



HELICOPTER ESCAPE TRAINING FOR OFFSHORE WORKERS

Debbie Pestell, MD

Consultant in Hyperbaric and Diving Medicine

OEMAC 35th Annual Scientific Conference

11-13 Jun 2017

DISCLOSURE STATEMENT

- I have no financial relationships or conflicts related to this talk to disclose
- I currently serve as the President of the Canadian Undersea and Hyperbaric Medical Association (CUHMA), but receive no salary
- I serve on a Specialty Committee with the Royal College of Physicians and Surgeons of Canada developing educational standards for physicians training in hyperbaric and diving medicine; I receive no remuneration

OVERVIEW

1. Introduction
2. Helicopter Underwater Escape Breathing Apparatus (HUEBA) in Helicopter Underwater Escape Training (HUET)
3. Risks and Mitigation
4. Pulmonary Barotrauma and AGE
5. Medical Screening and Contraindications for HUEBA in HUET
 - asthma (reactive airways)
 - COPD and emphysema
 - pneumothorax
 - Tb and sarcoidosis
6. Conclusion

INTRODUCTION

- significant oil and natural gas deposits in Atlantic Canada
 - multiple offshore oil and gas platforms in Nova Scotia and Newfoundland employ hundreds of personnel
- transportation to and from platforms is via helicopter – open ocean transit
 - basic survival training (BST) is mandated part of safety training
 - this includes Helicopter Underwater Escape Training (HUET)



Hibernia Platform, Newfoundland



Deep Panuke, Nova Scotia

HUEBA in HUET

- several initiatives implemented over past 10 y by CAPP (Canadian Association of Petroleum Producers) to increase likelihood of surviving helicopter ditching
 - in Jan 2006, use of compressed gas to increase chance of survival introduced for first time
 - Helicopter Underwater Escape Breathing Apparatus (HUEBA) to be used on survival suits and in BST
- medical task group could not reach consensus regarding medical screening
- in fall 2007, new survival suits introduced offshore without HUEBA attached



HUEBA in HUET

- although the military safely using compressed gas cylinders in helicopter escape training for many years, civilian offshore industry does not
 - no other oil and gas producing nation uses compressed gas in training (i.e. UK, Norway, Netherlands, USA)
- in Dec 2008, recommendation made to implement use of compressed air device with surface training
 - use of Shallow Water Egress Trainer (SWET chair) was to commence 1 May 2009
- then, on 12 Mar 2009, Cougar 491 crashed off coast of Newfoundland



SWET III - Survival Systems

Debbie L. Pestell

HUEBA in HUET

- loss of Cougar Flight 491 in Mar 2009 was tragic reminder that open-ocean helicopter transit is not without risk
 - 17 of 18 on board died
 - no fatal injuries on impact, all drowned
 - 5 never made it out of their straps
- drowning is primary cause of death during a helicopter ditching
 - Brooks et al, 2008; Clifford, 1996
- impact injuries often minor –
Shanahan, 2004



Photo Copyright: Transportation Safety Board of Canada.

Recovered parts of Cougar Flight 491

HUEBA in HUET

- fatalities usually a combination of inability to breath-hold during escape, and disorientation – Brooks et al, 2001
- even under the controlled conditions of HUET, it is difficult to breath-hold >15 sec
- during an accident in frigid, choppy Atlantic Ocean, ***cold shock response*** and panic would significantly reduce breath-hold time



Helicopter Underwater Escape Trainer

HUEBA in HUET

- ***cold shock response*** lasts for <1 min but can be deadly:
 1. initial automatic gasp reflex can lead to drowning if head underwater
 - response to rapid skin cooling
 2. physiological stress makes it *very* difficult to hold breath
 3. disorientation and panic
 4. dramatic increase in BP and work demand on the heart
- during controlled ditch, HUEBA could provide critical breaths of air until gasp reflex and hyperventilation pass, and person becomes oriented



Helicopter
Underwater
Emergency
Breathing
Apparatus

HUEBA in HUET

- in their crash investigation report, Transportation Safety Board (TSB) made 4 key safety recommendations
 - emergency breathing equipment on all flights where survival suits worn
 - still not used in training

'TRAIN LIKE YOU FIGHT!'



