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CONSENSUS STATEMENT OF THE UIAA MEDICAL COMMISSION

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Portable Hyperbaric Chambers

Intended for Doctors, Interested Non-medical Persons
and Trekking or Expedition Operators

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1 Introduction

Portable hyperbaric chambers are designed as lightweight equipment to be used for emergency treatment of severe cases of acute mountain sickness (AMS), high altitude pulmonary oedema (HAPE), and high altitude cerebral oedema (HACE). The devices must be inflated or pressurized by hand or foot pumps. The mechanism of action is a rapid pressurization of the patient (increase of oxygen pressure) which simulates a descent of about 1500 to 2500 m.

2 Principles and Safety Management Concerning High Altitude Diseases

- Prevention of altitude diseases is the “Gold Standard”!
 - Prevention is better than the best treatment!
 - Plan sensible altitude profiles giving adequate acclimatization!
- Hyperbaric chambers should not be used in cases of mild AMS for either prevention or treatment.
 - If a bag has to be used stay another day at the respective altitude to acclimatize properly! Pressurized bags are NOT designed to treat mild symptoms of AMS or to facilitate continued ascent just to proceed the next day without adequate acclimatisation.
- There is no doubt, that hyperbaric chambers relieve symptoms of severe altitude diseases (AMS, HAPE, HACE)
 - But hyperbaric bag treatment only gives relief, buying valuable time.
 - Use that time to retreat from altitude.
 - The patient should never retreat unaccompanied.
 - During retreat take the chamber with you in the case of rebound
 - To avoid rebound symptoms in severe cases the patient should not walk – not even for a short distance – unless it is totally impossible to avoid the patient walking for the vital descent. He / she should be as exertion-free as possible.

- Bag use is a procedure for emergency treatment only.
 - It is not a substitute for descent or evacuation to lower altitude.
- The strategy in case of severe altitude disease should be as follows:
 1. Descent or evacuation to lower altitude, at least to the altitude where the patient felt well before.
 - Try to descend for at least 300-500m
 2. Oxygen / drugs should only be used to buy time for the vital descent (for details see {Kupper, 2008 #4094}).
 3. Hyperbaric chamber (must be combined with 1. & 2., see also UIAA MedCom Consensus Paper No.2 “Emergency field management of AMS, HAPE, and HACE” [1])
- Preconditions of the personnel using the chamber:
 - Only trained persons should use the chamber! Severe complications (e.g. severe hypercapnia, eardrum rupture etc.) have been reported after use by untrained persons.
 - A chamber demonstration exercise, followed by all group members performing this exercise under experienced supervision, should be undertaken before ascent.
 - Handling a hyperbaric chamber is very strenuous, especially at high altitude. Therefore the practical upper limit for its use is about about 7000 m. Above this, treatment with oxygen and drugs may be preferred whilst descending.

3 Where to take a hyperbaric chamber?

- There is no data that supports the belief that a hyperbaric chamber must be carried by all organised trekking or expedition companies. There are no laws which requiring chambers, and nor is there any related litigation to date. A careful ascent profile is more important!
 - If the trekking companies follow proper acclimatization profiles such chambers are unnecessary for nearly all trekking routes and many expeditions [2], [3].
- A portable hyperbaric chamber should be specifically considered when visiting a high altitude area without a quick and easy possibility of descent to lower regions such as a high altitude valley where descent is impossible without initial ascent..
 - It should be considered, for instance, for camps situated in a saddle or valley at high altitude, where a descent is impossible without an ascent.
 - If a chamber is to be taken, normally its position is best at the highest camp for two main reasons:
 1. The incidence of altitude induced health problems is more likely there, and

2. Transporting a chamber down to a lower camp is much easier and quicker than ascending with the chamber to a high altitude camp. This decision is influenced by many other factors and must be integrated into the expedition's safety management.

