Traumatologia cranica
Aneurismi intracranici

NEURO UPDATE TORINO

Update in Traumatologia Cranica

Sistema Socio Sanitario
Regione Lombardia
ASST Spedali Civili

FRANK A. RASULO
ANESTHESIOLOGY, INTENSIVE CARE, PERIOPERATIVE CARE and PAIN MEDICINE
Spedali Civili
University Hospital
Brescia, Italy

Cosa chiedo all'autoregolazione cerebrale?

NO CONFLICTS

Che cos'è l'autoregolazione cerebrale?

Sir William Maddock Bayliss

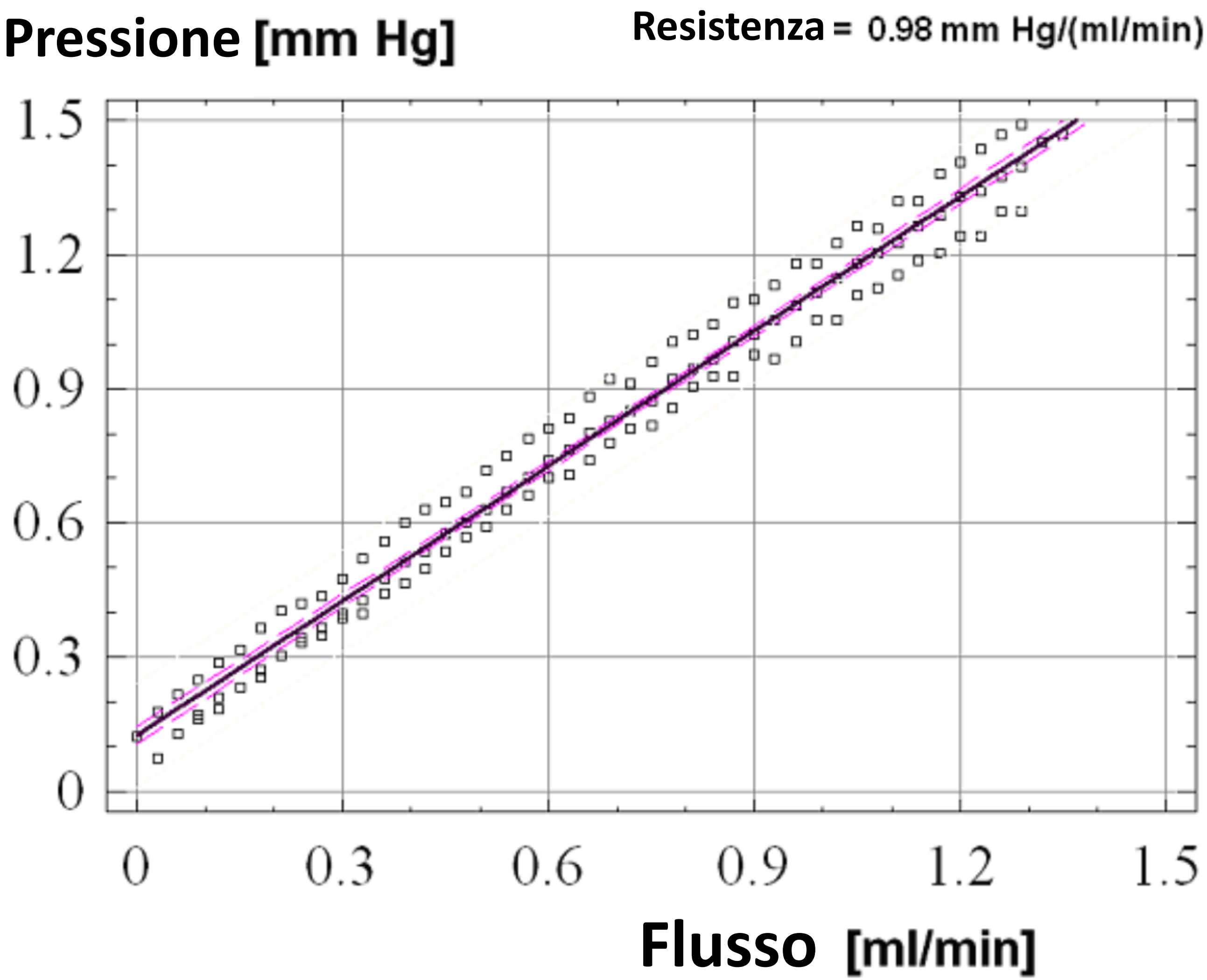
On Intra-Cranial Pressure and the Cerebral Circulation: part I. Physiological; Part II. Histological. Bayliss WM et al. J Physiol **1895**;18(4):334-62

Hill L: The Physiology and Pathology of the Cerebral Circulation. Churchill, London, 1896

Fog M: Cerebral circulation. I. Reaction of the pial arteries to a fall of blood pressure. Arch Neurol Psychiat **37**: 351-364, 1937

Carlyle A, Grayson J: Factors involved in the control of cerebral blood flow. J Physiol **133**: 10-30, 1956

Il flusso di un liquido all'interno di un **tubo rigido**



PHYSIOLOGICAL REVIEWS

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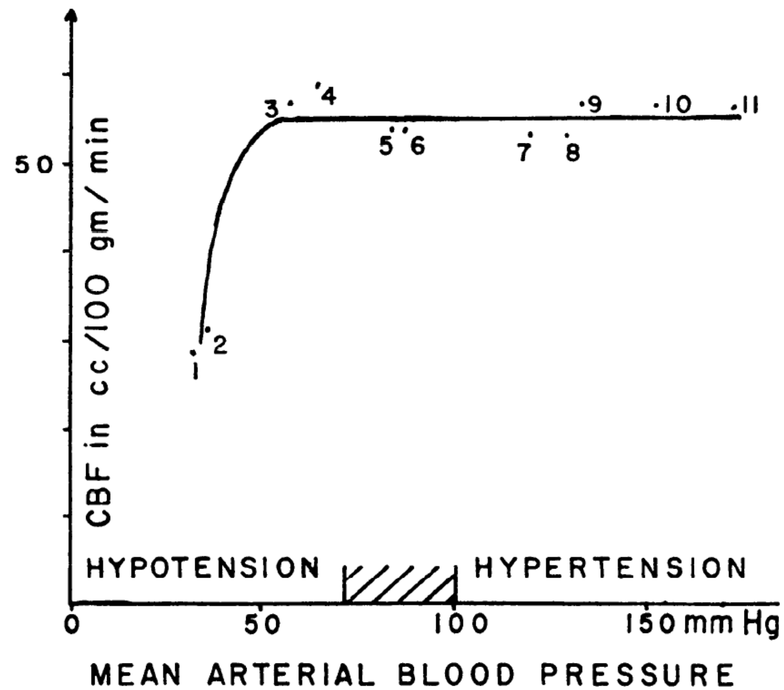
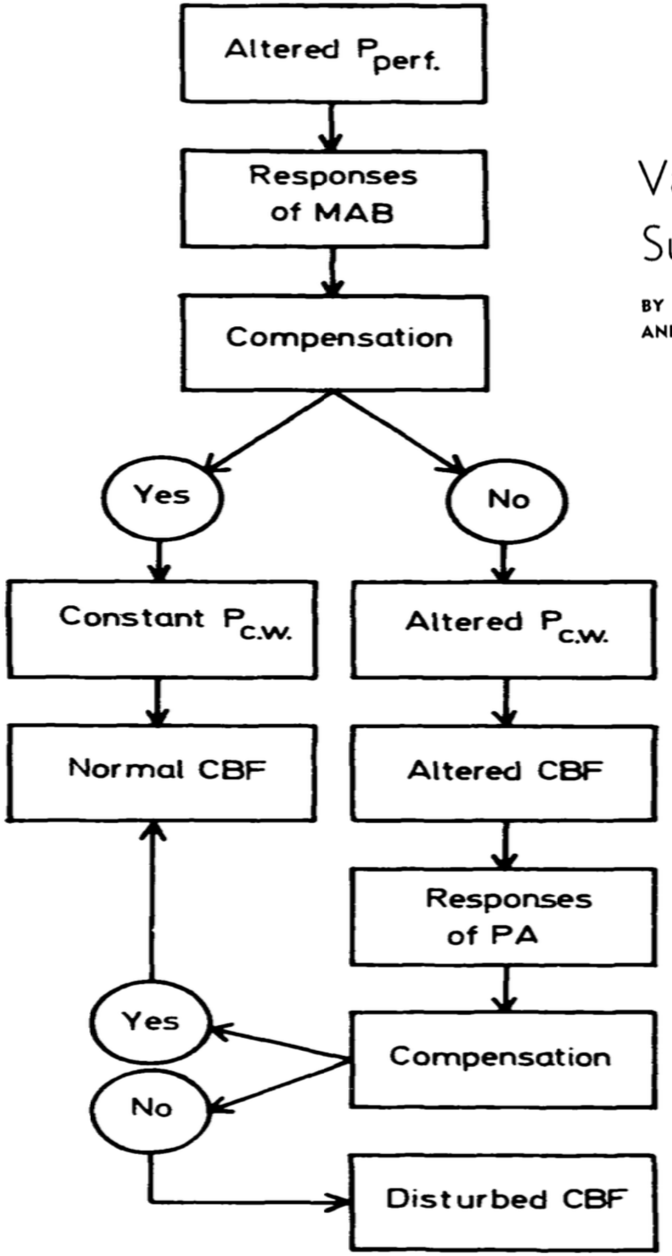
VOLUME 39 APRIL 1959 NUMBER 2

Cerebral Blood Flow and Oxygen Consumption in Man

NIELS A. LASSEN[1]

Laboratory of Clinical Science, National Institute of Mental Health, National Institutes of Health, Bethesda, Maryland





Vascular Mechanisms Controlling a Constant Blood Supply to the Brain ("Autoregulation")

BY GEORGE I. MCHEDLISHVILI, M.D.,* NODAR P. MITAGVARIA, AND LEILA G. ORMOTSADZE

Stroke, Vol. 4, September-October 1973

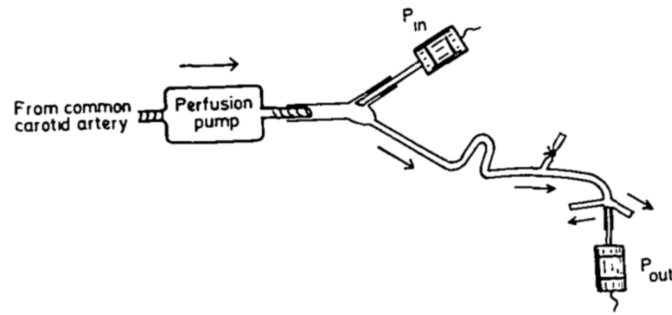


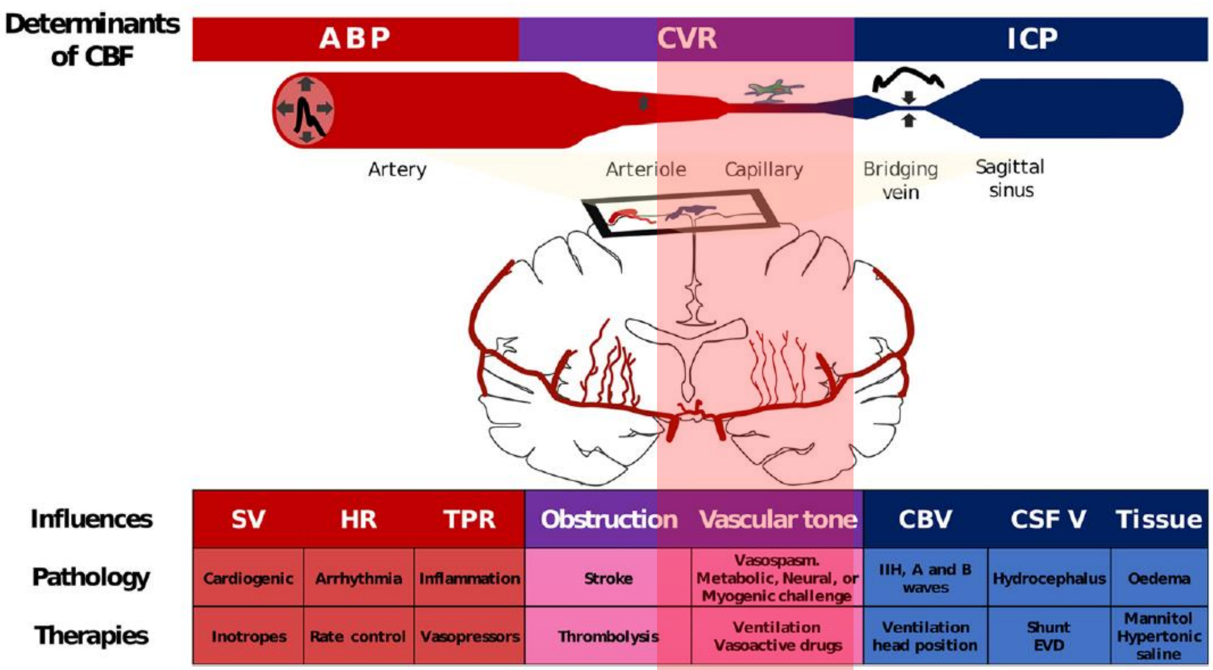
FIGURE 1

REVIEW Open Access

Regulation of the cerebral circulation: bedside assessment and clinical implications

Donnelly *et al. Critical Care* (2016) 20:129

Joseph Donnelly[1] et al.

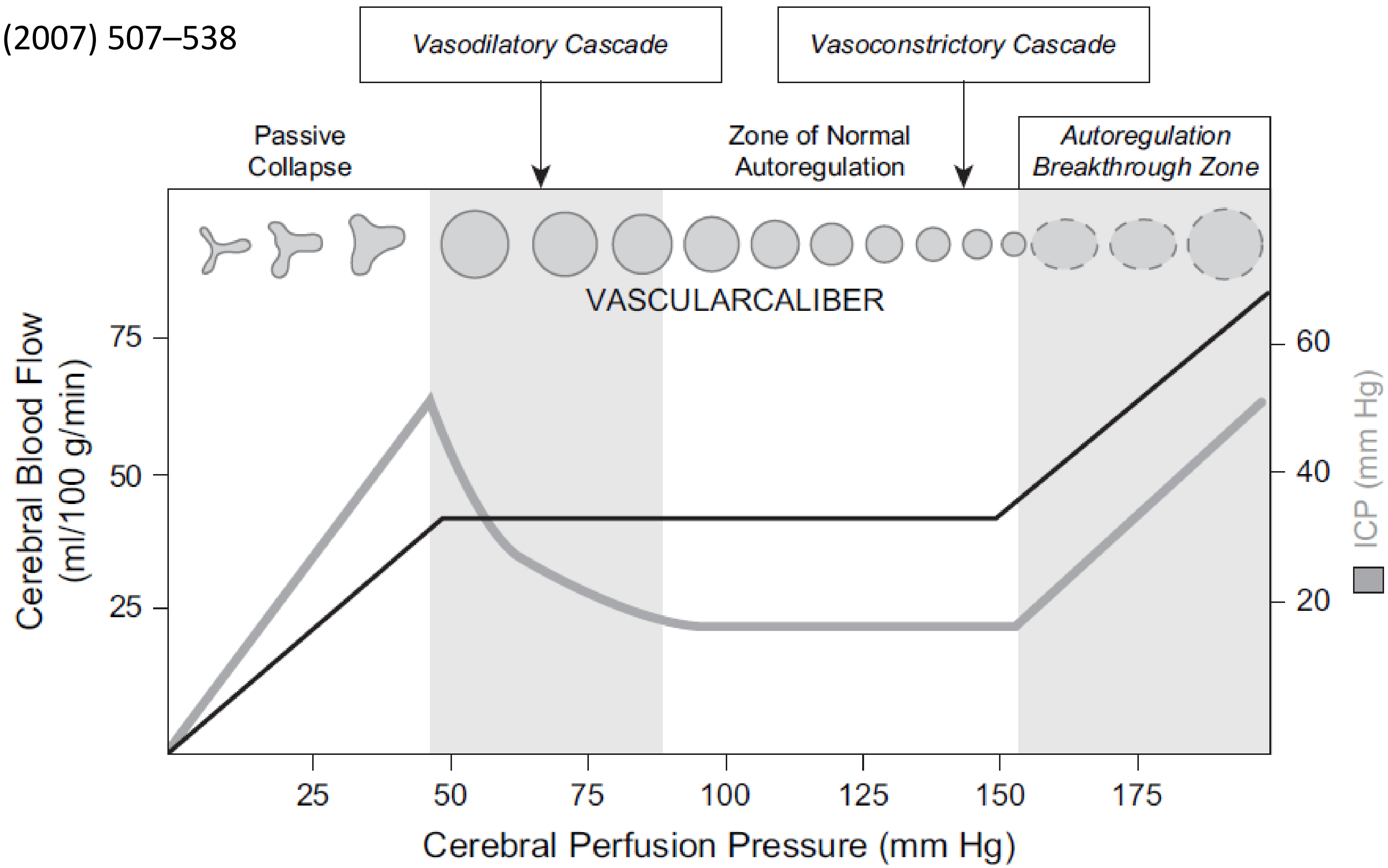


Multimodality Monitoring in Neurocritical Care

Katja Elfriede Wartenberg, MD[a,d],
J. Michael Schmidt, PhD[a,b],
Stephan A. Mayer, MD, FCCM[a,b,c,*]

Crit Care Clin 23 (2007) 507–538

$$CBF = \frac{ABP - ICP}{CVR}$$

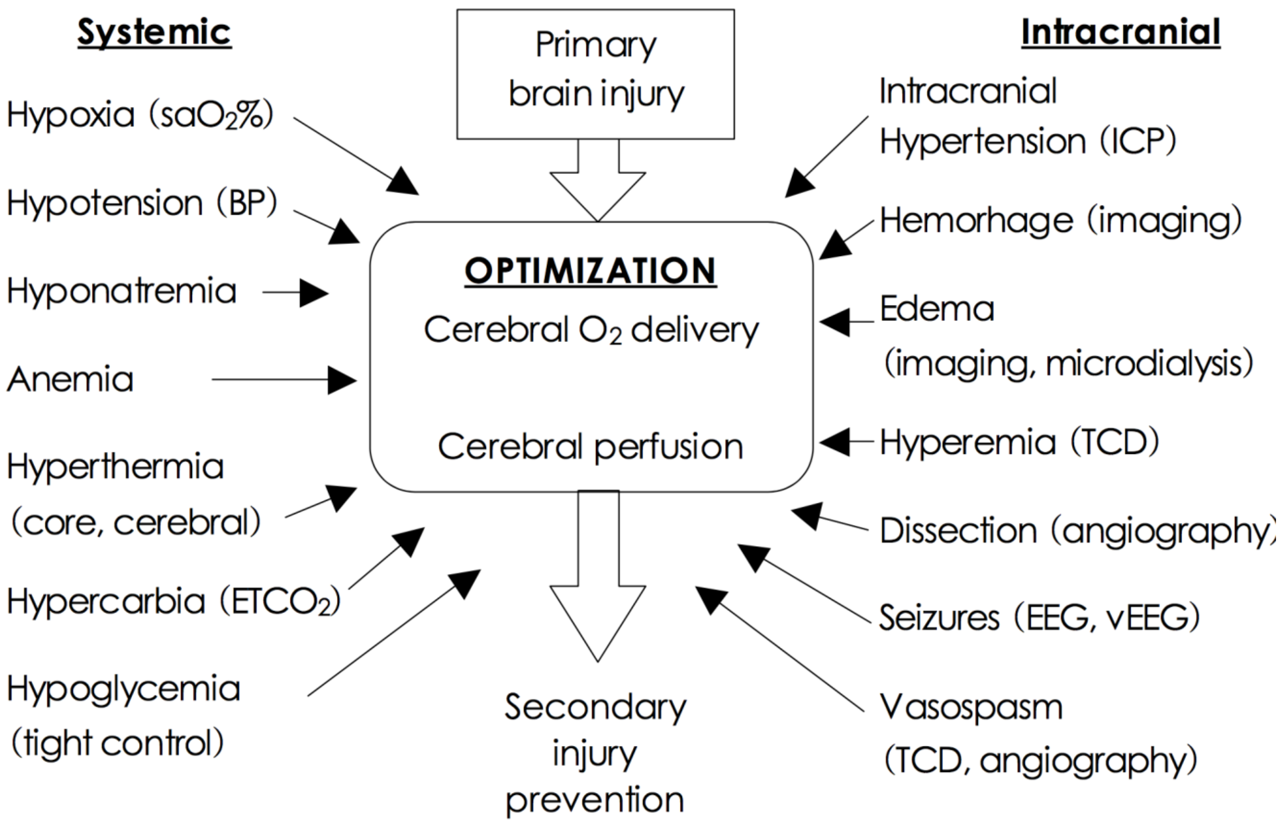


WHY IS AUTOREGULATION IMPORTANT IN BRAIN INJURY ?