- main concern using HUEBA in training is risk of ***pulmonary barotrauma*** on ascent
- only one published report of an AGE following HUET using similar device in healthy RN pilot – Benton et al, 1996
 - follow-up investigations found no underlying lung pathology
 - full recovery following recompression

HUEBA in HUET

- in Feb 2015, CAPP Task Group concluded that compressed air could be safely integrated into HUET training
 - retained by CAPP to develop medical screening for compressed gas breathing as part of offshore medical, and develop physician training seminar
 - deemed unnecessary for CAPP doctors to be qualified diving physicians
 - training providers to develop competency based training using HUEBA in HUET
- full implementation of HUEBA in HUET began ***1 Jun 2016***
- in July 2015, Canadian Aviation Regulation mandated 'operators to provide HUEBA for each occupant onboard offshore Cdn flights'

RISKS AND MITIGATIONS

- we must be careful not to become *risk averse* but rather *risk aware* - all training comes with risk, but risk can be mitigated

Risk

- underlying lung pathology that could cause gas trapping on ascent and lead to an arterial gas embolism (AGE) - *medical*

Mitigation

- enhanced respiratory screening during CAPP medical (eg. hx of asthma, COPD, pneumothorax, etc.)
- chest x-ray and/or spirometry, if indicated, based on screening questionnaire
- restrictions on use of compressed air if medical contraindications exist

RISKS AND MITIGATIONS

Risk

- breath-holding on ascent due to panic with resultant AGE - *training*
 - those that panic and breath-hold on ascent are also more likely to panic during escape and drown

Mitigation

- this is a trainable risk done through periodic training with the HUEBA equipment
 - 4 training facilities - 2 in St. John's, 2 in Halifax
- access to a recompression chamber within 1 h of pool where HUEBA in HUET is conducted
 - QEII Hyperbaric Medicine Unit in Halifax is <30 min from trainer
 - Health Sciences Centre Hyperbaric Medicine Unit in St. John's is <45 min from trainer

BAROTRAUMA

- barotrauma refers to tissue damage that occurs within closed spaces in the body as a result of the expansion or contraction of gases (IAW Boyle's Law)
- because gas cannot enter or escape a closed space, a pressure differential develops with resultant tissue damage
- barotrauma can be either pulmonary or non-pulmonary
 - non-pulmonary barotrauma is quite common
 - pulmonary barotrauma is equally rare

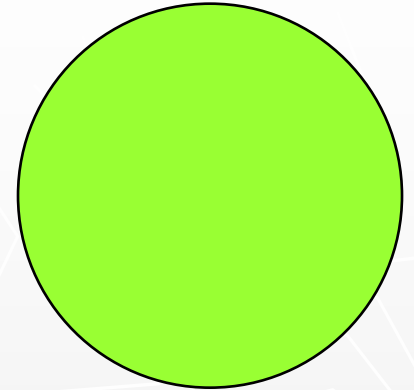
BAROTRAUMA

Boyle's Law

$$P_1V_1 = P_2V_2$$

at a constant temperature, the volume of a gas will vary inversely with the absolute pressure

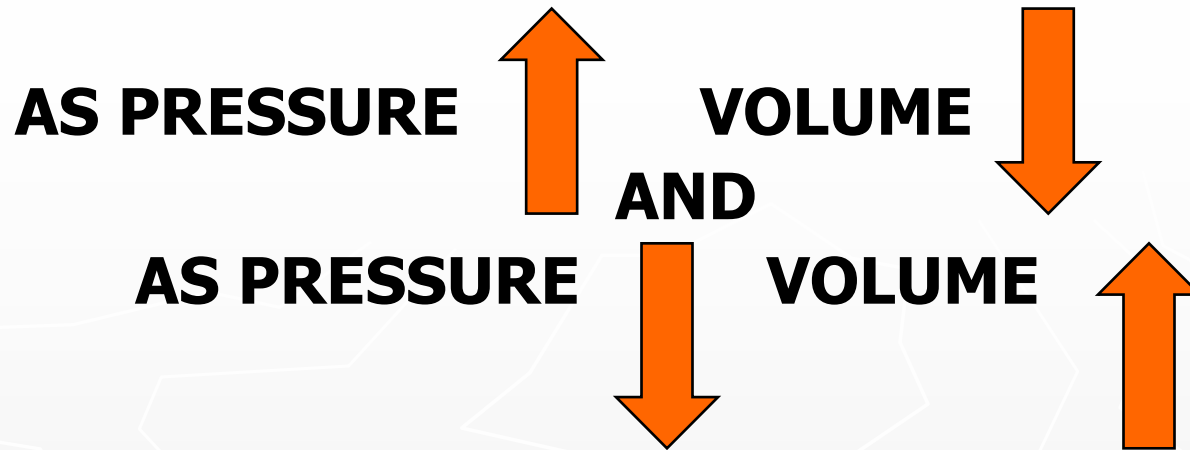
1 ATA
25 Litres



5 ATA
5 Litres



BAROTRAUMA



- barotrauma is primarily a shallow water problem – it only takes **46 mmHg** of pressure (<1 msw) to cause tissue damage
 - the largest volume changes occur near the surface

e.g., 40 m to 30 m = a volume increase of 25%
(5 ATA / 4 ATA = 1.25:1 ratio)

