Medical aspects of field experiments studying breathing under avalanche snow

Lenka Horáková[1-3], Václav Ort[1], Šimon Walzel[1], Ladislav Bís[1] & Karel Roubík[1]

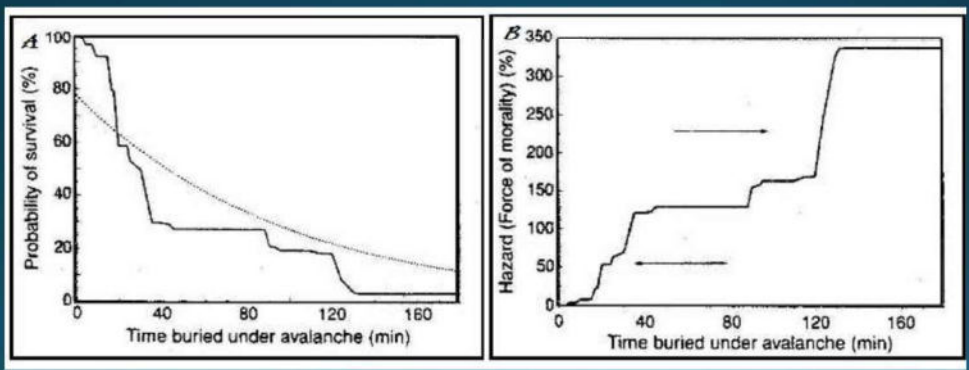
[1] Czech Technical University in Prague, Faculty of Biomedical Engineering, Czech Republic

[2] Charles University in Prague, Department of Anaesthesiology, Intensive Care and Emergency Medicine, Prague, Czech Republic

[3] UIAA Medical Commission

Survival chances of avalanche buried victims

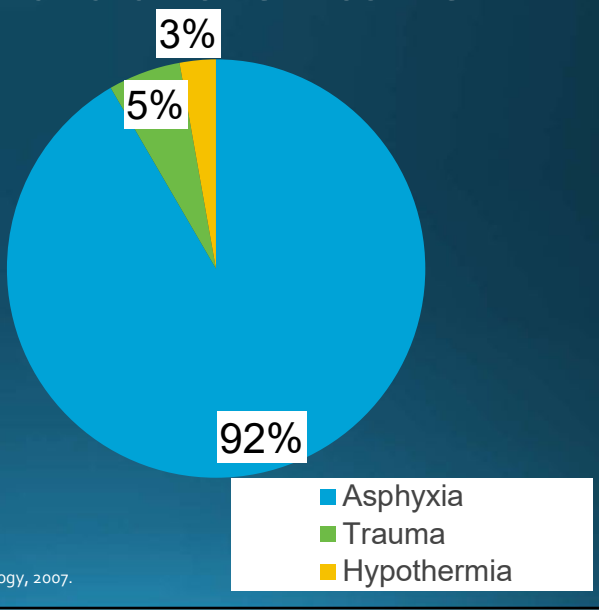
- in the Alps, between 1980 and 2015 there were on average 100 avalanche fatalities annually
- mortality increases rapidly with the time buried



Falk M, Brugger H, Adler-Kastner L., Nature, 1994.

Causes of death of snow avalanche victims

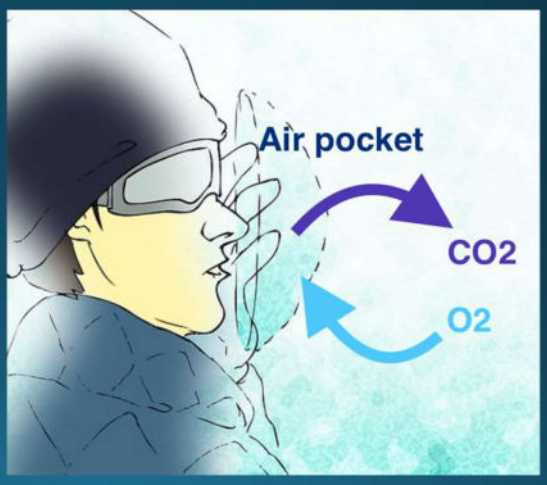
- commonest cause of death: asphyxia
- survival chances depend on:
  - trauma sustained
  - length and depth of burial
  - presence of air pocket



Hohlrieder et al., High Altitude Medicine and Biology, 2007.

