Aerospace Medical Association
Safety Committee
November 1999

Position Paper in Response to NTSB Recommendations A-99-1 and-2

A-99-1. Restrict all pilots with special issuance certificates due to cardiac conditions that could affect their G-tolerance from engaging in aerobatic flight.
A-99-2. Restrict all pilots taking medication that reduces G-tolerance from engaging in aerobatic flight

Background

In late 1998, the National Transportation Safety Board issued the above recommendations to the Federal Aviation Administration. The reason for analyzing the accident data base to determine if aerobatics by pilots with cardiovascular conditions posed an increased risk is obscure, but the initial NTSB report cited three accidents caused by decreased g force tolerance in aircraft flown by pilots with special issuance certificates. The Civil Aeromedical Association, and the Experimental Aircraft Association both reviewed the NTSB data and concluded that the three accidents were not caused by decreased g tolerance, and advocated that the FAA not act on the NTSB recommendation.

The Aerospace Medical Association, upon the recommendation of its Safety Committee, issued a preliminary recommendation to the FAA that the NTSB recommendation not be adopted. In this paper, we will document and expand the analysis that leads to this policy position.

Aerobatic Flight

The FAA definition of aerobatic flight is "an intentional maneuver involving an abrupt change in an aircraft's attitude, an abnormal attitude, or abnormal acceleration, not necessary for normal flight." (FAR 91.303) A parachute must be worn for any maneuver that exceeds 60 degrees of bank or nose-up or nose-down attitude of 30 degrees relative to the horizon. (FAR 91.307) Single or series maneuvers above these parameters may impose extraordinary muscular and cardiovascular workloads, as witnessed in airshows, or may not. For instance, a simple aileron roll through 360 degrees of bank imposes no workload above level flight. Aerobatic maneuvers may require special attention to aircraft control and to spatial orientation. These considerations are not addressed in this position paper.

Theoretical Risk

The adverse effects of positive acceleration in flight are a loss of peripheral vision (tunnel vision), which may progress to complete loss of vision while conscious (blackout). Ultimately G –Induced Loss of Consciousness (GLOC) may occur. G tolerance is defined in the research laboratory as the decrease in the visual field to 28^0 either side of the focal point of vision. In the air, this degree of loss of peripheral vision allows adequate aircraft control. These effects are caused by the increase in the weight of the column of blood from the heart to the brain. Without any compensatory action, in the healthy aviator, these progressive effects occur at about the five G level after 5-6 seconds, the time at which the dissolved oxygen in the brain has been metabolized. G tolerance may be raised and prolonged by wearing a g suit; by a trained, coordinated series of chest and lower body muscle contractions, the "anti-g straining maneuver"(AGSM) that increases blood pressure; and by positively pressurizing the lungs (PPG). These measures are additive, and military aviators routinely tolerate up to 9G for up to 15 seconds. Civilian aerobatic pilots often impose even greater g loading, both positive and negative, but typically for a duration of time shorter than the 5-6 seconds of brain oxygen reserve.

An operational definition of G tolerance is also used in research centrifuges, one that includes an endurance component. Two common profiles are the Simulated Air Combat Maneuvering (SACM) and the Tactical Air Combat Maneuvering profiles. Both of these impose repeated 4-9G loads for varying duration on the subject to a self-determined fatigue endpoint.

With complete blackout of vision, aircraft control may be compromised, but in practice the aviator should immediately begin straining and unload the aircraft to avoid ensuing GLOC. If GLOC supervenes, consciousness is lost for a period of about 15-17 seconds (1), during which no control inputs will occur. In other words, the aircraft flight path will assume a ballistic, tangential vector. Unfortunately, in many instances, that vector is downward. Full cognitive performance is not available for 30 seconds to 2 minutes, but instant recovery from the perceived dive is usually observed when GLOC is recorded on aircraft audio or video.

In theory, any environmental or pathological factor that reduces cardiac output or reduces blood pressure will compromise g tolerance, whether the aviator is relaxed or straining. In the normal aviator with normal cardiac output, for instance, high ambient temperature causes the skin blood vessels to dilate to act as a heat radiating mechanism. This lowers blood pressure and thus lowers g tolerance. Similarly, dehydration from lack of fluid intake or from perspiration reduces blood pressure and g tolerance. More obscurely, repeated exposure to g forces over a period of minutes causes a form of internal dehydration as fluid is squeezed osmotically out of the blood vessels into the spaces between cells. These influences can be additive and can result in marked temporary decreases in g tolerance. Another very important influence on second-to-second G tolerance is the preceding G level. If the aircraft is pushed into less than 1G positive flight just before positive g onset, G tolerance is markedly reduced (Push-Pull effect), but the time constants do not change. Because of these factors, alone or in combination, incapacitation from GLOC may occur at G levels as low as 2-3G, and at low onset rates of G.

If cardiac output is reduced by previous cardiac muscle damage; or by drugs which reduce the strength of contraction; or by ineffective, extra beats; or by abnormally fast heart rate, g tolerance will be reduced. Similarly, damage or paralysis of the nervous control system of the heart, or damping by cardiovascular drugs, may prevent the augmentation of cardiac output necessary for exercise or blood pressure maintenance under G stress. Transplanted hearts, for example, do not respond well to these stimuli.

Because of acceleration physiology and the adverse effects of cardiovascular pathology, the NTSB recommendations seem eminently sensible. However, the overall aviation safety experience, and human centrifuge testing of pilots with cardiovascular disease and/or cardiovascular drug use lead to a more permissive policy recommendation.

