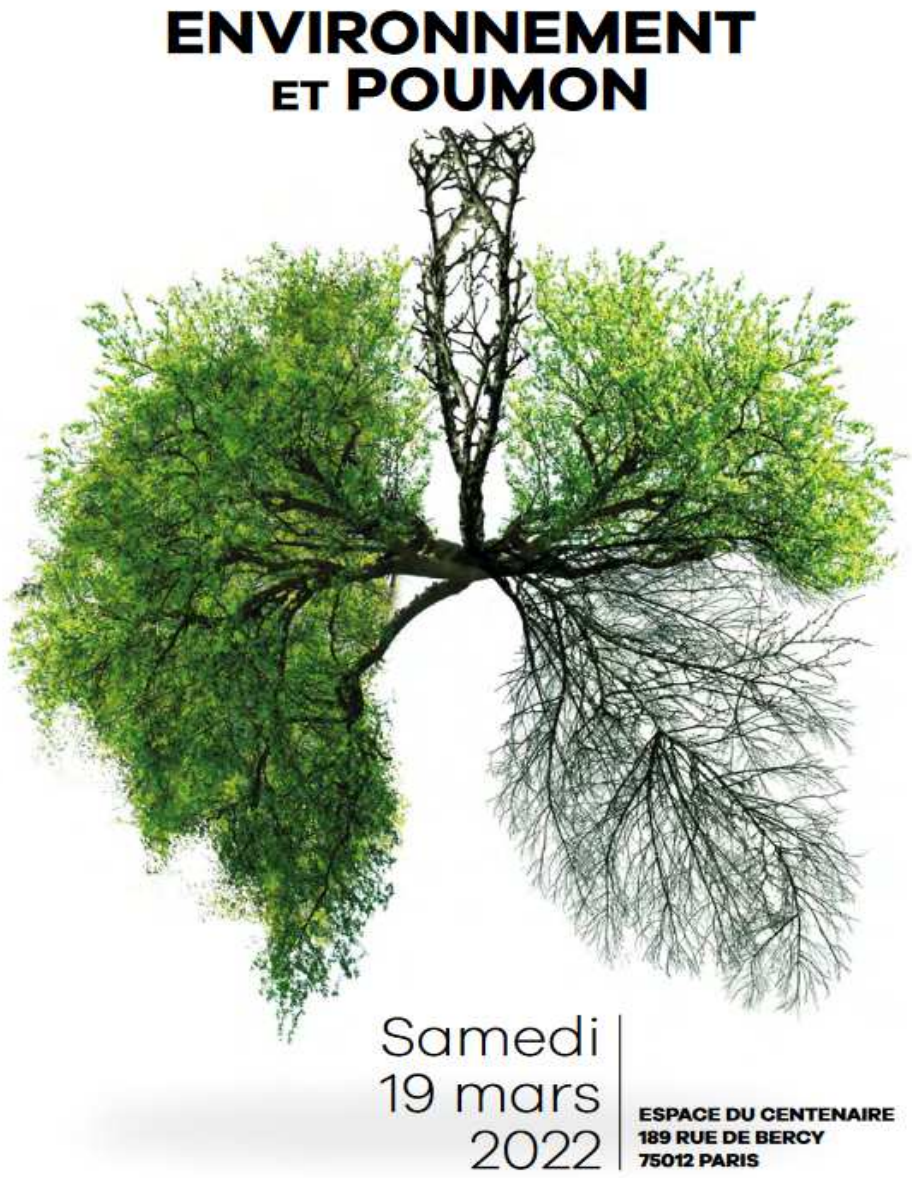

SPIF | Société de Pneumologie d'Ile-de-France

www.laspif.org

Pathologies respiratoires en altitude / voyages aériens

Thomas GILLE (MCU-PH)

Inserm UMR 1272 "Hypoxie et Poumon", UFR SMBH, Univ. Sorbonne Paris Nord
Hôpitaux Universitaires de Paris Seine-St-Denis, AP-HP, Bobigny

UFR SMBH — SANTE, MEDECINE BIOLOGIE HUMAINE

Inserm

ASSISTANCE PUBLIQUE HÔPITAUX DE PARIS

Université Sorbonne Paris Nord

OrphaLung — Centre de Référence Maladies Pulmonaires Rares

Hôpitaux Universitaires Avicenne Jean-Verdier René-Muret Paris-Seine Saint-Denis

Conflits d'intérêt

Laboratoires pharmaceutiques

- Boeringher Ingelheim
- Roche

Prestataires de services

- Oxyvie
- France Oxygène
- LVL Médical
- Vitalaire

Pas de conflits d'intérêts en lien avec la présentation

Plan

- **Réponses physiologiques à l'altitude**
- **Pathologies spécifiques de l'altitude**
- **Altitude et maladies respiratoires pré-existantes**
- **Maladies respiratoires et voyage aérien**

Plan

- **Réponses physiologiques à l'altitude**
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Haute altitude

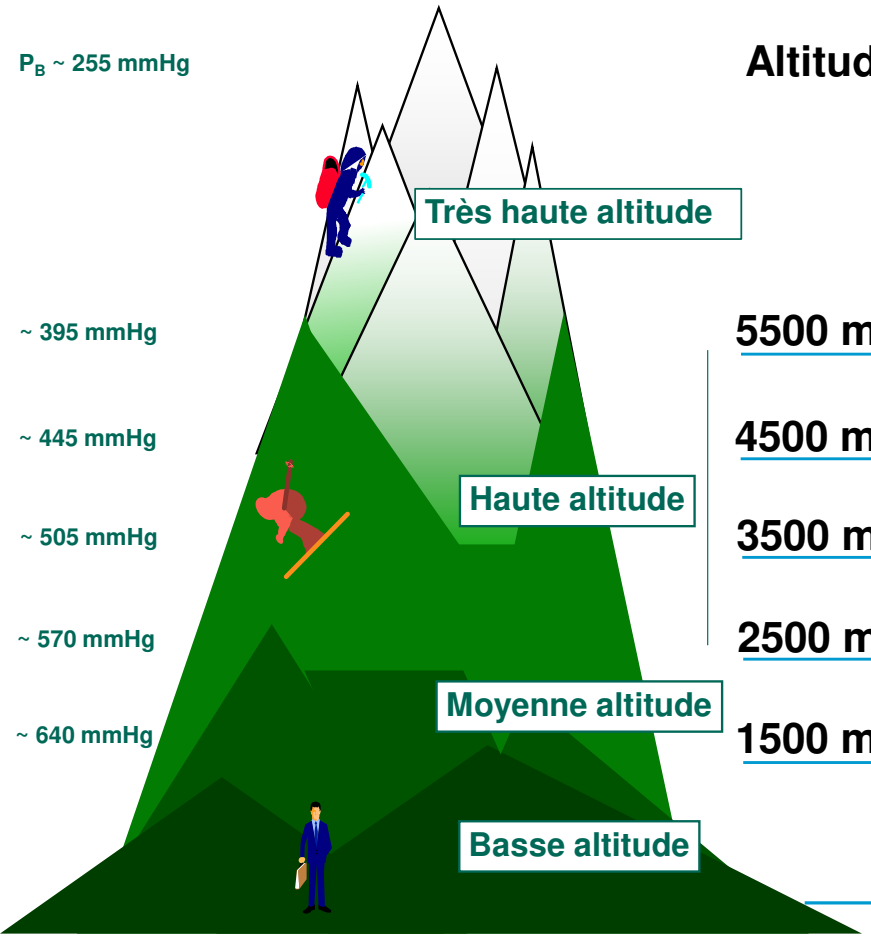
- Pas de définition consensuelle
  - **> 2000 - 2500 m**

- 140 000 000 personnes vivant en permanence > 2500 m
- 200 000 000 / an voyageant > 1500 m (± activité physique)

- Environnement potentiellement hostile
  - **Hypoxie hypobare +++**
  - Basses températures
  - Faible humidité
  - Rayonnement UV
  - (Effets propres de l'hypobarie ?)

Doutreleau, *Rev Mal Respir* (38) 2021
Wuyam *et al.*, *Rev Mal Respir* (39) 2022

Hypoxie hypobare



Altitude : 8848 m — vie impossible ?

