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Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY REPORT

Aviation Research and Analysis Report - B2006/0170

Final

**Pilot Incapacitation:
Analysis of Medical Conditions Affecting Pilots
Involved in Accidents and Incidents
1 January 1975 to 31 March 2006**

Dr David G. Newman

MB, BS, DAvMed, PhD, MRaES, FAICD, AFAIM

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Analysis of Medical Conditions Affecting Pilots Involved in Accidents and Incidents: 1 January 1975 to 31 March 2006

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EXECUTIVE SUMMARY

Incapacitation of a pilot due to the effects of a medical condition or a physiological impairment represents a serious potential threat to flight safety. The purpose of this research project was to investigate the prevalence, type, nature and significance of in-flight medical conditions and incapacitation events occurring in civil aviation. A search of the Australian Transport Safety Bureau's accident and incident database was conducted for medical conditions and incapacitation events between 1 January 1975 and 31 March 2006. There were 98 occurrences in which the pilot of the aircraft was incapacitated for medical or physiological reasons (16 accidents, one serious incident and 81 incidents). Such events accounted for only 0.6 of a percentage point of all the occurrences listed in the Australian Transport Safety Bureau's database. The majority of the events occurred in airline operations, with private flying the next most common (22.4 per cent of events). In 10 occurrences (10.2 per cent), the outcome of the event was a fatal accident. All of these accidents involved single-pilot operations, and in the majority of cases, heart attack was the most common cause. The majority (21 per cent) of in-flight medical and incapacitation events in Australian civil pilots for the study period were due to acute gastrointestinal illness (usually food poisoning), a finding consistent with other published studies. The next most common cause was exposure to toxic smoke and fumes on board the aircraft, of which 25 per cent were due to carbon monoxide. The results of this study demonstrate that the risk of a pilot suffering from an in-flight medical condition or incapacitation event is low. However, if the pilot suffers a heart attack the risk of a fatal accident occurring increases. The aeromedical certification process must keep pace with the evolving nature of modern medical science to ensure that the risk of in-flight incapacitation remains low.

ABBREVIATIONS

ATSB	Australian Transport Safety Bureau
ICAO	International Civil Aviation Organization

Incapacitation of a pilot represents a serious potential threat to flight safety. This incapacitation may be subtle or sudden, partial or complete. It may be due to the effects of a pre-existing medical condition manifesting themselves in flight, or the development of an acute medical condition, or some physiological event that renders an otherwise fit and well pilot temporarily unable to fly or safely operate the aircraft. Whatever the cause, such an event compromises the safety of the flight and puts the crew and passengers at risk.

Over the years, a number of studies have been done that document the extent of this problem in various pilot populations (see references 3-6, 8-10, 12, 13, 15, 16, 18-20, 22-28, 30, 32-34, 40). To date, a comprehensive review of such events has not been done in the Australian civil aviation context. Knowledge of the sorts of medical problems Australian pilots are experiencing in flight (particularly those that led to an incident, serious incident or accident) is extremely useful, especially in relation to the regulatory aspects of flight crew licensing and the development of appropriate, evidence-based medical standards. Increasingly, medical standards for aircrew are being re-evaluated, using an evidence-based approach to their creation and application. As such, knowledge of what medical conditions or problems are affecting pilots and possibly contributing to an accident or incident would be useful in assisting the on-going evolution of the aeromedical regulatory process.

Aeromedical standards for civil aviation are in general terms set by the International Civil Aviation Organization (ICAO). These standards have (with very few exceptions) been incorporated into the Civil Aviation Safety Regulations in Australia, since Australia is a contracting state with ICAO. As such, Australia's system of aeromedical certification for civil aviation is essentially ICAO-compliant. The aeromedical certification system is designed to ensure that individuals who are granted a flight crew licence for either private or commercial aviation activities in Australia meet the internationally-accepted medical standards. As such, these individuals then represent a medically fit pilot population, at an acceptably low risk of in-flight performance impairment or incapacitation. The entire exercise of certification is one of risk management, to ensure that medically fit pilots are able to continue flying, and those that are suffering from medical conditions with a high attendant risk of incapacitation are restricted or disqualified from flying, in the interests of overall flight safety.

The purpose of this research project was to investigate the prevalence, type, nature and significance of in-flight medical conditions and incapacitation events occurring in civil aviation. The aim was to document the prevalence, nature, extent and the consequences of these medical events in Australian civil aviation. In addition, another aim was to determine the most common condition responsible for in-flight incapacitation events, and also which condition accounted for the majority of fatal accidents in which medical and incapacitation events were considered to be significant factors in the accident.

