Monitoring Cerebral Perfusion:

Update and New Developments

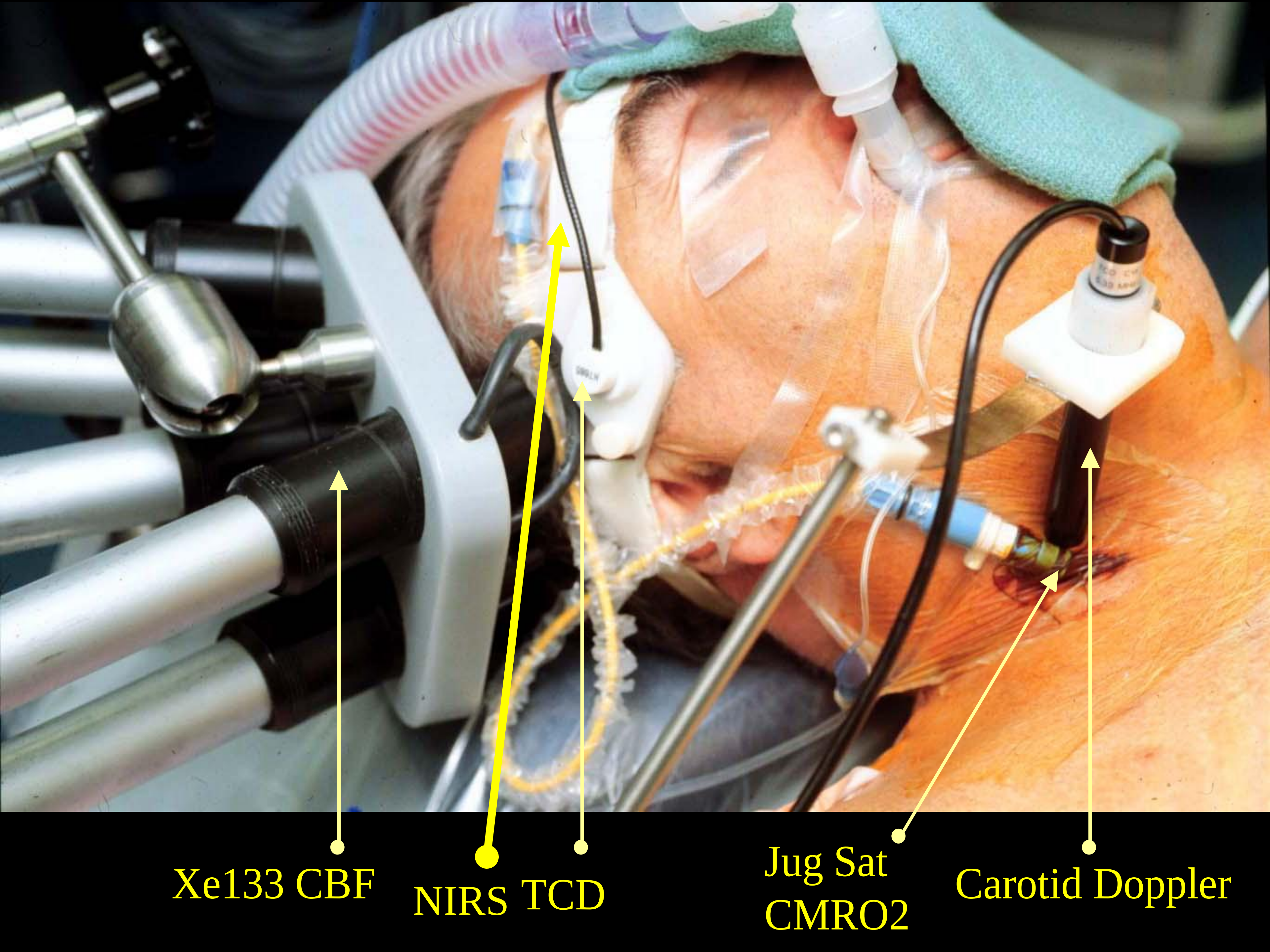
John M Murkin MD,FRCPC

Professor of Anesthesiology
Director of Cardiac Anesthesiology Research
Department of Anesthesiology and Perioperative Medicine
Schulich School of Medicine
University of Western Ontario

London, Canada

London .....the 'other' London

LHSC
London, Ontario
Canada


Xe133 CBF
NIRS TCD
Jug Sat
CMRO2
Carotid Doppler

Monitoring Cerebral Perfusion

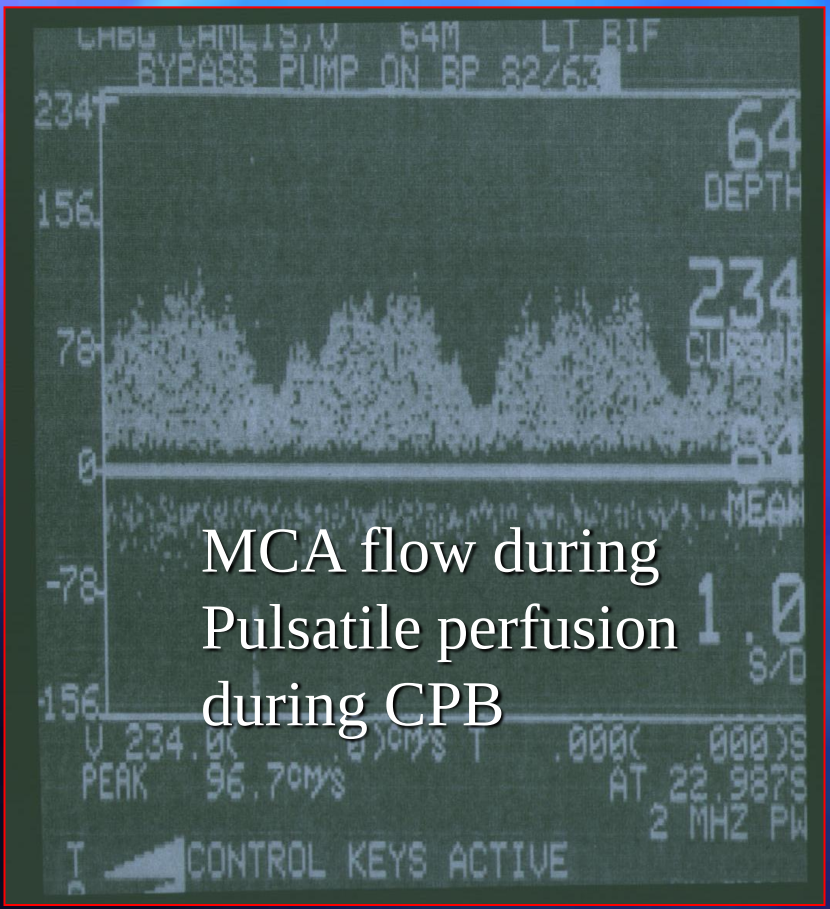
- ^{133}Xenon X intermittent
- Jugular bulb saturation X invasive, mixed venous
- TCD
- Cerebral oximetry

Dynamic cerebral autoregulation

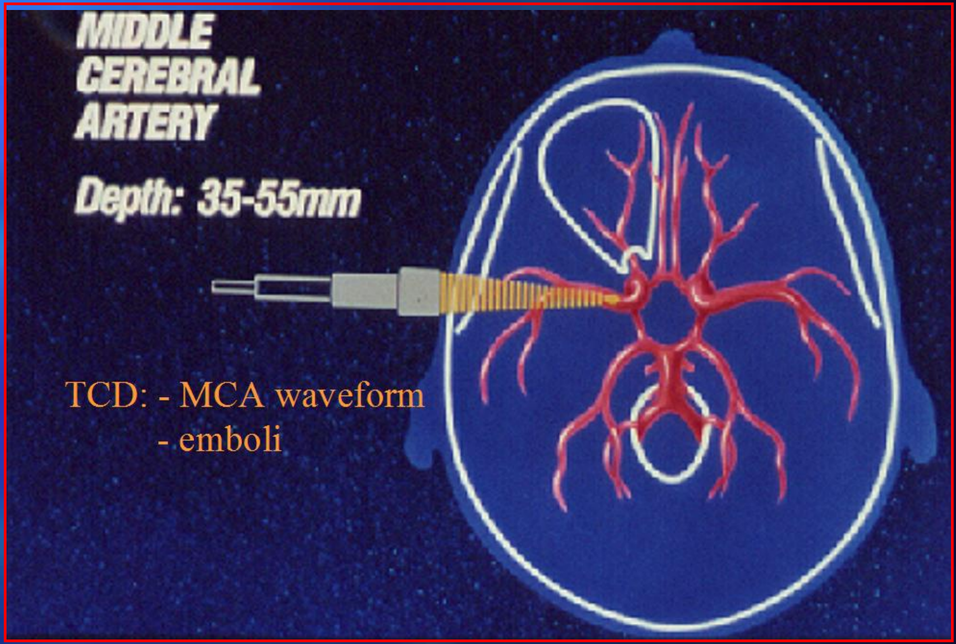
Perioperative Multimodality Neuromonitoring

1. Technology
2. Evidence for benefit
3. Cerebral Autoregulation
4. Extracerebral tissue
5. Ultrasound Tagged NIRS - CBF

TransCranial Doppler: Flow, Emboli



MCA flow during Pulsatile perfusion during CPB



TCD: - MCA waveform
- emboli

Transcranial Doppler

- <u>Transtemporal 'window'</u> : inadequate in 20-30% adults
- <u>Flow velocity ~ blood flow</u>: constant arterial diameter (PaCO2, vasodilators)
- <u>Insonation angle Θ = velocity</u>: unsteady, susceptible to movement
- <u>Emboli</u>: poor discrimination, micro air = macro particles (multifrequency?)

