INTRACRANIAL PRESSURE CHANGES IN NEUROSURGICAL PATIENTS DURING HYPOTENSION INDUCED WITH SODIUM NITROPRUSSIDE OR TRIMETAPHAN

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SUMMARY

Intracranial pressure has been measured in 45 patients undergoing neurosurgery during the induction of deliberate hypotension using either sodium nitroprusside or trimetaphan. A statistically significant increase in intracranial pressure (ICP) occurred during the early stages of the infusion of nitroprusside in normocapnic patients. A non-significant increase in ICP was obtained in hypocapnic patients. The mean ICP increased from 6.3 mm Hg to 11.7 mm Hg when the arterial pressure was reduced slightly, but the response in individual patients varied widely (range -1.6 mm Hg to +20.9 mm Hg). When the arterial pressure (BP) had decreased to 70% of the value existing before infusion of nitroprusside, mean ICP returned to control values and thereafter decreased with further reductions in BP. In patients rendered hypotensive with trimetaphan, there was no change in mean ICP but two patients showed moderate increases (+9.3 mm Hg and +5.7 mm Hg). The mechanism of the increase in ICP with nitroprusside is thought to be expansion of the intracranial blood volume as a result of cerebral vasodilation. Trimetaphan does not usually produce ICP changes except when intracranial compression is severe, for in these circumstances a small change in intracranial blood volume consequent upon autoregulation may trigger an increase in ICP.

Fig. 4. The BP and ICP records in one individual patient. The increase in ICP with the onset of nitroprusside-induced hypotension can be seen, but note also that a subsequent inadvertent recovery of BP led to a further marked increase in ICP. The gaps in the time trace indicate 1-min intervals.
Simultaneous analysis of ‘slow’ changes in arterial pressure and ICP

System with disturbed pressure-reactivity

Pressure-reactivity works properly
Continuous Assessment of the Cerebral Vasomotor Reactivity in Head Injury

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PRx- Calculation principles

Input signals ICP, ABP

Primary analysis

10 sec window

Mean(ABP)
Mean(ICP)

5 min window

MAP
MICP

Correlation(MAP, MICP)

Output trend PRx

Thanks to Dr. P. Smielewski
PRx is a rather ‘noisy’ parameter
Some smoothing is required

Thanks to Dr. P. Smielewski
Intracranial Hypertension
Plateau Wave
Arterial Hypertension
PRx correlates with PET-static rate of autoregulation

Cerebrovascular pressure reactivity is related to global cerebral oxygen metabolism after head injury

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J Neural Neurosurg Psychiatry 2003;74:765-770
PRx and the LLA

- ABP lowered to zero in piglet
- LDF vs. CPP to find lower limit of autoregulation
- PRx compared against LLA

AUC=0.91!!

Positive end-expiratory pressure oscillation facilitates brain vascular reactivity monitoring

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LOOK at two Periods 1: PRX ~-1 and 2: PRx~+1
Individual trends are most important...
Monitoring of Pressure Reactivity Index

ICM+ software: www.neurosurg.cm.ac.uk/icmplus
Ups and downs... Final was not very optimistic
Deterioration of PRx precedes refractory intracranial hypertension?
Refractory intracranial hypertension (2)
Mortality rate dramatically depends on PRX.
Both PRx and Mx show the U-shape relationship with mean CPP (200 patients!). This indicates that for low CPP and CPP above 90 mm Hg both autoregulation and pressure reactivity are defective. There is an ‘optimal’ CPP from 70 to 90 mm Hg which helps to restore vascular functions after head injury.

New results 2003-2009

Thanks to Dr. M. Aries
If we can see it in statistical evaluation of big series of patients, can we see it in individual cases?

The chart shows that lowest PRx values corresponding to the strongest autoregulation level fall in the CPP range of 73-79 mmHg.

Thanks to Dr. P. Smielewski.
Optimal CPP in individual cases

Thanks to Dr. L. Steiner
Optimal CPP oriented therapy?

