Hypoxia Occurrence in a Military Aviator Below 3048 m

Lesli R. Tristan

INTRODUCTION: Despite technological advances, hypoxia remains a concern in aviation. Hypoxia can present with a vast array of symptoms that are unique to each aviator. Military aviators undergo hypoxia awareness trainings to learn their unique constellation of hypoxia symptoms.

CASE REPORT: This case report describes a military aviator who was flying in a B1 when the cabin depressurized. While performing the emergency checklist, the aviator was moving about the cabin and began to experience hypoxia symptoms. His symptoms occurred at an altitude below 3048 m (10,000 ft), and his fellow crewmembers remained asymptomatic. Previous hypoxia awareness trainings enabled the aviator to recognize his symptoms as hypoxic. His symptoms resolved within seconds of applying supplemental oxygen via his facemask, and he did not have any recurrence of his symptoms.

DISCUSSION: Aviators reliably remember their hypoxic symptoms from previous hypoxia awareness trainings up to 4.5 yr later. This enables the aviator to quickly take action to correct his or her symptoms. While hypoxia is commonly thought to only occur at altitudes greater than 4267 m (14,000 ft), it can occur at lower altitudes, especially if it is compounded with the physiological changes from exercise.

KEYWORDS: altitude, aviation, decompression, depressurization.

Tristan LR. *Hypoxia occurrence in a military aviator below 3048 m.* Aerosp Med Hum Perform. 2017; 88(1):61–64.

Hypoxia has been a known risk of aviation since 1862 when James Glassier and Henry Coxwell ascended over 8839 m (29,000 ft) in a hot air balloon.[4] Over the years, the aviation industry has devised methods to combat hypobaric hypoxia which include cabin pressurization, oxygen breathing systems, and hypoxia warning systems.[3,5,9] However, despite these technological advances, hypoxia in aviators continues to remain a concern because of the potential for catastrophic consequences should it go unrecognized.

There are a large variety of symptoms that occur as a result of hypoxia. These may include, but are not limited to, impaired cognitive function (mental slowing, poor concentration, confusion, amnesia, and drowsiness), visual disturbances (decreased color vision, tunnel vision, and blurry vision), poor coordination, tremors, shortness of breath, flushing, and dizziness.[7,11] Hyperventilation is common in aviation, especially in stressful environments. It is important to remember that symptoms of hyperventilation can mimic hypoxia. However, misdiagnosis can have grave consequences so aircrew must assume and treat for hypoxia.[7]

While there are a multitude of symptoms that can be attributed to hypoxia, the specific combination experienced by a hypoxic aviator is unique to that individual. This has been referred to as the individual's “hypoxia signature.”[11] The “hypoxia signature” describes not only the unique constellation of symptoms experienced, but also the order of onset and severity of these symptoms.[11] This “hypoxia signature” is expected to remain relatively constant over time[11] and is one of the reasons that the military conducts hypoxia familiarization training.[2,3]

The hypoxia familiarization training enables an aviator to experience his or her hypoxia symptoms in a controlled environment. The primary goal of hypoxia training is timely recognition of hypoxia symptoms, which theoretically allows the aviator to take prompt actions to correct the hypoxia before it progresses.[8] Quick recognition of hypoxia symptoms is imperative because, dependent upon the altitude (and thus the partial pressure oxygen content of the atmosphere), the length of time for which the aviator is functional can range from as little as 20 s at 12,192 m (40,000 ft) to 160 s at 7620 m (25,000 ft).[5]

From Flight Medicine, U.S. Air Force, Abilene, TX.

This manuscript was received for review in July 2016. It was accepted for publication in September 2016.

Address correspondence to: Lesli R. Tristan, M.D., U.S. Air Force, 3217 Woodlake Dr., Abilene, TX 79606; lesli.tristan.1@us.af.mil.

