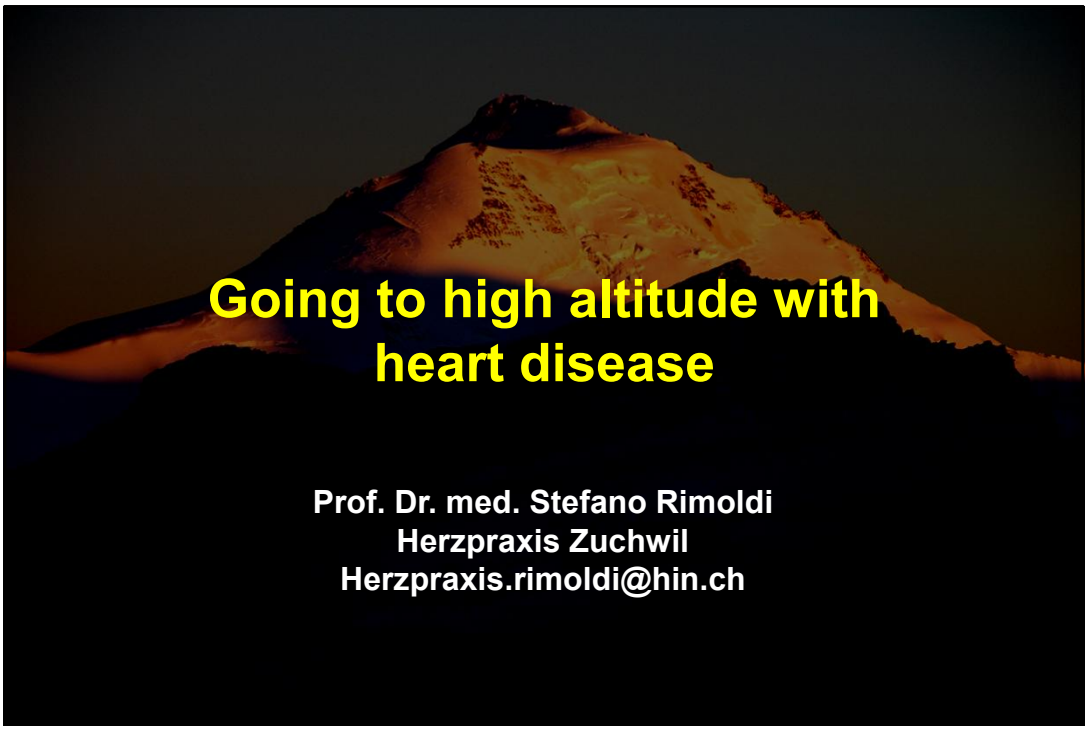

Going to high altitude with heart disease

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Herzpraxis Zuchwil
Herzpraxis.rimoldi@hin.ch

There are very few studies on patients with heart disease going at high altitude.

Real world is…

63 days at Jungfraujoch (3454m)

~ 5000 subjects/day

↓

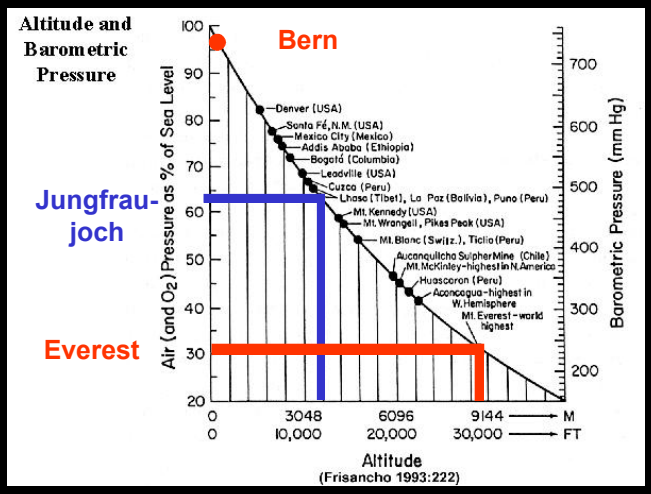
315'000 subjects

↓

Only one patient evacuated with ACS

Physiology and Adaptation

Barometric pressure and partial pressure of oxygen decrease with altitude



High altitude (>2500m)

Altitude at which the oxygen saturation of hemoglobin is < 90%.

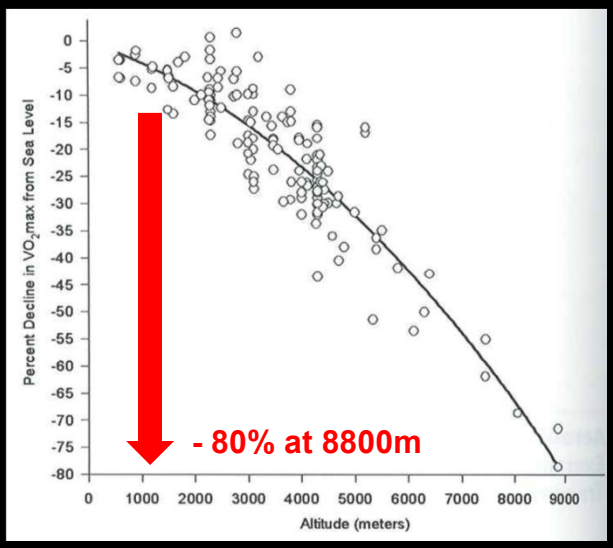
High altitude (>2500m)

Altitude at which the oxygen saturation of hemoglobin is < 90%. Under this limit the tissues are hypo-oxygenated

Adaptation

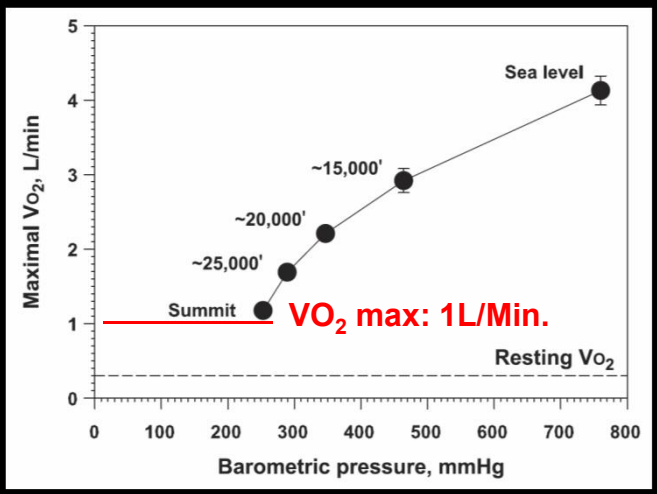
Hypoxia/Hypoxemia stimulate the cardiovascular and ventilatory system in order to maintain a sufficient oxygenation of the tissues