10 m to the surface = a volume increase of 100%
(2 ATA / 1 ATA = 2:1 ratio)

PULMONARY BAROTRAUMA

- pulmonary barotrauma occurs when gas trapped in obstructed airways *on ascent* causes the lung to rupture
- alveolar sacs dilate and rupture when trans-pulmonary pressure exceeds *80 mmHg*
- shallowest depth on record is 3.47 ft (1 m)
 - has occurred in backyard swimming pools using SCUBA
- deepest depth during HUET using HUEBA is 1.8m (6 ft), so the possibility for pulmonary barotrauma exists

PULMONARY BAROTRAUMA

- when breathing compressed air, pulmonary barotrauma can occur due to:
 1. breath-holding on ascent (panic) - ***training issue***
 2. after normal ascent in those with underlying lung pathology - ***medical issue***
 - a) mucous plugs 2° to inflammation (eg. RAD/asthma)
 - b) COPD, emphysema
 - c) non-ventilating bullae or blebs (eg. previous pneumothorax)
 - d) infection (eg. TB, sarcoidosis)
 - e) undiagnosed tumors

PULMONARY BAROTRAUMA

- once the elastic limit of the alveoli is reached, lung injury will occur in one of 3 locations:

1. pleural space

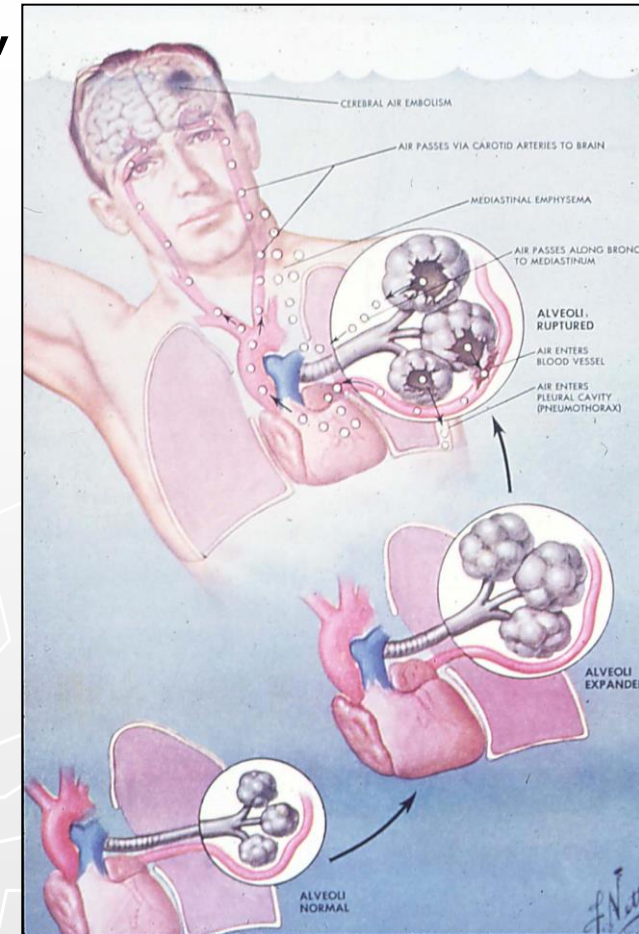
- within the chest cavity - a *pneumothorax*
- uncommon, but can occur with underlying lung pathology

