

## CHAPTER 12 - AVIATION NEUROLOGY

### 1 INTRODUCTION

Neurological assessment for aviation fitness, as with other systems, must include the present physical fitness, but also the likely natural history of a particular condition and the future risk to flight safety.

### 2 PATHOLOGY OF THE NERVOUS SYSTEM

Pathology of the nervous system may:

- a Reduce or distort the sensory input from, and appreciation of the external and internal environment.
- b Impair assessment, judgement and decision making.
- c Affect the motor skills necessary for good piloting. Effects of such pathology may be episodic, static or progressive. Neurological assessment should include careful history and physical examination with particular attention being paid to those areas mentioned in the standards and particularly recognised as aviation problems. Consultation with appropriate specialists is essential in doubtful cases or when questionable findings are noted.

### 3 NEUROLOGICAL FITNESS

A satisfactory assessment may be achieved if:

- a there is no abnormality of history, examination or performance;
- b any abnormality noted has an acceptable risk of hazard to the safety of the flight operation concerned. Such abnormality may be a single event, or recurrent, static, or progressive or intermittent but potentially recurrent. The condition may improve but subsequently relapse. Neurological 'fitness' for aviation purposes must therefore be demonstrated at initial examination and predicted to be maintained throughout the defined period of medical certificate validation.

### 4 CONGENITAL NEUROLOGICAL PATHOLOGY

In congenital disorders of the nervous system each case must be considered individually, and the decision on fitness should be based on present physical fitness and the risk of incapacitation in the future.

### 5 ACQUIRED NEUROLOGICAL PATHOLOGY

This area may be considered under the headings of trauma, infection, metabolic, vascular, neoplastic, auto immune, allergic and degenerative.

#### 5.1 Traumatic pathology

##### a *Trauma*

Any blunt head injury is associated with a risk of permanent damage to the brain. Brain damage occurs following a penetration brain injury, depressed skull fracture particularly with a torn dura, or in a severe blunt head injury. Secondary complications may occur subsequent to the loss of cerebrovascular autoregulation and formation of intracranial

haematoma or traumatic subarachnoid haemorrhage. Further difficulties may ensue associated with infection, surgery or CSF fistulae. Long term one may see the development of post traumatic epilepsy and hydrocephalus.

The severity of head injury should be assessed by:

- i duration of unconsciousness;
- ii duration of post traumatic amnesia (PTA);
- iii the presence of a skull fracture, particularly a depressed fracture and whether it is associated with a torn dura;
- iv the presence of a demonstrable neurological deficit.

Professional aircrew who have suffered minor brain injury (loss of consciousness or amnesia < 30 minutes) associated with concussion may be returned to flying after a minimum of four weeks.

A moderate head injury (loss of consciousness or amnesia for 30 minutes to 24 hours or a skull fracture), but with full apparent recovery may require longer periods of temporarily unfit assessment usually associated with full neurological assessment. A full neurological assessment should include neurological examination, EEG, CT scan, MRI, and neuropsychological examination, as needed.

Severe head injury (loss of consciousness or amnesia > 24 hours, subdural haematoma or brain contusion) including perforation of the meninges must be assessed individually and usually requires extended observation (minimum two years) before consideration for recertification, and there should frequently be an initial restriction to multi-pilot operations. One of the main concerns is the risk of post traumatic epilepsy, the risk of which falls off progressively with time to some extent.

***This assessment applies to Class 2 however Class 2 'OSL' may be appropriate initially.***

b *Spinal Injury*

In the absence of major neurological deficit the results can be assessed operationally after stabilisation has occurred, normally at least 6 months post injury. Minor degrees of functional loss may be accepted.

## 5.2 Cerebral infection

Acute infection, abscess, acute meningitis or encephalitis are disqualifying. Each recovered case will require individual assessment for return to flying with primary consideration being given to long term sequelae.