Maximal O_2 uptake and altitude



Fulco CS Aviat Space Environ Med 1998

Maximal attainable O_2 uptake decrease with altitude



Wagner PD. High Alt Med & Biol 2010

VO_2 max = maximal attainable O_2 uptake

Maximal O_2 uptake

Cardiac output

Systemic art. O_2

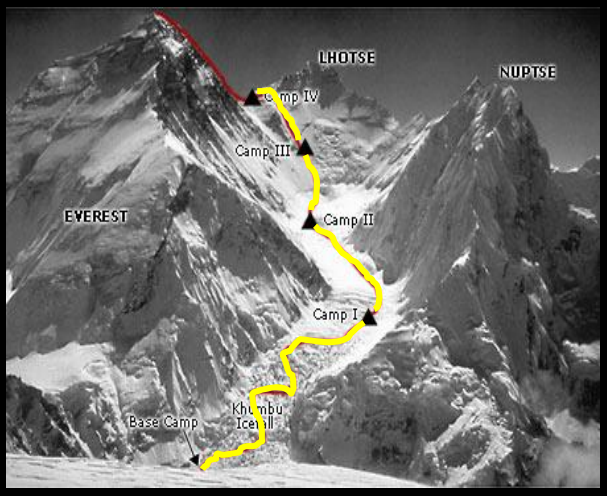
Systemic ven. O_2

$$VO_2\ max = Q \times (CaO_2 - CvO_2)$$

- Heart rate
- Contractility

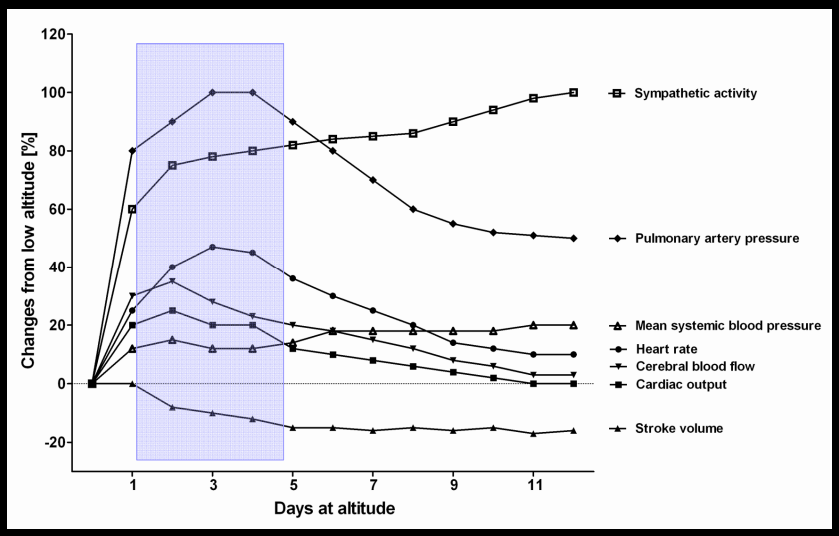
- Ventilation
- Hb-Affinity
- EPO

Acclimatization to altitude



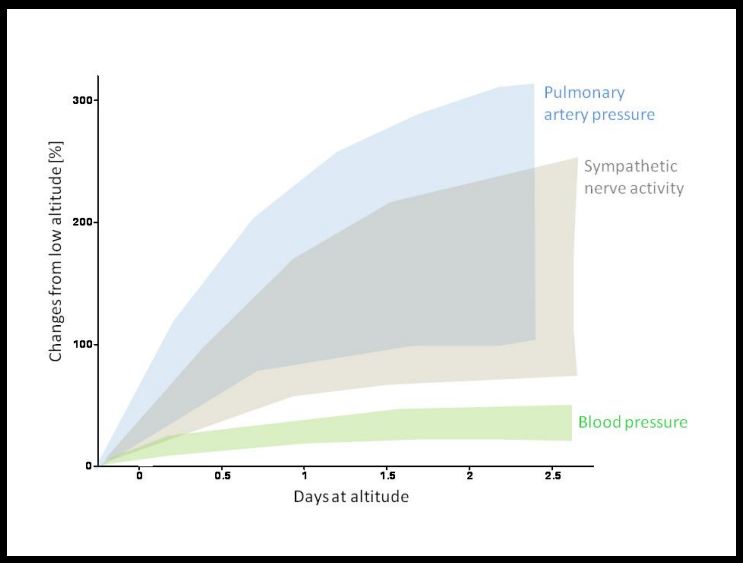
- Erythrocytosis
- ↑ affinity oxygen-hemoglobin
- Pulmonary vasoconstriction, cerebral–muscular vasodilation
- ↑ ventilation and cardiac output

Cardiovascular acclimatization



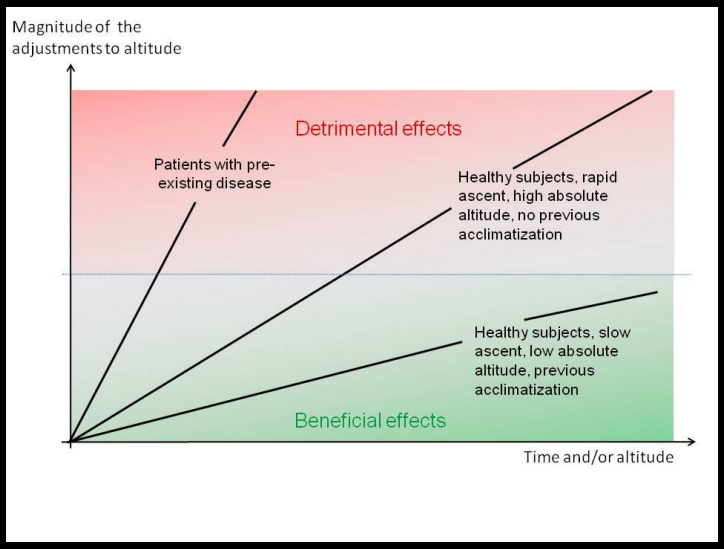
Rimoldi, Sartori et al Prog Cardiovasc Dis 2010;52:512-24

