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Acute Mountain Sickness

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Abstract

Overview of Acute Mountain Sickness including Diagnosis, risk factors and treatment/prevention, as well as the pathophysiology effects of AMS.

Keywords

Acute Mountain Sickness, AMS

Disciplines

Disorders of Environmental Origin | Environmental Health | Medicine and Health Sciences

Comments

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Acute Mountain Sickness

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Introduction

According to Garrido et al. (2019), every year, more than 100 million people visit or travel to high mountain areas for professional, touristic, sports or religious reasons, reaching high altitudes. However, at higher altitudes, the decreased partial pressure of oxygen can cause several pathological presentations, such as altitude sickness. The most common of which is Acute Mountain Sickness, also known as AMS (Prince et al., 2021). Acute Mountain Sickness was clinically classified in 1913 by the British doctor Thomas Ravenhill, however the exact pathogenic mechanism or the conditions that set AMS into motion are still not fully understood (Garrido et al., 2019). Prince et al. (2021) suggest that Acute Mountain Sickness is caused by the body's reaction to the reduced oxygen level in respired air and results in tissue hypoxia. Garrdio et al. (2019) suggest that the most feasible mechanisms are encephalic vasodilation, vasogenic edema, increased intracranial pressure and meningeal distension or, simply put, an increased swelling of the centeral nervous system. This makes sense since the brain is the most sensitive organ regarding hypoxia and oxygen stress (Prince et al., 2021).

AMS typically occurs at an altitude of greater than 2500 meters for non-acclimated individuals; however, it can occur at lower elevations for those who are high-risk (Ahluwalia et al., 2020). AMS typically occurs within hours, usually 4 to 12 h after arrival at a new altitude (Luka et al., 2017). AMS may progress from nonspecific symptoms to life-threatening high-altitude cerebral edema although it should not get to this point if treated (Meier et al., 2017). Most common symptoms inlcude headaches, nausea/vomiting, light-headedness, insomnia, and fatigue (Aksel et al., 2019).

Diagnosis

Diagnosis of AMS is commonly based on the use of the Lake Louise Scoring system or LLS (Burtscher et al., 2021). The LLS is a self-assessment questionnaire including five main symptoms: headaches, nausea, dizziness, fatigue, and difficulty sleeping. Each symptom is rated with a score from 0 to 3 with 0 for no discomfort, 1 for mild, 2 for moderate, and 3 for severe symptoms (Burtscher et al., 2021). Another form of diagnosis is VAS or the Visual Analog Scale. This is known for measuring changes in the intensity of symptoms such as headache or nausea (Frühauf et al., 2016). However as stated by Frühauf et al (2016), this method uses few descriptive words and generally consists of a continuous 100 mm scale, reaching from the non-occurrence (left side) to the highest intensity of possible symptoms (right side). Another form of diagnosis is the AMS-C. The AMS-C score was derived from the Environmental Symptom Questionnaire (ESQ), which was formulated in 1979 to assess symptoms induced upon exposure to extreme environmental conditions (Ahluwalia et al., 2020). However Ahluwalia et al. (2020) go on and explain that the AMS-C score is used less frequently due to it being an intricate assessment tool.

Risk Factors

Some individuals are more prone to the occurrence of acute mountain sickness (AMS) than others. Typically, the risk factors include the rate of ascent and absolute altitude reached (Lawrence and Reid, 2016). Other risk factors for AMS include age, sex, smoking, and obesity but they are disputed (Lawrence and Reid, 2016). Suh and Flaherty (2019) stated that some studies have shown advanced age to be protective against AMS, whereas others have found no association between age and AMS. Due to the dispute of risk factors, many other factors have been proposed; for example, the idea that endurance-trained athletes are at greater risk of developing AMS. Sareban et al. (2019) suggest that endurance-trained athletes with a high maximal oxygen uptake may be at increased risk for AMS due to the possible underlying mechanisms which include a training-induced increase in resting parasympathetic activity, higher resting metabolic rate (RMR), and lower hypoxic ventilatory response. Interestingly, at the end of study, it was found that endurance-trained athletes are at higher risk for developing AMS on the first day after passive and rapid ascent, possibly due to an increased parasympathetic activity and an increased RMR (Sareban et al., 2019).