Acute symptomatic seizures associated with acute cerebral inflammation or infection are not necessarily permanently disqualifying, although demonstrated full recovery over an extended period of time with a satisfactory EEG may be required. In some conditions such as cerebral abscess, the risk of epilepsy is so high that a long term unfit assessment will result.

Approximately 20% of HIV positive individuals present with neurological symptoms (including dementia). However such a presentation is usually gradual with little chance of acute, sudden incapacitation. From this point of view it would therefore seem unreasonable to assess as temporarily unfit the asymptomatic HIV positive individual however, restriction to multi-pilot operation with at least 6 monthly review is necessary. Once symptoms of the AIDS-related complex have appeared a long term unfit assessment would appear inevitable as, despite remissions, the usual course is of progressive deterioration. The psychological trauma of HIV sero-positivity is major and formal psychiatric opinion is recommended before any return to flying can be considered. More recent publications would indicate that damage to the individual immune response can be staged (see Chapter on Sexually Transmitted Diseases and Other Infections), therefore making assessment somewhat easier.

***This assessment applies to Class 2. Class 2 'OSL' may be appropriate if immune staging not available.***

### 5.3 **Metabolic cerebral disorders**

The problems here are normally secondary, i.e. hyper and hypoglycaemia, acidosis associated with renal failure, or hepatic failure, and are therefore already disqualifying. Cerebral symptoms associated with hyper- or hypothyroidism may fully recover and so be returned to flying after stabilisation and operational assessment (see metabolic chapter). Alcohol abuse, both acute and chronic can produce cerebral problems (for assessment see psychiatric notes). The alcohol withdrawal convulsion is an excellent example of a toxic convulsion which may have a good subsequent prognosis when associated with successful rehabilitation, but note the pilot who may have a constitutional predisposition to epilepsy which is made overt by alcohol. Acute decompression and hypoxia are further causes of metabolic disturbance that may recover fully in due course.

### 5.4 **Cerebrovascular disorders**

Vascular lesions cause ischaemia or infarction with a variable degree of brain damage and although the effects may appear reversible, there may be long term sequelae. In thromboembolic atherosclerotic vascular disease there is a high risk of recurrence, or of other vascular disease such as myocardial infarct.

Lesions may be:

- a Haemorrhagic (aneurysms, arteriovenous malformation (AVMs) and spontaneous (intracerebral) bleeds.
- b Vaso-occlusive (thrombo-embolism).

Clinically all such conditions are potentially incapacitating, because of the risk of sudden unpredictable onset.

Transient Cerebral Ischaemic Attacks (TIAs) carry an increased risk (approximately 5% per annum) of stroke, CVA and also sudden death (approximately 5% per annum usually myocardial infarction). If the diagnosis is confirmed, the risk of recurrence or of other vascular disorders is unacceptably high and results in long term loss of medical certification.

Cerebro Vascular Accident (CVA) requires immediate grounding. 5% per annum will recur, and in addition there is an increased risk of other vascular disease, particularly myocardial infarction .

Spontaneous Subarachnoid Haemorrhage is associated with:

- i aneurysm (80%)
- ii arteriovenous malformation (15%)
- iii unidentified cause (<5%).

When a diagnosis of (i) or (ii) is confirmed and if the abnormality is supratentorial, the high risk of epilepsy would make revalidation unlikely. Surgical repair of an aneurysm is associated with an additional risk of epilepsy due to craniotomy. In certain circumstances, where the risk of epilepsy eventually falls to less than 1% per annum, class 1 recertification may be considered with an 'OML' restriction.

Aneurysms which are located below the tentorium cerebri (i.e. basilar aneurysms) are not associated with a risk of epilepsy, and provided they are successfully treated surgically and the person has made a full recovery, recertification is possible.

Where no structural disease is identified after angiography as the cause of the subarachnoid haemorrhage, and after a complete recover, multi-pilot certification may be considered after 9 months. Restricted (multi-pilot) certification is likely to be required long term.

