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New technique to fight acute mountain sickness

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1. Introduction

Acute mountain sickness (AMS) is a well-known problem of many mountaineers [1] [2] [3]. The phenomena can appear early around 2500m of elevation, with symptoms like headaches, sleepiness troubles, abnormal fatigue. The technique described here permits to recover enough force and wellness, to spend a safe and comfortable night staying at the same altitude, or to allow a safe descent to a lower altitude.

2. Physical considerations

It has been proven for many years that mountain sickness is due to the reduced partial pressure of oxygen in air. It will not be described here all symptoms and physiological consequences as this has been remarkably done in many papers [4]. In this physical approach, the problem to solve is “*if the decrease of the partial pressure of oxygen is responsible of the AMS, how to increase artificially, over a shorter or longer period, the pressure in the lungs*”.

2.1 Partial pressure of oxygen

Let's start with some physics and the definition of the partial pressure [5]

In a mixture of ideal gases, each gas has a partial pressure which is the hypothetical pressure of that gas if it alone occupied the volume of the mixture at the same temperature. The total pressure of a gas mixture is the sum of the partial pressures of each individual gas in the mixture.

The partial pressure P_x relies on the following isotherm relation

$$P_x / V_x = P_{tot} / V_{tot} \quad \text{giving} \quad P_x = (P_{tot} \times V_x) / V_{tot} \quad [\text{eq. 1}]$$

where:

- V_x is the partial volume of any individual gas component (X)
- V_{tot} is the total volume in gas mixture
- P_x is the partial pressure of gas (X)
- P_{tot} is the total pressure of gas mixture

Air follows approximately this rule - approximately as air is not a perfect gas. On earth, in normal conditions - out of pollution or confined space - at any altitude the percentage of oxygen is constant and very approximately 20%. Therefore we can consider that the partial pressure of oxygen, represented as P_x in our formula, is five times less than the atmospheric pressure P_{tot} ; and this, independently of the altitude.

2.2 How to increase artificially the partial pressure of oxygen

Considering equation 1, the partial pressure of oxygen - our problem - can be increased by three

ways:

- *increase of the ambient pressure P_{tot}*
- *increase of the concentration of oxygen in air V_x*
- *decrease of the total volume V_{tot}*

Let discuss now on these three possibilities. The first two are well-known and commonly used:

- *increase of ambient pressure* is the mechanism when using a hyperbaric chamber. Ambient pressure is increased by artificially blowing air into the chamber.
- *increase of the concentration of oxygen in air* is done while inhaling pure oxygen

Both methods have been experimented in extreme altitude and are commonly used in expeditions [2][3]. Nevertheless, these studied methods are probably more inconvenient than advantageous, and often difficult, if not impossible, to implement and operate for a standard mountain practitioner:

- In case of a sub-aquatic accident, an hyperbaric chamber is necessary, and is the right therapy to apply. The full body is put again in higher pressure to avoid or minimize barotraumas [6]. These phenomena are well-known from scuba-divers, but in our opinion the use of a hyperbaric chamber is inadequate and over-dimensioned in case of AMS. Nevertheless, even if efficient, disadvantages are numerous, as the weight and volume for transport, difficulty of use at high altitude, problem with vomiting patient, and the non-possibility of assistance in case of degradation of the health state of the victim - the chamber being only for one person [7][8].
- Pure oxygen inhalation is very efficient [9], as it theoretically increase the partial pressure of oxygen by a factor of 5. But again, this therapy is difficult to provide within usual mountain activities.

The third way is our proposed method:

decrease of the total volume of air inside the lungs to increase the partial pressure of oxygen

3. Technique description

An easy way to artificially increase the pressure inside lungs, is by “thoracic cage embracing”. This method, easy to implement, implies only one assistant to help the victim suffering of AMS to quickly recover.



- the assistant sits behind the victim. The victim therefore sits comfortably in front of the assistant using the assistant chest as a back chair [fig. 1]
- the assistant intertwines both arms around the victim chest
- the victim inhales slightly over normal and hold his breath for about 3 seconds
- the assistant exerts a pressure with his arms while the victim hold his breath

Common sense using this empirical approach, helps to understand the following considerations:

- the victim breathes slowly, without effort
- the breath-in, slightly exaggerated, should not be too deep; as well as the expiration
- rhythm is about 6 to 8 cycles per minute
- the assistant should put the “right” pressure

Here is the next questioning: “what is the right pressure”. Let's try to estimate a reasonable pressure, first using a physical approach, then physiological one, to finally conclude empirically as Fernand Raynaud in his sketch “Après un coup de feu, combien de temps met le fusil à refroidir”.

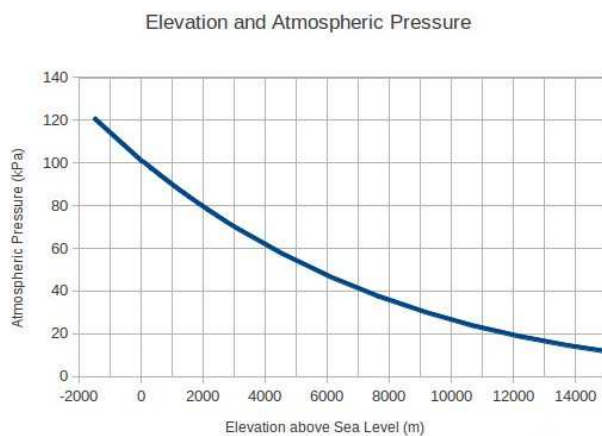
Physical approach

The local atmospheric pressure depends on several factors, as the gradient temperature, the water vapor concentration, the wind pattern (weather conditions) and the altitude. For simplification only the altitude will be considered, pressure being less sensible to other factors. We can therefore consider that the atmospheric pressure decreases exponentially with the altitude, according to the following approximation. This approximation is fully justified in our range of elevation:

$$P = P_0 \exp(h / h_0) \text{ [eq. 2]}$$

with:

