The pilot often smelt oily fumes while flying (sufficient to cause a sore throat on some occasions) but, like many, saw this as a normal part of flying this type of aircraft. Within a year of flying this aircraft, the pilot developed gastrointestinal symptoms and skin ulcerations on the parts of his body that were exposed to the air vents in the cockpit. Routine medical investigations and laboratory tests undertaken by a general practitioner (GP), a consultant dermatologist and a general surgeon failed to reveal the cause of these complaints. The pilot reported a gradual reduction in cognitive performance over the last two years, but suffered a marked deterioration in cognitive function following a recent contaminated air event. This event was serious enough to provoke symptoms of light headedness, stinging eyes and sore throat, in both the pilot and co-pilot, and they filed an air safety report on landing. The pilot resumed flying within a few days but developed insomnia, fatigue, coordination problems, joint weakness, excessive sweating, and poor memory and concentration. The pilot became concerned about flight safety and his ability to cope in an emergency, and consulted a GP at work. The pilot was advised that his symptoms were non-specific and could be due to a large number of factors. The GP signed the pilot off work and referred the pilot for neurological, neurophysiological and clinical psychological assessment.

Neurological examination found evidence of coordination problems and positive Romberg sign (a tendency to imbalance when eyes are closed), mild sensory neuropathy, and autonomic nervous system dysfunction consistent with exposure to organophosphate compounds. Serum autoantibody tests showed increased autoantibodies against nervous system proteins which was suggestive of neuronal injury as a result of chemical injury. Neuropsychological assessment did not find evidence of global intellectual decline and scores were above the cut-off for abnormality. However, compared with estimates of premorbid ability, the pilot showed evidence of mild irregular underfunctioning on tests of information-processing

5_MackenzieRoss 11/12/06 4:12 PM Page 525

speed, auditory working memory span, verbal learning and mental flexibility. The pilot passed a test of malingering.

The pilot's medical records were reviewed but there was no history of disease, injury, substance abuse, metabolic or endocrine disorder, or psychiatric illness which might otherwise account for his symptoms. Indeed, pilots are evaluated by aviation industry doctors every 6–12 months to ensure that they are fit to fly and do not suffer from psychiatric illness, substance abuse, heart, vascular or serious systemic disease, or neurological injury or disease. Objective assessment of mood state did not find evidence of mood disorder, somatisation disorder, conversion disorder, pain disorder or hypochondriasis as defined in the American diagnostic manual DSM-IV.[22] It was concluded that exposure to engine oil fumes was the most likely factor involved in the aetiology of the pilot's cognitive impairment.

Since this assessment, the relevant aviation authority has withdrawn the pilot's licence to fly on psychiatric grounds, despite the fact that the pilot is not suffering from a mood disorder and has never been examined by a psychiatrist.

Discussion

The purpose of this article is to raise awareness among physicians and OHS practitioners working in the aviation industry of the short- and long-term health effects that may develop after exposure to pyrolised synthetic jet engine oil, and a case study was used to illustrate some of the issues regarding causation and diagnosis — in particular, the contentious matter of whether symptoms reported by aircrew reflect a psychosomatic disorder or neurological injury.

When physicians encounter medical symptoms for which they can find no explanation, they often conclude that the patient is suffering from "hysteria" or "psychosomatic disorder". These terms encourage doctors to think that they have arrived at a diagnosis when, in reality, these concepts are no more than descriptions and do not reflect disease states. Labelling a patient's symptoms as "psychosomatic" can have a devastating impact on the way in which that individual will be viewed and treated in the future.

The terms psychosomatic or somatoform disorder encompass several mental health disorders whereby patients report physical symptoms which appear to be caused, or worsened, by psychological factors. Individuals with psychosomatic disorders make two to three times as many visits to physicians and generally complain of a large number of symptoms which recur but do not usually indicate major disease and for which they take many medications. Psychosomatic disorders are particularly common among out-patients and are more frequent in certain specialist clinics, for example, gastroenterology and cardiac clinics. These disorders are associated with a family history of illness, neurotic personality, early trauma, coping style, psychiatric disorder and secondary gain. They are more common in women, tend to occur between the ages of 18 and 30 years, are usually preceded by severe life stress, and are associated with significant impairment in occupational and social functioning.[23,24]

Aircrew are unlikely to share the characteristics of patients with psychosomatic disorders (except for the fact that they suffer from a variety of physical symptoms) because employment selection criteria exclude those with a history of medical or psychiatric illness from entering the profession. The concept of "industrial hysteria" or "psychosomatic disorder" loses further credibility, given the fact that some types of aircraft report significantly higher incidences of contaminated air events than others (for example, the BAe 146), and individuals who fly on these aircraft report a higher incidence of symptoms than other aircrews. There is a close temporal relationship between exposure and the onset of ill health, and initially symptoms resolve when exposure ceases. Aircrews around the world report similar symptoms to physicians, but are generally reluctant to discuss their situation with co-workers due to employment fears. These symptoms are occurring in a relatively young and previously fit and healthy population.

