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Pro: Pulse Oximetry Is Useful in Predicting Acute Mountain Sickness

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PULSE OXIMETERS ARE EASY TO USE, noninvasive tools for the assessment of individuals at high altitude. These instruments provide an estimate in percentage of arterial hemoglobin oxygen saturation, which is a function of arterial partial pressure of oxygen. The percentage denotes the hemoglobin binding sites that are occupied at any one time by oxygen. At sea level, healthy individuals will be on the flat portion of the oxyhemoglobin dissociation curve, but at high altitude as the partial pressure of oxygen decreases with ascent, individuals will be at the steep portion of the curve (a slippery slope by comparison) where saturation changes significantly with respect to small changes in the partial pressure.

Most trekking and expedition groups use pulse oximeters as a novelty item, and many groups carry an inexpensive, pocket pulse oximeter (some as little as US $30) to periodically check the oxygen saturation (Spo_2) as they as ascend up the trail. Based on medical literature, the pulse oximetery, though not 100% accurate, is useful in predicting acute mountain sickness (AMS).

Many studies have attempted to see if there is a link between hypoxemia and the likelihood of developing AMS. Some of these studies have used a prospective design to determine if decreased oxygen saturation earlier in the trip have increased the likelihood of suffering from AMS (Roach et al., 1998; Tannheimer et al., 2002; Karinen et al., 2010; Chen et al., 2012; Wagner et al., 2012; Faulhaber et al., 2014). Except for two studies above (Chen et al. and Wagner et al.), all the other studies in these prospective observations found a link. For example, Karinen et al. (2010) studied 83 ascents during eight expeditions. They measured both resting Spo_2 (R-Spo_2) and exercise Spo_2 (Ex-Spo_2) after moderate daily exercise [50 m walking, target heart rate 150 bpm] at altitudes of 2400 to 5300 m during ascent. The Lake Louise Score (Roach, 1993) was used in the diagnosis of AMS. Ex-Spo_2 was lower at all altitudes among those climbers suffering from AMS during the expeditions than among those climbers who did not get AMS at any altitude during the expeditions. Reduced R-Spo_2 and Ex-Spo_2 measured at altitudes of 3500 and 4300 m seem to predict impending AMS at altitudes of 4300 m and 5300 m.

Why were the studies by Chen et al. (2012) and Wagner et al. (2012) different from the rest? One explanation may lie in the methodology of these studies. Error ranges in various pulse oximeters may be different. Large error ranges may not be good enough when small differences are being looked for. Other reasons for the differing results may be test performance methods, and possibly differences in assessment of clinical significance.

There are no randomized controlled trials (RCTs) of hypoxemic individuals to determine if starting them on AMS prophylaxis after they are identified as having a low Spo_2 prevents AMS later in the trip. But RCTs using acetazolamide vs. other drugs or placebo in the prevention of AMS in the Everest region have consistently shown that those participants on acetazolamide were not only significantly more protected from AMS, but also had significant increased changes in their Spo_2 compared to the drug or placebo group from the baseline, even though the actual changes were small (Basnyat et al., 2003; Gertsch et al., 2004; Basnyat et al., 2011). This is not to advocate using pulse oximetry to determine who should take acetazolamide.

An important review (Burtscher et al., 2008) of exposure to simulated hypoxia with measurement of arterial oxygen saturation to determine AMS susceptibility has also been carried out. Sixteen studies were reviewed where Sao_2 was measured 20 to 30 min after exposure to simulated hypoxia equivalent to 2300 to 4200 m. The saturation values correctly predicted AMS susceptibility $>80\%$ of cases. Recently another study (Faulhaber et al., 2014) revealed that the additional determination of breathing frequency to oxygen saturation reading after 30 min exposure to simulated hypoxia can improve success in AMS prediction. Yet another interesting study (Tannheimer et al., 2009) revealed that the time necessary to complete a running task at high altitude on

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Mont Blanc (4808 m) and the lowest oxygen saturation while performing this task was predictive of an individual's risk of developing altitude sickness with further ascent. Hence other easily measurable parameters (such as respiratory rate, exercise time) in addition to measurement of Spo_2 at high altitude may help improve the accuracy of the Spo_2 readings vis a vis prediction of AMS. A fascinating, comprehensive recent study (Richalet et al., 2012) of 1326 subjects revealed that oxygen desaturation equal to or greater than 22% at exercise in hypoxia before a sojourn to >4000 m was an independent risk factor for predisposing a person to severe altitude sickness. The study did not address predisposition to the more benign form of the disease (i.e., AMS) and the study also had a methodological flaw in that more than two-thirds of the subjects did not complete the study.

Indeed, there is no dearth of medical literature supporting the use of pulse oximetry to predict AMS at a higher altitude from a baseline reading. At least one possible pathophysiological rationale for the link between AMS and decreased Spo_2 may be adequate ventilation. If hyperventilation is the cornerstone of acclimatization, AMS patients may have hypoventilation with resultant decreased Spo_2 (Basnyat and Murdoch, 2003). Another pathophysiological mechanism may be subclinical pulmonary edema as shown by Ge and colleagues (1997) who measured pulmonary diffusion capacity for carbon monoxide (DLCO) in a group of 32 subjects at 2260 m and following ascent to 4700 m. In subjects without AMS, the DLCO increased at higher altitude while in AMS patients the DLCO did not increase significantly. However when Dehnert et al. (2010) tried to reproduce this finding in individuals sojourning up to 4559 m, they were unable to replicate these results.

Pulse oximeters are even being used to predict summit success(Tannheimer et al., 2002). But clearly there are potential pitfalls of pulse oximeter readings; for example, individual variations, cut- offs for altitudes, and large standard deviations of the Spo_2 need to be taken into account (Luks and Swenson, 2011; Windsor, 2012; Zafren, 2012).

Given the popularity of pulse oximeters, mountain sojourners will continue to use them to try to predict AMS, regardless of where we stand on this issue today. It is therefore very important to do further studies on this topic (including accuracy of particular pulse oximeters and their error ranges, uniform measurement methods, and avoiding misinterpretation of data) to ''refine'' this science.

Author Disclosure Statement

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