Multimodal Neurocritical Care Monitoring: Conceptual Approach and Indications

J Neurocrit Care 2008;1:117-127

Scott G. Glickman, DO, PhD, MPH and Axel J. Rosengart, MD, PhD



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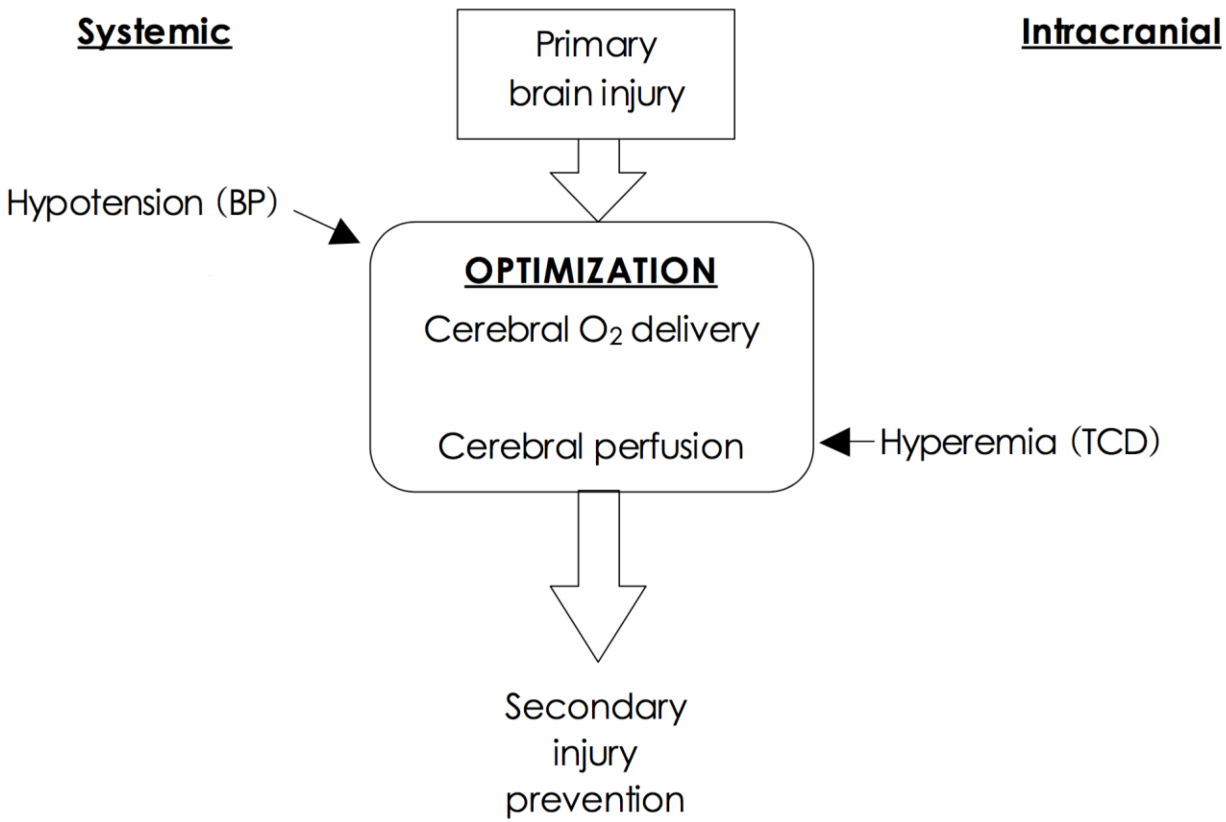

Table 3 Cerebral haemodynamics in critical illness

Critical illness	Effect of disease on cerebral haemodynamics			Does the cerebral haemodynamic parameter relate to prognosis?		
	Flow	Cerebral autoregulation	CO_2 reactivity	Flow	Cerebral autoregulation	CO_2 reactivity
TBI	Decreased [45, 46, 111] then increased [46, 112]	Decreased [44, 113]	Decreased [44, 49, 114, 115]	Yes: decreased [44–46, 111] and increased [44, 112] CBF related to poor outcome	Yes [44, 47]	Most studies find yes [44, 49], while some find no [51]
SAH	Decreased (vasospasm) [14, 55]	Decreased [54, 56]	Decreased [55]	Yes [62]	Yes [60, 62, 116]	Yes [117]
Stroke	Decreased [66, 67, 118]	Decreased [70, 71]	Decreased [68, 69]	Yes [66, 67]	Yes [71]	Yes [69]
Sepsis	Unchanged [78, 81], or decreased [5]	Unchanged [82], decreased [78, 79], or increased [83, 84]	Unchanged [82] or decreased [77]	Unknown	Unknown	Unknown
Preterm infants	Decreased [87, 89, 119]	Unchanged [93] or decreased [87, 88]	Decreased [88, 90]	Yes [119]	Yes [88, 95, 120]	Yes [88, 90]

CBF cerebral blood flow, *CO_2* carbon dioxide, *SAH*, subarachnoid haemorrhage; *TBI*, traumatic brain injury

Crit Care Clin 23 (2007) 507–538
KE Wartenberg et al.

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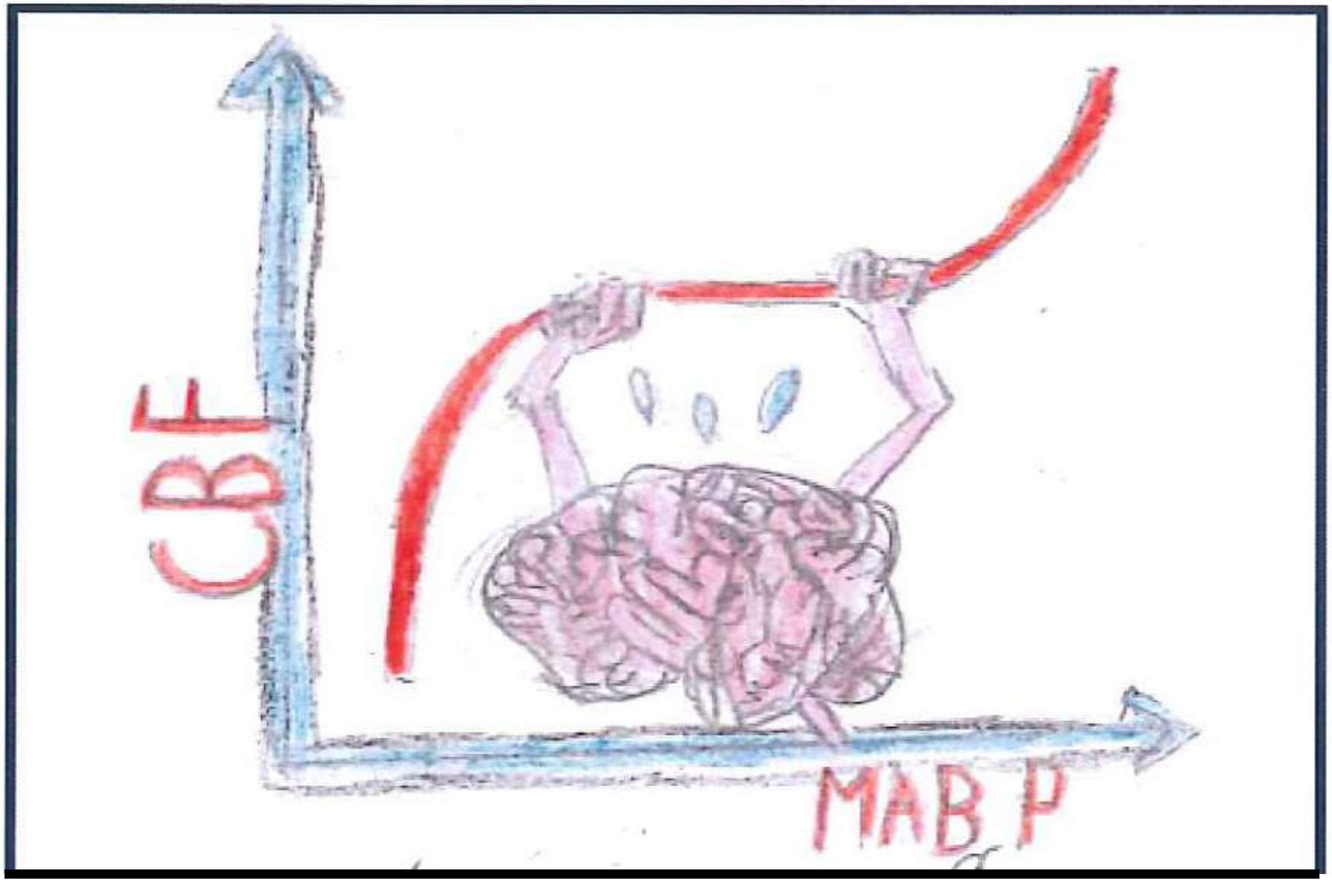
CBF cerebral blood flow, *CO_2* carbon dioxide, *SAH*, subarachnoid haemorrhage; *TBI*, traumatic brain injury

Crit Care Clin 23 (2007) 507–538
KE Wartenberg et al.

Your Brain after you bump your head



PhD thesis by Gitte Holst Hahn

Drawing of her daughter (age 7)

Brain Trauma Foundation

Guidelines for the Management of Severe Traumatic Brain Injury
4th Edition

17. Cerebral Perfusion Pressure Thresholds

Level II B

- The recommended target cerebral perfusion pressure (CPP) value for survival and favorable outcomes is between 60 and 70 mm Hg. Whether 60 or 70 mm Hg is the minimum optimal CPP threshold is unclear and may depend upon the patient's autoregulatory status.

10mmHg

Level III

- Avoiding aggressive attempts to maintain CPP above 70 mm Hg with fluids and pressors may be considered because of the risk of adult respiratory failure.

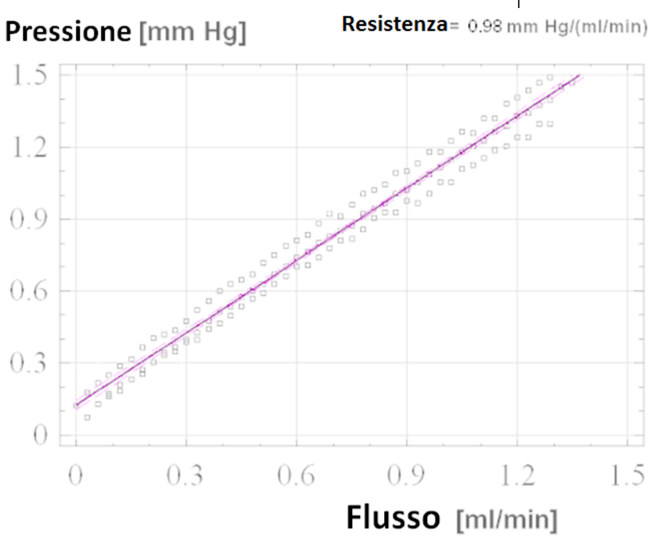

How we look at a CVA curve in TBI
Secondary
Injury
PULMONARY EDEMA
ARDS
60 – 70
BTF
60
80
50
100
Modified from
A. Lavinio

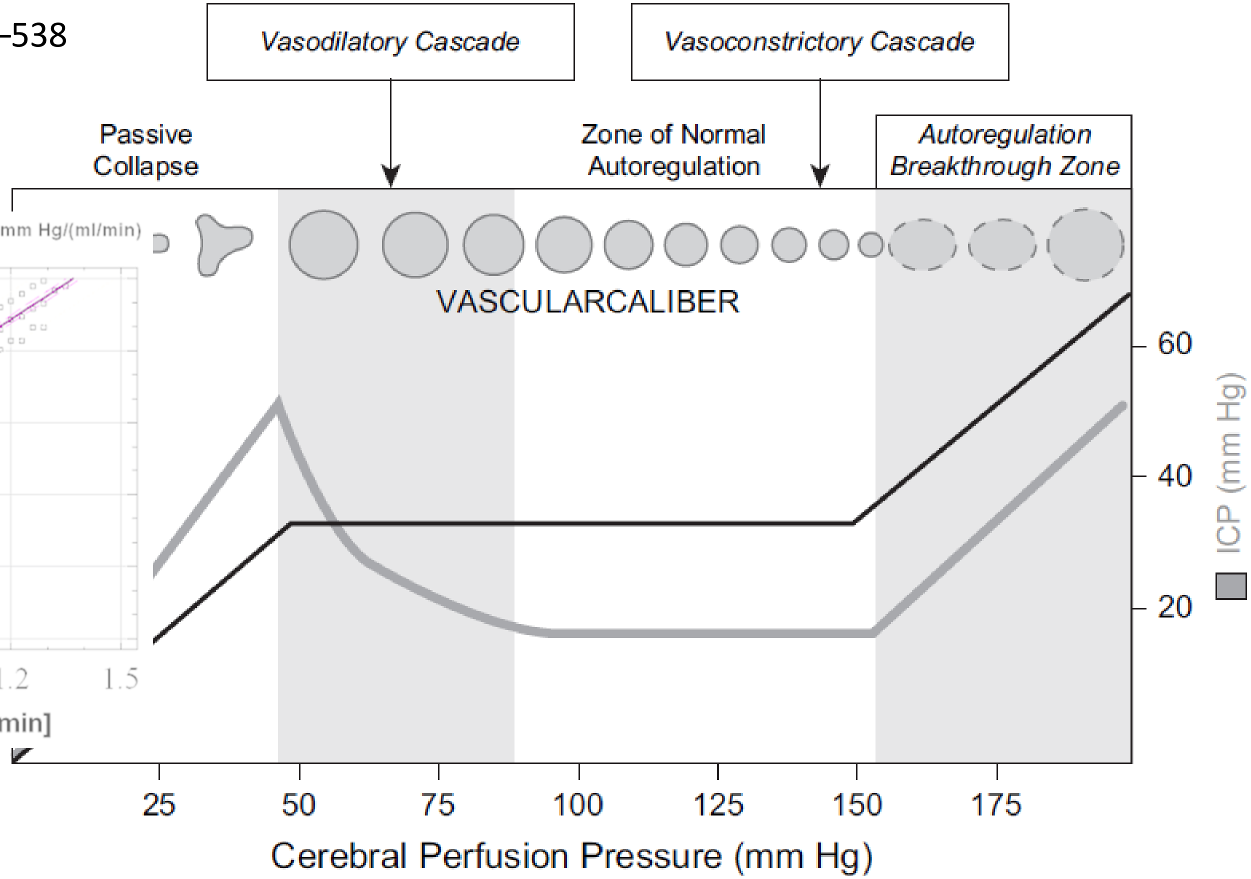
Multimodality Monitoring in Neurocritical Care

Katja Elfriede Wartenberg, MD[a,d], J. Michael Schmidt, PhD[a,b], Stephan A. Mayer, MD, FCCM[a,b,c,*]

Crit Care Clin 23 (2007) 507–538

$$CBF = \frac{ABP - ICP}{CVR}$$





Consensus Summary Statement of the International Multidisciplinary Consensus Conference on Multimodality Monitoring in Neurocritical Care

A statement for healthcare professionals from the Neurocritical Care Society and the European Society of Intensive Care Medicine

Intensive Care Med. 2014 Sep;40(9):1189-209

Peter Le Roux · David K. Menon · Giuseppe Citerio · Paul Vespa · Mary Kay Bader · Gretchen M. Brophy · Michael N. Diringer · Nino Stocchetti · Walter Videtta · Rocco Armonda · Neeraj Badjatia · Julian Böesel · Randall Chesnut · Sherry Chou · Jan Claassen · Marek Czosnyka · Michael De Georgia · Anthony Figaji · Jennifer Fugate · Raimund Helbok · David Horowitz · Peter Hutchinson · Monisha Kumar · Molly McNett · Chad Miller · Andrew Naidech · Mauro Oddo · DaiWai Olson · Kristine O'Phelan · J. Javier Provencio · Corinna Puppo · Richard Riker · Claudia Robertson · Michael Schmidt · Fabio Taccone

Cerebral Autoregulation

Questions Addressed

1. Does monitoring of cerebral autoregulation help guide management and contribute to prognostication?
2. Which technique and methodology most reliably evaluates the state of autoregulation in ABI?

Recommendations

1. We suggest that monitoring and assessment of autoregulation may be useful in broad targeting of cerebral perfusion management goals and prognostication in ABI. (Weak recommendation, moderate quality of evidence.)
2. Continuous bedside monitoring of autoregulation is now feasible, and we suggest that it should be considered as a part of MMM. Measurement of pressure reactivity has been commonly used for this purpose, but many different approaches may be equally valid. (Weak recommendation, moderate quality of evidence.)

Assessment of Cerebral Pressure Autoregulation
Frank A Rasulo, Marcella Balestreri, Basil Matta.
Current Opinion in Anesthesiology. October 2002

HOW TO MEASURE CEREBROVASCULAR AUTOREGULATION

Testing

* Clear stimulation:
-drug to rise ABP
-leg cuff release
-head down tilt
-lower body pressure
-slow respiration
-transient compression

➢ Static Autoregulation: %Δ CVR / %Δ MAP

Monitoring

*No stimulation; spontaneaous waves
of ABP
or CPP

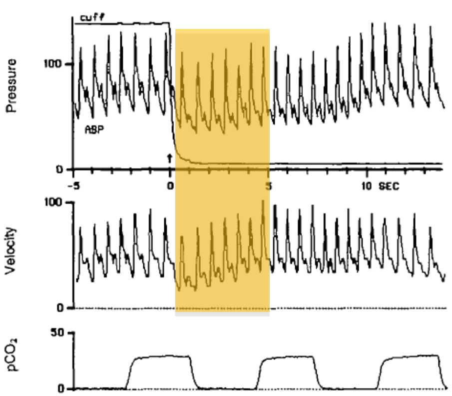
Testing

* Clear stimulation:

-drug to rise ABP

-leg cuff release

➢ Dynamic Autoregulation: **Rate** of % Δ CVR / % Δ MAP



Autoregulatory is seen from the blood velocity returning to pretest values after 4 seconds.

Monitoring

*No stimulation; spontaneaous waves of ABP

or CPP

Testing

* Clear stimulation:

-drug to rise ABP

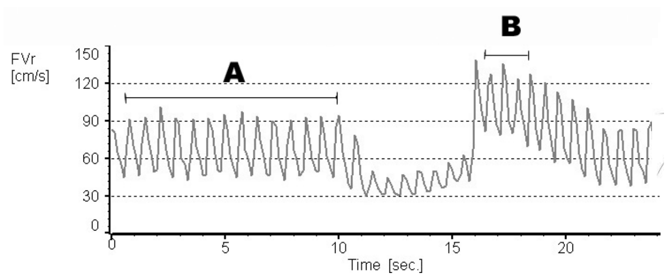
-leg cuff release

-head down tilt

-lower body pressure

-slow respiration

-transient compression



circa 5 secondi

- Better accuracy
- One-off measurement

Monitoring

*No stimulation; spontaneaous waves of ABP or CPP

Testing

* Clear stimulation:

-drug to rise ABP

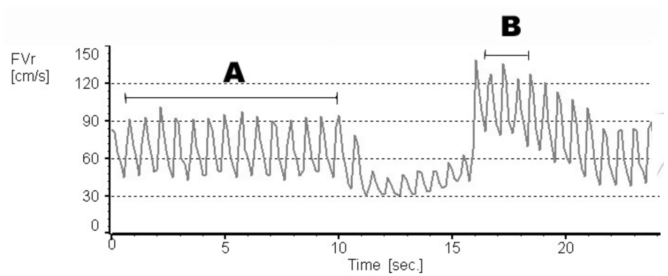
-leg cuff release

-head down tilt

-lower body pressure

-slow respiration

-transient compression



circa 5 secondi

- Better accuracy
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Monitoring

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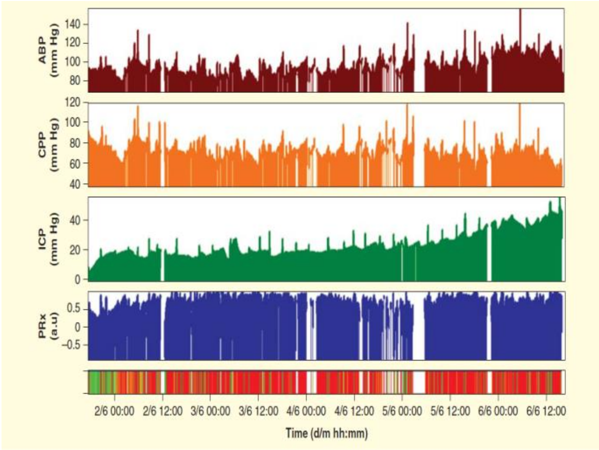
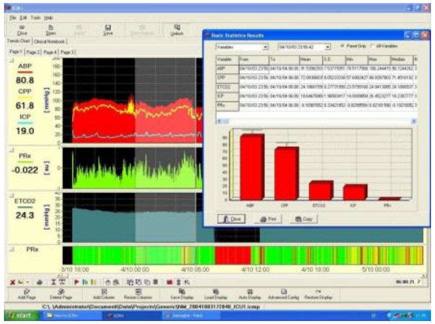


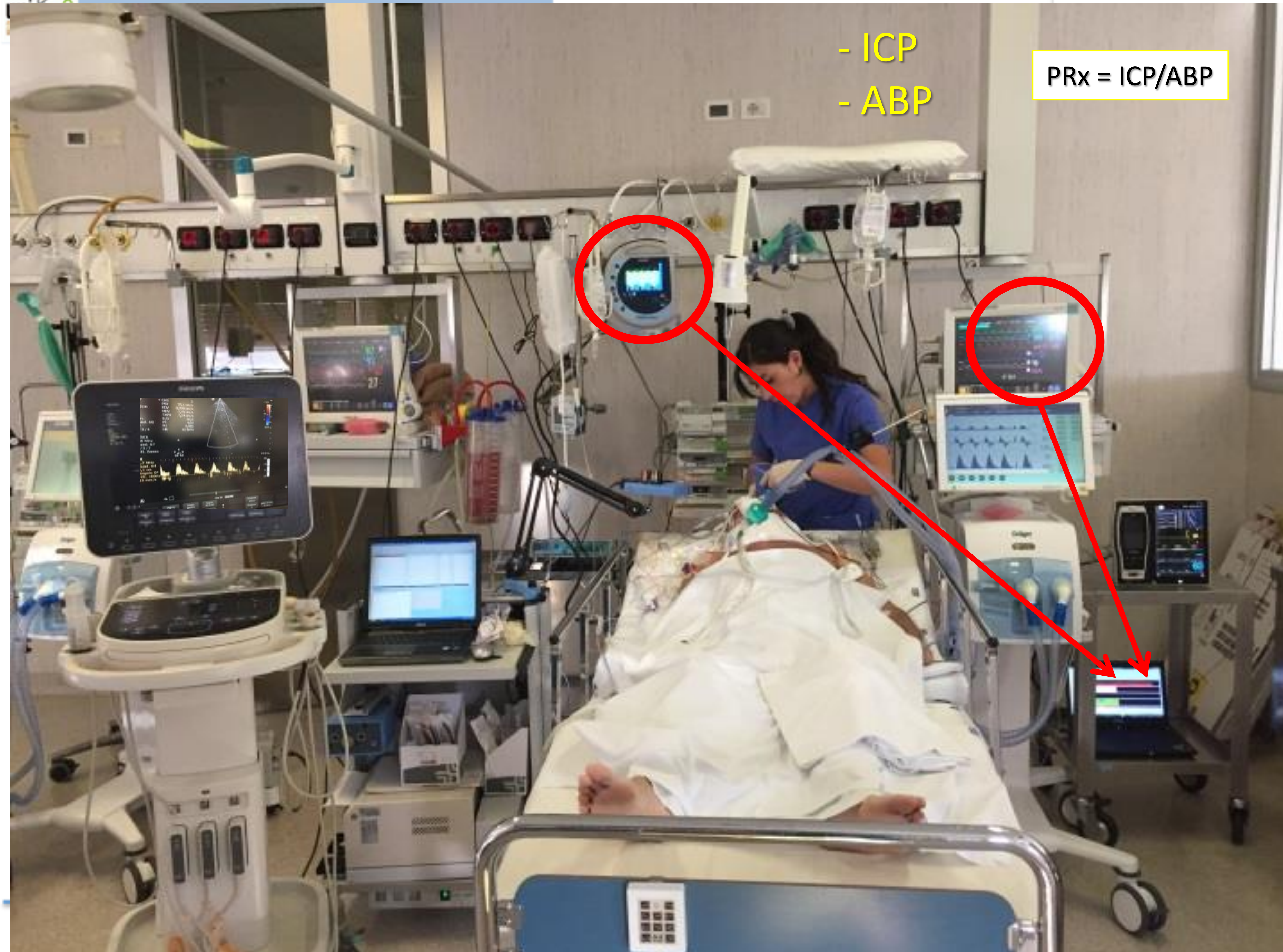
Table 2 Summary of autoregulation indices

