Dynamic changes of peripheral saturation and perfusion index during rapid desaturation

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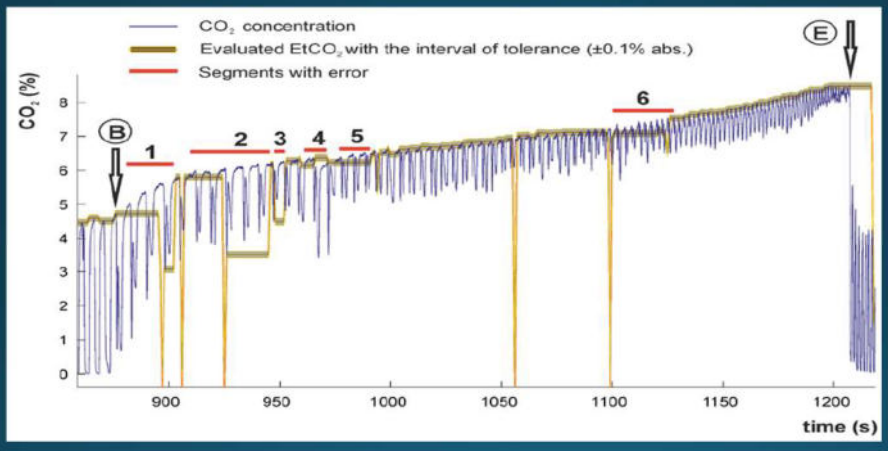
Hypoxia – how to measure it?

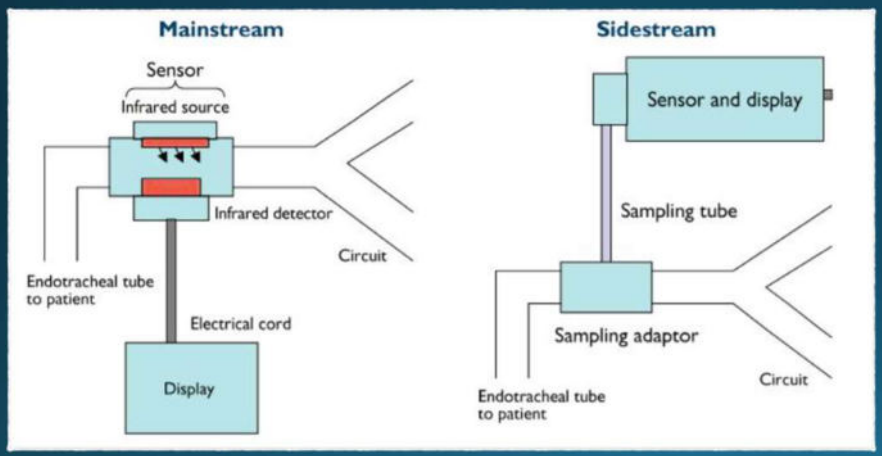
Motivation: observed error in capnography



- blue line: capnographic curve
- yellow line: trend (numeric) values of $EtCO_2$
- o average 30% of time these values did not correspond (13-93% času)

Roubík K., Filip J., Lékař a technika, 2017.

