THE OPTIMAL ARTERIAL BLOOD PRESSURE DURING CARDIOPULMONARY BYPASS: DOES ONE FIT ALL?

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Disclosures

HOSPITAL OF LITHUANIAN UNIVERSITY OF HEALTH SCIENCES KAUNO KLINIKOS

Project no. 01.2.2-CPVA-K-703-03-0025
"Innovative non-invasive neuroprotection technologies for cardiac surgery, neurosurgery and ophthalmology”

European Regional Development Fund, no. 01.2.2-CPVA-K-703
"Promoting the activities of competence centers and innovation and technology transfer centers"

Interactive CardioVascular and Thoracic Surgery 30 (2020) 161–202
doi:10.1093/icvts/ivz251 Advance Access publication 2 October 2019

European Association of Cardiothoracic Anaesthesiologists

EACTS/EACTA/EBCP GUIDELINES

2019 EACTS/EACTA/EBCP guidelines on cardiopulmonary bypass in adult cardiac surgery

Authors/Task Force Members: Luc Puis[a,*,†] (Chairperson) (Belgium), Milan Milojevic[b,c,*,†] (Serbia, Netherlands), Christa Boer[d] (Netherlands), Filip M.J.J. De Somer[e] (Belgium), Tomas Gudbjartsson[f] (Iceland), Jenny van den Goor[g] (Netherlands), Timothy J. Jones[h] (UK), Vladimir Lomivorotov[i] (Russia), Frank Merkle[j] (Germany), Marco Ranucci[k] (Italy), Gudrun Kunst[l,*,†] (Chairperson) (UK) and Alexander Wahba[m,n,*,†] (Chairperson) (Norway)

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EACTS/EACTA/EBCP Committee Reviewers: Peter Alston[1] (UK), David Fitzgerald[2] (USA), Aleksandar Nikolic[3] (North Macedonia), Francesco Onorati[4] (Italy), Bodil Steen Rasmussen[5] (Denmark) and Staffan Svenmarker[6] (Sweden). The other reviewer wishes to remain anonymous

MAP is used as a surrogate marker of organ perfusion and should be maintained between

50 and 80 mmHg.

Recommendations for control of mean arterial blood pressure during cardiopulmonary bypass

Recommendations	Class[a]	Level[b]	Ref[c]
It is recommended to adjust the MAP during CPB with the use of arte1rial vasodilators (if MAP >80 mmHg) or vasoconstrictors (if MAP <50 mmHg), after checking and adjusting the depth of anaesthesia and assuming sufficiently targeted pump flow.	I	A	186,187
The use of vasopressors to force the MAP during CPB at values higher than 80 mmHg is not recommended.	III	B	186,191,199
It is recommended that vasoplegic syndrome during CPB be treated with α1 adrenergic agonist vasopressors.	I	C	
In patients with vasoplegic syndrome refractory to α1-adrenergic agonist vasopressors, alternative drugs (vasopressin, terlipressin or methylene blue) should be used, alone or in combination with α1-agonists.	IIa	B	194,196,197
Hydroxocobalamin may be used to treat vasoplegic syndrome during CPB.	IIb	C	

Original Manuscript

Perfusion

Perfusion
2022, Vol. 0(0) 1–9

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DOI: 10.1177/02676591221129737

The effect of relative cerebral hyperperfusion during cardiac surgery with cardiopulmonary bypass to delayed neurocognitive recovery

de of blood pressure below cereb
ıld during cardiopulmonary bypa

frontiers | Frontiers in Psychiatry

REVIEW
published: 15 June 2022
doi: 10.3389/fpsyt.2022.884907

An Update on Postoperative Cognitive Dysfunction Following Cardiac Surgery

Tony Vu[1,2] and Julian A. Smith[1,2]*

[1] Department of Cardiothoracic Surgery, Monash Health, Melbourne, VIC, Australia, [2] Department of Surgery, School of Clinical Sciences at Monash Health, Monash University, Melbourne, VIC, Australia

Anaesthesia 2019, 74, 33–44

Original Article

A prospective, observational study of ce
autoregulation and its association witl
cardiac surgery

British Journal of Anaesthesia **113** (6): 1009–17 (2014)
Advance Access publication 25 September 2014 · doi:10.1093/bja/aeu319

Arterial pressure above the upper cere
limit during cardiopulmonary bypass i
postoperative delirium

D. Hori[1], C. Brown[2], M. Ono[1], T. Rappold[2], F. Sieber[2], A. Gottschalk
H. Adachi[5] and C. W. Hogue[2*]

ORIGINAL RESEARCH ARTICLE

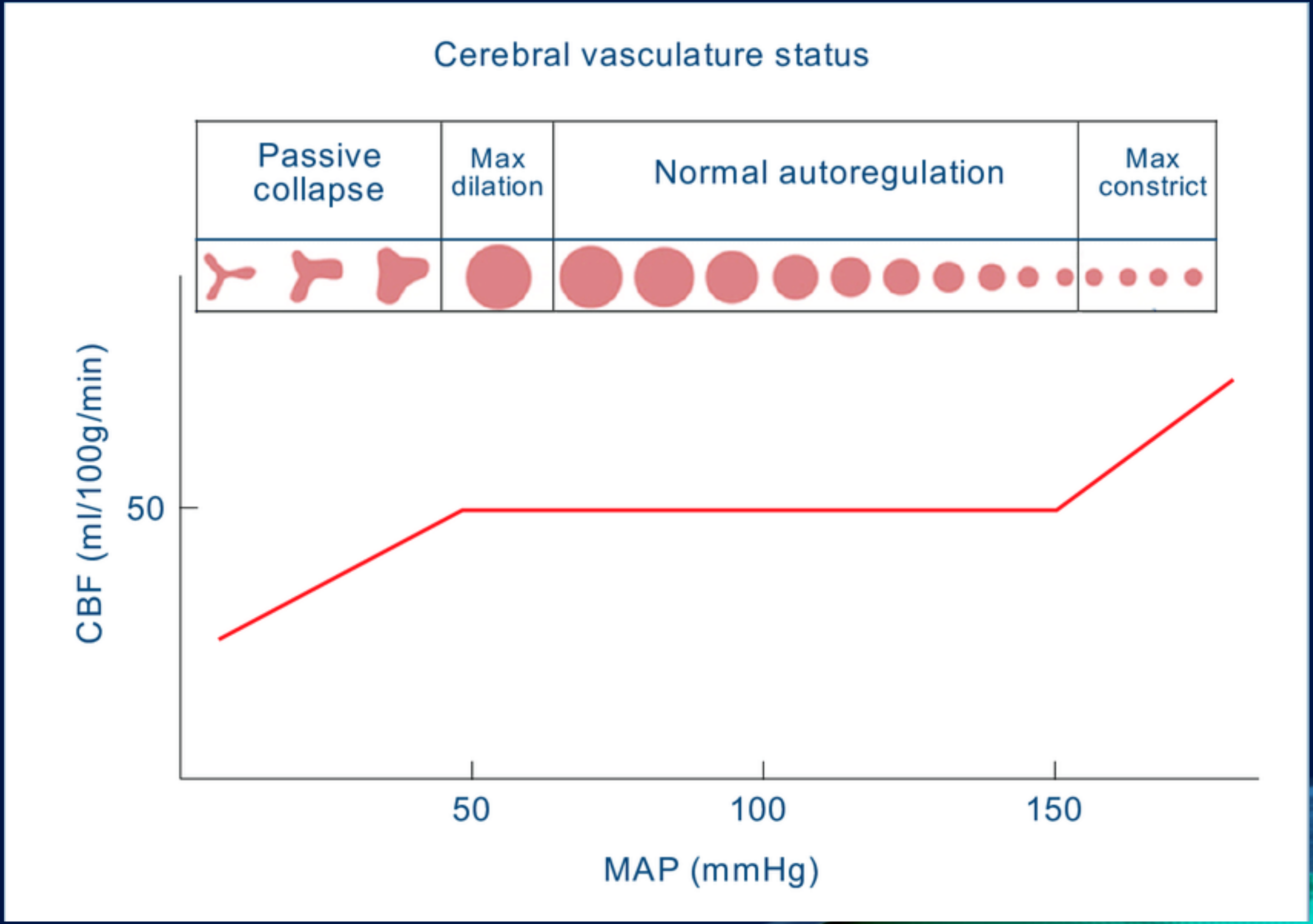
High-Target Versus Low-Target Blood Pressure Management During Cardiopulmonary Bypass to Prevent Cerebral Injury in Cardiac Surgery Patients

A Randomized Controlled Trial

Editorial, see p 1781

Anne G. Vedel, MD

Lassen curve



documents from iCloud.