2 METHODOLOGY

2.1 Data sources

A comprehensive search of the accident and incident database held and managed by the Australian Transport Safety Bureau (ATSB) was conducted. The search period was 1 January 1975 to 31 March 2006. The database was searched for various medical conditions and causes of in-flight pilot incapacitation. Occurrences reported to the ATSB include Australian civil registered aircraft operating both within and outside Australian airspace and foreign registered aircraft operating within Australian airspace.

The ATSB database records events according to occurrence type in accordance with the *Transport Safety Investigation Act 2003*. The occurrence types searched were accidents, serious incidents and incidents. The ATSB definition of an accident is “an investigable matter involving a transport vehicle where: (a) a person dies or suffers serious injury as a result of an occurrence associated with the operation of the vehicle; or (b) the vehicle is destroyed or seriously damaged as a result of an occurrence associated with the operation of the vehicle; or (c) any property is destroyed or seriously damaged as a result of an occurrence associated with the operation of the vehicle.”

A serious incident is an occurrence involving circumstances indicating that an accident nearly occurred. According to International Civil Aviation Organization (ICAO), the difference between an accident and a serious incident is essentially in terms of the end result. An incident is defined as all other investigable and reportable matters where safety was potentially affected.

2.2 Method of analysis

The collected data was then tabulated in a commercially-available spreadsheet program and analysed. For each event, the following parameters were recorded: occurrence date, occurrence type, aircraft class, nature of operations, pilot licence held, type of medical condition, cause of incapacitation, and outcome of medical condition or incapacitation.

3 RESULTS

The ATSB database, for the search period 1 January 1975 to 31 March 2006, comprised an all-cause, all-classification total of 8,302 accidents, 95 serious incidents, and 151,941 incidents, giving an overall occurrence total for the study period of 160,338 events.

3.1 Medical events by occurrence type

In terms of medical causes and inflight incapacitation events, for the study period, there were 98 occurrences in which the pilot of the aircraft was incapacitated for medical or physiological reasons, or experienced a significant medical event. Of these 98 events, 16 were classed as accidents, one as a serious incident and 81 as incidents involving medical issues and pilot incapacitation. These figures are shown in table 1.

Table 1: Medical events by occurrence type

Occurrence type	Number
Accident	16
Serious incident	1
Incident	81
Total	98

3.2 Medical events by operation type

Table 2 shows the type of air operations being conducted for each event.

Table 2: Medical events by operation type

Operation type	Number	Percentage of total
Agriculture	1	1.0%
Airlines	29	29.6%
Business	6	6.1%
Charter	15	15.3%
Commuter	4	4.1%
Flying training	8	8.2%
Gliding	2	2.0%
Military ¹	1	1.0%

¹ While the ATSB does not investigate military accidents or incidents where there was no civil aircraft or infrastructure involved, this particular incident involved a civil registered aircraft leased to and operated by the Australian Defence Force.

Table 2: Continued

Operation type	Number	Percentage of total
Other aerial work	7	7.1%
Private	22	22.4%
Sport aviation	1	1.0%
Unknown	2	2.0%
Total	98	100%

Note: Components may not sum to totals due to rounding.

The majority of the medical and incapacitation events occurred in airline operations, with private flying the next most common (22.4 per cent of events).

3.3 Medical and incapacitation events by aircraft class

Table 3 shows the aircraft types involved in these events, with the vast majority are in the aeroplane category.

Table 3: Medical and incapacitation events by aircraft class

Aircraft class	Number	Percentage of total
Aeroplane	90	92%
Glider	2	2%
Helicopter	5	5%
Ultralight	1	1%
Total	98	100%

3.4 Highest class of licence held

Table 4 shows the breakdown of pilots by licence held. As the table shows, the majority of pilots (65 per cent) involved in these occurrences held professional aircrew licences (airline transport or commercial licence).

Table 4: Highest class of licence held

Licence held	Number	Percentage of total
Airline transport	31	31.6%
Commercial	33	33.7%
Private	19	19.4%
Student	1	1.0%
Unknown	14	14.3%
Total	98	100%

3.5 Highest injury outcome

Table 5 shows the injuries sustained as a result of the occurrence. In the majority of cases, the injuries sustained were not specified. This may be due to differences in the data entry process for the ATSB database over the course of the study period, but is more likely to reflect the fact that a temporary medical impairment or in-flight incapacitation was not considered to represent an injury as such. For the majority of events, the incapacitation or medical event did not lead to an accident or serious incident, and as such details on the nature of what was most likely a trivial, transient, non-permanent condition were not recorded.

In 10 occurrences (10.2 per cent), the outcome of the in-flight medical condition or incapacitation event was fatal.