Capnometry - principle

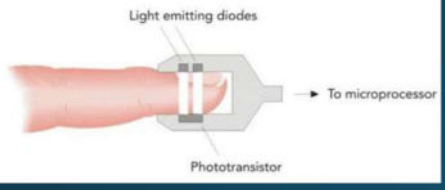


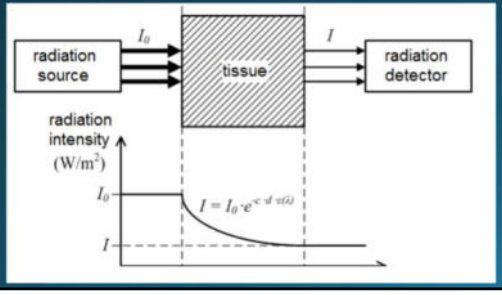
Pulse oximetry

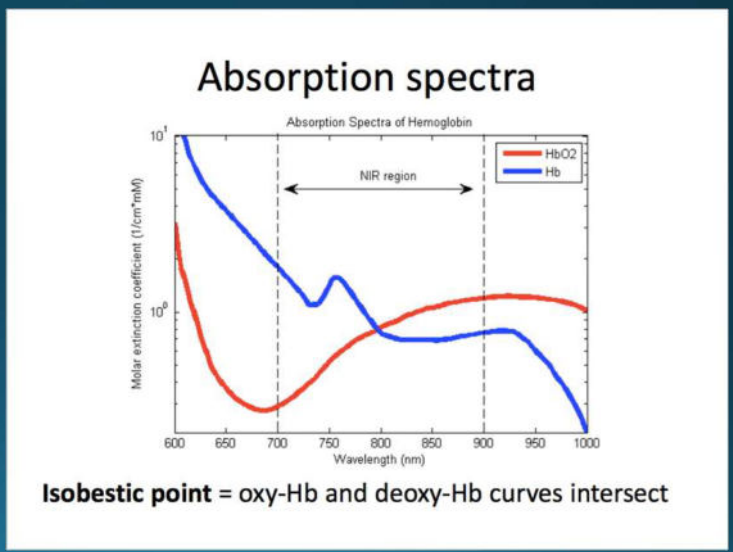
- standard monitoring of patients
- frequent endpoint in many hypoxic studies
  - 5 different pulse oximeters for breathing trials simulating breathing under avalanche snow

Pulse oximetry - principle

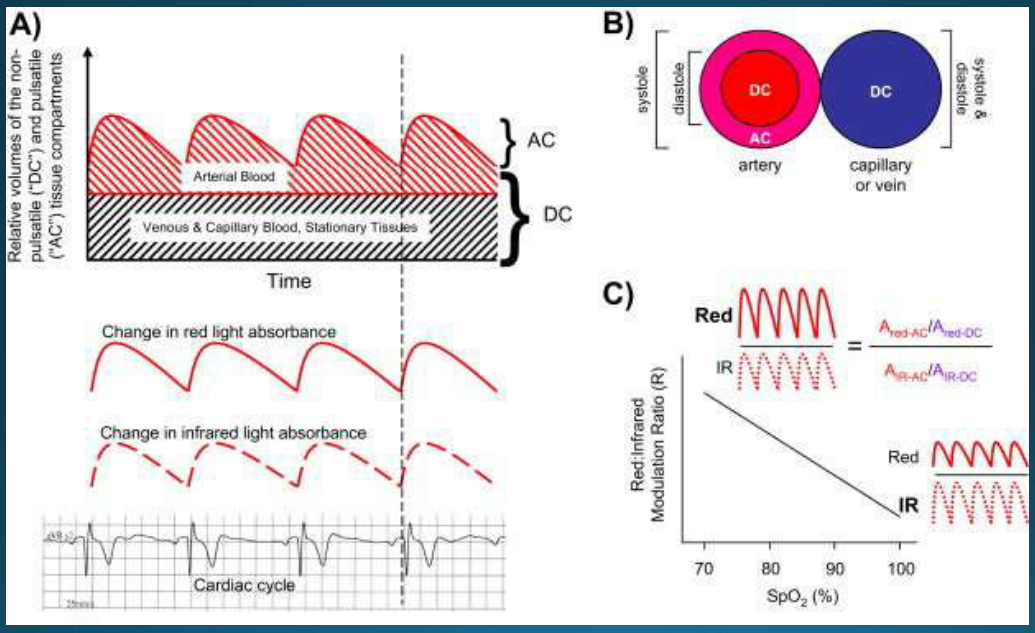
– λ_1 = **660 nm** (red)
– λ_2 = **940 nm** (infrared)



