IN-DEPTH REVIEW

The value of screening tests in applicants for professional pilot medical certification

S. J. Mitchell and C. P. Schenk

Introduction

For professional pilots, the initial medical examination includes a number of screening tests to identify those who have, or may be at increased risk of, an illness that could lead to an incapacitating event while flying. Any pilot incapacitation in flight has the potential to lead to an accident. The argument exists that if pilots who might be predisposed to an illness that could lead to an incapacitation could be screened out at the start of their career, then there would be fewer incapacitations and therefore fewer accidents. This rationale for the use of screening tests was not always evidence based but was founded on a perceived benefit to flight safety, particularly in the military, where there is a high proportion of single pilot operations and a high cost of training of aircrew. For civilian commercial operations, the vast majority are in two pilot aircraft with many advanced autopilot aids. This means that any acute incapacitation is likely to result in an accident in less than 1 in 1000 events, and this should be taken into account when setting medical standards [1].

It is not just the diagnostic value and monetary costs of investigations that should be questioned, but the hazards of obtaining the information and any consequences of the knowledge gained. The risks to physical and mental well-being are frequently not appreciated [2]. Screening asymptomatic patients for disease may thus lead to a course of action that does more harm than good. For example, if a person who wishes to pursue flying as a second career attends for an EEG which includes photic stimulation, causing a seizure, their lifestyle and current employment could be severely affected. Such issues surrounding the concept of the Periodic Medical Examination in screening for disease in aircrew have been discussed by McLoughlin and Jenkins in the accompanying article in this series. The principal purposes of the screening tests at the initial medical are to measure performance objectively (e.g. audiogram) and detect latent, undiagnosed or undeclared disease such as diabetes, asthma, epilepsy or cardiac problems. This review concentrates on the more contentious issues of blood testing, ECG recording, chest X-ray and EEG at the initial aircrew medical examination.

Blood testing

Blood haemoglobin is now measured at the initial and every subsequent medical. A recent review of routine periodic blood testing on army aviators has shown a positive pickup rate of haemoglobin estimation of 1.7%. The positive predictive value was only 0.3% and only 0.16% of tests resulted in therapeutic intervention [3]. If preventative action against the development of coronary disease is the ultimate aim of this screening, then there...
are doubts about the value of purely measuring total cholesterol [9]. The other risk factors should also be assessed. It must be noted that while it seems intuitive to examine known risk factors for disease, this approach should be used with caution as a risk factor has to be very strongly associated with a disorder if it is to be a worthwhile screening test [10].

Other biochemical screening tests of aircrew have been carried out on civilian pilots [11] and military aircrew [12,13]. While mention has been made of measuring liver function tests, in particular γ-glutamyltransferase as an indicator of excessive alcohol consumption, studies have shown that a simple alcohol questionnaire and counseling are more effective in reducing the risk from alcohol misuse.

**Electrocardiogram (ECG)**

Cardiovascular disease, particularly coronary artery disease, accounts for ~30% of permanent groundings of aircrew and in the past over 50% of serious incapacitations were reported as having a cardiovascular cause [14–17]. However, a recent study has suggested that fewer than 3% of reported in-flight incapacitations were cardiovascular in origin [18]. The proportionate fall in cardiovascular events could be explained by more effective surveillance, the pilot population becoming fitter or by different reporting criteria.

Koley and Dham [19] reviewed 3000 routine ECGs in armed forces personnel reporting for annual medical examination. They found that minor ECG changes of doubtful significance are quite common and when investigated further with exercise ECG and ultimately coronary arteriography, they found a positive predictive value of only 15.5%. This correlates with the figure of between 4.9 and 16.7% suggested by Joy and Trump [20]. Sox et al. [21] specifically looked at the resting ECG as a screening test. They highlighted the importance of looking at the prevalence in the population being studied, noting that the Framingham risk score is only 1.4 per 1000 at 40 years, but 7.4 per 1000 at 60 years of age. They pointed out that the resting ECG is an imperfect reflection of existing coronary artery disease and a poor predictor of future heart disease while noting that very little is known of the prognosis of coronary artery disease in asymptomatic persons. They concluded that performing a resting ECG in men without evidence of cardiovascular disease or risk factors for coronary artery disease is not recommended. Hampton [22] has also reviewed the resting ECG and found that minor abnormalities of the ST segment and T wave are present in ~1% of the ‘normal’ population, although in young people they are often not present when the recording is repeated.

In a study of all the initial professional medical certificated applicants in the UK over a 2 year period, of the 1898 examinations performed, only one applicant had an abnormality detected on the ECG which led to the denial of a licence [23].

Joy and Trump [20] argued that while 5700 resting ECGs and 37 exercise ECGs per 10 000 civilian professional pilot licence holders per annum were performed, which led to the loss of only eight licences from significant coronary artery disease, this was still a potential benefit to flight safety. On the other hand, due to poor sensitivity and specificity, it has been calculated that each air accident prevented by ECG screening costs over €100 million [24].

