Intraoperative use of trancutaneous CO$_2$ measuring in paediatric and neonatal anaesthesia

Michael Brackhahn, Kinder- und Jugendkrankenhaus auf der Bult, Hannover
What are you talking about?

Intraoperative tcCO$_2$ measuring

And why ?!
Why caring about intraoperative CO₂
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 encephalopathia

McCann et al. Pediatrics 2014; 133: e751-757
Regulation of cerebral blood flow (CBF)

- Arterial $O_2$ and $CO_2$ are main determinants for CBF
- 1 mmHg $PaCO_2$ up to 6% change of CBF
- pH / H+ shifts as main cause
- $\uparrow$H+ $\rightarrow$ $\uparrow$K+ efflux from smooth muscle cells of cerebral arteries and arterioles $\rightarrow$ Vasodilatation

Intraventricular haemorrhage $\uparrow$ CBF, $\uparrow$ ICP

The 10-N matrix for safe conduct of paediatric anaesthesia
The SAFETOTS initiative
Hypocapnia of the neonate

- **Mild:** 30 – 35 mmHg etCO$_2$
- **Moderate:** 24 – 30 mmHg etCO$_2$
- **Severe:** < 24 mmHg etCO$_2$

Values < 22.5 mmHg = brain damage within few minutes

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

Pappas A – J Pediatr 2011
Effects of hypotension and/or hypocapnia during sevoflurane anaesthesia on perfusion and metabolites in the developing brain

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

Combination of hypotension and hypocapnia is especially defavourable for cerebral perfusion
CO₂ measurement

- ABG: Gold standard
- Endtidal CO₂
- Transcutaneous CO₂
Arterial Blood Gas = gold standard

- Invasive / iatrogenic blood loss
- No real time monitoring / discontinuous
Intraoperative ventilation: 
etCO\textsubscript{2}-Monitoring = standard of care!

- No latency / no delay
- Control of endotracheal tube placement
- CO\textsubscript{2}-graph

With special adapters possible as side stream measurement
Limitations of endtidal capnography

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

Transcutaneous CO₂ Measurement

- Severinghaus (linear relation $P_{tc\text{CO}_2}$ and $P_{a\text{CO}_2}$) 20–74mmHg
- The heating element induces hyperperfusion within 3 – 10 minutes
  - After heating approximation of capillary and arterial $P_{\text{CO}_2}$

Temperature needed for
- $P_{tc\text{O}_2}$: 43 – 44°C
- $P_{tc\text{CO}_2}$: 37 – 40°C
tcCO₂ – Principles of operation

- Thin layer of electrolyte solution between sensor surface and CO₂ permeable membrane contacting patient’s skin
- Sensor measures pH change in electrolyte solution
  - Calculation of PaCO₂ by correcting temperature to 37°C
  - Subtraction of estimate of local metabolic bias
- Heat increases the metabolic rate of the skin and thus local CO₂ production (+4-5%/°C)
tc CO₂ measurement - Indications

- Indications:
  - (Intraoperative) limitations of et-measurements
  - NIV and spontaneous ventilation
  - HFO
  - Right-left shunt
  - Ventilation-perfusion-mismatch
CO₂ Measurement – possible sensor sites
tcCO₂ 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)


- Combination with SpO2
- 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. NORMOXEMIA
6. NORMOCARBIA
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$_2$ measurement during paediatric anaesthesia

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

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!

And in the left corner with 2782 knockouts...