### PARIS SOF CMC 2022 - Session 5A SOF physical constraints



# MEDICAL SUPPORT OF HIGH-ALTITUDE MILITARY PARACHUTING







# O PLAN

- 1. High-Altitude (HA) military parachuting
  - ✓ Definition
  - ✓ Environmental constraints
- 2. Environmental pathologies
  - ✓ Stress
  - ✓ Extrem temperature range
  - ✓ Altitude hypobaria pathologies
- 3. Medical regards for prevention & treatment

### 4. Precautionary principle Vs tyranny of standards





Morand et al,, The medical constraints of high altitude for the military parachutist at very great height. International review of the Armed Forces Medical Services, , 2021

# HIGH-ALTITUDE MILITARY PARACHUTING

### ✓ How does it usually work ?

- HA High Opening HAHO > HALO Low Opening
- By night for operationnal use
- Piloting the canopy according his flight plan until landing zone



### ✓ Why using <u>HA</u> parachuting ?

- The highest & the farthest your aircraft fly, the stealthiest you are
- The higher you jump, the farther you can land
- Safety & Tactical advantage
- Just a 3D way of tactical infiltration for a operation on the ground....



### $\checkmark$ Activities at High-Altitude (HA):

- **> FL 120**
- France = très grande altitude SOTGH (vs grande altitude SOGH)

### ✓ Altitude reference = Fly Level (FL) :

- Standard of aeronautical measurement
- Altitude pression instead of Altitude heigh
  - $1hPa \simeq 28 ft$
- FL = Altitude-Pression / 100
  - > 1 feet (ft) = 0,3048 meter (m)
  - FL 120  $\simeq$  12 000 ft = 3650m



- ENVIRONMENTAL CONSTRAINTS OF HA

### When you climb, everything decreases, except the stress !

✤ Hypobaria : ↘ atmospherical / barometrical pressure (Pb)



# - ENVIRONMENTAL PATHOLOGIES

### ✓ STRESS



- Heart Rythm 
   A at each relevant moment & in complicated conditions
- Increasing of HR mitigated with HAHO training & experience



Aigle et al, Stress au cours du saut en parachute à très grande hauteur. Médecine et Armées. 2006

### **Prevention of stress concequencies ???:** Medical & military selection



# - ENVIRONMENTAL PATHOLOGIES

### ✓ HYPOTHERMIA & FROSTBITES

- Even if T° at ground level is 50° C...
- Reinforced by « wind chill » effect
- Non specific of parachuting





Gruppo et al, Ocular Problems in Military Free Fall Parachutists, Military Medicine ,2002

## 

### ✓ Boyle-Mariotte's laws

- Pressure x Volume = Constante
- ➢ If FL ↗, Pb ↘, air volume ↗ too



Air is a liquid

Stable air composition : O2 ≈ 21% N2 ≈ 78%



### - BASIC PRINCIPLES OF GAS EXCHANGE HYPOBARIA PATHOLOGIES

### ✓ Boyle-Mariotte's laws

- Pressure x Volume = Constant
- > If FL  $\land$ , Pb > , air volume  $\land$  too

 Volume = 1
 Surface, P = 1 bar

 P x V = C

 Volume = 1/2
 10 meters, P = 2 bar

 Volume = 1/2
 D meters, P = 2 bar

 Volume = 1/2
 D meters, P = 3 bar

 Volume = 1/4
 30 meters, P = 4 bar

 Volume = 1/4
 30 meters, P = 4 bar

 Volume = 1/5
 40 meters, P = 5 bar

Air is a liquid

Stable air composition : O2 ≈ 21% N2 ≈ 78%



# - ENVIRONMENTAL PATHOLOGIES

### ✓ BAROTRAUMA

- Dental pain / aeroodontalgie until tooth fracture
- Sinusal & otitis barotrauma

(acute or chronic eustachian tubal non-permeability)

Pulmonary barotrauma

Severe but rare



Table 1 Cases of pulmonary barotrauma during rapid decompression training in hypobaric chamber. PTX, pneumothorax