Accidents Cited

A T-6, a former military advanced training aircraft capable of high g aerobatics, was observed to have an engine failure. The aircraft remained in a left bank, entered a right spin and impacted the ground with 2 fatalities. The pilot flew with a Special Issuance third class medical certificate for coronary artery disease, and was found at autopsy to be taking fluoxetine, an anti-depressant drug; diltiazem, a blood pressure drug known to reduce cardiac output; and cimetidine, a stomach acid suppressant drug without cardiovascular side effects. Based on the limited information in the accident report, the aircraft's flight path reflected control inputs, especially to enter a spin, and the engine was being restarted, also reflecting coordinated, conscious switch inputs. We conclude that incapacitation, from low G tolerance or other cardiovascular compromise, was not the cause of this accident.

In June of 1976, a pilot with undisclosed heart disease entered an uncontrolled descent and crashed while practicing aerobatics. This accident is not available in the Internet NTSB database. In any case, the proposed NTSB restriction would not have prevented this accident, since the pilot was not aware of, or hid, his heart disease.

The third cited accident occurred during an airshow in Concord, NH on 26 Jun 93. The NTSB concluded that the accident was caused by incapacitation. The pilot, who did not have a Special Issuance medical certificate, was found to have severe atherosclerosis and an old myocardial infarction. However, review of videotape by expert airshow witnesses confirm that control inputs continued through impact. It is therefore certain that GLOC did not cause incapacitation. It is possible that the pilot suffered a sudden, distracting pain or lightheadedness from his heart disease that caused improper performance of the accident maneuver. We consider this possibility to be highly unlikely.

The last accident cited occurred in 1980. An aerobatic aircraft crashed, apparently while performing aerobatics. However, the toxicology showed nothing of significance, and there was no known cardiovascular disease or Special Issuance certificate.

In sum, we conclude that these cited accidents did not occur because of cardiovascular compromise.

Further Data Analyses

The Safety Committee were kindly provided a draft copy of an epidemiological analysis of known aerobatic accidents in the period 1993-99. No increase in risk was found among pilots with known cardiovascular disease or Special Issuance certificates.

A search of the internet NTSB for the key words GLOC, aerobatic, and cardiovascular did not reveal any accidents with overt causation by cardiovascular compromise.

It was suggested that the Safety Committee review an accident occurring just after the completion of a grueling, high G, hot temperature air race. Insufficient details about the aircraft G loading just prior to an unanticipated descent, near recovery, and impact are available to infer causation in this pilot with a Special Issuance medical certificate for coronary artery disease that had been treated with an angioplasty.

Aeromedical Research Data

G tolerance and human performance, and more recently the two together, are assessed on the human centrifuge by several research groups in different nations. An important aspect of this research is determining the effects of drugs on both cognitive performance and g tolerance. However, very few of the dozens of cardiovascular drugs have been formally studied to discern their effects, if any, on the g tolerance of groups of experimental subjects.

A search of the aeromedical literature via Grateful Med using the search terms g force and drugs produced one published paper only. In this paper, about 0.3g decrement in the slow onset centrifuge runs was caused by low dose captopril, an anti-hypertensive drug of the angiotensin converting enzyme inhibitor class. This research condition imposes 0.1g/sec stress to tolerance level, and is not a realistic flight condition. The converse, rapid onset, realistic g stress was not affected by the captopril. The endurance component was not tested. (2)

At the annual scientific meeting of the Aerospace Medical Association in 1999, the assembled directors of all the world's human research centrifuges were asked to comment on their experience in evaluating pilots with cardiovascular disease and on the effects of cardiovascular drugs. Comments were received from Singaporean, French, British, and US groups, over half of the research centrifuges. Uniformly, they reported that g tolerance is not adversely affected in pilots being evaluated for possible cardiovascular compromise. However the number of such evaluees is small.

It should also be noted that all air force medical establishments recommend grounding high performance aviators with heart disease, despite their acceptable performance on the centrifuge in general.

Civilian Pilot Aeromedical Training

Presently, aerobatic pilots undergo no specified medical clearance. They also receive no mandatory training in G tolerance techniques. There are FAA Advisory Circulars which describe the physiology of high g tolerance.

Aviator Population at Risk

The NTSB recommendations were derived from a study of historical accidents. There are an increasing number of high performance aircraft registered, such as ex-military propeller and jet fighters, and experimental or homebuilt high g airplanes.

Airshow Pilots

One of the cited accidents occurred during an airshow. It appears not to be caused by cardiovascular disease or drugs. Nonetheless, there is special risk at airshow performances by unexamined performers who might be at risk from known or unknown heart disease.

CONCLUSIONS

1. The NTSB recommendations are theoretically sound, but not supported by experience and research.
2. Considerable uncertainty exists about the actual incidence of aerobatic accidents caused by cardiovascular disease or drugs.
3. An aerobatic maneuver, as presently defined, may or may not impose unusual physiologic stress.
4. Training of aerobatic pilots in G physiology is inadequate.
5. An increasing number of aviators have access to high performance aircraft.

RECOMMENDATIONS

1. Research into the effects of cardiovascular disease and drugs on g tolerance should be expanded.
2. Airshow pilots should be screened for cardiovascular disease and drugs.
3. FAA restrictions on aerobatic pilots who have cardiovascular disease should be specific, individualized, and based on predicted tolerance of the pilot.
4. Aeromedical training for aerobatic pilots should be mandatory.

References

1. North Atlantic treaty Organization Advisory Group for Aerospace Research and Development. AGARDograph No 322, High G Physiological Protection Training, Ch3.
2. Paul MA, et al. The effect of captopril on +Gz tolerance of normotensives. Aviat Space Environ Med. 1992 Aug;63(8):706-8.
3. Federal Aviation Regulations, US Department of Transportation.