- P the calculated pressure
- P₀ the atmospheric pressure at sea level (h = 0), 1 atm or 1013 hPa
- h the altitude
- h₀ the scale height : approximately 7000m



The local atmospheric pressure, compared to sea level pressure, is therefore approximately:

- 30% less at 3000m
- divided by 2 around 5500m
- less than .32 atm. over 8000m

Furthermore, considering for a perfect gas the theory: *volume time pressure is constant*, expressed by the formula:

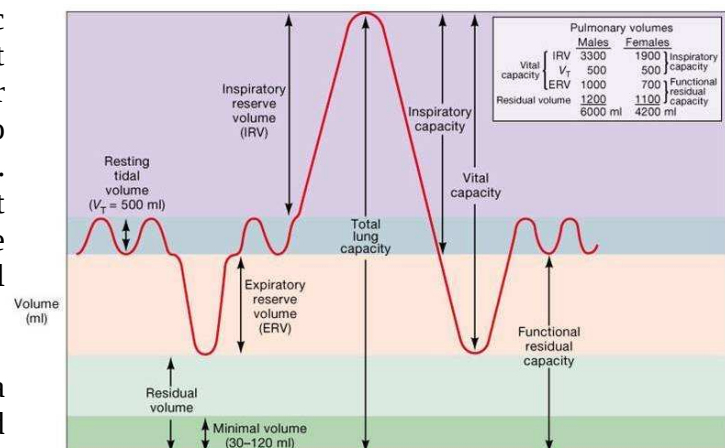
$$P \times V = \text{Cste} \text{ [eq. 3]}$$

for the same quantity of air, a decrease of x% of volume provides an increase of x% of the gas pressure. According to equation 2, at an altitude of 3000m, we can estimate that a compression of the thoracic cage of 30% will simulate sea level conditions.

Physiological approach

Is a compression of 30% of the thoracic cage reasonable? In average, for an adult human male, by normal breathing, air contained in lungs varies from 2200 to 2700ml - the resting tidal volume (V_T). The total lung capacity (TLC) is about 6000ml and by forced expiration, volume can decrease to 1200ml - the residual volume (RV).

It is therefore reasonable to estimate a volume of 3500ml after a slight forced inspiration, and a possible decrease of this



volume to 2200ml - the functional residual capacity (FRC) - after breath holding and artificial compression of the thoracic cage.

Considering this case, a rough calculation gives, by embracing compression, a decrease of volume inside lungs of about 20 to 30%:

$$\text{Volume decrease} = 1 - (2200/3500) = .28 = 28\%$$

and as demonstrated, this volume decrease implies an artificial increase of the partial pressure of oxygen in the same ratio. Applied to an altitude of 3000m, this diminution of 30% of the volume of air contained in lungs compression, brings back artificially the victim to the sea level conditions.

Empirical approach

As no scientific measurements has been done to estimate the ratio of compression of the thoracic cage, the above empirical and theoretical estimations remain hypotheses. And, in the following experiments, the right compression ratio used has been driven by the victim sensations.

While using the embracing method, the communication between the victim and the assistant is essential. Everything is just about feeling and comfort. As during physiological re-education and while hard training anyone can feel “good pains” of which you can work on, and “bad pains” where your body advises you to stop the exercise. The same way, every time the embracing method has been applied, the victim has always been able to give the right instructions to the assistant.

4. Results



This technique has been tested several times, notably during skitouring activities – backcountry skiing in American English – at CAF-RSF [10]. The method was applied while staying overnight at high altitude, when symptoms of ACM were obvious: headache, fatigue, cough, nausea or vomiting. Once the technique was also used after climbing the Bishorn (4153m), Valais, Switzerland, and a strong effort to ski down back to Cabane du Tracuit (3275m).

In each case, 5 to 10 minutes of artificial increasing of air pressure in the lungs were sufficient for the victim to recover, allowing either a comfortable night at the same altitude and fulfilling the programme the next day, or a safe descent, skiing down back to the valley.

5. Conclusion

For mountain adepts, we have provided evidence of a new technique for treatment - and probably prevention – of acute mountain sickness. This technique, named here “thoracic cage embracing”, is easy to operate and shows significant improvements of the patient physical condition within ten minutes. If results presented are impressive, the purpose of this paper is to initiate further research inside a scientific structure.

The study, based on personal experience is lacking of scientific rigorism. Experiments were processed only on a single specimen, without scientific measurements, with a repetition which does

not permit any statistics. Risks regarding the compression of the thoracic cage should be addressed, especially concerning barotrauma. Measurements regarding lung pressure and concentration of gases in blood should be performed.

Several other questions remain opened and should serve as a focus to future research. A protocol has been proposed for AMS treatment, and it should be possible to develop one for prevention. The possibility to apply the technique over a longer period, as well as a confection of a device to supply the role of the assistant.

To conclude, the thoracic cage embracing technique opens new hope to common mountain adepts suffering easily of AMS. But anyone should not forget for his own health and security, the recommendation to lose altitude as soon as possible, whenever severe AMS symptoms appear.

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Figures

- 1.
- 2.
- 3.

Pictures

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