***Class 2 'OSL' assessment is also appropriate. Class 2 may be considered after 2 years.***

## 5.5 Tumour/neoplasia

Intracerebral tumours may be benign or malignant, primary or secondary. They may be associated with progressive focal deficit, as well as increased incidence of epilepsy. The diagnosis is incompatible with certification.

Potential exceptions are:

- a Hamartoma are dysplastic rather than neoplastic, and each case must be considered on its merits but the potential risk of epilepsy in intracerebral abnormalities may be high and prevent certification.
- b Benign extracerebral neoplasms presenting with cerebral distortion but not epilepsy. Commonly meningiomata, may be considered for recertification two years post-operatively as there is a significant risk of post operative epilepsy.
- c 'Cured' neoplasia. The 'benign' tumours of childhood reticulosos and haemangioblastomata. Each may be considered on its merits after exclusion of late complication, multiple tumours, recurrence and systemic involvement.
- d Benign extramedullary spinal or nerve neoplasms. These are neurofibromata or meningiomata. Recertification can be considered after full recovery, but again the potential risk of epilepsy must be considered if the tumour was adjacent to the cerebral hemispheres.

Whenever recertification is considered the pilot must have undergone a neurological assessment by a consultant neurologist and the AMS must be satisfied that any neurological deficit is compatible with pilotage (medical flight test), and that the risk of epilepsy is minimal (less than 1% per annum). Certification should be limited to multi-pilot (Class 1 'OML') operation for an extended period. Reference should also be made to the oncology chapter.

***This assessment also applies to Class 2.***

## 5.6 Auto-immune and allergic conditions

Peripheral neuropathies and fitness to fly is dependent on the underlying pathology, present neurological deficit, and prognosis. The Guillain-Barre syndrome often recovers completely and applicants can be assessed purely by their functional ability. Recurrences occur rarely. Myopathy with significant weakness and myasthenia gravis are incompatible with certification.

## 5.7 [Neuro]degenerative diseases

Neurodegenerative disease is progressive and therefore usually incompatible with certification.

### a *Motor Neurone Disease*

The disease usually progresses rapidly, and the applicant must be grounded. The more benign spinal muscular atrophy may be compatible with continuation of flying subject to regular neurological assessment and flight simulator checks.

b *Parkinson's Disease*

In the very early stages, mild symptoms may allow continuation of certification with a multi-pilot (Class 1 'OML') restriction, but as the condition progresses loss of certification becomes inevitable. Most medication for Parkinson's Disease is incompatible with flying, exceptions being amantadine and selegiline. Frequent follow-up by an accepted neurologist is required. A practical flight test or simulator check may be necessary.

***This assessment applies to Class 1 and Class 2.***

c *Dementia*

A confirmed diagnosis of dementia is incompatible with fitness to fly.

d *Spinal Spondylosis/Degenerative Disc Disease*

This is a common condition and flight crew are not excluded, particularly those who may have experienced ejection seat trauma, whilst escaping from military aircraft. Poor posture, vibration and adverse ergonomic factors are likely to exacerbate any tendencies towards back problems.

Spinal root compression caused by cervical or lumbar (intravertebral) disc degeneration and protrusion are a further common cause of back pain. Aircrew developing such problems should be treated in the normal clinical fashion. However, before returning a pilot to flying duties due consideration must be given to the possibility of emergency asymmetric rudder in the event of engine failure of a multi-engine aircraft. A simple test of the type of movement and loads involved is the ability to step up onto a kitchen chair or wooden box 40 cms high. If this can be completed without pain, the pilot is considered fit for flying. Surgical procedures such as laminectomy require a similar degree of recovery before clearance to fly and pilots will usually remain unfit for about 3 months.

## 5.8 **Cerebral decompression sickness**

Cerebral decompression sickness is due to the formation of bubbles of nitrogen in body organs following a reduction in ambient pressure. Such bubbles may coalesce and produce local symptoms or, if in the blood, circulate throughout the body including the brain. Decompression sickness is rare in normal aircraft operations but should be considered when unpressurised aircrafts are flying above 15 000 feet, although it can even occur at lower cabin altitudes when flying immediately after SCUBA diving. Individuals who have experienced this condition as divers or in previous military flying should be carefully reviewed as permanent damage may be caused by repeated exposure.

