

Strategies and modern technologies of continuous blood gas monitoring  
SenTec Symposium - Venice, November 1st 2017



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## Intraoperative use of transcutaneous CO<sub>2</sub> measuring in paediatric and neonatal anaesthesia

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**What are you talking about ?**

**Intraoperative tcCO<sub>2</sub> measuring**

**And why ?!**

# Why caring about intraoperative CO<sub>2</sub>



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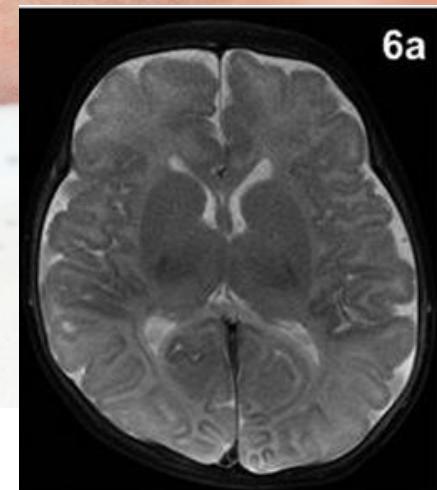
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# Postoperative encephalopathy

- 6 infants (4 Preterm, 26. - 34. SSW)
- Duration of anesthesia 120-180 min
- Gestational age < 48 weeks
- intraoperative
  - Hypotension
  - Hypoglycemia
  - Hyperthermia
  - Hyperoxia
  - Hypocapnia
- Postoperative seizures < 25h
- 1x death, 2x brain injury

Small children+ Σ small problems ⇒ postoperative encephalopathy



# Regulation of cerebral blood flow (CBF)

- Arterial O<sub>2</sub> and CO<sub>2</sub> are main determinants for CBF
  - 1 mmHg PaCO<sub>2</sub> up to 6% change of CBF
- pH / H+ shifts as main cause
  - ↑H+ → ↑K+ efflux from smooth muscle cells of cerebral arteries and arterioles → Vasodilatation

Intraventricular haemorrhage



↑ CBF, ↑ ICP

# The 10-N matrix for safe conduct of paediatric anaesthesia

## The SAFETOTS initiative



# Hypocapnia of the neonate

- Mild:      30 – 35 mmHg etCO<sub>2</sub>
- Moderate:    24 – 30 mmHg etCO<sub>2</sub>
- Severe:      < 24 mmHg etCO<sub>2</sub>



Values < 22.5 mmHg =  
brain damage within few minutes

- Periventricular leukomalacia
- Cerebral palsy
- Learning deficits
- Hearing deficits



## Effects of hypotension and/or hypocapnia during sevoflurane anaesthesia on perfusion and metabolites in the developing brain

Ringer SK<sup>1</sup>, Ohlerth S<sup>2</sup>, Carrera I<sup>3</sup>, Mauch J<sup>3</sup>, Spielmann N<sup>4</sup>, Kircher P<sup>2</sup>, Bettschart-Wolfensberger R<sup>1</sup>, Weiss M<sup>4</sup>

<sup>1</sup>Section Anaesthesiology and Clinic of Diagnostic Imaging<sup>2</sup>, Vetsuisse Faculty University of Zurich, Switzerland; <sup>3</sup>Department of Anaesthesiology, Luzerner Kantonsspital, Switzerland; <sup>4</sup>Department of Anaesthesiology, University Children's Hospital Zurich, Switzerland

- Animal studies
- reduced cerebral perfusion
- cerebral dysfunction
- Early detection of ischemic lesions

Combination of hypotension and hypocapnia is especially defarourable for cerebral perfusion

# CO<sub>2</sub> measurement

- ABG: Gold standard
- Endtidal CO<sub>2</sub>
- Transcutaneous CO<sub>2</sub>

# ArterialBloodGas = gold standard



- Invasive / iatrogenic blood loss
- No real time monitoring / discontinuous

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# Intraoperative ventilation: etCO<sub>2</sub>-Monitoring = standard of care!

With special adapters  
possible as side  
stream measurement

- No latency / no delay
- Control of endotracheal tube placement
- CO<sub>2</sub>-graph

# Limitations of endtidal capnography

- small tidal volumes
- high ventilation frequencies
- leakage
- Side stream measurement

Badgwell JM et al. Anesth Analg. 1993 Oct;77(4):708-12.

Saidman LJ, Smith NT. Monitoring in Anaesthesia. Butterworth Heinemann 1993

Wulkan ML, Vasudevan SA. Pediatr Surg. 2001 Aug;36(8):1234-6.