ORIGINAL RESEARCH

American Heart Association | American Stroke Association

Relationship Between the Ambulatory Arterial Stiffness Index and the Lower Limit of Cerebral Autoregulation During Cardiac Surgery

Yurie Obata, MD; Viachaslau Barodka, MD; Dan E. Berkowitz, MD; Allan Gottschalk, MD, PhD; Charles W. Hogue, MD; Jochen Steppan, MD, DESA

HHS Public Access
Author manuscript
Anesth Analg. Author manuscript; available in PMC 2019 Decemb
Published in final edited form as:
Anesth Analg. 2018 December ; 127(6): 1314–1322. doi:10.1213/ANE.00000000

Cerebral Small Vessel, But Not Large Vessel Disea Associated With Impaired Cerebral Autoregulation Cardiopulmonary Bypass: A Retrospective Cohort Study

Yohei Nomura, MD*, Roland Faegle, MD†, Daijiro Hori, MD*, Abbas Al-Qamari, MD‡, Alexander J. Nemeth, MD§,‖, Rebecca Gottesman, MD, PhD†, Gayane Yenokyan, PhD¶, Charles Brown, MD, MS#, and Charles W. Hogue, MD‡

Volume 2022, Article ID 7701947, 8 pages
https://doi.org/10.1155/2022/7701947

Research Article

Higher Mean Arterial Pressure during Cardiopulmonary Bypass May Not Prevent Acute Kidney Injury in Elderly Patients Undergoing Cardiac Surgery

Yunfen Ge,[1] Tapas Ranjan Behera,[2] Ming Yu,[3] Shuyang Xie,[3] Yue Chen,[1] Hui Mao,[1] Qiong Xu,[1] Yu Zhao,[4] Shuijun Zhang,[5] and Quanquan Shen[6]

Observational Study > Minerva Anestesiol. 2019 Jun;85(6):594-603.
doi: 10.23736/S0375-9393.18.12358-3. Epub 2018 May 11.

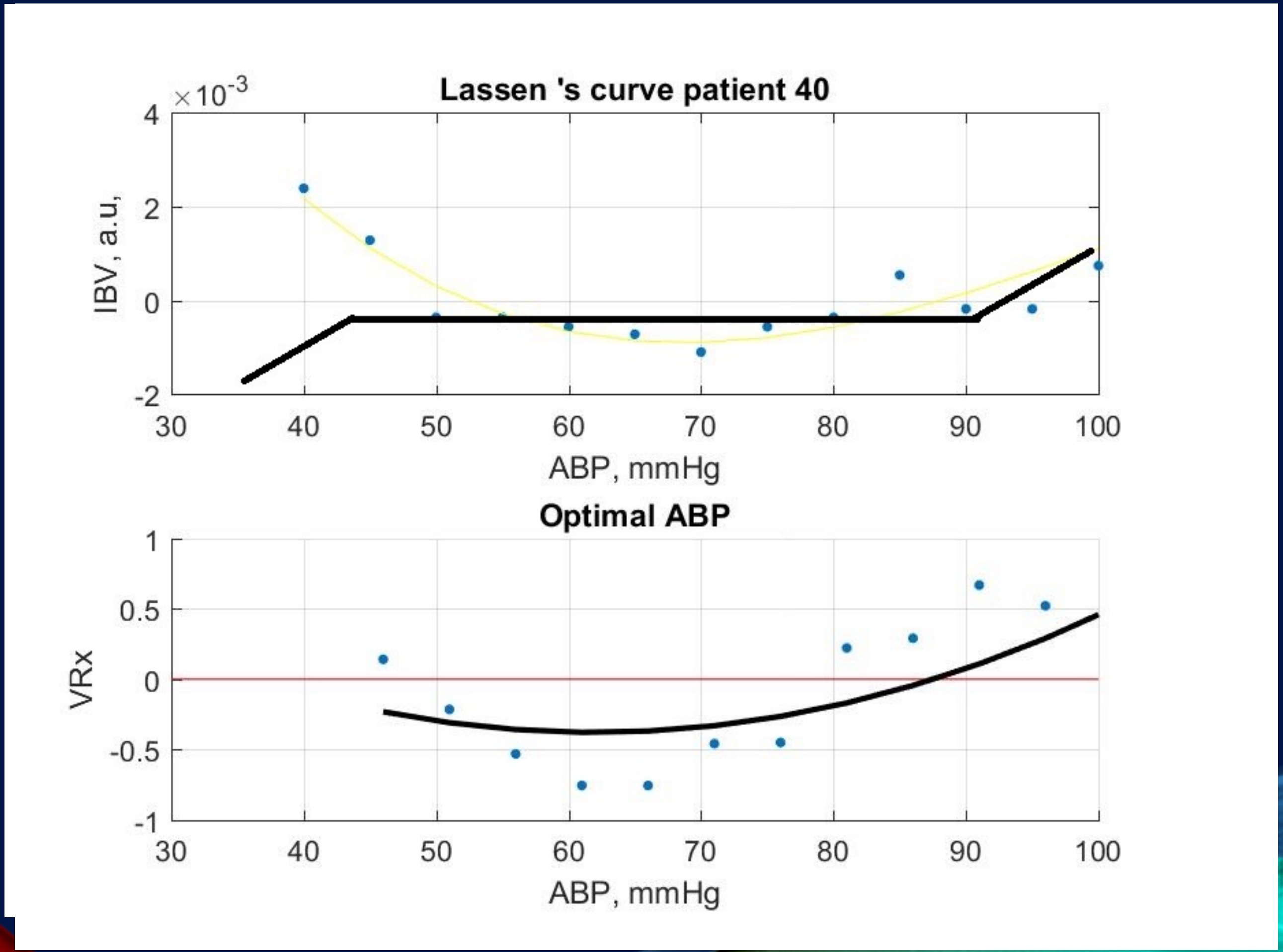
Cerebrovascular autoregulation impairments during cardiac surgery with cardiopulmonary bypass are related to postoperative cognitive deterioration: prospective observational study

Birute Kumpaitiene [1], Milda Svagzdiene [2 3], Edmundas Sirvinskas [2 3], Virginija Adomaitiene [2], Vytautas Petkus [4], Rolandas Zakelis [4], Solventa Krakauskaite [4], Romanas Chomskis [4], Arminas Ragauskas [4], Rimantas Benetis [2 3]

