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Morning sick call was uneventful; you breezed through a stack of 469s, then 422s, returned flyers updating their 2992s, and added the finishing touches for a complicated waiver. It was just another day in the clinic, and now you are putting on warm gear for this snowy winter evening to enjoy a well-earned low-level night vision goggle flight on a C-17. As you gather your gear, preparing to leave the clinic, a nurse pops in and asks you to see a patient. She is a 32-yr-old reservist living in Connecticut and a new Air Force nurse on active duty orders at this base for aeromedical evacuation training. She complains of right post-auricular numbness that started about 2 h ago. Upon questioning, she states the only difference in her normal routine was the altitude chamber training and exposure given to her class to help them understand their individual symptoms of hypoxia. The chamber ride was entirely uneventful, reached an altitude of 25,000 ft, and occurred approximately 28 h ago; no one else from the class has presented to the flight medicine clinic. The remainder of the history as well as the physical exam is unremarkable.

1. What diagnosis is your primary consideration?

A. Fibromyalgia.
B. Lyme disease.
C. Decompression illness (DCI).
D. Multiple sclerosis.
E. Mixed connective tissue disorder.

ANSWER/DISCUSSION

1. C. Decompression illness (DCI). Decompression sickness (DCS) is a clinical syndrome associated with formation of bubbles from gases dissolved in body tissues after a reduction in ambient pressure. Arterial gas embolism occurs when gas enters the pulmonary vasculature as a consequence of pulmonary barotrauma. Although separate clinical entities, DCS and arterial gas embolism are difficult to distinguish, frequently coexist, and have similar treatment regimens, so they are grouped by some into a larger category of DCI.[13]

There is no pathognomonic symptom or specific laboratory test, so DCI is a diagnosis of exclusion. Therefore, other possible etiologies, including the choices above of fibromyalgia, Lyme disease, multiple sclerosis, and mixed connective tissue disorder, should be investigated during the history and physical as any of these could present to the flight clinic with identical symptoms. However, a high index of suspicion for DCI is needed in this setting because the nature of the symptoms at onset does not predict the ensuing severity of the case. Consequently, a low threshold to transport the patient to a hyperbaric facility, the definitive treatment, is prudent. Fortunately, hyperbaric therapy is a relatively low-risk intervention, so it can be used in equivocal cases. However, caution is needed so appropriate therapy is not withheld as a result of misdiagnosis. For example, mistaking chest pain and respiratory distress from myocardial ischemia as "the chokes" risks morbidity and mortality.

Do not be misled by the long onset to symptoms in this patient. While it's uncommon for symptoms to begin so long out, 28 h in this case, DCS should remain in the differential diagnosis even after 24–48 h for any patient with credible exposure.[9]

2. Which is NOT a characteristic manifestation of DCS?

A. Bends.
B. Chokes.
C. Staggers.
D. Burns.
E. Skin bends.

ANSWER/DISCUSSION

2. D. Burns. The bends, or Caisson disease, is the most familiar condition. It results when nitrogen bubbles come out of solution and into a joint—predominantly large joints, including the shoulders, elbows, wrists, hips, knees, and ankles. The pain can range from a mild dull ache to an excruciating sharp pain exacerbated by movement of the joint. The chokes occur when nitrogen bubbles come out of solution and into the lungs, which causes a deep, substernal chest pain usually described as burning and exacerbated by breathing. Associated symptoms are dyspnea and dry cough.

The staggers, or neurological DCS, occurs when nitrogen bubbles come out of solution and into the brain, resulting in vertigo, dizziness, diplopia, confusion, headache, seizure, scotoma, extreme fatigue,

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behavior changes, nausea, vomiting, and unconsciousness. In this case of neurological DCS, bubble formation occurred in the spinal cord at the cervical level, resulting in paresthesia as the sole presenting complaint. Additional suggestive symptoms of this condition could include girdling chest or abdominal pain, urinary and rectal incontinence, as well as tingling/burning/stinging pain, which may occur along with weakness or paralysis extending from the feet cephalad.

Skin bends occur when nitrogen bubbles come out of solution and into the skin, causing itching or what is described as formication (the sensation of innumerable tiny insects crawling under the skin). The skin may look marbled (cutis marmorata), which, interestingly, seems to be of more concern in the setting of altitude DCS than diving DCS,[4] although this is unclear and a case-by-case assessment is required.

The patient is accompanied by her wingman, who had no trouble in the chamber, but is worried about getting DCS on her upcoming training mission.

3. In which group do the most acute human exposures to hypobaric conditions occur?

A. High-altitude/high-G jet aircraft pilots.
B. Commercial aviation passengers.
C. Physiological training courses.
D. Commercial (professional) divers.
E. All of the above occur in equal proportions.

