High Altitude DCS in U2 Pilots
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Disorders from Rapid Changes in Altitude
- Decompression Illness (DCI)
- Decompression Sickness (DCS)
- Cerebral Arterial Gas Embolism (CAGE)

Decompression Illnesses
Reduction in ambient pressure causes formation of inert gas bubbles causing primary or secondary organ dysfunction. (Embolic vs. autochthonous)

U-2 Mission
- High altitude (+60,000 ft) reconnaissance
- USAF’s sole remaining manned high altitude platform

Very High-Stress Physiological Profile
- High risk of DCS without preventative measures
- Standard DCS Prevention Measures
  - Full pressure suit, 1-hour resting pre-breath, 100% O2
- Historical DCS Incidence in U-2 Program (Prior to 1998)
  - Many unreported cases of joint/skin DCS
  - No recorded cases of CNS-related DCS
  - No recorded cases of permanent neurological damage

Gravity is a myth, the Earth sucks.
Decompression Illnesses
- DCS vs. DCI

The unsuitable environment
- Low Thermal
- Low Oxygen
- Low humidity

Background
- U-2 Mission
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Historical Background
- 1845 – Caissens Disease
- 1878 – Paul Bert defines DCS
- Snakes in vacuum
- Drs Smith (Eads) & Moir (Brooklyn)
- Royal Navy tables

Tiny Bubbles...
- Under pressure
  - Increased inert gas
  - Nitrogen (N2) absorbed in solution
- Decreasing pressure
  - N2 released into gas (Henry's Law)
  - Bubbles deposit in joint fluids or block vessels
  - Splendid vs. conical
- Endothelial effects
  - Leuk/plt adhesion
  - Complement cascade

DCS Symptom Recognition
- Type-1
  - Stabbing joint pain!
  - Itching of skin
- Type-2
  - Dry Cough
  - Dyspnea (labored breathing)
  - Substernal Chest Pain

CNS Presentations
- Fatigue (Commonly Discounted)
- Dull Persistent Headache
- Decreased Mentation
- Confusion/Delirium
- Poor Concentration
- Personality Changes
- Loss of Orientation
- Abnormal Neuro Exam
- Spotty sensory & motor signs
- Migratory Symptoms
- Flashing/Fluctuating of Lights/Blind Spots
- Partial Paralysis
- Vertigo

Kelly Johnson – designer
- -1957, U-2
- Pratt & Whitney J57
- Maintain at 10,000 ft above V (90% of flight)
- (Keep the flyers flying)
- ER-2 (NASA)

Intelligence, Surveillance, Reconnaissance (ISR)
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U-2 High Flight Preparation

P-4
These suits will fly in all high altitude aircraft:

- USAF
- Palmdale Test Pilots
- NASA ER-2
- B-57 Program

Altitude Chamber/FFS Training

U-2 take off roll

U-2 take off roll

U-2 landing
Hank’s Wild Ride

- 2.5 hrs into flight, FL680, CP280
- Knee pain – dialed up suit
- Ankle pain
- AC rolling – sick - Vis illusion
- MFD task difficulty (5/10)
- Frontal HA
- Hot flashes (cabin temp 55°)
- Hypoxia? – green apple
- Weakness – pupils?
- Second guessing – “am I screwing up?”
- Dehydrated?
- All MOC? Head home?
- ~5.5 hrs into flight, MFD-confusion, can’t transfer files
- “monkey on my chest”
- Sudden vomiting – scared
- SPG only, diff seeing instruments
- “in my happy place” MOC talking gibberish

Lapses in memory for event
- Emirate Mirages scrambled
descends into weather (spiral)
- Next thing I know I’m at FL160
- faintly remembers AI
- Sees concrete – Abu Dhabi IA at 2000 ft
- “650 ft over airfield is too low”
- Banked turn over hangers – 5 ft AGL
- “bailing out will get you to the medics quicker
- “get it together or get out”
- No strength to pull handles
- 9.5 hrs into flight – gets it together
Disclaimers

- Approved for public release by 9RW/PA
- Research was approved by USAF David Grant Medical Center IRB (#FDG20100012H)
- The authors have no conflicts of interest
- Views & opinions expressed in this presentation are solely those of the authors & do not represent official policy of the Department of the Air Force, Department of Defense, or the U.S. Government

CNS Neurological DCS Cases (1991-2001)

- 22 recorded DCS incidents of ALL types
- Two (2) confirmed chokes cases
- Three (3) confirmed neurological DCS cases
- Two possible cases of neuro DCS (1991, 2000)
- Five subjects*, all men
- Incomplete data on body habitus, age, & tests

* Cases don't add up to 5 because some subjects had multiple incidents and/or multiple symptoms (chokes/other)

Neurological Decompression Sickness In U-2 Pilots: A Case Series 2002-2009

Sean Jersey, Maj, USAF, MC, FS
Robert S. Michaelson, Col, USAF, MC, SFS
Kelly West, Lt Col, USAF, MC, SFS
Andy Pilmanis, PhD

CNS Neurological DCS (2002-2009)