Interindividual variability

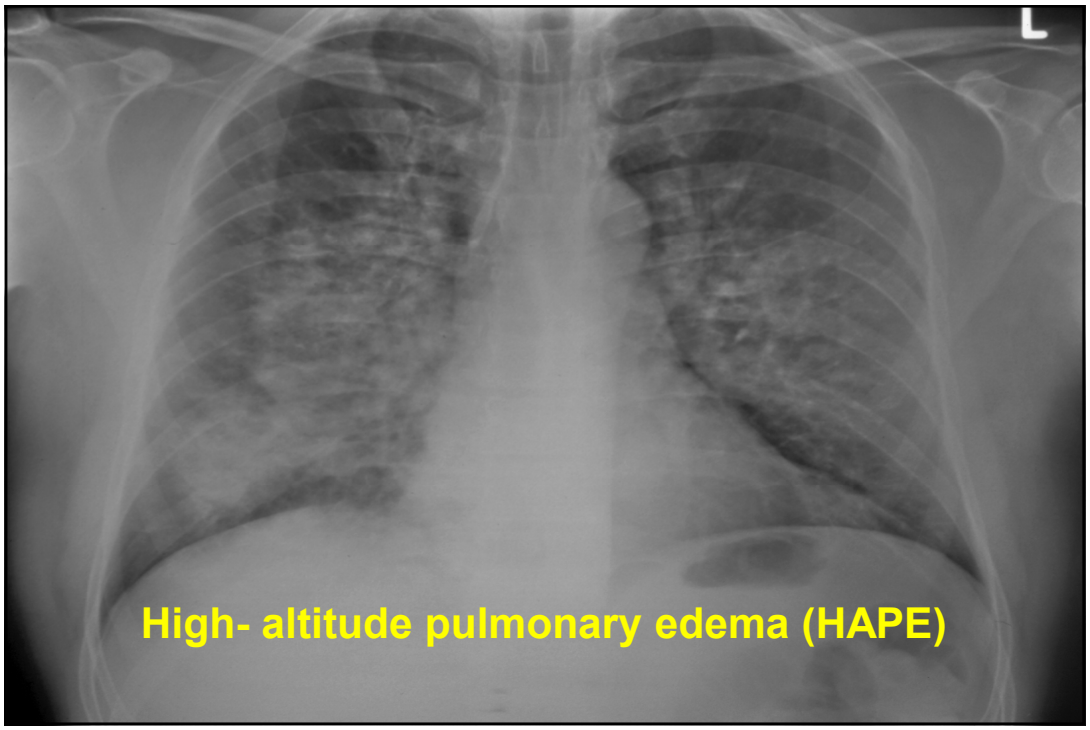


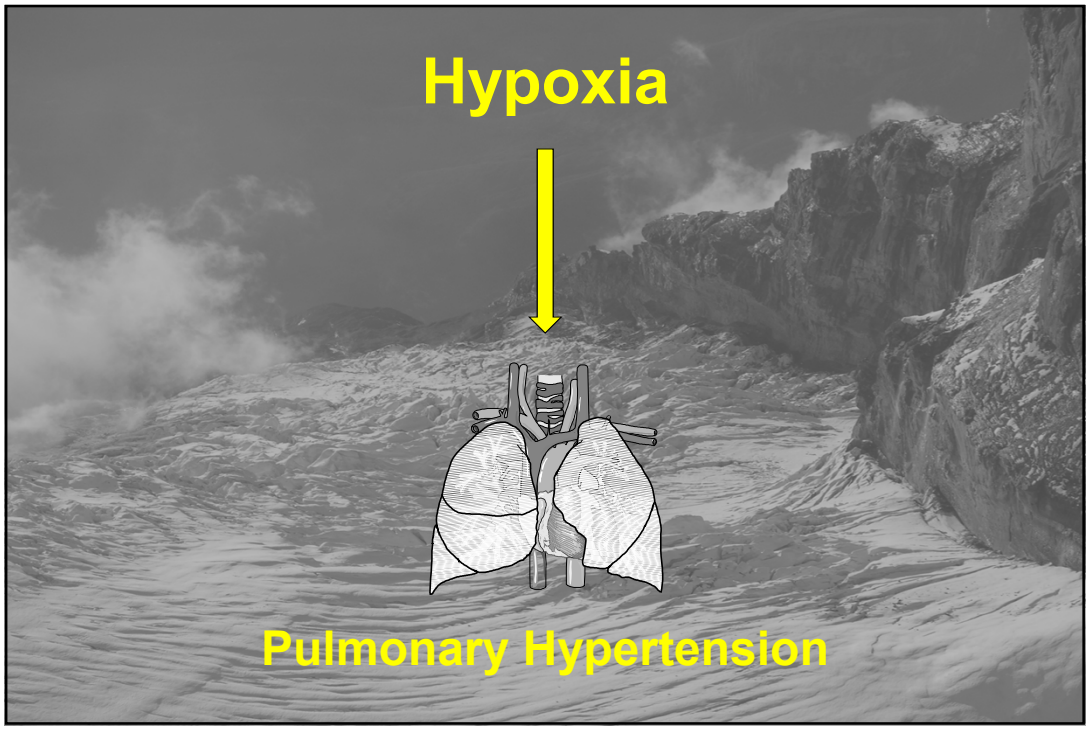
Rimoldi, Sartori et al Prog Cardiovasc Dis 2010;52:512-24