Affiliations + expand

PMID: 29756691 DOI: 10.23736/S0375-9393.18.12358-3

Individual limits of MAP



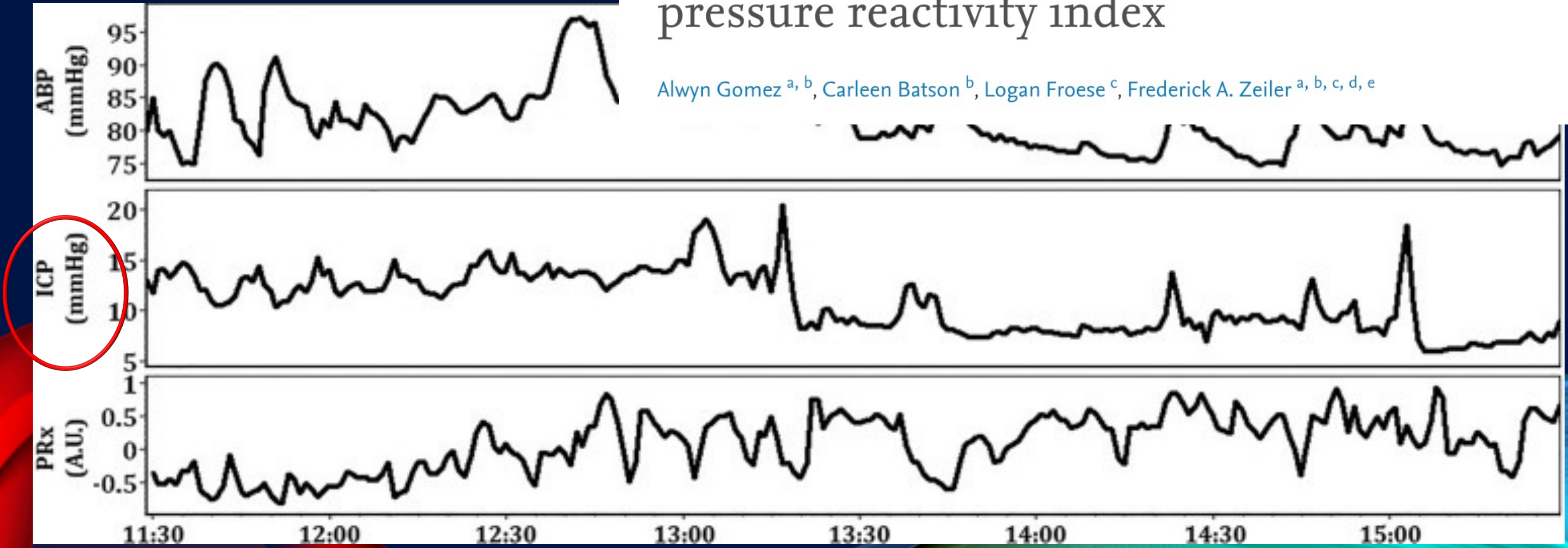
ACADEMIC PRESS

Diagnosis and Treatment of Traumatic Brain Injury

2022, Pages 169-180

Chapter 13 - Traumatic brain injury: Linking intracranial pressure, arterial pressure, and the pressure reactivity index

Alwyn Gomez [a, b], Carleen Batson [b], Logan Froese [c], Frederick A. Zeiler [a, b, c, d, e]



mean velocity index – Mx → TCD

cerebral oximetry index – Cox → NIRS

Hb volume index – HVx → NIRS

cerebral flow velocity index – CFVx → UT–NIRS

Transcranial Doppler Is Valid for Determination of the Lower Limit of Cerebral Blood Flow Autoregulation

Fin Stolze Larsen, MD; Karsten Skovgaard Olsen, MD; Bent Adel Hansen, MD; Olaf B. Paulson, MD; Gitte Moos Knudsen, MD

Patient Oriented Outcomes

Alwyn Gomez[1,2], Logan Froese[3], Amanjyot Singh Sainbhi[3], Carleen Batson[2] and Frederick A. Zeiler[1,2,3,4,5]*

Clin Auton Res (2009) 19:197–211
DOI 10.1007/s10286-009-0011-8

REVIEW ARTICLE

Transcranial Doppler for evaluation of cerebral autoregulation

Ronney B. Panerai

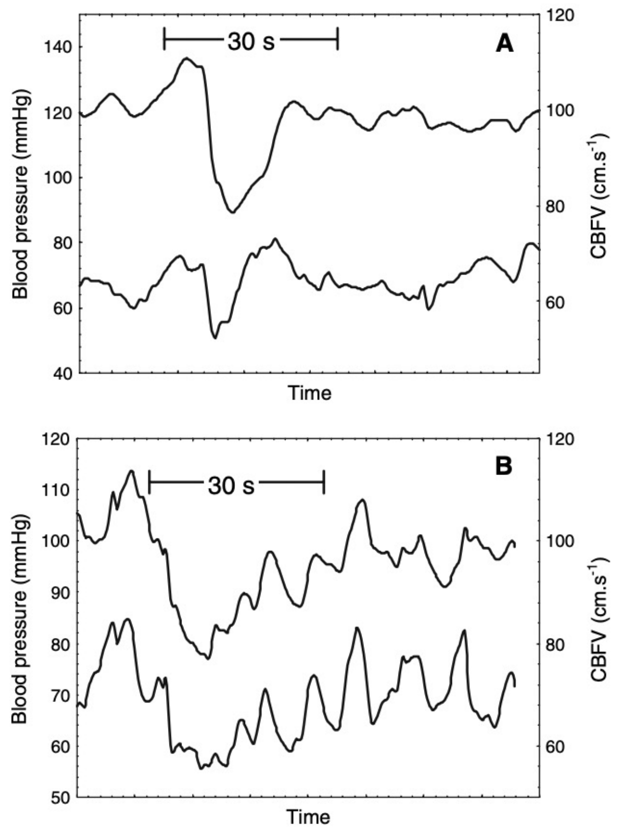


Fig. 2 Mean arterial blood pressure (*top trace*) and cerebral blood flow velocity (*bottom trace*) following the sudden release of inflated thigh-cuffs. **a** The fast return of the CBFV signal to its baseline value indicates a normal autoregulatory response. **b** CBFV follows the BP tracing in a subject with an abnormal CA response

an autoregulatory dilatio
ssels.
The lower limit of auto
entified in all subjects by th
11 of 12 subjects by TC
nilar values for the lower
ward higher values was fou
the lack of identification
bject, may have been cau
ange in probe positioning
ease the measured V_{mean} i
ent as the vessel is no lo
trasound beam. Fixation
nd as well as fixation gel
ture studies.
Our findings disagree to s
udy in which V_{mean} decrea
mained constant in patier
d orthostatic hypotension
AP of approximately 20 r
is explained by the authors
active dilatation of the M
planation is not supported
gulation may actually have
ationary detector system w
on was applied for repeate
ly 6 to 8 mCi ^{133}Xe was i
gnificant scatter of the res
ethod might have been
anges in CBF, and it woul
te the possible absence
mic failure within a larger
th more sensitive methods
Below the lower limit of a
ed significantly with cha
eviously pointed out, V_m

Published in final edited form as:
Anesth Analg. 2013 January ; 116(1): 198–204. doi:10.1213/ANE.0b013e318271fb10.

Validation of a Stand-Alone Near Infrared Spectroscopy System for Monitoring Cerebral Autoregulation during Cardiac Surgery

Masahiro Ono, MD, PhD[1], **Yueying Zheng, MD**[2], **Brijen Joshi, MD**[3], **Jeffrey C. Sigl, PhD**[4], and **Charles W. Hogue, MD**[5]