DOI: https://doi.org/10.3357/AMHP.4722.2017

The U.S. Air Force (USAF) uses a cabin altitude greater than 3048 m (10,000 ft) above mean sea level (AMSL) as the cutoff for supplemental oxygen. Supplemental oxygen is employed by the aviator any time the cabin altitude is above 3048 m (10,000 ft), unless it is mission essential. In times that the mission requires unpressurized operations, the altitude is limited to 4267 m (14,000 ft) AMSL without supplemental oxygen and the length of the operation is limited dependent upon the operating altitude.[1] In the case of cabin depressurization, USAF aviators are instructed to immediately descend to the "lowest practical altitude" or less than 5486 m (18,000 ft) AMSL.[1] This case report describes an aviator who became symptomatically hypoxic below 3048 m (10,000 ft) AMSL while his fellow crewmembers remained asymptomatic.

CASE REPORT

A 39-yr-old USAF B1 Weapons System Operator (WSO) with no past medical history underwent evaluation by a flight surgeon following a physiological incident that occurred during flight. During the second half of the flight, the aircraft climbed to 7620 m (25,000 ft) AMSL. After approximately 15 min at this altitude, the aircraft commander notified the crew that they needed to go onto supplemental oxygen. The WSO was able to have his oxygen mask up within seconds of this notification. Shortly after his mask was in place, the Cabin Over 10,000 light came on. He recalled that the depressurization was quick but not violent. There were no noticeable changes in sounds or airflow within the cabin. The aircrew terminated what they were doing and descended to 4572 m (15,000 ft) AMSL. Once they reached 4572 m (15,000 ft) AMSL, they began to troubleshoot and run emergency procedure checklists. They ran the entire checklist without improvement in cabin pressurization. The last step of the checklist involved the WSO evaluating the pressure regulator in the aft cabin. He waited until the aircraft had descended to below 3048 m (10,000 ft) AMSL before disconnecting from his oxygen hose and heading toward the aft cabin (unable to be reached with his oxygen hose in place). Troubleshooting of the pressure regulator was unsuccessful. He then scanned the cabin for any venting or light coming into the cabin that could possibly indicate the source for depressurization. There was no obvious cause of cabin depressurization. Once finished in the aft cabin, he proceeded back to his seat. At this time, he had been off supplemental oxygen for approximately 3 min (per his memory). In order to return to his seat, he had to duck under a half door to return to the main cabin. Upon standing up, he experienced loss of color and peripheral vision along with associated dizziness. He noticed that these symptoms were consistent with his previously experienced hypoxia symptoms that occurred during his hypoxia chamber training. Upon recognizing his symptoms, he reattached his mask to oxygen and notified the crew of his hypoxia symptoms. The WSO stated that after 1-2 deep breaths with supplemental oxygen, his vision began to return to normal. After multiple deep breaths on supplemental oxygen, his symptoms completely resolved. The total duration of his hypoxic symptoms was approximately 15 s. He denied any loss of consciousness. Upon identifying the hypoxia symptoms, the flight was terminated and the aircrew returned home at an altitude of 3353 m (11,000 ft) AMSL. Upon landing, the WSO was evaluated on the flight line by a flight surgeon. His symptoms had completely resolved at this point and no intervention was required. He was instructed to monitor for any delayed symptoms of decompression illness and contact the flight surgeon if needed. He did not experience any delayed symptoms and remained asymptomatic.

DISCUSSION

The aviator's in-flight hypoxic episode was consistent with his recalled hypoxic symptoms from his hypoxia familiarization training. His last hypoxia training was 1.5 yr ago and he remembered that decreased peripheral vision, muted color vision, and tingling of his fingers composed his "hypoxia signature." Knowledge from his previous hypoxia awareness trainings enabled the WSO to quickly recognize his symptoms and appropriately attribute them to hypoxia. Timely diagnosis enabled him to quickly take the necessary steps to resolve his hypoxia and prevent further deterioration.