# Transcutaneous CO<sub>2</sub> Measurement

- Severinghaus (linear relation Ptc<sub>CO<sub>2</sub></sub> and Pa<sub>CO<sub>2</sub></sub>) 20–74mmHg
- The heating element induces hyperperfusion within 3 – 10 minutes
  - After heating approximation of capillary and arterial P<sub>CO<sub>2</sub></sub>



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Temperature needed for

- PtcO<sub>2</sub>: 43 – 44°C
- Ptc<sub>CO<sub>2</sub></sub>: 37 – 40°C



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# tcCO<sub>2</sub> – Principles of operation



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- Thin layer of electrolyte solution between sensor surface and CO<sub>2</sub> permeable membrane contacting patient's skin
- Sensor measures pH change in electrolyte solution
  - Calculation of PaCO<sub>2</sub> by correcting temperature to 37°C
  - Subtraction of estimate of local metabolic bias
- Heat increases the metabolic rate of the skin and thus local CO<sub>2</sub> production (+4-5%/°C)

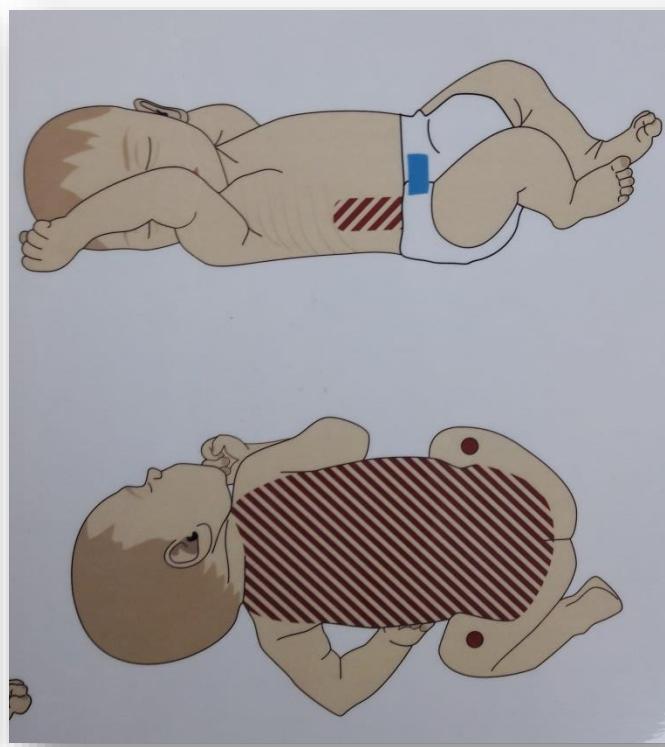
# tc CO<sub>2</sub> measurement - Indications

- Indications:
  - (Intraoperative) limitations of et-measurements
  - NIV and spontaneous ventilation
  - HFO
  - Right-left shunt
  - Ventilation-perfusion-missmatch



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# CO<sub>2</sub> Measurement – possible sensor sites



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# tcCO<sub>2</sub> measurements - limitations



- Vasoactive agents / oedemas
- Sensor temperature → change of sensor site
- Hypothermia / Temperatur variations
- Sensor site
  - Space (surgical site / competing measurement)
  - access (surgeons)
  - Skin integrety (EB-child / burns / dermatosis)



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# tc CO<sub>2</sub> measurement - Progress

- Combination with SpO<sub>2</sub>
- Smaller sensors
- Longer calibration intervals
- Site protection
  - Lower temperature
  - Automated time limitation
- Facilitated membrane-change
- Direct interface to PDM-Systems

Complication:  
Thermal injury!

# To conclude ...



Dr. Robert in an ethical dilemma....

# The 10-N paediatric anaesthesia SAFETOTS

- 1 NO FEAR**
- 2 NORMOTENSION**
- 3 NORMAL HEART RATE**
- 4 NORMOVOLEMIA**
- 5 NORMOOXEMIA**
- 6 NORMOCARBARIA**
- 7 NORMONATREMIA**
- 8 NORMOGLYCEMIA**
- 9 NORMOTHERMIA**
- 10 NO PAIN**



Concept of 10-N-Quality Pediatric Anesthesia: Markus, Weiss, Zurich.  
Cartoonist: Marco Brunori, Zurich (2014).

# Transcutaneous CO<sub>2</sub> measurement during paediatric anaesthesia

- Intraoperative

- small tidal volume
- high ventilation frequencies
- Single lung ventilation
- Spontaneous breathing
- Non invasive ventilation

<3kg

Hypocapnia (in combination with hypotension)  
is disadvantageous for cerebral perfusion

# Conclusion

## Pediatric Anesthesia

EDITORIAL

### Anesthetists rather than anesthetics are the threat to baby brains

Markus Weiss, Bruno Bissonnette, Thomas Engelhardt, Sulpicio Soriano - 2013

- Focussing on obvious dangers  
(Hypoxia, Hypotension, Hypocapnia, ...)
- Reasonable use of technical possibilities



# Thank you for your attention!



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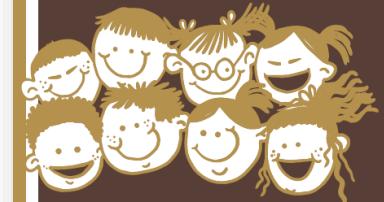
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## IAPA MEETING

**2<sup>nd</sup> International Assembly  
for Pediatric Anesthesia –  
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ESPA – European Society  
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September 6–8, 2018  
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