ANSWER/DISCUSSION

3. C. Physiological training courses. When it comes to altitude DCS, most cases occur during physiological training[1] and are on the order of ~3/1000 exposures per year.[9] This is because the subjects are necessarily exposed to the hypobaric condition, unlike the pressurized cockpit of high-altitude/high-G jet aircraft pilots or the pressurized cabin of commercial aviation passengers. In these settings, exposure to hypobaria only occurs during an accidental depressurization, which is a possible, but uncommon, occurrence. In our case, a reserve nurse was activated for aeromedical evacuation training that included education of hypoxia symptoms in a low-pressure chamber.

4. Above what altitude is considered a credible exposure for DCS?

A. 10,000 ft.
B. 18,000 ft.
C. 25,000 ft.
D. 33,000 ft.
E. 63,000 ft.

ANSWER/DISCUSSION

4. B. 18,000 ft. It is important to recognize that there is no absolute altitude exposure threshold below which one can be assured not to develop altitude DCS. However, below 18,000 ft, while still possible, DCS is a clinical oddity.[6] Above 18,000 ft, the risk of developing DCS is approximately 1 in 1000 and increases as altitude increases. Most cases of altitude DCS occur at exposures to altitudes above 25,000 ft.

During this precipitating event, the patient was taken to an altitude of 25,000 ft, where she, along with 11 other students in the chamber, removed her mask and was given up to 4 min to familiarize herself with the symptoms of hypoxia. Symptoms are individualized and include anxiety, shortness of breath, belligerence, confusion, and, in this patient's case, euphoria. Subjects are guided by instructors to don masks at the 4-min mark if they have not done so already on their own, since unconsciousness occurs around 5 min at this altitude. It is important to recognize that while the risk of developing altitude DCS increases with increase in altitude, there is not a direct relationship between exposure to altitude and severity of DCS.[2] An inverse relationship between time to onset of symptoms and altitude has been described.[14]

5. Which is a predisposing factor that influences the development of altitude DCS?[10]

A. Altitude attained.
B. Rate of ascent.
C. Body type.
D. Scuba diving before altitude exposure.
E. All of the above.

ANSWER/DISCUSSION

5. E. All of the above. As discussed above, although there is no absolute altitude exposure threshold, it is worth noting that the higher the altitude exposure, the greater the risk of DCS. Also, the faster the rate of ascent to altitude, the greater the risk of developing altitude DCS. For example, an individual who experiences a high rate of ascent to 18,000 ft (such as would occur in a rapid decompression) has a greater risk of altitude DCS than one who reaches the same altitude but over a longer period of time. Body fat represents approximately 15% of an average adult body. However, due to poor blood supply, nitrogen is stored in greater amounts in fat tissues. In fact, it stores over half of the total amount of nitrogen, around 1 L, normally dissolved in the body. So individuals with higher body fat content are at a greater risk of altitude DCS. Scuba divers are subjected to increased pressure as a result of the overlying water column while breathing air under high pressure. This, in turn, significantly increases the amount of dissolved nitrogen in the body and the deeper the dive, the greater the rate of body nitrogen saturation. Also, it is important to remember that when diving at altitude, such as in a mountain lake, body nitrogen saturation is exaggerated, resulting in greater body nitrogen saturation compared with diving at the same sea level depth. Therefore, if enough time is not given to eliminate excess stored nitrogen, altitude DCS can occur at 5000 ft or less.[2]

6. Which is an alternative to the altitude chamber?

A. Reduced oxygen breathing device (ROBD).
B. Nitrogen replacement breathing apparatus.
C. Ground-level altitude chamber.
D. Nitrox aviation mask.
E. Sea level oxygen device.

ANSWER/DISCUSSION

6. A. Reduced oxygen breathing device. ROBD has proven an effective way to simulate altitudes up to 43,000 ft,[12] safely familiarizing aviators with their individual response to the effects of hypoxia.[17] Rather than decreasing atmospheric pressure as in a low-pressure chamber, ROBD feeds bottled gasses to a sealed mask, allowing specific adjustments of the oxygen and nitrogen mixture to create an atmosphere with a defined oxygen content that correlates with the desired altitude. ROBD training also more closely approximates actual flight conditions. In traditional low-pressure chambers, hypoxia is objectively evaluated by having subjects perform simple coordination tasks. In contrast, ROBD can be used in conjunction with a flight simulator, enabling context-specific hypoxic training.[3] Of significance, because there is no change in pressure, the risk of barotrauma, including DCS and ear/sinus damage, is eliminated.[8] There is one disadvantage of the ROBD and that is its inability to simulate a rapid decompression. Consequently, initial training is still done in a low-pressure chamber and refresher training is done with ROBD,[15] which still results in significant savings.

The patient wants to know if she will ever get to fly now that she has had an incident of DCS.