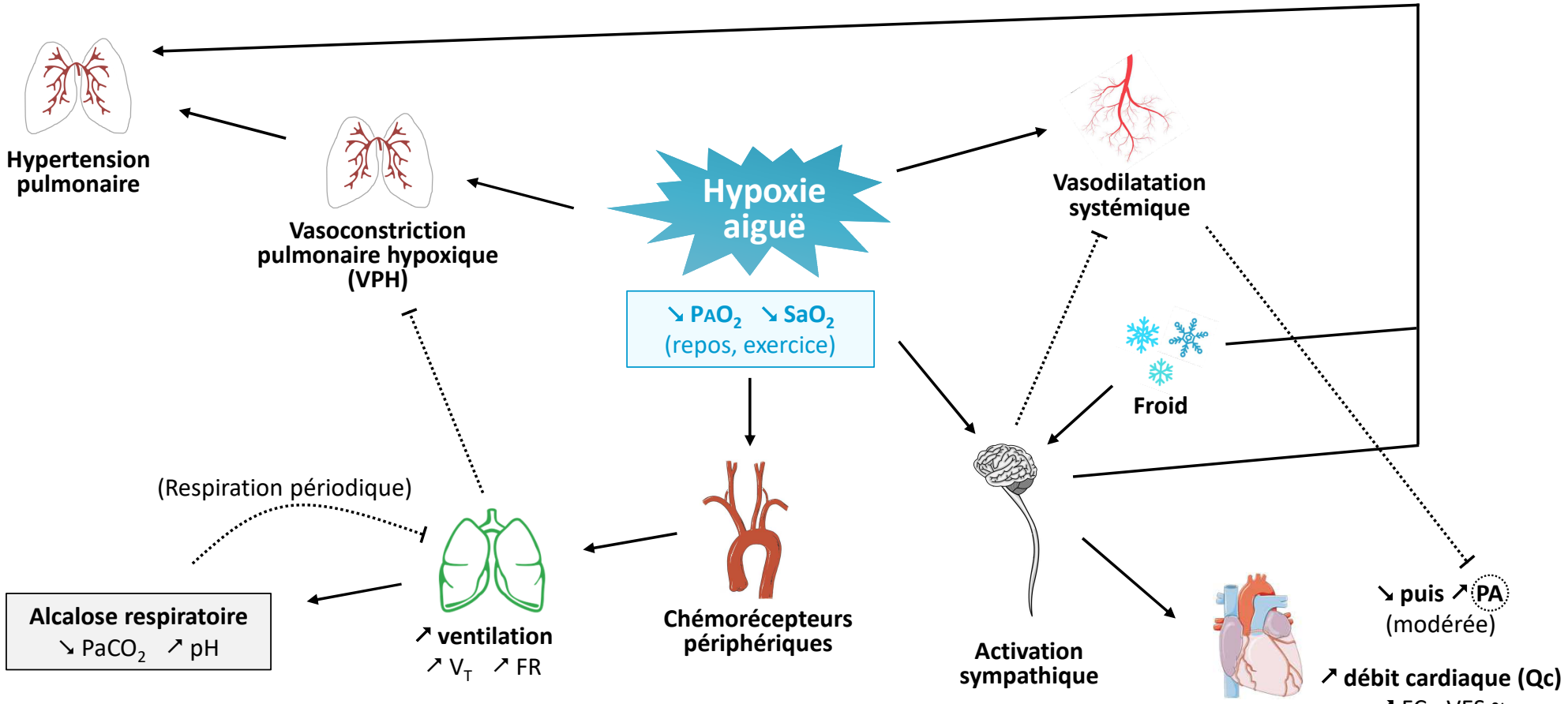
vie permanente impossible

SpO_2

5500 m	70-80 %	
4500 m	75-85 %	effets ressentis au repos
3500 m	82-88 %	
2500 m	90-95 %	effets sur la performance maximale
1500 m	93-97 %	
	96-99 %	pas d'effet

Luks & Hackett, *N Engl J Med* (386) 2022

Réponses physiologiques



Doutreleau, *Rev Mal Respir* (38) 2021

SPIF

Symptômes en haute altitude

Box 1
How travelers feel differently at high altitude

Heart rate at rest and with any level of exertion is higher than at altitude of residence

Increased respiratory rate and tidal volume

More frequent sighs

Increased frequency of urination

Dyspnea on exertion that resolves quickly with rest

Difficulty sleeping including frequent arousals, insomnia, vivid dreams

Transient lightheadedness on rising to a standing position

Johnson & Luks, *Med Clin N Am* (100) 2016

Plan

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Mal aigu des montagnes (MAM)

- Apparaît en quelques heures à quelques jours (avant J5), bénin
- Secondaire à l ’exposition à l’hypoxie (**maladaptation**)
  - Possible dès 1900 m
  - **Fréquent > 2500 m** : incidence moyenne 25 % (> 5000 m : jusque 75 %)
- Syndrome non spécifique
  - **Céphalées** (constantes), fronto-temporales bilatérales
  - Nausées / vomissements
  - Anorexie
  - Sensations pseudo-vertigineuses
  - Asthénie
  - Dyspnée

Intensité variable

Doutreleau, *Rev Mal Respir* (38) 2021
Herbert & Luks, *ERS Monograph* 2020

Mal aigu des montagnes (MAM)

Score de Lake Louise modifié (2018) [1] (MAM suspecté si score ≥ 3)	
Céphalées (obligatoires)	0- Pas de céphalées 1- Céphalées légères 2- Céphalées modérées 3- Céphalées importantes et invalidantes
Symptômes digestifs	0- Pas de symptômes – bon appétit 1- Anorexie / nausées 2- Nausées / vomissements minimes 3- Vomissements invalidants
Fatigue / faiblesse	0- Pas de fatigue / faiblesse 1- Fatigue / faiblesse légères 2- Fatigue / faiblesse modérées 3- Fatigue / faiblesse importantes et invalidantes
Vertiges / étourdissements	0- Pas de vertiges / étourdissements 1- Vertiges / étourdissements légers 2- Vertiges / étourdissements modérés 3- Vertiges / étourdissements importants et invalidants

Facteurs de risque

- **Susceptibilité individuelle +++** **(antécédent ?)**
- **Altitude absolue +++**
- **Vitesse d'ascension +++**
- Faibles réponses ventilatoire et cardiaque au stimulus Hx
- Profondeur de la désaturation lors d'un exercice en Hx
- Sexe féminin
- Age ≤ 45 ans
- Pratique d'une activité physique régulière
- Obésité
- Tabagisme
- Terrain migraineux

Facteur protecteur

- Pré-acclimatation

1. Roach *et al., High Alt Med Biol* (19) 2018

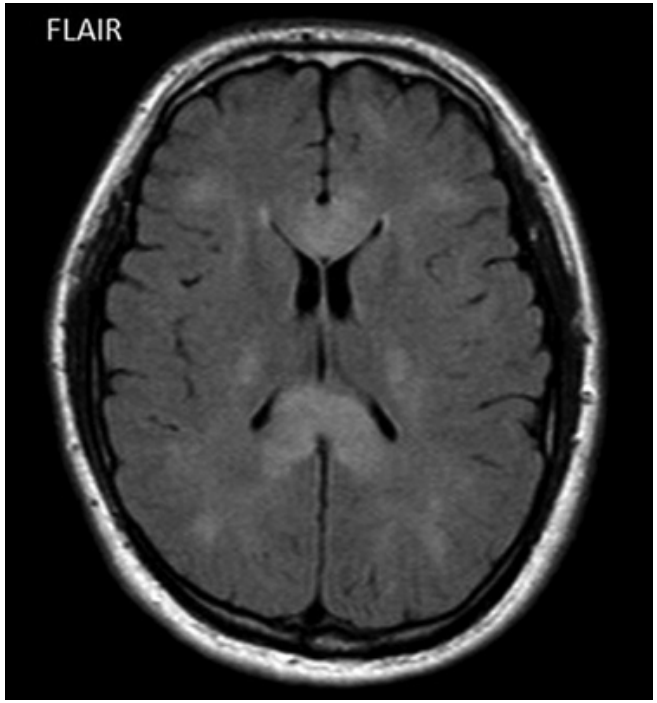
Doutreleau, *Rev Mal Respir* (38) 2021
Herbert & Luks, *ERS Monograph* 2020

Œdème cérébral de haute altitude (OCHA)

- Continuum physiopathologique avec le MAM
- Met en jeu le **pronostic vital**

- Rare < 4000 m
  - Incidence moyenne 0,5 - 1 %

- MAM sévère
  - Céphalées non calmées
  - Vomissements en jet
- Signes neurologiques
  - Ataxie, diplopie, troubles d'élocution
  - Irritabilité, hallucinations, troubles de la conscience, coma
  - Convulsion, déficit moteur