Autoregulation metric	Input signals	Calculation	Interpretation	Comment
Autoregulation index (ARI)	ABP, Fv	Compares the CBF response to changes in ABP with those predicted from a parametric model with 10 different 'strengths' of autoregulation [110]	ARI = 0 absent autoregulation, ARI = 9 perfect autoregulation	Moderately complex signal processing required
Flow index (Mx, Sx, Dx)	ABP (CPP), Fv	Pearson correlation between CPP and mean Fv (300-s window of 10-s averages). Sx and Dx calculated with systolic and diastolic flow velocity, respectively	Impaired autoregulation = higher Mx, Dx, and Sx	Simplistic yet prognostically relevant
Transfer function (phase, gain, coherence)	ABP, Fv	Derived from the transfer function of fast Fourier transform of ABP and Fv signals. Phase is the shift required to align Fv and ABP signals, gain the transmission from ABP to Fv, and coherence the statistical association between ABP and Fv	Impaired autoregulation = low phase, high gain, high coherence	Moderately complex signal processing. Some prognostic relevance
TOx, COx, THx, HVx	ABP (CPP), NIRS oxygenation	Pearson correlation between 30 consecutive 10-s means of ABP and tissue oxygenation (or total haemoglobin for THx and HVx)	Impaired autoregulation = higher TOx, COx, THx, HVx	Correlated with TCD methods but allows for longer term monitoring
TOIHRx	HR, NIRS oxygenation	Correlation between 30 consecutive 10-s means of HR and NIRS oxygenation	?Higher TOIHRx = impaired autoregulation	Used in preterm infants. Further comparisons with standard autoregulation indices required
Transfer function (phase, gain, coherence)	ABP, NIRS oxygenation	Derived from the transfer function of fast Fourier transform of ABP and oxygenation signals. Phase is the shift required to align oxygenation and ABP signals, gain the transmission from ABP to NIRS oxygenation, and coherence the statistical association between ABP and NIRS oxygenation	Impaired autoregulation = low phase, high gain, high coherence	Moderately complex signal processing
PRx	ABP, ICP	Correlation between 30 consecutive 10-s means of ABP and ICP	Higher PRx = impaired autoregulation	Robust measure for long monitoring periods. Simplistic and prognostically relevant
PAx	ABP, amplitude of ICP	Correlation between 30 consecutive 10-s means of ABP and ICP	Higher PAx = impaired autoregulation	Similar to PRx, may allow better estimate of pressure reactivity when the "pressure–volume" compensatory curve is flat, i.e. at low ICP
ORx	CPP (ABP), P_BTO_2	Correlation between 30 consecutive 10-s means of ABP and P_BTO_2	High ORx = impaired autoregulation	Further validation required

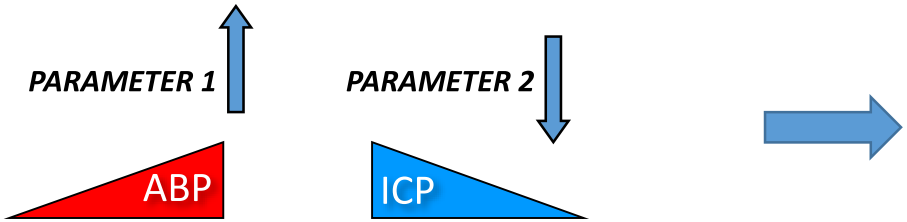


Crit Care Clin 23 (2007) 507–538
KE Wartenberg et al.

Spedali Civili, University Hospital of Brescia, Italy

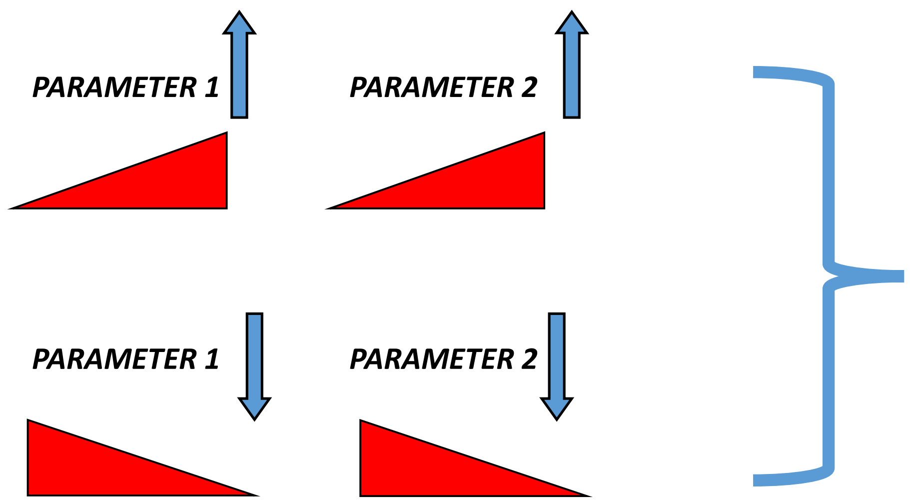

- ICP
- ABP
PRx = ICP/ABP

CEREBROVASCULAR AUTOREGULATION



Negative Correlation
Autoregulation **PRESERVED**

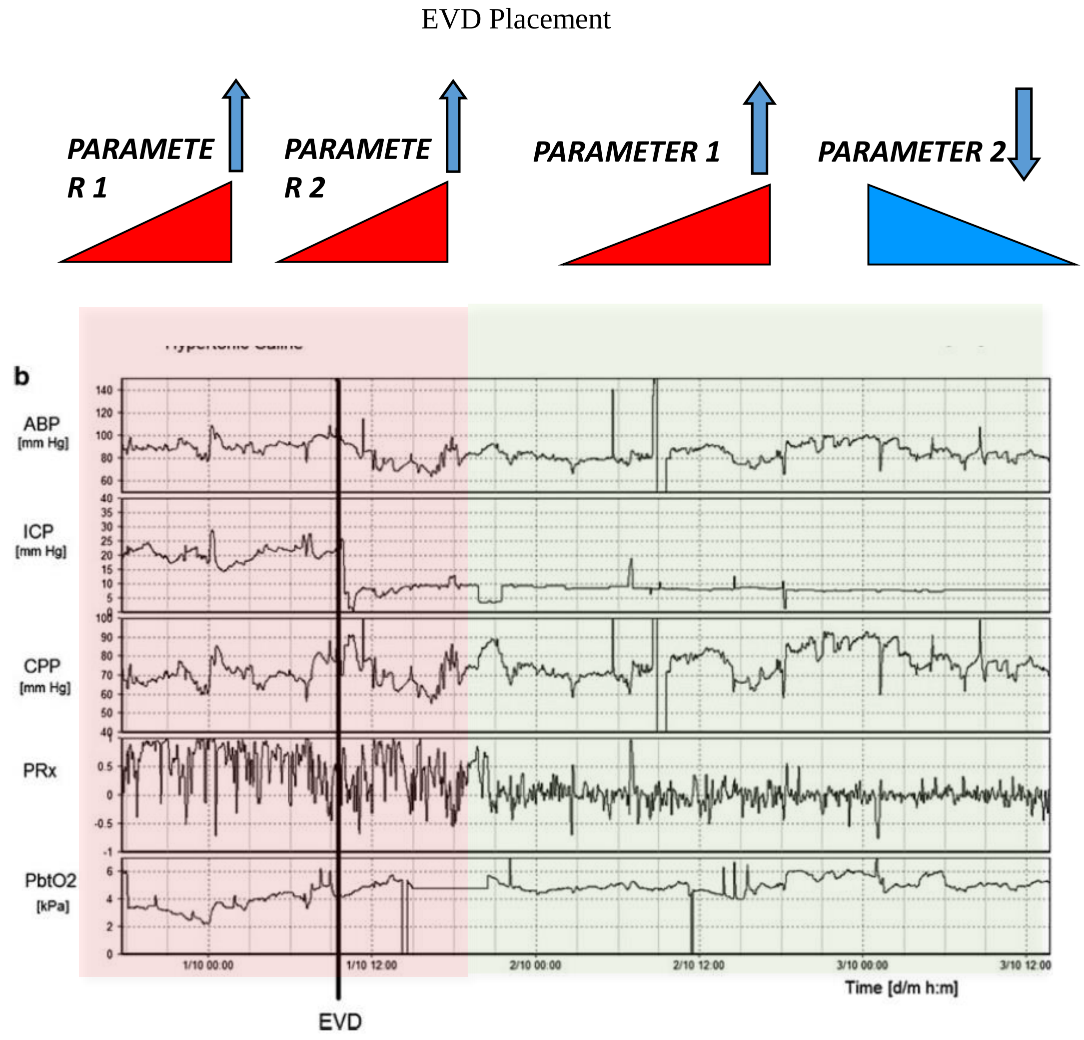
< 0.2

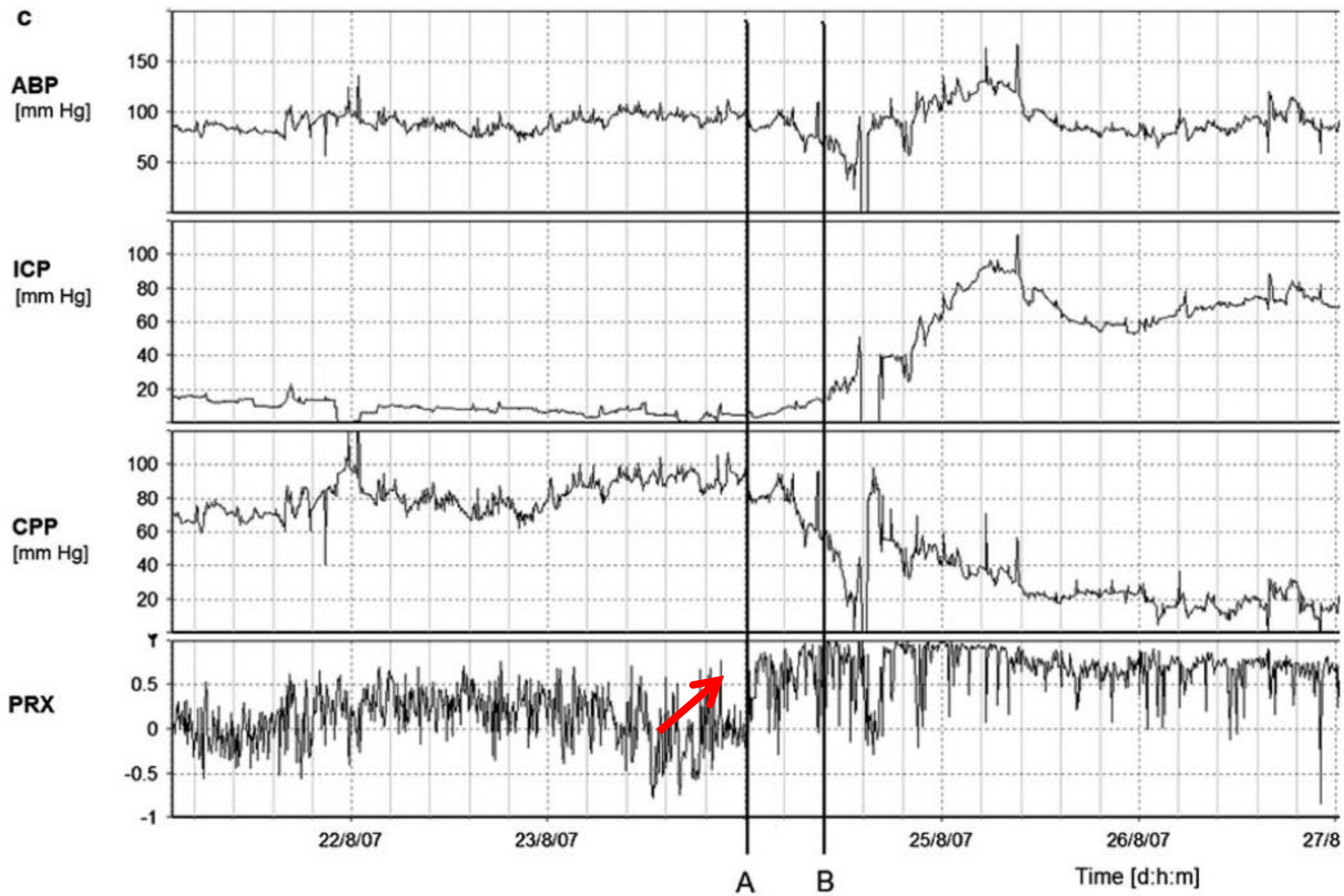


PRESSURE PASSIVE

Positive Correlation
Autoregulation **DISTURBED**

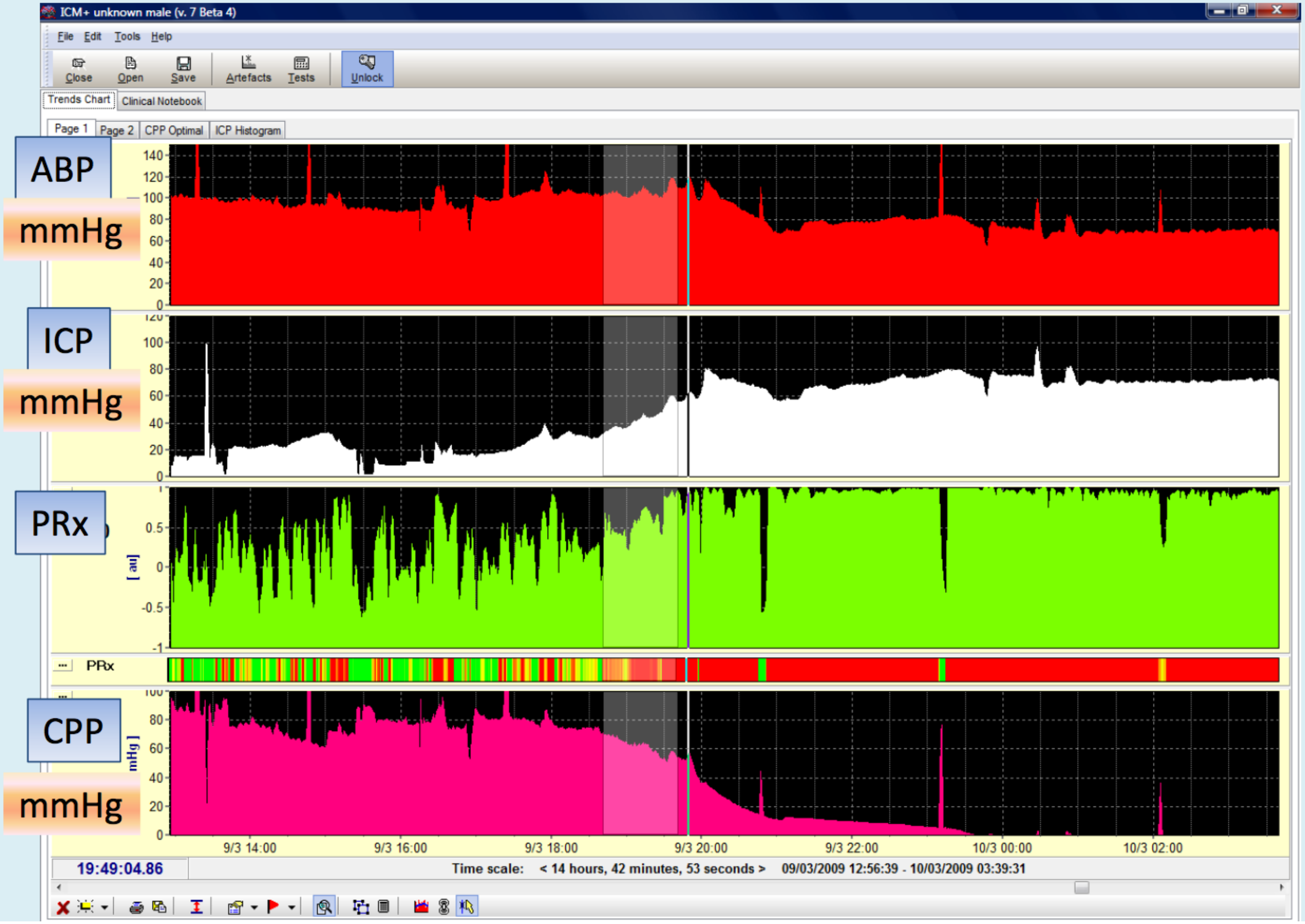
CEREBROVASCULAR AUTOREGULATION

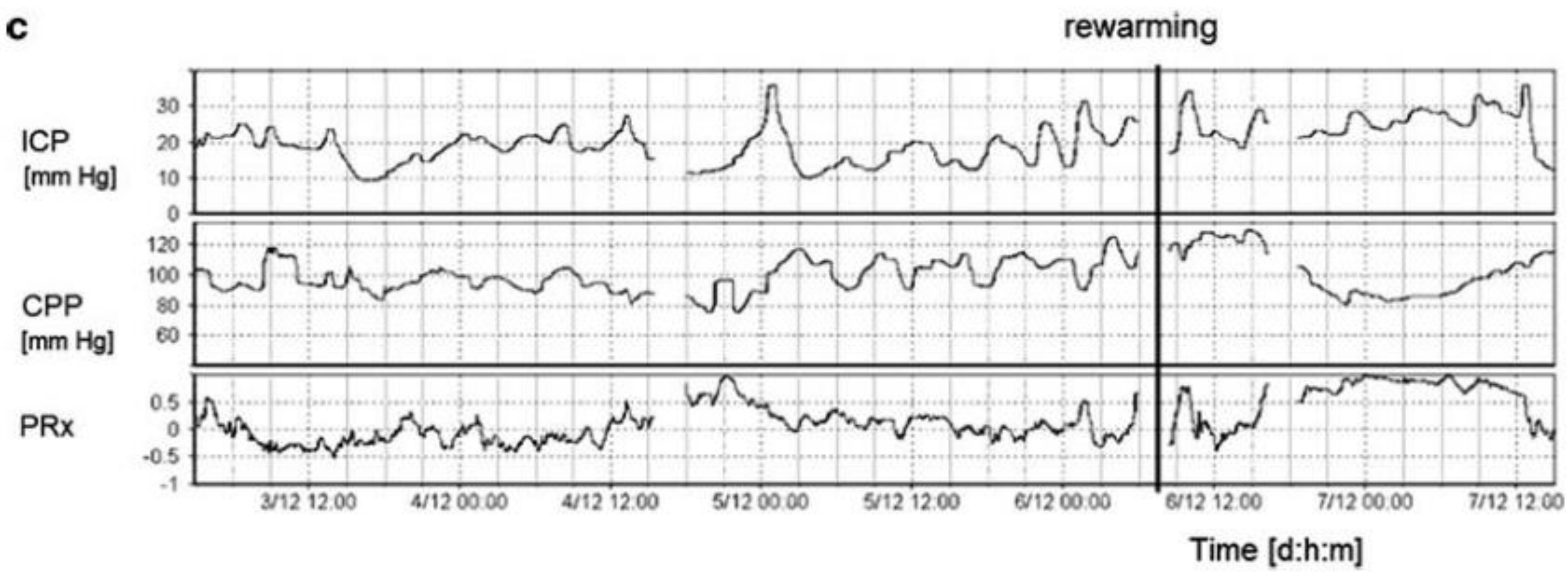




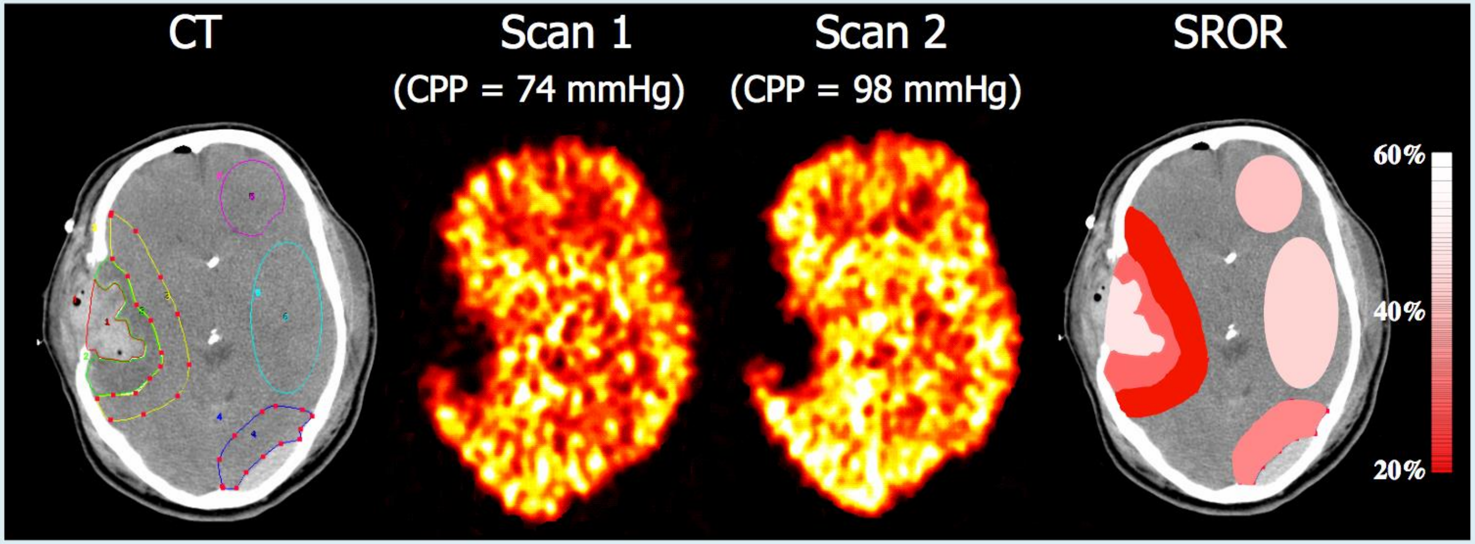
Neurocrit Care (2009) 10:373–386

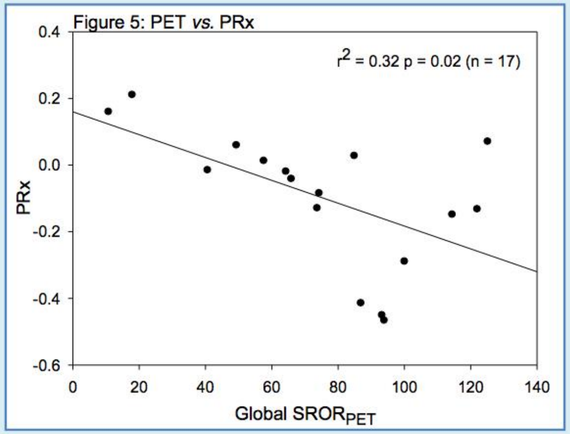
Refractory intracranial hypertension (2)