Avalanche buried victim

- air pocket = any space surrounding victim's nose and mouth (with patent airways)
- victim can breath air contained in snow
- decreasing oxygen level and accumulation of CO_2 = limiting factors
- mechanisms of gas exchange not yet fully clarified

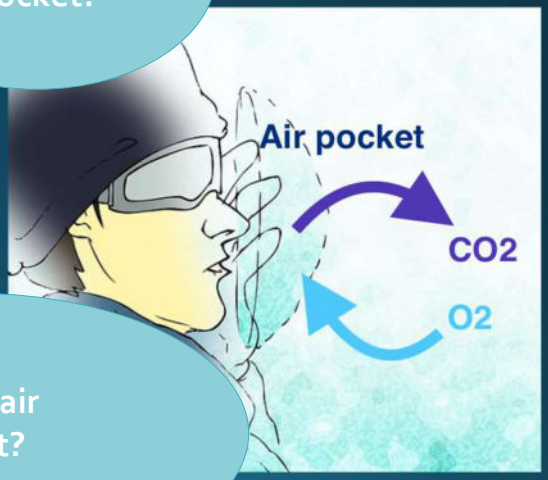


Picture edited, wiki How to Survive an Avalanche

1 litre air pocket?

2 litre air pocket?

How does the gas exchange in air pocket work?



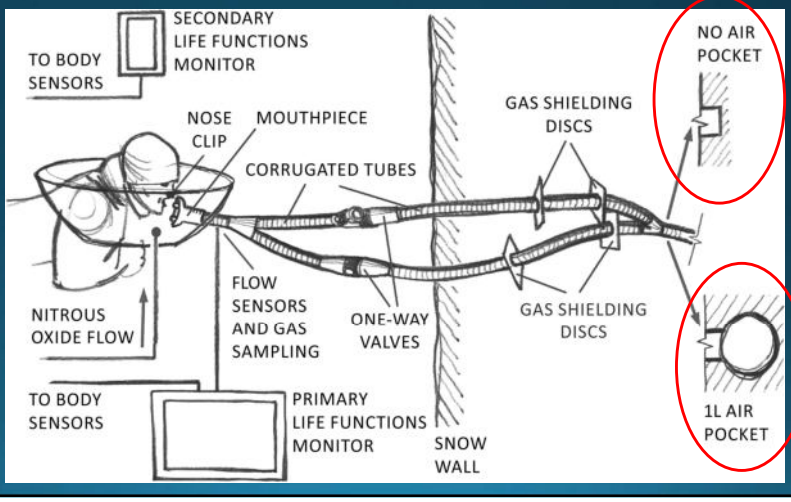
4 litre air pocket?