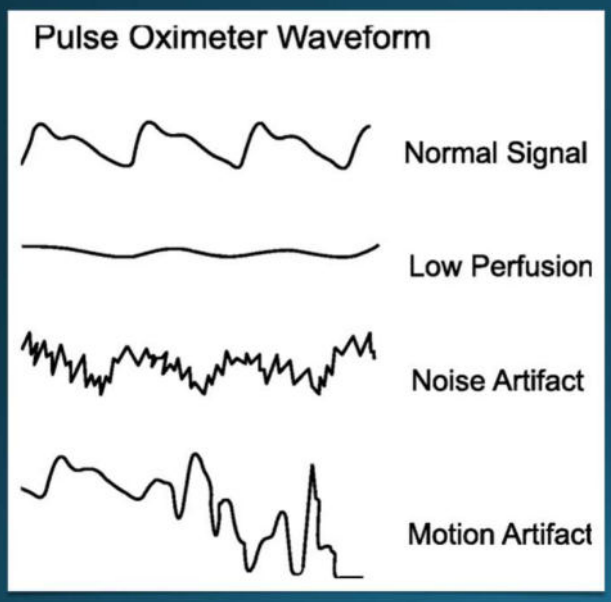




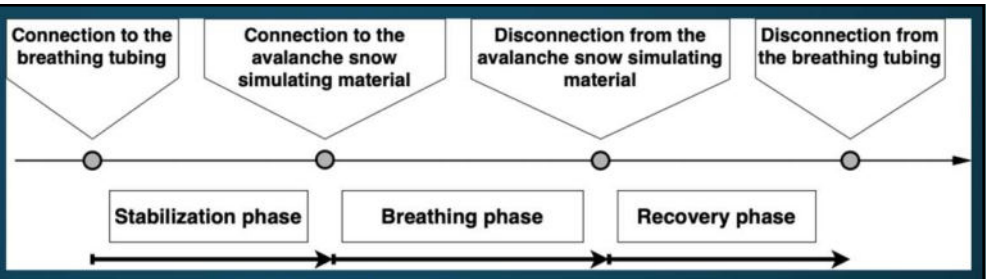
Isobestic point = oxy-Hb and deoxy-Hb curves intersect