Cerebrovascular reactivity during hypothermia and rewarming.
Lavinio A et al. Br J Anaesth. 2007;99:237–44





PRx correlates with PET-static rate of autoregulation

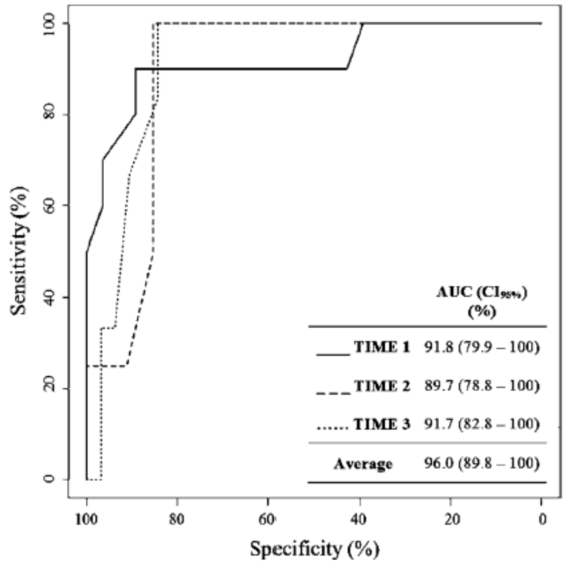
Steiner LA, Coles JP, Johnston AJ, Chatfield DA, Smielewski P, Fryer TD, Aigbirhio FI, Clark JC, Pickard JD, Menon DK, Czosnyka M. Assessment of Cerebrovascular Autoregulation in Head-Injured Patients. A Validation Study.Stroke. 2003 34:2404-2409

RESEARCH Open Access

The accuracy of transcranial Doppler in excluding intracranial hypertension following acute brain injury: a multicenter prospective pilot study

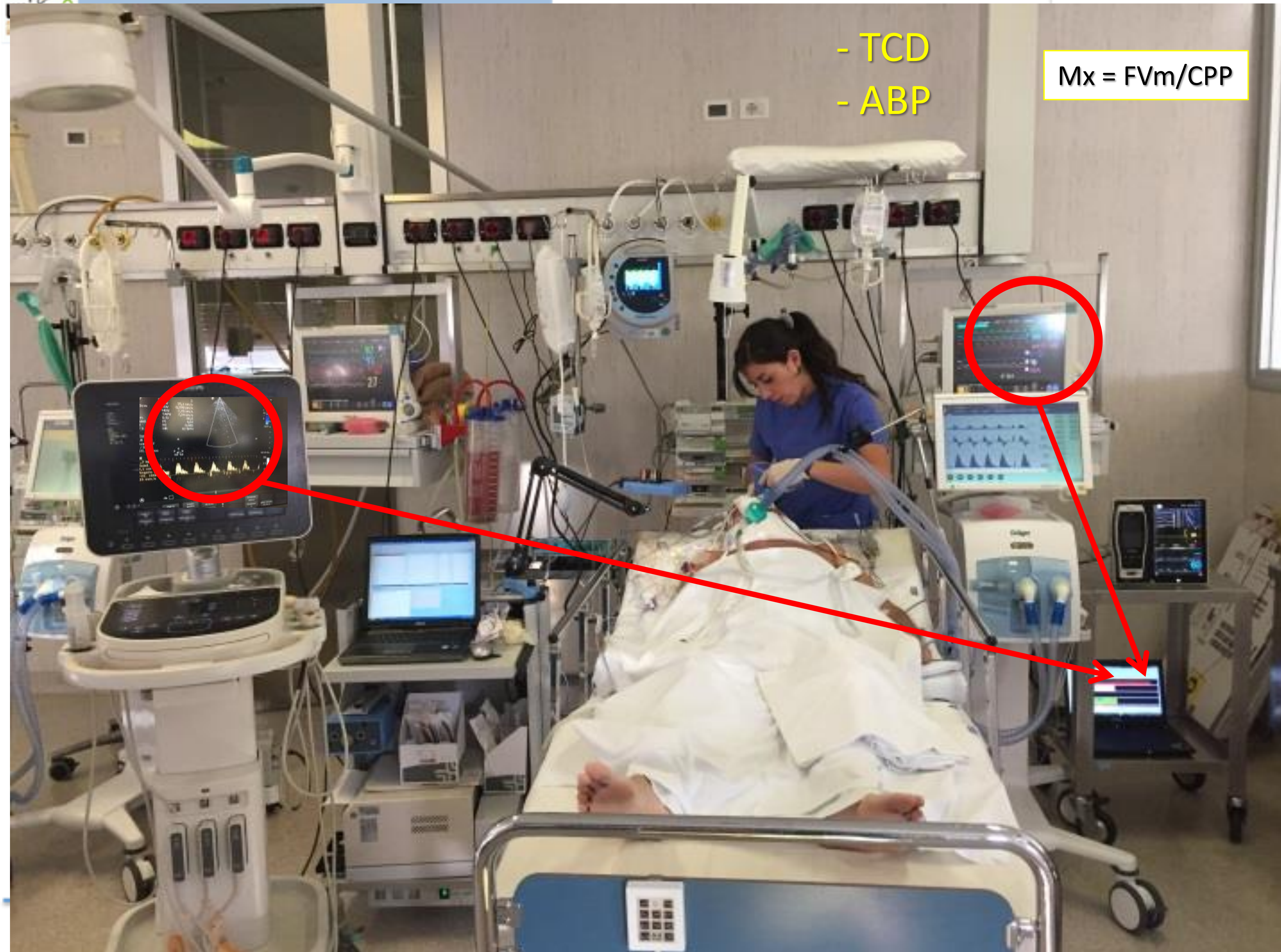
Critical Care (2017) 21:44

Frank A. Rasulo[1,2*], Rita Bertuetti[1], Chiara Robba[3], Francesco Lusenti[4], Alfredo Cantoni[5], Marta Bernini[6]
Alan Girardini[7], Stefano Calza[8], Simone Piva[1], Nazzareno Fagoni[1] and Nicola Latronico[1,2]

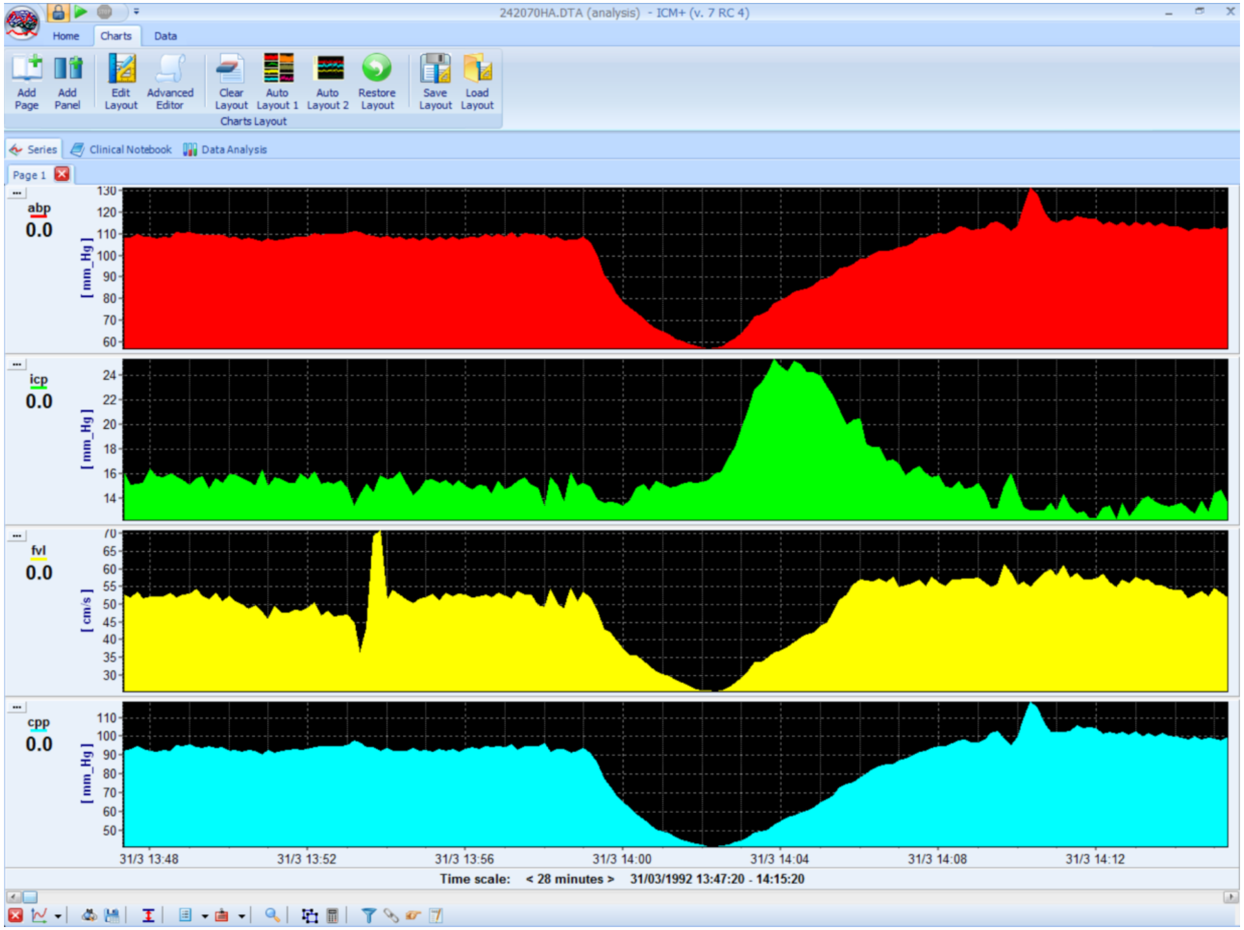


Conclusions: This study provides preliminary evidence that ICPtcd may accurately exclude intracranial hypertension in patients with acute brain injury.

FUTURE *PRx* ➡ $ICP_{non\text{-}invasive}$ /ABP

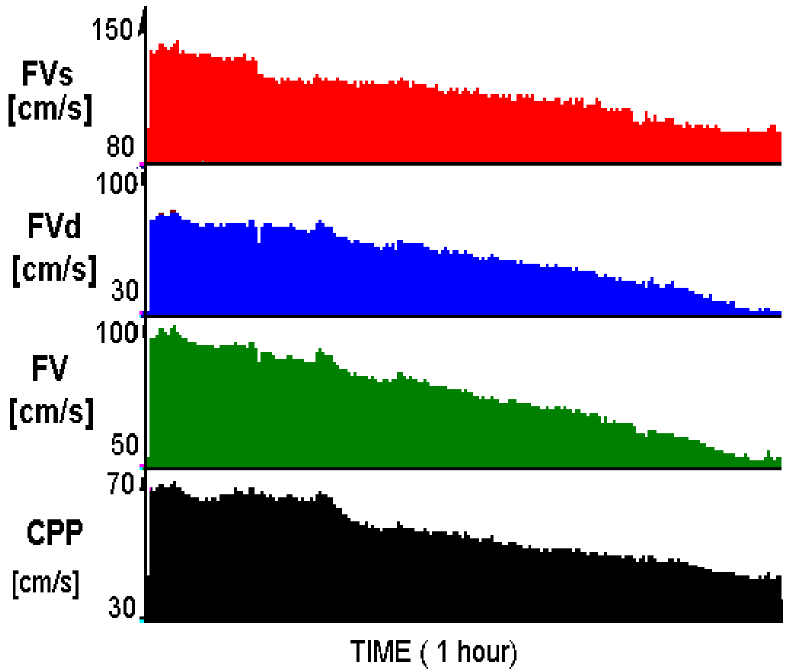

- TCD
- ABP
Mx = FVm/CPP

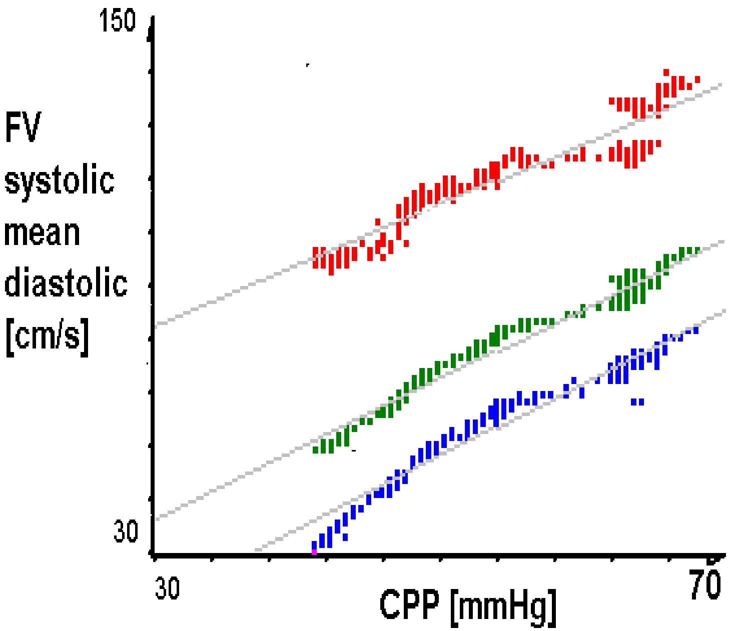
Consequence of ***disturbed CVA*** and ***hypotension***