Other proposed forms of risk factors that can increase the likelihood of AMS occuring include pre-existing disease. Prince et al. (2020) suggested that pre-existing diseases can increase Acute Mountain Sickness risk by magnifying the effects of hypoxia. The most common conditions include anemia, with a reduced oxygen-carrying capacity of the blood, and chronic obstructive pulmonary disease, due to the reduced degree of oxygenation occurring in the lungs (Prince et al., 2020). It is interesting to note that a history of pre-existing hypertension is common in people participating in mountain activities (Duke et al., 2020). Duke et al. (2020) created a set of experiments to determine the relationship between hypertention and AMS and found no relationship between measured BP values and AMS. However, their results suggest that the risk of AMS may be lower in people with a history of pre-existing hypertension (Duke et al., 2020).

AMS is not limited to just physical factors but also includes potential psychological factors (Niedermeier et al., 2017). Exposure to high altitude may lead to psychological change such as anxiety, the most prevalent mood state associated with AMS (Yu et al., 2016). Hüfner et al. (2019) suggested that anxiety at high altitudes correlates with the severity of insomnia and tachycardia. High levels of anxiety before high altitude exposure were associated with higher anxiety during the climb and higher levels of AMS within individuals (Hüfner et al., 2019). It's also important to note that at high altitudes, the sleep alterations aggravate anxiety which cause a nightmarish loop which increases the chances of AMS in individuals (Yu et al., 2016). Lastly, Prince et al. (2020) stated that any travelers with prior episodes of Acute Mountain Sickness are at greater risk than those who have tolerated similar trips in the past.

Pathophysiology of AMS

As stated before, hypoxia has been associated with increased susceptibility to the neurological syndrome, known as acute mountain sickness (Bailey and Ogoh, 2017). Hypoxia is known to be caused by a decrease in the partial pressure of oxygen in the atmosphere. Berger et al. (2020) suggest that once hypoxia is established, it may cause AMS by following distinct pathways. At high altitude, cranial blood flow (CBF) increases to maintain oxygen delivery to the brain (Berger et al., 2020). In hypoxia, CBF is determined by arterial blood pressure and by the balance between pressure of oxygen (Po2) and the partial pressure of carbon dioxide (Pco2), with vasodilation caused by hypoxemia dominating over vasoconstriction caused by hypocapnia (Berger et al., 2020). Berger et al. (2020) suggest that the hypoxemia in AMS induces a greater amount of cerebral blood flow, meaning that there will be an increase of intracranial pressure. Low levels of partial pressure in the atmosphere caused by hypoxia increase CBV or cerebral blood volume (Gunga et al., 2015). This makes sense since the increased amount of blood flow would go hand in hand with an increase of CBV; both of these play a part in the increase of pressure within the capillaries and ultimately lead to vasogenic edema (Gunga et al., 2015). Vasogenic edema is defined as extracellular accumulation of fluid resulting from disruption of the blood-brain barrier or the BBB (Michinaga and Koyama, 2015). Such factors cause insufficient cerebrospinal compliance due to hypoxia-induced brain swelling. The swelling increases intracranial pressure and causes brain compression and headaches, which leads to being susceptibile to AMS (Lu et al., 2015).

Another distinct pathway that ultimately can lead to AMS happens yet again when partial pressures of oxygen (Po2) fall throughout the body during exposure to high altitude (Lu et al., 2015). Lu et al. (2015) suggested that to limit the drop in arterial oxygen content, the body immediately reacts by increaing cardiac output through sympathetic activation. This sympathic activation causes a cascade throughout the body, ultimately affecting the kidneys and increasing water retention. As a result, this, again, leads to the increase in capillary pressure and then vasogenic edema (Lu et al., 2015). From there, the body is again susceptible to AMS.

Lastly, Lu et al. (2015) suggested that hypoxia-induced hypoxemia triggers an inflammatory response. The release of inflammatory mediators contributes to an increase in capillary pressure by vasodilatation and overperfusion, leading to a disruption of the BBB and increased BBB permeability; this is also known as the blood-brain barrier theory (Lu et al., 2015).