70 pts

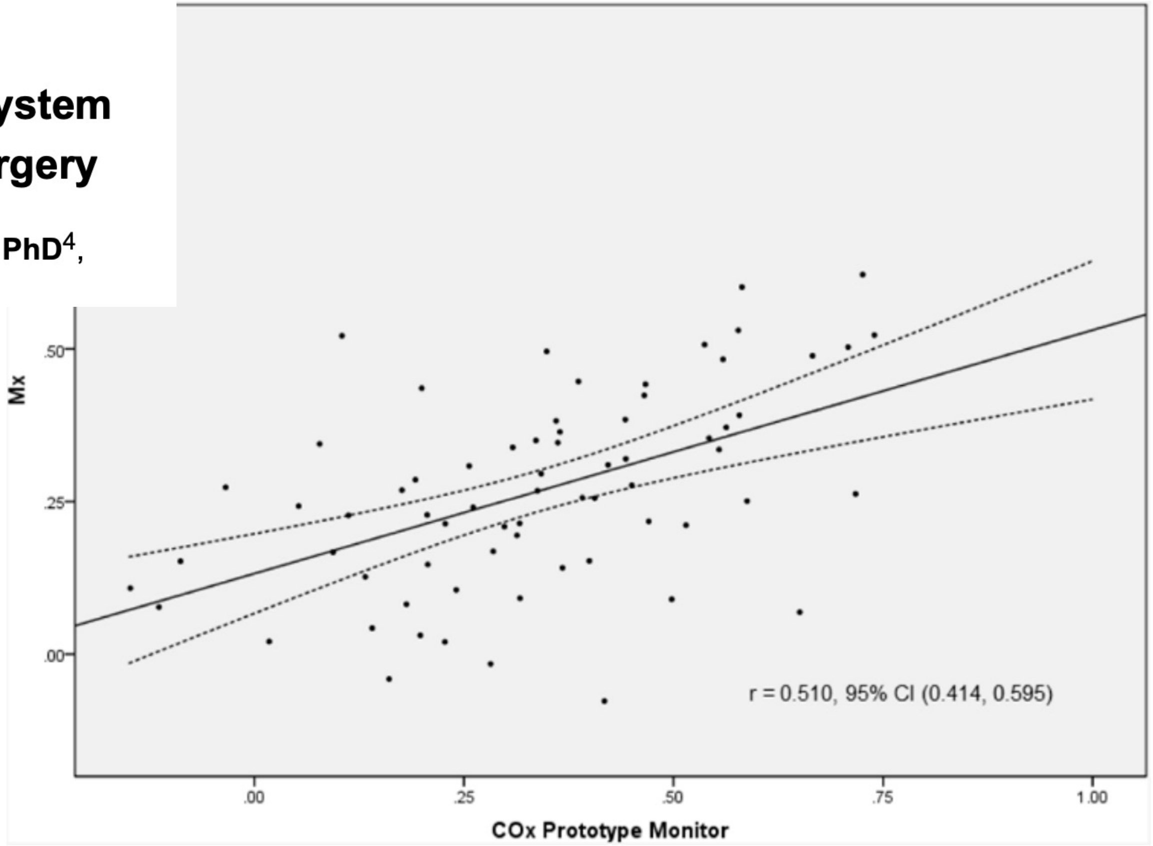


Figure 2.
Correlation and 95% confidence intervals between mean velocity index (M×) and cerebral oximetry index (CO×). M× was determined with a personal computer based system as the correlation coefficient between transcranial Doppler measured cerebral blood flow velocity and mean arterial pressure. CO× is the correlation between near infrared spectroscopy-measured cerebral oximetry and mean arterial pressure.

Comparison of different metrics of cerebral autoregulation in association with major morbidity and mortality after cardiac surgery

Xiuyun Liu1,2,*, Joseph Donnelly3, Ken M. Brady4, Kei Akiyoshi1, Brian Bush1, Raymond C. Koehler1, Jennifer K. Lee1, Charles W. Hogue5, Marek Czosnyka6,7, Peter Smielewski6 and Charles H. Brown IV 1,*

Received: 12 March 2021; Accepted: 10 March 2022

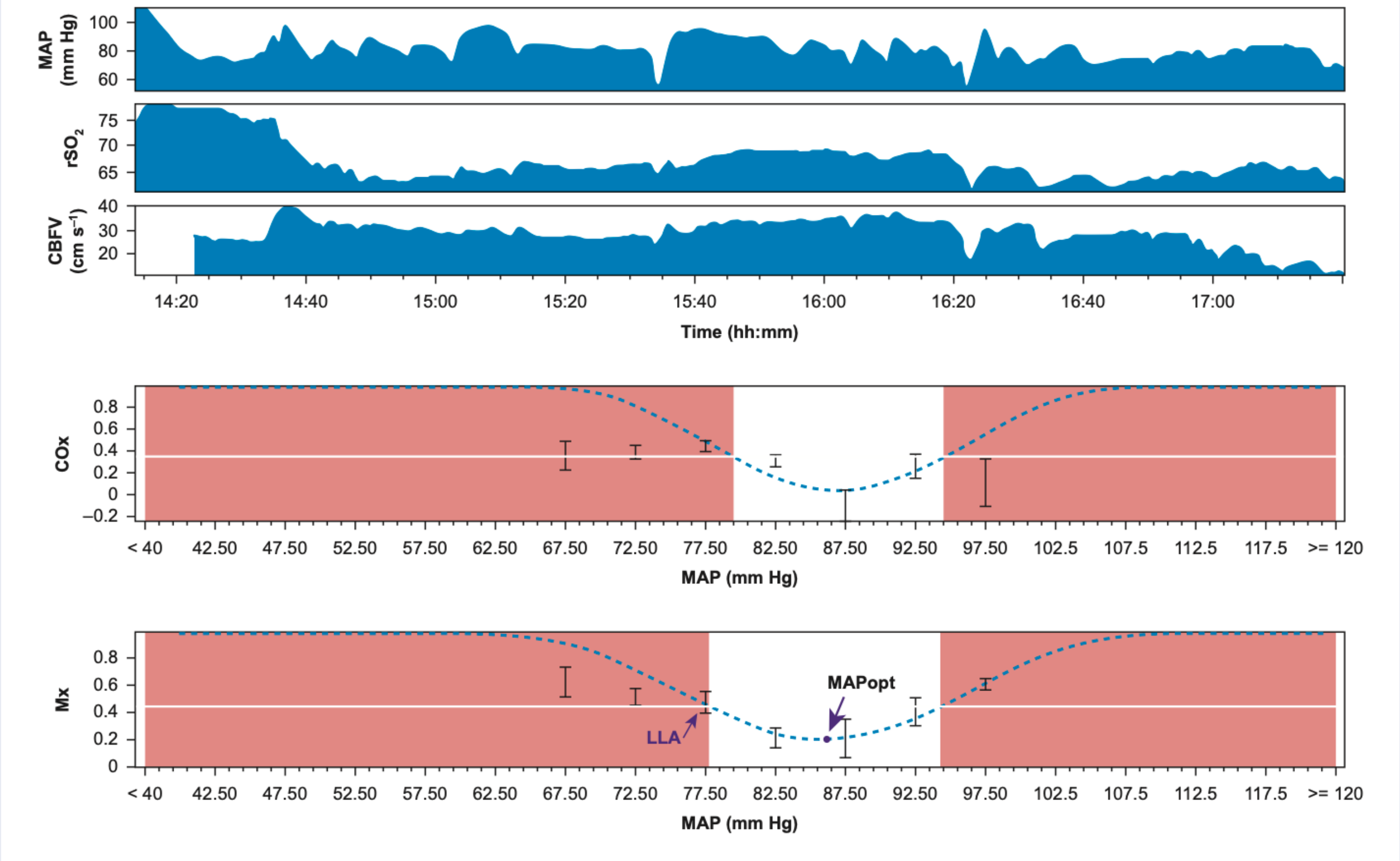


Fig 1. Identification of optimal arterial blood pressure (MAPopt) and lower limit of autoregulation (LLA), as indicated by the arrows. Mx, mean flow index; COx, cerebral oximetry index; CBFV, cerebral blood flow velocity; rSO_2, regional cortical oxygen saturation.

British Journal of Anaesthesia **113** (6): 1009–17 (2014)
Advance Access publication 25 September 2014 · doi:10.1093/bja/aeu319

BJA

Arterial pressure above the upper cerebral autoregulation limit during cardiopulmonary bypass is associated with postoperative delirium