Cerebral Oximetry: Technology

- Robust: adhesive patches, frontal access
- Continuous, non-invasive
- Low cerebral saturation

  preoperative: poor prognosis, > Euroscore

  intraoperative: cognitive dysfunction

  major organ dysfunction
- Treatment Algorithm

  Improve outcomes
- Dynamic Cerebral Autoregulation
- Extracerebral Contamination

Evidence for Benefit

- Preoperative Risk Assessment
- Intraoperative Desaturation
- Treatment Algorithm
- Directed Interventions

Preoperative Risk Assessment

Preoperative Cerebral Oxygen Saturation and Clinical Outcomes in Cardiac Surgery

Matthias Heringlake, M.D.,* Christof Garbers, Cand. Med.,† Jan-Hendrik Käbler, Cand. Med.,† Ingrid Anderson, Cand. Med.,† Hermann Heinze, M.D.,‡ Julika Schön, M.D.,‡ Klaus-Ulrich Berger, M.D.,‡ Leif Dibbelt, M.D.,§ Hans-Hinrich Sievers, M.D.,‖ Thorsten Hanke, M.D.#

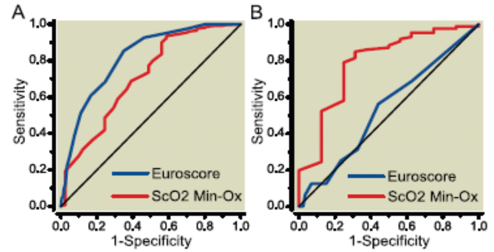


Fig. 3. Receiver-operating curve analyses of minimal preoperative cerebral oxygen saturation during oxygen insufflation ($Sco_{2min\text{-}ox}$, *broken line*) and additive EuroSCORE (*unbroken line*) for 30-day mortality in the total cohort of 1,178 patients (*A*) and in 102 high-risk patients with a EuroSCORE more than 10 (*B*) showing a significantly better predictive accuracy of the EuroSCORE in the total cohort (P = 0.015) and of $Sco_{2min\text{-}ox}$ in the high-risk group (P = 0.0044).

What We Know about This Topic

- Intraoperative cerebral oxygen saturation (Sco_2) monitoring has been used to assess the adequacy of cerebral oxygen delivery to demand.

What This Article Tells Us That Is New

- Preoperative Sco_2 concentrations are reflective of baseline severity of cardiopulmonary dysfunction, associated with short- and long-term mortality and morbidity, and may add to preoperative risk stratification in patients undergoing cardiac surgery.

Cerebral Oximetry

Monitoring the Brain as the Index Organ

Anesthesiology 2011; 114:12–3

John M. Murkin

"Preoperative ScO2 levels are reflective of the severity of cardiopulmonary dysfunction, and are associated with short and long-term mortality and morbidity"

Low cerebral saturation: Preoperative

20 neonates without pre-existing brain damage underwent arterial switch Sx

"Patients with lower preop ScO2 had lower DQ at 30-36 mo…"

"Preoperative cerebral desaturation may be underestimated as possible cause of adverse postoperative outcome"

Exp Brain Res (2005) 165: 343–350
DOI 10.1007/s00221-005-2300-3

RESEARCH ARTICLE

Mona C. Toet · Annebeth Flinterman
Ingrid van de Laar · Jaap W. de. Vries
Ger B. W. E. Bennink · Cuno S. P. M. Uiterwaal
Frank van Bel

Cerebral oxygen saturation and electrical brain activity before, during, and up to 36 hours after arterial switch procedure in neonates without pre-existing brain damage: its relationship to neurodevelopmental outcome

Received: 29 October 2004 / Accepted: 2 February 2005 / Published online: 7 June 2005

Abstract *Objective*: To monitor the pattern of cerebral oxygen saturation (rSat), by use of NIRS, in term infants before, during and after the arterial switch operation and to evaluate its relation to neurodevelopmental outcome. *Methods*: In 20 neonates without pre-existing brain damage hemodynamics and arterial oxygen saturation (AO_2-Sat) were monitored simultaneously with rSat and amplitude-integrated EEG (aEEG) from 4 h to 12 h before up to 36 h after cardiopulmonary bypass (CPB) and short duration of cardiac arrest during deep hypothermia (DHCA). The Bayleys developmental scale was performed at 30 months. *Results*: Before surgery rSat was $<50\%$ in 16 patients. During CPB rSat increased to normal values, with a sharp decrease during brief CA (median 6.5 min). Post-CPB rSat showed a transient decrease (30–45%) despite normal PaO_2 with sustained normalization after 6–26 h. Recovery time of the rSat seemed longer when pre-operative rSat was below 35%, and for lower minimum nasopharyngeal temperature and longer duration of CPB and of DHCA. Recovery time of the aEEG varied and did not correlate with normalization of rSat. Neurodevelopmental outcome was normal in all but two patients. Patients with lower pre-operative rSat ($<35\%$) tended to have lower DQ (developmental quotient) scores at 30–36 months. (median: mental 102 and motor 101 (range 58–125) compared with mental 100 and motor 110 (range 83–125)) *Conclusion*: Despite prompt normalization of circulation and oxygenation after surgery, recovery of rSat of the brain took 6–26 h, probably because of higher energy demand after CPB. Pre-operative cerebral oxygenation may be underestimated as a possible cause of adverse post-operative outcome.

Keywords Newborn · Arterial switch operation · Cerebral oxygenation · Electrical brain activity · Neurodevelopmental outcome

Abbreviations aEEG: Amplitude integrated electroencephalogram · CPB: Cardiopulmonary bypass · CA: Cardiac arrest · DHCA: Circulatory arrest during deep hypothermia · NIRS: Near infrared spectroscopy · rSAT: Regional cerebral oxygen saturation · TGA: Transposition of the great arteries · CVP: Central venous pressure · PaO_2: Arterial oxygen pressure · AO_2-sat: Arterial oxygen saturation · CBV: Cerebral blood volume · DQ: Developmental Quotient

M. C. Toet (✉) · A. Flinterman · I. Laar · F. Bel
Department of Neonatology, KE 04.123.1, University Medical Center Utrecht/Wilhelmina Children's Hospital,
P.B. 85090, 3508 Utrecht, The Netherlands
E-mail: M.Toet@WKZ.AZU.nl
Tel.: +31-30-2504545
Fax: +31-30-2505320

Intraoperative Desaturation

Cerebral Oxygen Desaturation Is Associated With Early Postoperative Neuropsychological Dysfunction in Patients Undergoing Cardiac Surgery

Fun-Sun

Cerebral Oxygen Desaturation Predicts Cognitive Decline and Longer Hospital Stay After Cardiac Surgery

James P. Slater, MD, Theresa Guarino, RN, Jessica Stack, BS, Kateki Vinod, BA,
Rami T. Rustami, PhD, John M. Brown III, MD, Alejandro L. Rodriguez, MD,
Chr
Gra

Noninvasive cerebral oxygenation may predict outcome in patients undergoing aortic arch surgery

Gregory W. Fischer,
Luozzo, MD,[b] Rand

Congenital Heart Disease

Relationship of Intraoperative Cerebral Oxygen Saturation to Neurodevelopmental Outcome and Brain Magnetic
ing

D;
MD;
5-254.)

Intraoperative desaturation implies adverse postoperative outcomes

"What can be done? Its like watching a traffic accident…"

Low cerebral saturation: Treatment Algorithm

Seminars in Cardiothoracic and Vascular Anesthesia
Volume XX Number X
Month XXXX xx-xx

10.1177/1089253207311685
http://scv.sagepub.com
hosted at
http://online.sagepub.com

A Proposed Algorithm for the Intraoperative Use of Cerebral Near-Infrared Spectroscopy

André Denault, MD, FRCPC, ABIM-CCM,
Alain Deschamps, MD, FRCPC, PhD,
and John M. Murkin, MD, FRCPC