**Chest X-ray (CXR)**

The World Health Organisation has published evidence that CXR screening is not justified except in those persons who are exposed to occupational lung hazards (25). This is largely due to the inability to detect clinically significant disease (26). Nevertheless, it is still a requirement in initial professional pilot medical examinations, this despite all the advice to the contrary.

Cox et al. [27] reviewed 3500 screening chest radiographs performed on aircrew for flight duty. The aircrew ranged in age from 18 to 47 years (average age 23 years). Abnormalities were initially detected in 107 (3%). Fifty-five of these were subsequently found to be false positive, but not before an additional 145 plain films, 11 chest CT scans, two MR scans, one chest fluoroscopy image, one angiogram and one liver ultrasound were undertaken, with the considerable extra individual risk that exposure to the radiation conferred. Only three medically significant conditions were found in the screened population. In Schenk’s study [23] of nearly 2000 aircrew applicants, in only five (0.26%) were anomalies detected, none of which resulted in denial of a medical certificate [23]. These very low yields re-emphasize the view that continued screening with CXR is not justified.

**Electroencephalogram (EEG)**

Because of the nature of a seizure, epilepsy remains for some one of the most worrying causes of acute incapacitation in aircrew. When defined as including those who have had more than one non-febrile seizure within the previous 2 years, the prevalence in adults is ~0.33%, of which ~70% is unexpected without a known pre-existing medical problem [28]. The average annual incidence rate for all types of seizures over a period of 30 years during adulthood has been approximated as 50 per 100 000 (0.05%) per year [29,30]. It follows that, if an average lifespan is considered to be 70 years, the chance of developing epilepsy is ~70 × 50/100 000, or 3.5%.
Only one-third to half of known epileptics have a ‘positive’ EEG, although this figure can be improved to 77% with repeated studies [31,32]. Conversely, EEG abnormalities have been shown in up to 8.1% of people who are not ‘epileptic’ and have never suffered a convulsion [33].

The EEG has been widely used as a screening device in potential aircrew since World War II [34]. The prevalence of abnormal EEG findings in aircrew or military applicants is ~0.7% (range 0.1–5.4%) [23,35–40]. The problem with the EEG as a screening test is that it has been difficult to calculate its sensitivity and specificity in aircrew or military applicants, as many have been rejected for service on account of an abnormal EEG have not been fully followed up to determine whether or not epilepsy has developed. Gregory et al. [36] followed 43 of 69 subjects with a positive EEG over a 5- to 29-year period and only one subsequently developed epilepsy. Everett and Jenkins [40] followed 14 subjects with abnormal EEGs over a 10- to 15-year period, noting that none of them developed a seizure disorder. LeTourneau and Merren [37] followed 31 out of 38 of subjects with an abnormal EEG, with only one subject developing epilepsy [37]. While the numbers of screened personnel who have an abnormal EEG and subsequently develop epilepsy appear to be very low (0–3%), an additional argument has been that those with normal EEGs may be more at risk of accidents than those with normal EEGs, but the evidence for this is weak [41,42].

Hendriksen and Elderson [43] attempted to calculate the predictive value of the EEG in screening candidate pilots. They calculated that a ‘positive’ EEG increased the risk of developing epilepsy by 16 times and that having a normal EEG reduced the likelihood of developing epilepsy by approximately half. They argued that any reduction in the risk of developing epilepsy was an advantage in aircrew selection and that the EEG was therefore useful in reducing the lifetime risk. This argument was countered somewhat in a reply by Clark and Riley [44], who calculated the sensitivity of the EEG to be 52% with a positive predictive value of only 8%, concluding that the EEG is not a good screening tool for epilepsy in aircrew.

The fear that an epileptiform attack in a pilot would lead, automatically, to an accident has led institutions involved in aircrew selection to vindicate the argument that prevention of one seizure would justify the effort. However, this is not necessarily the case. For example, for a non-screened population of 10 000 pilots with an annual risk of 0.05% and an average time in the air of 500 h (1/20 of the year), 0.25 in-flight seizures might be expected in that time (10 000 × 0.05% × 1/20). Therefore, reducing the risk by half, as suggested above, to 0.025% by screening out those with EEG abnormalities might prevent 0.125 seizures per annum, or one seizure every 8 years. However, in the derivation of acceptable incapacitation risk, it is estimated that only 1/1000 in-flight incapacitations will result in an accident [45]. Therefore, the use of a screening EEG might prevent one accident every 8000 years. If ~1000 EEGs at a cost of €300 each are performed on applicants each year in the UK, every accident prevented costs in the region of €2.4 billion (300 × 1000 × 8000).

Conclusions
Screening tests originally developed for use in hospital populations should be applied with caution in low prevalence populations. Even in a safety critical industry, the allocation of resources to screening programmes to identify pilots at an increased risk of medical incapacitation should be continuously analysed and benchmarked with other measures which might have a greater benefit to flight safety.

References
11. Hardarson T, Thordarson U, Arnarson EO, Franzon L.