- 15 recorded DCS incidents of ALL types (37 pilots)
- 13 confirmed cases neurological DCS (14 pilots)
  - Three (3) neurological + pulmonary DCS [2 at OL2]!
  - Five (5) life and/or aircraft threatening [4 at OL2]!
- 4 possible cases of neurological DCS (4 pilots)
- Observations:
  - Majority were men (one woman)
  - No correlation to age, body habitus, or GelDex use
  - No PFO detected among 6 pilots tested
  - One pilot with MRI lesions among 9 tested

Unusual Symptoms for Aviation-Related DCS

- Late Onset of Neurological Symptoms
  - 9 cases: sudden onset severe symptoms >4hrs in-flight
  - 7 cases: delayed recognition of symptoms after landing

- Recurrent Symptoms After Indicated Treatment
  - Temporal association with commercial airline flights
  - 2 cases flew home approximately 72hrs after treatment
Unusual Symptoms for Aviation-Related DCS (con’t.)

- Symptoms Persist Despite Indicated Treatment
  - Subtle neuropsychological symptoms persist for years
  - One case of PTSD (one additional case possible)
- Permanent Neurological Sequelae in 1 Case
  - Correlating lesions on MRI
  - Severe case – clinical equivalent of ischemic stroke
- Common in Diving-Related DCS, but Not Aviation

Most Severe U-2 Neurological DCS Case:

- Several prior (undisclosed), incidents of DCS
- 1-hour resting pre-breath, otherwise healthy male
- Cabin altitude 28,000 ft (8,534 m)
- Gradual onset of symptoms after 2.5 hrs flight
  - Joint pain progressing to fatigue, confusion, visual disturbances, difficulty breathing, chest pain, shock

- Pilot required coaching for flying, periods of unconsciousness, nearly crashed on landing
- Most severe symptoms resolved with HBOT
- Brain lesions on MRI improved after HBOT
- Permanent symptoms, corresponding MRI lesions
  - Headaches, fatigue, personality changes, memory deficits, vision problems
- Permanently disqualified from flying

Possible Causes

- Pilots More Willing to Report
  - Classification barriers removed
  - No more “two strikes” penalty
  - Operational culture changed after 2006 incident
- Normal Statistical Variation?
  - True incidence unknown, relatively small numbers
- Increased Operations Tempo
  - Frequency & duration of flights unprecedented
  - Workload falling on fewer pilots (reduced manning)

Mission Duration & Frequency

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<tbody>
<tr>
<td>Number of Pilots Available</td>
<td>49</td>
<td>37</td>
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<tr>
<td>Average Annual Hours per Pilot</td>
<td>207</td>
<td>353</td>
</tr>
<tr>
<td>Average Annual Sorties per Pilot</td>
<td>42</td>
<td>92</td>
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<tr>
<td>Time to Achieve “1,000-Hour” Status</td>
<td>7-10 years</td>
<td>3-5 years</td>
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Bottom Line: increased duration & frequency of hypobaric exposure
Other Causes Ruled Out by Investigation

- No correlation with aircraft tail number
- No mechanical failures in aircraft or life support systems
- No changes in equipment or integration/launch procedures
- No aircraft/LOX systems, LOX supply contamination
- No unique environmental contamination sources
- No correlation with amphetamine (GelDex ‘go-pill’) use
- No correlation with anthropomorphic variables or pre-existing medical conditions
- No evidence of malingering

Possible Risk Mitigation Measures

- Address Known Major Risk Factors for DCS:
  - Pre-breath, altitude, activity & exposure time at altitude
  - Exercise Enhanced Pre-Breathe
  - Risk reduction is population-based
- Reduce Time of Exposure (Sortie Length)
- Reduce Mission Operating Altitude
- Fly with Pressure Suit Partially Inflated at All Times
- Increase Rest Cycle Between Missions, Deployments
- Educate – Lower Threshold for Treatment Needed
- Return flights home with supplemental oxygen

Clinical Outcomes

Symptoms Similar to Traumatic Brain Injury (TBI)
- Normal imaging studies & neurological exam
- Persistent subtle symptoms, often overlooked
- Fatigue, headaches, irritability, sleep disturbances, difficulty focusing, memory problems
- Risk of concurrent PTSD
- Permanent deficits in most severely injured patient
- Suggests common final pathway of injury
- Window of increased susceptibility for re-injury?

Conclusions

- Increased Number of Neuro DCS Incidents Among U-2 Pilots
  - Coincident with persistent, increased tempo of operations
- Unusual Symptoms for Aviation-Related DCS
  - Onset of neurological DCS after >4 hours at altitude
  - Recurrence of symptoms after indicated treatment
- Subtle, but persistent neuropsychological symptoms
- Permanent injuries in some
- Suggests common final pathway for brain injury
- Implications for Aeromedical Management
  - Should neuro DCS patients be managed as head injuries?
- Implications for Treatment
  - Immediate HBOT for ANY SUSPECTED neuro DCS
  - Operational patients at risk for concurrent PTSD
  - Could TBI treatments benefit neuro DCS patients (and vice versa)?
What Questions do u have?