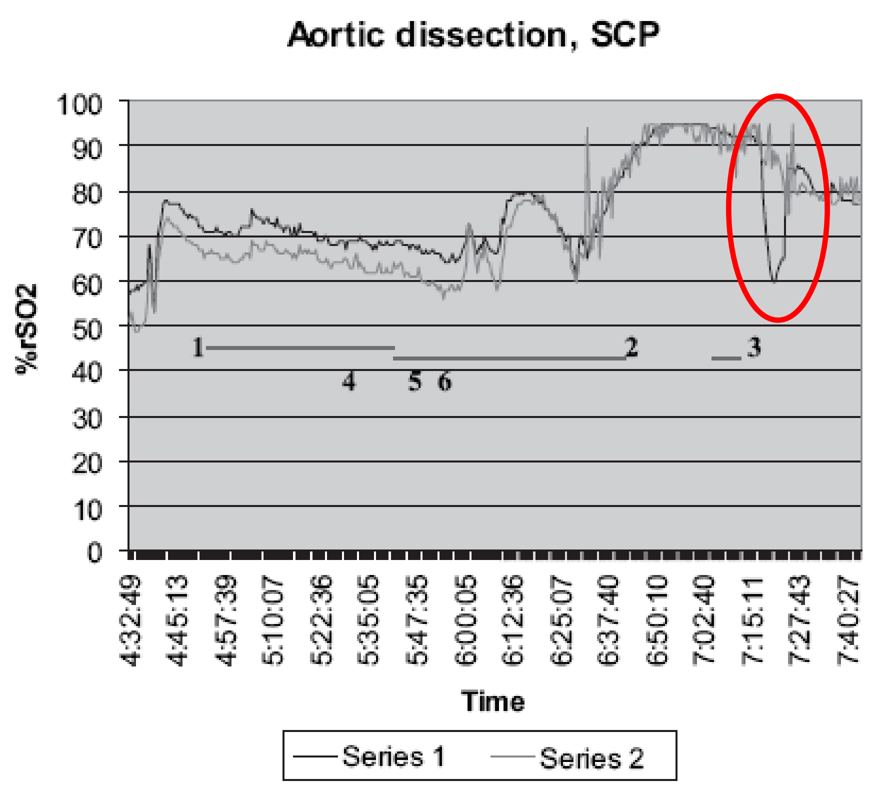
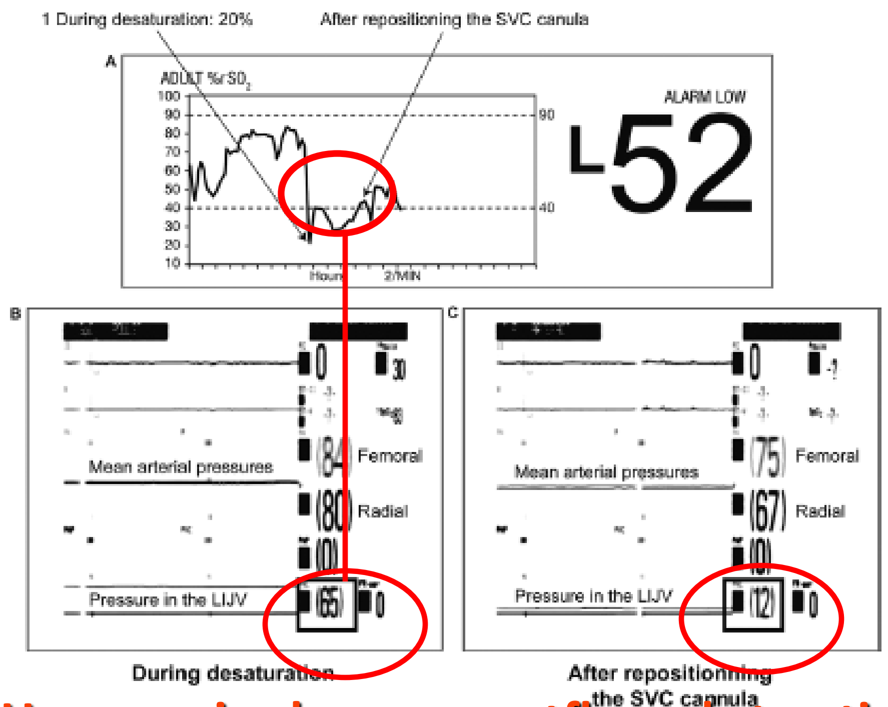
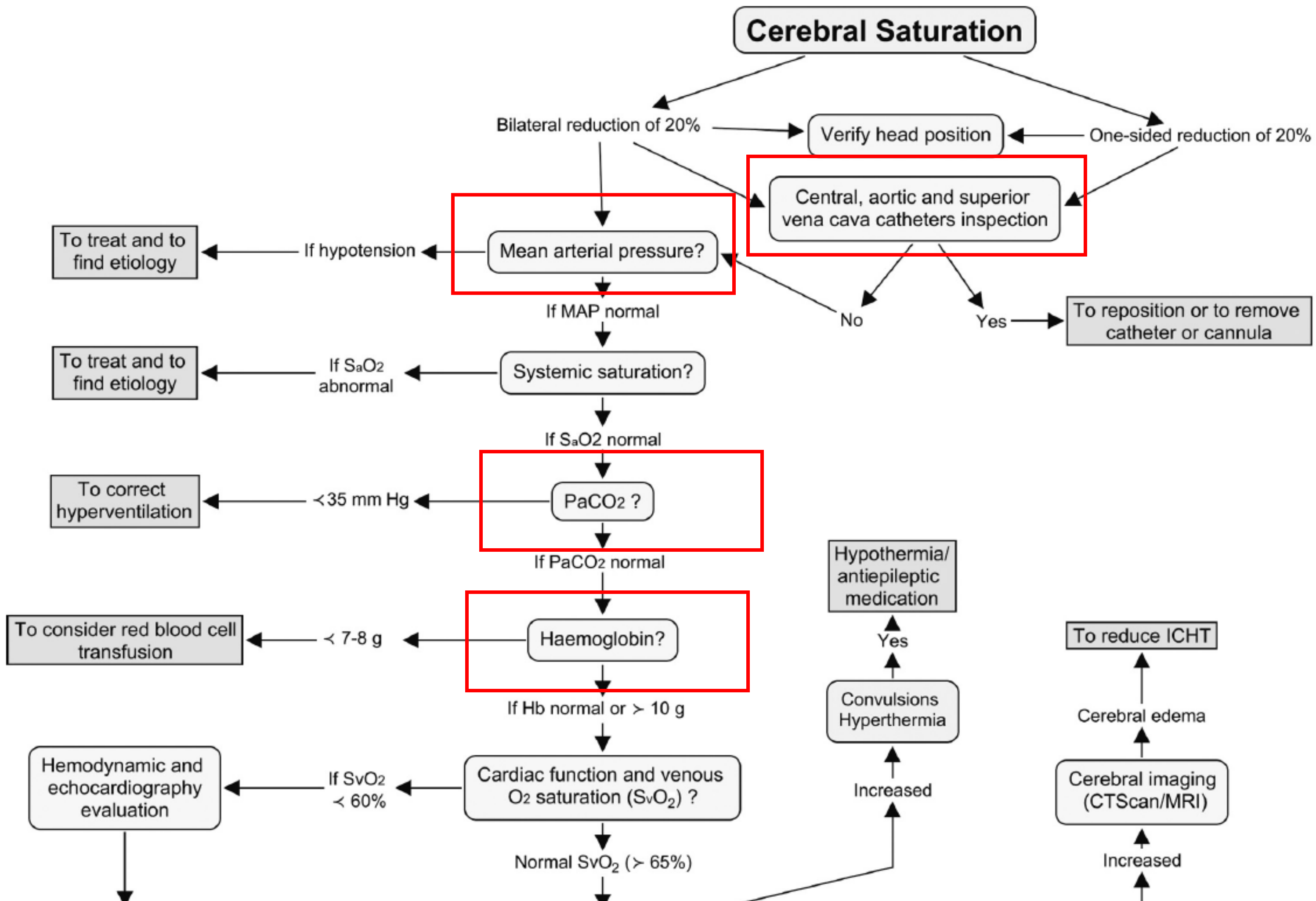


Figure 3. Aortic dissection with unilateral cerebral perfusion via innominate artery. Immediate profound decrease in left rSO_2 followed by perfusion via left carotid artery cannula with restoration of left rSO_2. 1, induction of anesthesia; 2, onset of CPB; 3, cooling on CPB; 4, 18°C onset SCP via innominate artery; 5, profound left desaturation; 6, perfusion via left carotid cannula. This unilateral desaturation is most probably because of incomplete circle of Willis.



Unrecognized venous outflow obstruction

Figure 4. Brain desaturation during cardiac transplantation. (A) A reduction down to 43% in brain saturation was observed. (B) Despite adequate mean arterial pressure (from radial and femoral transducers) during cardiopulmonary bypass, the desaturation was associated with an increase in the left internal jugular vein (LIJV) pressure of 65 mm Hg. At that point, the cardiothoracic surgeon decided to reposition the superior vena cava (SVC) cannula that was occluding cerebral venous return. The brain oximetry value increased. (C) The LIJV pressure decreased to 12 mm Hg.



CAS meeting 2010: Denault and colleagues report >90% success restoring basal ScO2

Figure 2. … MAP, mean arter…

Directed Interventions: MOMM

Monitoring Brain Oxygen Saturation During Coronary Bypass Surgery: A Randomized, Prospective Study

John M. Murkin, MD, FRCPC*
Sandra J. Adams, RN*
Richard J. Novick, MD, FRCSC§
Mackenzie Quantz, MD, FRCPS§
Daniel Bainbridge, MD, FRCPC*
Ivan Iglesias, MD*

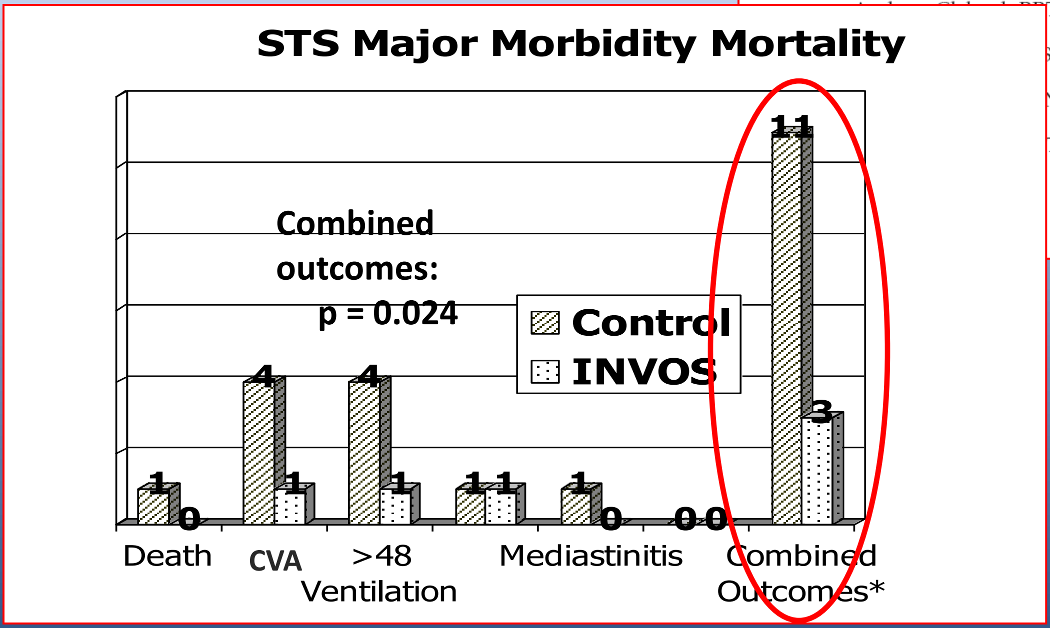
BACKGROUND: Cerebral deoxygenation is associated with various adverse systemic outcomes. We hypothesized, by using the brain as an index organ, that interventions to improve cerebral oxygenation would have systemic benefits in cardiac surgical patients.