Table 5: Highest injury outcome

Injury level	Number	Percentage of total
Fatal	10	10.2%
Serious	5	5.1%
Minor	4	4.1%
None	5	5.1%
Not specified	74	75.5%
Total	98	100%

3.6 Type of medical event or incapacitation

Table 6 lists the different types of medical event or in-flight incapacitation sustained by the pilot. It is readily apparent from this data set that the majority of in-flight medical and incapacitation events in Australian civil pilots for the study period were due to acute gastrointestinal illness, most commonly associated with food poisoning. This category accounted for 21 per cent of the events. In 43 per cent of these cases, the pilots involved were operating commercial passenger-carrying flights for airlines. In one typical example, the first officer developed symptoms of food poisoning and the aircraft was diverted into Singapore.

The next most common specified medical event, at 12 per cent, was exposure to toxic smoke and fumes on board the aircraft. Three of the cases in the smoke and fumes category (25 per cent) were due to carbon monoxide exposure, leading to pilot incapacitation. One of these cases involved a single-pilot private operation in which the aircraft was overdue and the subject of a subsequent search. The aircraft was eventually located on a disused runway 150 nautical miles from its intended destination. The pilot was unable to remember the final 90 minutes of the flight. The pilot had made a precautionary landing after feeling unwell. Subsequent examination of the aircraft revealed problems with the exhaust and heater system, which resulted in the pilot becoming incapacitated by exposure to carbon monoxide. In this case, the pilot was clearly very lucky to have survived. Had he not been able to make the precautionary landing, the chances were high that a fatal accident would have resulted.

Loss of consciousness accounted for 9.18 per cent of occurrences. The reason for the loss of consciousness was in most cases not specified. In one case, the affected pilot lost consciousness for several minutes whilst operating a medical flight. The on-board flight nurse revived him and the flight was diverted. Five cases of infectious disease were also reported, where the pilot was affected by symptoms during the flight. While most of these were simple cases of viral infection, one case was due to the acute symptoms of malaria becoming evident in the pilot during flight.

There were a total of eight cases where heart attack occurred in flight (8.16 per cent of in-flight medical and incapacitation occurrences). Five were fatal. The other three events all occurred during private aeroplane operations, but the outcome was not a fatal accident. In two cases, the pilot suffered chest pain and was able to land successfully and be transferred to hospital. In the other case, a non-qualified passenger took over the controls after the pilot suffered a heart attack in flight. The passenger, with some occasional, intermittent instruction from the incapacitated pilot, managed to successfully land the aircraft.

Of the two cases of head injury reported, one involved a propeller strike while on the ground. This event, due to the pilot attempting to start the aircraft engine via “prop-swinging”, resulted in a serious penetrating head injury to the individual concerned. The other case involved an experienced helicopter flight instructor, who was struck by the rotor blade after exiting from the aircraft. The rotor blades, turning at low speed, developed a blade sail phenomenon² and struck the pilot on the head. This was classed as a serious injury. In fact, approximately two and a half months later the pilot died as a result of the injuries sustained in the event. This was not classed as a fatal event in this study, due to the significant time period between suffering the injury and subsequent death³.

Table 6: Type of medical event or incapacitation

Condition	Number	Percentage of total
Acute pain	5	5.10%
Appendicitis	1	1.02%
Illicit drugs	1	1.02%
Fitting episode	2	2.04%
Gastrointestinal illness	21	21.43%
Head injury	2	2.04%
Heart attack	8	8.16%
Hypoglycaemia	1	1.02%

² Blade sailing is the undesired flapping of helicopter rotors at low-rotor revolutions per minute. This mainly occurs at start-up, shutdown, and in high wind conditions (21).

³ In accordance with ICAO Annex 13, *International Standards and Recommended Practices*, an injury resulting in death within 30 days of an accident is classified as a fatal injury (17).

Table 6: Continued

Condition	Number	Percentage of total
Hypoxia	3 ⁴	3.06%
Infectious diseases	5	5.10%
Loss of consciousness	9	9.18%
Motion sickness	3	3.06%
Neurological impairment	1	1.02%
Pressure effects	3	3.06%
Psychological	3	3.06%
Respiratory illness	4	4.08%
Smoke and fumes	12	12.24%
Spatial disorientation	1	1.02%
Thermal stress	2	2.04%
Trauma	5	5.10%
Vascular disease	1	1.02%
Unspecified	5	5.10%
Total	98	100%

Note: Components may not sum to totals due to rounding.

The five cases of trauma included such causes as bird strike (two cases) in which a bird (a duck and an eagle, in these cases) penetrated the cockpit and struck the pilot, injuries sustained after windscreen failure due to extensive hail damage during a thunderstorm, and a fractured collar-bone sustained by a co-pilot during an emergency ground evacuation from a Boeing 747-400 aircraft.

Respiratory illness included such conditions as acute pneumonia and severe emphysema. In one case, a helicopter pilot landed in a field after feeling unwell and being unable to continue the flight. The pilot was found unconscious in the aircraft by a ground party and was subsequently diagnosed with severe pneumonia.

