INCIDENCE OF DECOMPRESSION SICKNESS IN HIGH ALTITUDE GLIDER OPERATIONS

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INTRODUCTION

High altitude glider operations possess the potential for causing decompression sickness (DCS), as a consequence of the altitudes reached and the times spent at those altitudes. The risk, and therefore the incidence, should be higher in glider pilots than in military pilots, because of the general lack of preventive measures taken in soaring. This paper discusses DCS in general, the risk in glider operations, and describes a study now underway to establish the incidence of DCS in the glider community.

DCS is the medical condition which occurs as a result of a reduction in ambient barometric pressure to such a degree that dissolved inert gas in the blood and tissues comes out of solution and forms bubbles. It is most commonly associated with diving, but also occurs in the aviation environment.

Physiology of DCS

The fluids of the body contain inert gases, in quantities consistent with Henry's Law. This states that the amount of gas that will dissolve in a liquid at a given temperature is directly proportional to the partial pressure of that gas over the liquid (1). All gases are absorbed and eliminated according to this law, but most gases are either metabolically active or have partial pressures too low to be of significance.

The inert gas of primary interest in DCS is nitrogen, since it constitues 79% of the atmosphere. It is not metabolized, thus it is absorbed and eliminated from the tissues and body fluids passively. The body tends towards saturation with nitrogen, so a diver absorbs additional nitrogen when breathing underwater under high pressure. When the diver returns to sea level pressures, the excess nitrogen must be eliminated.

Nitrogen is absorbed and eliminated through the lungs, and further disseminated through the circulatory system. Different tissues have different rates of absorption and elimination, complicating the issue of predicting total body nitrogen levels. This area has been extensively researched, primarily in the diving environment, as part of dive table development.

When one has been at sea level for a prolonged period (days), then one is saturated with nitrogen. An ascent to higher altitude (lower pressure) results in supersaturation, and the individual begins to off-gas the excess nitrogen. The degree of supersaturation necessary for bubbles to form is defined by the critical supersaturation ratio:

$$P_{N2}/P_B = CSR$$

in which P_{N2} is the partial pressure of nitrogen at the equilibrated altitude, and PB is the total barometric pressure at the altitude of interest. In aviation one is rarely concerned with mixed gas use, so only air (79% nitrogen, 20.9% oxygen) is considered here. For air, the critical supersaturation ratio is 1.58. When a reduction in pressure is made which exceeds this level then DCS becomes possible. For those equilibrated to sea level pressures (760 mm Hg), this occurs at approximately 18,500 feet (5,600 meters). The CSR threshold is based on the assumption that the linear ascent threshold well-known in the diving community extends into the altitude realm. Recent studies (2, 3) indicate that the altitude threshold may actually be considerably below lower. Nonetheless, 18,500 feet can be used as a rule of

This questionnaire is being distributed as part of a research project by the Royal Air Force Institute of Aviation Medicine. The purpose of this questionnaire is to collect some details of glider wave flights. We would be grateful if you would take the 2 or 3 minutes necessary to complete it. All information you provide will be confidential; your personal details are requested simply because, we may, if you agree, like to discuss some details further with you. However, if you prefer, you can complete the questionnaire anonymously.

Personal Details

Name:____Todays date:____________

Address: ____

____

Phone number:____

Total hours of glider flying time_______Total hours of flying time (all types, including gliders)_______

Did you make more than one wave flight today?

YES ( ) NO ( )

If you answered yes, then please fill out a separate questionnaire for each flight. The answers in this questionnaire refer to which of todays' flights:

First ( )
Second ( )
Third ( )
Other (specify)________ ( )

Details of This Flight

1. What was the profile of the flight you have just completed? (Please tick one)

Altitude ( )
Duration ( )
Cross country ( )
Other (specify)________ ( )

2. What was the duration of the flight?__________________(hours:minutes)

3. What was your average rate of climb?__________________(fpm or knots)

4. What was the maximum altitude you reached?______________(feet or meters)

5. If your maximum altitude exceeded 18,000 feet, for how long did you stay at or above 18,000 feet?

____________________(hours:minutes)

Oxygen Supply

6. Did you use an oxygen supply system during this flight?

YES ( ) NO ( )

(front)

FIGURE 1. Questionaire.

thumb in describing the potential onset threshold.