METHODS: Two-hundred coronary artery bypass patients were randomized to either intraoperative cerebral regional oxygen saturation (rSO_2) monitoring with active display and treatment intervention protocol (intervention, $n = 100$), or underwent blinded rSO_2 monitoring (control, $n = 100$). Predefined clinical outcomes were assessed by a blinded observer.

RESULTS: Significantly more patients in the control group demonstrated prolonged cerebral desaturation ($P = 0.014$) and longer duration in the intensive care unit ($P = 0.029$) versus intervention patients. There was no difference in overall incidence of adverse complications, but significantly more control patients had major organ morbidity or mortality (death, ventilation >48 h, stroke, myocardial infarction, return for re-exploration) versus intervention group patients ($P = 0.048$). Patients experiencing major organ morbidity or mortality had lower baseline and mean rSO_2, more cerebral desaturations and longer lengths of stay in the intensive care unit and postoperative hospitalization, than patients without such complications. There was a significant ($r^2 = 0.29$) inverse correlation between intraoperative rSO_2 and duration of postoperative hospitalization in patients requiring ≥10 days postoperative length of stay.

CONCLUSION: Monitoring cerebral rSO_2 in coronary artery bypass patients avoids profound cerebral desaturation and is associated with significantly fewer incidences of major organ dysfunction.

(Anesth Analg 2007;104:51–8)



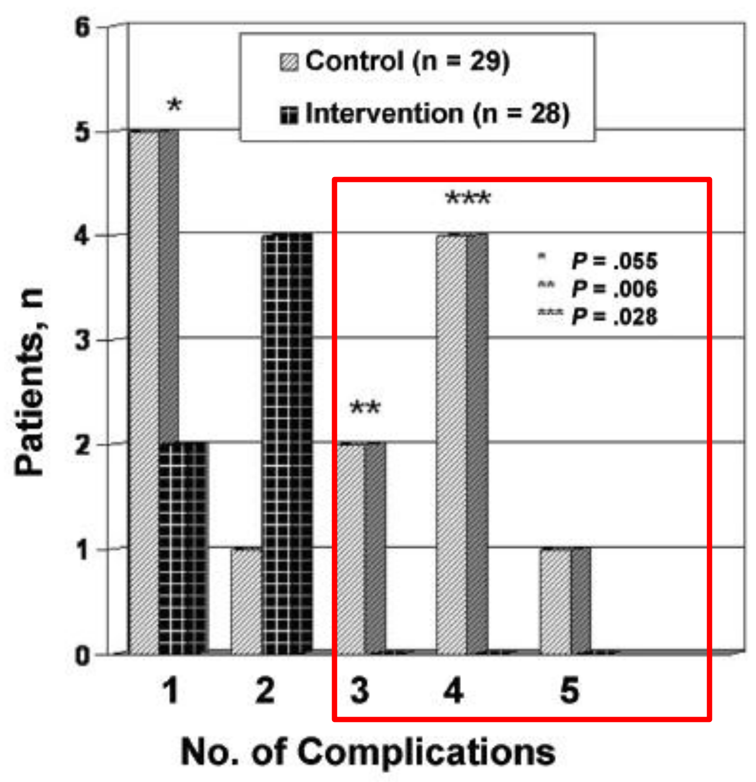
Directed Interventions: Diabetic MOMM

The Heart Surgery Forum #2010-1065
13 (6), 2010
doi: 10.1532/HSF98.20101065

Online address: http://cardenjennings.metapress.com

Monitoring Brain Oxygen Saturation During Coronary Bypass Surgery Improves Outcomes in Diabetic Patients: A Post Hoc Analysis

ms, RN,[1]
nzie, MD
e, and [2]Surg



Post hoc analysis of incidence of complications in diabetic patients in the control and intervention groups.

Table 3. Thirty-Day Postoperative Morbidity and Mortality in All Diabetic Patients*

	Control (n = 29)	Intervention (n = 28)	P
Myocardial infarction, n	1	1	.745
Postoperative IABP use, n	2	2	.681
New-onset stroke, n†	1	0	.508
Sternal infection, n	5	0	.028
Mediastinitis, n†	1	0	.508
Arrhythmia requiring treatment, n	1	0	.508
Reoperation for bleeding, n†	0	1	.491
Surgical reintervention, n†	1	0	.508
Renal failure requiring dialysis, n†	0	0	1.0
Death, n†	0	0	1.0
Ventilation time, min	1096 ± 1778	649 ± 313	.097
Ventilation time >24 h, n	2	0	.254
Ventilation time >48 h, n†	2	0	.254
ICU time, d	2.8 ± 4.1	1.4 ± 1.0	.045
ICU time >2 d, n	6	1	.056
ICU time >5 d, n	2	0	.254
Total no. of ICU days	80	39	
Length of stay, d	8.2 ± 6.1	5.7 ± 1.7	.036
Length of stay ≥7 d, n	8	2	.044
Length of stay ≥10 d, n	5	2	.225
Readmission to hospital within 30 d, n	4	3	.520
Patients ≥1 complication, n	13	6	.055
Patients ≥2 complications, n	7	0	.006
MOMM, n†	4	1	.187
No. of events/patients, n	34/13	9/6	

*Data are categorical or presented as the mean ± SD. IABP indicates intra-aortic balloon pump; ICU, intensive care unit; MOMM, major-organ morbidity and mortality.

†Indicates variables comprising MOMM, as derived from Society of Thoracic Surgeons database analysis [Shroyer 2003].

Directed Interventions: delirium

Interactive CardioVascular and Thoracic Surgery Advance Access published July 9, 2012

Interactive CardioVascular and Thoracic Surgery 0 (2012) 1–7
doi:10.1093/icvts/ivs317

ORIGINAL ARTICLE

CARDIAC GENERAL

Improved perioperative neurological monitoring of coronary artery bypass graft patients reduces the incidence of postoperative delirium: the Haga Brain Care Strategy

Wijnand A.C. Palmbergen[a], Agnes van Sonderen[a], Ali M. Keyhan-Falsafi[b], Ruud
and Ron Wolterbeek[c]

[a] Department of Neurology and Clinical Neurophysiology, Haga Teaching Hospitals, The Hague, The Netherlands
[b] Department of Cardiosurgery, Haga Teaching Hospitals, The Hague, The Netherlands
[c] Department of Medical Statistics and Bioinformatics, Leiden, The Netherlands

* Corresponding author. Department of Neurology, Haga Teaching Hospitals, Leyweg 275, 2545 CH The Hague, The Netherlands.
e-mail: r.keunen@hagaziekenhuis.nl (R.W.M. Keunen).

Received 9 December 2011; received in revised form 7 June 2012; accepted 18 June 2012

Abstract

OBJECTIVES: Postoperative delirium is a major cause of morbidity and mortality after cardiovascular sur
operative delirium include poor cerebral haemodynamics and perioperative cerebral desaturations. Our ai
operative delirium rate by using a new prevention strategy called the Haga Brain Care Strategy. This study e
implementation of the Haga Brain Care Strategy to reduce the postoperative delirium rate after elective c
(CABG) procedures. The primary endpoint was the postoperative delirium rate, and the secondary endpoi
the intensive care unit.

METHODS: The Haga Brain Care Strategy consisted of the conventional screening protocol for delirium wit
tive transcranial Doppler examinations, perioperative cerebral oximetry, modified Rankin score, delirium r
duplex examination of the carotid arteries. In case of poor preoperative haemodynamics, the cerebral bloo
mized by angioplasty or the patient was operated on under mild hypothermic conditions. Perioperative c
outside the normal range resulted in intervention to restore cerebral oxygenation. Cerebral oximetry was c
regained consciousness. Patients undergoing elective CABG procedures in 2010 were compared with patie
bypass graft procedures in 2009 who had not been exposed to additional Haga Brain Care Strategy assessme

RESULTS: A total of 233 and 409 patients were included in 2009 and 2010, respectively. The number of pa
transcranial Doppler examinations, cerebral oximetry or both (Haga Brain Care Strategy) were 262 (64.
(34.0%), respectively. The overall rate of postoperative delirium decreased from 31 (13.3%) in 2009 to 30
A binary logistic regression model showed that the Haga Brain Care Strategy was an independent predictor
oping a postoperative delirium (odd ratio = 0.37, $P = 0.021$).

CONCLUSIONS: With the implementation of the Haga Brain Care Strategy in 2010, a reduction of the incide
ium in patients undergoing elective CABG procedures was observed. In addition, the length of stay in the int
overall tendency to decline. The limited number of observations and the current study design do not all
Haga Brain Care Strategy but the data support the idea that a sophisticated preoperative assessment of ce
perioperative monitoring of cerebral oximetry reduce the incidence of the postoperative delirium in CABG s

Keywords: Postoperative delirium • Cerebral oximetry • Transcranial Doppler • Coronary artery bypass graftin

OPEN ACCESS Freely available online

PLoS one

Optimised Anaesthesia to Reduce Post Operative Cognitive Decline (POCD) in Older Patients Undergoing Elective Surgery, a Randomised Controlled Trial

Clive Ballard[1]*, Emma Jones[1], Nathan Gauge[1], Dag Aarsland[2,3], Odd Bjarte Nilsen[3], Brian K. Saxby[4], David Lowery[5], Anne Corbett[6], Keith Wesnes[7], Eirini Katsaiti[1], James Arden[8], Derek Amaoko[8], Nicholas Prophet[8], Balaji Purushothaman[8], David Green[8]

1 Wolfson Centre for Age-Related Diseases, King's College London, London, United Kingdom, **2** Department of Neurobiology, Ward and Society, Karolinska Institute, Stockholm, Sweden, Norway, **3** Faculty of Science and Technology, Stavanger University Hospital, Stavanger, Norway, **4** Institute of Ageing and Health, University of Newcastle, Newcastle, United Kingdom, **5** Research Department of Primary Care and Population Health, University College London, London, United Kingdom, **6** Research Directorate, Alzheimer's Society (UK), London, United Kingdom, **7** Centre for Human Psychopharmacology, Swinburne University, Melbourne, Australia, **8** Department of Anaesthetics, King's College Hospital, London, United Kingdom

Abstract

Background: The study determined the one year incidence of post operative cognitive decline (POCD) and evaluated the effectiveness of an intra-operative anaesthetic intervention in reducing post-operative cognitive impairment in older adults (over 60 years of age) undergoing elective orthopaedic or abdominal surgery.