4 How to use hyperbaric chambers

- Hyperbaric chamber treatment should be performed as follows:
 - Combine with drug therapy (dexamethasone for severe AMS / HACE, nifedipine slow release for HAPE)
 - Check the patient's ability to pressurize (pop) his / hers ears before entering the chamber! ENT problems are common at altitude. Inflate slowly and check whether the patient pressurizes (pops) their ears (if not: slow down!).
 - If the patient reports ear problems use decongestant spray (eg Xylometazoline) before entering the bag, wait 5 –10 min until the onset of the spray's effectiveness takes place, and take the spray into the bag.
 - Patients should urinate or defecate before entering the chamber (if necessary).
 - Position patient in chamber so they can see you and you can see the patient's pulse oximeter and altimeter (if applicable and available).
 - Pressurize for 60 to 120 minutes. After 120 minutes no further improvement can be expected. For pressurization pump the bag until the pop-off valve hisses.
 - There is no upper limit for the duration of chamber therapy. Normally symptoms of AMS will not further ameliorate after two hours, but in a survival situation a patient may stay pressurized until evacuation is possible.
 - Although there are no data observations indicate that a longer therapy may be of advantage when the patient suffers from HAPE or HACE.
 - Always take care to pump additional air into the pressurized chamber (about 40 l/min, resp. pump 8 – 12 times / min)! This does not only provide constant pressure but also maintains high oxygen and low carbon dioxide partial pressure and avoid CO₂ intoxication.
 - Survey the patient's SaO₂ with pulse oximeter (if available). The device should be visible through the bag's window.
 - HAPE patients may not be able to tolerate lying down in a flat body position. Use the terrain to support their body at an angle of about 30° with their head uphill.
 - In severe cases additional oxygen breathing inside the chamber at a flow- rate of 4 – 6 l/min from a bottle inside the bag and applied via

- mask may further improve the symptoms (within the chamber this causes no danger of fire or explosion).
- If symptoms are reduced after 60 to 120 minutes, try to descend. Take the hyperbaric chamber with you for an additional chamber session in case the symptoms should worsen again!
 - There are experiences from numerous cases – although no systematic scientific data – that the amelioration of altitude related symptoms after a therapy in a hyperbaric chamber is limited – if any. However, if descent should be impossible the team therapy in the hypobaric chamber should be continued if this is possible by the team (exhaustive work at high altitude!)
 - If symptoms are not reduced after 120 minutes, complications or additional diagnoses must be considered (thromboembolism, infection, sunstroke, hypothermia, severe dehydration, and others).
 - In case of doubt, treatment with hyperbaric chamber can be tried, because there is no contraindication except that resuscitation is not possible until the patient is removed from the bag.
 - Unconsciousness is not a contraindication if the body position is appropriate (recovery position).
 - If the patient reports pressure or pain inside the ears while deflating the chamber, slow down immediately. If the patient cannot equalize the pressure, decrease the chamber's pressure by about 25% and then ask the patient to "pop" his ears.
 - Therapy with descent, oxygen and drugs is always preferred, especially in the case of an unconscious patient where monitoring the patient in the bag will be difficult..
 - **Note:** The amount of oxygen available is limited whereas the use of the hyperbaric chamber is only limited by the human power to pressurize and to ventilate it!
 - Ensure a comfortable temperature!
 - Always insulate the chamber from ground, cold or frozen surfaces! In cold environment the patient must be insulated from cold inside the chamber by sleeping bag or clothes.
 - Do not use down clothes to insulate the patient inside the chamber. Because of the high humidity inside the bag. Fleece material is preferable.
 - Avoid direct sunlight or provide shade! Direct sunlight may significantly heat the chamber to very uncomfortable levels.
 - If the chamber suddenly deflates by accident, the patient should avoid breath holding and exhale hard.
 - It will always be psychologically stressful for a patient in a bag. Always keep in contact with the patient! The patient should know always what is happening around or with him or her.
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- Ensure an adequate supply of fresh air. Do not use the bag inside closed tents, especially if stoves or fuel fired lamps are in use.

5 Results of treatment / further proceeding

- Controlled and uncontrolled studies show a rapid and – in most cases – a decrease of symptoms which lasts for some hours.
- However, when staying at altitude, most patients will suffer from a rebound, in most cases within 12 hours.
- To date, there is a lack of controlled studies of hyperbaric bags in severe cases of HAPE or HACE, but field results show good results even with severe cases.
- After some days of complete recovery a very cautious re-ascent may be tried (e.g. [4]).
 - Take care for perfect acclimatization. The altitude profile should be more “defensive” than it was before.
 - Monitor any symptom of altitude disease and descent immediately to the last altitude where you felt completely well if symptoms should arise.
 - Never re-ascent while taking any drugs which may mask symptoms of altitude disease, especially dexamethasone
 - Acetazolamide may be used with caution in such a situation
 - **Note:** if there should be any doubt about the health status do not ascent again! Return home and contact a physician who is trained in altitude medicine for further advice.