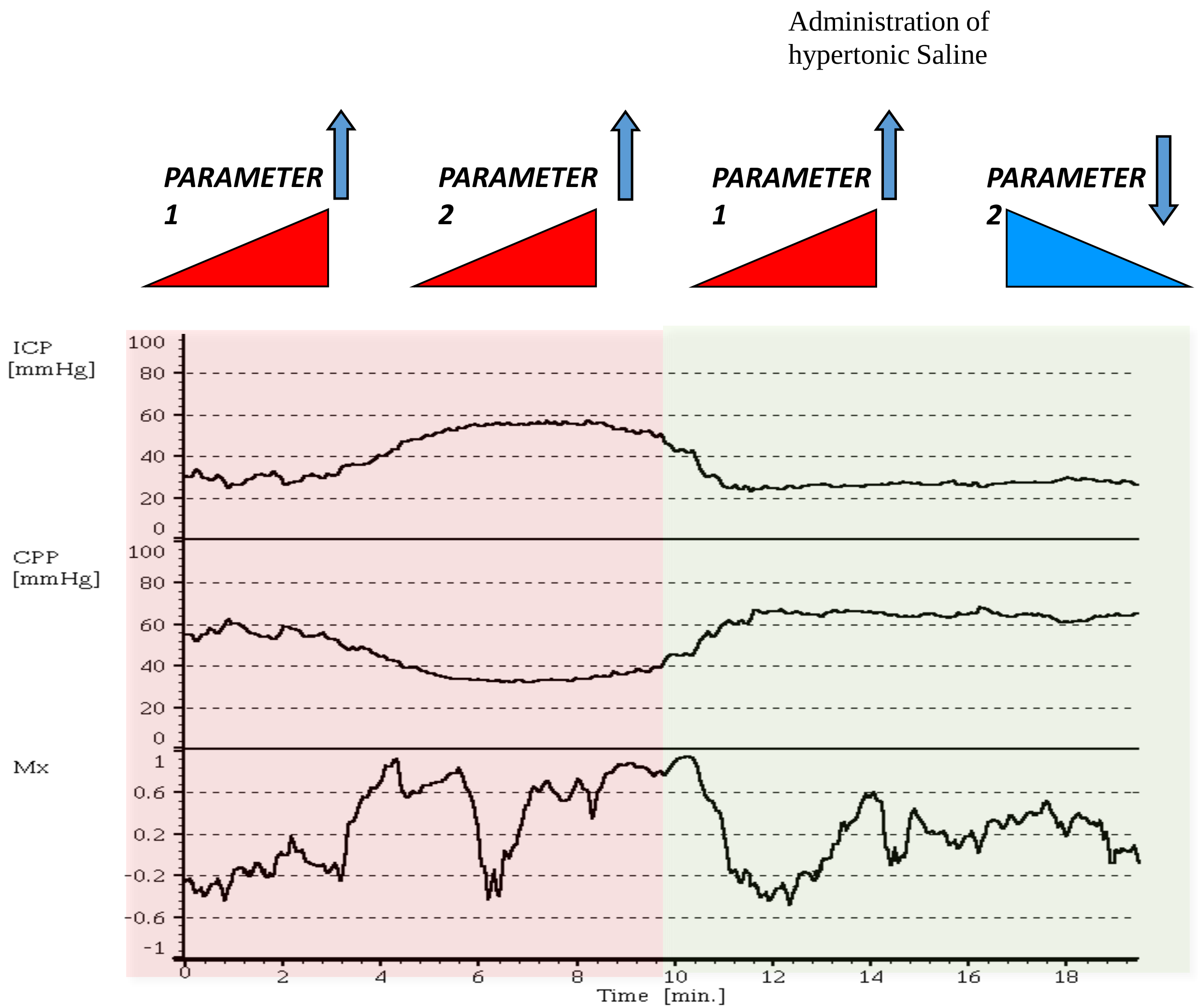
Mx

AutoregulazioneCompromessa



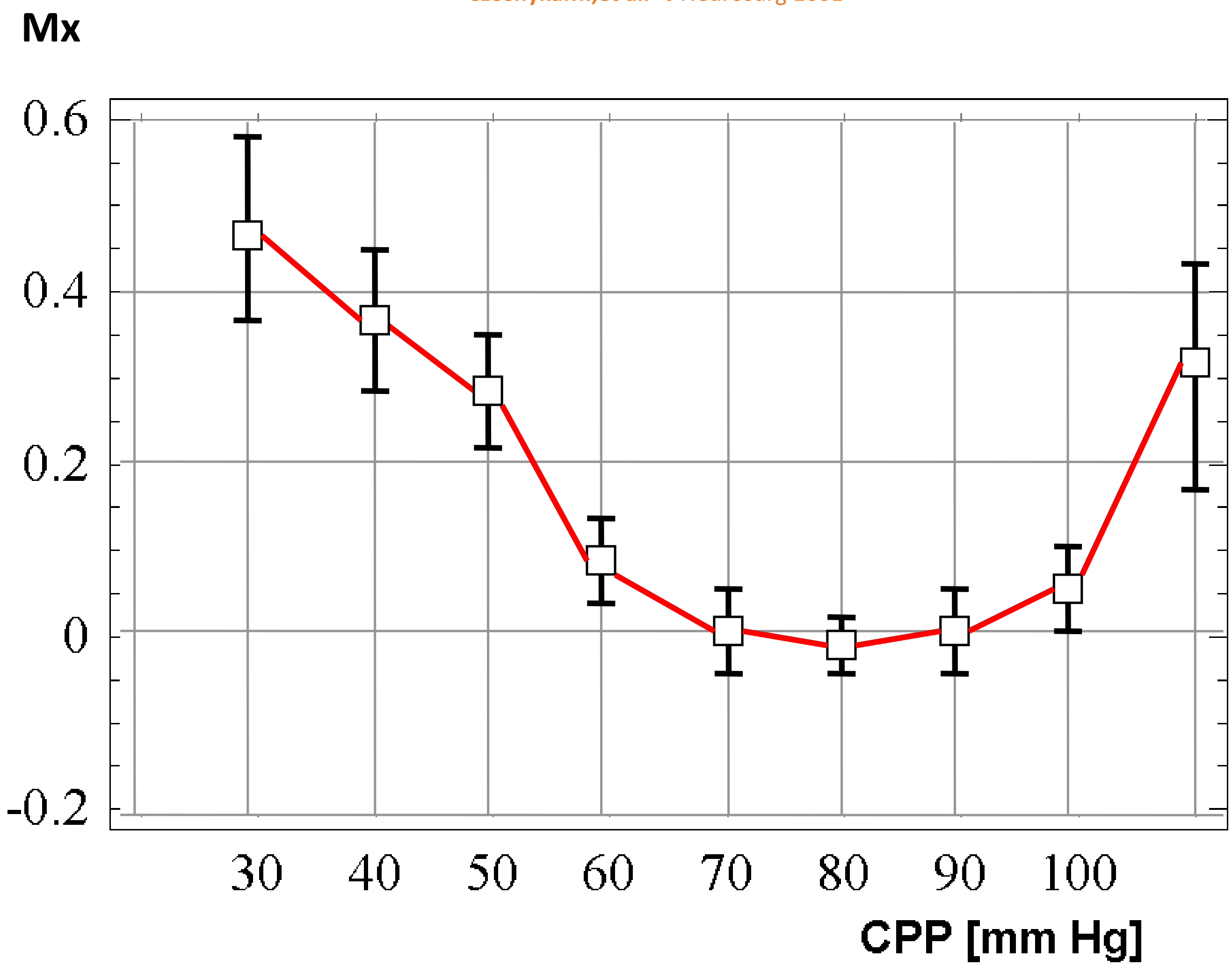


CEREBROVASCULAR AUTOREGULATION



Autoregulation and Cerebral Perfusion Pressure

CzosnykaM.,et al. J Neurosurg 2001



Autoregulation and Cerebral Perfusion Pressure

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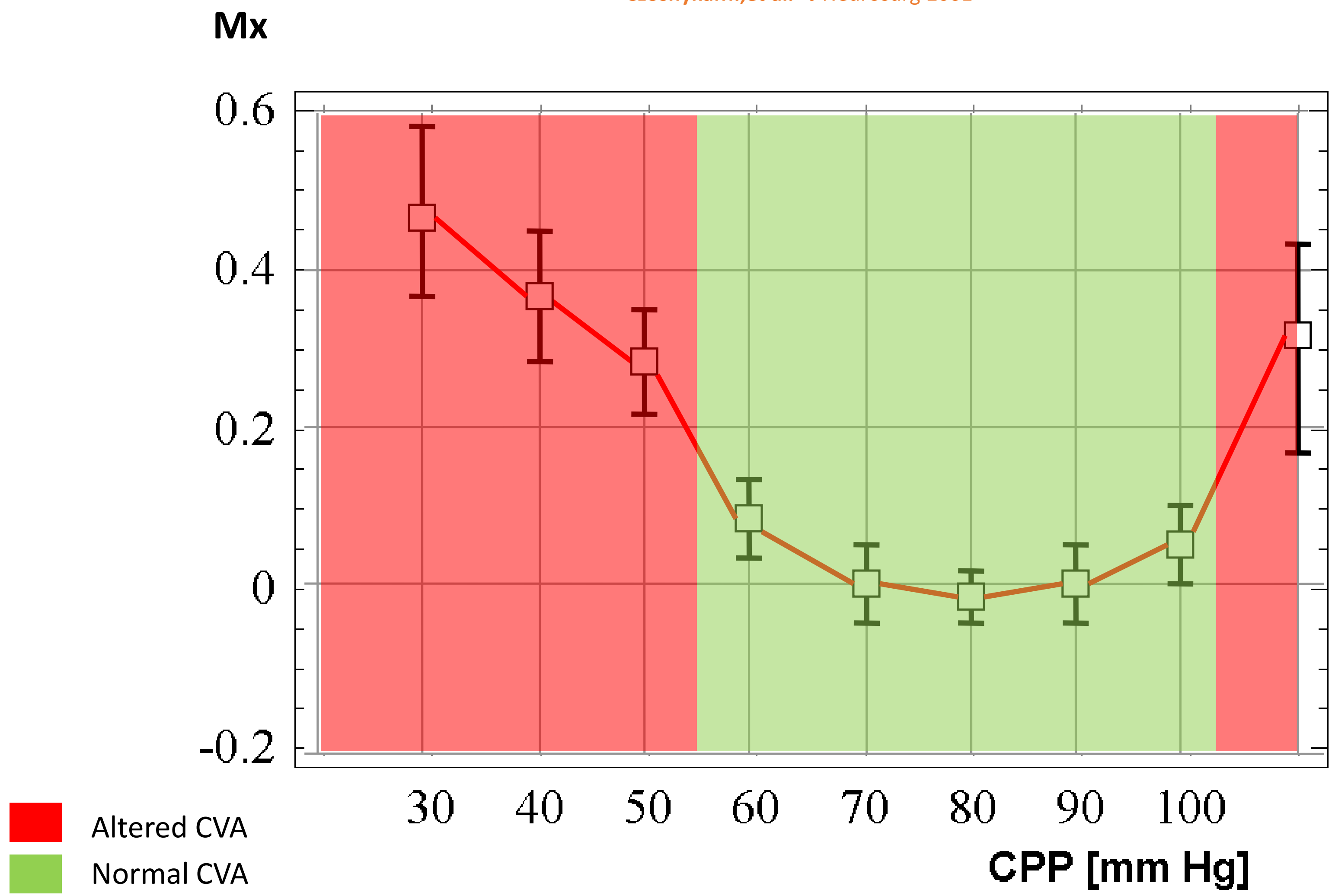
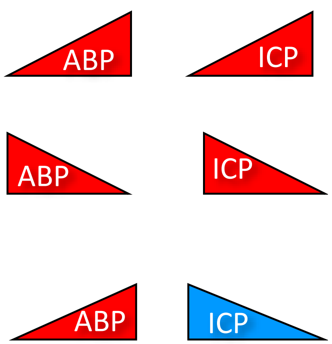


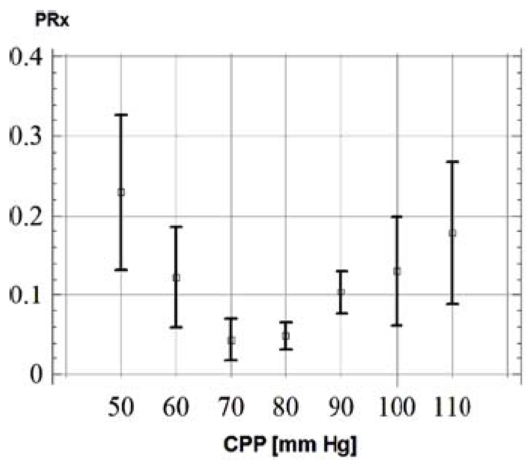
CEREBROVASCULAR AUTOREGULATION

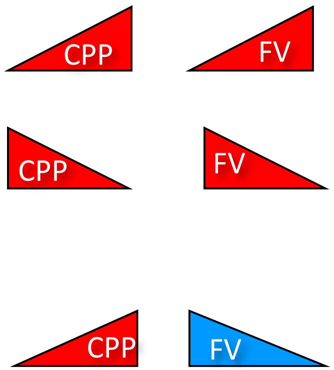
Monitoring of Cerebrovascular Autoregulation: Facts, Myths, and Missing Links

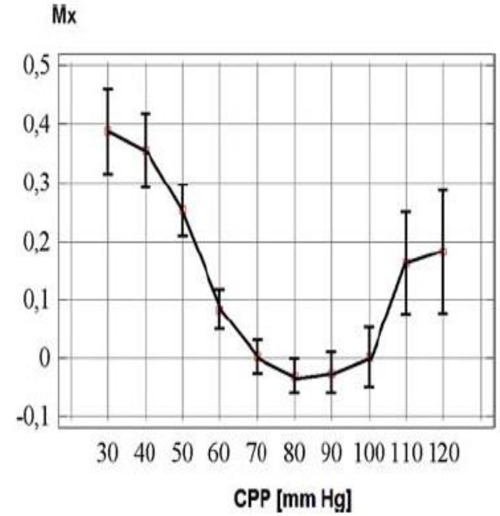
Neurocrit Care (2009) 10:373–386

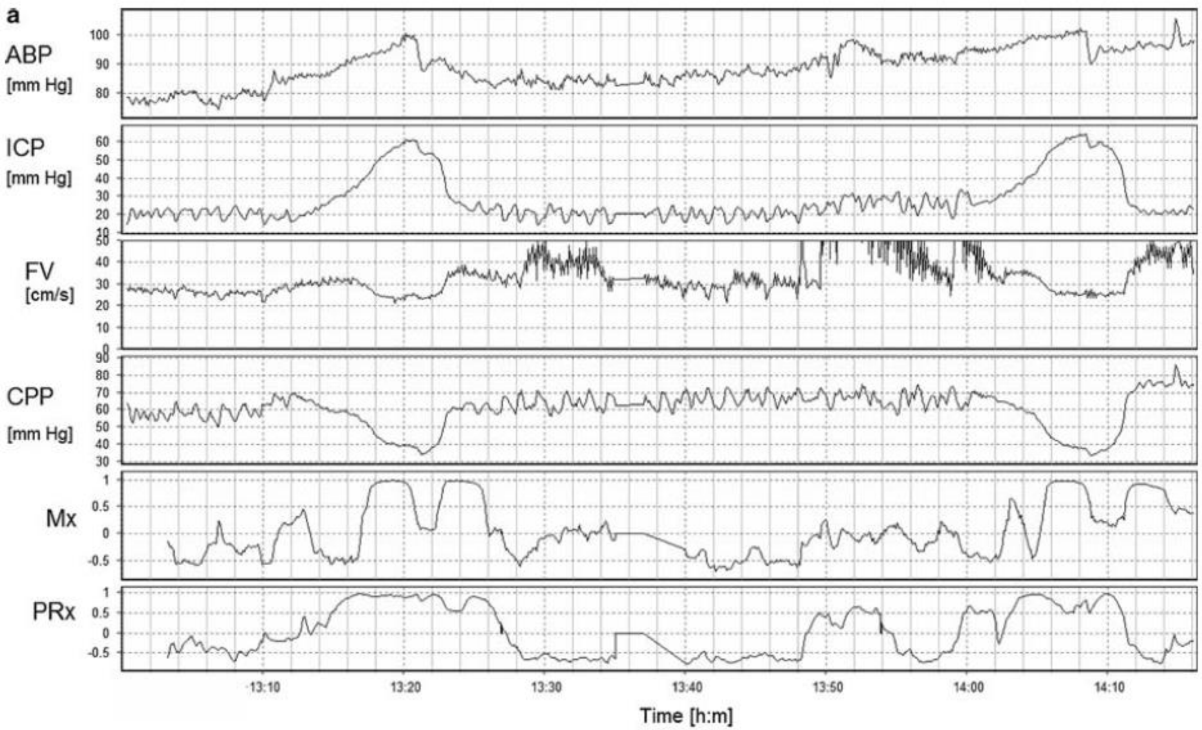
Marek Czosnyka · Ken Brady · Matthias Reinhard ·
Piotr Smielewski · Luzius A. Steiner







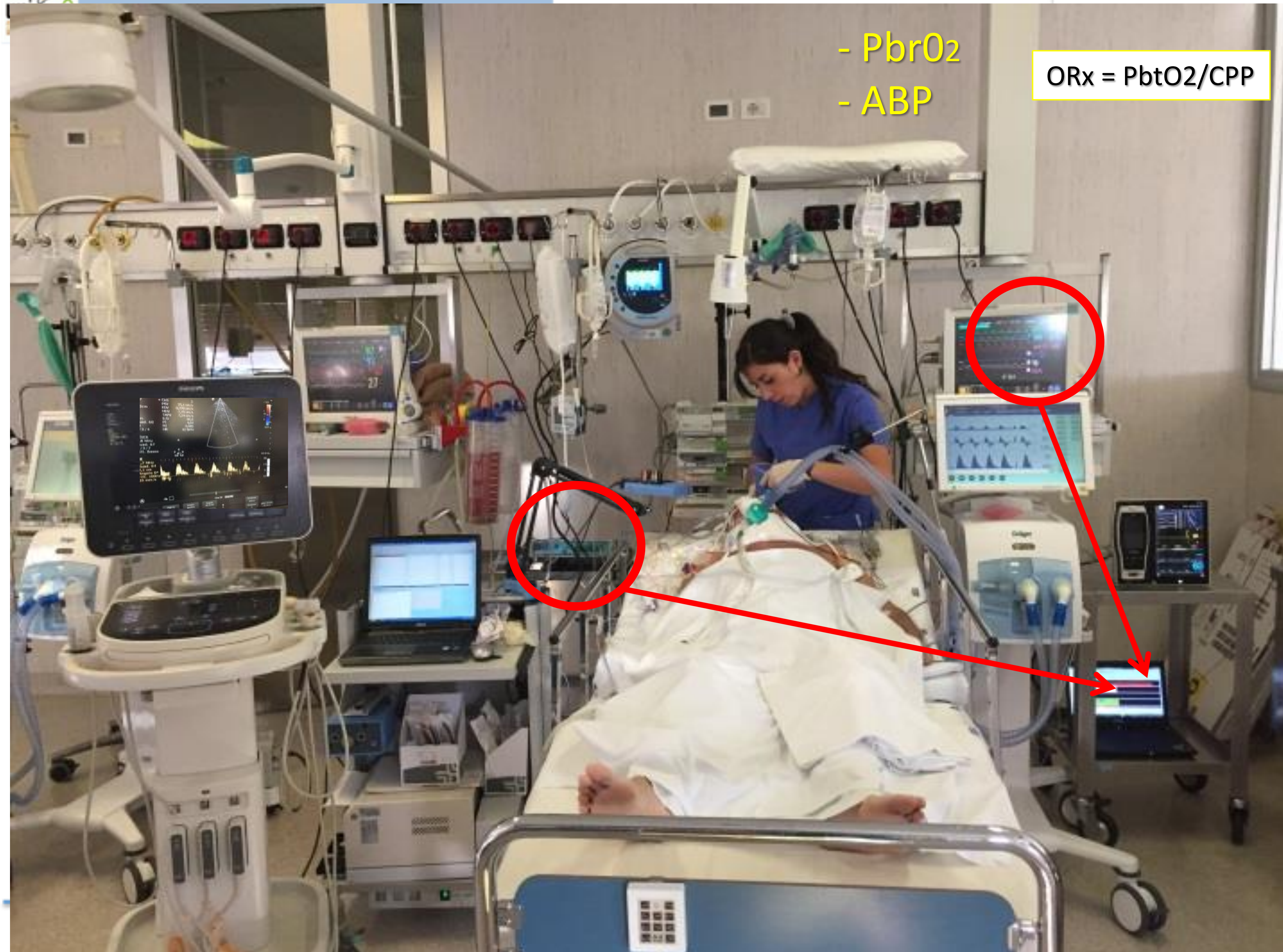




Neurocrit Care (2009) 10:373–386

Monitoring of Autoregulation Without Measurement of CBF?


- NIRS
- ABP
TOx = TOI/CPP


- PbrO2
- ABP
ORx = PbtO2/CPP

Monitoring Cerebral Autoregulation After Brain Injury: Multimodal Assessment of Cerebral Slow-Wave Oscillations Using Near-Infrared Spectroscopy

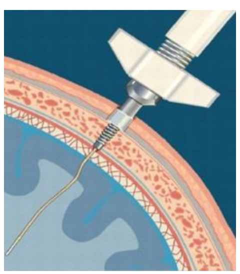
Anesth Analg. 2015 July ; 121(1): 198–205.

David Highton, MBChB, FRCA, FFICM*, **Arnab Ghosh, MBChB, BSc, MRCS***, **Ilias Tachtsidis, PhD**†, **Jasmina Panovska-Griffiths, PhD**†, **Clare E. Elwell, PhD**†, and **Martin Smith, MBBS, FRCA, FFICM***

Near-Infrared Spectroscopy can Monitor Dynamic Cerebral Autoregulation in Adults

Luzius A. Steiner

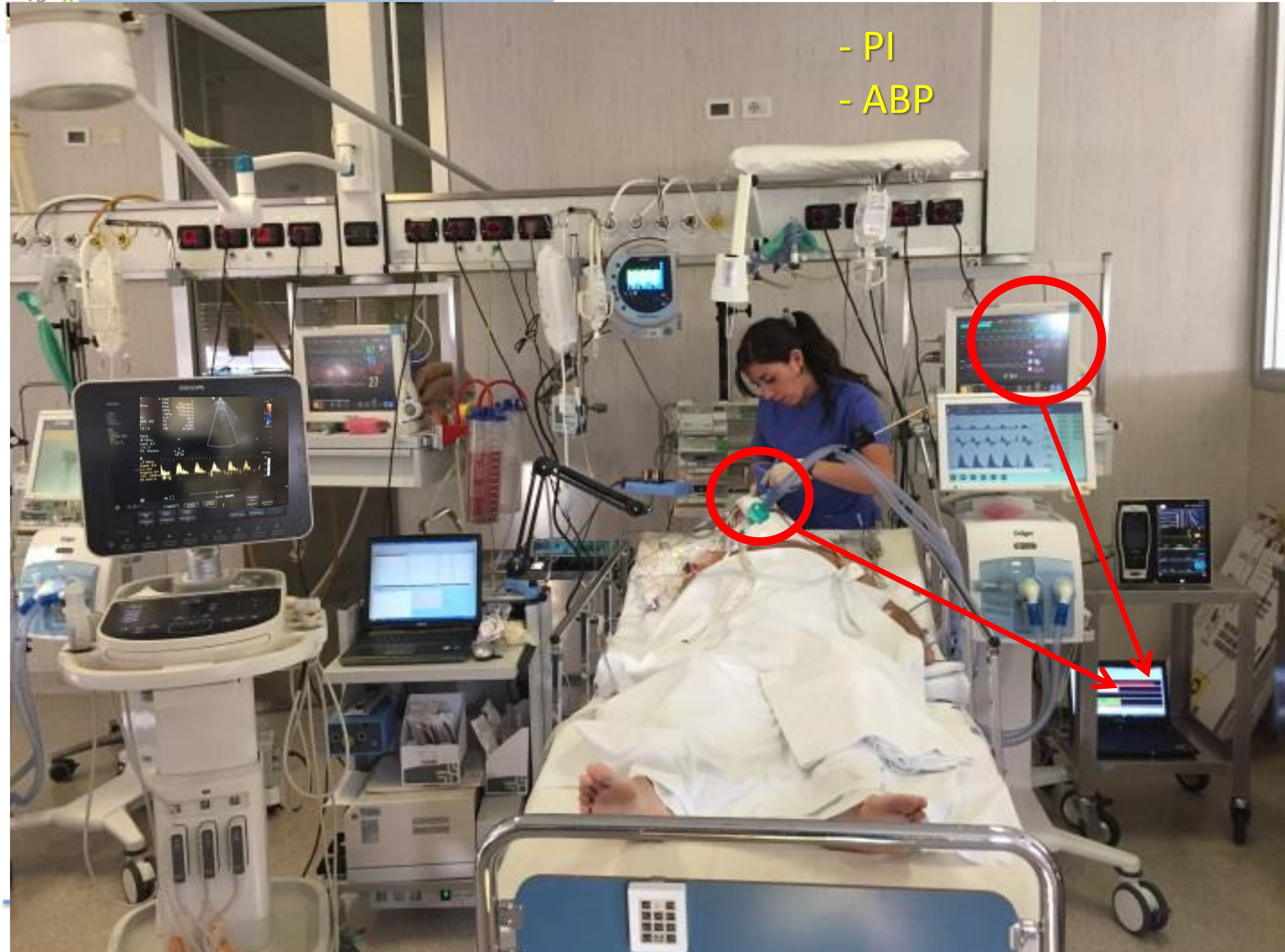
Neurocrit Care (2009) 10:122–128



Continuous assessment of cerebrovascular autoregulation after traumatic brain injury using brain tissue oxygen pressure reactivity.

Jaeger M., et al

Crit Care Med. 2006 Jun;34(6):1783-8


- PI
- ABP

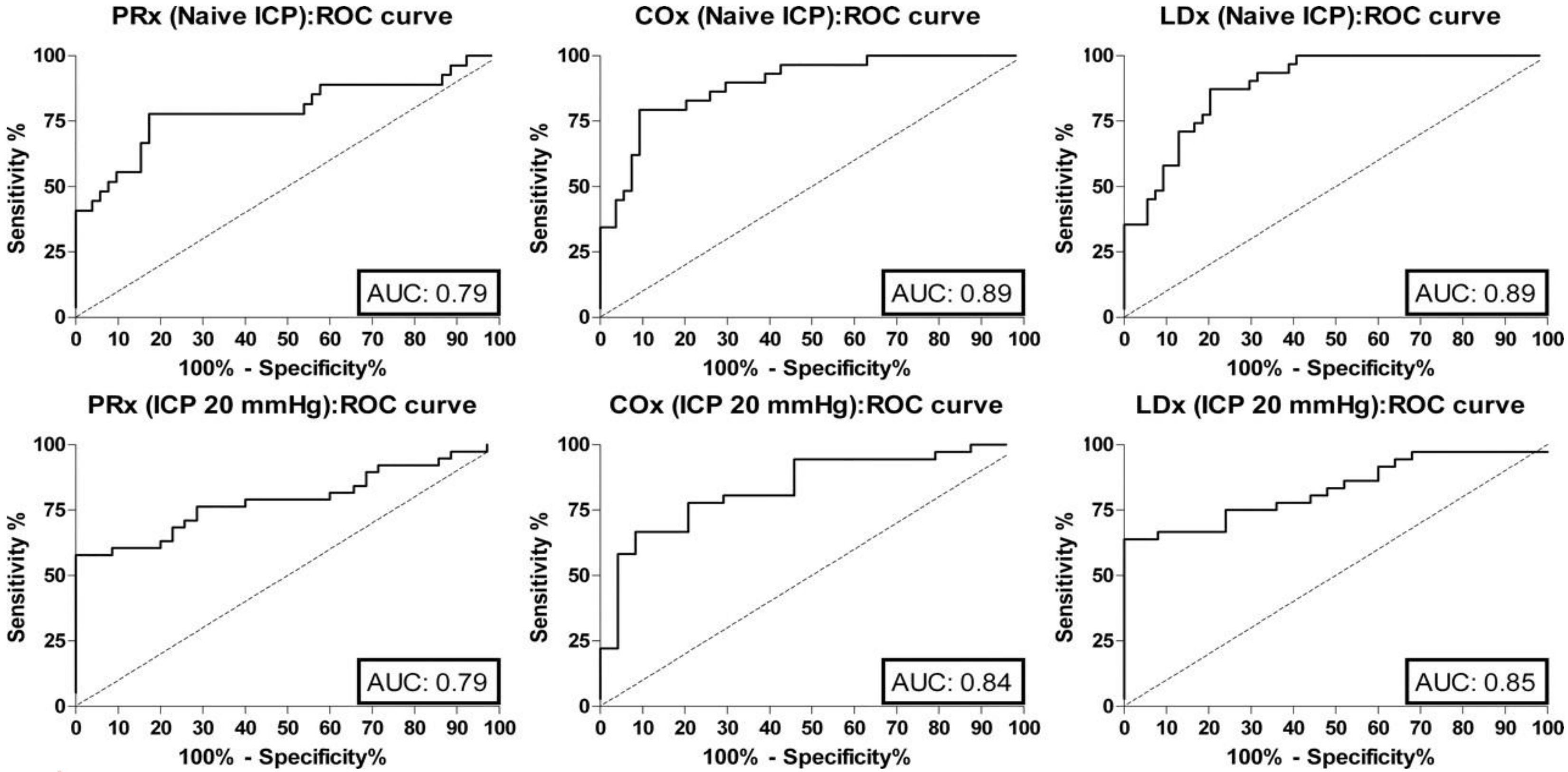
Continuous Measurement of Autoregulation by Spontaneous Fluctuations in Cerebral Perfusion Pressure

Ken M. Brady et al.

Stroke Volume 39(9):2531-2537 September 1, 2008

Piglets 5 to10 days old with intracranial pressure (ICP) at naïve or elevated (20 mm Hg) levels had gradual arterial hypotension induced by a balloon catheter in the inferior vena cava.

Three indices of autoregulation were simultaneously and continuously calculated.