Methods and Trial Design: The design was a prospective cohort study with a nested randomised, controlled intervention trial, using intra-operative BiSpectral index and cerebral oxygen saturation monitoring to enable optimisation of anaesthesia depth and cerebral oxygen saturation in older adults undergoing surgery.

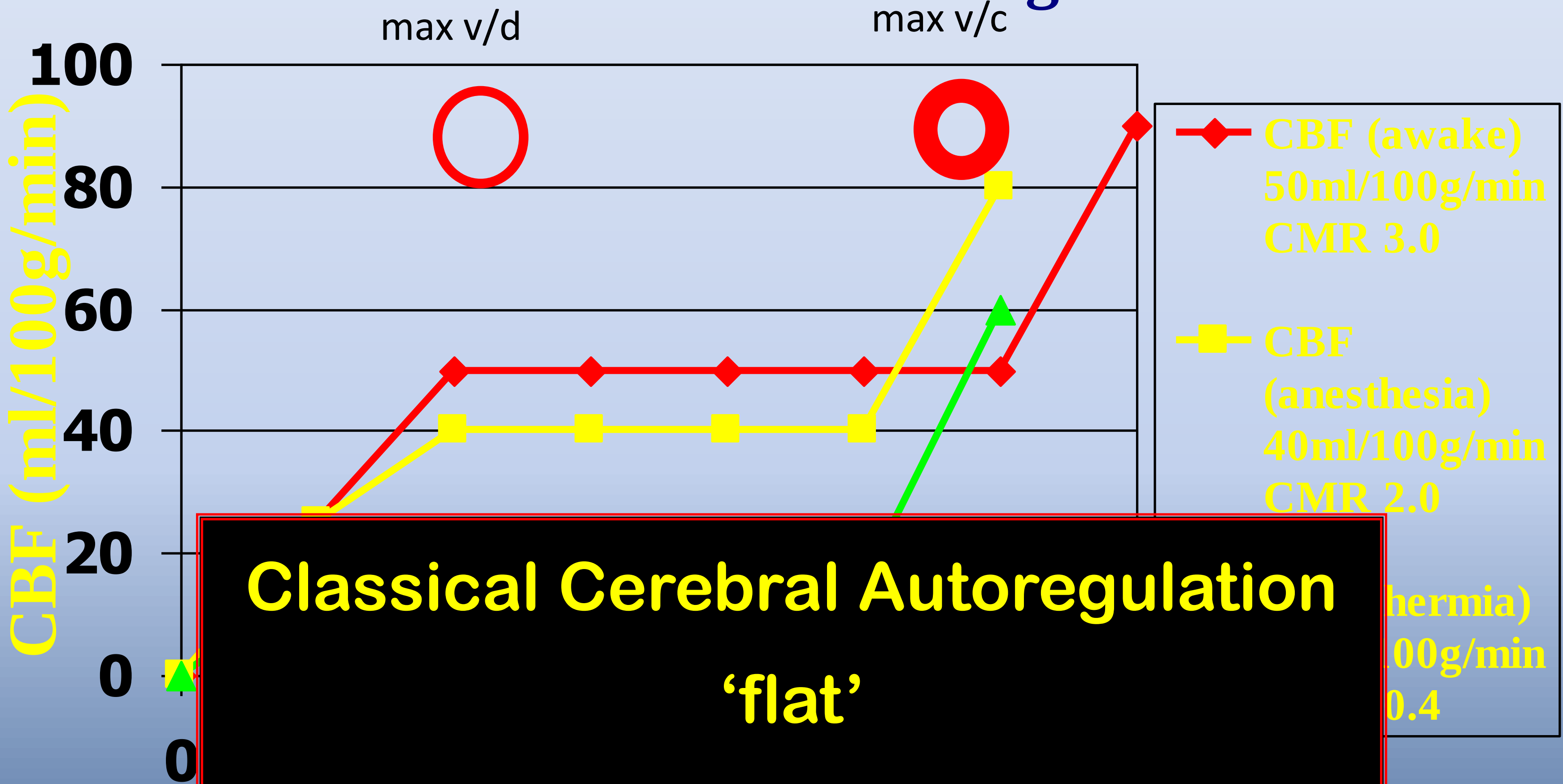
Results: In the 52 week prospective cohort study (192 surgical patients and 138 controls), mild ($\chi^2 = 17.9$ $p < 0.0001$), moderate ($\chi^2 = 7.8$ $p = 0.005$) and severe ($\chi^2 = 5.1$ $p = 0.02$) POCD were all significantly higher after 52 weeks in the surgical patients than among the age matched controls. In the nested RCT, 81 patients were randomized, 73 contributing to the data analysis (34 intervention, 39 control). In the intervention group mild POCD was significantly reduced at 1, 12 and 52 weeks (Fisher's Exact Test $p = 0.018$, $\chi^2 = 5.1$ $p = 0.02$ and $\chi^2 = 5.9$ $p = 0.015$), and moderate POCD was reduced at 1 and 52 weeks ($\chi^2 = 4.4$ $p = 0{\cdot}037$ and $\chi^2 = 5.4$ $p = 0.02$). In addition there was significant improvement in reaction time at all time-points (Vigilance Reaction Time MWU $Z = -2.1$ $p = 0.03$, MWU $Z = -2.7$ $p = 0.004$, MWU $Z = -3.0$ $p = 0.005$), in MMSE at one and 52 weeks (MWU $Z = -2.9$ $p = 0.003$, MWU $Z = -3.3$ $p = 0.001$), and in executive function at 12 and 52 weeks (Trail Making MWU $Z = -2.4$ $p = .0018$, MWU $Z = -2.4$ $p = 0.019$).

Conclusion: POCD is common and persistent in older adults following surgery. The results of the nested RCT indicate the potential benefits of intra-operative monitoring of anaesthetic depth and cerebral oxygenation as a pragmatic intervention to reduce post-operative cognitive impairment.

Trial Registration: Controlled-Trials.com ISRCTN39503939

Cerebral Oximetry?

Cerebral Pressure Autoregulation



Classical Cerebral Autoregulation

'flat'

Dynamic Autoregulation

'fluctuant'

ie. microcirculatory dynamics

Dynamic Autoregulation: ‘fluctuant’

ie. microcirculatory dynamics

- Instantaneous correlation between TCD ΔMCA-FV vs ΔICP
- Modification: Δ NIRS vs Δ MAP
- Moving average (300 sec)
- Probability coefficient: Ø – 1.0

    ie. no correlation vs complete correlation

    (presence vs absence autoregulation)

- Functional cutoff: < 0.4

DAR: Very sensitive, variable onset/duration

Dynamic Cerebral Autoregulation

Continuous T
Autoregula

Ken M. Brady, MD;
Marek Czosnyka, PhD; R.

Background and Purpose—As
actively optimizing cerebr
autoregulatory vasoreactivity
near-infrared spectroscopic m
Methods—Piglets were made pr
vena cava, and the breakpoint
index (COx) was determined
waveforms during 300-secon
with the same parameters (LI
Results—An increase in the co
indicative of a pressure-passiv
This COx had 92% sensitivit
attributable to hypotension
characteristics curve for the C
to the CPP at which they we
Conclusions—The COx is sensi
tool for determining optimal

Key Words: autoregu

British Journal of Anaesthesia **109** (3): 391–8 (2012)
Advance Access publication 1 June 2012 · doi:10.1093/bja/aes148

BJA

NEUROSCIENCES AND NEUROANAESTHESIA

Risks for impaired cerebral autoregulation during cardiopulmonary bypass and postoperative stroke

M. Ono[1], B. Joshi[2], K. Brady[3], R. B. Easley[3], Y. Zheng[4], C. Brown[2], W. Baumgartner[1] and C. W. Hogue[2]*

[1] Division of Cardiac Surgery, Department of Surgery and [2] Department of Anesthesiology and Critical Care Medicine, The Johns Hopkins University School of Medicine, Baltimore, MD, USA
[3] Department of Pediatrics and Anesthesiology, Baylor College of Medicine, Texas Children's Hospital, Huston, TX, USA
[4] Department of Anesthesiology, The First Affiliated Hospital, School of Medicine, Zhejiang University, Hangzhou, China
* Corresponding author: The Johns Hopkins Hospital, 600 North Wolfe Street, Tower 711, Baltimore, MD 21287, USA.
E-mail: chogue2@jhmi.edu

Editor's key points

- Impaired cerebral autoregulation may predispose to ischaemic brain injury.
- The authors found that impaired cerebral autoregulation occurred in 20% of patients duirng cardiopulmonary bypass.
- An autoregulation index measured with near infrared spectroscopy was able to identify impaired autoregulation.
- Impaired autoregulation was more common in patients developing stroke after surgery than those without a stroke.