Study/Year	Type of pulmonary barotrauma	No. of subjects	Decompression in feet	
Clark 1945 [9]	pneumomedistinum	2	from 8,000 to 31,000	
Luft 1954 [10]	PTX	1	from 8,000 to 30,000	
Holmstrom 1958 [11]	Pneumomediastinum, PTX, subcutaneous emphysema	2	from 8,000 to 22,000	
Cable 2000 [12]	pulmonary barotrauma with cerebral arterial gas embolism	1	from 8,000 to 25,000	

### Prevention of barotrauma ??? :

Service de santé des armées

Selection & medical check before becoming HA parachuting-qualified

# - BASIC PRINCIPLES OF GAS EXCHANGE

(fraction of each gaz inside air mix)

### ✓ Boyle-Mariotte's laws

- Pressure x Volume = Constante
- ➢ If FL ↗, air volume ↗ too

### ✓ Dalton's law

- Pb = Σ Ppi
- Ppi = Pb. Fi
- Σ Fi = 100%
- > Pb =  $\Sigma$  Ppi =  $\Sigma$  (Ppi/Fi)
- ➢ If FL ↗, Pb ↘ & each Ppi (PpO2, PpN2) ↘

### Diffusion's law

 Movement of a substance from high to low concentration







### BASIC PRINCIPLES OF GAS EXCHANGE HYPOBARIA PATHOLOGIES

### **Boyle-Mariotte's laws**

- Pressure x Volume = Constante •
- If FL ↗, air volume ↗ too

### Dalton's law

•  $Pb = \Sigma Ppi$ 

(partial pressure of each gas in air mix)

Volume = 1

Volume = 1/2

- Ppi = Pb. Fi •
- $\Sigma Fi = 100\%$ •
- $\blacktriangleright$  Pb =  $\Sigma$  Ppi =  $\Sigma$  (Ppi/Fi)
- > If FL  $\nearrow$ , Pb  $\searrow$  & each Ppi ( $\stackrel{P}{P}O2$ ,  $\stackrel{P}{P}N2$ )  $\searrow$



PxV=C

Surface, P = 1 bar

10 meters, P = 2 bar

Barotrauma

Decompression Illness (DCI)

Hypoxia

Decompression Illness (DCI)

### **Diffusion's law**

Movement of a substance ٠ from high to low concentration





Decompression Illness (DCI)

O ENVIRONMENTAL PATHOLOGIES

### ✓ ALTITUDE HYPOXIA



### Symptoms of hypoxia :

- Kind of symptoms depand on the individual
- Reproducible for everyone

Table 2. Common Symptoms Associated with Hypoxia.

#### **Common Symptoms**

Tingling Shortness of Breath Hot Flashes Blurred Vision Cold Flashes Nausea Dizziness Apprehension Tunnel Vision Pressure in Eves **Trouble Concentrating** Fatigue Light Dimming Lack of Coordination Euphoria Headache

#### Impaired judgment

If you know & indentify your own first hypoxia symptoms during TUC, you diagnose your hypoxia and are able to treat that.

Philips et al, Hypoxia: Exposure Time Until Significant Performance Effects - NAMRU-D REPORT n° 16-19 – mars 2016

Table 1. Standard Time of Useful Consciousness Values.

Effe	ctive Peri	formance Time at	
	Al	titude	
Altitude		Effective	
(m)	(ft)	Performance Time	
5,500	18,000	15 min	
6,700	22,000	10 min	
7,600	25,000	3 to 5 min	
8,500	28,000	2.5 to 3 min	
9,100	30,000	1 to 2 min	
10,700	35,000	30 sec to 1 min	
12,200	40,000	15 to 20 sec	
13,100	43,000	9 to 12 sec	
15,200	50,000	9 to 12 sec	

### Prevention of Hypoxia ???:

Individual hypoxia symptoms card

Avoid lack O2

Low prevalence of altitude hypoxia in airborne operations

- No case reports for parachuting, only accidental cabin depressurization or O2 system failure (2 hypoxia in 47 accidental depressurization in 21 years in Canada)
- $\circ~$  Depend on FL of the drop & TUC
- $\circ$  Starting from the drop, altitude  $\searrow$  so TUC 7 & risk of severe hypoxia  $\searrow$
- SoF: rustic & trained military
   limited exposure until the drop