Clinical Features of DCS

Once bubbles form, they can have a variety of effects, ranging from simple joint pain, through to death. The degree of symptoms and their location depend on the numbers of bubbles, and where they travel after they have formed (4). Bubbles cause symptoms through two basic mechanisms: mechanical effects and surface activity effects.

Mechanical effects are those which occur as a result of

If you answered YES, please answer questions 7 - 9. If NO, please go to question 10 in the next section.

7. What sort of oxygen system did you use?

- Constant flow ( )
- Diluter demand ( )
- Pressure demand ( )
- Other (specify)______________ ( )

8. What sort of oxygen delivery system did you use?

- Aviator's mask ( )
- Hospital-style mask ( )
- Nasal tubing ( )
- Other (specify)______________ ( )

9. At what altitude did you start using your oxygen system?____________________(feet or meters)

Physical Symptoms During and After Flight

10. Did you experience any of the following symptoms either during or after the flight?

Joint pain	YES ( )	NO ( )
Numbness	YES ( )	NO ( )
Weakness	YES ( )	NO ( )
Headache	YES ( )	NO ( )
Confusion/difficulty thinking	YES ( )	NO ( )
Chest pain/shortness of breath	YES ( )	NO ( )

If you answered YES to any of the symptoms listed in question 10, then please answer questions 11 -12.

11. When did you FIRST notice the symptom or symptoms?

- Before putting on the oxygen ( )
- Before reaching maximum altitude ( )
- At maximum altitude ( )
- During descent ( )
- Since landing ( )

12. Do you have any of the symptoms listed above now?

YES ( ) NO ( )

If you answered YES, are your symptoms:

- Getting better ( )
- Just the same ( )
- Getting worse ( )

If you experienced any of the symptoms listed above either during or after the flight, then please seek medical attention, and explain that you have recently been exposed to high altitude.

Thank you for your cooperation. Please give your completed questionnaire to the operators of this glider club or site. We would be grateful if you would take the post card attached away with you and answer the questions on it in 24 hours time. If you have any queries about this survey, please contact Dr. Robert Weien at:

Royal Air Force Institute of Aviation Medicine
Farnborough, Hants
GU14 6SZ
Telephone: (0252) 394435

(back)

Please complete this 24 hours after the flight, and post it as soon as convenient.

In the day following your wave flight and the completion of the first questionnaire, did you experience any of the following:

Joint pain	YES ( )	NO ( )
Numbness	YES ( )	NO ( )
Weakness	YES ( )	NO ( )
Headache	YES ( )	NO ( )
Confusion/difficulty thinking	YES ( )	NO ( )
Chest pain/shortness of breath	YES ( )	NO ( )

If you experienced any of these symptoms, please seek medical attention, and explain that you have been exposed to high altitude recently.

Thank you for your cooperation. If you have any queries concerning this survey, please contact Dr. Robert Weien at:

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FIGURE 2. Postcard.

the physical presence of the bubble. These include obstruction of blood vessels and tissue distortion/disruption. When a vessel is obstructed the flow of blood downstream of that vessel is restricted or eliminated, resulting in symptoms of tissue hypoxia. Tissue changes can be caused by expansion of gas bubbles through a Boyle's Law effect. Boyle's Law is the pressure/volume relationship: as the ambient pressure is reduced, a bubble will expand, and exert force on the surrounding tissues.

The surface activity effects are those resulting from the body's active response to a foreign body. The surface of a bubble is viewed as a foreign body and several systems respond to it as such, including the complement cascade and platelets.

Common presentations of altitude DCS include joint pain (the "bends"), skin symptoms (often itching), neurologic symptoms (headache, numbness, weakness, or paralysis), and respiratory symptoms (shortness of breath, substernal chest pain).