Chan E., Chan M., Chan M., Respiratory Medicine 2013

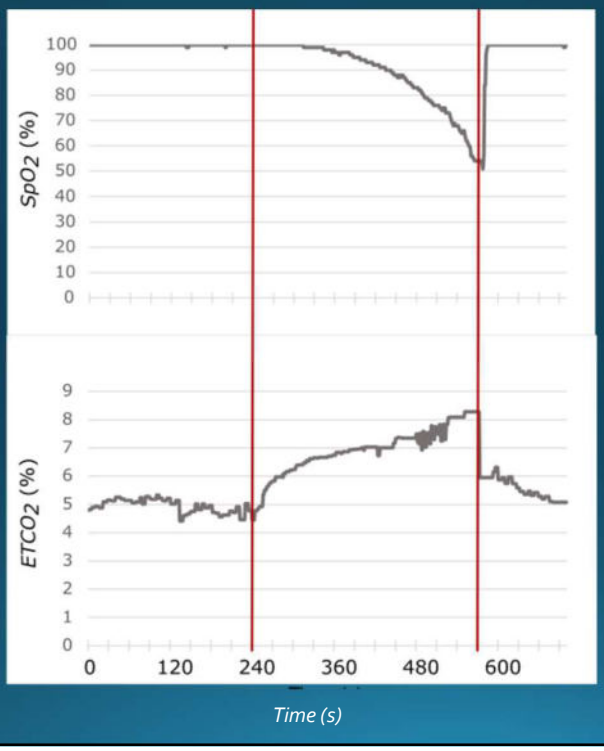


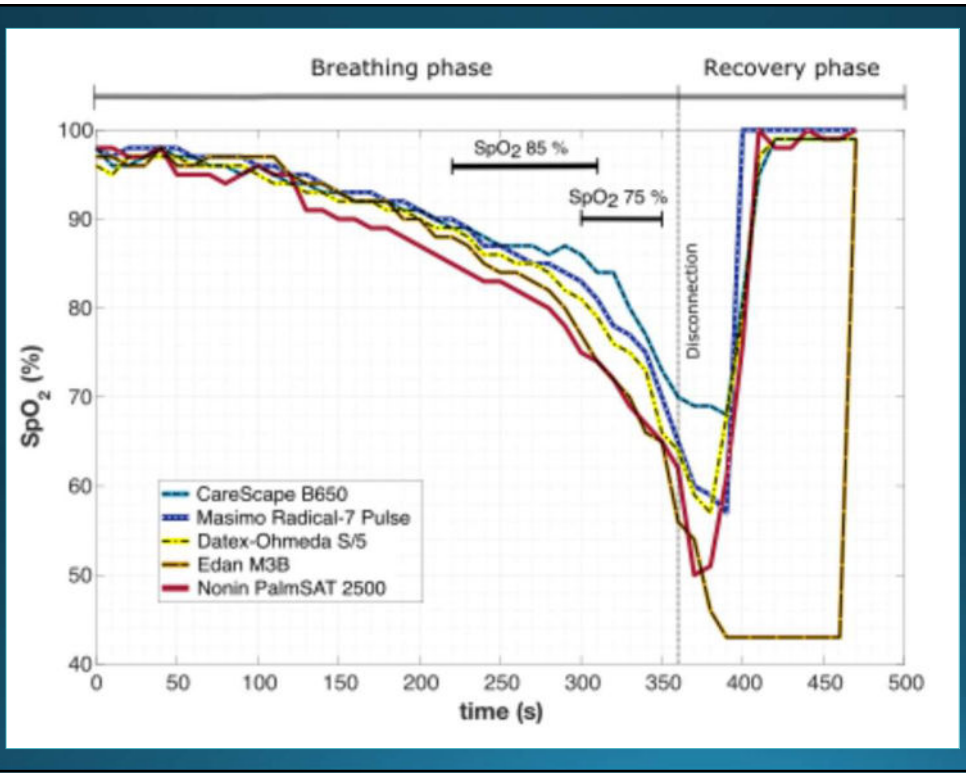
Jubran A., Critical Care, 2015.



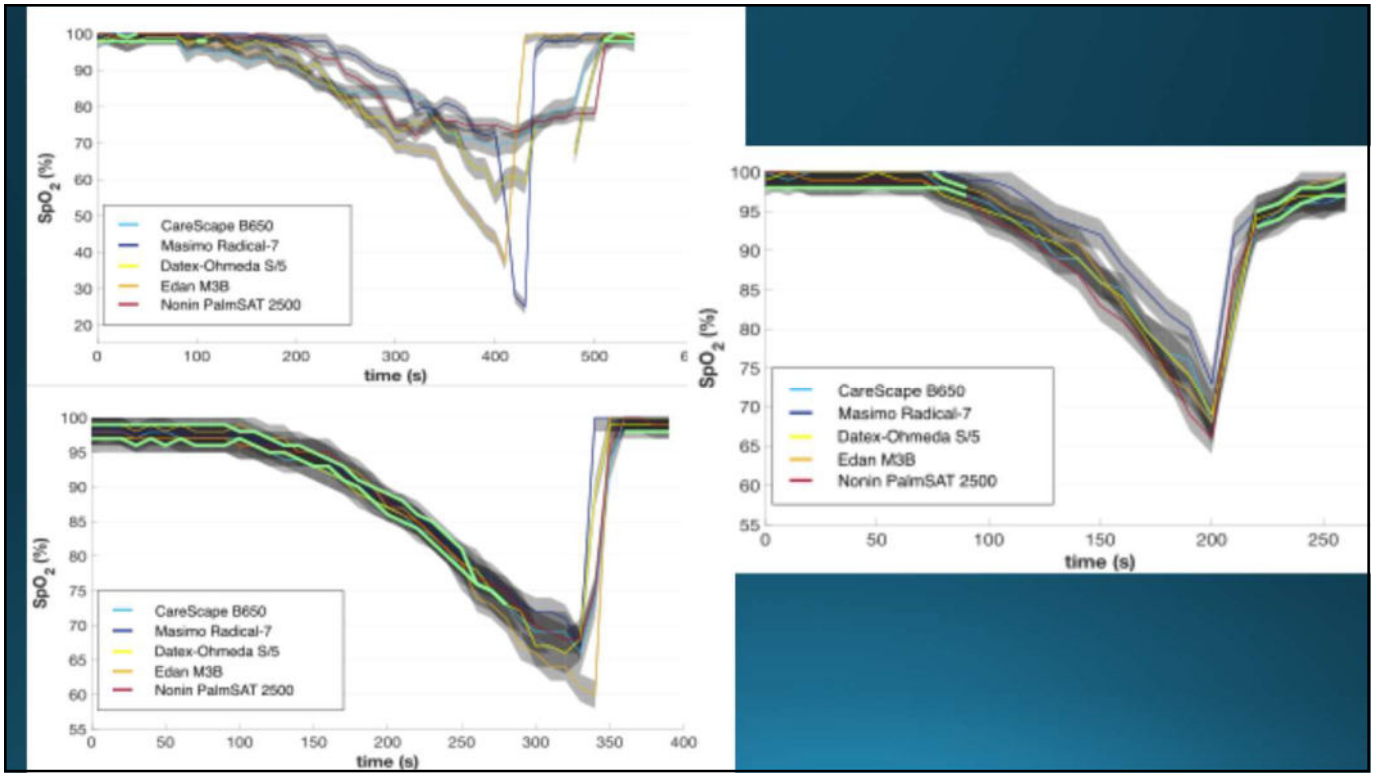
- 13 healthy volunteers
- 3 different snow model materials
- 3 breathing experimental phases
- progressive hypoxia and hypercapnia