2. interstitial space

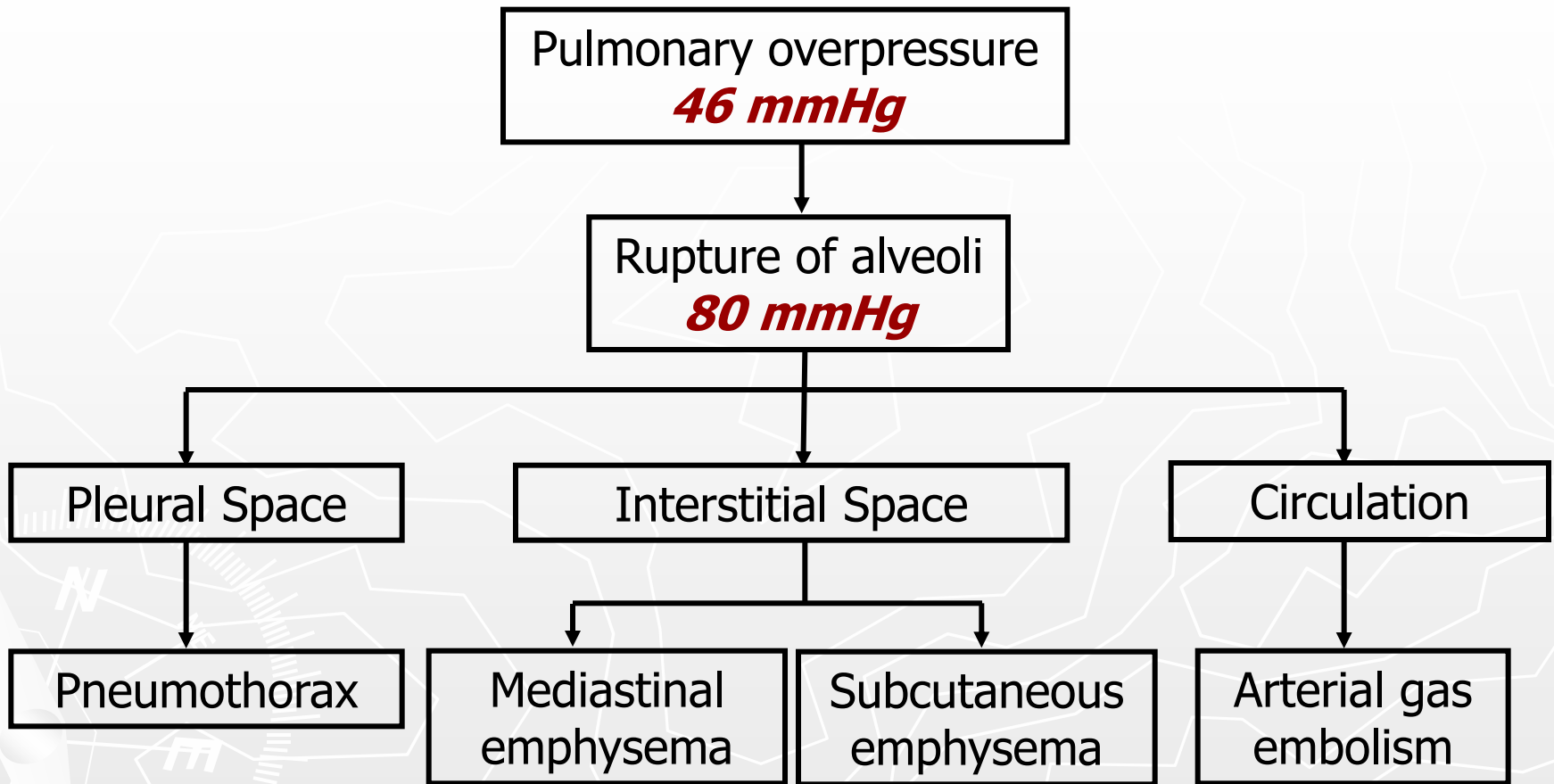
- tissue planes within the lung
- gas travels into space around the heart (*mediastinal emphysema*) or tissues of the neck and larynx (*subcutaneous emphysema*)

3. circulation

- gas bubbles move from right (venous) to left (arterial) side of the heart causing an *arterial gas embolism* (AGE)



PULMONARY BAROTRAUMA



ARTERIAL GAS EMBOLISM (AGE)

- **AGE** can occur as a result of any environmental gas introduced into the systemic circulation ('air stroke')
 - seen in divers - uncontrolled ascent to surface with breath hold
 - iatrogenic **AGE** may occur due to cardiopulmonary bypass accidents, bronchoscopy, hemodialysis
- clinical presentation can be dramatic and life-threatening:
 - sudden LOC
 - bloody, frothy sputum
 - convulsions/seizure
 - cessation of breathing
 - diffuse CNS dysfunction
 - possible paralysis

ARTERIAL GAS EMBOLISM (AGE)