D. Hori[1], C. Brown[2], M. Ono[1], T. Rappold[2], F. Sieber[2], A. G
H. Adachi[5] and C. W. Hogue[2]*

491 pts

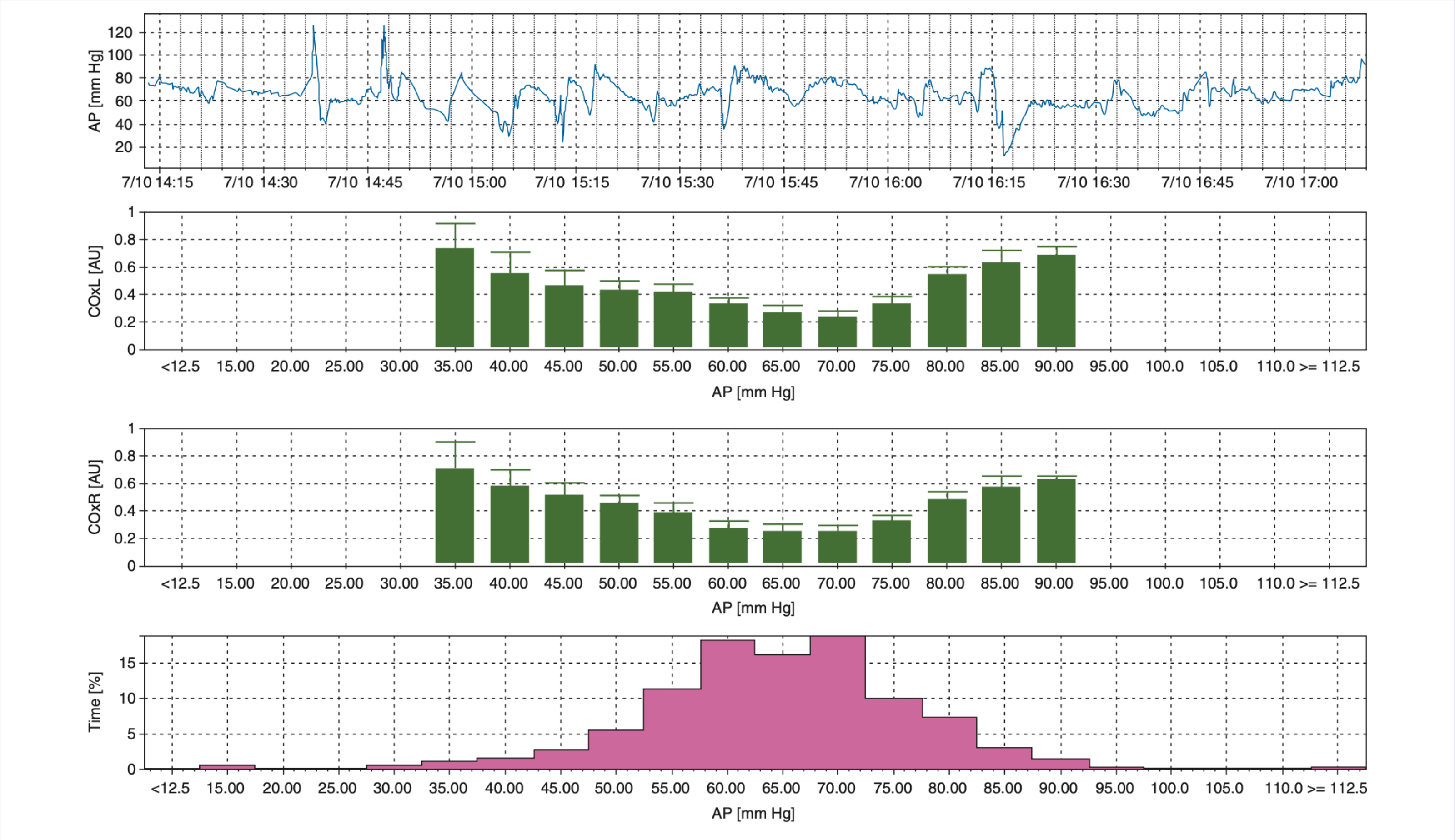


Fig 1 The representative graph of autoregulation monitoring during CPB. The COx represents the correlation coefficient between low-frequency regional cerebral oxygen saturation and MAP. When arterial pressure is above or below the autoregulation threshold, COx approaches 1, but when autoregulation is functional, COx is near zero. In this example, the lower limit of autoregulation based on the MAP at which COx $\geq$0.3 is ~55 mm Hg, and an ULA is at a MAP of 75 mm Hg. AP, arterial pressure.

British Journal of Anaesthesia, 121 (3): 523–526 (2018)
doi: 10.1016/j.bja.2018.05.058
Advance Access Publication Date: 29 June 2018

Near-infrared spectroscopy: unfulfilled promises

D. Cardim[1] and D. E. Griesdale[1,2,*]

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Cardiovascular and Thoracic Anesthesiology

Cardiovascular and Thoracic Anesthesiology Section Editor: **Nikolaos J. Skubas**
Hemostasis and Thrombosis Section Editor: **Roman M. Sniecinski**

Impact of 2 Distinct Levels of Mean Arterial Pressure on Near-Infrared Spectroscopy During Cardiac Surgery: Secondary Outcome From a Randomized Clinical Trial

Frederik Holmgaard, BMSc,* Anne G. Vedel, MD,* Theis Lange, MSc, PhD,†‡
Jens C. Nilsson, MD, PhD,* and Hanne B. Ravn, MD, PhD, DMSc*

s 67 mm Hg ± SD 5.0 in the HMAP group (n =
(n = 88). Mean $rScO_2$ was significantly lower in
5; 95% confidence interval, 0.9–6.1; *P* = .010).
ied time points during the intraoperative period
nts experienced desaturation below 10% and
up (*P* = .013 and *P* = .009, respectively), and the cerebral desaturation load below 10% relative to $rScO_2$ baseline was more pronounced in the HMAP group (*P* = .042).
CONCLUSIONS: In a randomized blinded study, we observed that a higher MAP induced by vasopressors, with a fixed CPB pump flow, leads to lower mean $rScO_2$ and more frequent and pronounced cerebral desaturation during CPB. The mechanism behind these observations is not clear. We cannot exclude extracranial contamination of the NIRS signal as a possible explanation. However, we cannot recommend increasing MAP by vasoconstrictors during cerebral desaturation because this is not supported by the findings of the present study. (Anesth Analg 2019;128:1081–8)

LIMITATIONS OF NIRS

- ✓ Penetration of light is limited to several centimetres in-depth, and the precise sampling volume and site of measurement are not fully clear [62].
- ✓ Hemoglobin in vessels of superficial structures may add extracerebral signals, and hence adding interference to CW-NIRS measurements [62].
- Bulky, sensitive to variations in room temperature, and exquisitely sensitive to outside light [63].
- The signals also display drift and are sensitive to movement artifact [63].
- Alterations in cerebral blood flow and metabolism following severe head injury are heterogeneous, and re-gional differences measured by NIRS may not be reflected by a global measurement such as jugular venous bulb oximetry [64].
- ✓ The $rS0_2$ index reflects a regional measure, while the jugular venous gas analysis is global [66].
- The pathlength factor and the depth concerning head swelling following trauma make the site of measure-ment and the volume sample ambiguous [66].
- ✓ The cerebral signal could be contaminated by a reflected signal from extracerebral structures (e.g., bone, mus-cle) with unpredictable partition and O_2 saturation characteristics [67].
- The clinical use of NIRS remains limited by potential sources of error that include contamination of the signal by the extracerebral circulation (principally the scalp), extraneous light, and the presence of extravascular blood [70].
- Hematomas may prevent sufficient photon transmission through the cortex due to excessive absorption by the concentrated blood [71].
- Edema directly beneath the optical probes may al
- In NIRS studies, many severe TBI patients are exc
- Other patient-related factors affecting the NIRS-d or scar), brain malformation, polycythemia, and s

sensors MDPI

Review

Near-Infrared Spectroscopy (NIRS) in Traumatic Brain Injury (TBI)

María Roldán and Panayiotis A. Kyriacou *

Research Centre for Biomedical Engineering, School of Mathematics, Computer Sciences and Engineering, University of London, London EC1V 0HB, UK; maria.roldan@city.ac.uk
* Correspondence: P.Kyriacou@city.ac.uk; Tel.: +44-(0)20-7040-8131

HHS Public Access

Author manuscript

Crit Care Med. Author manuscript; available in PMC 2022 April 01.

Published in final edited form as:

Crit Care Med. 2021 April 01; 49(4): 650–660. doi:10.1097/CCM.0000000000004737.