2018 French pre-study in French SOF at FL140 without O2 vs FL120 (Dr Coz) :

20 SOF parachutists, 13 Aircraft CrewMembers (ACM) → 3 flies & drops Parachutists : no difference found with FL120 drop

Service de santé des armées

ACM: 70% differences found with FL 120 drop (tiredness & tachycardia)

# - BASIC PRINCIPLES OF GAS EXCHANGE

### ✓ Boyle-Mariotte's laws

- Pressure x Volume = Constante
- ➢ If FL ↗, air volume ↗ too

### ✓ Dalton's law

- Pb = Σ Ppi
- Ppi = Pb. Fi
- Σ Fi = 100%
- Pb = Σ Ppi = Σ (Ppi/Fi)
- ➢ If FL ↗, Pb ↘ & each Ppi (PpO2(PpN2) ↘

### ✓ Henry's law

• Amount of a dissolved gas in a liquid is proportional to Ppi inside

### ✓ Diffusion's law

• Movement of a substance from high to low concentration



Boyle's Law:

/olume = 1/3

Volume = 1

Volume = 1/2

Pressure x Volume = Constant

PxV=C

me = 1/4

Surface, P = 1 bar

10 meters, P = 2 bar

20 meters, P = 3 ba

30 meters, P = 4 bal



(partial pressure of each gas in air mix)

(fraction of each gaz inside air mix)

### BASIC PRINCIPLES OF GAS EXCHANGE **HYPOBARIA PATHOLOGIES**

### **Boyle-Mariotte's laws**

- Pressure x Volume = Constante •
- If FL ↗, air volume ↗ too

### **Dalton's law**

- $Pb = \Sigma Ppi$
- Ppi = Pb. Fi •
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- $\blacktriangleright$  Pb =  $\Sigma$  Ppi =  $\Sigma$  (Ppi/Fi)
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### ✓ Henry's law

Amount of a dissolved gas in a liquid is proportional to Ppi inside

### **Diffusion's law**

Movement of a substance • from high to low concentration



## O ENVIRONMENTAL PATHOLOGIES

✓ DECOMPRESSION ILLNESS DCI – Accident de Désaturation ADD



✤Gas bubbles formation in Decompression Illness :

- Depend on speed of ascent & > of ambient pressure (Pb)
- moving from body storage to outside via pulmonary exchanges

□ N2 stocked in fat tissus (70%), bones, muscles & tendons

- Fast migration from muscle & tendinous tissues
- Longer migration (hours) from bones & fat tissue → inside tissus trapped N2 bubbles
   & Venous Gas Embolism VGE (= DCS DC Sickness)
- Abrupt depressurization : Arterial GE (if left-right shunt)
- Local tissus inflammatory reactions



### Table 1. Signs and symptoms of Altitude Decompression Sickness.

DCS Type	Bubble Location	Signs & Symptoms (Clinical Manifestations)	11 - and the	
BENDS	Mostly large joints of the body (elbows,	<ul> <li>Localized deep pain, ranging from mild (a "niggle") to excruciating. Sometimes a dull ache, but rarely a sharp pain.</li> </ul>	770	
60-70% shoulders, hip, write knees, ankles)	shoulders, hip, wrists,	Active and passive motion of the joint aggravates the pain.		
	kilees, alikies)	Pain can occur at altitude, during the descent, or many hours later.	A trainer	
NEUROLOGIC Manifestations	Brain	Confusion or memory loss	endernite con	
		• Headache		
		<ul> <li>Spots in visual field (scotoma), tunnel vision, double vision (diplopia), or blurry vision</li> </ul>	Altitude-induced	
10–15 %–		Unexplained extreme fatigue or behavior changes	Decompression Sickness	
	-	Seizures, dizziness, vertigo, nausea, vomiting and unconsciousness may occur		
	Spinal Cord	Abnormal sensations such as burning, stinging, and tingling around the lower chest and back	Pilot Safety Brochure	
		Symptoms may spread from the feet up and may be accompanied by ascending weakness or paralysis	www.faa.gov/pilots, safety	
		Girdling abdominal or chest pain		
	Peripheral Nerves	Urinary and rectal incontinence		
		<ul> <li>Abnormal sensations, such as numbness, burning, stinging and tingling (paresthesia)</li> </ul>		
	-	Muscle weakness or twitching	ANU AVIAN	
CHOKES	Lungs	Burning deep chest pain (under the sternum)	Federal Aviation	
		Pain is aggravated by breathing	Administration	
<b>&lt;3</b> %		Shortness of breath (dyspnea)		
	-	Dry constant cough	A COLUMN TWO IS NOT	
SKIN BENDS	Skin	<ul> <li>Itching usually around the ears, face, neck arms, and upper torso</li> </ul>	A	
		Sensation of tiny insects crawling over the skin     CUtis marmorata		
10-15%		Mottled or marbled skin usually around the shoulders, upper chest and abdomen, accompanied by itching	A CONTRACT	
10-13/0		• Swelling of the skin, accompanied by tiny scar-like skin depressions (pitting edema)	and the second second second	