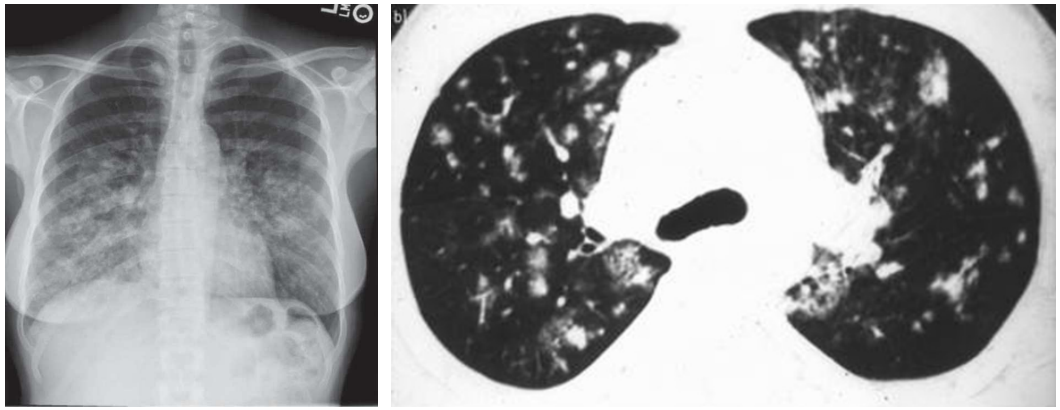
Doutreleau, *Rev Mal Respir* (38) 2021
Herbert & Luks, *ERS Monograph* 2020

Œdème pulmonaire de haute altitude (OPHA)

- Indépendant du MAM / OCHA
  - Association possible, rôle aggravant par ↗ hypoxie
- Rare < 3000 m : incidence moyenne ~ 6 %
- Symptômes respiratoires
  - Dyspnée au moindre effort / repos
  - Orthopnée
  - Sensations de ↘ capacité thoracique
  - Toux ± expectorations rosées
  - Grésillement laryngé
  - Cyanose
  - Encéphalopathie hypoxique
  - (Tachycardie, fièvre…)

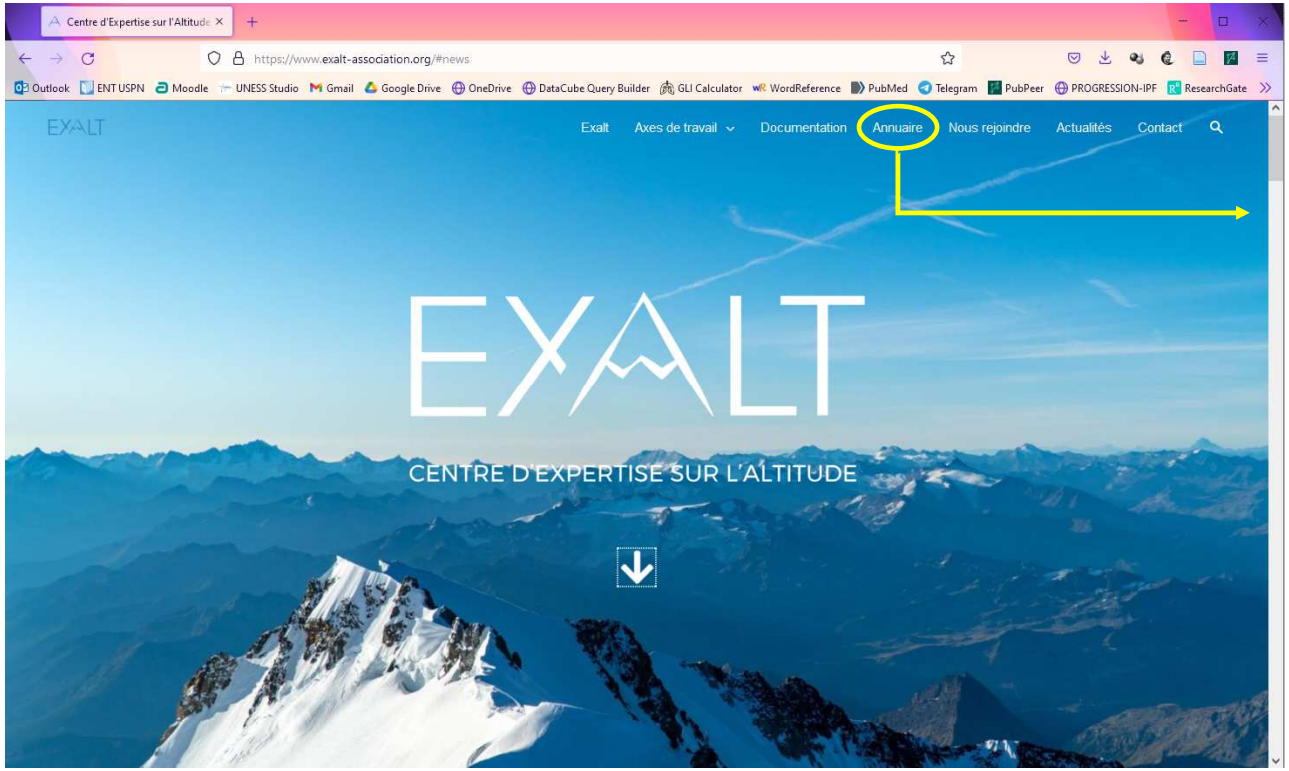
Facteurs de risque

- **FDR de MAM / OCHA**
- VPH exagérée avec ↗ importante PAP



Doutreleau, *Rev Mal Respir* (38) 2021
Herbert & Luks, *ERS Monograph* 2020

Prédiction du risque de pathologie d'altitude



https://www.exalt-association.org/

Ile-de-France :

Hôpital Jean verdier (Bondy)
Médecine du Sport

Hôpital de Poissy (St Germain)
Médecine du Sport

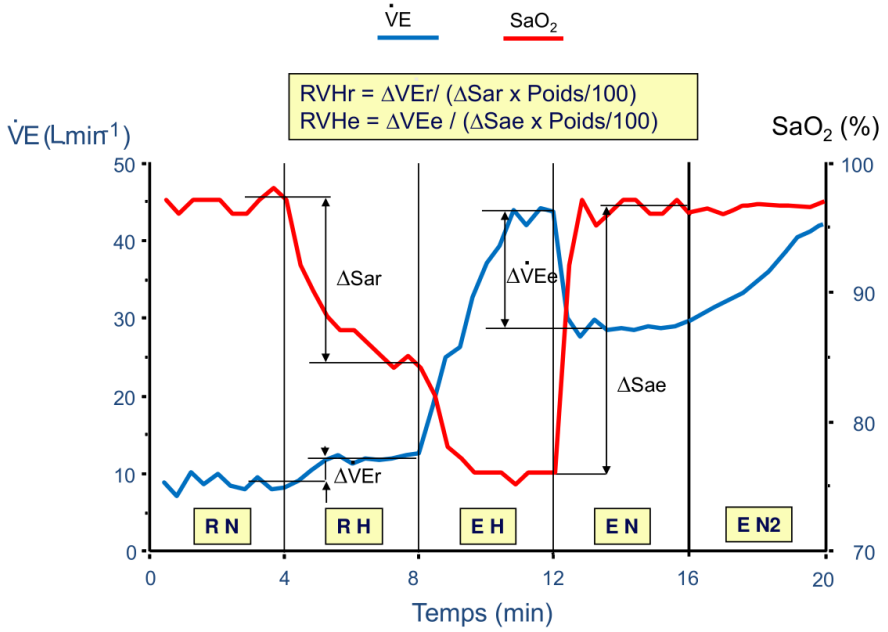
Prédiction du risque de pathologie d'altitude

Table 3
Risk categories for acute altitude illness in unacclimatized individuals [1]

Risk Category	Description
Low	Individuals with no prior history of altitude illness and ascending to ≤2800 m Individuals taking ≥2 d to arrive at 2500–3000 m with subsequent increases in sleeping elevation <500 m/d and an extra day for acclimatization every 1000 m
Moderate	Individuals with prior history of AMS and ascending to 2500–2800 m in 1 d No history of AMS and ascending to >2800 m in 1 d All individuals ascending >500 m/d (increase in sleeping elevation) at altitudes >3000 m but with an extra day for acclimatization every 1000 m
High	Individuals with a history of AMS and ascending to >2800 m in 1 d All individuals with a prior history of HACE or HAPE All individuals ascending to >3500 m in 1 d All individuals ascending >500 m/d (increase in sleeping elevation) >3000 m without extra days for acclimatization Very rapid ascents (eg, Mount Kilimanjaro)