Determining thresholds for three indices of autoregulation to identify the lower limit of autoregulation during cardiac surgery

Xiuyun Liu, PhD[1], Kei Akiyoshi, MD[1], Mitsunori Nakano, MD[1,2], Ken Brady, MD[3], Brian Bush, MD, MHS[1], Rohan Nadkarni, MS[4], Archana Ver… Koehler, PhD[1], Jennifer K. Lee, MD[1], Charles W. Hog… Peter Smielewski, PhD[7], Charles H. Brown, MD, MHS…

226 pts → 58 pts (27 %)

168 pts

↓

no Lassen curve

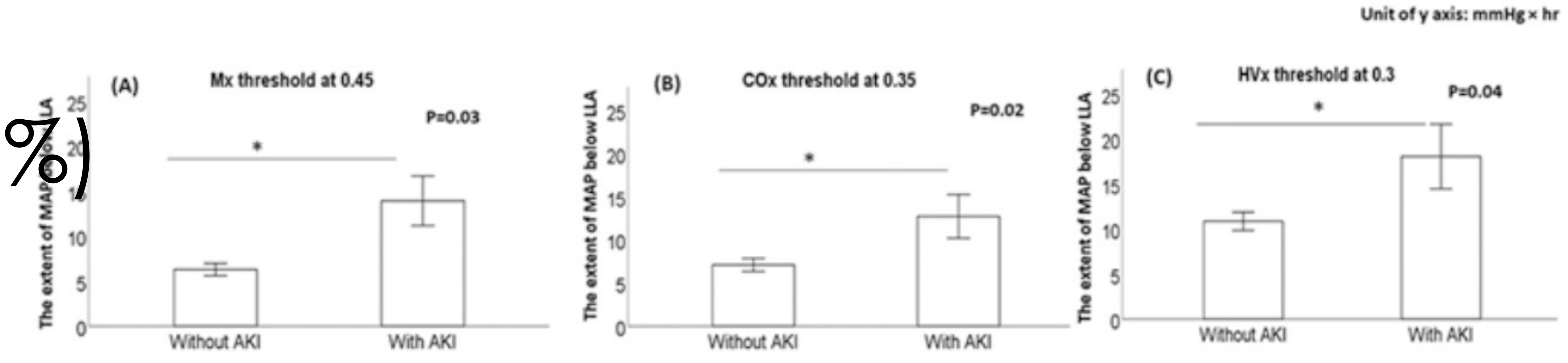


Figure 3.

The extent of mean arterial blood pressure (MAP) below the lower limit of autoregulation (LLA; defined by Mx, Cox, and HVx) in patients with and without acute kidney injury (AKI) using Mann-Whitney tests. The bar is expressed as mean ± SEM; n=176 for (A), n=200 for (B) and n=192 for (C). More details can be found in Supplementary Table 2. *$p<0.05$. Mx = mean flow index; COx = cerebral oximetry index; HVx = hemoglobin volume index.

Intraoperative Cerebral Autoregulation Assessment Using Ultrasound-Tagged Near-Infrared-Based Cerebral Blood Flow in Comparison to Transcranial Doppler Cerebral Flow Velocity: A Pilot Study

John M. Murkin, MD, FRCPC,* Moshe Kamar, MD,† Zmira Silman, MSc,† Michal Balberg, PhD,†
and Sandra J. Adams, RN*

Journal of Cardiothoracic and Vascular Anesthesia, Vol 29, No 5 (October), 2015: pp 1187–1193

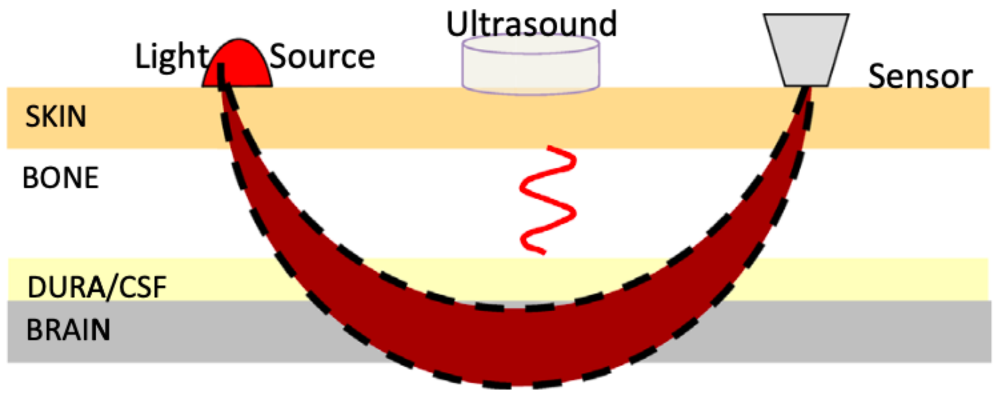


Fig 4. **Schematic of US-tagged NIR device, in which light source indicates laser NIR, ultrasound indicates integral ultrasound crystal incorporated into the device and imparting Doppler shift to NIR light, sensor represents sensing component of UTLight Flowmetry NIR device, and skin, bone, dura/CSF and brain represent various tissue layers.**

Published in final edited form as:

Anesth Analg. 2015 November ; 121(5): 1187

Cerebral Autoregulation Mor
Near-Infrared Spectroscopy

Hori D., Hogue Jr.C.W., Shah A., Brown C., Neufeld K.J., Conte J.V., Price J., Sciortino C., Max L., Laflam A., Adachi H., Cameron D.E., Mandal K.

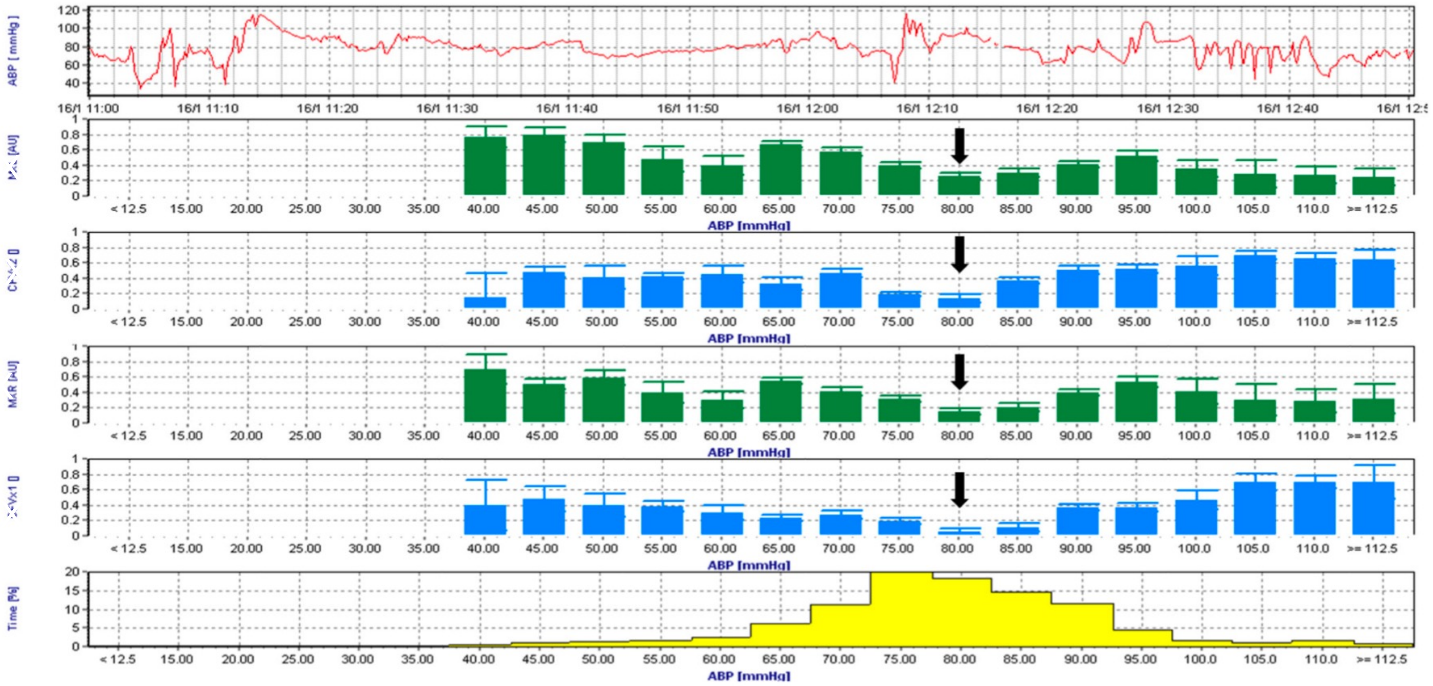


Figure 2.