5_MackenzieRoss 11/12/06 4:12 PM Page 526

Patients with neurological diseases are occasionally misdiagnosed as suffering from psychological disorders.[25-27] History has demonstrated that, at any one time, there are illnesses which are not recognised and dismissed as being psychological. Among patients who have seen a neurologist, the rate of misdiagnosis is between 5% and 10%.[28] Misdiagnosis appears to be more common in patients with movement disorders and in those with a psychiatric history. There has been a clear decline in the rate of misdiagnosis over the past 50 years, and the percentage of patients initially diagnosed with a psychosomatic disorder and later identified as having an organic disorder has been decreasing.[29,30] This is partly explained by the development of more sophisticated diagnostic techniques and neuroimaging. The availability of modern diagnostic techniques has made it easier to identify neurological disorders (such as multiple sclerosis) which historically have frequently been misdiagnosed as hysteria. In a recent study, Moene et al examined consecutive patients with a diagnosis of conversion disorder (referred for psychiatric opinion) and found that 11.8% of patients appeared to have a neurological disorder.[28] However, it took a surplus of supplemental examinations before the final diagnosis could be made.

The case study described in this article was referred to clinical psychology after routine investigations failed to reveal a diagnosis. The pilot had been advised that his symptoms could be attributed to a large number of conditions, including psychological factors, but psychological assessment did not find evidence of a mood or psychosomatic disorder. Psychometric assessment revealed a pattern of mild cognitive deficits similar to those seen in Australian BAe 146 aircrew who had been exposed to engine oil fumes — suggesting that neurological injury had been sustained.[19]

Indeed, a research team in the US found radiological evidence of organic brain damage in crew members complaining of ill health following exposure to contaminated air. Heuser et al examined 26 North American flight attendants who presented with a range of disabling physical complaints which had not been thoroughly investigated and had often been trivialised by physicians.[17] Each flight attendant had a neurological examination and a neuropsychological assessment, and 12 subjects underwent neuroimaging (PET scans). Neurological abnormalities were detected in 15 flight attendants. Many had impaired balance and coordination and some had developed a movement disorder (postural bilateral tremor). All showed evidence of cognitive impairment. Abnormalities were found in all of the aircrew who had PET scans, including imbalance of function between cortical (decrease) and subcortical (increase) areas, frontal (decrease) and occipital (increase) areas, and increased function in some limbic areas, especially the extended amygdale region. Heuser et al concluded that aircrew who have been exposed to contaminated air deserve more medical attention and sophisticated investigations (that is, neuroimaging) than is routine, and suggested that a medical protocol should be created which outlines the evaluations that flight personnel should undergo.

Conclusion

The potential contamination of aircraft cabin air by engine oil fumes is a serious aviation safety concern for both aircrew and passengers. As such, further research is needed to determine the potential toxicity of pyrolised engine oil under aviation conditions (that is, at altitude in a reduced oxygen environment after being subjected to extreme temperature).

The medical profession should develop internationally agreed medical protocols for the evaluation and treatment of affected individuals. Aircrew who report ill health following exposure to contaminated air should be referred for further investigations, including psychological, neurological and neurophysiological assessment, neuroimaging and respiratory testing. Diagnoses such as industrial hysteria and psychosomatic disorder are unhelpful and misleading, and should only be made if there is clear evidence that psychological factors are involved

5_MackenzieRoss 11/12/06 4:12 PM Page 527

in the aetiology of a patient's complaints. The absence of underlying pathology following medical examination is not proof of an actual non-organic condition, particularly in the context of a history that might reasonably account for the symptoms.

Acknowledgment

The authors of this article are grateful to the patient in this study for giving permission to use the data collected from his examination.