Prevention of AMS

The most common measures to be considered for the prevention of AMS include the following: gradual ascent, acetazolamide and ibuprofen (Lukas et al., 2019). Dexamethasone and inhaled budesonide have also been suggested as prevention to AMS however they are disputed to whether or not they should be fully considered as preventions against AMS (Lukas et al., 2019). Lukes et al. states that these recommendations are intended to apply to all travelers to high altitude, whether they are traveling to high altitude for work or recreation. Gradual ascent is the best prevention strategy to prevent all forms of high altitude illnesses (HAI) since the major risk factors are the absolute change in altitude and rate of ascent (Aksel et al., 2019). Aksel et al. (2019) also stated that gradual ascent gives sufficient time to develop an adequate degree of altitude acclimatization. Controlling the rate of ascent, in terms of the number of meters gained per day, is a highly effective means of preventing acute altitude illness; however, in planning the rate of ascent, the altitude at which someone sleeps is considered more important than the altitude reached during waking hours (Lukas et al., 2019). It's important to state that one must be on the lookout from HAI symptoms because proceeding to higher sleeping altitude is never recommended for an individual who has shown symptoms of AMS or HAI (Aksel et al., 2019).

Acetazolamide is the most common medication used for acute mountain sickness prevention (Lipman et al., 2020). It is a carbonic anhydrase inhibitor which can help an individual acclimatize quicker (Kanaan et al., 2017). Gao et al. (2021) created a study following the effects of acetazolamide and found that acetazolamide is an effective prophylaxis for the prevention of AMS in doses of 125, 250, and 375 mg/bid. The greater the doses of acetazolamde cause more frequent and pronounced side effects and they do not convey greater efficacy therefore, the recommended adult dose for acetazolamide is 125 mg every 12 hours (Lukas et al., 2019). Interestingly, a study was done to compare a lower dose to the recommended dose. The study found that a reduced dose of acetazolamide of 62.5 mg is as effective as the currently recommended dose of 125 mg for the prevention (McIntosh et al., 2017).

Ibuprofen can be used for AMS prevention in persons who do not wish to take acetazolamide, have allergies, or have an intolerance to acetazolamide (Lukas et al., 2019). Irons et al. (2020) created a double-blinded, randomized, field-based clinical trial of metoclopramide and ibuprofen to check how well they preventeted AMS. The study found that ibuprofen was effective at reducing AMS symptoms, including headache and nausea, but that metoclopramida was more effective at reducing nausea (Irons et al., 2020). Despite this, ibuprofen is still considered a useful way to prevent AMS.

The suggestion of dexamethasone as a way to prevent AMS has been disputed, with a more recent study done by Furian et al (2018) refuting older studies regarding its usefulness. Likewise, inhaled budesonide has been suggested as a novel prevention for acute mountain sickness yet, efficacy has not been compared with the standard acute mountain sickness prevention medication such as acetazolamide (Lipman et al., 2018). Therefore, a study was conducted comparing budesonide and acetazolamide. The study concluded that budesonide was ineffective for the prevention of acute mountain sickness compared to acetazolamide (Lipman et al., 2018). Due to the budesonide constantly being proposed as a way to prevent AMS, another study was done in order to further test its ablililes against preventing AMS. But, once again, the result of the study indicated that inhaled budesonide does not protect against AMS or severe AMS. It did, however, succeed at reducing the heart rate and increasing SPO2 without any side effects within the individual (Zhu et al., 2020).

Treatments for AMS

Potential therapeutic/treatments options for AMS and HACE include the following: descent, supplemental oxygen, portable hyperbaric chambers, as well as ibuprofen and acetazolamide (Lukas et al., 2019). Treatment of mild AMS cases are usually treated with supportive care including rest, and medications for headache such as ibuprofen, however more severe cases can be treated with oxygen given through a nasal cannula as well as with prescription medications such as acetazolamide (Jin, 2017). Although descent remains the single best treatment for AMS, it is not necessary in all circumstances and therefore individuals shouldn’t descend if terrain, weather, or injuries make descent impossible (Lukas et al., 2019). If descent is required, supplemental oxygen can be used alongside to help treat AMS symptoms although not necessary (Davis and Hackett., 2017). If descent is not possible or if AMS is apparent in a large group and supplemental oxygen is available, then the oxygen delivered by nasal cannula should be sufficient enough to relieve symptoms and can provide a suitable alternative to descent (Lukas et al., 2019).