Background. Impaired cerebral autoregulation may predispose patients to cerebral hypoperfusion during cardiopulmonary bypass (CPB). The purpose of this study was to identify risk factors for impaired autoregulation during coronary artery bypass graft, valve surgery with CPB, or both and to evaluate whether near-infrared spectroscopy (NIRS) autoregulation monitoring could be used to identify this condition.

Methods. Two hundred and thirty-four patients were monitored with transcranial Doppler and NIRS. A continuous, moving Pearson's correlation coefficient was calculated between mean arterial pressure (MAP) and cerebral blood flow (CBF) velocity, and between MAP and NIRS data, to generate the mean velocity index (Mx) and cerebral oximetry index (COx), respectively. Functional autoregulation is indicated by an Mx and COx that approach zero (no correlation between CBF and MAP); impaired autoregulation is indicated by an Mx and COx approaching 1. Impaired autoregulation was defined as an Mx $\geq$0.40 at all MAPs during CPB.

Results. Twenty per cent of patients demonstrated impaired autoregulation during CPB. Based on multivariate logistic regression analysis, time-averaged COx during CPB, male gender, Pa_{CO_2}, CBF velocity, and preoperative aspirin use were independently associated with impaired CBF autoregulation. Perioperative stroke occurred in six of 47 (12.8%) patients with impaired autoregulation compared with five of 187 (2.7%) patients with preserved autoregulation (P=0.011).

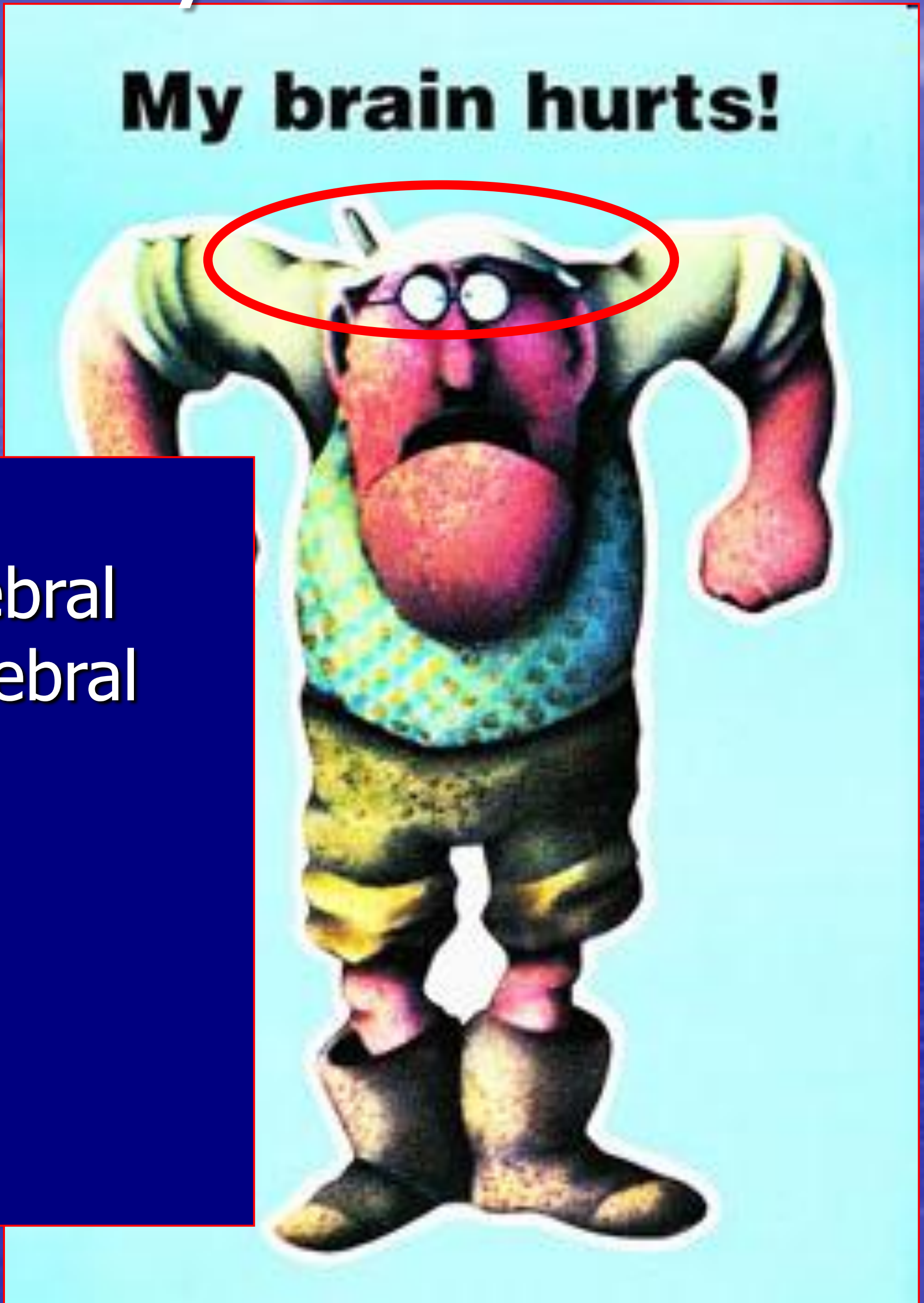
Conclusions. Impaired CBF autoregulation occurs in 20% of patients during CPB. Patients with impaired autoregulation are more likely than those with functional autoregulation to have perioperative stroke. Non-invasive monitoring autoregulation may provide an accurate means to predict impaired autoregulation.
Clinical trials registration. www.clinicaltrials.gov (NCT00769691).

Keywords: cardiac surgery; cardiopulmonary bypass; cerebral autoregulation; stroke

Accepted for publication: 29 February 2012

Issues:

Cerebral Oximetry: Extracerebral



Cerebral NIRS s

85-95% intracerebral

5-15% extracerebral

Confounds:

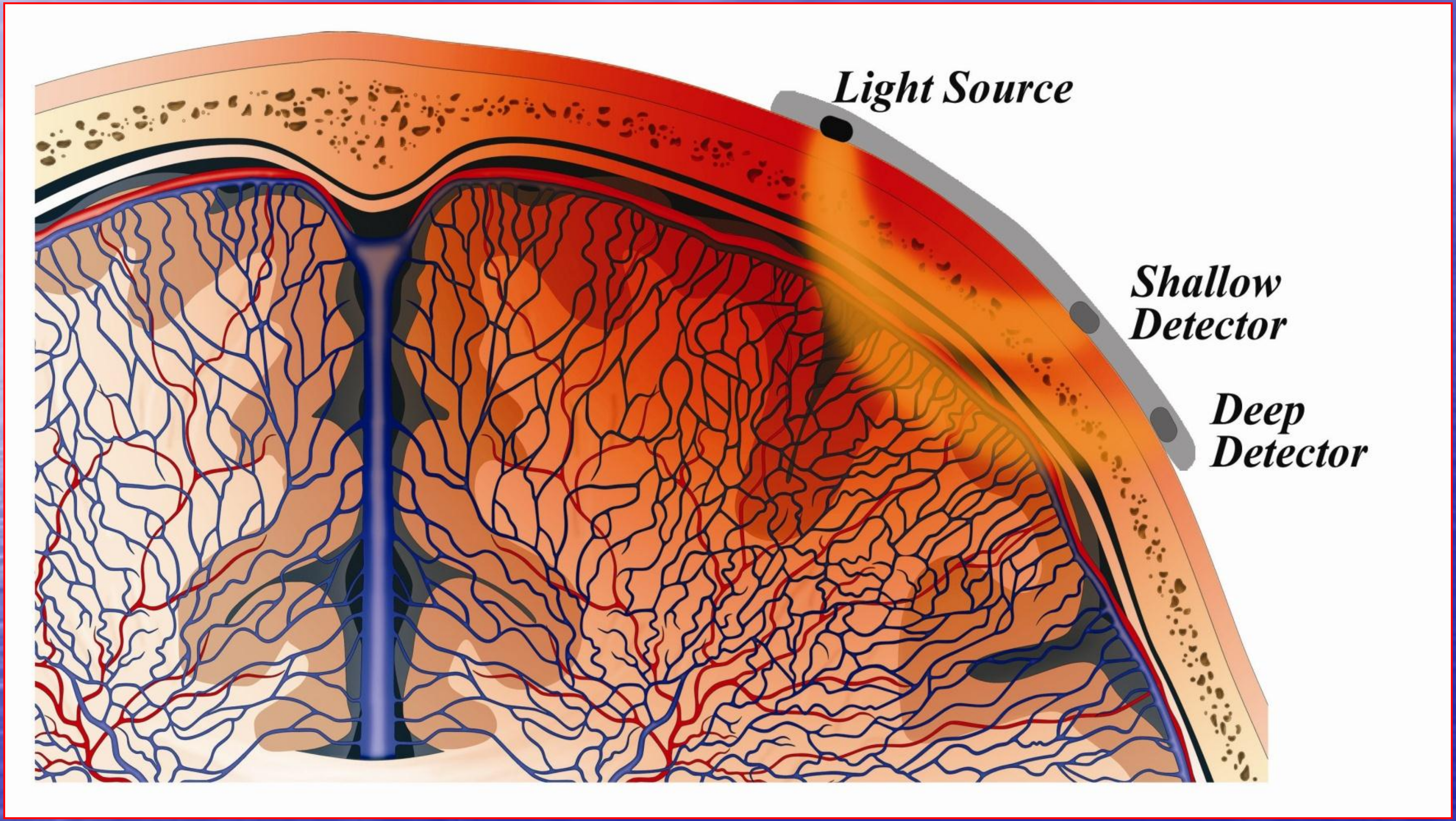
Scalp edema,

Hematoma

SDH

Frontal sinus

Cerebral Oximetry: Extracerebral Contamination



Elliptical photon path depth approx 1/3 receiver/transmitter separation

Subtraction algorithm to separate superficial from deep tissue

Cerebral Oximetry: Extracerebral Contamination

Impact of Extracranial Contamination on Regional Cerebral Oxygen Saturation

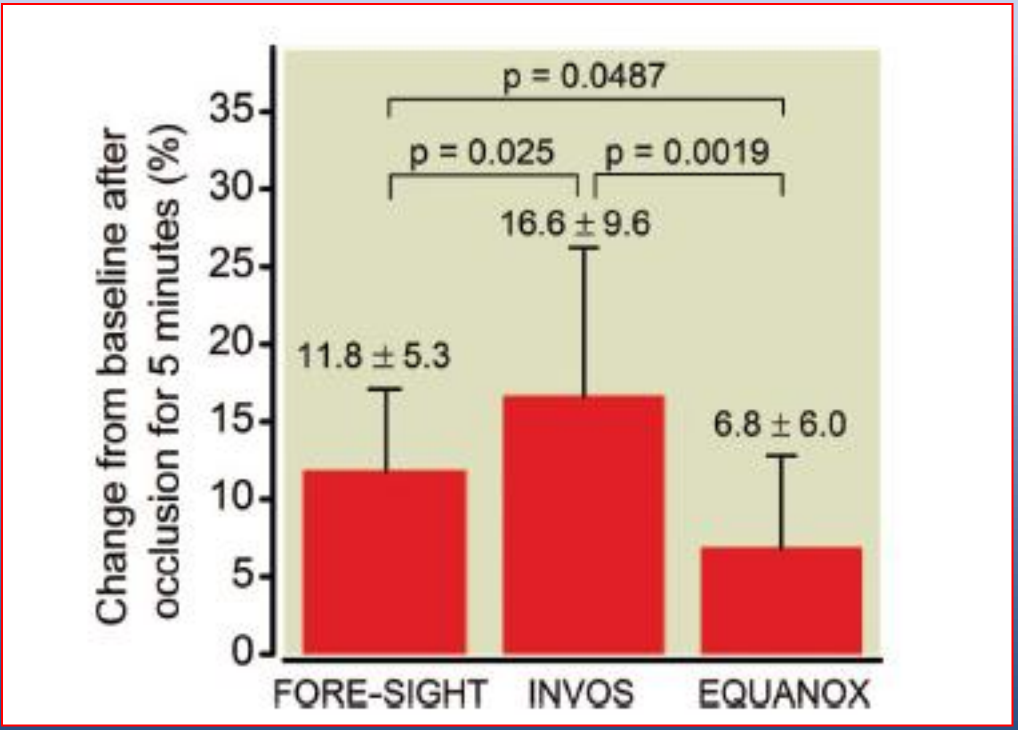
A Comparison of Three Cerebral Oximetry Technologies

Sophie N. Davie, B.Sc.,* Hilary P. Grocott, M.D., F.R.C.P.C.†

Anesthesiology 2012; 116:834 – 40

"…a significant reduction in regional cerebral oxygen saturation measurements in all three NIRS devices studied"

"Extracerebral contamination appears to significantly affect NIRS measurements of cerebral oxygen saturation"



Cerebral Oximetry: Extracerebral Contamination

British Journal of Anaesthesia **107** (2): 209–17 (2011)
Advance Access publication 3 June 2011 · doi:10.1093/bja/aer150

BJA

NEUROSCIENCES AND NEUROANAESTHESIA

Effect of phenylephrine and ephedrine bolus treatment on cerebral oxygenation in anaesthetized patients

L. Meng[1*], M. Cannesson[1], B. S. Alexander[1], Z. Yu[2], Z. N. Kain[1], A. E. Cerussi[3], B. J. Tromberg[3] and W. W. Mantulin[3]

neurocritical care society Neurocrit Care (2010) 12:17–23
DOI 10.1007/s12028-009-9313-x

ORIGINAL ARTICLE

Phenylephrine but not Ephedrine Reduces Frontal Lobe Oxygenation Following Anesthesia-Induced Hypotension

Peter Nissen · Patrice Brassard · Thomas B. Jørgensen · Niels H. Secher

Neurocrit Care (2010) 12:17–23

Cerebral Oximetry: Extracerebral Contamination

Cutaneous Vasoconstriction Affects Near-infrared Spectroscopy Determined Cerebral Oxygen Saturation during Administration of Norepinephrine

Henrik Sørensen, M.Sc.,* Niels H. Secher, M.D., D.M.Sc.,† Christoph Siebenmann, M.Sc.,‡ Henning B. Nielsen, M.D., D.M.Sc.,§ Matthias Kohl-Bareis, Ph.D.,|| Carsten Lundby, Ph.D.,# Peter Rasmussen, Ph.D.**

Anesthesiology, V 117 • No 2 August 2012

"skin oxygenation contributes about 30% to the NIRS signal…"

"…nevertheless spatial resolved NIRS is able to detect cerebral deoxygenation associated with hyperventilation and systemic hypoxic exposure…"

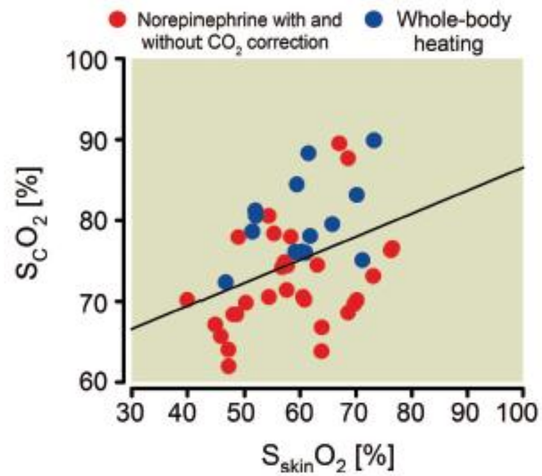
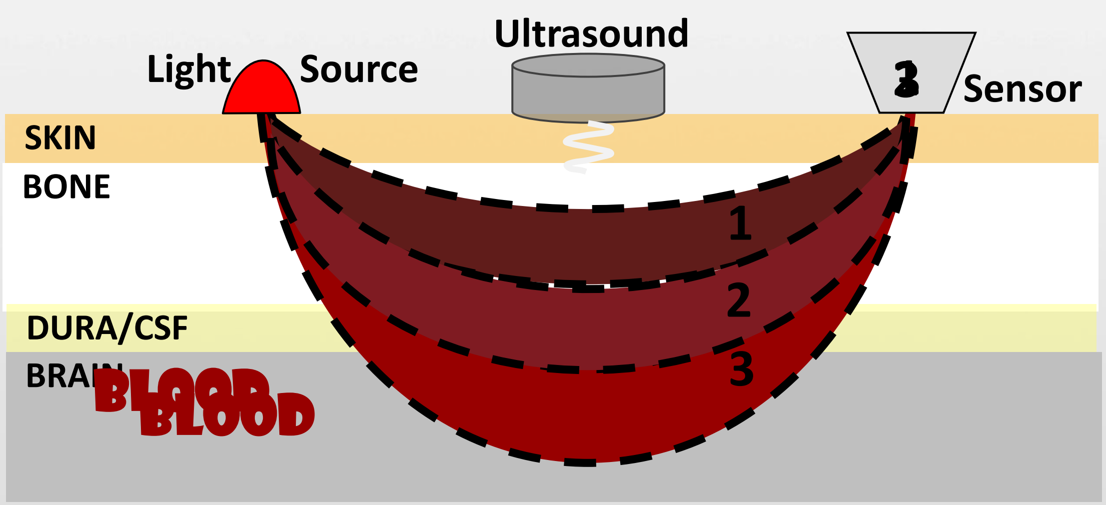


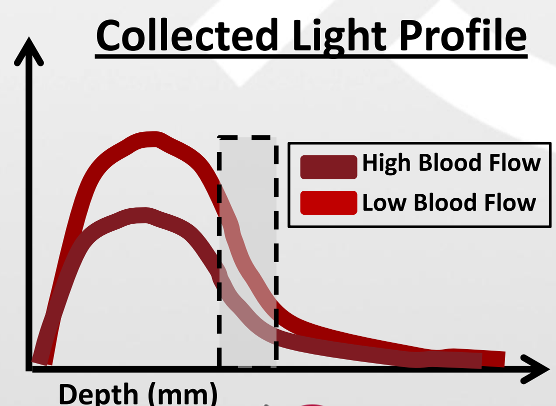
Fig. 3. Correlation of skin oxygen saturation and cerebral oxygen saturation during administration of norepinephrine with and without P_{ETCO_2} correction, represented as *red dots*, and whole-body heating presented as *blue dots*. For all data in the plot, r = 0.64 ($P < 0.0001$), with r = 0.6 ($P < 0.0001$) for administration of norepinephrine and r = 0.4 ($P = 0.15$) for whole-body heating. sco_2 = cerebral oxygen saturation; $s_{skin}O_2$ = skin oxygen saturation.

What’s New?

UTLight technology

- Photons that travel through the path of the ultrasound wave are “tagged” and can be identified upon detection, by detecting an artificial Doppler shift induced by the moving ultrasound waves
- Ultrasound waves are directional, and travel slowly.
- Thus the path of the photons is measured and not assumed to be equal – The profile of the light is measured along the ultrasound path
- Oxygen saturation is calculated from the ratio of three different profiles (at different wavelengths), at a certain depth.
- Flow is calculated from the flow induced Doppler shift of the light profile.