A number of predisposing factors have been noted. These include:

1) Exercise: Physical exercise, especially during or in the hours immediately after an altitude exposure, increases the likelihood of DCS.
2) Cold: Low temperature increases the risk of DCS, probably due to vasoconstriction resulting in poor perfusion of peripheral areas. This, in turn, leads to incomplete clearing of nitrogen from the poorly perfused tissues.
3) Age: Increasing age increases risk.
4) Obesity: Fat is a long half-time tissue: that is, it absorbs and eliminates nitrogen over a much longer time course than "fast" tissues, such as blood. This leads to localized areas of increased off-gassing gradient where bubbles can form.
5) Dehydration: This leads to reduced circulating blood volume, resulting in poor perfusion, and can result in incomplete clearing of excess nitrogen.
6) Physical injury: Inflammation associated with an injury is a common site for DCS symptoms.
7) Flying after diving: If one has participated in diving activities and absorbed extra nitrogen, this increases the total need for nitrogen elimination, and lowers the altitude at which the CSR will be exceeded.
8) Gender: Females are at significantly higher risk of DCS than males (6).

Onset of symptoms is usually rapid. Approximately half the cases occur while at altitude, or in the first hour after return to ground level in altitude chamber runs. The initial symptom occurs within 12 hours in 86% of cases and within 24 hours in 97% (5).

DCS responds well to correct treatment. Recompression therapy in a hyperbaric (diving) chamber is the standard treatment: in a recent ten year review of the USAF's experience with altitude DCS, 98.5% had complete resolution (6). In the absence of a hyperbaric chamber, or until a patient can be transported to one, 100% oxygen should be used. This treatment is not as effective, however.

Prevention of DCS

The rate of DCS can be reduced through preventive measures (7). If 100% oxygen is breathed, then nitrogen is cleared from the system in a process termed denitrogenation. This is somewhat of a misnomer, however, since denitrogenation results only in partial elimination of the nitrogen in the body. The longer the course of denitrogenation, the higher the threshold for DCS. Symptoms are also less likely to be severe. The USAF uses a 30 minute denitrogenation during its altitude chamber training (8). Space shuttle astronauts who perform extravehicular activities combine prebreathing with staged decompression of the entire shuttle cabin, prior to working in a 4.3 psia (30,000 feet, or 9,250 meters) space suit (9).

How big a problem is DCS in aviation? Estimates of incidence are usually made from records of military altitude chamber training. A number of these have been published in recent years. The range is from approximately 0.5 to 3 cases per 1000 exposures (10). Some of the variability in incidence rates may be due to underand over-reporting of cases.

Potential for DCS in Gliding

The potential for DCS in high altitude glider operations is great, for a number of reasons.

1) The altitudes reached are high enough for DCS to occur. Flights above 25,000 feet are common. The world altitude record is now above 49,000 feet.
2) No preventive measures are taken against DCS. Wave pilots typically do not don their oxygen masks until at 10,000 feet or above.
3) Oxygen systems in gliders are not standardized, and so may not provide 100% oxygen. Denitrogenation may not occur, even when the mask is in place .
4) There is no system to alert pilots with predisposing factors, to allow them to reduce their risk.

The incidence of DCS in high altitude glider operations would therefore be expected to be higher than that experienced in military aviation. We have not been able to find any reported cases of DCS among glider pilots, in the medical literature, or in gliding publications, or via informal inquiries at several gliding sites known for wave.

DCS Incidence Study

The Royal Air Force Institute of Aviation Medicine (RAF IAM) has begun a study to establish the incidence of DCS in glider pilots during the wave season 1993-1994, comprising a questionnaire-based survey of pilots returning from wave flights.

All occupants of gliders returning from wave flights are asked to fill out a questionnaire (Figure 1) stating basic flight parameters, type of oxygen system, and symptoms common in altitude DCS. Attached to the questionnaire is a postcard (Figure 2) to be completed and returned 24 to 48 hours after the wave flight. The data from the survey will be entered into a microcomputer and analyzed. The results of this study will be published as an IAM technical report, and may be further published in the gliding and aerospace medicine literature.

The two possible outcomes are:

1) The anecdotal evidence is correct and DCS occurs much less frequently in the glider population than in military aviation. This would be a surprising result, and would require further investigation of glider flight profiles to determine the reason. If true, then lessons learned could be applied to military aviation.
2) Glider pilots have an incidence of DCS as high or higher than military experience would suggest. This is the most likely outcome, and could be used a basis for communicating DCS prevention techniques to wave flying pilots, in a effort to enhance safety.

Conclusion

DCS is a likely side effect of high altitude glider operations, but is a risk which can be minimized through the use of proper preventive techniques. A study is currently underway to determine the size of the DCS problem in gliding, and the results will be further reported.

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