## 6 **EPISODIC NEUROLOGICAL PROBLEMS**

### 6.1 **Migraine**

Migraine is a common constitutional disorder which is unpredictable and potentially disabling. The symptoms vary in severity, from the classical triad of visual aura, cephalgia and nausea (migraine with aura) to a recurrent vascular type of headache with nausea but without neurological symptoms (migrain without aura). Migraine is frequently disabling and unpredictable, frequently associated with visual disturbances which may be severe, and is therefore a potential flight hazard. Anyone with a history of migraine should not be selected for Class 1 certification due to the unpredictability and disabling nature of the condition but those who present after qualification should be neurologically assessed. If no underlying disease is found and the individual remains

free of further attacks for a period of 3 to 6 months, a return to flying may be approved in a multipilot (Class 1 'OML') role but should be considered unfit solo. Exceptions would be if the migraine attacks are infrequent and due to a specific precipitant, and avoidance of this precipitant results in no further migraines for a period of more than 2 years. Class 2 certificate holders may be allowed to fly solo if their attacks are mild and very infrequent (no more than two attacks per year). Frequent migraines are incompatible with any form of flying.

## 6.2 Cluster headache

Cluster headache is temporarily disabling and incompatible with flying until the person has been in remission and off treatment for at least 3 months. Recertification (Class 1 and Class 2) may then be allowed.

## 6.3 Neuralgic Syndromes

Trigeminal neuralgia and other neuralgic syndromes are extremely painful and unpredictable, and require neurological assessment. Medical treatment is incompatible with fitness to fly but following surgical treatment or after a natural remission if the person has been off treatment for more than 3 months without recurrence then they could be considered fit for recertification.

## 6.4 Excessive daytime drowsiness

Conditions causing excessive drowsiness while awake are either due to natural sleep loss, narcolepsy, idiopathic hypersomnia, or sleep apnoea. Daytime episodic drowsiness of whatever cause, except transient poor sleep hygiene, is unacceptable. Narcolepsy, even when treated successfully, is incompatible with fitness to fly.

## 6.5 Sleep Apnoea Syndrome

The sleep apnoea syndrome is primary (central) or obstructive. The latter most commonly affects overweight males, especially between the ages of 40 and 60 years. The syndrome results from frequent apnoeas during sleep, associated with loud snoring. Sleep recordings reveal apnoeic episodes in REM and non REM sleep. There may be an absence of respiratory effort with cessation of diaphragmatic movement. The upper airway can remain open even without airflow (central apnoea) or there may be excessive respiratory effort due to airways obstruction. The chronically disturbed nocturnal sleep and hypoxaemia causes excessive daytime sleepiness. This leads to inappropriate and unrefreshing naps, an obvious safety hazard in a pilot whose sleep is often already disturbed by disruption of circadian rhythm.

The sleep apnoea syndrome evolves gradually and may not be fully described by the sufferer. It should be considered with any presentation of excessive sleepiness which is not improved by a period of undisturbed sleep. Investigation should include respiratory studies and sleep recordings. The condition can be treated but a diagnosis will require flight crew to be assessed temporarily unfit until all aspects of the recovery and treatment can be considered by the AMS. (See the Respiratory System Chapter).

## 6.6 Demyelinating diseases of the Central Nervous System

Episodic neurological symptoms, often with full recovery, give rise to suspicion of multiple sclerosis. Any part of the central nervous system may be affected, however optic neuritis is a frequent presentation. Over 70% of such cases subsequently develop multiple sclerosis. There are no screening tests for MS but a family history does increase the risk. The disease profile is variable – over 20 years some will progressively deteriorate and die whereas others may have a single episode with remission over 20 years before further symptoms. Initial applicants with an established history must therefore be refused certification although it may be possible to continue certification of established aircrew in the multipilot role (Class 1 'OML' or Class 2 'OSL'). In

exceptional circumstances, with a long disease-free interval, unrestricted certification may be possible. Review and review intervals will be determined by the AMS.