Roubik K. et al., Scientific Reports 2022



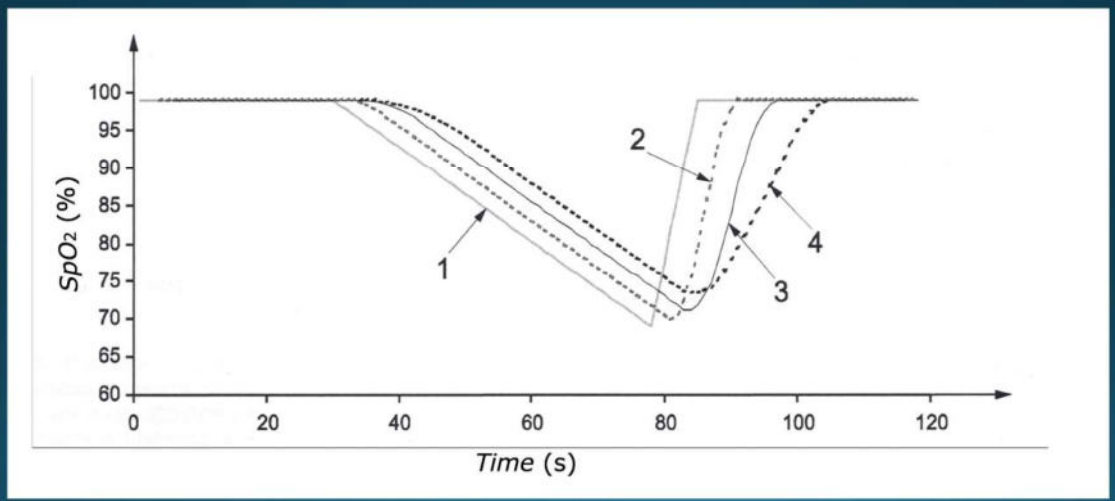


Pulse Oximeter	Finger	Interval of SpO_2 Measurement	Accuracy in Adults (No Motion)	Response Time (Minimal)
Datex-Ohmeda S/5 anesthesia monitor	V.	40–100%	80–100% ± 2% 50–80% ± 3%	beat-to-beat
Masimo Radical-7 Pulse CO-Oximeter	IV.	0–100%	70–100% ± 2%	3 s
CareScape B650	III.	40–100%	80–100% ± 2% 50–80% ± 3%	2 to 4 s
Edan M3B	II.	0–100%	70–100% ± 2%	not adjustable
Nonin PalmSAT 2500	I.	0–100%	70–100% ± 2%	not adjustable

