

Beyond an Oximeter:

NIRS Monitoring of Cerebral Autoregulation

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Monday, March 22, 2010

Disclosures



Under a licensing agreement with Somanetics, Dr. Brady is entitled to a share of fees and royalty received by The Johns Hopkins University on the monitoring technology described in this talk. The terms of this arrangement are being managed by the Johns Hopkins University in accordance with its conflict of interest policies.



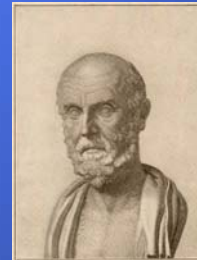
Pediatric TBI



- A 2 year old girl chased a ladybug through her second story window. She fell two flights, into a stairwell and hit her head on the edge of a concrete step.
- She arrives seizing, without iv access, without a measurable blood pressure, and her lips are blue.



Secondary Injury



"There is no injury to the head so trivial that it can be ignored, and no injury so severe that it should invoke despair."

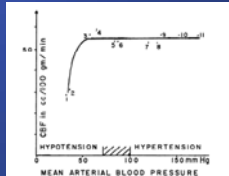
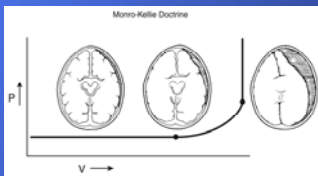
-Hippocrates



Hypoperfusion from high ICP or low ABP

1820's Monro-Kellie Doctrine:

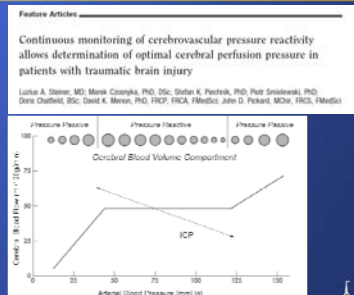
1959 Lassen's Curve



-Monroe A, Observations on the structure and function of the nervous system, 1823
-Kellie G, ...Some reflections on the pathology of the brain... 1824
-Lassen NA, Physiological Reviews, 1959