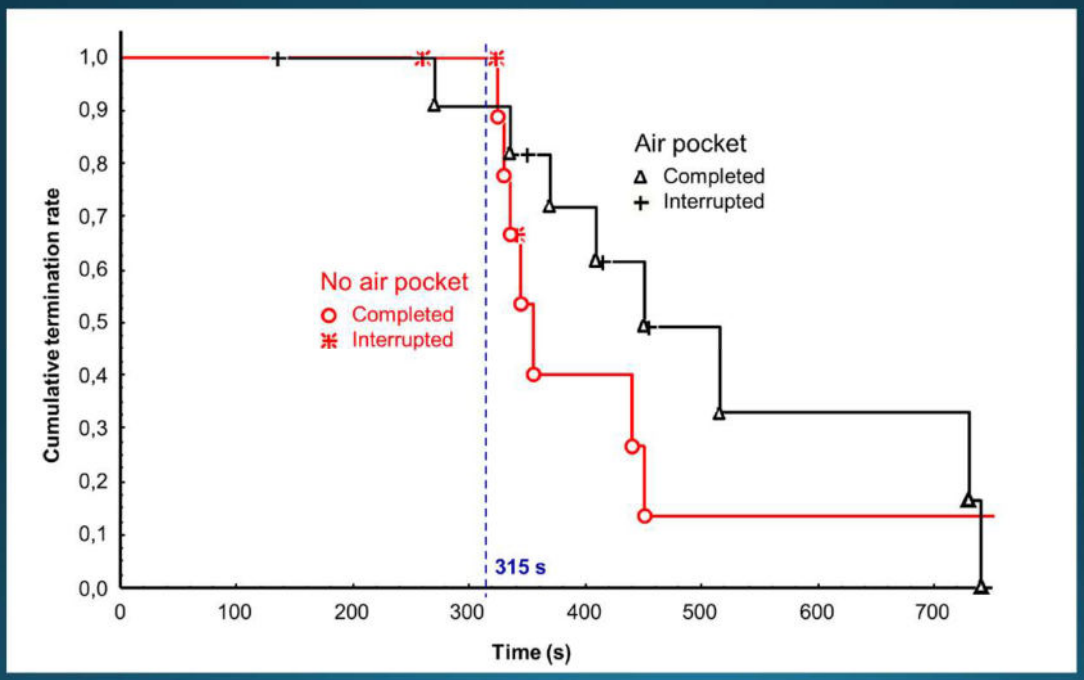
PLOS ONE

RESEARCH ARTICLE

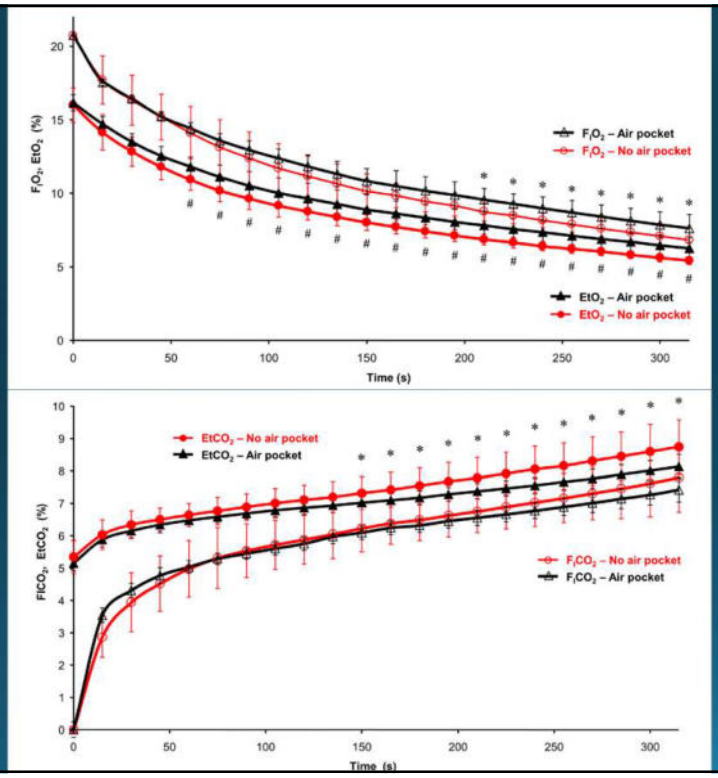
Work of Breathing into Snow in the Presence versus Absence of an Artificial Air Pocket Affects Hypoxia and Hypercapnia of a Victim Covered with Avalanche Snow: A Randomized Double Blind Crossover Study

Karel Roubík[1]*, Ladislav Sieger[2], Karel Sykora[2]





Roubík K., Sieger L, Sýkora K, PLOSOne, 2015.



Roubík K., Sieger L, Sýkora K, PLOSOne, 2015.