The single case of vascular disease is an interesting one. The pilot suffered an acute, potentially life-threatening tear in the aorta (the major artery leaving the heart taking blood to the rest of the body). In many cases such an event is rapidly fatal. The pilot managed to land the aircraft and a fatal accident was avoided. The pilot was later treated in hospital. The neurological impairment case consisted of a commercial helicopter pilot with a recent history of headaches and associated visual disturbances (blurred and double vision). This pilot was involved in a fatal crash, with the medical conditions listed as a significant factor in the accident.

⁴ This includes the fatal accident of a Beech Super King Air 200 aircraft (VH-SKC) near Burketown, Queensland on 4 September 2000 (ATSB Report: 200003771). The ATSB's investigation determined that the incapacitation of the pilot and seven passengers was probably due to hypobaric hypoxia because of the high cabin altitude and not receiving supplemental oxygen (2).

3.7 Fatal accidents

Table 7 shows the details of the 10 fatal cases. All of these fatal accidents involved single-pilot operations. In 10 accidents, a total of 24 fatalities were recorded⁵. There was only one survivor (the wife of the accident pilot), who sustained serious injuries after being ejected from the aircraft during the crash sequence.

Table 7: Fatal accidents due to medical events and incapacitation

Fatal accident number	Aircraft class	Operations	Cause	Fatalities	Serious injuries
1	Aeroplane	Private	Loss of consciousness	3	1
2	Glider	Gliding	Heart attack	1	0
3	Aeroplane	Private	Heart attack	1	0
4	Aeroplane	Private	Heart attack	5	0
5	Aeroplane	Business	Heart attack	2	0
6	Helicopter	Charter	Heart attack	1	0
7	Aeroplane	Private	Loss of consciousness	1	0
8	Ultralight	Sport aviation	Respiratory disease	1	0
9	Helicopter	Business	Neurological impairment	1	0
10	Aeroplane	Charter	Hypoxia	8	0
Total				24	1

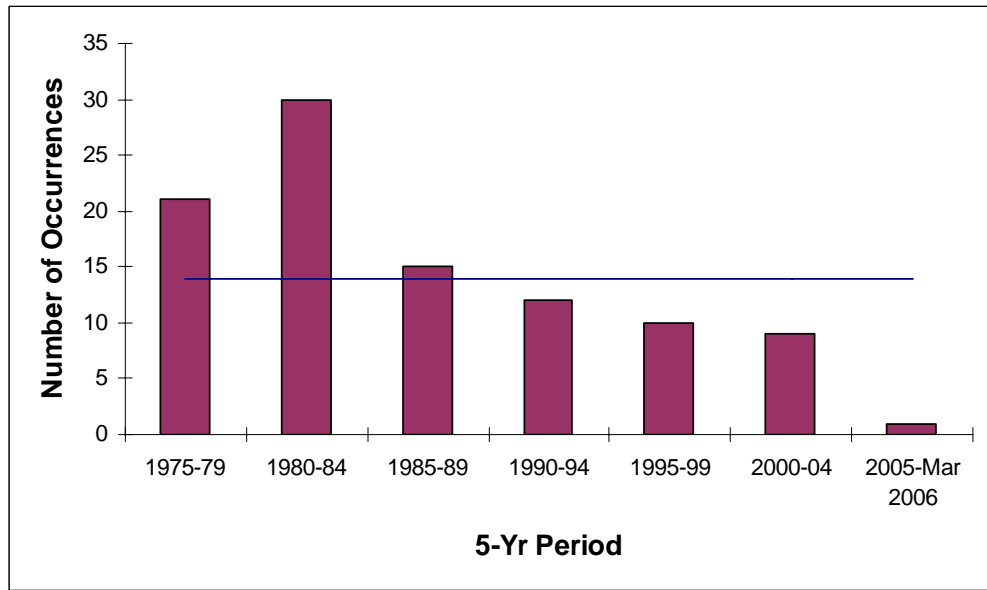
Table 7 demonstrates that in the majority of fatal accidents where medical conditions or incapacitation occurred, the most common cause was heart attack, in 50 per cent of cases. In multi-crew operations, a second pilot would have been able to assume control of the aircraft and prevent an accident. Since all of these cases were single-pilot operations, this was not possible. It is noteworthy that in the present study none of the in-flight medical conditions or incapacitation events that occurred in airline operations resulted in a fatal accident.

3.8 Medical events by 5-year periods

Figure 1 shows the incidence of these occurrences in 5-year epochs across the study period. The majority of the reported occurrences in the study period were in the 1980-84 period. In the time since this epoch, the number of occurrences has gradually declined. The average number of medical and incapacitation events per 5-year epoch is 14 (shown on the graph). The 2005 to 31 March 2006 epoch represents an incomplete 5-year period.