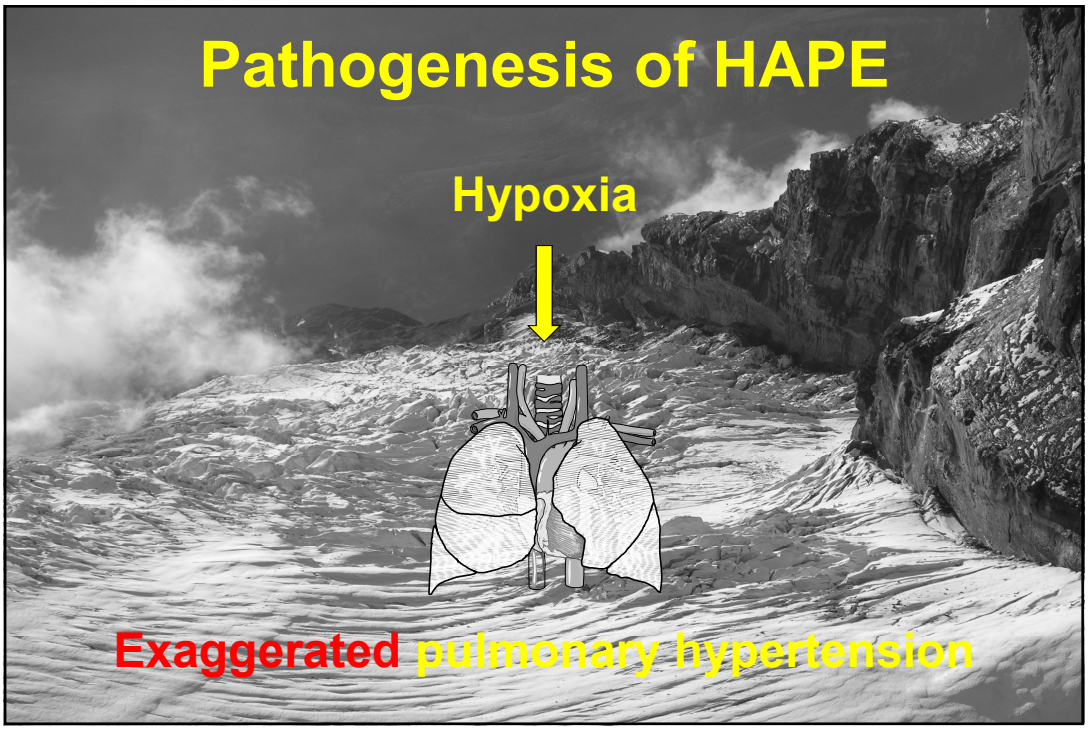
Individual predisposition

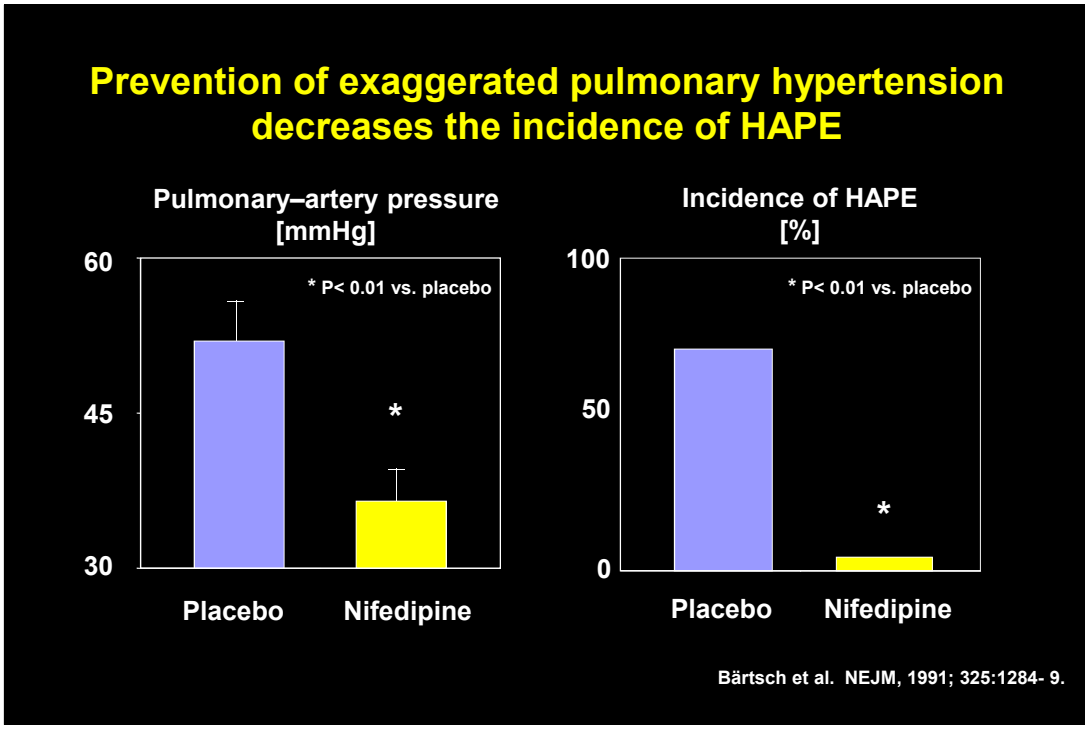


Rimoldi, Sartori et al Prog Cardiovasc Dis 2010;52:512-24


L
High- altitude pulmonary edema (HAPE)


Hypoxia
Pulmonary Hypertension


Pathogenesis of HAPE
Hypoxia
Exaggerated pulmonary hypertension


Prevention of exaggerated pulmonary hypertension decreases the incidence of HAPE
Pulmonary–artery pressure [mmHg]
60
45
30
* P< 0.01 vs. placebo
*
Placebo
Nifedipine
Incidence of HAPE [%]
100
50
0
* P< 0.01 vs. placebo
*
Placebo
Nifedipine
Bärtsch et al. NEJM, 1991; 325:1284- 9.

How identify HAPE susceptible subjects at low altitude ?