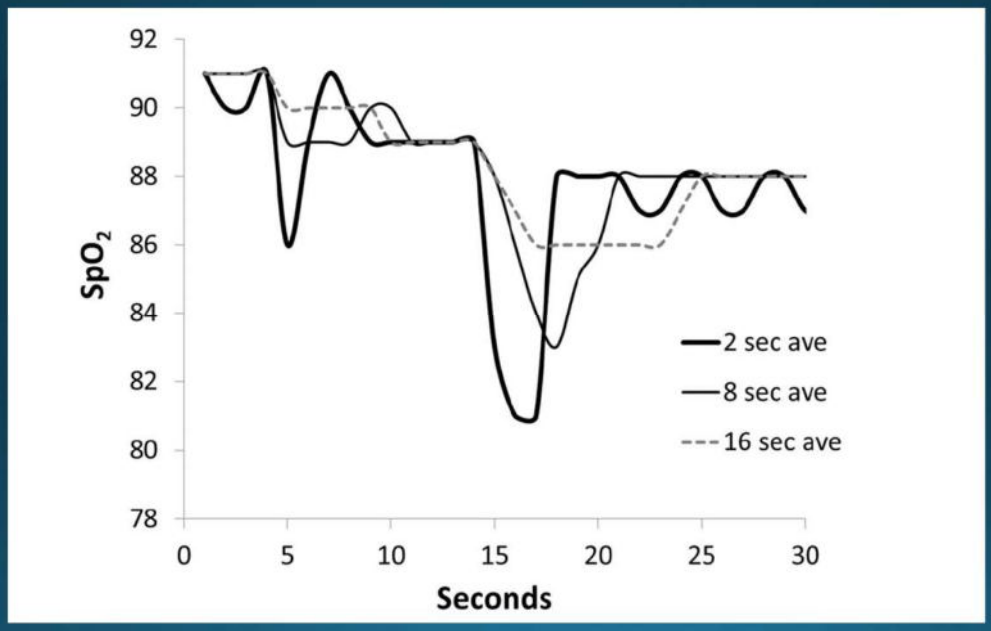


The effect of averiging

1: SaO2, 2-4:SpO2 different averiging



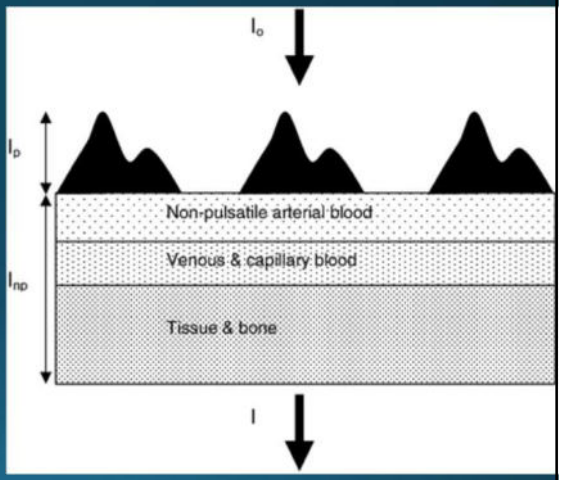
ISO 80601-2-61:2017. 2019