MANIFESTATIONS OF AGE

85% of symptoms occur within
5 min of surfacing

100% of symptoms occur within
10 min of surfacing

- beyond 1 h, the diagnosis of **AGE** very doubtful

MEDICAL SCREENING FOR HUEBA IN HUET

- CAPP introduced enhanced medical screening for compressed gas breathing for all offshore personnel on 1 Jun 2016
 - 5 additional screening questions incorporated into current offshore medicals
 - must be completed *prior* to undergoing HUEBA in HUET
- since CAPP medicals are biennial, HUEBA in HUET will be gradually implemented over a 2 y period
- disposition of those found to be medically unfit to undergo HUEBA in HUET to be decided by the operators
 - if otherwise medically fit to work offshore, no repercussions aside from unfit training with HUEBA

MEDICAL SCREENING FOR HUEBA IN HUET

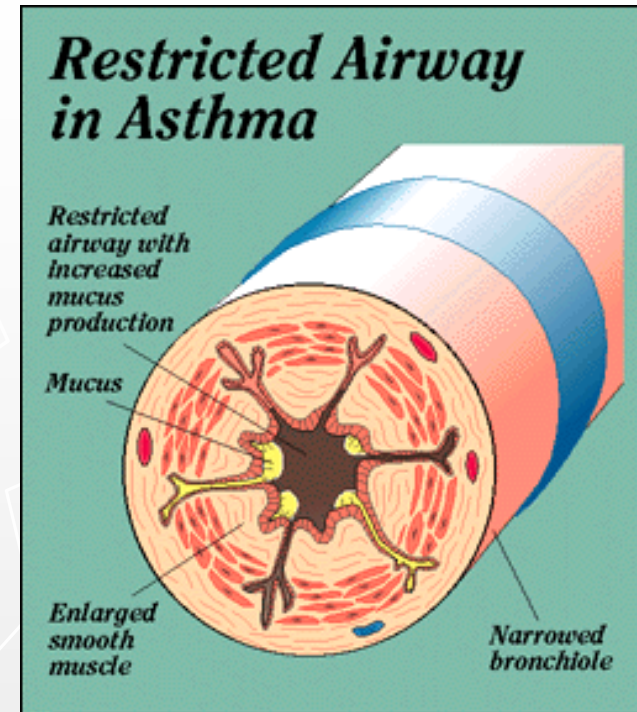
Compressed Gas Breathing Questions

Do you have any personal history of:

- | | YES | NO |
|--|--------------------------|--------------------------|
| 1. Asthma or RAD (reactive airways disease), including any history of childhood asthma | <input type="checkbox"/> | <input type="checkbox"/> |
| 2. A history of COPD or emphysema | <input type="checkbox"/> | <input type="checkbox"/> |
| 3. Current or past use of inhalers/puffers for asthma, COPD or respiratory infections | <input type="checkbox"/> | <input type="checkbox"/> |
| 4. Spontaneous or traumatic pneumothorax | <input type="checkbox"/> | <input type="checkbox"/> |
| 5. Tuberculosis, sarcoidosis or pulmonary fibrosis | <input type="checkbox"/> | <input type="checkbox"/> |

ASTHMA (REACTIVE AIRWAYS)

- asthma (RAD) is characterized by intermittent airway inflammation and hyper-reactivity leading to bronchoconstriction and wheezing
- common triggers include cold air, exercise, respiratory infection, allergens and stress
- narrowed bronchi and excessive mucus production can lead to gas trapping on ascent during HUEBA with resultant pulmonary barotrauma (especially AGE)



ASTHMA (REACTIVE AIRWAYS)

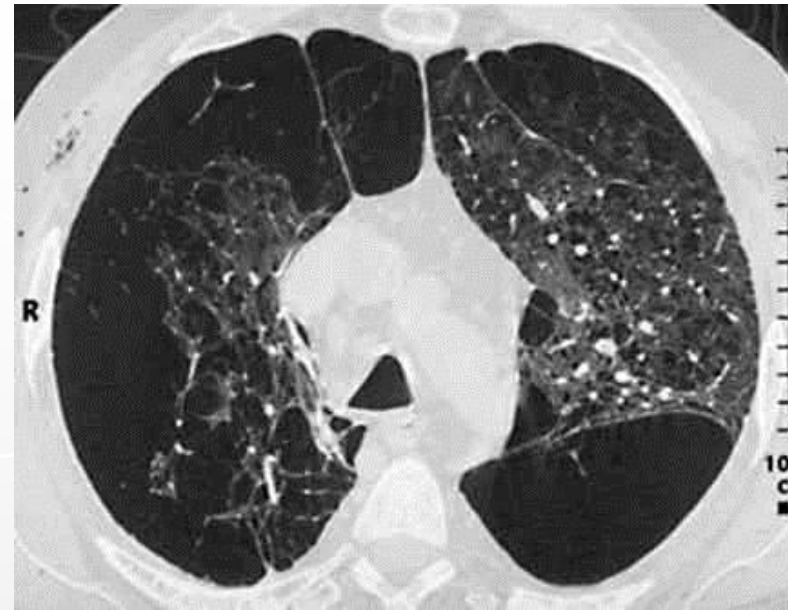
- severity of asthma ranges from mild to severe
 - occupational disposition requires clarification of where on the spectrum each individual lies
- worrisome historical features:
 1. exercise or stress-induced asthma
 2. regular medications required for symptomatic control, especially with frequent use of rescue inhalers
 3. previous hospitalization +/- intubation
- any individual with a positive history for asthma after age 12 requires spirometry
 - chest x-ray/CT scan is not helpful in assessment of asthma