7. Regarding aeromedical disposition, when can this patient return to flying status?

A. Immediate return to flying status (RTFS).
B. Duties not including flying (DNIF) for 7 d then RTFS if symptoms have not recurred.
C. RTFS by the local flight surgeon after consultation, 2-wk DNIF, and required studies.
D. RTFS after 6-mo DNIF and Medical Evaluation Board.
E. Permanent disqualification from flying duties.

ANSWER/DISCUSSION

7. C. RTFS by the local flight surgeon after consultation, 2-wk DNIF, and required studies. As you are well aware, the practice of medicine is both art and science. So you may not be surprised that the Air Force, Navy, Army, and Federal Aviation Administration have their own approach to DCS aeromedical disposition and take into account whether the episode was simple or serious.

For the Army, simple DCS does not require a waiver. For serious DCS, a waiver would be required and considered on an individual basis so long as at least 1 mo has passed since the incident, there is complete resolution of symptoms, and neurological/neuropsychiatric testing is normal.[16]

The Navy considers DCS, in the setting of a full recovery, not disqualifying. However, if there are residual symptoms after treatment, it is disqualifying with waiver considered (neurology and potentially neuropsychological examinations are required). Simple DCS requires a minimum 3-d DNIF and no residual effects; serious DCS requires a minimum 14-d DNIF and no residual effects.[11]

DCS is not mentioned directly in the Federal Aviation Administration's Guide for Aviation Medical Examiners; however, the effects of serious DCS would be disqualifying. For simple DCS without residua, a medical certification would be possible.[7]

This Air Force reservist developed gas bubbles subsequent to chamber exposure that then embolized to the spinal cord, causing localized symptoms at the C2 level. Upon initial presentation, the patient was immediately treated with 100% oxygen via nonrebreathing mask in the flight medicine clinic. Because of the sensory distribution and history of credible exposure, the flight surgeon diagnosed serious DCS and transferred the patient to a local hyperbaric chamber, where she received recompression therapy using U.S. Navy Treatment Table 6: she was descended at 20 ft $\cdot$ min^{-1}, time on oxygen began at 60 fsw, where she spent 75 min and was then ascended at 1 ft $\cdot$ min^{-1} to 30 fsw, where she spent 2 h and 30 min before ascending at 1 ft $\cdot$ min^{-1} to ambient pressure. All of the patient's symptoms subsequently resolved completely in a total time frame of 3 d and no further treatment was required. No labs were indicated. She made a complete recovery and was returned to flying duties by the local flight surgeon following a 2-wk DNIF after consultation with both the base and major command Chief of Aerospace Medicine, having documented 1) symptoms and response to recompression therapy; 2) neurological exam performed by a neurologist; 3) magnetic resonance imaging with images reviewed by the Aeromedical Consultation Service; 4) consultation with the U.S. Air Force School of Aerospace Medicine Hyperbaric Medicine Branch; and 5) Aeromedical Consultation Service review.[5]

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Erratum

Reynolds RJ, Day SM. *Mortality due to cardiovascular disease among Apollo lunar astronauts.* Aerosp Med Hum Perform; 2017; 88(5):492–496. DOI: https://doi.org/10.3357/AMHP.4757.2017

In the May 2017 issue of *Aerospace Medicine and Human Performance* the authors reported the results of an investigation of cardiovascular mortality among U.S. astronauts who either completed circumlunar flights or landed on the lunar surface ("lunar astronauts").[1] We regret to inform readers of AMHP that the standardized mortality ratios comparing lunar astronauts to the U.S. general population presented in Table III of the paper are incorrect. We present here a corrected table using appropriate cause-specific mortality rates.[2-4]

The discussion in the original article, in spite of the error and in light of these corrected results, remains broadly accurate, and the main conclusion in the original article is unchanged: presently there is no credible evidence of increased cardiovascular mortality among astronauts — lunar or otherwise.

We apologize for any inconvenience caused by this error.

Table. Standardized Mortality Ratios for Lunar Astronauts in Comparison to the U.S. General Population.

	ALL CAUSES				CARDIOVASCULAR ONLY			
PERIOD	**OBS***	**EXP†**	**SMR‡**	**(95% CI)**	**OBS***	**EXP†**	**SMR‡**	**(95% CI)**
1990-1999	5	3.9	127	(41—296)	2	1.5	130	(16—471)
2000-2009	0	6.4	0	(0—47)	0	2.4	0	(0—127)
2010-2015	1	6.6	15	(0—84)	1	2.1	49	(1—271)
1968-2015	7	20.4	34	(14—71)	3	7.3	41	(8—120)

* Observed number of deaths due to selected cause in the lunar astronaut group.
† Expected number of deaths in the lunar astronaut group based on mortality rates from the general population.
‡ Standardized mortality ratio comparing cause-specific mortality rates in the Lunar Astronaut cohort (numerator) to those in the general population (denominator). An SMR greater than 100 indicates an excess of deaths in the Lunar Astronaut group.

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