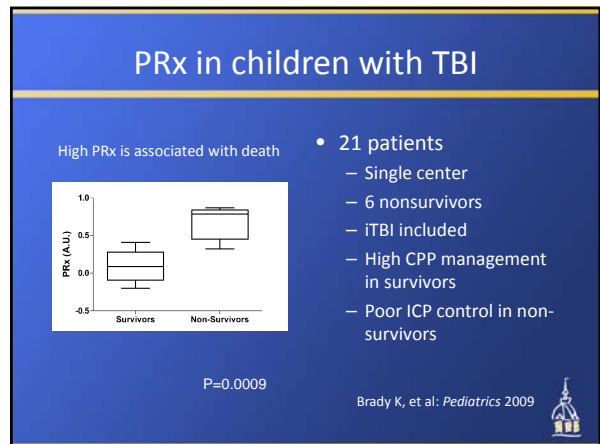
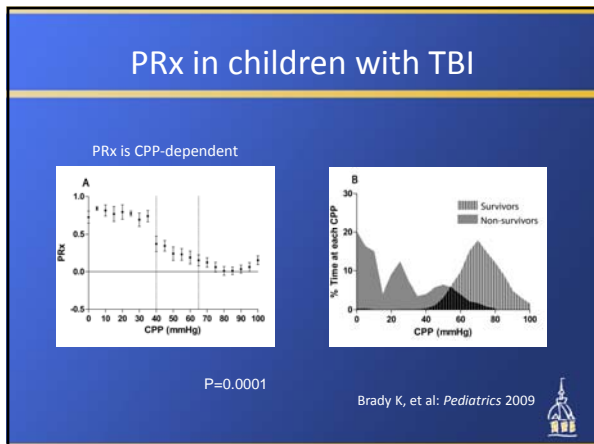
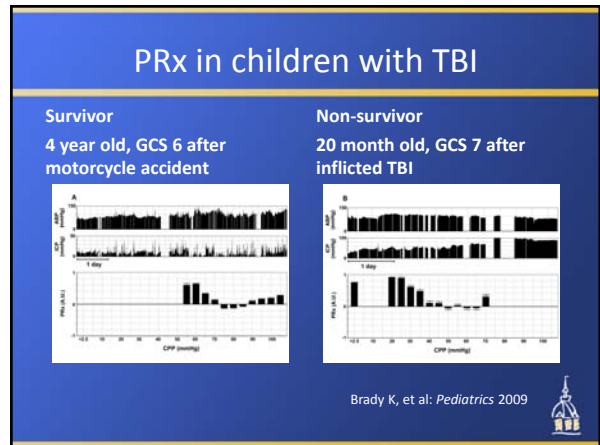
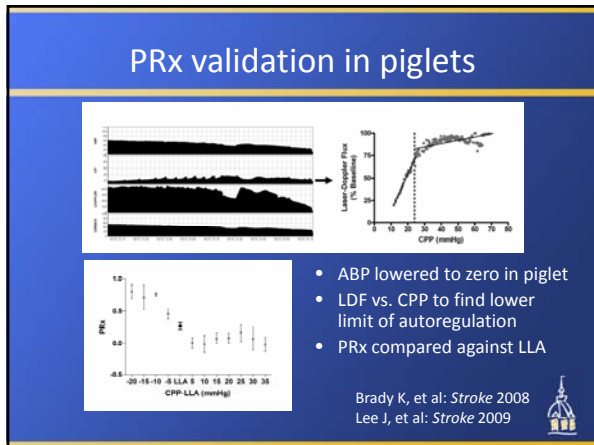
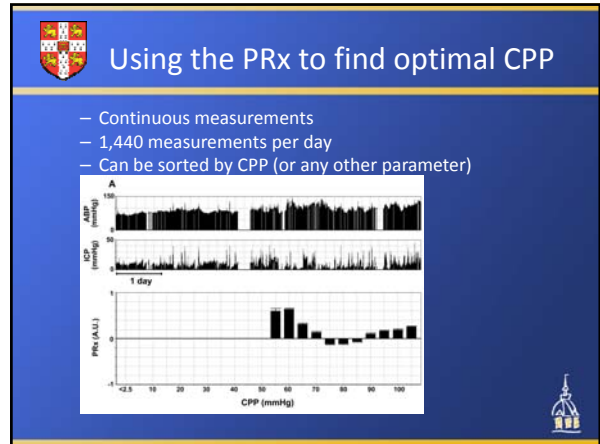
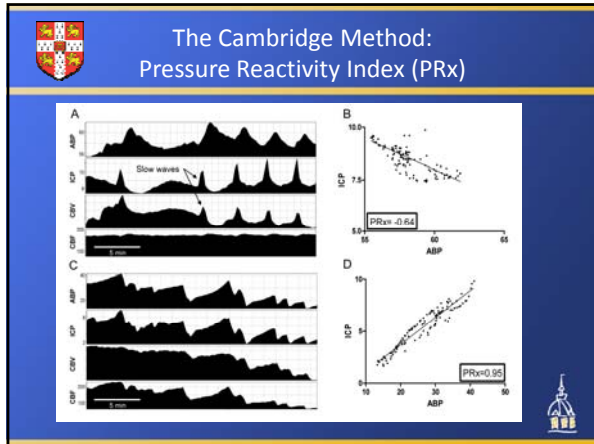


The Cambridge Hypothesis



•Czosnyka M, Stroke, 1996
•Steiner LA, Crit Care Med, 2002





Brain Injury and CPB



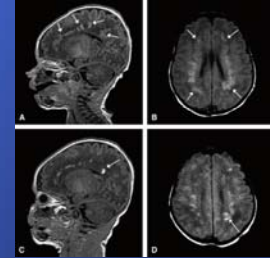
- Clinical Stroke: 1-3%
- MRI Lesions: 30-75%
- Neurocognitive Dysfunction: 50%

Andropoulos D, *et al JTCVS* (2010)
Wernovsky G, *et al Curr Opin Cardiol* (2005)



Brain Injury from CPB is multifactorial

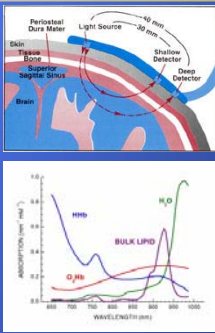
- Ischemic Vulnerability
 - Delayed maturation
- Clinical Insults
 - Hypoxia
 - DHCA
 - Emboli
 - Anemia
 - **Hypotension**



Andropoulos D, *et al JTCVS* (2010)



NIRS can trend CBF and CBV non-invasively



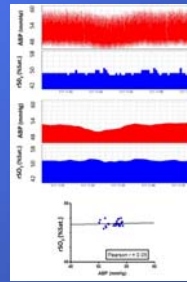
- rSO_2 :
 - CBF
 - CMRO₂
 - HCT
 - SaO₂
- BVI :
 - CBV
 - HCT



