HBOT Treatment and Risk Assessment for Altitude-Induced Decompression Sickness

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Introduction

Altitude-Induced Decompression Sickness

Onset:

- Exposure to low barometric pressures causes inert gases (mainly nitrogen), normally dissolved in body fluids and tissues, to form bubbles in various areas of the body.
- Symptoms may occur during flight or many hours later.

Signs and Symptoms:

- Joint Pain or Numbness
- Confusion or Memory Loss
- Shortness of Breath
- Dizziness and nausea
- Other Symptoms Associated with DCS

Prevalence in Fight Jet Pilots

Between 1991 and 2001, there were only nine recorded DCS incidents of all types, and 41 incidents between 2002 and 2009[13]. Pilmanis[13] found that actually 60-80% of pilots had experienced altitude-DCS symptoms, 13% having neurological involvement and 34% affecting mission performance. Pilots have many reasons to be reluctant to report altitude DCS, including: mission protection, career protection, inability to detect and diagnose, perception of unimportance, treatment inconvenience, peer pressure, distrust of medical involvement, and concern of impact on operational aspects[13].

Treatment of Altitude DCS is return to sea level and hyperbaric oxygen treatment (HBOT). We present a case where HBOT successfully treated altitude-induced DCS. The pilot had minimal risk (<10%[1]) based on to current guidelines for DCS; however, additional factors increased his risk for DCS: lack of preoxygenation, absence of transport protocol, 6G flight maneuvering, and night-before alcohol consumption.

Materials and Methods

Patient Medical History:

- 31 years old, male, physically fit
- No history of DCS
- Non-smoker, occasional drinker
- Reported drinking the night before Flight 1

Flight 1 (Four Days Before Admission to UCLA)

Aircraft	:	F-16 Fighter Jet (Fig. 1)
Maximum Altitude	:	43,000 Feet
Sustained Altitude	:	41,000 Feet
Total Time at Altitude	:	2+ Hours
Cabin Pressure	:	18,000 Feet
Maximum Acceleration	:	6G

Flight 2 (Two Days Before Admission to UCLA)

Aircraft	:	F-16 Fighter Jet
Sustained Altitude	:	22,000 Feet
Total Time at Altitude	:	2+ Hours
Cabin Pressure	:	18,000 Feet
Maximum Acceleration	:	6G

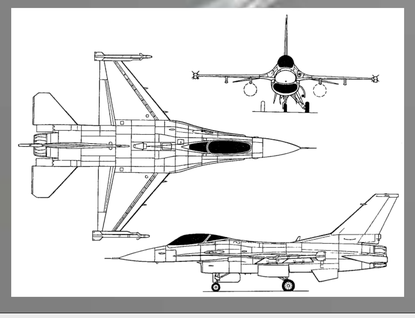

Fig 1: Diagram of F-16 Fighter Jet (Credit: coroflot.com/georgegreen)

Materials and Methods

DCI Symptom Onset

- During Flight 1, no symptoms reported, but patient put himself on 100% oxygen for 15 minutes mid-flight
- A few hours after Flight 2, arm pain develops in left elbow and forearm
- No mechanical explanation of pain

Admission to UCLA Hyperbaric Center

- Driving with a friend to UCLA from his home in Lancaster (elevation 2,300 ft), the patient experienced an onset of numbness in the affected arm at 3,200 feet (Fig 2).
- Numbness persisted but reduced as he reached sea level.
- Upon admission: Patient diagnosed with Type II DCS, and prescribed hyperbaric oxygen treatment.

Treatment Plan

Day 1: The patient given Navy Treatment Table 6 (Fig. 3) if symptoms improved with pressure.

Without improvement, Navy TT5 (Fig. 3) would be used.

Day 2+ : Navy TT5 used daily until symptoms plateau.

If pain persists after neurologic symptoms plateau, the patient is treated with Navy Treatment Table 9 (Fig. 3)

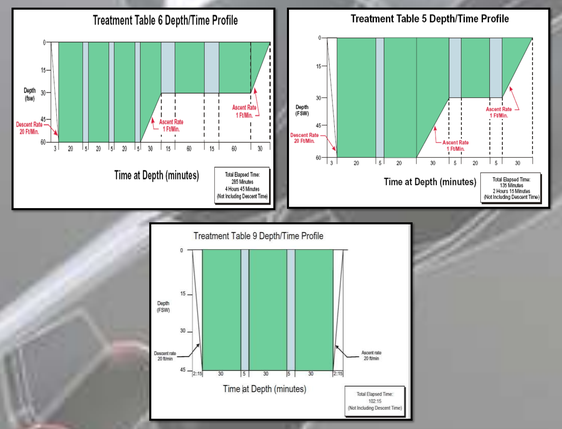

Fig. 3: U.S NAVY Treatment Tables 5 and 6

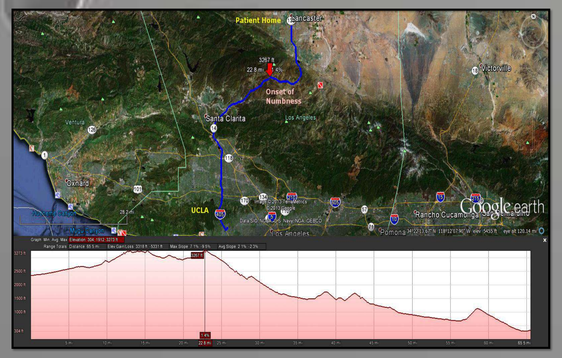

Fig. 2: Patient Route and Elevation Change
(Red Arrow Indicates Highest Elevation and Onset of Arm Numbness)

Results

Treatment Results

Day 1: *Navy Treatment Table 6 (Fig. 3)*
Within 10 minutes at 60 FSW, numbness resolved
After 30 minutes at 60 FSW, arm pain reduced to 4/10
After treatment, pain reduced to "soreness."