ASTHMA (REACTIVE AIRWAYS)

- spirometry results:
 1. a normal FEV₁ **DOES NOT** rule out risk for gas trapping
 2. small airways function is the most critical for those breathing compressed gas
- minimum results of spirometry for HUEBA in HUET:
FEV₁ ≥ 80% predicted
FEV₁/FVC ≥ 70% predicted
FEF 25-75% ≥ 50% predicted
- mild asthmatics may be considered fit for HUEBA in HUET if:
 1. screening spirometry is normal
 2. free of all symptoms and does not deteriorate with exercise
 3. well controlled with/without inhaled steroids, and no regular use of rescue inhalers

COPD AND EMPHYSEMA

- chronic obstructive lung disease (COPD) is characterized by chronic inflammation of bronchi and airflow obstruction
- emphysema and chronic bronchitis are two most common conditions contributing to COPD
- cough, inflamed bronchi +/- mucous production, and damaged alveoli all increase risk for gas trapping and pulmonary barotrauma
- COPD caused by smoking in 80-90% of cases - many continue to smoke after diagnosis



Advanced emphysematous changes on CT scan

COPD AND EMPHYSEMA

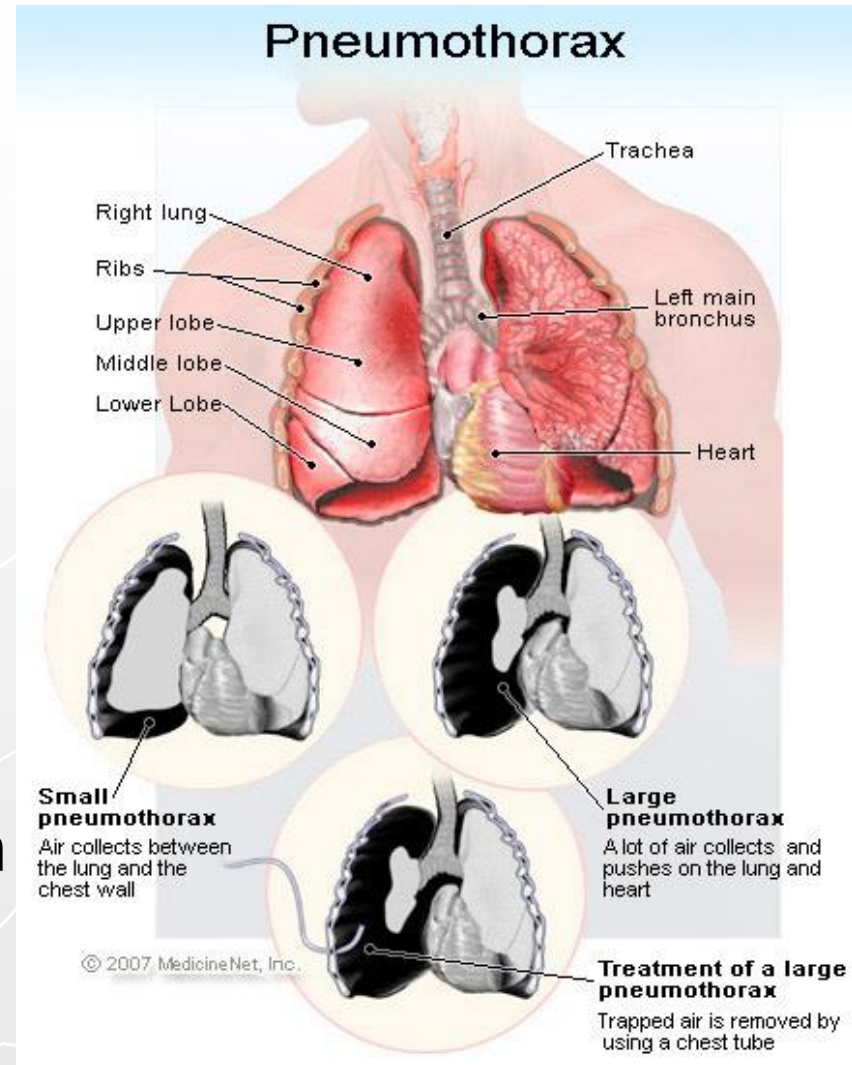
- whereas lung changes caused by asthma are reversible, lungs of individuals with COPD *never* return to normal
 - risk for pulmonary barotrauma is always present and may continue to increase
- those requiring further investigation include:
 1. previous diagnosis of COPD
 2. long-term smokers with sputum production and chronic cough
 3. those with hyper-resonant breath sounds and/or wheezing on chest exam
 4. history of recurrent respiratory infections requiring puffer use
- investigations may include spirometry, chest x-ray or CT scan based on clinical judgement
 - lung bullae, blebs or cysts are an *absolute contraindication* for compressed gas breathing and HUEBA in HUET