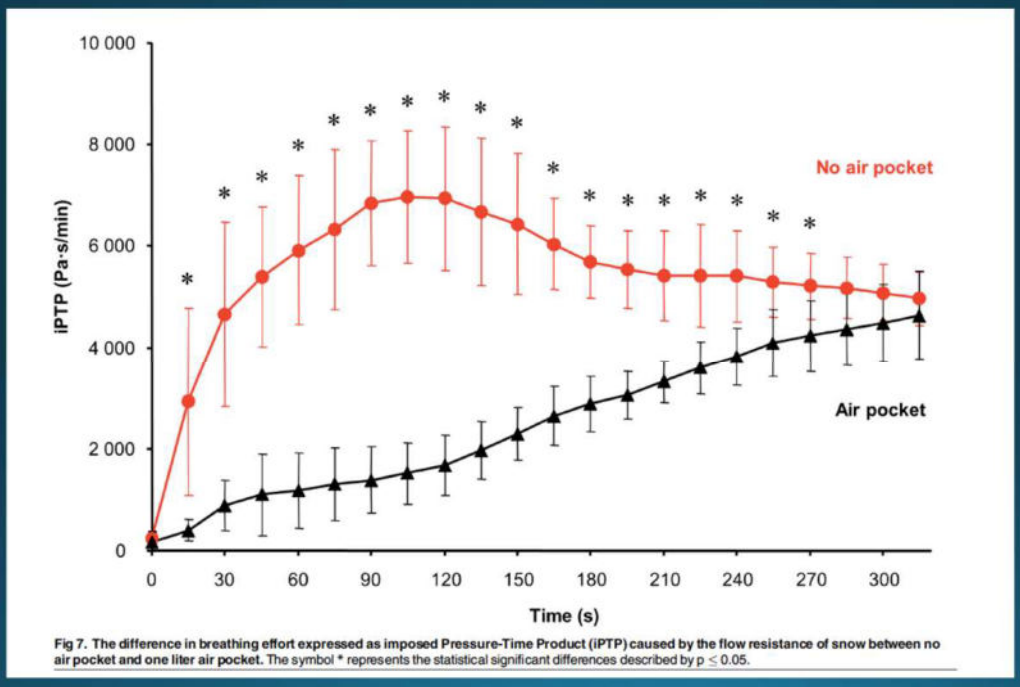
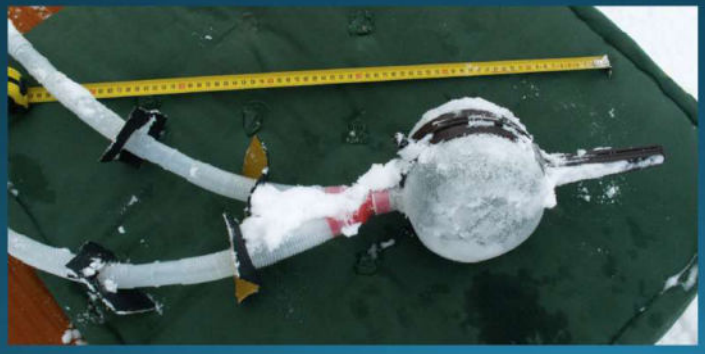


Fig 7. The difference in breathing effort expressed as imposed Pressure-Time Product (iPTP) caused by the flow resistance of snow between no air pocket and one liter air pocket. The symbol * represents the statistical significant differences described by $p \leq 0.05$.

Roubík K., Sieger L, Sýkora K, PLOSOne, 2015.