References

1. Winder, C and Balouet, J-C. Aircrew exposure to chemicals in aircraft: symptoms of irritation and toxicity. *J Occup Health Safety — Aust NZ* 2001, 17(5): 471-483.
2. Winder, C and Balouet, J-C. The toxicity of commercial jet oils. *Environ Res* 2002, 89: 146-164.
3. Winder, C, Fonteyn, P and Balouet, J-C. Aerotoxic syndrome: a descriptive epidemiological survey of aircrew exposed to in-cabin airborne contaminants. *J Occup Health Safety — Aust NZ* 2002, 18(4): 321-338.
4. Montgomery, MR, Weir, T, Zieve, FJ and Anders, MW. Human intoxication following inhalation exposure to synthetic jet lubricating oil. *Clinical Toxicology* 1977, 11: 423-426.
5. Winder, C and Michaelis, S. Aircraft air quality malfunction incidents. In Hocking, M (ed). *Air quality in airplane cabins and similar enclosed spaces. The handbook of environmental chemistry.* Berlin: Springer-Verlag, 2005, pp 211-228.
6. Winder, C and Michaelis, S. Crew effects from toxic exposures on aircraft. In Hocking, M (ed). *Air quality in airplane cabins and similar enclosed spaces. The handbook of environmental chemistry.* Berlin: Springer-Verlag, 2005, pp 229-248.
7. McAuslan, J. Contaminated air protection conference closing speech. *J Occup Health Safety — Aust NZ* 2005, 21(5): 475-477.
8. Van Netten, C. Aircraft air quality incidents: symptoms, exposures and possible solutions. *J Occup Health Safety — Aust NZ* 2005, 21(5): 460-468.
9. Karalliedde, LD, Edwards, P and Marrs, TC. Variables influencing the toxic response to organophosphates in humans. *Food Chem Toxicol* 2003, 41: 1-13.
10. Abou-Donia, M, Wilmarth, KR, Abdel-Rahman, A, Jensen, KF, Oeheme, FW and Kurt, TL. Increased neurotoxicity following concurrent exposure to pyridostigmine bromide, DEET, and chlorpyrifos. *Fundam Appl Toxicol* 1996, 34: 201-222
11. Burdon, J and Glanville, AR. Lung injury following hydrocarbon inhalation in BAe 146 aircrew. *J Occup Health Safety — Aust NZ* 2005, 21(5): 450-454.
12. Cox, L and Michaelis, S. A survey of health symptoms in BAe 146 aircrew. *J Occup Health Safety — Aust NZ* 2002, 18(4): 305-312.
13. Senate Rural and Regional Affairs and Transport References Committee. *Air safety and cabin air quality in the BAe 146 aircraft.* Canberra: Parliament of the Commonwealth of Australia, 2000.
14. Michaelis, S. A survey of health symptoms in BALPA Boeing 757 pilots. *J Occup Health Safety — Aust NZ* 2003, 19(3): 253-261.
15. Hartman, DE. *Neuropsychological toxicology: identification and assessment of human neurotoxic syndromes.* London: Pergamon Press 1988.
16. Harper, A. A survey of health effects in aircrew exposed to airborne contaminants. *J Occup Health Safety — Aust NZ* 2005, 21(5): 433-439.
17. Heuser G, Aguilera, O, Heuser, S and Gordon, R. Clinical evaluation of flight attendants after exposure to fumes in cabin air. *J Occup Health Safety — Aust NZ* 2005, 21(5): 455-459.
18. Somers, M. Aircrew exposed to fumes on the BAe 146: an assessment of symptoms. *J Occup Health Safety — Aust NZ* 2005, 21(5): 440-449.
19. Coxon, L. Neuropsychological assessment of a group of BAe 146 aircraft crew members exposed to jet engine oil emissions. *J Occup Health Safety — Aust NZ* 2002, 18(4): 313-319.
20. British Aerospace. Evidence to the Senate Rural and Regional Affairs and Transport References Committee. *Air safety and cabin air quality in the BAe 146 aircraft.* Canberra: Parliament of the Commonwealth of Australia, 2000.
21. Ansett Australia. Consensus statement, external panel of specialists — BAe 146 odour occurrences. Evidence to the Senate Rural and Regional Affairs and Transport References Committee. *Air safety and cabin air quality in the BAe 146 aircraft.* Canberra: Parliament of the Commonwealth of Australia, 2000.
22. American Psychiatric Association. *Diagnostic and statistical manual of mental disorders* (4th ed). Washington DC: APA, 1994.

5_MackenzieRoss 11/12/06 4:12 PM Page 528

23. Mayou, R, Bass, C and Sharpe, M (eds). *Treatment of functional somatic symptoms*. Oxford, UK: Oxford University Press, 1995.

24. Drossman, DA, Creed, FH, Olden, KW, Svedlund, J, Toner, BB and Whitehead, WE. Psychosocial aspects of the functional gastrointestinal disorders. *Gut* 1999, 45: 1125-1130.

25. Marsden, CD. Hysteria — a neurologist's view. *Psychol Med* 1986, 16: 277-288.

26. Lezak, MD. *Neuropsychological assessment* (3rd ed). Oxford, UK: Oxford University Press, 1995.

27. Mackenzie Ross, SJ et al. Progressive biparietal atrophy: an atypical presentation of Alzheimer's disease. *J Neurol Neurosurg Psychiatry* 1995, 61: 388-395.

28. Stone, J, Zeidler, M and Sharpe, M. Misdiagnosis of conversion disorder. *Am J Psychiatry* 2003, 160: 391.

29. Stone, J et al. Systematic review of misdiagnosis of conversion symptoms and "hysteria". *Br Med J* 2005, 331: 989-995.

30. Moene, FC et al. Organic syndromes diagnosed as conversion disorder: identification and frequency in a study of 85 patients. *J Psychosom Res* 2000, 49: 7-12