Any neurological event of any note requires specialist neurological assessment. If multiple sclerosis is considered a strong possibility investigation may include cerebrospinal fluid (protein bands) MRI scans and evoked potentials (visual, auditory and somatosensitive). Should the probability remain high but symptoms are fully recovered an individual may be considered for multipilot operations after six months. The mean of symptom recurrence is approximately four years with only 5% being sudden and 20% severe. The inflight risk is therefore small (less than 1% per annum or one in  $10^{-7}$  flying hours). Individuals who are certificated in this fashion require six monthly review:

- a visual acuity, visual fields and colour perception;
- b operationally (simulator) to assess attention overload and judgement;
- c neurological review.

Any individual who is left with a significant neurological deficit after an exacerbation must be considered unfit.

***A similar assessment is appropriate for Class 2 'OSL'.***

Peripheral nerve lesions e.g. entrapment syndromes and mononeuropathies must be clearly diagnosed and their individual deficit assessed against operational criteria.

#### **6.7 Epilepsy [and other causes of loss of consciousness]**

A diagnosis of epilepsy is disqualifying because of the high risk of the recurrence and the risk of a generalised seizure in the cockpit being unacceptable. A diagnosis of epilepsy cannot be made until at least two seizures have occurred, but a single unprecipitated afebrile seizure carries an unacceptably high risk of recurrence, and will result in loss of certification for a minimum period of 10 years. If after that time, in the opinion of a consultant neurologist, there is no continuing evidence of an increased risk of recurrence of seizures, recertification may be possible, Class 1 multipilot "OML" or Class 2 without limitation.

Although the majority of genetically determined epilepsies become apparent earlier than the age of 20, a significant minority occur in the third and sometimes fourth decade. The risk of recurrence of a single seizure is initially 50% and the increased risk does not fall to that of the general population until at least 10 years have elapsed.

#### **6.8 Benign febrile seizures of childhood**

Benign febrile seizure of childhood occurring before the age of 5 are compatible with certification.

#### **6.9 Benign Rolandic epilepsy of childhood**

This is a specific type of epileptic syndrome occurring children associated with a characteristic abnormality on the EEG. Seizure cease after the age of 15 with a very low rate of recurrence, and if the diagnosis is well documented and confirmed by a consultant neurologist, and the applicant has been free of seizure for 10 years then certification is possible.

#### **6.10 Pharmacological control of epilepsy**

Although epileptics who appear well controlled on medication may recover driving privileges, this approach is not considered acceptable in flying. Pharmacological response varies and even apparently stable individuals have a seizure recurrence rate far higher than the nominal aeromedical risk of 1% per annum.

## 7 THE ELECTROENCEPHALOGRAPH (EEG) IN AVIATION NEUROLOGY

The EEG is a clinical tool useful in epilepsy and, despite its limitations, is used to screen aircrew applicants for latent predisposition for epilepsy. Its sensitivity and specificity under such circumstances remains ill-defined. Nevertheless, the risk to safety occasioned by in-flight convulsion is such that an EEG is required for all initial Class 1 medical examinations.

*Electroencephalograph technique.* In order to reduce variation in interpretation, the technique used must be standardised where possible. The national aeromedical department shall ensure EEG recording facilities are to a high standard and that the tracings are read centrally.