⁵ Of the 24 fatalities, eight were attributed to the fatal accident of VH-SKC (ATSB Report: 200003771) on 4 September 2000 (2).

Figure 1: Medical events by 5-year periods



The results of this study demonstrate that the risk of a pilot suffering from an in-flight medical condition or incapacitation is low. Such events account for only 0.6 per cent of all the occurrences listed in the ATSB database for the period 1 January 1975 to 31 March 2006. Furthermore, these events account for only 0.19 per cent of all accidents, 1.0 per cent of all serious incidents, and only 0.05 per cent of all incidents. The most common cause of the medical event or incapacitation for affected flights was gastrointestinal illness, usually secondary to food poisoning. Exposure of the crew to smoke and fumes, and loss of consciousness were the next most common causes. All fatal accidents occurred in single-pilot operations, where heart attack in the pilot was the most common cause of the subsequent accident.

There have been many studies over the last several decades that have examined the issue of medical conditions affecting pilots in-flight and the prevalence of incapacitation events (3-6, 8-10, 12, 13, 15, 16, 18-20, 22-28, 30, 32-34, 40). A large number of these studies date back several decades. As some authors have pointed out, the nature of commercial air transport operations has changed considerably over this time period. Flights are now conducted on average for longer time periods than previously, and the aircraft themselves are more efficient, modern and highly automated. As such, the critical phases of flight (takeoff and landing) account for a smaller proportion of the total flight time than previously (27). Furthermore, clinical medicine has also evolved, with considerable improvements in morbidity and mortality rates being observed for a great number of medical conditions, including cardiovascular disease. For these reasons, comparison of the data in the current study with those of much older studies is somewhat problematic. However, there are a number of recent studies that can be more readily compared with the Australian experience of in-flight medical and incapacitation events.

The majority of cases of in-flight medical and incapacitation events in this study were a consequence of gastrointestinal illness, most usually a result of food poisoning. The significance of such incapacitating illness in pilots has been a consistent finding in a number of studies. James and Green conducted a large survey of airline pilots, and found that 29 per cent of respondents to the survey had experienced an in-flight incapacitation event, with 48 per cent taking the view that safety of the aircraft had been or could have been affected as a result (18). In this survey, the most common cause of in-flight pilot incapacitation was gastrointestinal illness, in 58 per cent of cases. Furthermore, they also found that this figure was consistent with a much earlier study in 1967, where the gastrointestinal figure was 65 per cent, and still the leading cause of pilot incapacitation. The high rate of gastrointestinal illness as a cause of in-flight incapacitation of the pilot has been cited by many others (3, 12).

The figure for gastrointestinal illness in the present study was 21 per cent, which was a lower figure than many of these previous studies. This is most likely the result of methodological differences between the present study and the others. This study looked at reportable events, whereas most of the other studies directly surveyed a large pilot population. As such, not all of those events may have been reported to the relevant investigating authority. This would seem to explain the lower figure for this cause found in the present study. Notwithstanding that, it is significant in practical terms that the current study found that gastrointestinal illness was the most common reason for an in-flight medical or incapacitating event.

Appropriate education programs and preventive strategies can help to reduce the potential impact on flight safety of an acute gastrointestinal event. It is important that crew meals are prepared to the highest possible hygiene standards, and that pilots receive different crew meals to help reduce the overall risk. However, it is not just in-flight catering that is important. In many cases, it is what the pilots eat and drink during their layover periods or in the pre-flight period that may be responsible. Contaminated food and water consumed in these periods may then produce an acute gastrointestinal illness some hours later, at which time the pilot may be in command of the aircraft and become incapacitated. Careful attention to this is clearly necessary.

An Air France study in 1990 examined in-flight incapacitations in their flight crews over a 20-year period (25). Only 10 cases were reported, out of a population of 1,800 personnel. Two of these events were due to cardiovascular disorders (but not heart attack – they were disorders of heart rate control). There were also two epileptic seizure events and two intestinal haemorrhages. These latter events are all significant and potentially life-threatening. One of the cases was due to physiological impairment of the whole flight deck crew (hypoxia subsequent to loss of cabin pressure). Nine of the events occurred in the air, and one on the ground. Interestingly, there were no reports of incapacitation due to gastrointestinal illness (ie food poisoning) in this small series.

Another French study examined 17 incapacitation events in professional pilots between 1948 and 1972. The majority of these events were due to cardiovascular disease (13 events), with 85 per cent of these due to heart attack (33). None of these events, however, resulted in an accident. The authors commented that the risk of an accident increases if the event affects the handling pilot suddenly and during a critical phase of flight (ie taking off or landing). In a general aviation study in the United States, it was found that three accidents per 1,000 total (or 15 out of every 1000 fatal accidents) are a direct result of incapacitation of the pilot (6).