Merriam-Webster

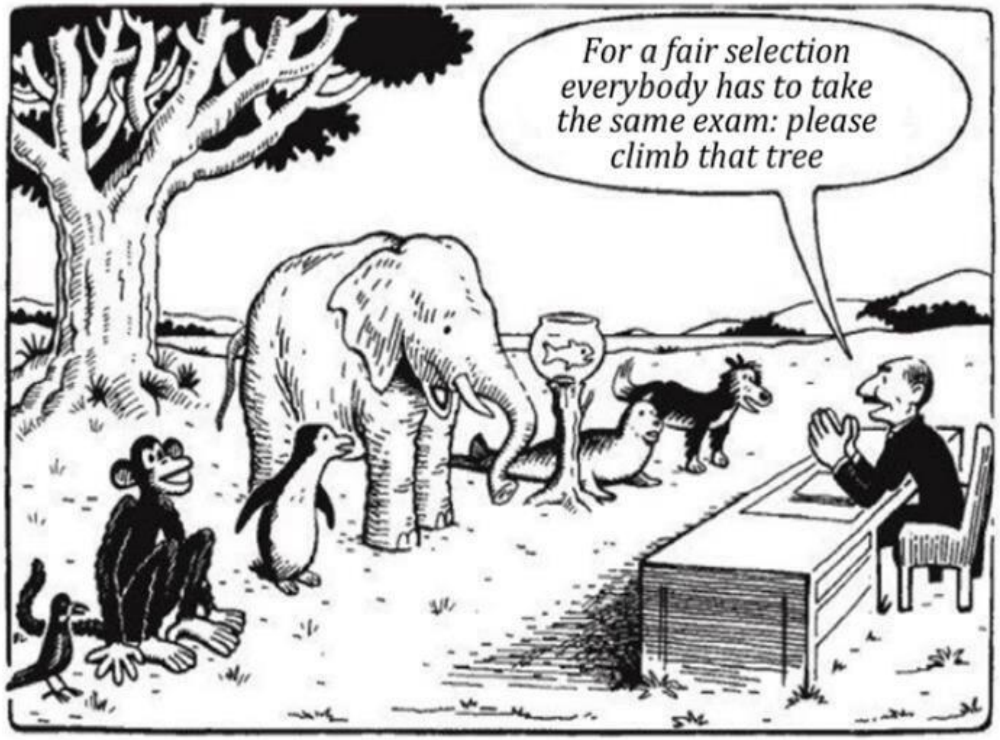
INDIVIDUALIZATION

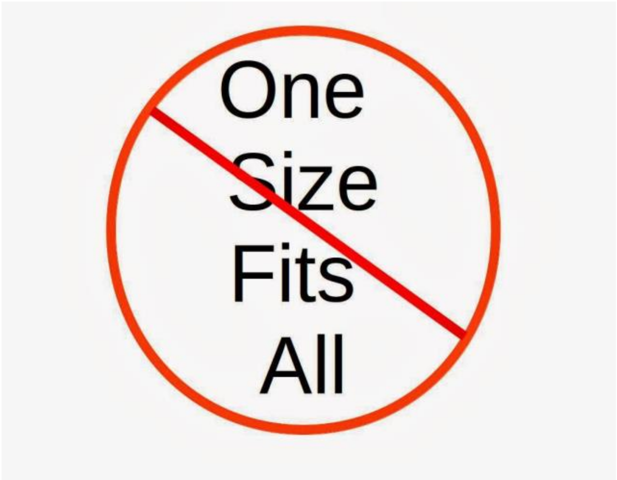
1 : to make individual in character

2 : to treat or notice individually : PARTICULARIZE

OPTIMIZATION

: an act, process, or methodology of making something (as a design, system, or decision) as fully perfect, functional, or effective as possible; *specifically* : the mathematical procedures (as finding the maximum of a function) involved in this





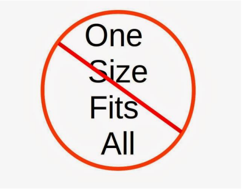
"Everybody is a genius. But if you judge a fish by its ability to climb a tree, it will live its whole life believing that it is stupid."

- Albert Einstein

Intracranial pressure monitoring: headstone or a new head start. The BEST TRIP trial in perspective

Randall M. Chesnut

Intensive Care Med (2013) 39:771–774



‘‘the strongest clinical implication of the results is that we shouldn’t abandon ICP monitoring but to refine its role in TBI management’’ ‘‘clinical methods for interpreting ICP in the setting of individual patient care’’.

“Cerebral autoregulation, cerebral perfusion pressure, cerebral blood flow, metabolic coupling etc., should allow us to recognize when ICP of 25 or 30mmHg might be cautiously accepted rather than lead to second-tier interventions”

“analytic approaches allowing protocolizing decision making for more meaningful subclassification of injury types, would highlight the true value of ICP monitoring as part of a multimodality approach to targeted therapy.”

“As ***intensivists***, we probably should be embarrassed that we are not at such a point in TBI management already.”

17. Cerebral Perfusion Pressure Thresholds

Level II B

- The recommended target cerebral perfusion pressure (CPP) value for survival and favorable outcomes is between 60 and 70 mm Hg. Whether 60 or 70 mm Hg is the minimum optimal CPP threshold is unclear and may depend upon the patient's autoregulatory status.

One Size Fits All

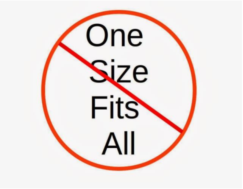
INDIVIDUALIZATION

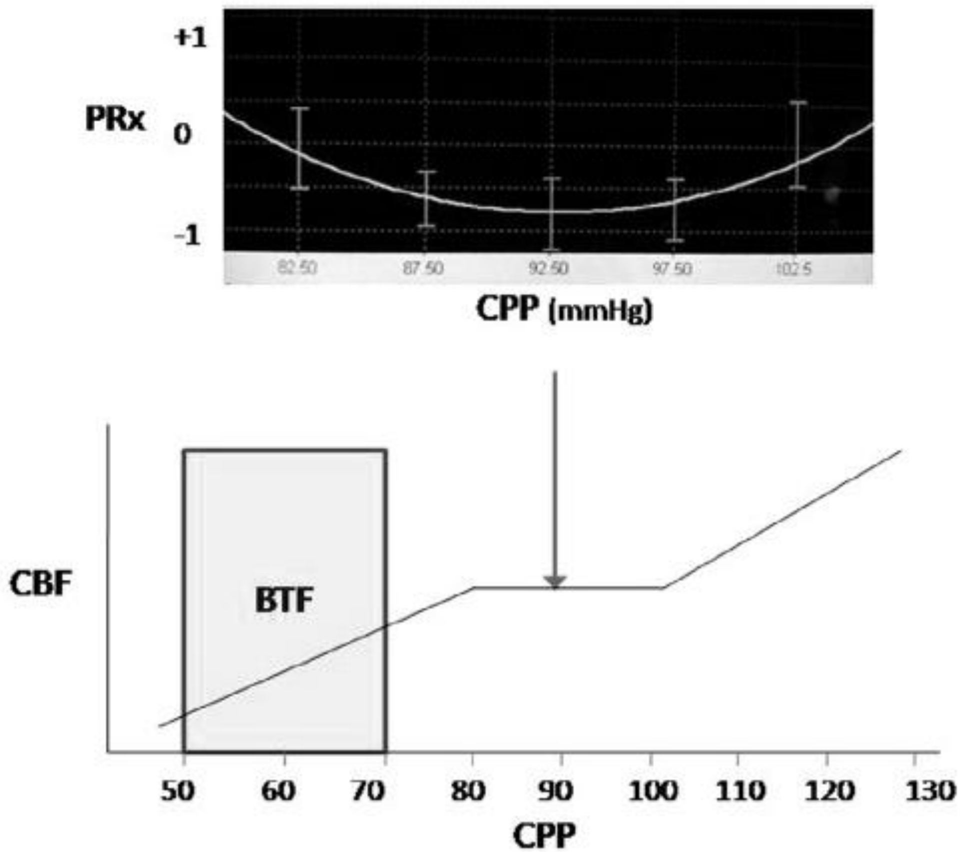
Reference, Study Topic	Study Design, N, and Outcomes	Data Class	Results Conclusion
Sorrentino et al., 2012*[4] ICP/CPP/PRx thresholds	Retrospective cohort N=459	Class 2	CPP 70 mm Hg for mortality and favorable outcome ICP thresholds 22 mm Hg for ICP for reduced mortality, 18 mm Hg for favorable outcomes in women and older patients. PRx 0.25 for mortality, 0.05 for favorable outcome.
Zweifel 2008*[13] Assessed pressure reactivity (PRx) and outcomes	Retrospective Cohort N=398 Single Center in Cambridge, U.K. Mortality and GOS at 6 months post-injury	Class 3	Optimal CPP for each patient was calculated based on the pressure reactivity index. Patients whose mean CPP varied above or below the optimal CPP were less likely to have a favorable outcome. 69% mortality in patients with PRx >0.25; <20% in patients with PRx <0.25 (p<0.0001).

Multimodal neuromonitoring for traumatic brain injury: A shift towards individualized therapy

Journal of Clinical Neuroscience 26 (2016) 8–13

Serge Makarenko [a], Donald E. Griesdale [b,c,d], Peter Gooderham [a], Mypinder S. Sekhon [d]



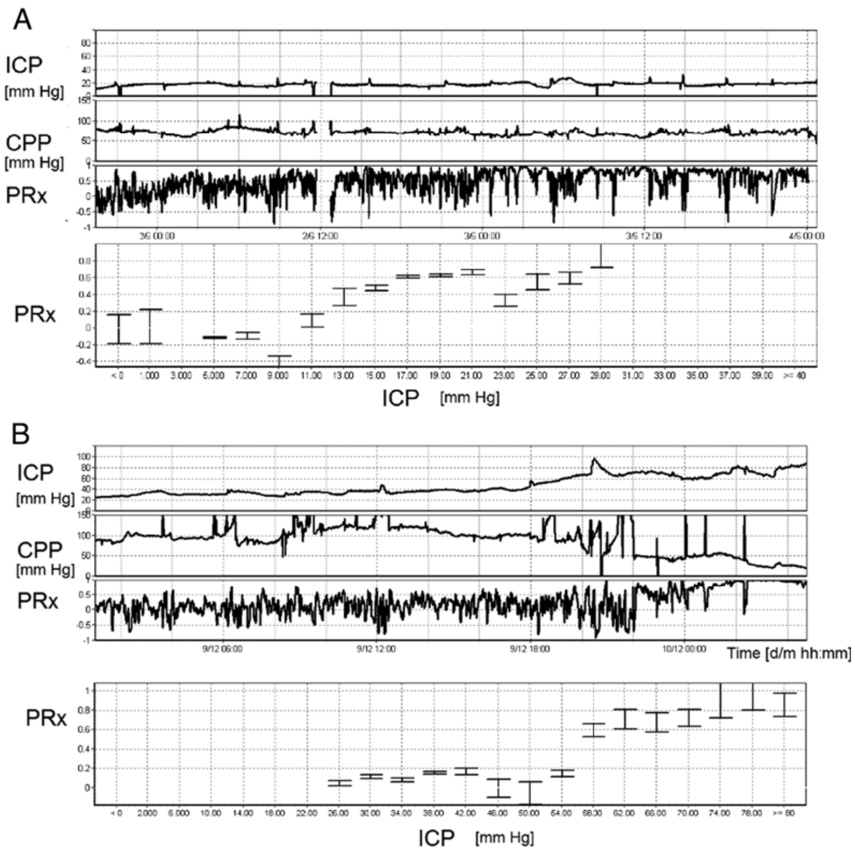


Patient-specific thresholds of intracranial pressure in severe traumatic brain injury

J Neurosurg 120:893–900, 2014

Clinical article

Christos Lazaridis, M.D.,[1,2] Stacia M. DeSantis, Ph.D.,[3] Peter Smielewski, Ph.D.,[1] David K. Menon, M.D., Ph.D., F.Med.Sci.,[4] Peter Hutchinson, F.R.C.S.(SN), Ph.D.,[1] John D. Pickard, F.R.C.S., M.Chir., F.Med.Sci.,[1] and Marek Czosnyka, Ph.D.[1]



Retrospective analysis of prospectively collected data from 327 patients TBI pts.

ICP doses derived by the recommended BTF threshold of 20 mm Hg.

VS

ICP dose based on individually assessed ICP thresholds Based on PRx-CVA

6-month outcome

Individualized doses of intracranial hypertension were stronger predictors of death than doses derived from the universal threshold of 20mm Hg.

PRx can individualize the ICP threshold

Can monitoring CVA be a clinically useful therapeutic target in TBI?

We must adjust the contributors to the complex cerebral autoregulation process.

Several potential methods for adjusting cerebral autoregulation include:

Optimization of CPP,

Optimization of ventilation,

Optimization of head-of-bed positioning,

Optimization of pharmacologic manipulation.

Conitinuous monitoring of cerebrovascular pressure reactivity allows determination of optimal cerebral perfusion pressure in patients with traumatic brain injury

Steiner L et al., *Crit Care Med 2002 vol 30, No 4*

We must adjust the contributors to the complex cerebral autoregulation process.

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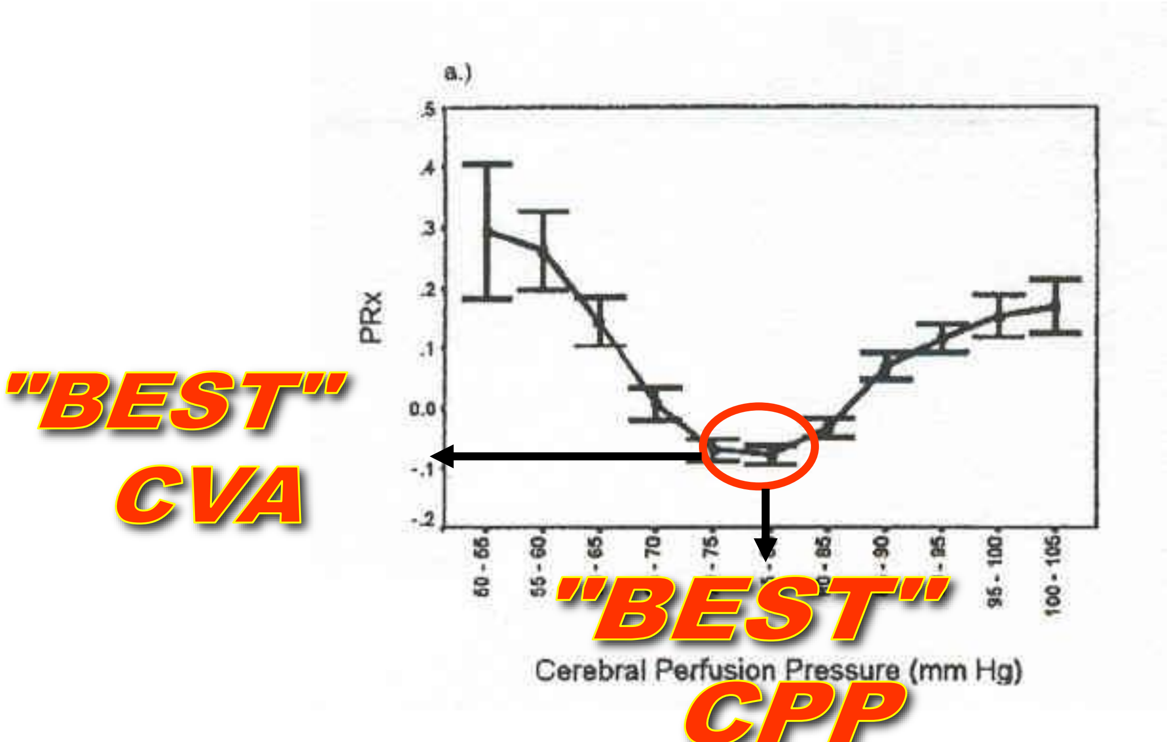
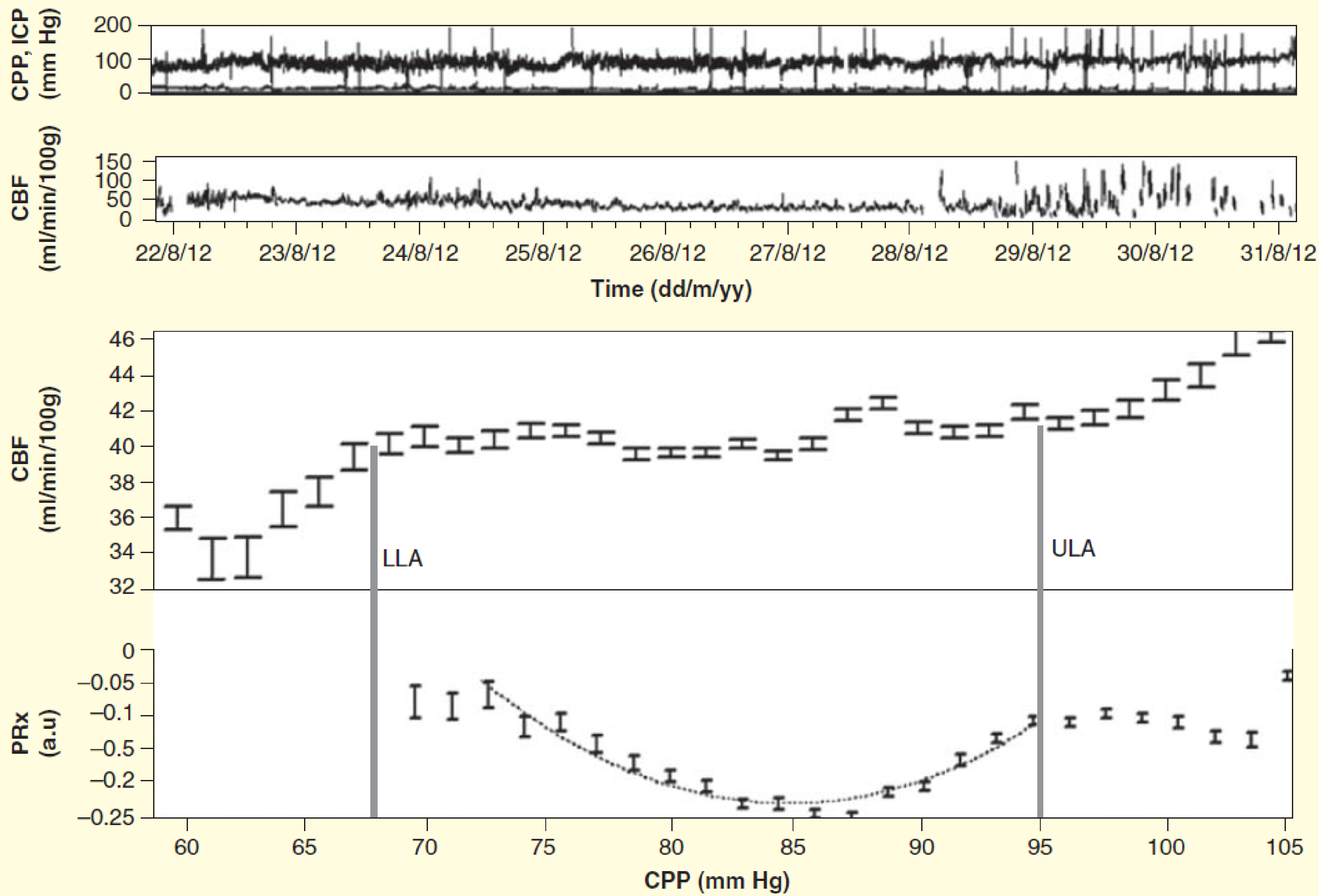
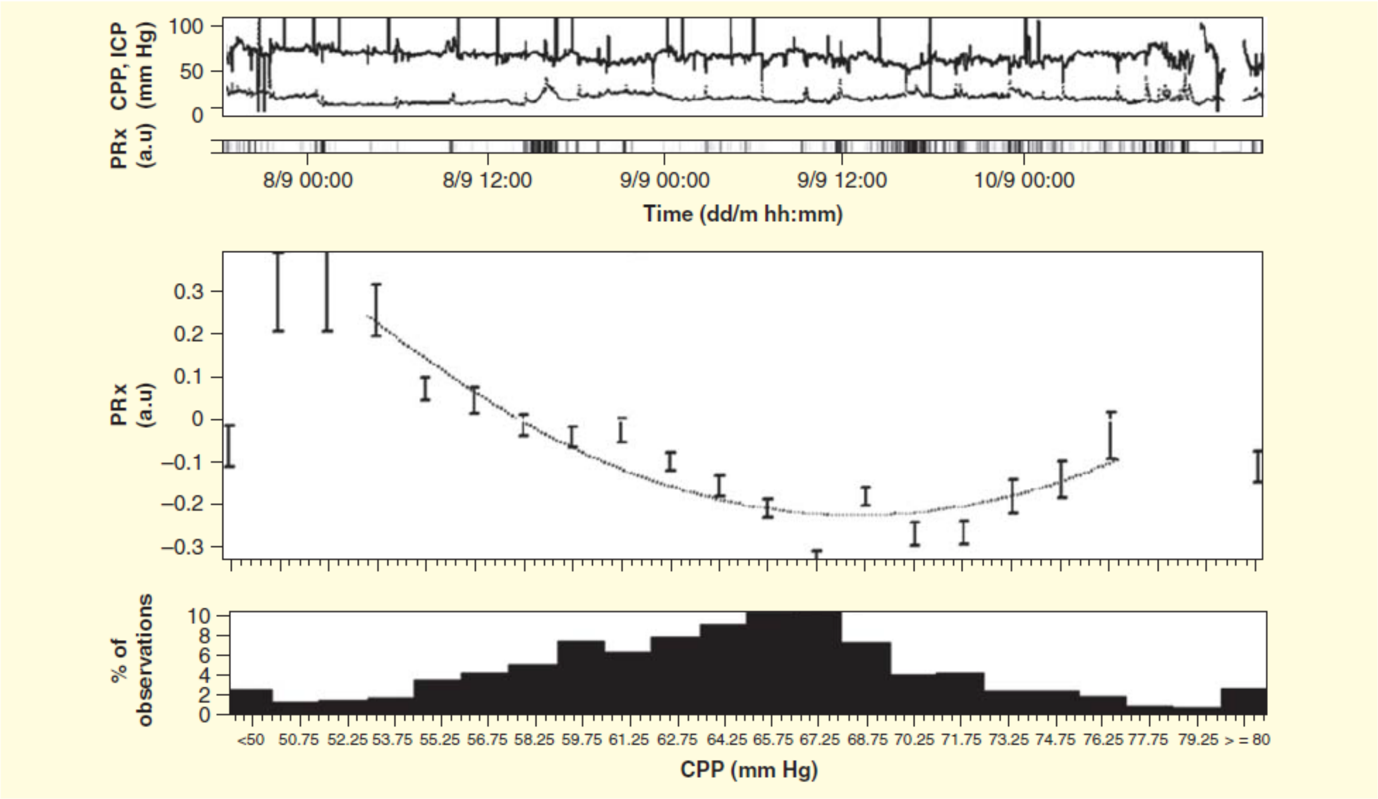
Optimization of CPP:



FRANK A. RASULO
Institute of Anesthesiology & Intensive Care
Neuro-critical Care Unit, Spedali Civili University Hospital of Brescia, ITALY



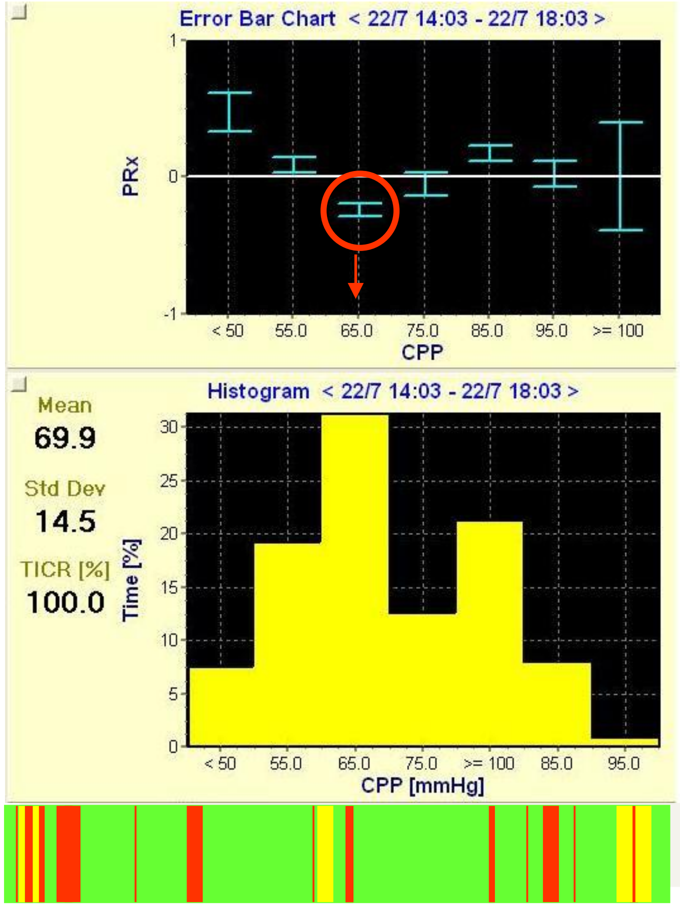
Donnelly J Expert Rev. Neurother. 15(2), 169–185 (2015)



Donnelly J Expert Rev. Neurother. 15(2), 169–185 (2015)

Continuous Assessment of Autoregulation (CPPopt)

CPPopt = CPP where PRx reaches its minimum value when plotted against CPP.