History of HAPE: pre-exposure assessment*
(Hypoxie-Test)

Echocardiographic assessment of:

- Right ventricular function and RV-RA gradient under normoxic and hypoxic ($FIO_2$12%)

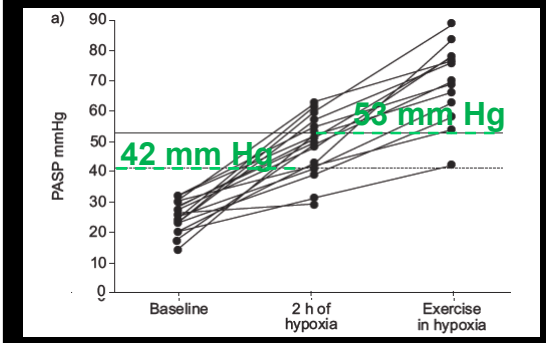
Avoid high-altitude exposure or prevention of HAPE if:

- deterioration of RV function
- $RV\text{-}RA_{FIO_2 12\%}$ > 42 mmHg at rest and/or > 53mmHg at exercise

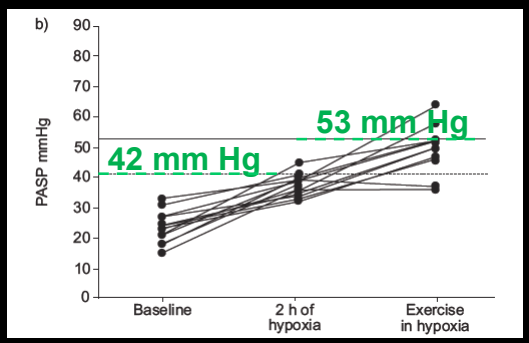
* Rimoldi, Sartori et al Prog Cardiovasc Dis 2010;52:512-24