There have been several military studies looking at the issue of incapacitation in flight (26, 30, 34). McCormick and Lyons found that neurological and cardiovascular disease were the most common reasons for incapacitation in 23 events with underlying medical conditions present in the pilot during 1978 to 1987 (26). In approximately half of these events, the pilot lost consciousness. In this study, the medical screening process apparently did not detect the presence of this underlying condition in the pilot, which manifested itself in flight.

Cardiovascular disease still ranks as the single biggest cause for medical disqualification of pilots, both military and civil, and continues to receive much research attention (1, 5, 7, 14, 16, 23, 28-31, 35-39, 41, 42). The well-known potential for cardiovascular disease to cause sudden incapacitation of the pilot in-flight has driven a considerable amount of the medical certification policy in international civil aviation (11-13, 15, 18, 27, 36-38). While in-flight cardiac events are actually relatively rare, there may well be some under-reporting, especially in difficult post-mortem circumstances, as noted by some authors (30, 36).

The so-called “1% rule” (19, 27) is based on the risk of a cardiovascular event, and represents the annual medical incapacitation risk limit in multi-crew commercial air transport operations. It assumes a target fatal accident rate due to medical incapacitation of the aircrew of one in 10^9 flying hours (27). While a comprehensive analysis of the “1% rule” is beyond the scope of this study, it is sufficient to say that there is currently some debate as to whether this rule is over-conservative, especially at the expense of pilot experience (13, 27). Some have argued that the risk of fatal accident from human error is much greater than that from in-flight medical incapacitation events. According to Froom et al, replacing older pilots with more chance of cardiovascular disease with younger pilots with less risk, but correspondingly less experience, might lead to more accidents through human error (13).

The results of this study show that only eight in-flight pilot heart attacks occurred during the study period. This figure translates into a prevalence of only 0.005 per cent of the total occurrences listed on the ATSB database for the study period. However, in-flight heart attack in pilots accounted for 50 per cent of the fatal accidents arising from medical or incapacitation events, and the death of seven accompanying passengers and serious injuries in another.

Several other studies have examined the prevalence of cardiovascular events in pilots during flight. In the United States, during the period 1974-75, 13 general aviation pilots died of cardiovascular disease in flight (28). This figure represents a total incidence of 0.93 per cent of all the fatal general aviation accidents for the period. In nine of these events, the pilots were operating the aircraft solo. In one of the other events, the non-pilot wife of the pilot managed to land the aircraft. A total of 18 people were killed in these 13 events, representing that in some cases the death or incapacitation of the pilot results in the death of all on board.

A study in which 1,000 consecutive fatal accidents were examined showed that cardiac disease was the most common finding in those fatal accidents where medical or toxicological factors were causal or contributory to the accident (10). In another study, 69 per cent of pilots killed in general aviation accidents demonstrated post-mortem evidence of cardiovascular disease (usually coronary atherosclerosis) ranging from minimal to severe (7). The severe form of heart disease was found in 2.5 per cent of cases. The incidence was dramatically raised with increasing age – from about six per 1,000 at under 40 years of age, to about 80 per 1,000 for more than 50 years of age.

In a 10-year period in the United Kingdom, there were 130 incapacitation events out of 21,285 reported safety occurrences (12). Significantly, this gives a prevalence of in-flight medical or incapacitation events of 0.6 per cent, which is the same as that found in the present study. Twenty of those were serious incidents in which there was loss or reduction of consciousness, and there were only two in-flight cardiac deaths of pilots. One death occurred during descent at 15,000 feet and the other during a period of in-flight crew rest (12). In none of these 130 events did an accident occur.

Indeed, cardiovascular disease does not tend to result in a fatal accident in high capacity, two-pilot commercial passenger-carrying operations. In the period 1980 to 1996, no fatal accidents anywhere in the world for commercial air transport operations above 5,700 kg occurred in which cardiovascular incapacitation of the crew was cited as a cause (27). The reasons for this satisfactory outcome are numerous, and include the presence of a second pilot on the flight-deck who is able to assume control. Furthermore, pilots are becoming fitter, mortality from heart disease in the general community is declining, and new, improved treatment regimes have been implemented (27, 37, 38). It must also be remembered that the aeromedical certification process does not automatically exclude pilots with cardiovascular disease from continuing to fly. Such pilots can be re-certified after developing heart disease (including suffering from a heart attack) provided they meet stringent guidelines and clinical criteria laid down by the relevant regulatory authorities (the Civil Aviation Safety Authority in the Australian context). Researchers have shown that if a pilot meets the relevant medical standard, then they can generally be considered as fit to fly, and therefore not to have any increased likelihood of having an accident (40).