CPP opt?

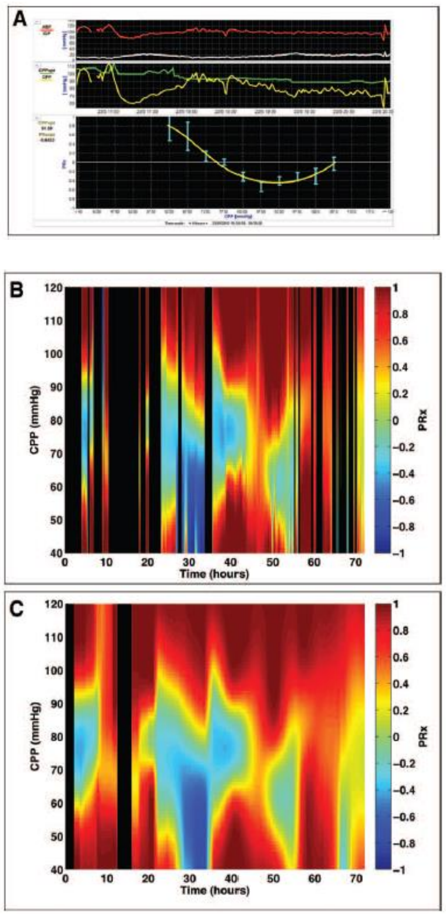
65 mmHg!

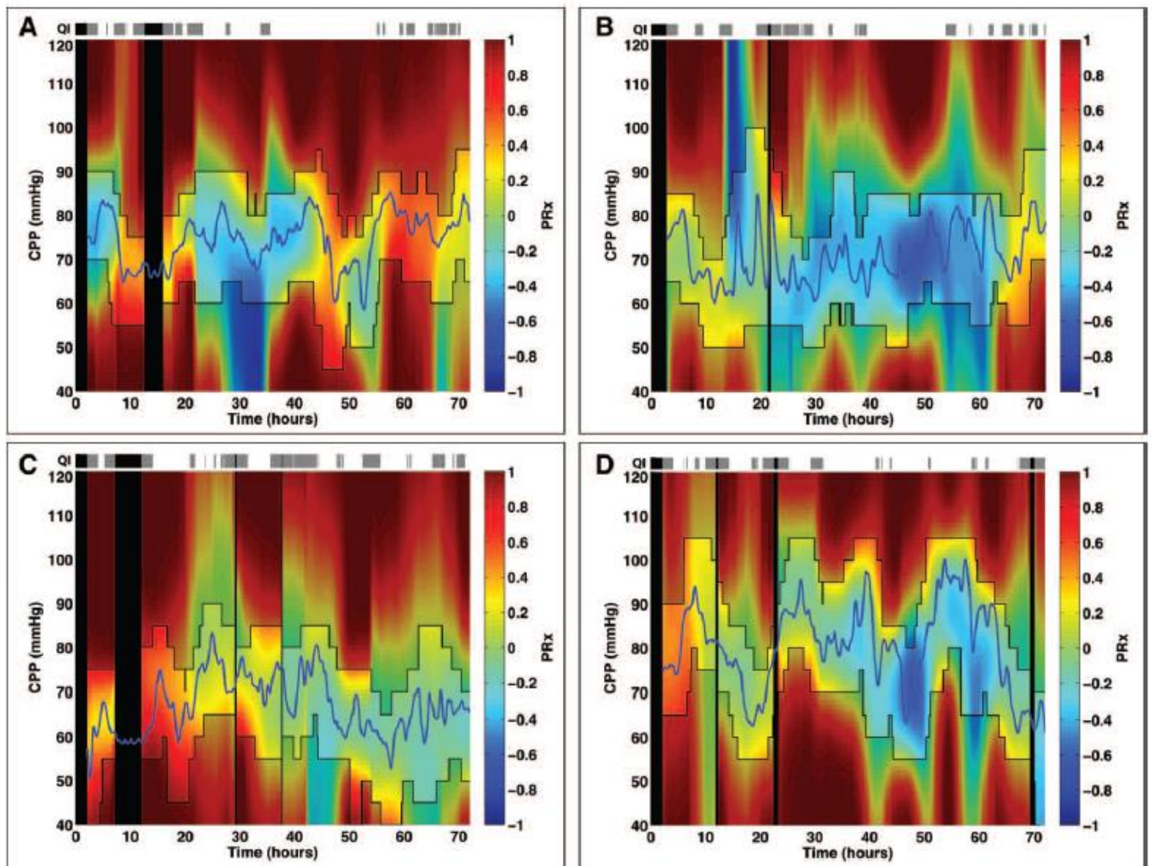
Enhanced Visualization of Optimal Cerebral Perfusion Pressure Over Time to Support Clinical Decision Making*

Marcel J. H. Aries

Critical Care Medicine October 2016 • Volume 44 • Number 10

We aim to improve the CPPopt methodology by introducing a new visualization method that may provide insight into the complete characteristics of the CPP-PRx relationship and its temporal evolution.





Can monitoring CVA be a clinically useful therapeutic target in TBI?

Several potential methods for adjusting cerebral autoregulation include:

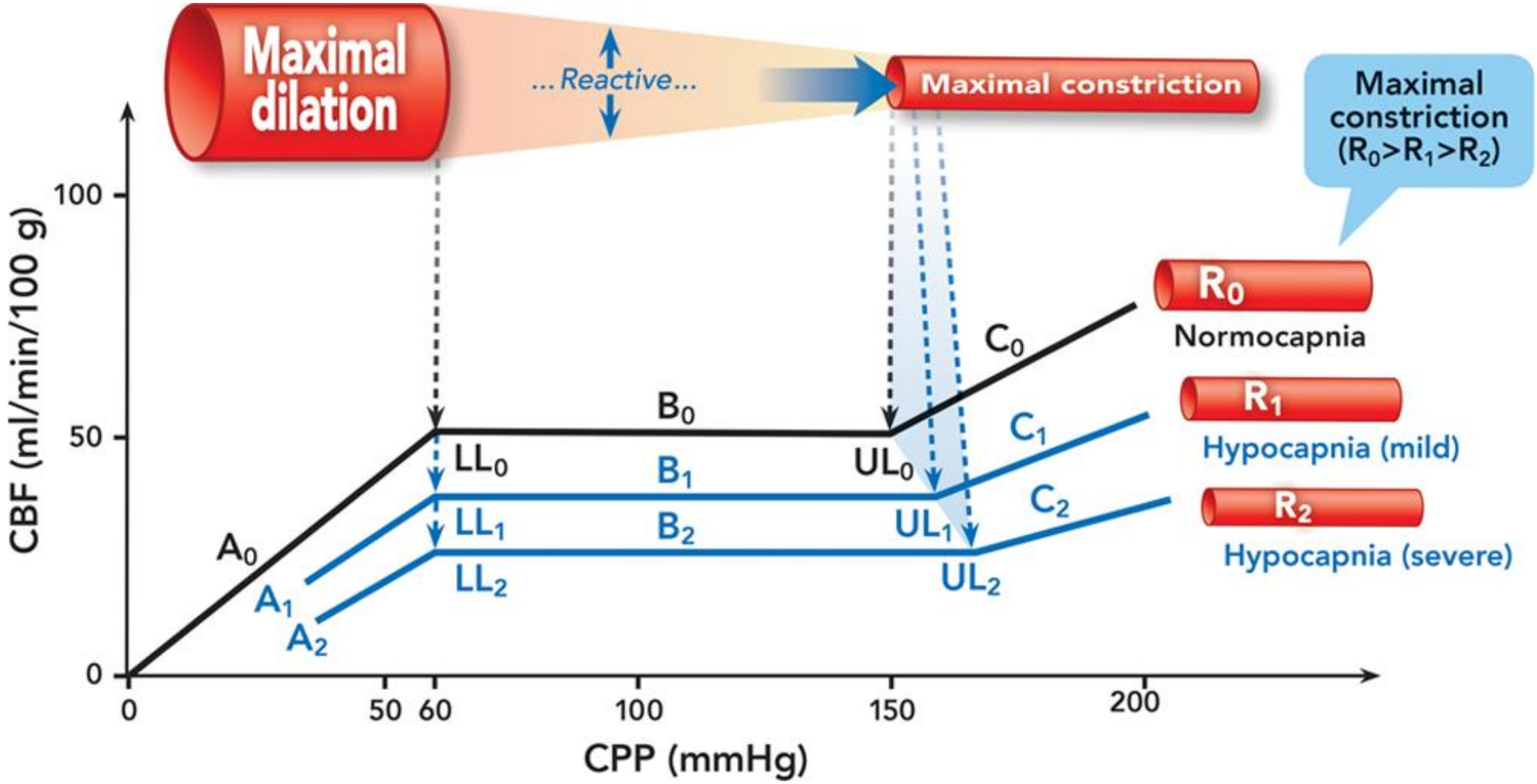
Optimization of CPP

Optimization of ventilation

Cerebral autoregulation dynamics in humans.
Aaslid R et al. Stroke 1989;20(1):45-52

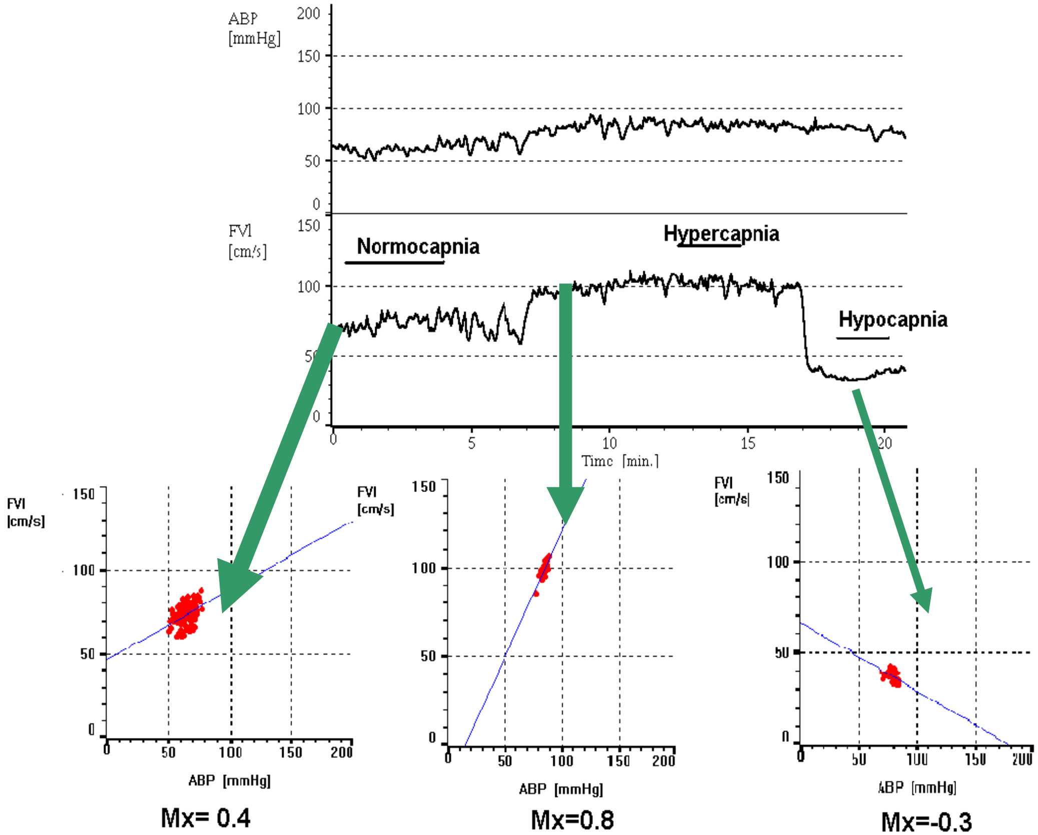
Adverse effects of prolonged hyperventilation in patients with severe head injury: a randomized clinical trial. J
Muizelaar JP et al. Neurosurg 1991;75:731-9

Autoregulation and arterial CO_2



Lingzhong Meng, Adrian W. Gelb. Anesthesiology 01 2015, Vol.122, 196-205

Autoregulation and arterial CO_2



Mx responds to $PaCO_2$ during routine CO_2-reactivity testing.

Can monitoring CVA be a clinically useful therapeutic target in TBI?

Several potential methods for adjusting cerebral autoregulation include:

Optimization of CPP

Optimization of ventilation

Optimization of head-of-bed positioning

Intracranial pressure pulse amplitude during changes in head elevation: a new parameter for determining optimum cerebral perfusion pressure?
Mahfoud F, et al. Acta Neurochir (Wien) 2010; 152(3):443-50

Effect of head elevation on intracranial pressure, cerebral perfusion pressure, and cerebral blood flow in head-injured patients.
Feldman Z et al. J Neurosurg 1992;76:207-11

Can monitoring CVA be a clinically useful therapeutic target in TBI?

Optimization of CPP

Optimization of ventilation

Optimization of head-of-bed positioning

Optimization of pharmacologic manipulation

Simvastatin.	Kirkpatrick PJ	Lancet Neurol 2014;13(7):666-75
EPO.	Rasmussen P	FASEB J 2012;26(3):1343-8
Recombinant human erythropoietin.	Ehrenreich H	Stroke 2009;40:e647-56
B-Blockers .	Strandgaard S	Eur J Clin Invest 1996;26(8)
Valsartan.	Takada J	Hypertens Res 2006;29(8):621-6
Angiotensin II AT2 receptor stimulation.	Na¨veri L,	Regul Pept 1994;52:21-9
Angiotensin converting enzyme.	Waldemar G	J Hypertens 1989;7: 229-35

Links Between CVA and TBI Outcome

Impact of intracranial pressure and cerebral perfusion pressure on severe disability and mortality after head injury.
Balestreri M et al.Neurocrit Care. 2006.

Association between dynamic cerebral autoregulation and mortality in severe head injury.
Panerai RB et al. Br J Neurosurg 2004

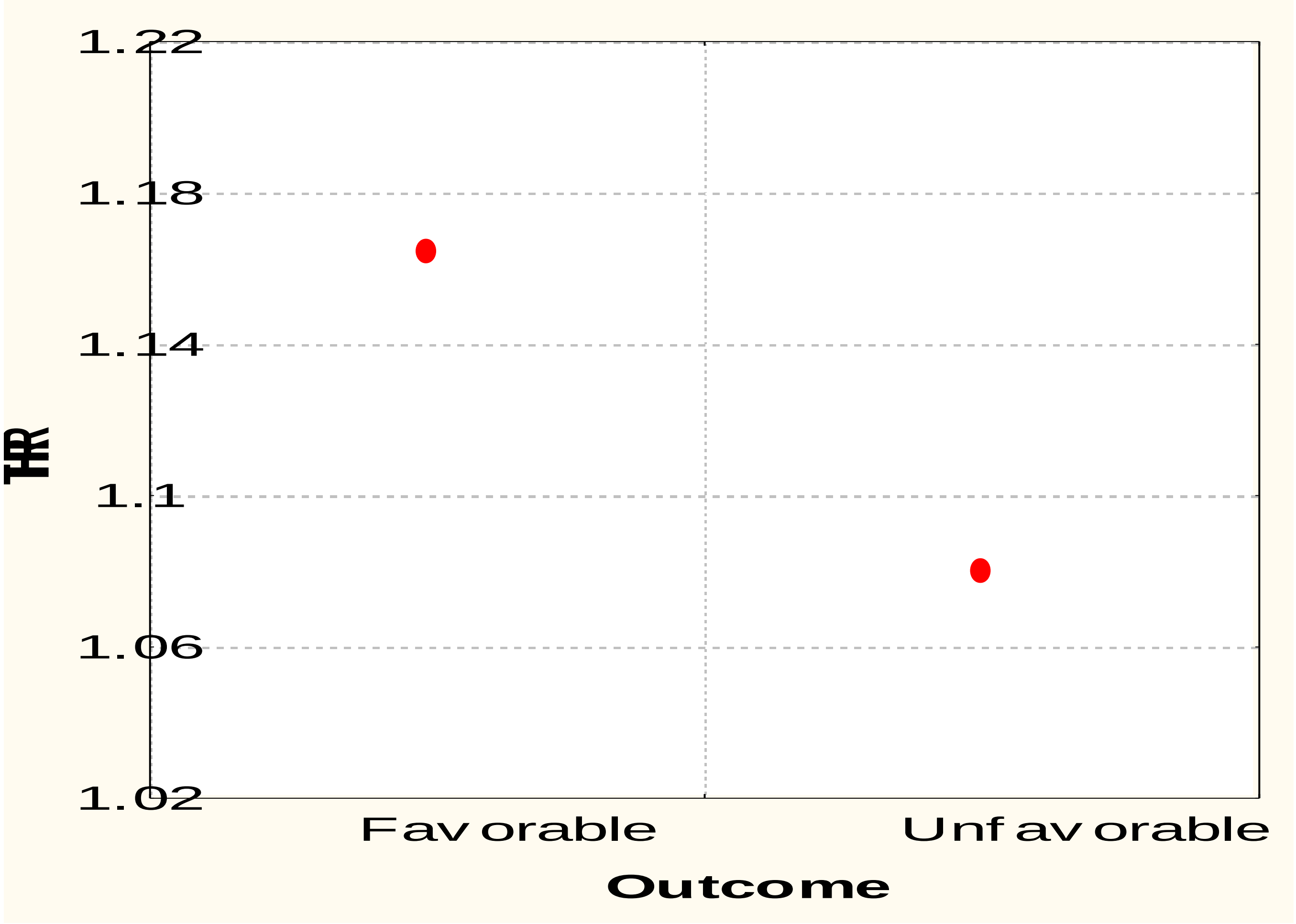
In a multivariate analysis, age, mean ICP, initial CT, and the CVA are all independent factors OF outcome

Both intermittently monitored TCD-based indices, the Mx and ARI, and continuous PRx have proven to be strongly and independently correlated with outcome

Plotting mortality rate versus averaged PRx allows detection of critical value for PRx. When the PRx increases above 0.3, mortality rate abruptly increases from 20% to 70%