Identification of HAPE susceptible subjets at low altitude

HAPE prone

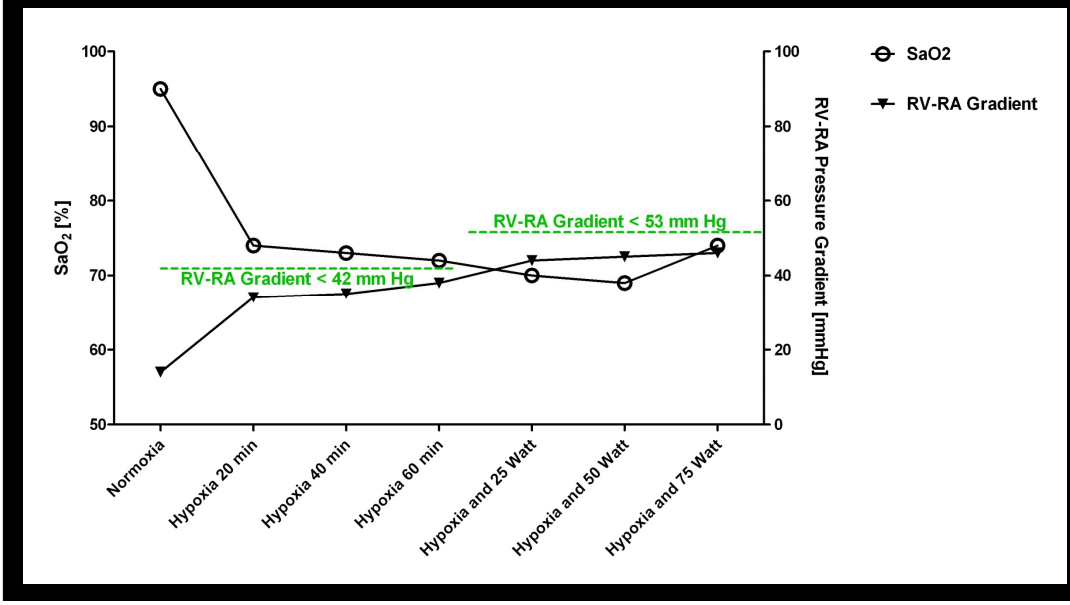


HAPE resistant

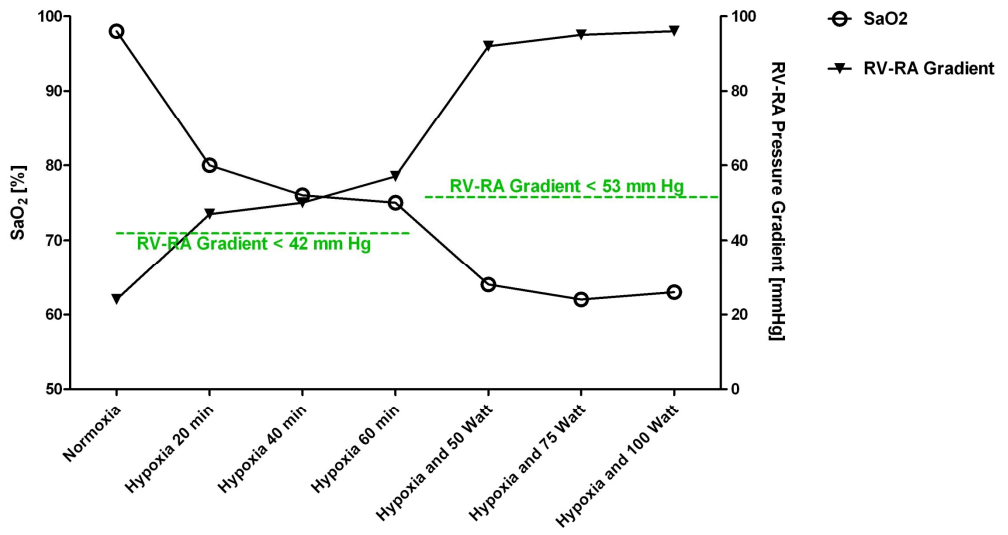


Dehnert et al, Eur Respir J 2005; 25 : 545-

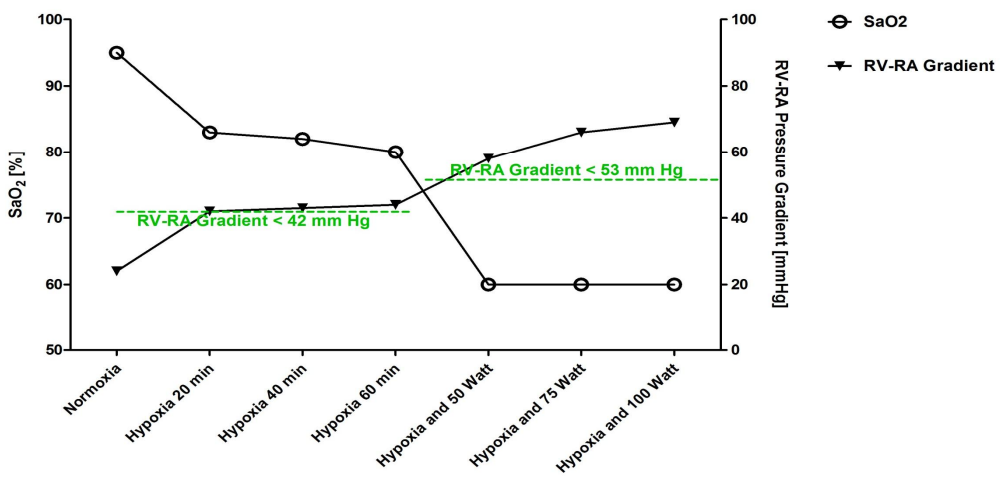
Example of Hypoxia test in a HAPE resistant subject



Example of Hypoxia test in a HAPE prone subject



Hypoxie-Test



PREVENTION

HAPE

Avoid direct transport to an altitude >2'750 m
Ascend at a slow rate (increase sleeping altitude <600 m/day)
Avoid overexertion, alcohol, and hypnotics
Adequate fluid intake

Nifedipine
(30-60 mg /day
starting 24 h before)

Dexamethasone
(4mg every 12 hrs
starting 24 h before)

Tadalafil
(20 mg /day
starting 24 h before)

TREATMENT

HAPE

DESCENT

Oxygen

Nifedipine
(20 mg slow-release
every 8 hours)

Sildenafil
(50 mg every 8 h)

Hyperbaric chamber

High altitude and coronary artery disease

HIGH ALTITUDE

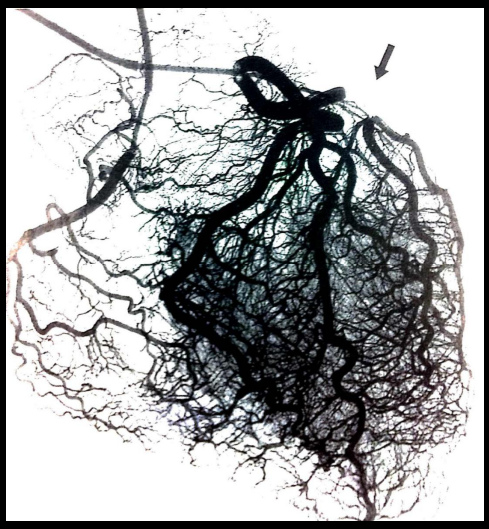
- Heart rate ↑
- Myocardial contractility ↑
- (Afterload ↑)

Ambient Hypoxia

O_2 demand ↑

High altitude and coronary artery disease

role of the collateral circulation



Seiler C. Collateral Circulation of the Heart, Springer 2009

High altitude and coronary artery disease Contraindications

- Unstable Angina
- Symptoms or sign of ischemia < 80 W / 5 MET
- Myocardial infarction / Revascularisation < 3 Months
- Dual platelet antiaggregation + oral anticoagulation

Rimoldi, Sartori et al Prog Cardiovasc Dis 2010;52:512-24

High altitude and coronary artery disease Preexposure assessment

- In all men > 50y and women > 60y at risk or with known CAD → exercise testing

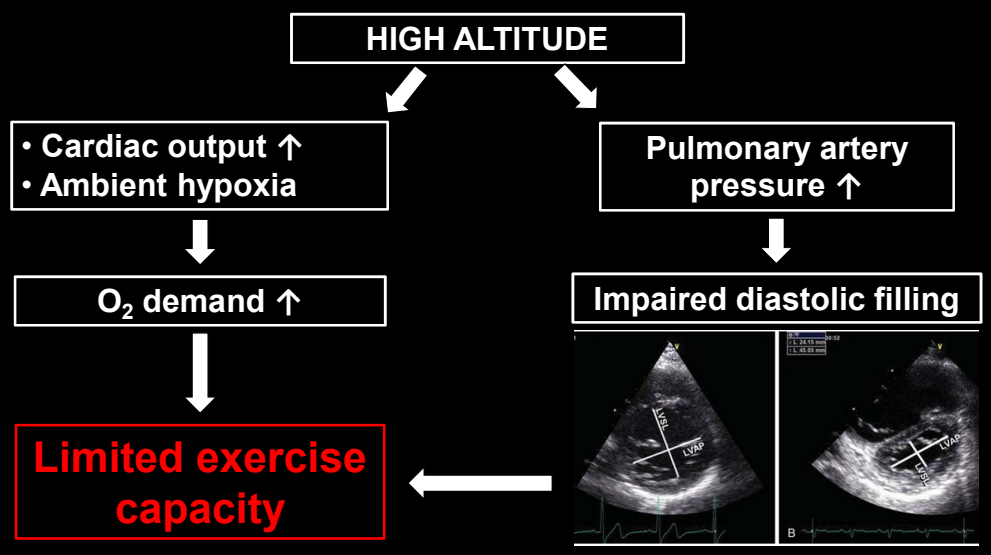
Rimoldi, Sartori et al Prog Cardiovasc Dis 2010;52:512-24

High altitude and coronary artery disease Recommendations

- ascent at slow rate at altitude > 2000 m
- increasing sleeping altitude by < 300 m/d
- avoid direct transportation to an altitude > 3000 m
- limit physical activity (< 70% max HR)
- If angina: administer antianginal drugs, descent

Rimoldi, Sartori et al Prog Cardiovasc Dis 2010;52:512-24

High altitude and congestive heart failure



High altitude and congestive heart failure Contraindications

- NYHA > II
- decompensated heart failure < 3 months
- ICD implant./intervent. for ventricular arrhythmia < 3 mo
- Dual platelet antiaggregation + oral anticoagulation

Rimoldi, Sartori et al Prog Cardiovasc Dis 2010;52:512-24

High altitude and congestrive heart failure Preexposure assessment

- In all patients transthoracic echocardiography at rest
- Exercise testing (ev. spiroergometry)
- If suspect of pulmonary hypertension → Hypoxia-test
- ev. Holter-ECG