In the present study, the majority of the fatal accidents were a result of the pilot suffering a heart attack. All of the 10 fatal accidents involved single-pilot operations. It is perhaps not surprising in such an environment that when the single pilot is incapacitated or dies in flight that the chances of a fatal accident occurring rise considerably. In the Australian context, in-flight pilot heart attacks resulted in a fatal accident in 63 per cent of cases.

None of the fatal accidents in this study were a result of an otherwise fit and healthy person suffering some form of short-term physiological impairment or minor, yet incapacitating illness. All the pilots involved in this series of fatal accidents had significant medical conditions that declared themselves in flight. What is unclear from the information in the reports is whether the existence of these conditions was known to either the pilot or the medical licensing authorities (ie the Civil Aviation Safety Authority of Australia) prior to the accident flight.

The majority of pilot incapacitation events recorded by the ATSB do not involve a chronic or pre-existing medical condition. That is, they are largely unforeseeable events, often involving acute illnesses or injury. Many are not in themselves life threatening, but are capable of impairing a pilot's performance to the extent that safe operation of the aircraft may be adversely affected. This study also confirms the findings from other international reports that gastrointestinal illness is the most common cause of in-flight incapacitation in the pilot population.

Of the 10 accidents that resulted in fatalities, all involved single-pilot operations and in half of these, heart conditions were identified as a significant contributing factor. The majority of these fatal accidents involved aircraft in private or business operations. Only one fatal accident involved a commercial charter operation, and in that case the source of pilot incapacitation appears to have been hypoxia and not any pre-existing medical condition. No fatal accidents were recorded for operations with two or more pilots operating the aircraft. Moreover, medical standards for commercial and airline pilots are more stringent and more regular than those required for private operations.

In general terms, the results of this study show that there is a low chance of a medical condition or incapacitation event adversely affecting the outcome of a flight. This finding is consistent with other studies around the world. Medical conditions and incapacitation events accounted for less than one per cent of all accidents and incidents between 1 January 1975 and 31 March 2006. This is a positive result, and indicates that in overall terms, the medical certification system appears to be working well. However, it remains important that this system continues to evolve with, and be based on, the changes and developments in scientific research and medical practice. This will ensure that the aeromedical certification process is evidence based, up to date, and reflects the current state of medical knowledge. In doing so, the risks to the travelling public of an in-flight medical event leading to incapacitation of the pilot can be minimised, and the overall safety of the air transport system can be enhanced.

1. Arva P, Wagstaff AS. Medical disqualification of 275 commercial pilots: changing patterns over 20 years. *Aviat Space Environ Med* 2004; 75:791-4.
2. Australian Transport Safety Bureau. Pilot and Passenger Incapacitation: Beech Super King Air 200 VH-SKC, Wernadinga Station, Qld, 4 September 2000. ATSB, Canberra: 200003771; 2002.
3. Beers KN, Mohler SR. Food poisoning as an in-flight safety hazard. *Aviat Space Environ Med* 1985; 56:594-7.
4. Bennett G. Psychiatric disorders in civilian pilots. *Aviat Space Environ Med* 1983; 54:588-9.
5. Benson OO. Coronary artery disease: report of fatal cardiac attack in a pilot while flying. *Aviat Med* 1937; 8:81-4.
6. Booze CF. Sudden inflight incapacitation in general aviation. *Aviat Space Environ Med* 1989; 60:332-5.
7. Booze CF, Staggs CM. A comparison of post-mortem coronary atherosclerosis findings in general aviation pilot fatalities. *Aviat Space Environ Med* 1987; 58:297-300.
8. Buley LE. Incidences, causes and results of airline pilot incapacitation while on duty. *Aerosp Med* 1969; 40:64-70.
9. Chapman PJ. The consequences of in-flight incapacitation in civil aviation. *Aviat Space Environ Med* 1984; 55:497-500.
10. Cullen SA, Drysdale HC, Mayes RW. Role of medical factors in 1000 fatal aviation accidents: Case note study. *Br J Med* 1997; 314:1592.
11. Dodds RL. Medical certification of pilots. *Aviat Space Environ Med* 1991; 62:1068-72.
12. Evans ADB. Inflight incapacitation in United Kingdom public transport operations: incidence and causes 1990-1999 [abstract]. *Aviat Space Environ Med* 2002; 73:242
13. From P, Benbassat J, Gross M, Ribak J, Lewis BS. Air accidents, pilot experience, and disease-related inflight sudden incapacitation. *Aviat Space Environ Med* 1978; 49:517-8.
14. Gray GW. Cardiovascular and pulmonary disease in NATO aircrew: an overview. In: *Cardiopulmonary aspects in aerospace medicine. Proceedings of NATO-AGARD Lecture Series 189*. Neuilly Sur Seine, France: NATO-AGARD. 1993; 1.2-1.5.
15. Harper CR, Kidera GJ, Cullen JF. Study of simulated airline pilot incapacitation: phase II. Subtle or partial loss of function. *Aerosp Med* 1971; 42:946-8.
16. Hemming FO. In-flight coronary occlusions: a short series of cases. *Aerosp Med* 1970; 41:773-5.