New: Ultrasound Tagged Cerebral NIRS

Acousto-optic Coupling

neurocritical care society Neurocrit Care (2012) 17:139–145
DOI 10.1007/s12028-012-9720-2

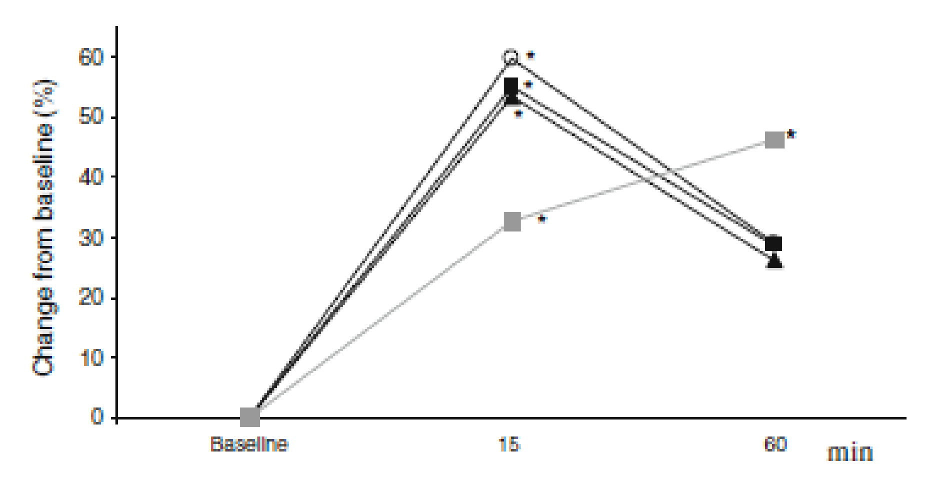
TAKE NOTICE TECHNOLOGY

A New Technology for Detecting Cerebral Blood Flow: A Comparative Study of Ultrasound Tagged NIRS and ^{133}Xe-SPECT

Henrik W. Schytz · Song Guo · Lars T. Jensen · Moshe Kamar · Asaph Nini · Daryl R. Gress · Messoud Ashina

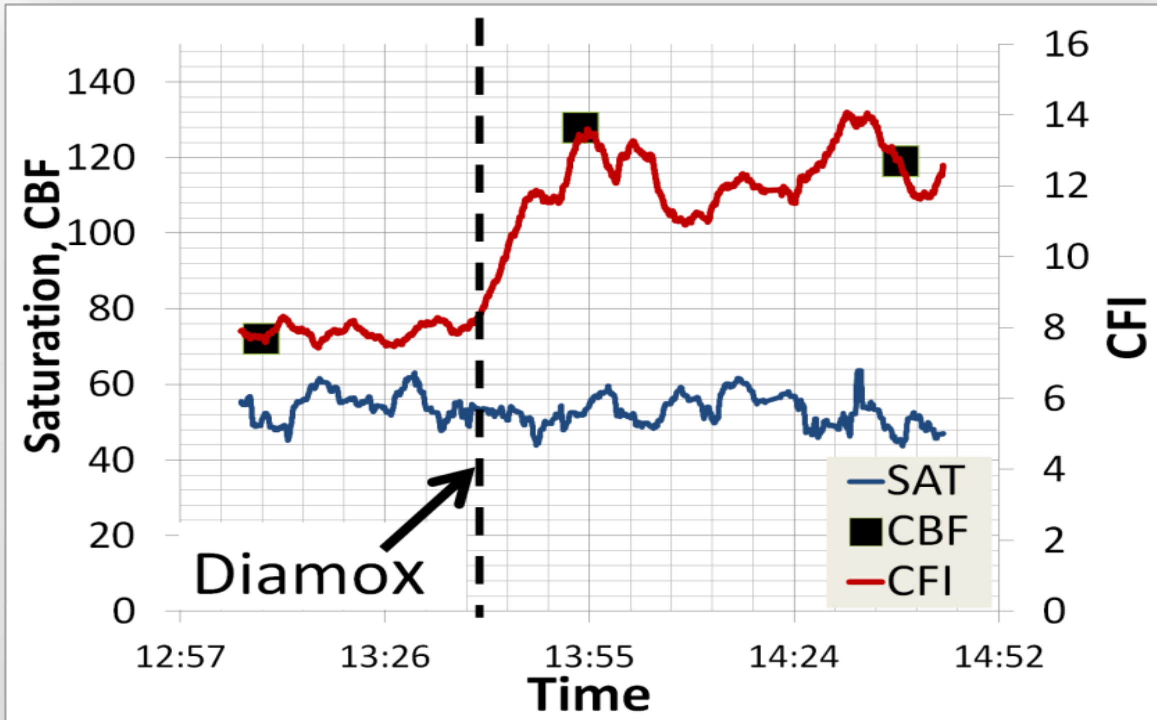
Neurocrit Care (2012) 17:139–145

- UT-NIRS allows measures of microcirculatory CBF
- Doppler U/S focusing removes extracerebral signal



Oximetry and Flow Following Acetazolamide

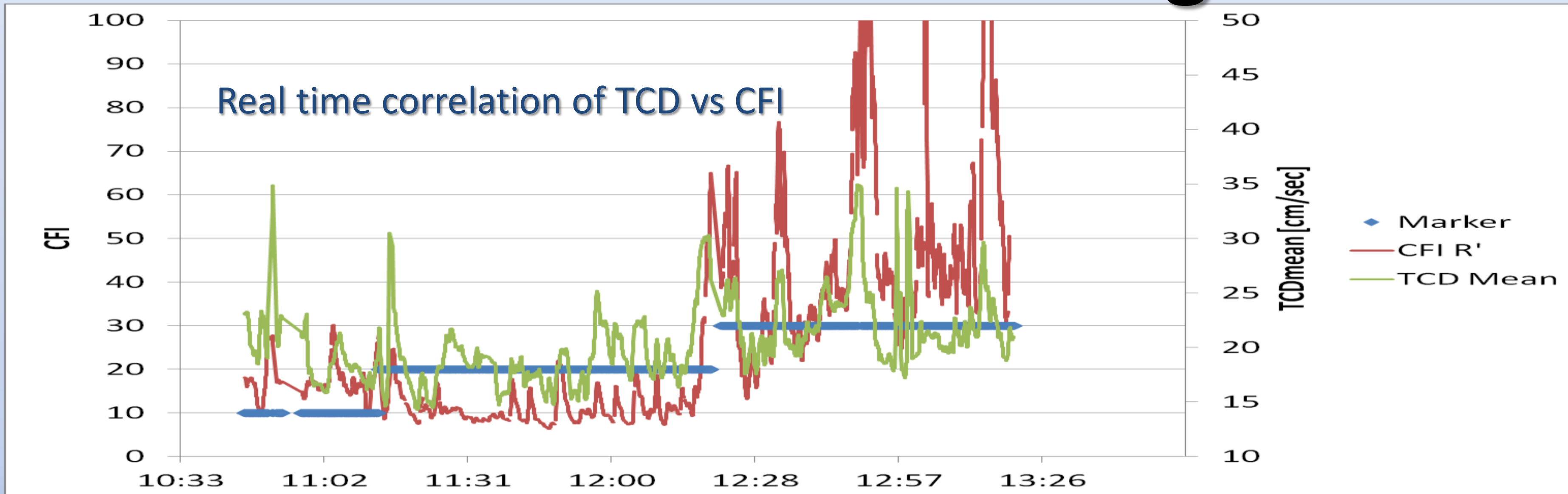
Concurrent measurement with CerOx and ^{133}Xe SPECT

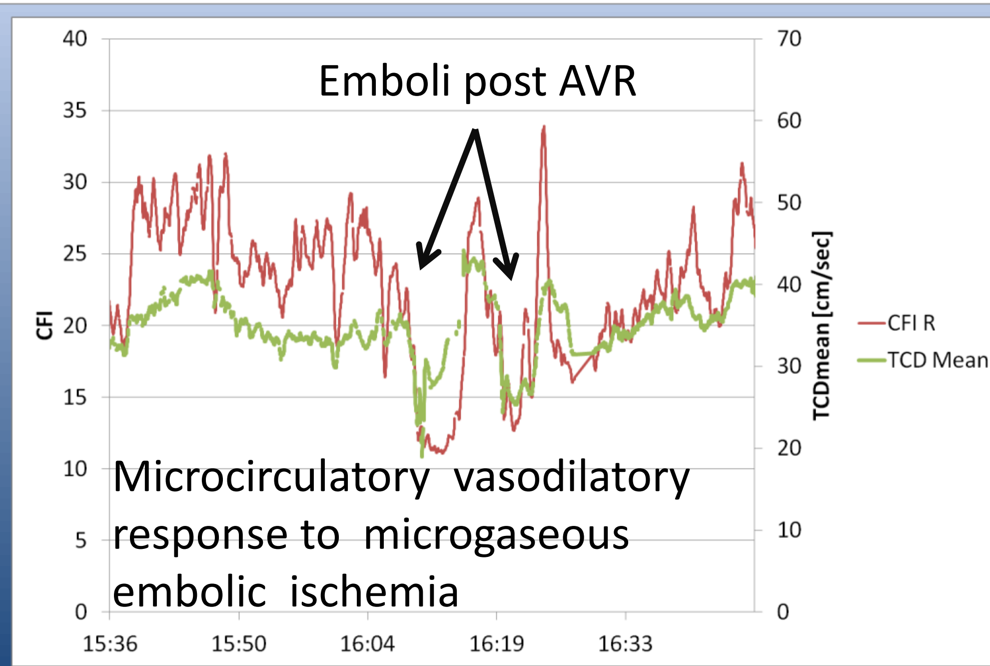


CONFIDENDIAL


60

CFI: Direct NIRS Monitoring of CBF





Murkin JM, et al
UWO, London, ON

Summary

- Cerebral oximetry reflects oxygen saturation in high risk/'protected' organ: brain
- If brain sats low, either:

  global hypoperfusion

  or

  localized brain ischemia
- Cerebral oximetry allows further preoperative quantification of risk/optimization
- 'false' positives d/t extracerebral tissue

  v/c (phenylephrine) may exacerbate
- → newer technology (precise ScO2 and CBF)


Thank you
Maxwelton Braes, Harrington, Ontario