Breathing circuits

zero pocket

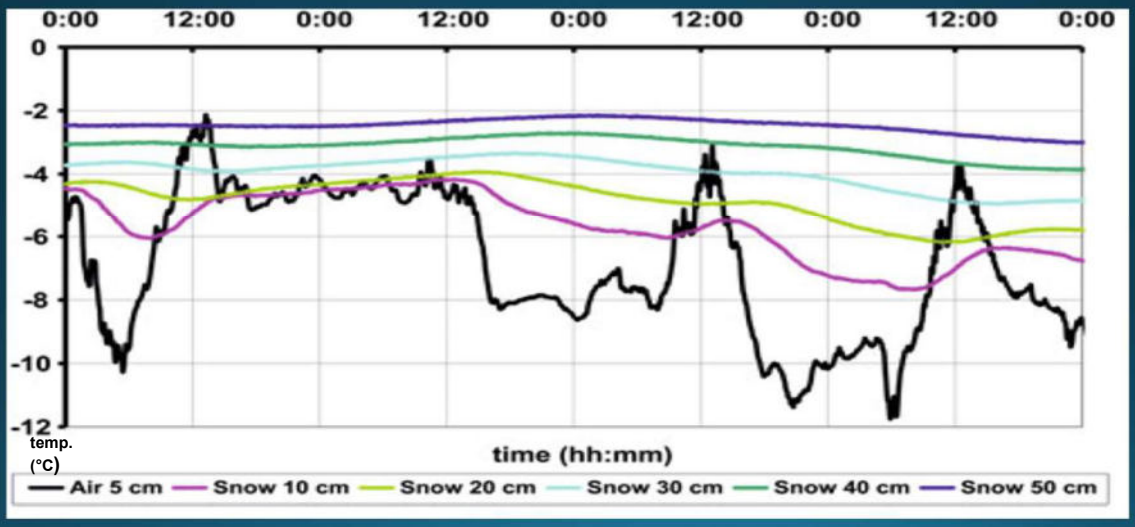


1 litre pocket

Measurements of snow properties

- snow density
- air/snow temperature
- large heat capacity

Variation of air and snow temperature

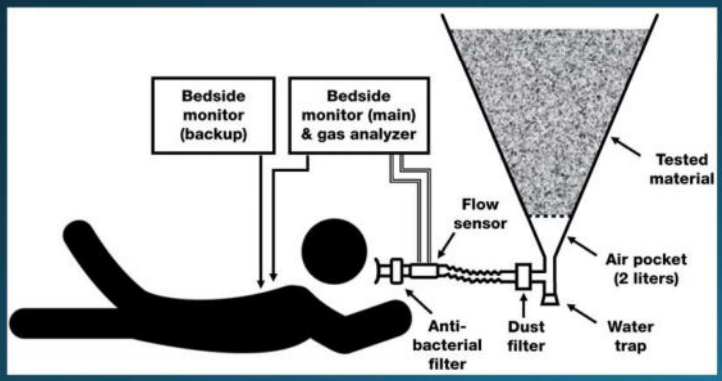


Measured according to the international standard ISO 2533:1975/Add.2:1997

scientific reports

OPEN **Perlite is a suitable model material for experiments investigating breathing in high density snow**

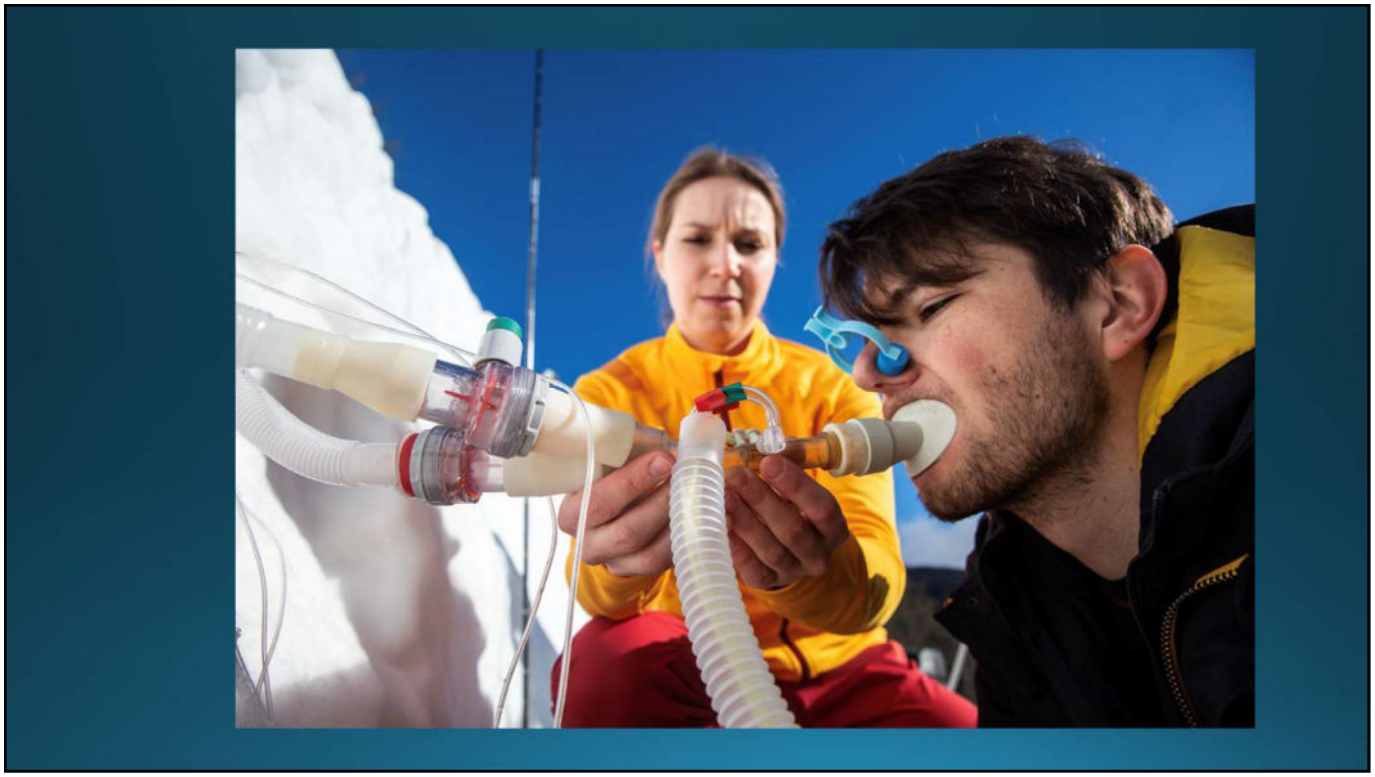
Karel Roubik[1,2], Karel Sykora[2,3], Ladislav Sieger[4], Vaclav Ort[1], Lenka Horakova[1] & Simon Walzel[1]