**Patient 1**

CPP_{OPT} and Outcome

- $r = -0.51$ (Spearman rank test)
- $p = 0.00001$

Thanks to Dr. L. Steiner
Method

- Retrospective analysis (single centre)
- Data base 2003-2009 (n=327)
- TBI pts (GCS <8 in 80%)
- Continuous ICP/ABP monitoring (50 Hz)
- Glasgow outcome scale at 6 months

Assumption:

- CPP optimal exists
- Narrow (one) CPP optimal range
- **CPP optimal = the CPP at best cerebral vasoreactivity**

(pressure) autoregulation parameter: PRx

- Correlation coefficient between ABP/ICP
- CPP optimal= CPP at lowest PRx
Continuous assessment of CPPopt and real-time comparison with median CPP - 4 hours window
Optimal CPP as an individual threshold for CPP oriented therapy

F value much greater than for set threshold
Rate of favourable outcome reaches maximum when CPP is close to optimal CPP. For lower CPPs mortality increases. For greater CPPs, rate of severe disability increases.
Comparison of the outcomes in two similar groups of the TBI patients treated on the base ICP/CPP protocol versus patient treated on the base of Autoregulation protocol with support of evaluation of vascular autoregulation using Prx index

Burdenko Neurosurgery Institute Russian Academy of Medical Sciences
Andrey Oshorov, Ivan Savin, Alexander Goriachev, Konstantin Popugaev, Alexander Polupan

![Bar chart showing the number of cases with different outcomes for two groups: Optimal CPP (N=40) and ICP/CPP (N=40). The chart indicates a significant difference (p=0.0014) between the two groups.]
CONCEPT

CPP_{opt} vs. standard CPP-based pressure management

Frankfurt 6. Mai 2012
IGNITE
Jennifer Diedler  Martin Schuhmann
In a meanwhile we are still doing observational studies:

Refractory intracranial hypertension- red line again
Matching Prx-CPP curve; only a left branch!
Road/work ahead..... (2)

• Large pooled TBI database
  – Does the relation with outcome hold?
  – Specific TBI pts benefit
    • Edema/contusions
    • DAI
  – Target or Direction?
  – Visual display of PRx/CPPopt (poster....)

• Artifact?
• Effect of therapy?
• Prolonged trend of ICP going down?
• Does it fit with the scan or other results?
• Does it matter (CA intact)?
“Optimal Cerebral Perfusion Pressure” in Poor Grade Patients After Subarachnoid Hemorrhage

Philippe Bijlenga · Marek Czosnyka · Karol P. Budohoski · Martin Soehle · John D. Pickard · Peter J. Kirkpatrick · Peter Smielewski

Thanks to Dr. P. Biljenga
Are Optimal Cerebral Perfusion Pressure and Cerebrovascular Autoregulation Related to Long-term Outcome in Patients With Aneurysmal Subarachnoid Hemorrhage?

Frank Anthony Rasulo, MD,* Alan Girardini, MD,* Andrea Lavinio, MD,*† Elena De Peri, MD,* Roberto Stefini, MD,‡ Marco Cenzato, MD,‡ Ilaria Nodari, MD,* † and Nicola Latronico, MD*

(J Neurosurg Anesthesiol 2011;00:000–000)
What do we know so far about PRx in SAH? (statin trial, placebo branch). PRx agrees with Transient Hyperaemic Response Test and gets worse in vasospasm.

Continuous Monitoring of Cerebrovascular Pressure Reactivity After Traumatic Brain Injury in Children

Ken M. Brady, Donald H. Shaffner, Jennifer K. Lee, R. Blaine Easley, Peter Smielewski, Marek Czosnyka, George I. Jallo and Anne-Marie Guerguerian

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The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://www.pediatrics.org/cgi/content/full/124/6/e1205

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**Figure 2**
PRx curves for individual children with TBI. Illustrative PRx (in arbitrary units [A.U.]) monitoring for prolonged periods is shown for a survivor (A) and a non-survivor (B) of TBI. The upper 2 panels for each subject show the arterial blood pressure (ABP) and ICP for the entire monitoring period. The lower panels show the PRx as a function of CPP for the entire monitoring period. A, Recording for a 4-year-old male patient who presented with a GCS score of 6 after a motorcycle accident. In this subject, CPP of <70 mm Hg or >90 mm Hg was associated with graded increases in the PRx. B, Recording for a 20-month old male patient who presented with a GCS score of 7 after suffering inflicted TBI. For this subject, CPP of <40 mm Hg was associated with graded increases in the PRx.
Summary

• Simple analysis of ABP-ICP interaction (low bandwidth)
• Positive association with outcome
• Detection of ‘optimal CPP’
• Good agreement with other more expensive methods
• Promising value of PRx after SAH