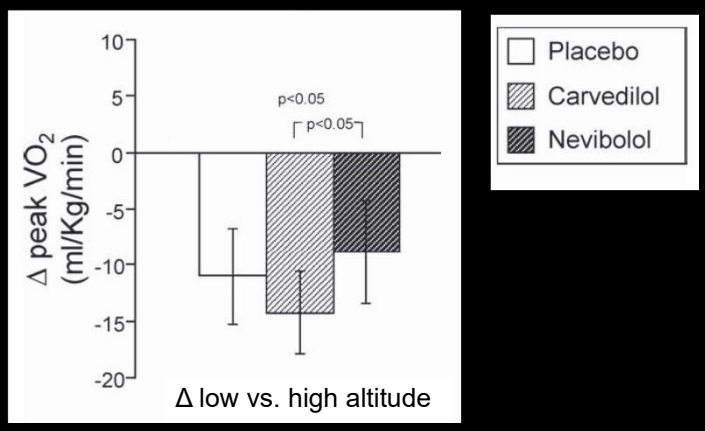
Rimoldi, Sartori et al Prog Cardiovasc Dis 2010;52:512-24

High altitude and congestive heart failure Recommendations

- ascent at slow rate > 2000 m (sleeping alt. by < 300 m/d)
- Restriction of salt intake
- if possible monitoring of body weight and fluid retention
- Self adjustment of diuretic dosage
- Maintain unchanged heart failure medications (i.e. β- blockers and ACE-I/ARB)

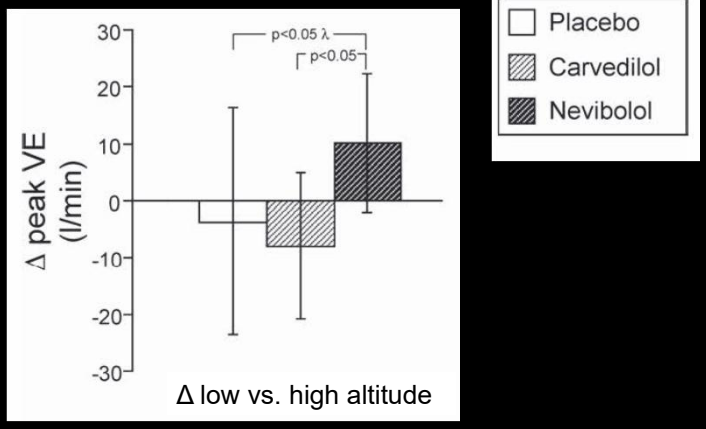
Rimoldi, Sartori et al Prog Cardiovasc Dis 2010;52:512-24

Betablockers at high altitude



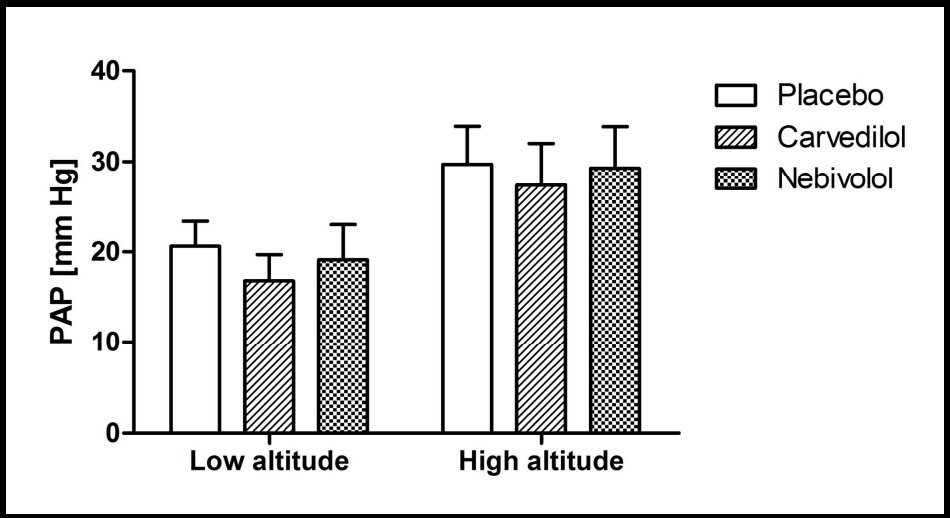
Valentini M et al., Cardiovasc Ther 2012;30:240-

Betablockers at high altitude



Valentini M et al., Cardiovasc Ther 2012;30:240-

Betablockers at high altitude



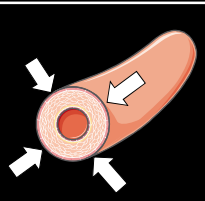
Valentini M et al., Cardiovasc Ther 2012;30:240-