**Risk factor :** altitude, T°, duration, dehydration, OH, age, physical effort, BodyFat Ratio, diving

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Delayed symptoms until 24h after exposition !!

Low prevalence of altitude DCI in airborne operations (1)

### US experience since 1941 (>50 years):



Butler et al, USAF Experience with Hyperbaric Therapy of Altitude Decompression Sickness (1941-1999) NATO RTO. 2001.

### Scientific litterature: 2 cases report after repeated military Free Fall: 100% recovery

Petruso et al, Definitive Treatment of Neurological Decompression Sickness in a Resource Limited Location. Aerosp Med Hum Perform. 2021 Butler et al, Decompression sickness presenting as optic neuropathy. Aviat Space Environ Med. 1991

French experience since 1998 (>20 years) : 22 bends & 2 chokes



✤ Why this low prevalence ?

 $\circ$  > risk factor :

SoF: rustic & ultratrained military (bodyfat ratio, dehydratation,

threshold of physical activities and tiredness, age....)

limited exposure until the drop

continuous descent after the drop (natural recompression)

### under-declaration for benign DCI

TABLE II. MAJOR DIFFERENCES BETWEEN DIVING AND ALTITUDE DECOMPRESSION SICKNESS (100).





# O MEDICAL REGARDS

### ✓ TREATMENT

- O2 100% +++
- Cabin Pressurization or aircraft emergency descent
- Ground level oxygen
- Complications treatment

If failure...



### <u>• Hyperbaric Oxygen</u>

Evacuation to facility under 1000ft

recovery > 95%



recovery 90%

Fig. 8. A hyperbaric stretcher being loaded onto a helicopter. (Courtesy



## vs PRECAUTIONARY PRINCIPLE vs TYRANNY OF STANDARDS

### ✓ ADAPT PROTOCOLS

### NATO STANAG 7056 Procedures

### • ADRAC Altitude DCS Risk Assessment Computer : validated tool to estimate the

risk of DCS with a range of variables. Laboratory research +++

Pilmanis et al, Operational medical issues in hypo- and hyperbaric conditions. Altitude decompression sickness risk prediction research internet. Defense Technical Information Center Compilation Part Notice, 2018.



### ✓ DON'T BLOCK A RISKY TACTICAL CAPABILITY & WELL ANALYSE

- Very few concerted scientific studies
- Rare « real » cases, low prevalence for rich theoric literature
- Differentiate standards for pilot and parachutists : not the same population / flight plan / exposure / missions & consequencies if sick
- Evaluate the risk of oxygen equipment in parachuting (weight, discomfort, fatigue, visual field) with regard to the expected benefit

### THE LESS IS MORE



# CONCLUSIONS

Accept risky activities for tactic/strategic capabilities

→ Monitoring principle instead of prevention principle

Involve « ground » physicians & HAHO qualified professional ++



Prepare PACE plan with MEDEVAC plan & locate HBO facility available Take O2 supply +++





# **QUESTIONS ?**

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