Another option are hyperbaric chambers or portable hyperbaric chambers. An example of a portable hyperbaric chamber is the Gammow Bag. The Gammow bag is the most important and popular device used in most trekking and high altitude expeditions to treat and prevent AMS (Sun et al., 2020). The Gammow bag is an inflatable cylindrical tube made of heavy rubber or durable fabric that pressurizes the atmosphere sealed within it to that of a much lower altitude (Sun et al., 2020). However, the Gammow bag is not always an acceptable therapy alternative in a predominantly elderly population and most types of portable hyperbaric chambers are monoplace chambers (Sun et al., 2020). This means that they would not be efficient within a group suffering from AMS. Not only this, but hyperbaric chambers require constant tending to by care providers and are difficult to use with claustrophobic or vomiting patients (Lukas et al., 2019). Also, symptoms of AMS may reoccur when individuals are removed from the chambers yet this should not prevent the use of the chamber when necessary (Lukas et al., 2019). However, in many cases, ill individuals may improve sufficiently to enable them to assist in their evacuation and descend once symptoms improve (Lukas et al., 2019). Yet, the popularity of these chambers have not dropped and due to this, these chambers have paved the way for new chamber ideas such as a newly designed multiplaced hyperbaric chamber. Like other portable hyperbaric chambers, based on the principle of increasing ambient pressure within the chamber, a new multiplace plateau hyperbaric chamber has been designed to satisfy the needs of patients who suffer from AMS (Sun et al., 2020). Unlike other portable hyperbaric chambers, atmospheric pressure is increased by adjusting the opening of the expiration valve in proportion to the ambient pressure (Sun et al., 2020). This new chamber was tested and the results found that the new multiplace plateau hyperbaric chamber can be used to alleviate plateau hypoxia by increasing patient PaO2 (Sun et al., 2020). However, Sun et al. (2020) were limited in their findings and could not find the value of the chamber for treating AMS since it was not tested in field conditions.

The Pandemic

With the current COVID-19 pandemic occurring in the world, clinicians and scientists have suggested therapies for the coronavirus disease-19 (COVID-19) that are known to be effective for other medical conditions (Berger et al., 2020). Not only this, but other clinicians and scientists have suggested similarities between other medical conditions and COVID-19 (Berger et al., 2020). An example of such is Soliz et al. (2020) who stated that acute mountain sickness (AMS) and SARS-CoV-2 virus-induced infection share striking similarities since COVID-19 may cause severe hypoxia in the absence of respiratory distress (Lari et al., 2020). Soliz et al. (2020) suggested that even though AMS and COVID-19 have different pathogenic mechanisms (barometric hypoxia vs. viral infection), the disease progression and specific symptoms show remarkable overlap. More specifically, Soliz et al. (2020) suggested that both illnesses similarly trigger a perfect storm in the respiratory system which affects the lungs and impair oxygen transport, gas exchange and the neural circuits controlling breathing. Yet, not everyone agrees with such claims. Berger et al. (2020) disagree and suggest that while the hypoxemia caused by COVID-19 can cause symptoms that also occur in AMS, it does not imply that similar pathways in AMS are involved in causing hypoxemia in COVID-19. Berger et al. (2020) also presented the fact that the AMS and the coronavirus don’t share the same cardinal symptom, since the cardinal symptom of AMS is headache. Lastly, Berger et al. (2020) debated the difference in time for symptom onset between AMS and COVID-19, with AMS symptoms occurring within 4-12 hours after being exposed to high elevation while COVID-19 includes an incubation period from 3-6 days and then an additional 8-12 days for symptoms to begin (Berger et al. 2020).

Conclusion

With the amount of people constantly visiting and traveling to areas of high elevation for work, sports or religious reasons, it's safe to say the AMS will constantly be prevalent. Because of its prevalence, many countermeasures have been tested and studied in order to prevent AMS. Although the exact pathogenic mechanisms of AMS are still highly debated/unknown, it is often associated with hypoxia. With the world's current pandemic, more research is going into AMS and its relationship with COVID-19.

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