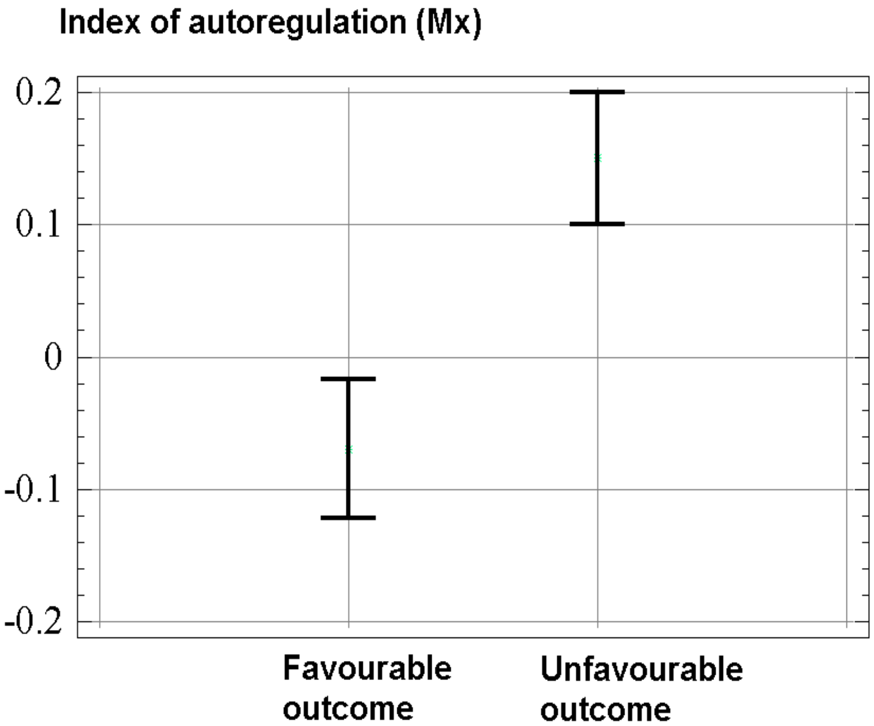
THRT e Outcome

TCG



AUTOREGULATION IS SIGNIFICANTLY WORSE
IN PATIENTS WITH UNFAVOURABLE OUTCOME

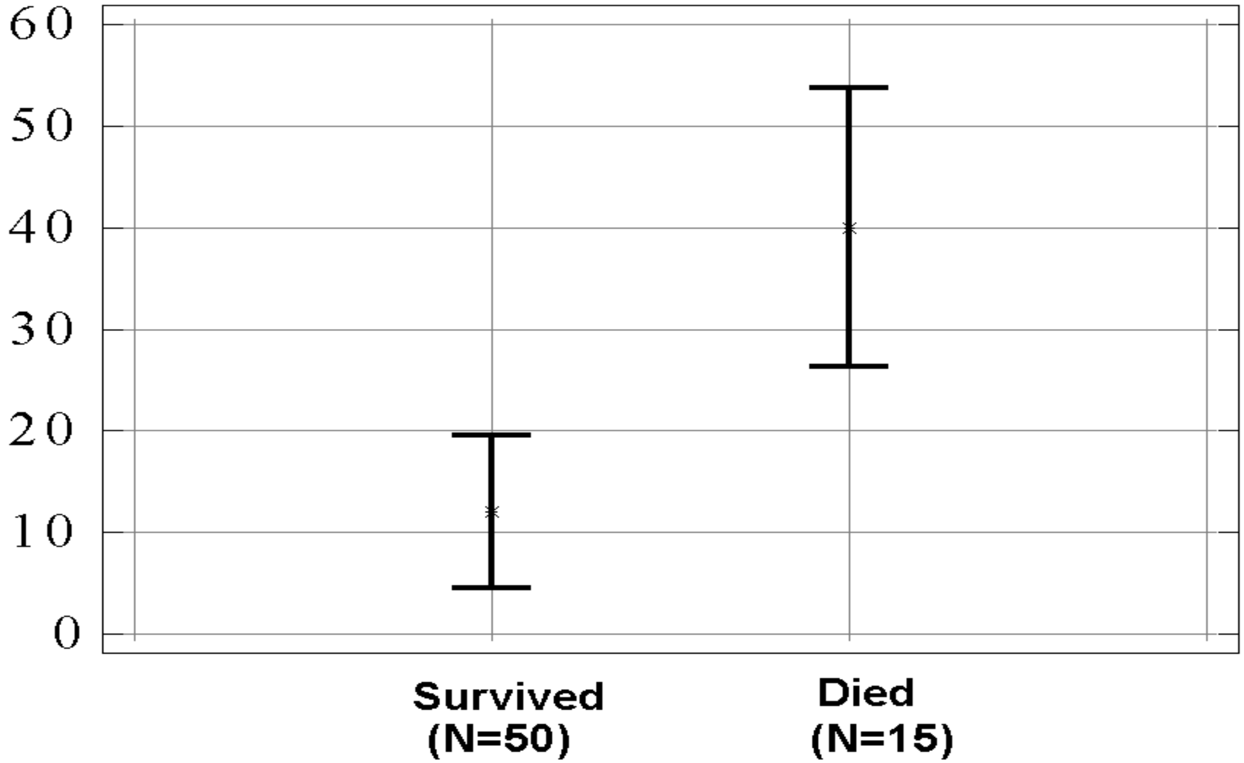
MX



Czosnyka M, Smielewski P, Piechnik S, Steiner LA, Pickard JD: Cerebral autoregulation following head injury. J Neurosurg 2001, 95 (5), 756-763

Autoregulation: Asymmetry and Mortality

Percent of patients having
significant left-right asymmetry in autoregulation



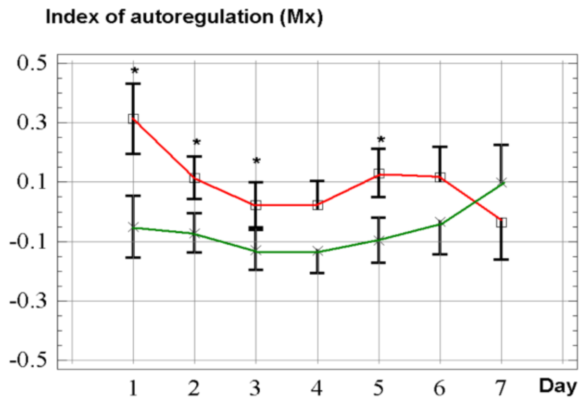
Cerebrovascular Autoregulation (CVA) and Outcome

Author	Paper	Pathology	N°pts.	Bad outcome
Overgaard J. et al.	J.Neurosurg. 1974	Head Trauma	43	68%
Czosnyka M. et al.	Stroke 1996	Head Trauma	82	70%
Lam JM. Et al.	J.Neurosurg. 1997	Head Trauma	31	65%
Ratsep et al	J.Neurosurg. 2001	SAH	76	68%
Lang E.W.	Crit. care med.2001	SAH	12	82%
Steiner L. et al.	JNNP 2003	Head Trauma	82	67%

Dose effect: patients with more severe impairment of cerbral autoregulation do have worse outcome

Time effect: the state of autoregulation change in time

Autoulation is worse first two days following trauma but only in patients who died (red line)



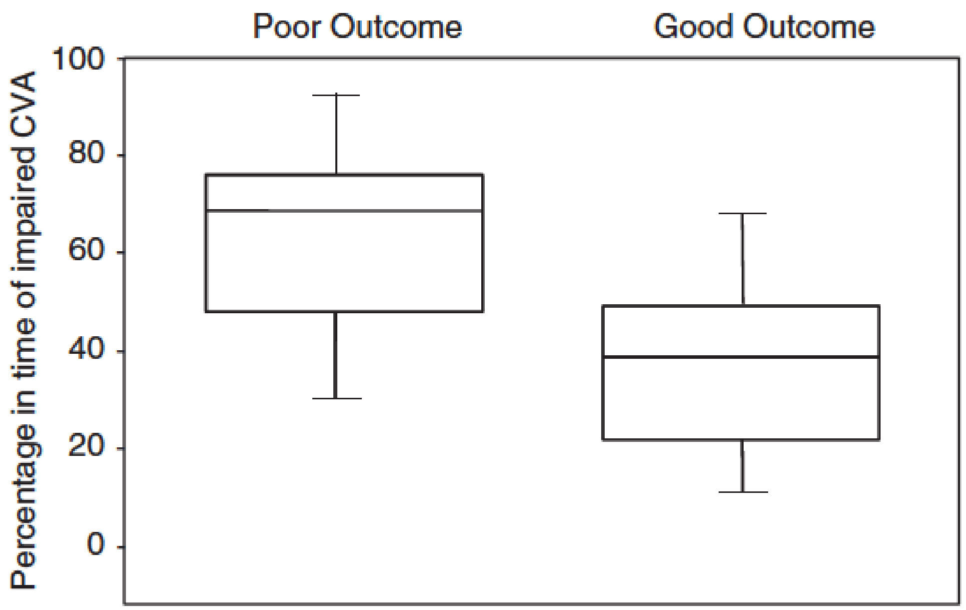
J Neurosurg 2001, 95 (5), 756-763

CLINICAL INVESTIGATION

J Neurosurg Anesthesiol • Volume 24, Number 1, January 2012

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

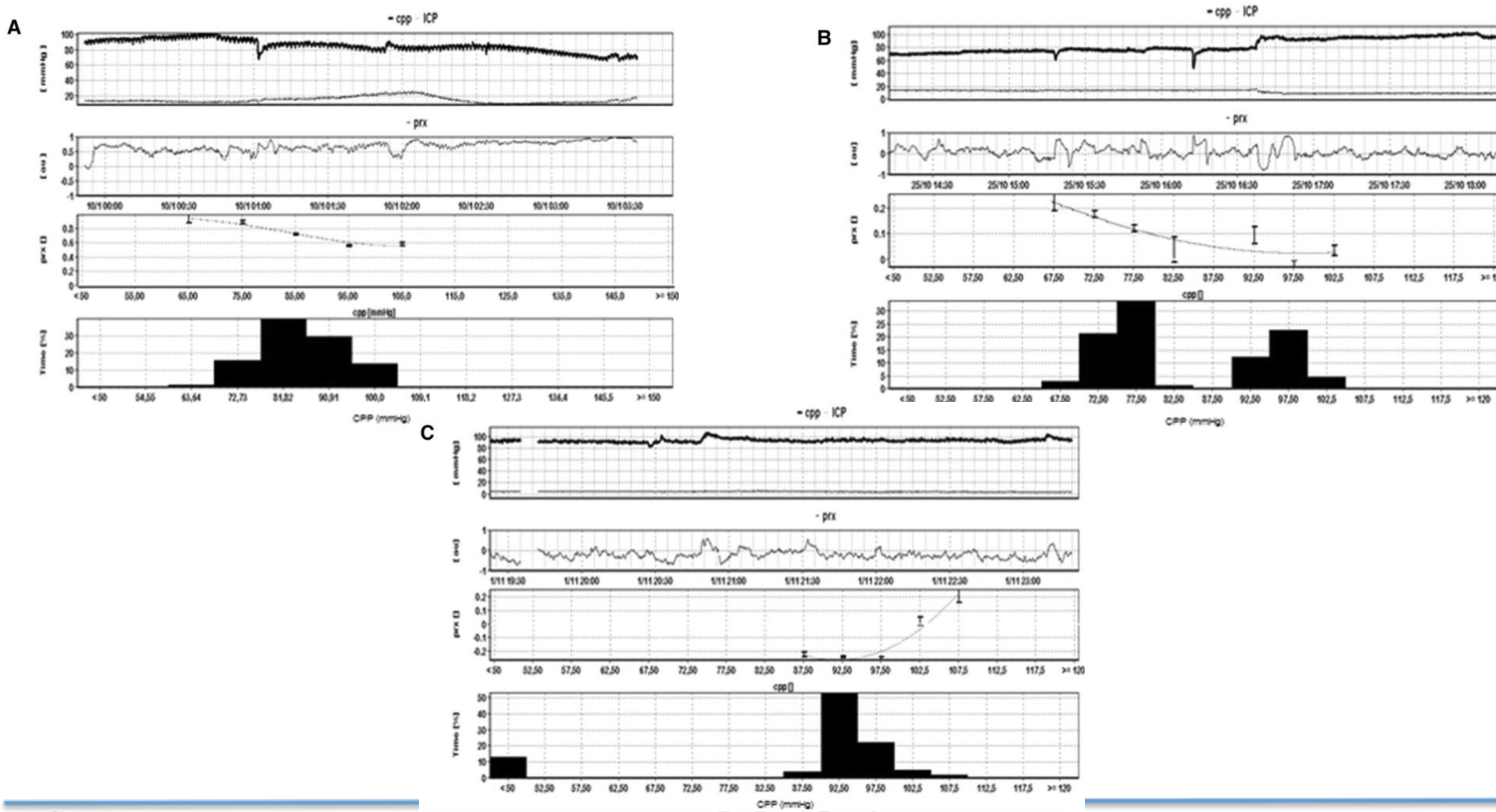
Frank Anthony Rasulo, MD, Alan Girardini, MD,* Andrea Lavinio, MD,*† Elena De Peri, MD,* Roberto Stefini, MD,‡ Marco Cenzato, MD,‡ Ilaria Nodari, MD,*† and Nicola Latronico, MD**

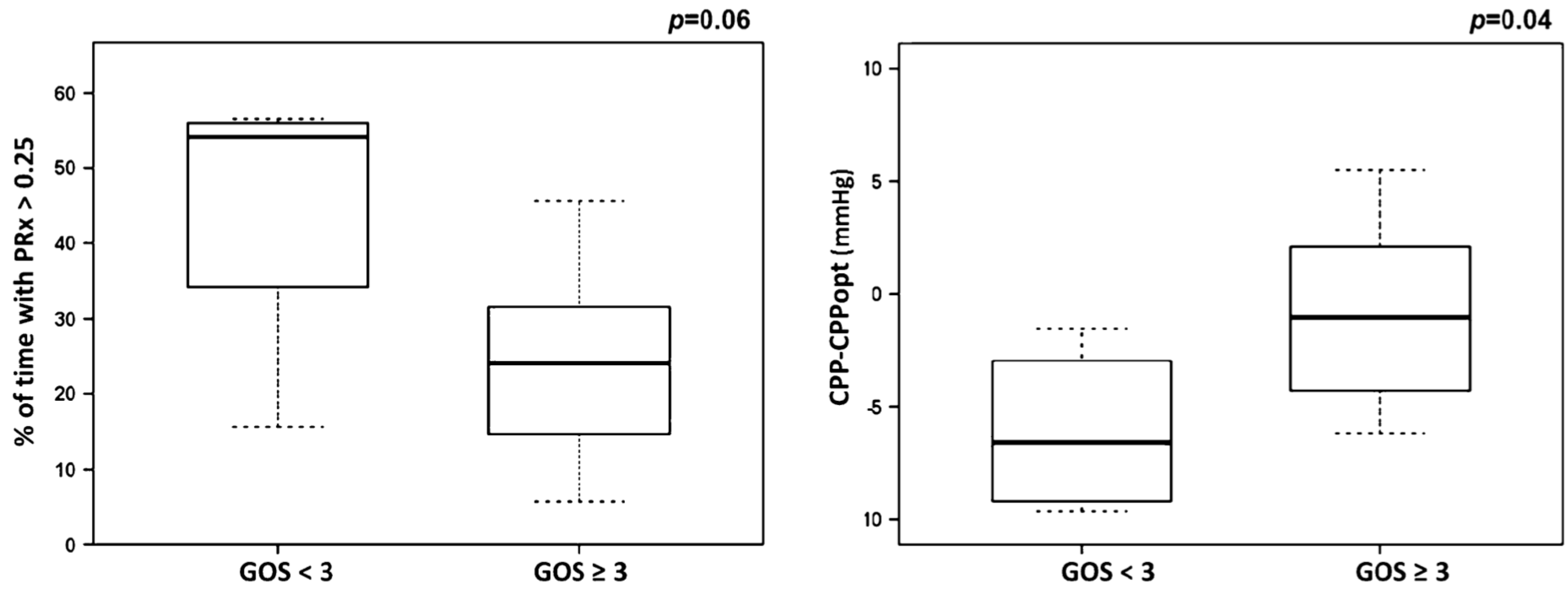


Optimal Cerebral Perfusion Pressure Management at Bedside: A Single-Center Pilot Study

neurocritical care society
Neurocrit Care (2015) 23:92–102
DOI 10.1007/s12028-014-0103-8

Celeste Dias et al.





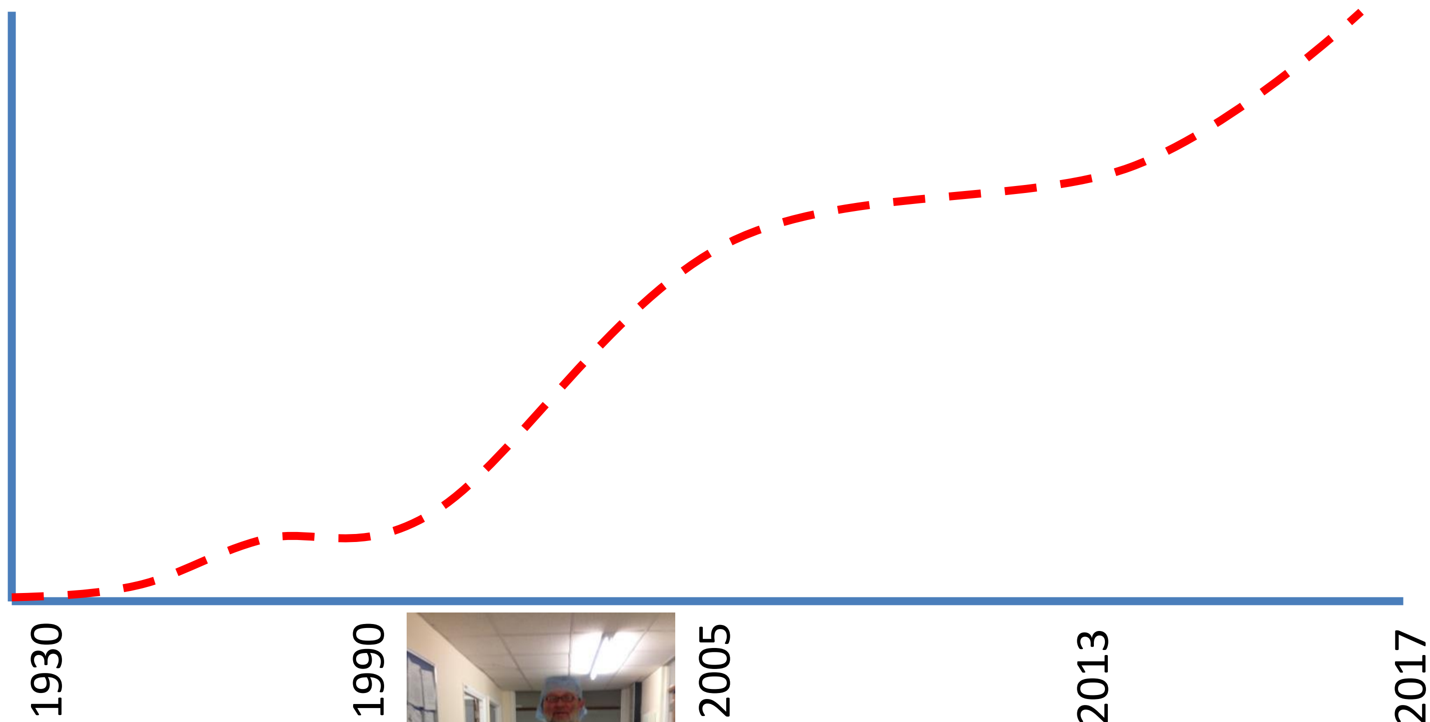
Patients with larger discrepancy (>10 mm Hg) between real CPP and CPPopt more likely have adverse outcome.

This finding stresses the importance of guiding TBI treatment using CVA indices in clinical practice.


35
30
25
CAUTION
WET FLOOR


TBI
CVA
OUTCOME

CVA monitoring in TBI passes from a level III to a level IIB recommendation in the new BTF guidelines.



1

ICP monitoring as clinically indicated. Primary targets:
ICP ≤ 20 mmHg and **CPP 60 to 70 mmHg**
If advanced monitoring is available, fine-tune treatment based on multimodality targets:
PRx < 0.2 LPR < 25; **PbtO2 ≥ 15 mmHg**; **SjO2 > 50%**

STAGE 1

2

- **Sedation:** Propofol 2-5 mg/kg/h, Fentanyl 1-4 μg/kg/h; consider Atracurium 0.5 mg/kg/h
- **Ventilation:** $SpO_2 \geq 97\%$; $PaCO_2$ 4.5-5.0 kPa (33-38 mmHg)
- **Circulation:** CVP 6 to 12 mmHg; vasopressors to maintain CPP > 60 mmHg
- **Temperature:** < 37°C (regular Paracetamol +/- ice-cold IV fluids)
- **Nursing:** 15° head up; avoid venous obstruction;
- **Nutrition:** early enteral; Insulin sliding scale (titrate to blood sugar ≤ 10 mmol/l)
- **DVT prophylaxis:** graduated stockings or pneumatic intermittent compression
- **Antiepileptics:** EEG to esclude seizures +/- institute or escalate antiepileptic therapy

ICP > 20 mmHg? Escalate to **STAGE 2,** consider re-scan +/- **SOL evacuation**

3

- **CSF drainage:** open EVD (or consider ventricular catheter insertion)
- **Osmotic therapy:** 5% NaCl 2 ml/kg or 20% Mannitol 2 ml/kg (up to Posm ≃ 320)
- **Mild hypothermia:** Temp ≃ 35°C (daily lipids, ECG and CK if still on propofol)

ICP > 20 mmHg? Escalate to **STAGE 3,** consider re-scan +/- **SOL evacuation**

4

- **Moderate hypothermia:** Temp ≃ 33°C; change sedation to midazolam
- **Ventilation:** PaCO2 ≃ 4.0 kPa (30mmHg) IF SjO2 >> 50% and PbtO2 >> 15 mmHg

ICP > 20 mmHg? Escalate to **STAGE 4,** consider re-scan +/- **decompression**

- **Burst suppression:** Thiopentone 5 mg/kg + 3-8 mg/Kg/h (titrate to EEG S.R. ≃ 50%)
- **Surgical decompression:** bifrontal or large fronto-temporo-parietal craniectomy

MINERVA ANESTESIOLOGICA

How to manage arterial blood pressure after brain injury?

Minerva Anestesiol 2016 Dec 16

Laurent CARTERON, Fabio Silvio TACCONE, Mauro ODDO

Early emergent phase

Pathology	Targets	Timing	Monitoring	Treatment
TBI	SBP≥100 mmHg (age 50-69 yrs) SBP≥110 mmHg (age 15-49 or >70 yrs) MAP>70 mmHg	immediately, until ICP monitoring	invasive MAP ICP monitoring	norepinephrine

ICU phase

Pathology	Targets	Timing	Monitoring	Treatment
TBI	***Individualized CPP*** CPP 60-70 mmHg Control ICP limit vasopressors optimize preload rule out adrenal dysfunction	***According to:*** Intra-cerebral lesions Brain CT scan ICP control	ICP $PbtO_2$ TCD PRx, ORx, Mx ?	Norepinephrine Phenylephrine

Monitoring of Cerebrovascular Autoregulation: Facts, Myths, and Missing Links

Neurocrit Care (2009) 10:373–386

Marek Czosnyka · Ken Brady · Matthias Reinhard ·
Piotr Smielewski · Luzius A. Steiner

Facts:

Poor autoregulation and loss of pressure-reactivity, as measured by PRx and Mx, are independent predictors of fatal outcome following head injury;

Continuous monitoring with the PRx can be used to direct CPP-oriented therapy by determining the optimal CPP for pressure-reactivity.

Monitoring of continuous cerebrovascular autoregulation is now possible and systems have become, and are becoming, more user-friendly;

Missing Links:

Despite the fact that monitoring CVA can be used in a variety of clinical scenarios and may be helpful in delineating optimal therapeutic strategies, the integration of CVA based protocols, to obtain a more individualized therapeutic strategy, is still lagging, do to lack of adequate trials.


GRAZIE