Test de réponse à l'hypoxie [2,3]

Effort de faible intensité à 11,5 % FiO_2 (« 4800 m »)



1. Bärtsch & Swenson, *N Engl Med J* (368) 2007

2. Richalet *et al.*, *Am J Respir Crit Care Med* (185) 2012

3. Canouï-Poitrine *et al.*, *Plos One* (9) 2014

Prévention du risque de pathologie d'altitude

- Conseils (vitesse d'ascension +++)
- Reconnaissance des signes et plan d'action adapté
- Traitement préventif si risque modéré ou sévère

Molécules disponibles pour la prévention des pathologies d'altitude		
MAM / OCHA	**Acétazolamide**	125 – 250 mg / 12 h
	Dexaméthasone	2 mg / 6 h ou 4 mg / 12 h
OPHA	**Nifédipine**	20 mg LP / 12 h
	Tadalafil **Sildénafil**	10 mg / 12 h 50 mg / 8 h
	Salmétérol	125 µg / 12 h (inhalation)

Doutreleau, *Rev Mal Respir* (38) 2021
Herbert & Luks, *ERS Monograph* 2020

Plan

- Réponses physiologiques à l'altitude
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Principes généraux

- Voyage en altitude souvent possible après évaluation et conseils
  - EFR, test de réponse à l'hypoxie ± ETT
- Contre-indication a priori si pathologie mal équilibrée / exacerbation récente

4 questions-clefs

1- Risque d'hypoxémie sévère ou d'apport tissulaire en O_2 insuffisant ?
↳ BPCO, mucoviscidose, PID, cardiopathie congénitale…

2- Risque de réponse ventilatoire à l'hypoxie diminuée ?
↳ Mécanique ventilatoire altérée (BPCO sévère, SOH, maladies neuromusculaires…)
↳ Commande ventilatoire altérée (chirurgie carotidienne…)

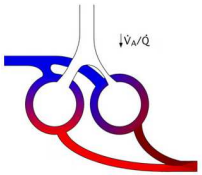
3- Risque de réponse vasculaire pulmonaire à l'hypoxie exagérée ?
↳ Hypertension pulmonaire, insuffisance cardiaque droite…

4- Risque d'altération des réponses physiologiques du fait des conditions environnementales ?
↳ Bronchospasme induit par l'air froid et sec chez l'asthmatique…

Johnson & Luks, *Med Clin N Am* (100) 2016

BPCO

Majoration des besoins ventilatoires



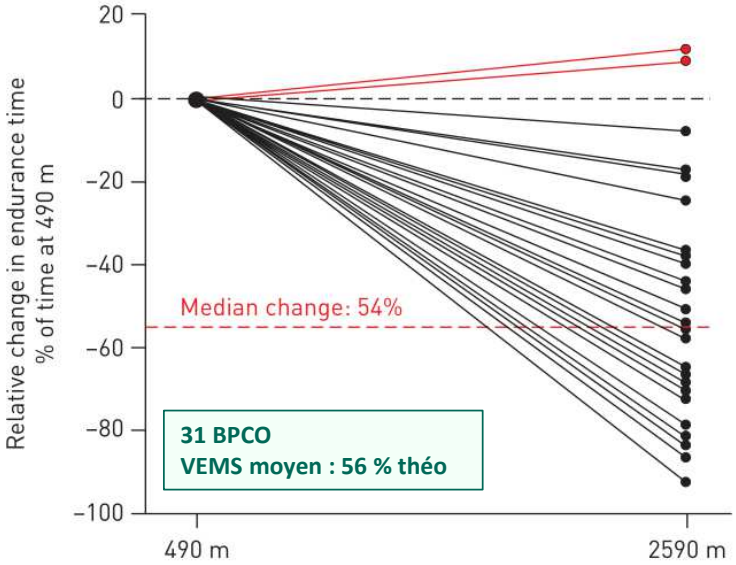
Majoration de l'hypoxémie

Risque d'HTAP secondaire accru
si hypoxémie au niveau de la mer

↳ Probable FDR OPHA

Peu de retentissement sur la fonction
(hormis ↘ DLCO et ↘ KCO par VPH)

↘ performances :



↘ temps d'endurance

↘ distance parcourue au TM6

Luks & Swenson, *Eur Respir J* (29) 2007
Wuyam *et al.*, *Rev Mal Respir* (39) 2022

Furian *et al.*, *Respiration* (95) 2018

BPCO

Avant le voyage

- Peu de données sur les voyages > 3000 m, ni sur les patients très sévères et/ou hypercapniques au niveau de la mer
- Evaluation du besoin d'une **supplémentation en O_2**
- Evaluation des **autres comorbidités** (cardiovasculaires ++)
- Long voyage déconseillé si **hypertension pulmonaire**
  - Si obligatoire : nifedipine
- **Acétazolamide déconseillé** si BPCO sévère (acidose métabolique)
  - Alternative : dexaméthasone
- **Vie en altitude déconseillée** (↗ mortalité)

Sur place

- **Poursuite des traitements habituels**
- Prévoir suffisamment de **flacons de bronchodilatateurs**
  - Quantité d'inhalations disponibles ↘ en haute altitude
- **Corticoïdes PO à disposition** en cas d'exacerbation
- **Concentrateur portable en O_2** si besoin ± **saturomètre**
- **Eviter les cigarettes** (trigger d'exacerbation)

- Rôle pour l'O_2 nocturne ? [1]

- Pas de surrisque identifié de PNO, même en cas d'emphysème
- Si PNO récent : attendre ≥ 2 semaines après résolution RP avant le voyage

1. Tan *et al.*, *JAMA Network Open* (6) 2020

Luks & Swenson, *Eur Respir J* (29) 2007
Wuyam *et al.*, *Rev Mal Respir* (39) 2022

Asthme

- Exposition moindre aux allergènes (acariens ++)
- Pollution plus faible en haute altitude en moyenne*

- Air froid et sec + hypocapnie : ↗ bronchoconstriction
- Pollution dans certaines étapes

Données contradictoires sur les éventuels effets propres de l'hypoxie sur l'HRB

Avant le voyage

- **Voyage déconseillé si asthme sévère ou mal équilibré**
- Décaler le voyage si exacerbation récente
  - Attendre le retour à la normale
- Attention aux zones très reculées
- Les autres patients peuvent a priori monter jusque 5000 m (rôle protecteur du cortisol endogène / des catécholamines ?)

Sur place

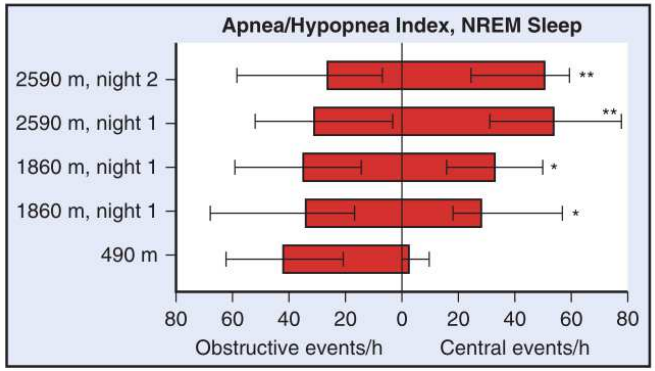
- **Protection des VAS** contre air froid et sec
- **Poursuite des traitements habituels**
- Surveillance du **peak flow** + **plan d'action pré-établi**
- Prévoir suffisamment de **flacons de bronchodilatateurs**
- **Corticoïdes PO à disposition** en cas d'exacerbation

Luks & Swenson, *Eur Respir J* (29) 2007
Wuyam *et al.*, *Rev Mal Respir* (39) 2022

SAOS

↘ densité de l'air : ↘ résistances des VAS

- Majoration des apnées/hypopnées centrales +++
- ↘ PiO_2 : ↗ profondeur des désaturations nocturnes ?