The reliability of an aviator to recall his or her hypoxia symptoms along with the consistency of these symptoms over time has been demonstrated by two different studies. Smith[11] found that 76% of aviators reliably remember their dominant hypoxia symptoms experienced during the hypoxia awareness training up to 3 yr later.[11] Johnson et al. performed a similar study in an attempt to confirm the results of Smith's study and assess if the aviators' memories extended past 3 yr. They found similar results to Smith and demonstrated that the aviators' recall of hypoxia symptoms reliably extended to 4.5 yr.[8] Both Smith and Johnson et al. yielded similar findings regarding aircrews' ability to reliably remember their dominant hypoxia symptoms even several years following the hypoxia awareness training.[8,11] The hypoxia symptoms experienced by this specific aviator mimics the symptoms that he experienced during his previous hypoxia trainings, which coincides with the results of the two aforementioned studies.

The aviator in this case report became hypoxic at an altitude less than 3048 m (10,000 ft) AMSL while his crewmembers remained asymptomatic. The effects of hypoxia are exhibited differently in each individual. These differences are not only limited to symptoms, but also include the altitude at which an aviator becomes symptomatically hypoxic. Some aviators experience symptoms at lower altitudes than others.[7,9] An altitude of 3048 m (10,000 ft) AMSL and below is often considered low risk for development of hypoxia symptoms.[10,12] Above 3048 m (10,000 ft) AMSL is commonly used as the cutoff value for which supplemental oxygen is employed.[1,6] The majority of cabin depressurization incidents occur between 6096 m (20,000 ft) and 9144 m (30,000 ft). One study reviewed 1055 military aircraft depressurization incidents that occurred from FY1981 to FY2003. They found that 48% of depressurization incidents with medical sequelae occurred between 6096 m (20,000 ft) and 9144 m (30,000 ft). Of the 1055 depressurization incidents reviewed, there were 350 with medical sequelae. Of these 350 incidents, there were 221 hypoxia incidents. Only 12 (5%) of the hypoxia incidents occurred at an altitude less than 4267 m (14,000 ft).[6] Based on their findings, the authors concluded that hypoxia and decompression sickness is considered unlikely at an altitude less than 4267 m (14,000 ft).[6]

While considered unlikely, this case report describes a symptomatic hypoxia event that occurred at a cabin altitude less than 3048 m (10,000 ft) AMSL. There are a variety of factors that can potentially increase the likelihood of hypoxia in an individual. These may include illness, antihistamine use, smoking, and increased oxygen requirements (including exercise).[7] Increased physical activity results in increased cardiac output. The increased cardiac output leads to decreased time for oxygen to diffuse across the pulmonary capillary bed. The decreased partial pressure of oxygen at altitude reduces the pressure gradient across the alveoli to the pulmonary capillaries. This reduction in oxygen pressure gradient results in a decreased driving force of oxygen from alveolar space into pulmonary capillaries.[9] Thus, the physiological changes of exercise plus decreased partial pressure of oxygen at altitude has the potential to increase an aviator's risk of hypoxia.

Review of the literature revealed a retrospective survey of Australian Army helicopter aircrews and their recall of previously observed hypoxia symptoms that occurred while operating below 3048 m (10,000 ft) AMSL. The study's author determined that the mean altitude for self-reported hypoxic incidents was 2568 m (8426 ft), but incidents were also described as low as 1981 m (6500 ft) AMSL.[12] In this study, loadmasters reported more hypoxic symptoms than pilots. During flight, the activity level of a loadmaster is significantly more when compared to a pilot. The increased incidence of hypoxia symptoms in loadmasters is likely secondary to the loadmasters' increased oxygen demands required to carry out their operational duties on the aircraft when compared to the pilots.[12] While this study was limited by its sample size and the potential recall bias of the aviators, it gives way to the idea of hypoxic events occurring below 3048 m (10,000 ft) AMSL.

A separate experimental, single-blind study of six healthy test subjects was conducted to determine if exercise affected the likelihood of hypoxia symptoms. Six subjects were exposed to simulated altitudes of 609 m, 2134 m, and 2743 m (2000 ft, 7000 ft, and 9000 ft) AMSL within a hypobaric chamber. They were then studied at both rest and while performing "light and moderate physical activity."[10] The subjects were administered a survey to assess for symptoms indicative of hypoxia along with correlation to a pulse oximetry reading. The study found that oxygen saturation and the development of symptomatic hypoxia was significantly affected by the presence of exercise. The initiation of exercise resulted in a drop in oxygen saturation which became clinically significant at an altitude of 2743 m (9000 ft) AMSL. The study found that oxygen saturation during exercise at 2134 m (7000 ft) and 2743 m (9000 ft) AMSL was consistent with a person at rest at 3658–4572 m (12,000–15,000 ft) AMSL.[10] While the sample size of this study was small, it reinforces the idea that exercise has the ability to increase the risk of symptomatic hypoxia and subsequently hypoxia that develops at lower altitudes.