*Recommended procedure:*

- a 20 leads with 10/20 (international placement);
- b the montage and machine settings shall be indicated on the tracing;
- c calibration is required at the beginning and end of each complete tracing;
- d each montage recorded should include eyes open as well as closed;
- e there should be 3 minutes of hyperventilation;
- f photic stimulation should be carried out in a darkened room with at least 10 exposures between 1 and 30 flashes per second of 10 seconds duration starting with eyes open for 5 seconds followed by eye closure during the stimulus and thereafter for 5 seconds. Photic stimulation should start with 16 flashes per second, and then sequences between 1 to 21 flashes per second should be recorded as above, followed by flashes at 25 and 50 per second;
- g a minimum of 20 minutes of recording on a 16 channel machine (or equivalent) is required;
- h if a subject falls asleep during the recording, it should be continued through the progressive phases of sleep, with intermittent arousal as appropriate.

*Interpretation of EEGs.* There has been much discussion regarding the significance of various wave forms, particularly in predicting epilepsy. There is general agreement that epileptiform paroxysmal phenomena (spike-wave), a photoconvulsive response and spike-and-wave complexes (2–4 Hz, irregular, generalised or focal) are significant and associated with an increased risk of epilepsy. Although such cases appear to be only 0.5% of apparently normal applicants, the published data indicate an increased risk of epilepsy above that acceptable for professional aircrew. A qualified private pilot, disqualified as above for Class 1 but with no significant history may be considered for Class 2 'OSL'.

## 8 DEFINITIONS

*Epileptiform pattern.* Interpretive term. Applies to distinctive waves or complexes, distinguished from background activity, and resembling those recorded in a proportion of human subjects suffering from epileptic disorders and in animals rendered epileptic experimentally. Epileptiform patterns include spikes and sharp waves, occurring singly or in bursts lasting at most a few seconds. Comments: (1) This term refers to interictal paroxysmal activity and not to seizure patterns. (2) The probability of association with clinical epileptic disorders is variable, but there is a small though significant increased risk of epilepsy. Epileptic paroxysmal spike wave at 3Hz

have been shown to be associated with transient diminution in cognitive function and should be regarded as seizures.

*Seizure pattern.* Phenomenon consisting of repetitive EEG discharges with relatively abrupt onset and termination and characteristic pattern of evolution, lasting at least several seconds. The component waves or complexes vary in form, frequency and topography. They are generally rhythmic and frequently display increasing amplitude and decreasing frequency during the same episode. When focal in onset, they tend to spread subsequently to other areas. Comment: EEG seizure patterns unaccompanied by clinical epileptic manifestations detected by the recordist and/or reported by the patient should be referred to as 'subclinical'. (cf. epileptiform pattern.)

*Paroxysm.* Phenomena with abrupt onset, rapid attainment of a maximum and sudden termination, distinguished from background activity. Comment: commonly used to refer to epileptiform patterns and seizure patterns if these consist of spike wave paroxysms, but not other paroxysmal slow wave activity which correlates less clearly with the predisposition to epilepsy.

*Spike.* A transient, clearly distinguished from background activity, with pointed peak at conventional paper speeds and duration from 20 to under 70 ms, i.e. 1/50–1/14 s, approximately. Main component is generally negative relative to other areas. Amplitude is variable. Comments: EEG spikes should be differentiated from sharp waves, i.e. transients having similar characteristics but longer durations. However, it is well to keep in mind that this distinction is largely arbitrary and serves primarily descriptive purposes. Practically, in ink written EEG records taken at 3 cm/s, spikes occupy 2 mm or less of paper width and sharp waves more than 2 mm.

*3 Hz spike-and-slow-waves.* Characteristic paroxysm consisting of a regular sequence of spike-and-slow-wave complexes which: (1) repeat at 3–5 Hz (measured during the first few seconds of the paroxysm), (2) are bilateral in their onset and termination, generalised and usually of maximal amplitude over the frontal areas, (3) are approximately synchronous and symmetrical on the two sides of the head throughout the paroxysm. Amplitude is variable but can reach values of 1 000  $\mu$ V (1 mV).

*Photoconvulsive response.* A generalised discharge of spikes or spike wave activity consistently elicited by intermittent photic stimulation, which is autonomous occurring asynchronously with respect to the stimulus, and self-sustaining outlasting the stimulus.

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