17. ICAO. Annex 13 to the Convention on International Civil Aviation: Aircraft accident and incident investigation (Ninth Edition). Montreal: International Civil Aviation Organization 2001.
18. James M, Green R. Airline pilot incapacitation survey. *Aviat Space Environ Med* 1991; 62:1068-72.
19. Joy M. Cardiological aspects of aviation safety: the new European perspective. *Eur Heart J* 1992; 13(Suppl H):21-6.
20. Kulak LL, Wick RL Jr, Billings CE. Epidemiological study of in-flight airline pilot incapacitation. *Aerosp Med* 1971; 42:670-2.
21. Kumar B., DeRemer D, Marshall DM. *An Illustrated Dictionary of Aviation*. McGraw-Hill 2005.
22. Lane JC. Risk of in-flight incapacitation of airline pilots. *Aerosp Med* 1971; 42:1319-21.
23. Lavernhe J, Pasquet J, Mathivat A. Incidence of cardiovascular diseases among the flight deck personnel of an airline. *Aerosp Med* 1969; 40:62-3.
24. Leighton-White RC. Airline pilot incapacitation in flight. *Aerosp Med* 1972; 43:661-4.
25. Martin-Saint-Laurent A, Lavernhe J, Casano G, Simkoff A. Clinical aspects of inflight incapacitations in commercial aviation. *Aviat Space Environ Med* 1990; 61:256-60.
26. McCormick TJ, Lyons TJ. Medical causes of in-flight incapacitation: USAF experience 1978-1987. *Aviat Space Environ Med* 1991; 62:884-7.
27. Mitchell SJ, Evans AD. Flight safety and medical incapacitation risk of airline pilots. *Aviat Space Environ Med* 2004; 75:260-8.
28. Mohler SR, Booze CF. U.S. fatal general aviation accidents due to cardiovascular incapacitation: 1974-75. *Aviat Space Environ Med* 1978; 49:1225-8.
29. Newman DG. Acquired left bundle branch block in an asymptomatic fighter pilot: a case report. *Aviat Space Environ Med* 1999; 70:1219-22.
30. Osswald S, Miles R, Nixon W, Celio P. Review of cardiac events in USAF aviators. *Aviat Space Environ Med* 1996; 67:1023-7.
31. Parker PE, Stepp RJ, Snyder QC. Morbidity among airline pilots: the AMAS experience. *Aviat Space Environ Med* 2001; 72:816-20.
32. Preston FS. Twelve year survey of airline pilots. *Aerosp Med* 1968; 39:312-4.
33. Raboutet J, Raboutet P. Sudden incapacitation encountered in flight by professional pilots in French civil aviation, 1948-1972. *Aviat Space Environ Med* 1975; 46:80-1.
34. Rayman RB, McNaughton GB. Sudden incapacitation: USAF experience, 1970-80. *Aviat Space Environ Med* 1983; 54:161-4.

35. Sexton UA, Wick RL Jr. Fifteen-year survey of pilots returned to flying status following a myocardial infarction. *Aerosp Med* 1973; 44:1287-9.
36. Taneja N, Wiegmann D. Prevalence of cardiovascular abnormalities in pilots involved in fatal general aviation airplane accidents. *Aviat Space Environ Med* 2002; 73:1025-30.
37. Tunstall-Pedoe H. Risk of a coronary heart attack in the normal population and how it might be modified in flyers. *Eur Heart J* 1984; 5:43-9.
38. Tunstall-Pedoe H. How cardiovascular risk varies with age, sex, and coronary risk factors : Do standard risk scores give an accurate perspective? *Eur Heart J* 1999; 1 (Suppl D):25-31.
39. Van Leusden AJ, Prendergast PR, Gray GW. Permanent grounding and flying restrictions in Canadian Forces pilots: a 10-year review. *Aviat Space Environ Med* 1991; 62:513-6.
40. Weber F, Kron M. Medical risk factors in fatal military aviation crashes: a case-control study. *Aviat Space Environ Med* 2003; 74:560-3.
41. Whitton RC. Medical disqualification in USAF pilots and navigators. *Aviat Space Environ Med* 1984; 55:332-6.
42. Wielgosz AT, Dodge RE. Canadian experience with civilian pilots allowed to fly following an acute myocardial infarction. *Can J Cardiol* 1990; 6:387-90.