The effects of altitudes over 4572 m (15,000 ft) AMSL are well documented. Review of the literature reveals less information on the occurrence of hypoxia at altitudes lower than 3048–4267 m (10,000–14,000 ft) AMSL. Bearing this in mind, it would initially appear that the WSO should not have become hypoxic at 3048 m (10,000 ft) AMSL even without supplemental oxygen. However, the combination of altitude (decreased partial pressure of oxygen) and physiological changes from exercise can result in an increased propensity for symptomatic hypoxia in an aviator who is moving about the cabin. This could potentially explain why this aviator was the only one of his four-man crew to become symptomatically hypoxic at an altitude less than 3048 m (10,000 ft) AMSL. Given the limited data regarding hypoxia at lower altitudes and the effects of exercise on hypoxia, more research into this subject is needed. Also important regarding this case was the ability of the aviator to quickly recognize his symptoms as hypoxic and take the appropriate countermeasures. The hypoxia familiarization training that he previously attended likely contributed to his ability to quickly assess what was occurring and resolve his symptoms within seconds. This further reinforces the importance of the military's hypoxia training to mitigate hypoxia episodes and potentially prevent safety events.

ACKNOWLEDGMENTS

The views and opinions expressed are those of the author and are not endorsed by the U.S. Air Force.

Author and affiliation: Lesli R. Tristan, M.D., U.S. Air Force, Abilene, TX.

REFERENCES

1. Air Force Instruction 11-202, vol. 3. Washington (DC): U.S. Air Force; 7 November 2014:19–21.
2. Artino AR, Folga RV, Swan BD. Mask-on hypoxia training for tactical jet aviators: evaluation of an alternate instructional paradigm. Aviat Space Environ Med. 2006; 77(8):857–863.
3. Deussing EC, Artino AR, Folga RV. In-flight hypoxia events in tactical jet aviation: characteristics compared to normobaric training. Aviat Space Environ Med. 2011; 82(8):775–781.
4. Doherty MJ. James Glaisher's 1862 account of balloon sickness: altitude, decompression injury, and hypoxemia. Neurology. 2003; 60(6): 1016–1018.
5. Ernsting J. Hypoxia in the aviation environment. Proc R Soc Med. 1973; 66(6):523–527.
6. Files DS, Webb JT, Pilmanis AA. Depressurization in military aircraft: rates, rapidity, and health effects for 1055 incidents. Aviat Space Environ Med. 2005; 76(6):523–529.
7. Harding RM, Mills FJ. Aviation medicine. Problems of altitude I: hypoxia and hyperventilation. Br Med J (Clin Res Ed). 1983; 286(6375):1408–1410.
8. Johnston BJ, Iremonger GS, Hunt S, Beattie E. Hypoxia training: symptom replication in experienced military aircrew. Aviat Space Environ Med. 2012; 83(10):962–967.

9. Petrassi FA, Hopkinson PD, Walters PL, Gaydo SJ. Hypoxic hypoxia at moderate altitudes: review of the state of the science. Aviat Space Environ Med. 2012; 83(10):975–984.
10. Smith AM. Acute hypoxia and related symptoms on mild exertion at simulated altitudes below 3048 m. Aviat Space Environ Med. 2007; 78(10):979–984.
11. Smith AM. Hypoxia symptoms in military aircrew: long-term recall vs. acute experience in training. Aviat Space Environ Med. 2008; 79(1):54–57.
12. Smith AM. Hypoxia symptoms reported during helicopter operations below 10,000 ft: a retrospective survey. Aviat Space Environ Med. 2005; 76(8):794–798.