Average Mx and CFVx during cardiopulmonary bypass in 5mmHg bins. Both Mx and CFVx shows increase in their value as mean arterial pressure moves away from the optimal blood pressure indicating trends towards pressure dependent changes in cerebral blood flow. Mean arterial pressure at lowest Mx or CFVx were defined as the optimal blood pressure (Black arrow). In this example, the optimal blood pressure based on MAP at which Mx is the lowest is 80 mmHg. Similarly, MAP at which CFVx is at the lowest is 80mmHg. MxR=Mx Right; CFVx1=CFVx Right; MxL=Mx Left; CFVx2=CFVx Left;

BJA

British Journal of Anaesthesia, 121 (3): 588–594 (2018)

doi: 10.1016/j.bja.2018.04.038
Advance Access Publication Date: 2 June 2018
Neuroscience and Neuroanaesthesia

NEUROSCIENCE AND NEUROANAESTHESIA

Ultrasound-tagged near-infrared spectroscopy does not disclose absent cerebral circulation in brain-dead adults

A. Caccioppola[1], M. Carbonara[1], M. Macrì[1], L. L
F. Ortolano[1], F. Triulzi[3,4], E. R. Zanier[5], T. Zoerl

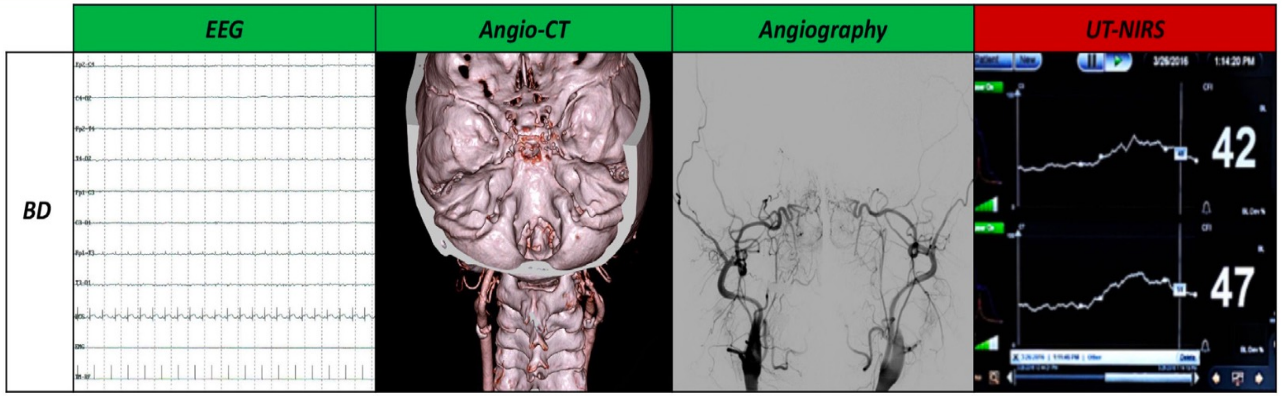


Fig 2. Instrumental findings in brain-dead patients. From left to right: EEG recording (showing isoelectric signal) and two images demonstrating absent intracranial progression of arterial blood flow, respectively, using angio-CT scan or angiography. These two images come from separate patients (because multiple confirmatory exams directly concerning cerebral blood flow are not indicated in the same subject). All these findings are consistent with absent cerebral blood flow. The last panel shows the ultrasound-tagged near-infrared spectroscopy (UT-NIRS) recording, which seems to indicate persistent cerebral flow index in both hemispheres, in contradiction with the other confirmatory tests. BD, brain dead.

Limits of CA detected before the surgery?

Real time monitoring?

"Interestingly, the method determined a change in the location of the LLA on average 7.0 times per case, with the mean of the standard deviations around the per-case mean LLA being 3.4 mmHg."

Montgomery D, et al. Intraoperative Determination and Reporting of Cerebral Autoregulation State Using Near-Infrared Spectroscopy. Anesth Analg. 2020 Nov;131(5):1520-1528. doi: 10.1213/ANE.0000000000004614. PMID: 33079875; PMCID: PMC7319873.

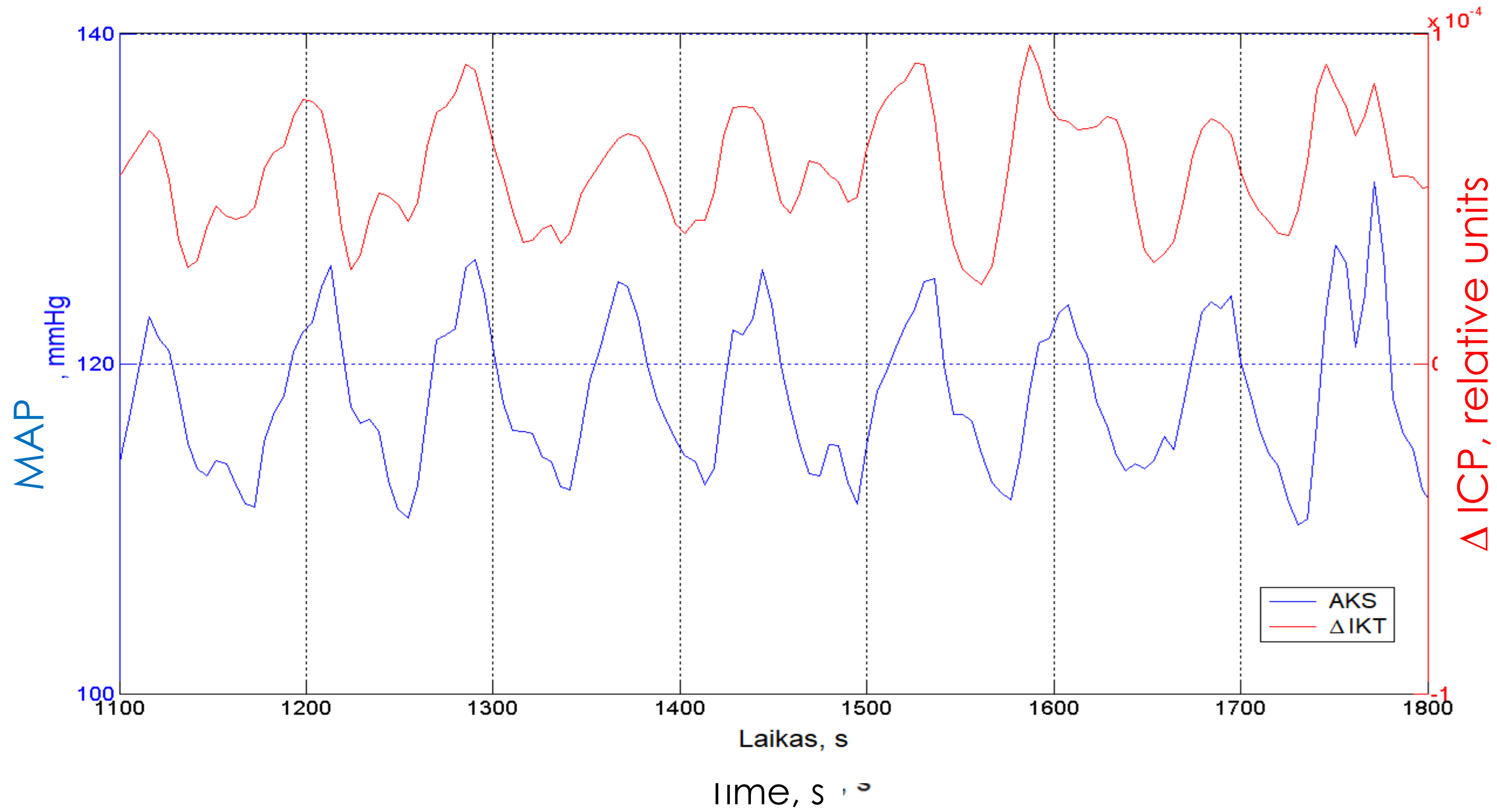
Anesthetics

t°C

Hb

PaO_2
$PaCO_2$

Effect of vasoactive agents



PMID: 29756691 DOI: 10.23736/S0375-9393.18.12358-3

MAP and relative intracranial volume (ICP) waves in impaired CA

Technology, Computing, and Simulation

ORIGINAL CLINICAL RESEARCH REPORT

OPEN

Real-Time Intraoperative Determination and Reporting of Cerebral Autoregulation State Using Near-Infrared Spectroscopy