1

Au total, aggravation du SAOS en altitude avec baisse des performances cognitives

Hypoxémie diurne au niveau de la mer = FDR hypertension pulmonaire et OPHA

Mesures conseillées

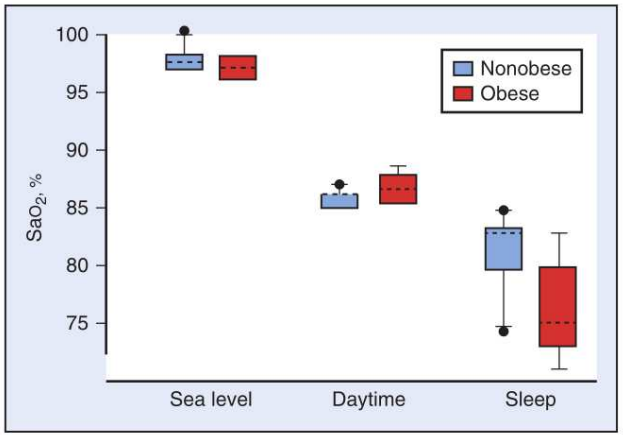
- **Voyage avec la PPC ± adaptation des pressions**
  - La plupart des appareils fonctionnent jusque 4000 m
  - **Humidificateur chauffant**
  - Attention à la **batterie / accès à l'électricité**
- **Adapter débit si O_2**
- Si apnées centrales prédominantes
  - Envisager acétazolamide
  - Equilibrer traitement si cardiomyopathie associée
- **ETT si hypoxémie diurne au niveau de la mer**
  - Si hypertension pulmonaire : nifédipine

1. Nussbaumer-Ochsner *et al.*, *Thorax* (65) 2010

Luks & Swenson, *Eur Respir J* (29) 2007

Wuyam *et al.*, *Rev Mal Respir* (39) 2022

Obésité et SOH



[1]

- Surrisque de MAM / OCHA (incidence ~ doublée)
- Majoration de la PAP : surrisque de décompensation cardiaque droite et d'OPHA
  ↳ même pour des altitudes de 2000-2500 m

Mesures conseillées

- **Voyage déconseillé**, notamment si SOH
- Envisager **O_2 diurne et nocturne**
- **Reconnaissance des signes de MAM / OCHA et OPHA**
  - Prévention : acétazolamide
- **Voyage avec la PPC si déjà prescrite**
  - **Adaptation des pressions**
  - **Humidificateur chauffant**
  - Attention à la **batterie / accès à l'électricité**

1. Ge *et al.*, *Ann Intern Med* (139) 2003

Luks & Swenson, *Eur Respir J* (29) 2007
Wuyam *et al.*, *Rev Mal Respir* (39) 2022

Hypertension pulmonaire

- Pas de données systématiques sur patients HTAP primitive en altitude
- Surrisque de décompensation cardiaque droite et d'OPHA
  - Même pour des altitudes < 3000 m
  - Pas de seuil de PAP au-dessus duquel le risque augmente

Mesures conseillées

- **Voyage déconseillé** si PAPm > 35 ou PAPs > 60 mmHg
- **O_2 diurne et nocturne**
  - A partir de **2000 m**
  - Même si PaO_2 normale au niveau de la mer
- **Reconnaissance des signes d'OPHA**
  - Réévaluer éventuel traitement spécifique
  - Prévention : nifédipine, sildenafil, tadalafil (voire dexaméthasone)

Luks & Swenson, *Eur Respir J* (29) 2007
Wuyam *et al.*, *Rev Mal Respir* (39) 2022

Autres cas de figure

Thromboembolic disease

- Continue any pre-existing anticoagulation regimen during high-altitude sojourn with close follow-up of INR before and after trip
- Do not initiate new anticoagulation prescription in patients not on a pre-existing regimen
- Discontinue oral contraceptives in females with pre-existing coagulopathy
- Avoid immobility and dehydration

(ou envisager AOD)

Interstitial lung disease

- Assess need for supplemental oxygen and administer during stay at high altitude if predicted P_{a,O_2} <50–55 mmHg
- Screen patients for pre-existing pulmonary hypertension and, if present, administer supplemental oxygen and prophylax with nifedipine SR 20 mg *b.i.d.*

Cystic fibrosis

- Assess need for supplemental oxygen in all patients and administer if predicted P_{a,O_2} <50–55 mmHg
- If predicted P_{a,O_2} >50–55 mmHg, consider supplemental oxygen if FEV_1 <50% predicted
- Continue pre-existing chest physiotherapy, mucolytics and antibiotics during high-altitude sojourn

Neuromuscular disorders

- Screen for the presence of sleep-disordered breathing and, if present, treat with bilevel positive airway pressure at altitude
- Screen for baseline hypoventilation and, if present, travel to high altitude with bilevel positive airway pressure
- Administer nocturnal supplemental oxygen in patients with history of nocturnal desaturations, but avoid "over-oxygenation" to prevent suppression of ventilatory drive
- Screen kyphoscoliosis patients for pre-existing pulmonary hypertension and, if present, administer supplemental oxygen and prophylax with nifedipine SR 20 mg *b.i.d.*
- Counsel patients with bilateral diaphragmatic paralysis against high-altitude travel; If travel cannot be avoided, administer bilevel positive airway pressure

+ drépanocytose, coronaropathie, HTA, insuffisance cardiaque congestive, diabète, insuffisance rénale, grossesse…

Luks & Swenson, *Eur Respir J* (29) 2007
Wuyam *et al.*, *Rev Mal Respir* (39) 2022

Précautions générales

Table 2. Contraindications to Travel above 2500 m.*

- Advanced COPD (FEV_1 <30% of predicted value or requirement for continuous oxygen therapy)
- Advanced cystic fibrosis (FEV_1 <30% of predicted value)
- Advanced restrictive lung disease (TLC <50% of predicted value or requirement for continuous oxygen therapy)
- Decompensated heart failure
- High-risk pregnancy
- Myocardial infarction or stroke within the past 90 days
- Poorly controlled seizure disorder
- Pulmonary hypertension (systolic PAP >60 mm Hg)
- Sickle cell disease
- Unstable angina
- Untreated, high-risk cerebrovascular abnormality (aneurysm or arteriovenous malformation)

Luks & Hackett, *N Engl J Med* (386) 2022

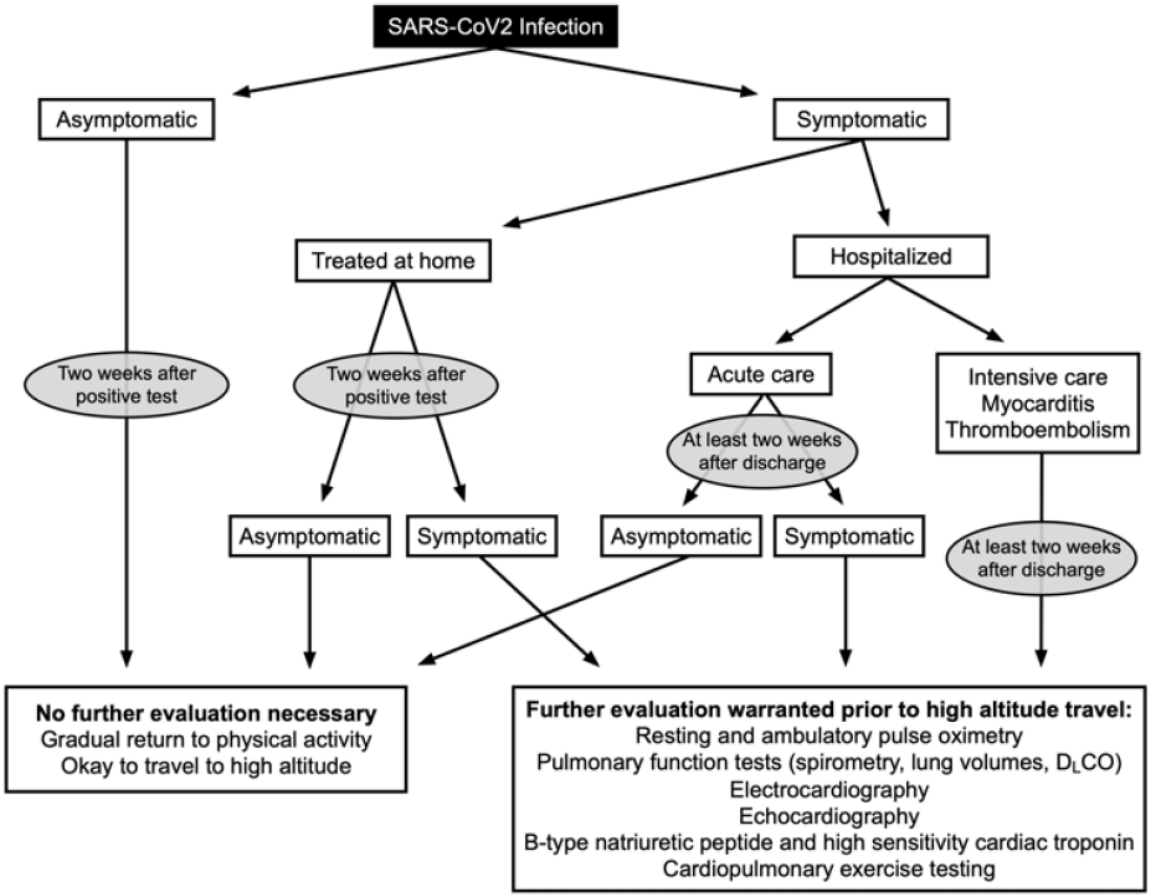
TABLE 3-4 Dose Adjustments and Other Medication Considerations for High-Altitude Travelers with Underlying Medical Conditions