COPD AND EMPHYSEMA

- minimum results of spirometry for HUEBA in HUET:
 $FEV_1 \geq 80\%$ predicted
 $FEV_1/FVC \geq 70\%$ predicted
 $FEF_{25-75} \geq 50\%$ predicted
- those with mild COPD may be considered fit for HUEBA in HUET if:
 1. they are no longer smoking
 2. screening spirometry is normal
 3. no wheezing on exam
 4. well controlled with/without inhaled steroids, and no regular use of rescue inhalers
 5. no blebs, bullae or cysts on CT scan

PNEUMOTHORAX

- a pneumothorax may be traumatic (from a knife wound or fractured rib), or spontaneous
- recurrence rates for spontaneous pneumothorax are high:
 - 33% within the first 2-3 years
 - 30% after 3 years
 - 60% long-term risk
- likelihood of another pneumothorax occurring during HUEBA in HUET, *extremely unlikely*



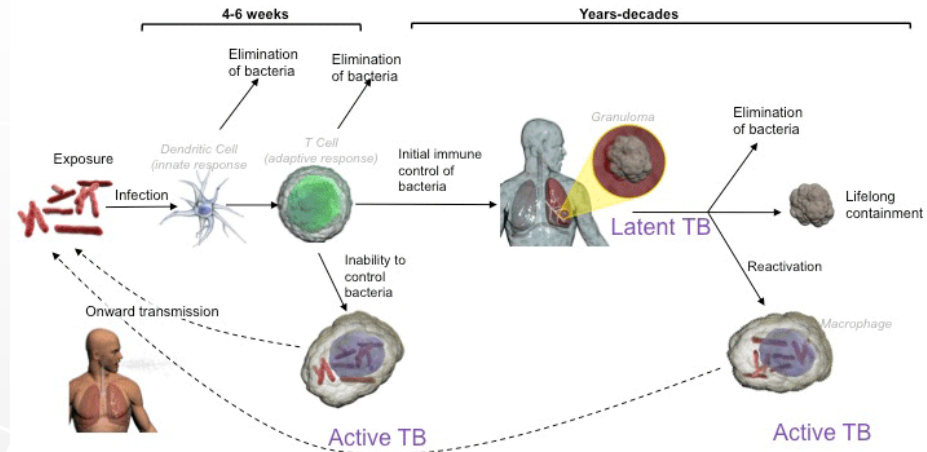
PNEUMOTHORAX

- more likely, other air-filled blebs and bullae in the lungs could rupture and cause an AGE on ascent during HUEBA in HUET
- following a traumatic pneumothorax, scarring and blebs may increase the risk for AGE on ascent during HUEBA in HUET
- recommendations:
 1. hx of spontaneous pneumothorax is an ***absolute contraindication*** to undergoing HUEBA in HUET
 2. if there is a FHx of spontaneous pneumothorax, CT scan to R/O presence of blebs
 3. if a history of traumatic pneumothorax, spiral or high resolution CT scan needed to R/O any scarring or blebs