Day 2: *Navy Treatment Table 5 (Fig. 3)*
At 60 FSW, pain remained at "soreness"
At 70 minutes, 5/10 pain only upon extension of the elbow
After treatment, 1/10 pain upon extension of the elbow

Day 3, Final Treatment: *Navy Treatment Table 5 (Fig. 3)*
During and after treatment, patient reported only soreness upon extension of the elbow.
Patient grounded for four weeks, and instructed to be evaluated by a flight doctor before flying again.

Conclusion

DCS can occur during exposure to altitude or during ascent from depth. A number of countermeasures have been found to reduce the risks of altitude DCS.

Altitude Prevention Measures

- Cabin and/or suit pressurization
- Limiting time of altitude exposure
- Minimization of exercise at the altitude
- Pre-breathing 100% O2

Pre-breathing 100% oxygen before exposure to low barometric pressure decreases altitude-DCS risk by removing nitrogen from bodily tissues. Breathing 100% oxygen only during flight, as our patient did, does not decrease altitude DCS risk, and should not be used in lieu of oxygen pre-breathing.

General Treatment Plan

Minor forms of DCS (mild bends and skin manifestations)

- Return to sea level
- Immediately initiate 2 hours of 100% ground level oxygen

More serious DCS or unresolved symptoms at sea level

- Hyperbaric Oxygen Therapy

Any episode of DCS requires a minimum of 72 hours DNIF (Duties not Involving Flying). Consultation with Hyperbaric Medicine and concurrence of MAJCOM/SGPA (Major Command) is required before RTF (Ready to Fly). In cases of DCS with neurological manifestations, an examination by a neurologist is required before RTF.

The US Air Force spends $7 million training each squadron annually. With pilots being such a large investment, an episode of DCS and subsequent grounding is costly to operation.

According to a study by Wirjosemito et al(1989)[15], hyperbaric therapy for altitude decompression sickness yields a 97.7% success rate.

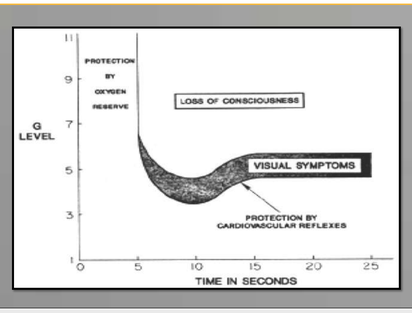

Fig. 4: G-time Tolerance Curve (also known as Stoll Curve)[12]

Significance & Recommendations

This case was significant because the pilot had minimal risk based on the current guidelines for DCS (<10%[1]); however, additional factors increased his risk for DCS or aggravated existing symptoms: lack of preoxygenation, transportation, 6G flight maneuvering, and night-before alcohol consumption. This case questions the safety of aviators everywhere.

Preoxygenation

Preoxygenation is an effective method to protect against altitude DCS.

- A 1-hour resting prebreathe prior to 4-hour exposure at 30,000 feet results in 77% risk of DCS.
- A 4-hour resting prebreathe prior to the same exposure results in approximately 40% DCS.

The USAF uses exercise-enhanced preoxygenation to increase effectiveness[7]. Exercise opens up additional vascular beds and speeds elimination of nitrogen from body tissues[13].

Disadvantage: preoxygenation involves considerable time to achieve an adequate level of protection, and it is neither logistically simple nor inexpensive[14]. Provided the means and resources are available, preoxygenation should be stressed to pilots engaging in activities at high altitudes.

Transport

The patient was fortunate to have a companion available to transport him to the treatment site. Had the patient driven himself, later-onset symptoms might have prevented him from making it to his destination safely.

We suggest:

- Emergency transportation services for DCS cases that worsen after leaving the base. The service would provide pilots unable to provide transportation for themselves, and ensure they get to treatment site safely and in a timely manner.
- Immediate oxygen treatment upon manifestation of any altitude-DCS symptoms on site. This would eliminate the need for self-transport to a hospital at a later hour when symptoms are aggravated.

Disadvantage: increased cost for treatment and possible unnecessary initiations of treatment.

6G Flight maneuvering & alcohol consumption

A force greater than 1G is particularly hazardous for pilots in the Gz axis. Consequences (Fig 4):

- Progressive loss of vision, known as "Red Out."
- G-induced loss of consciousness (GLOC)

Similarly, exercise at a symptom-free altitude for 4 hours produces 40% incidence of DCS[9].

According to the FAA[14], the after effects of alcohol consumption increase susceptibility to DCS and degrade G tolerance. Prevention of GLOC is through rest, hydration, physical fitness (aerobic and anaerobic), and the anti-G straining maneuver.

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