Medication	Dose Adjustments: Renal Insufficiency	Dose Adjustments: Hepatic Insufficiency	Other Considerations
Acetazolamide	Avoid use in patients with GFR <10 mL/min, metabolic acidosis, hypokalemia, hypercalcemia, hyperphosphatemia, or recurrent nephrolithiasis.	Acetazolamide use is contraindicated.	Avoid in patients taking chronically high doses of aspirin. Avoid in patients with ventilatory limitation (FEV_1 <25% predicted). Use caution in patients with documented severe sulfa allergy. Limit concurrent use with topiramate and ophthalmic carbonic anhydrase inhibitors to 3-5 days.
Dexamethasone	No contraindication and no dose adjustments necessary	No contraindication and no dose adjustments necessary	May increase blood glucose values in diabetic patients Avoid in patients at risk for peptic ulcer disease or upper gastrointestinal bleeding. Use caution in patients at risk for strongyloidiasis.
Nifedipine	No contraindication and no dose adjustments necessary	Best to avoid If use is necessary, give at reduced dose (10 mg twice daily)	Use caution in patients taking medications metabolized by CYP-450 3A4 and 1A2 pathways. Use caution during concurrent use with other antihypertensive medications.
Salmeterol	No contraindication and no dose adjustments necessary	Insufficient data	Potential for adverse effects in patients with coronary artery disease prone to arrhythmia Avoid concurrent use of β-blockers. Avoid concurrent use of monoamine oxidase inhibitors or tricyclic antidepressants.
Sildenafil	Dose adjustments necessary if GFR <30 mL/min	Dose reductions recommended Starting dose: 25 mg three times daily Avoid use in patients with known esophageal or gastric varices.	Increased risk of GER Use caution in patients taking medications metabolized by CYP-450 3A4 pathway. Avoid concurrent use of nitrates or α-blockers.
Tadalafil	Dose adjustments necessary if GFR <50 mL/min If GFR 30-50 mL/min, use 5-mg dose, maximum 10 mg in 48 hr If GFR <30 mL/min, no more than 5 mg	Child's Class A and Class B: maximum 10 mg daily Child's Class C: do not use tadalafil.	Increased risk of GER Use caution in patients taking medications metabolized by CYP-450 3A4 pathway. Avoid concurrent use of nitrates or α-blockers.

Modified from Luks AM, Swenson ER: Medication and dosage considerations in the prophylaxis and treatment of high-altitude illness, *Chest* 133:744-755, 2008.
CYP-450, Cytochrome P-450; *FEV_1*, forced expiratory volume in 1 second; *GER*, gastroesophageal reflux; *GFR*, glomerular filtration rate.

Pour en savoir plus

Série d'articles « pratiques » :



Luks & Grissom, *High Alt Med Biol* (22) 2021

Plan

- Réponses physiologiques à l'altitude
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- **Maladies respiratoires et voyage aérien**

Urgences respiratoires en vol

3-4 milliards passagers / an

Urgence en vol : 1 / 604 vols

JAMA | Review

In-Flight Medical Emergencies
A Review

Christian Martin-Gill, MD, MPH; Thomas J. Doyle, MD, MPH; Donald M. Yealy, MD

RESPIRATORY DISTRESS

10% of all in-flight emergencies

Initial assessment

- ☐ Identify history of respiratory disease, scuba diving, extremity swelling, or infectious symptoms.
- ☐ If available, check pulse oximetry.

Management and expected course

- ☐ **If ongoing dyspnea or known oxygen saturation is <95%** ▸ Administer oxygen.
  - If passenger's portable oxygen concentrator fails or is not used for a patient with preexisting lung disease, consider trial of oxygen therapy.
  - If passenger uses ≥4 L/min on the ground, the onboard oxygen supply may not be enough to reverse hypoxia.
  - Monitor flow rate of oxygen administered; canister consumption is variable and aircraft may not have sufficient oxygen for continuous use for the duration of the flight.
- ☐ **If bronchospasm** ▸ Administer albuterol, 2.5 mg inhaled.
- ☐ **If allergic reaction** ▸ Refer to allergic reaction card.
- ☐ **If passenger does not improve** ▸ Contact ground-based medical support for additional recommendations.

Martin-Gill *et al.*, *JAMA* (320) 2018
Ergan *et al.*, *Eur Respir Rev* (27) 2018

Pressurisation de la cabine

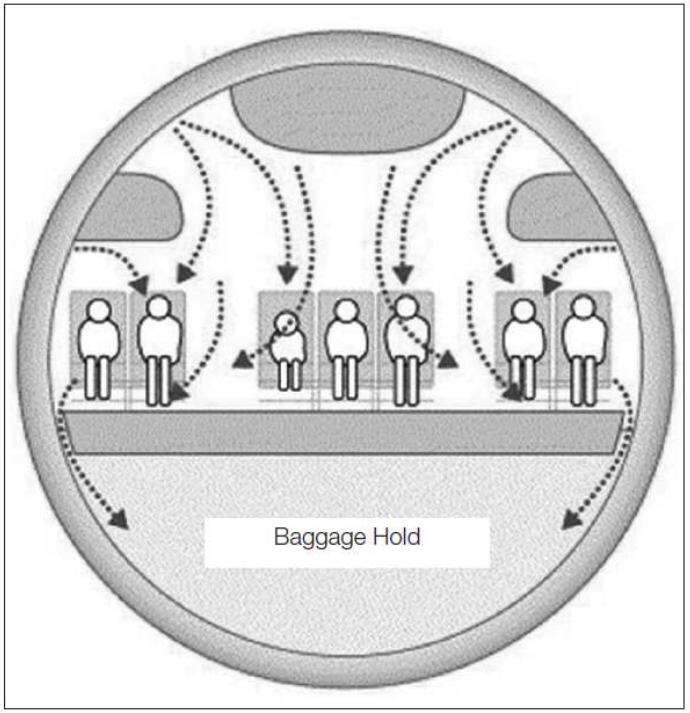


Figure 3. Schematic of the cabin ventilation system in a commercial aircraft.

- Altitude des vols commerciaux : 10000 – 13000 m
- Pressurisation minimale de la cabine à « 2438 m »
- En pratique, varie entre 1500 m et 2450 m

- Pas de problème chez sujet sain
- BPCO : surrisque dyspnée, hyperventilation, hypoxémie
- Evaluation préalable nécessaire en cas de pathologie respiratoire : supplémentation en O_2 ?

García Río *et al.*, *Arch Bronchoneumol* (42) 2007
SPLF, *Rev Mal Respir* (24) 2007
Ahmedzai *et al.*, *Thorax* (66) 2011
Ergan *et al.*, *Eur Respir Rev* (27) 2018

Autorisation au voyage aérien

Respiratory Contraindications for Air Travel

Absolute
- Acute respiratory failure
- Sputum-positive tuberculosis
- Passengers from areas with recent local outbreaks of severe acute respiratory syndrome (SARS) with respiratory symptoms
- Contacts of probable or confirmed cases of SARS who have been exposed in the last 10 days
- Undrained pneumothorax
- Thoracic surgery within the last 2 weeks
- Lung contusion
- Subcutaneous or mediastinal emphysema

Relative
- Resolution of a spontaneous pneumothorax in the last 6 weeks
- Major thoracic surgery within the last 6 weeks
- Scuba diving in the last 24 hours

Respiratory Indications for Clinical Evaluation Prior to Air Travel

- Moderate to severe chronic obstructive pulmonary disease
- Persistent severe asthma
- Severe restrictive disease (including diseases of the chest wall and respiratory muscles), especially with hypoxemia or hypercapnia
- Cystic fibrosis
- History of intolerance of air travel due to respiratory symptoms (dyspnea, chest pain, confusion, or syncope)
- Comorbid conditions that are worsened by hypoxemia (cerebrovascular disease, ischemic heart disease, heart failure)
- Pulmonary tuberculosis
- Patients from areas with recent local outbreaks of severe acute respiratory syndrome
- Recent pneumothorax
- Risk or previous episode of venous thromboembolic disease
- Prior use of oxygen therapy or ventilatory support