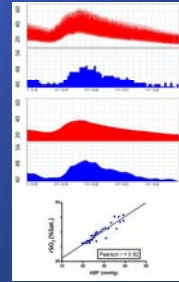
Cerebral Oximetry Index

(Substitute rSO_2 for TCD in Cambridge Equation)

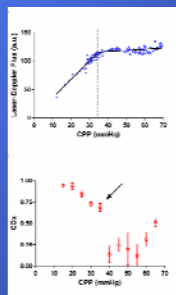
Intact Autoregulation



Impaired Autoregulation



Cerebral Oximetry Index (COx)

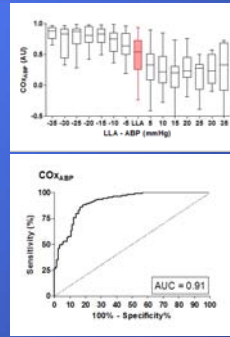


- NIRS as a surrogate measure of CBF
- NIRS-ABP correlation is low above the LLA
- NIRS-ABP correlation is high below the LLA

Brady K, *et al: Stroke* 2007



COx: Receiver Operator Characteristics

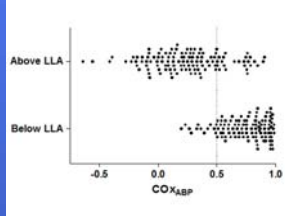


- 25 piglet experiments
- Naive intracranial compartment
- ABP lowered to zero over 3-4 hours
- LLA determined with L-doppler
- COx curves compared against L-doppler curves

Brady K, *et al: A&A in press*



COx: Finding a Threshold Value

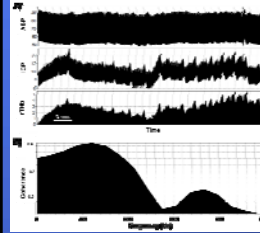


- $COx > 0.5$:
 - 89% Sensitive
 - 81% Specific for ABP below the LLA

Brady K, et al: *A&A* in press



NIRS can also trend CBV

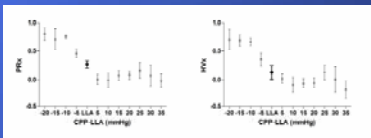


- ICP slow waves replicated with measurements of blood volume
- ICP and blood volume are coherent at “slow wave” frequency

Lee J, et al: *Stroke* 2009



Hemoglobin Volume Index

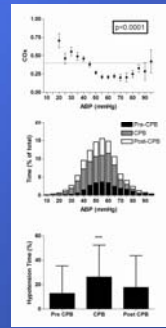


- Substituting cerebral blood volume for ICP in the Cambridge equation re-creates the PRx

Lee J, et al: *Stroke* 2009



Where is the pediatric LLA during CPB?

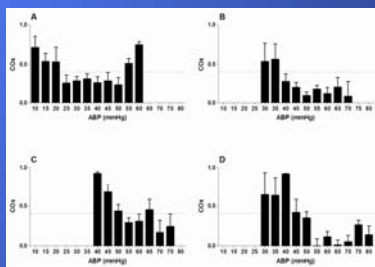


- COx is significantly ABP-dependent
- Time below the cohort LLA is overrepresented by the recordings from CPB.

Brady K, et al: *Stroke* in press



COx: individual monitoring during CPB



- 6-day-old: IAA (LLA 25 mmHg)
- 7-month-old: VSD (LLA 40 mmHg)
- 2-year-old: VSD (LLA at 50 mmHg)
- 7-year-old: anomalous right coronary artery, (LLA at 45 mmHg)

Brady K, et al: *Stroke* in press



Summary



- Autoregulation monitoring can help optimize CPP for patients with head trauma
- NIRS can be used to monitor autoregulation in patients on CPB



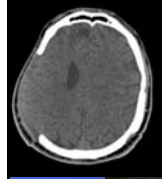
Summary



- COx uses rSO_2 as a surrogate for CBF to detect pressure-passive flow.
- HVx uses BVI as a surrogate for CBV to detect pressure-passive vascular diameter
- Individual hemodynamic optimization



Thank You



- Blaine Easley
- Kathy Blizzard
- Jen Mytar
- Jen Lee
- Marek Czosnyka
- Peter Smielewski
- Charles Hogue
- Ray Koehler
- Hal Shaffner
- John Ulatowski
- Adam Sapirstein