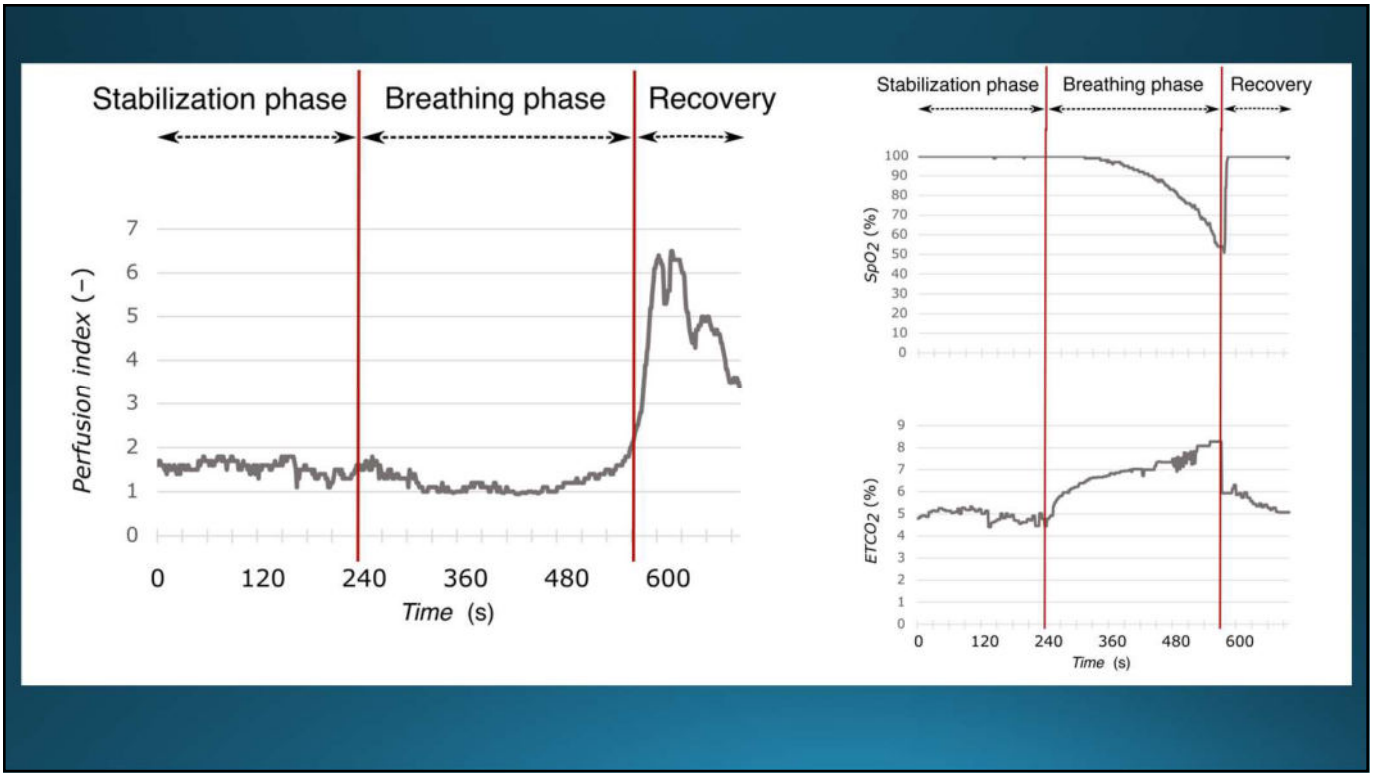


Vantanajal, et al. Journal of Applied Physiology 2007.

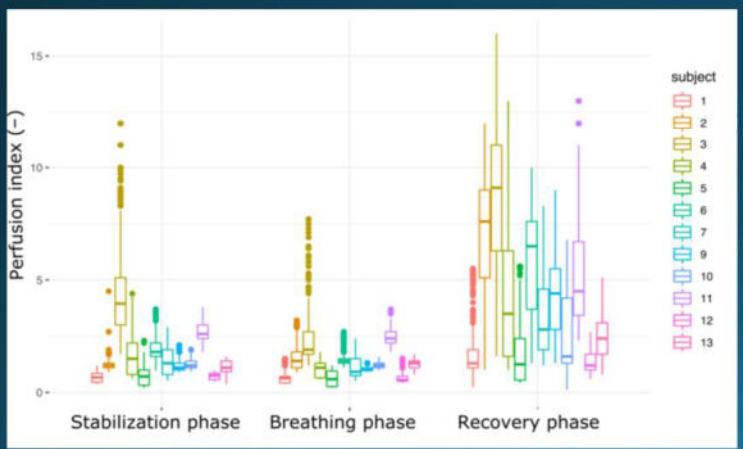
Perfusion index (PI)