García Río *et al.*, *Arch Bronchoneumol* (42) 2007
SPLF, *Rev Mal Respir* (24) 2007
Ahmedzai *et al.*, *Thorax* (66) 2011

SPIF

Prédiction de la PaO_2 en vol

Equations for the Prediction of In-Flight Hypoxemia*

Equation	Reference
PaO_2 ALT=22.8–(0.00274×Alt)+(0.68×PaO_2 SL)	67
PaO_2 ALT=1.59+(0.98×PaO_2 SL)+(0.0031×Alt)–(0.00006×PaO_2 SL×Alt)–(0.00006×$PaCO_2$ SL×Alt)+(0.000000092×Alt^2)	70
PaO_2 2438 m=0.410×PaO_2 SL+17.652	28
PaO_2 2438 m=(0.417×PaO_2 SL)+17.802	69
PaO_2 2438 m=(0.519×PaO_2 SL)+(11.855×FEV_1 [L])–1760	28
PaO_2 2438 m=(0.453×PaO_2 SL)+(0.386×FEV_1 [% predicted])+2440	28
PaO_2 2438 m=(0.294×PaO_2 SL)+(0.086×FEV_1 [% predicted])+23.211	69
PaO_2 2438 m=(0.245×PaO_2 SL)+(0.171×FEV_1/FVC [% predicted])+21.028	69
PaO_2 2438 m=(0.238×PaO_2 SL)+(20.098×FEV_1/FVC)+22.258	69
PaO_2 2438 m=PaO_2 SL×$e^{-(0.02002-[0.00976\times FEV_1\,[L]]\times(PiO_2G-PiO_2ALT)}$	66
PaO_2 2438 m=PaO_2 SL×$e^{-(0.01731-[0.00019\times FEV_1\,[\%\ predicted]]\times(PiO_2G-PiO_2ALT)}$	66
PaO_2 2438 m=5.55+(0.390×PaO_2 SL)+(0.2475×DLCO [% predicted])	71
PaO_2 2438 m=(0.54×PaO_2 SL)+4700	72

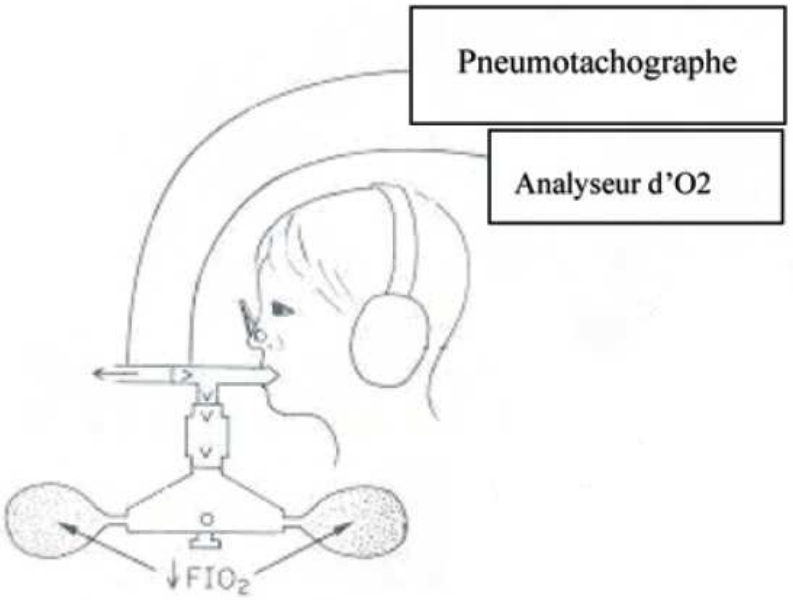
*Alt indicates altitude in feet; PaO_2 ALT, PaO_2 estimated at altitude (mm Hg); PaO_2 2438 m, PaO_2 estimated at 2438 m (8000 feet); PaO_2 SL, PaO_2 at sea level (mm Hg); PiO_2 G, partial pressure of inspired oxygen saturated with water vapor on the ground; PiO_2 ALT, partial pressure of inspired oxygen saturated with water vapor at altitude; FEV_1, forced expiratory volume in 1 second; FVC, forced vital capacity; DLCO, diffusing capacity of the lung for carbon monoxide; $PaCO_2$ SL, partial pressure of carbon dioxide at sea level (mm Hg).

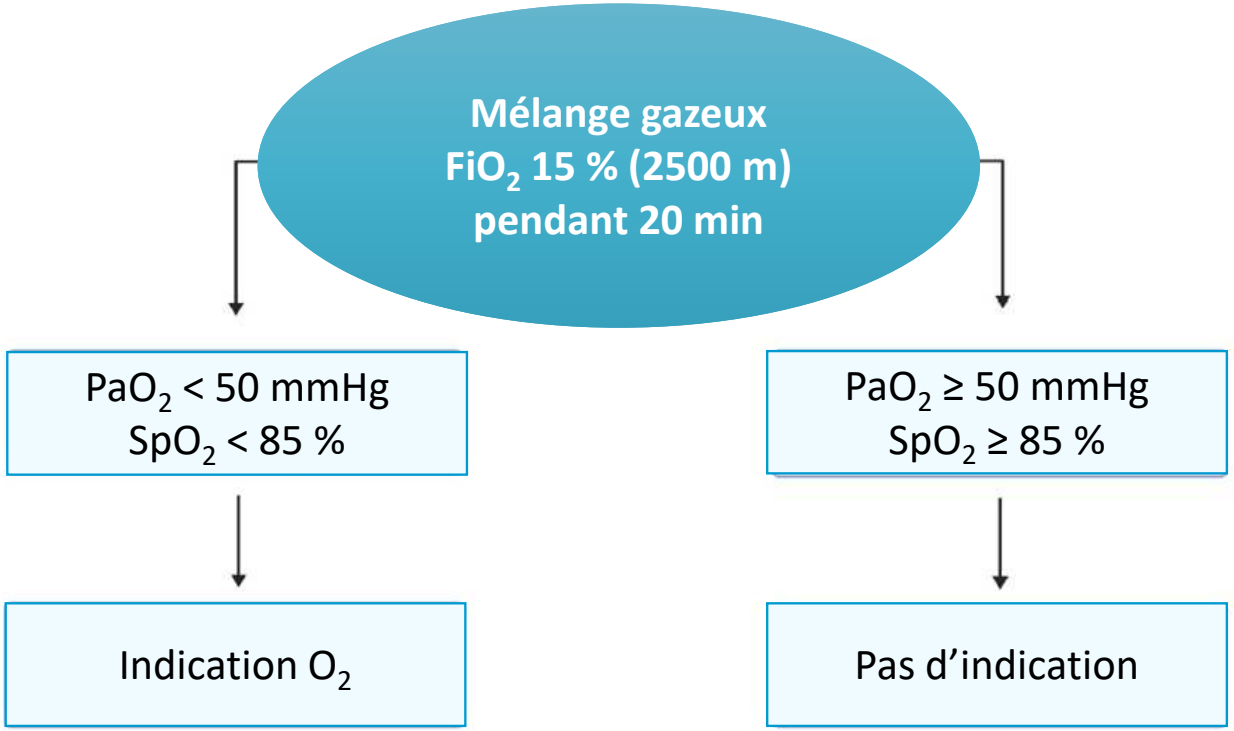
→ **Tendent à sous-estimer PaO_2 prédite par rapport à PaO_2 observée**

García Río *et al., Arch Bronchoneumol* (42) 2007

Test en hypoxie normobare

Indications formelles pour BPCO : VEMS < 30 % ou DLCO < 50 % ; hypoxémie de repos





García Río *et al., Arch Bronchoneumol* (42) 2007
SPLF, *Rev Mal Respir* (24) 2007
Ahmedzai *et al., Thorax* (66) 2011

Mais en général ne répond pas à la question : « Quel débit ? »
Cas limite (50-60 mmHg) : faire un TM6 complémentaire ?