Dean Montgomery, PhD,* Charles Brown, MD,† Charles W. Hogue, MD,‡ Ken Brady, MD,‡§
Mitsunori Nakano, M

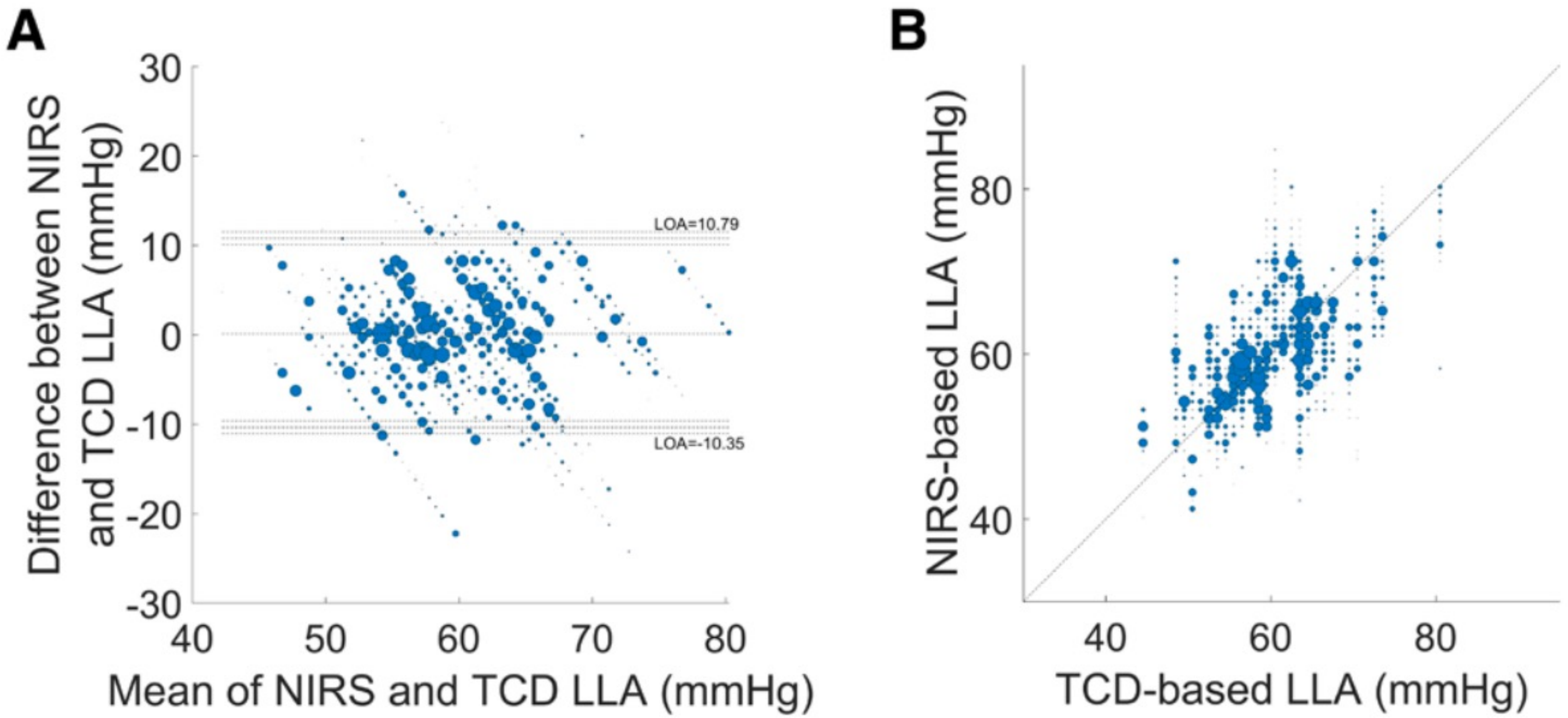


Figure 4. Cotrending algorithm performance versus TCD reference. A, Histogram of the LLA references taken from TCD signal for the 69 patients in this study. Many guidelines indicate a blood pressure management of 50 or 60 mmHg, but approximately 50% of patients have an LLA higher than 60 mmHg and 95% have an LLA >50 mmHg. B, Histogram of the LLAs calculated with our method. The distribution strongly resembles the reference LLA distribution. LLA indicates lower limit of autoregulation; NIRS, near-infrared spectroscopy; TCD, transcranial Doppler.

MAP, mean arterial pressure; rSo_2, regional oxygen saturation; TCD, transcranial Doppler.

British Journal of Anaesthesia, 128 (3): 405–408 (2022)
doi: 10.1016/j.bja.2021.12.013
Advance Access Publication Date: 5 January 2022

High-resolution perioperative cerebral blood flow autoregulation measurement: a practical and feasible approach for widespread clinical monitoring

Eric L. Vu[1,2], Kenneth Brady[1,2] and Charles W. Hogue[1,*

[1]Department of Anesthesiology, Northwestern University Feinberg S
Robert H. Lurie Children's Hospital of Chicago, Chicago, IL, USA

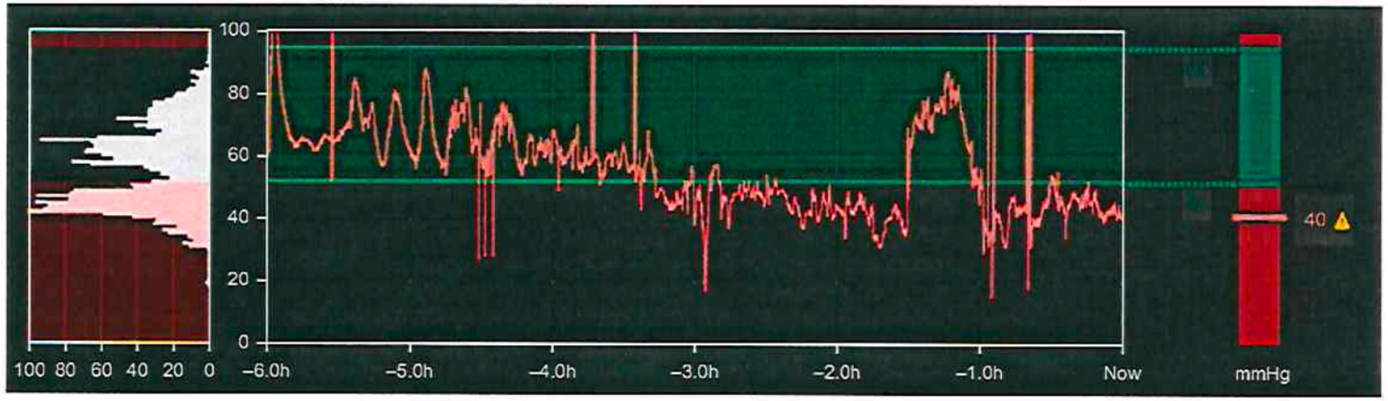


Fig 1. Real-time autoregulation display. Graph displaying mean arterial BP (mm Hg) (red line) over 6 h during congenital heart surgery. Fluctuations of mean arterial BP expected during surgery attributable to surgical stimulation, arterial line flushes, surgical manipulations, and vasoactive medication administration are shown. The limits of autoregulation are calculated and updated in green (lower limit of autoregulation of 52 mm Hg and upper limit of autoregulation of 95 mm Hg). The right bar graph denotes the current pressure (mean arterial BP of 40 mm Hg) in relationship to the limits of autoregulation (shaded in green). A warning flag is displayed because the current pressure is below the lower limit of autoregulation. The histogram inset to the left represents the duration of the recording at each arterial pressure.

Better postoperative outcomes for my patient…

Real-time noninvasive CA monitoring?