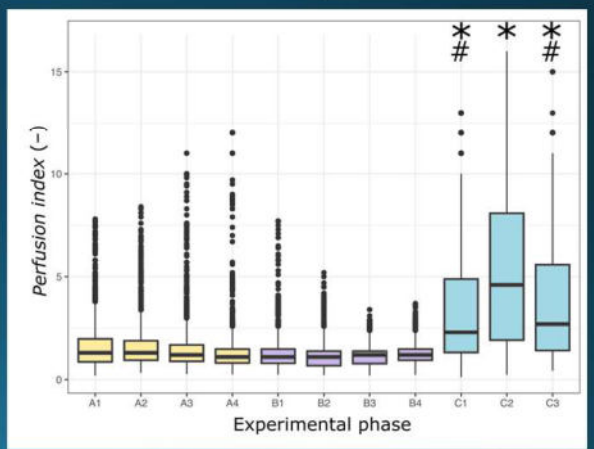
- derived from pulse oximetry
- calculated as the ratio of the pulsatile to the non-pulsatile signal amplitude of the infrared signal of the plethysmography waveform
- **PI 0.02–20.0**
- higher PI ~ better perfusion, vasodilation
- significant inter-individual differences, absence of „normal" values –> more as a trend parameter
- healthy volunteers: PI = 1:4 (0.7–3.0)

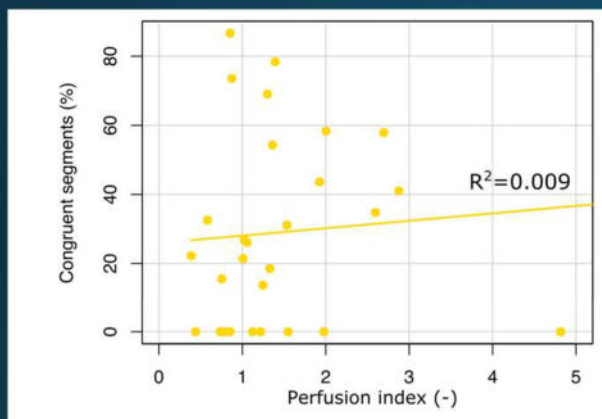


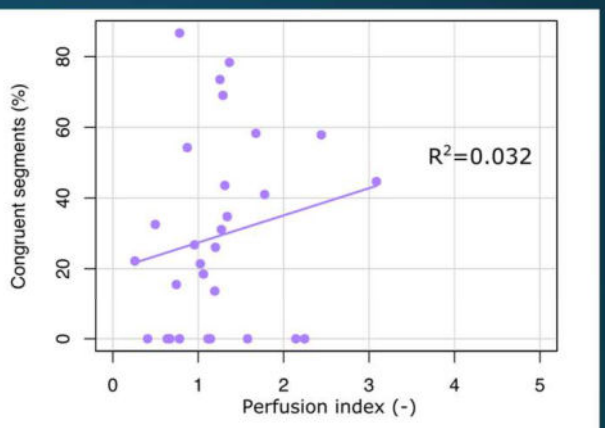


Perfusion index	Experimental phase		
	Stabilization phase	*Breathing phase*	*Recovery phase*
Mean ± SD	1.58 ± 1.34	1.25 ± 0.71	3.92 ± 3.36
Median (IQR)	1.20 (0.85–1.8)	1.1 (0.78 – 1.5)	3.0 (1.5 – 6.2)









breathing phase

p = 0.62

recovery phase

p = 0.35

Conclusions

- Vital sign monitors can display data different from the raw measurements (due to setting, software algorithmss, etc.)
- The choice of a particular device may affect the experiment.
- Especially study endpoints should rely on more parameters.
- Raw data analysis is preferred for certain applications.

You should know the limitations of your equipment…