Test en hypoxie normobare

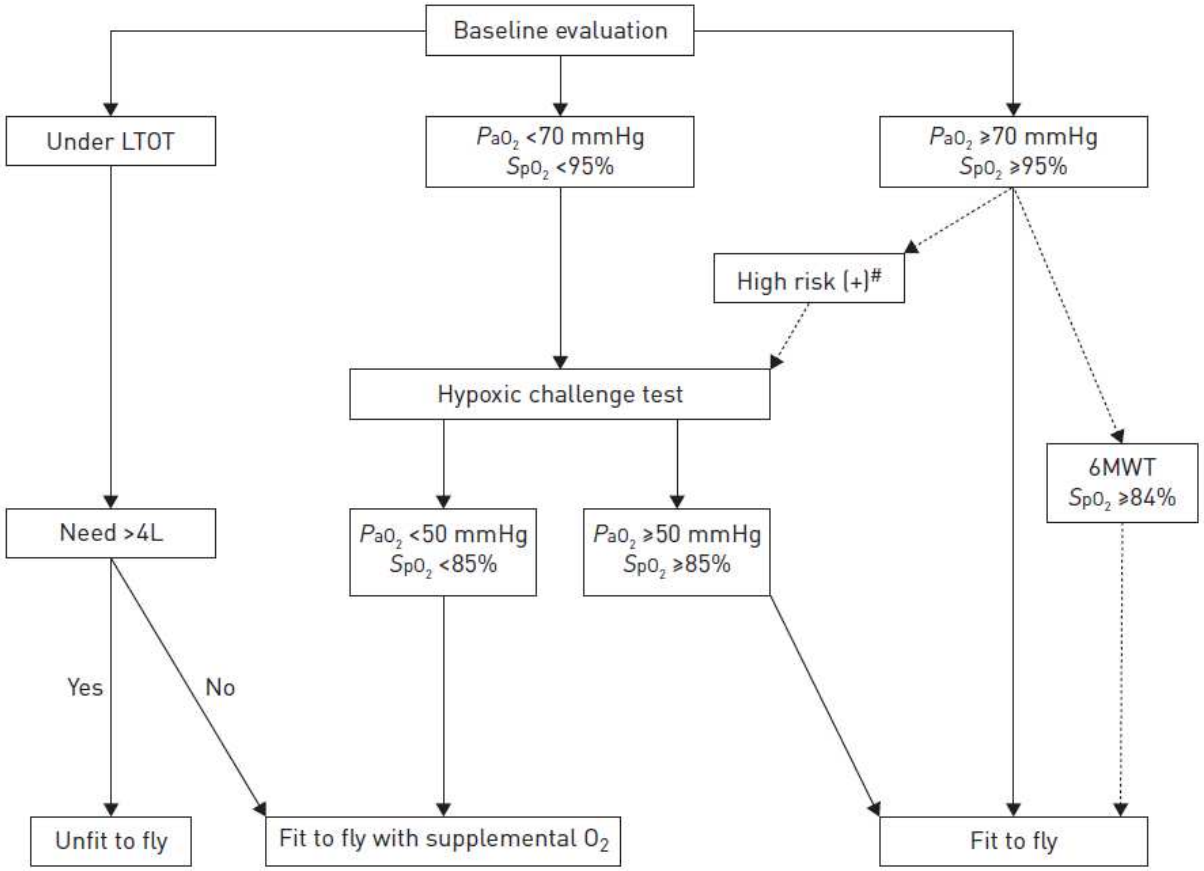


FIGURE 4 Algorithm for the assessment of fitness to fly in chronic obstructive pulmonary disease patients. LTOT: long-term oxygen therapy; $Pa0_2$: arterial oxygen tension; $Sp0_2$: arterial oxygen saturation measured by pulse oximetry; 6MWT: 6-min walk test. #: if dyspnoea on exertion, forced expiratory volume in 1 s <1.5 L or <30% predicted, a pre-existing requirement of oxygen/ventilatory support, bullous lung disease, comorbid conditions that may worsen hypoxaemia like cardiac disease and significant symptoms during previous air travel.

Débit d'O_2 : en général 2-4 l/min

Ergan *et al.*, *Eur Respir Rev* (27) 2018

Conclusion

- **Effets de l'altitude : principalement hypoxie +++**
- **Recommandations basées… surtout sur le bon sens**
- **Evaluation avant voyage +++**

Merci de votre attention

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Table 23.1 Recommendations for patients with underlying lung disease

General recommendations
• SpO_2 monitoring can be considered for any patient with lung disease
• "Home" oxygen is available in many high-altitude locations and can be arranged before or after arrival at high altitude
Chronic obstructive pulmonary disease
• Avoid travel above 2,000 m without supplemental oxygen in patients with:
– $FEV_1 < 1$ L
– CO_2 retention
– Pulmonary hypertension
– Active or recent exacerbation. Symptoms should be back at baseline prior to any planned travel
• Patients with FEV_1 1.0–1.5 L: assess need for supplemental oxygen using prediction equations with baseline FEV_1 [14] or the hypoxia inhalation test [188]:
– If the P_aO_2 is predicted to be <50 mmHg: travel with portable oxygen or a prescription to fill at destination
– If already on supplemental oxygen, increase flow rate by the ratio of higher to lower barometric pressure
• Patients with $FEV_1 > 1.0$ L can monitor pulse oximetry upon arrival and seek attention for severe hypoxemia or increasing dyspnea and fatigue
• Patients with $FEV_1 < 25$ % predicted should use dexamethasone rather than acetazolamide for AMS prophylaxis or treatment
• Travel with supply of rescue inhalers and oral steroids in event of exacerbation
Interstitial lung disease
• Avoid high-altitude travel with TLC < 40 % predicted or supplemental oxygen requirement at home elevation
• Patients with less severe disease: assess for supplemental oxygen [23] and travel with portable oxygen or prescription to fill at destination if predicted $P_aO_2 < 50$ mmHg
• Patients not requiring supplemental oxygen should monitor pulse oximetry upon arrival and seek attention for severe hypoxemia or increasing dyspnea and fatigue
Asthma
• Avoid high-altitude travel in patients with moderate persistent or severe asthma or in patients with recent or active exacerbations or recent increase in rescue inhaler use. Following an exacerbation, symptoms should be back at baseline prior to the planned sojourn
• Patients with mild-intermittent or mild-persistent asthma can ascend to high altitude and should remain on preexisting medications and carry a supply of rescue inhalers and steroids for exacerbations
• Patients traveling in cold environments must keep inhalers warm and be aware that the number of puffs per inhaler may be decreased at elevations above 3,000 m [189]

Cystic fibrosis

- High-altitude travel should be avoided with baseline $FEV_1 < 30$ % predicted
- Patients with an FEV_1 30–50 % of predicted should undergo pretravel assessment to determine need for supplemental oxygen [44] and should travel with portable oxygen or prescription to fill at destination if predicted $P_aO_2 < 50$ mmHg
- Patients not requiring supplemental oxygen should monitor pulse oximetry upon arrival and seek attention for severe hypoxemia or increasing dyspnea and fatigue
- Continue preexisting airway clearance techniques, prophylactic antibiotics, and mucolytic therapy during sojourn

Pulmonary hypertension

- Patients with moderate to severe pulmonary hypertension (mean PA pressure ≥35 mmHg or systolic pressure ≥50 mmHg) should avoid high-altitude travel without supplementary oxygen. Patients should:

– Be counseled regarding recognition and management of HAPE

– Monitor oxygen saturation during their high-altitude stay

– Use nifedipine 30 mg SR BID as HAPE prophylaxis if not already on vasodilator therapy

- Patients with mild pulmonary hypertension (mean PA pressure ≤35 mmHg or systolic pressure <50 mmHg) may travel to high altitude but might consider prophylaxis with nifedipine SR 30 mg BID and consider monitoring oxygen saturation and symptoms following arrival at high altitude

Obstructive sleep apnea

- Patients with moderate to severe obstructive sleep apnea should travel to high altitude with their CPAP machine if reliable power access can be assured
- Acetazolamide should be used in addition or as an alternative to CPAP to decrease the incidence and severity of central sleep apnea
- Patients using older generation machines (>10 years old) that lack pressure-compensating features will need to adjust the intended CPAP pressure at high altitude [72]

Neuromuscular disorders

- Patients with hypoventilation at sea level should travel with supplemental oxygen and bi-level positive airway pressure for use at night
- Patients with blunted hypoxic ventilatory responses should monitor pulse oximetry and travel with a prescription for supplemental oxygen to fill if severe hypoxemia develops
- Patients with kyphoscoliosis and other disorders associated with pulmonary hypertension should be screened with echocardiography and managed according to guidelines for pulmonary hypertension
- Patients with bilateral diaphragmatic paralysis should consider travel with supplemental oxygen for use at night