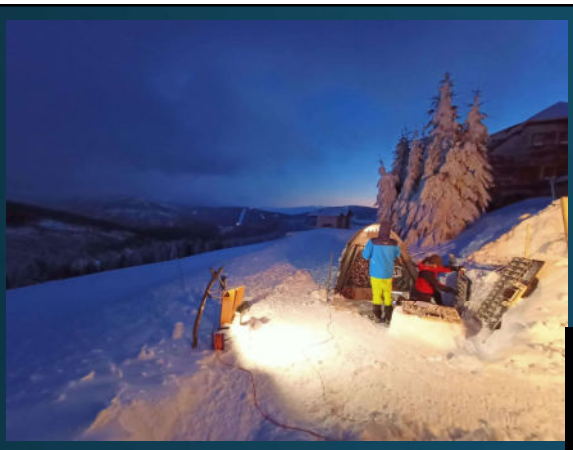


Hypoxia & hypercapnia

Arrhythmias

Hypothermia





Outdoor experiments: non-standard conditions

Standard vital sign monitors used in ICU

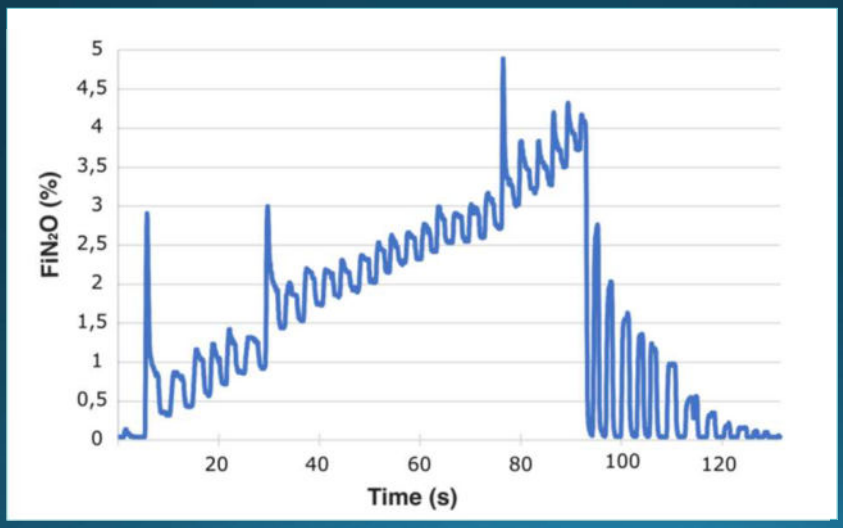
- monitoring of experimental subjects
- providing data for subsequent analysis
- affected by temperature fluctuations

Vital sign monitor	Operating temperature (°C)	Storage temperature (°C)	Atmospheric pressure (kPa) (altitude)	Humidity (%)
Datex-Ohmeda S/5[1]	10–35	(-10)–50	66–106	10–90 non-condensing
GE CareScape B650[1]	10–35	(-20)–60	not specified	10–90 non-condensing
Masimo Radical-7[1]	0–50	(-40)–70	50–106 (-304 m to 5486 m)	10–95 non-condensing
Nonin PalmSAT[1]	(-20)–50	(-40)–70	above 19 (up to 12000 m)	10–95 non-condensing
Edan M3B[1]	5–40	not specified	not specified	not specified
Philips HeartStart MRx[2]	0–45	(-20)–70	57–101 (0 m to 4500 m)	up to 95
LIFEPAK 15[3]	0–45	(-20)–65	57–106 (-382 m to 4572 m)	5–95 non-condensing
ZOLL X Series[4]	0–50	(-30)–70	57–103 (-170 m to 4572 m)	15–95 non-condensing

N_2O as a tracer gas

- leak detection in breathing circuits crucial for the experiments
- N_2O - easily detectable by anaesthetic gas analysers
- flow of the gas in the vicinity of participant's airways
- N_2O detection in the circuit ⇒ experiment ceased

Positive end-tidal nitrous oxide during experiment



ET N_2O (%)

Conclusion

- outdoor breathing experiments present numerous technical and medical issues which need specific solutions
- medical devices are used in conditions substantially different from a standard ICU
- vital sign parameters of the experimental subjects change rapidly from normal increasing the risk of complications
- safety limits of physiological parameters must be interpreted considering these conditions

Thank you