TB AND SARCOIDOSIS

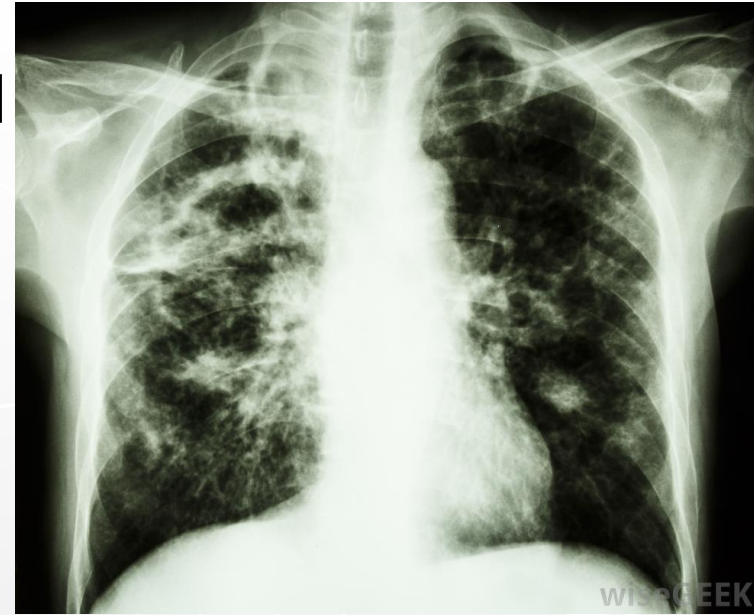
- TB is a chronic bacterial infection usually affecting the lungs
- most persons infected with *Mycobacterium tuberculosis* harbour the bacterium without symptoms (latent TB)
- 2-8 weeks after infection the immune system walls off the infected cells, and TB becomes dormant

Natural history of TB infection



TB AND SARCOIDOSIS

- most people heal and bacteria dies off, however walled-off tubercles and granulomas produce areas of lung collapse and gas trapping
- this increases the risk for AGE on ascent during HUEBA in HUET
- if there is a history of TB exposure, chest x-ray required to R/O granulomas



Granulomas secondary to TB infection

TB AND SARCOIDOSIS

- sarcoidosis is a systemic inflammatory disease
 - over 90% of patients have lung involvement
 - 50% develop permanent pulmonary abnormalities
 - 5-15% have progressive fibrosis of the lung parenchyma
- it is primarily an interstitial lung disease in which inflammation affects alveoli, small bronchi and small blood vessels
- any patient with a history of sarcoidosis must be carefully evaluated with CT scan and spirometry
 - high risk for gas trapping and AGE on ascent with HUEBA in HUET

CONCLUSIONS

- HUEBA in HUET provides experiential training in the escape from a submerged helicopter
 - it provides realistic input and physiological effects and may one day be life-saving
- since its full implementation 1 Jun 2016, approximately 500 offshore personnel have been trained using compressed gas air cylinders
 - no medical incidents or training accidents have occurred
- the UK, Norway and the Netherlands are closely monitoring our results

QUESTIONS



Frank Kook
Frank Kook Photo

12 Jun 2017

Debbie L. Pestell

REFERENCES

- Brooks CJ, MacDonald CV, Donati L, Taber MJ. 'Civilian helicopter accidents into water: Analysis of 46 cases, 1979-2006. Aviat Space Environ Med. 2008; 79(10): 1-6.
- Brooks C J, Muir HC, Gibbs PNG. 'The basis for the development of a fuselage evacuation time for a ditched helicopter'. Aviat, Space Environ Med. 2001; 71: 879–888.
- Benton PJ, Woodfine JD, Westwood PR. 'Arterial gas embolism following a 1m ascent during helicopter training: a case report'. Aviat Space Environ Med. 1996; 67: 63-4.
- Clifford, WS. 'Helicopter crashworthiness, Study I: A review of UK military and world civil helicopter water impacts over the period 1971-1992'. CAA Paper 96005, Civil Aviation Authority. 1996.
- Hui, CPS. 'Acute Otitis Externa'. Paediatr Child Health. 2013; 18(2): 96-98.
- House JW, Toh EH, Perez A. 'Diving after Stapedectomy: Clinical Experience and Recommendations'. Otolaryngol Head Neck Surg. 2001; 125(4): 356-360.

REFERENCES

- MacFie, DD. 'ENT Problems of Diving'. Med Serv J Canada. 1964; 20: 845-861.
- Shanahan, DF. 'Human tolerances and crash survivability'. Paper presented at RTO HFM Lecture Series on '*Pathological Aspects and Associated Biodynamics in Aircraft Accident Investigation*', Madrid, Spain. 2004; RTO-EN-HFM-113.