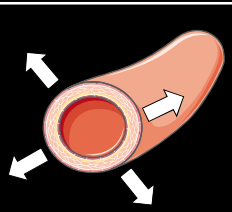
High altitude and arterial hypertension

HIGH ALTITUDE

Sympathetic activation → Vasoconstriction

Ambient hypoxia → Vasodilation





High altitude and arterial hypertension

HIGH ALTITUDE

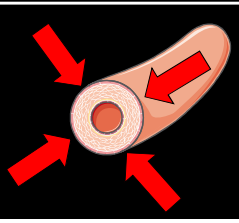
Sympathetic activation

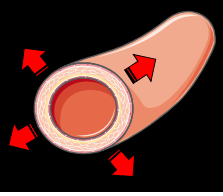
Ambient hypoxia

Arterial hypertension

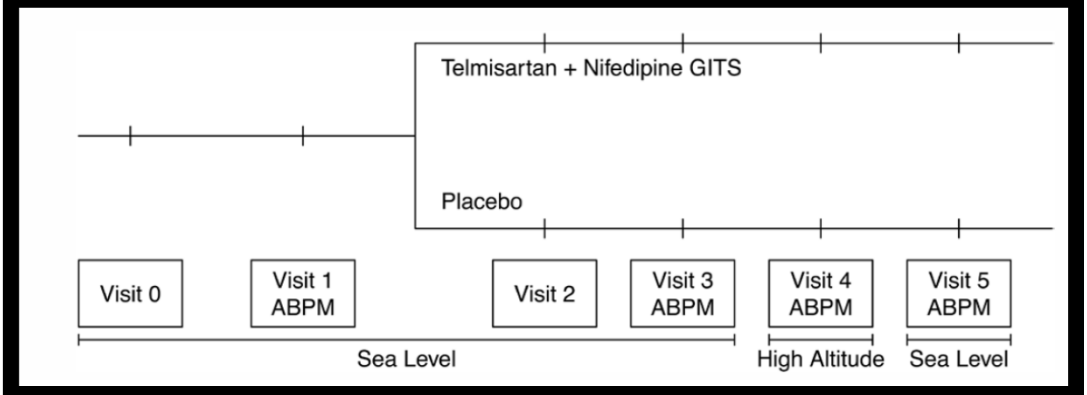
Exaggerated Vasoconstriction

Impaired Vasodilation



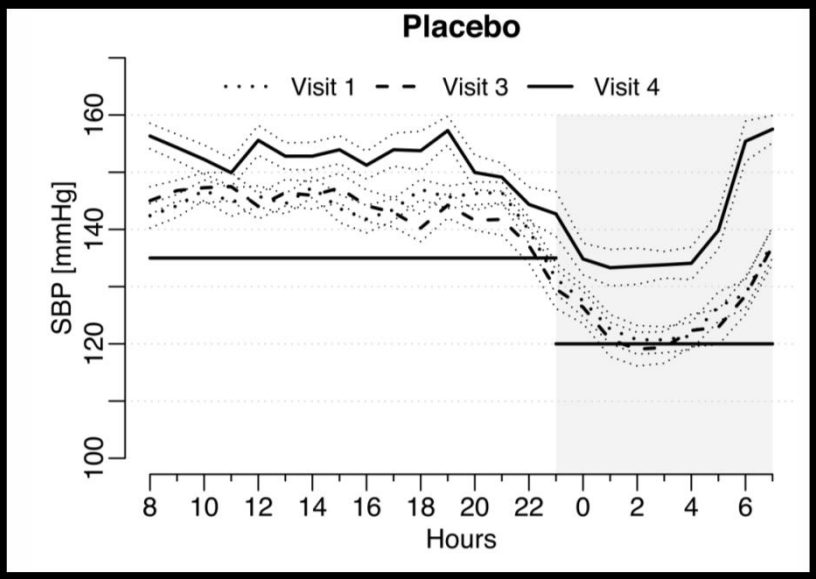


Antihypertensive Therapy at high altitude: study design



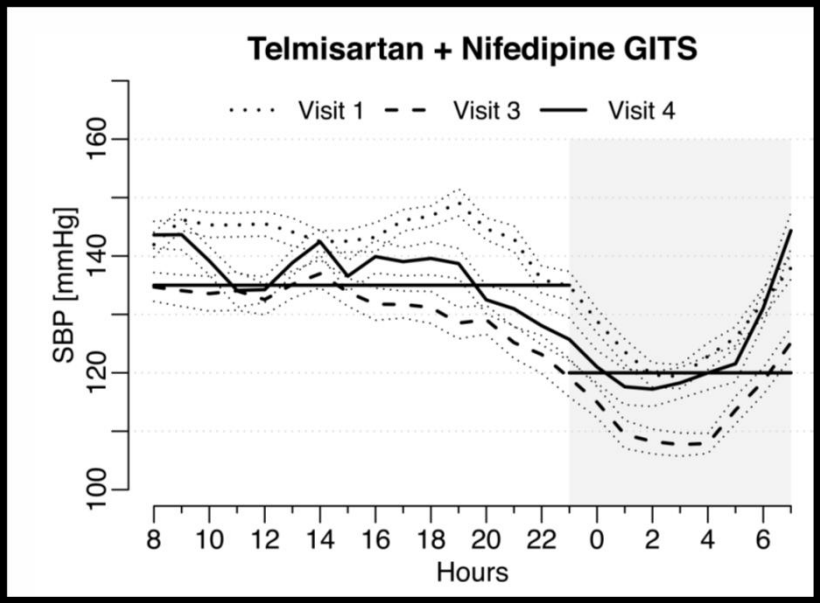
Bilo G et al, Hypertension. 2015;65:1266-

24h ABPM during placebo



Bilo G et al, Hypertension. 2015;65:1266-

24h ABPM during active treatment



Bilo G et al, Hypertension. 2015;65:1266-

High altitude and arterial hypertension Contraindications

- BP at rest > 160 / 100 mm Hg
- > 220 mm Hg systolic BP during exercise
- poorly controlled atrial arrhythmia

Rimoldi, Sartori et al Prog Cardiovasc Dis 2010;52:512-24

High altitude and arterial hypertension Preexposure assessment

- If not well controlled: 24h ambulatory BP measurement
- Exercise testing if exaggerated BP increase suspected

Rimoldi, Sartori et al Prog Cardiovasc Dis 2010;52:512-24

High altitude and arterial hypertension Recommendations

- Self-monitoring if possible
- if BP controlled: don't change the therapy
- All antihypertensive drugs are admitted
- Ca^{2+} -blockers may have additional beneficial effects for HAPE prevention
- β- blockers may limit exercise capacity

Rimoldi, Sartori et al Prog Cardiovasc Dis 2010;52:512-24

Summary

General prerequisites at low altitude

a. Stable clinical condition

b. Asymptomatic at rest

c. Functional class < II

Summary

General reccomandations at high altitude

a. Ascent at a slow rate (sleeping alt. < 300 m/d)

b. Avoid overexertion

c. Avoid direct transportation to an alt. > 3000 m

Summary

Absolute contraindications

a. Unstable clinical conditions
   - i.e. unstable angina, symptom or sign of ischemia < 8 W / 5 MET, decompesated CHF, uncontrolled arrhythmia

b. Major cardiovascular events < 3 months

c. Marked systemic or pulmonary hypertension

d. Cyanotic congenital heart disease

Summary

Preexposure assessment

a. CAD: revascularization > 6 mo -> exercise test

b. Impaired LVEF: echo + exercise test

c. Arterial hypertension: ev. 24h ABPM + exercise

d. Pulmonary hypertension: “Hypoxia-test”