6 Problems with hyperbaric chambers

- CO₂-intoxication may result from low airflow
 - Ensure adequate ventilation of the chamber (>40 l/min, see above)!
- AMS / HACE: nausea and vomiting inside the bag.
 - Take a plastic bag inside the chamber
 - Anti-emetic drugs may be used before entering the chamber
- HAPE: patients may not tolerate flat position.
 - Use the terrain to put the upper body in elevated position
- Anxiety / claustrophobia
 - Keep in permanent visible and auditable contact with the patient
 - Place the bag and the patient in a position that the patient can look outside at any time and in a comfortable position.

- Try to explain him / her that the situation may be psychologically uncomfortable for a while, but altitude disease may be life threatening. This means: the chamber is the better option.
- Pumping requires a considerable effort at altitude to maintain pressure and airflow.
- Leakage of the zipper, valves, or the bag itself
 - Carry the chamber with care and handle it properly.
 - Test the bag before every trip
 - Take duct/gaffer tape for repairs

7 Types of chambers

- GAMOW Bag
 - Cylindrical shaped, 2.5 x 0.6 m
 - Inflation / ventilation by foot pump
 - 12 pump strokes / min required to maintain pressure (+104 mmHg / +139 mbar) and to avoid CO₂ intoxication
 - Weight: 6.5 kg
 - Not easy to enter for a severely ill patient.
 - For details about costs etc. see www.chinookmed.com
- CERTEC Bag
 - Conical shaped, 2.2 x 0.65 m
 - Inflation / ventilation by hand pump
 - 8 pump strokes / min required to maintain pressure (+165 mmHg / +220 mbar) and to avoid CO₂ intoxication
 - Weight: 4.8 kg
 - Of all constructions this is the easiest to enter by a severe ill patient
 - For details about costs etc. see www.certec.eu.com
- Portable Altitude Chamber (PAC)
 - Mummy shape, otherwise (pressure / pumping) comparable to GAMOW bag (no pressure gauge).
 - Weight (incl. pump etc.) 8 kg
 - Entering the bag may be difficult for a non-cooperative patient.
 - For details about costs etc. see www.treccsafe.com.au
- TAR helmet (not yet available, but may be an alternative in future)
 - Small lightweight device (complete system less than 1 kg, pump included), under development (prototypes successfully tested).

UIAA MedCom Consensus Statement No.3: Portable Hyperbaric Chambers

- Since there are not yet sufficient data available (pressure, flow etc.), UIAA MedCom decided to wait before including a statement about the system.

8 References

1. Kupper, T, et al. *Consensus Statement of the UIAA Medical Commission Vol.2: Emergency Field Management of Acute Mountain Sickness, High Altitude Pulmonary Oedema, and High Altitude Cerebral Oedema*. 2008; www.theuiaa.org/medical_advice.html.
2. Kupper, T, D Hillebrandt, and N Mason, *Medical and Commercial Ethics in Altitude Trekking*. High Alt Med Biol, 2012. **13**(1): p. 1-2.
3. Goebbels, K, et al., *Cough and dyspnoea of an asthmatic patient at Mt. Kilimanjaro: a difficult differential diagnosis*. Travel Med Infect Dis, 2011. **8**(1): p. 22-8.
4. Litch, JA and RA Bishop, *Reascent following resolution of high altitude pulmonary edema (HAPE)*. High Alt Med Biol, 2001. **2**(1): p. 53-5.

9 Further reading

- Travel at High Altitude (several languages, available at: http://medex.org.uk/medex_book/about_book.php)
- T. Küpper, K. Ebel, U. Gieseler: *Moderne Berg- und Höhenmedizin*, Gentner Verlag, Stuttgart, 2010, ISBN 978-3-87247-690-6

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History of this recommendation paper

The first edition was written by P. Baertsch, F. Berghold, J.P. Herry, and O. Oelz (2000). During the same year it was modified by J. Milledge. At the UIAA MedCom Meeting at Snowdonia in 2006 the commission decided to update all their recommendations. The version presented here was approved at the UIAA MedCom Meeting at Adršpach – Zdoňov / Czech Republic in 2008.

The actual update was finished in spring 2012 and approved at the UIAA MedCom meeting at Whistler, Canada, in July 2012.