ARISTOTLE UNIVERSITY OF THESSALONIKI

ΠΑΡΑΚΟΛΟΥΘΗΣΗ του ΚΝΣ στη ΜΕΝΝ
CNS monitoring in the NICU

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ΘΕΜΑΤΑ

- Βασικές τεχνικές παρακολούθησης ΚΝΣ
- Πλεονεκτήματα-μειονεκτήματα
- Κλινικά παραδείγματα
- Συμπεράσματα

Προς τι η ΚΝΣ παρακολούθηση ?

- Η **Νευρολογική Εξέταση** είναι αναξιόπιστη & υποκειμενική
- **Νεογνική Εγκεφαλοπάθεια (ΝΕ)**: εκτίμηση βαρύτητας προσβολής εγκεφάλου/λοιπών οργάνων, διάγνωση/αντιμετώπιση σπασμών, πρόγνωση

Harvey-Jones K et al 2021

- **ΥΙΕ**: αναγνώριση υποψήφιων για ΥΘ, κατευθύνουν την θεραπεία, ανταπόκριση στην ΥΘ
- Η παρακολούθηση του ΚΝΣ είναι ζωτικής σημασίας για την διασφάλιση της **υγείας** του εγκεφάλου
- Τελικός στόχος η **επιβίωση χωρίς νευρολογικές/νευροαναπτυξιακές δι-χές**
- **Υπάρχουν** διαθέσιμα εργαλεία

The Vulnerable Newborn Brain

Perinatal Brain Injury Novak et al. Clin Perinatol 2018

Aspects of common etiologies of perinatal brain injury

Perinatal Brain Injury Type	Gestational Age	Mechanism of Injury	Neuropathologic Findings	Preventive Measures
Hypoxic–ischemic encephalopathy	Late preterm, term (>35 wk) 1-2‰	Hypoxia–ischemia leading to common pathway of injury	Diffuse gray and white matter injury affecting most vulnerable regions of brain	Therapeutic hypothermia Postnatal erythropoietin
Intraventricular hemorrhage	Preterm (primarily <32 wk) <28 wk: 31-36%, severe IVH 17%	Injury to fragile premature vessels of germinal matrix	Germinal matrix bleeding with extension into ventricular system	Antenatal corticosteroids Delayed umbilical cord clamping
Periventricular leukomalacia	Preterm (primarily <32 wk)	Hypoperfusion to border zone regions of brain	Periventricular focal necrosis, cystic formation, or diffuse white matter injury	None
Perinatal stroke	Preterm, term 2,5‰	Regional ischemia owing to arterial or sinovenous occlusion or hemorrhagic infarction	Regional infarction owing to vascular occlusion or hemorrhage	None
Cerebral palsy	Preterm, term	Multifactorial, only 10%–20% of cases owing to an intrapartum hypoxic–ischemic event	Clinical syndrome with variable findings depending on underlying etiology	Magnesium sulfate

Novak CM et al. Clin Perinatol 2018

The 4 Pillars of Neuro-Nurturing NICU

- Neuro-Assessment
  - Clinical /pain assessment
  - Metabolic
  - MRI/MRS
  - Ultrasound
  - Follow up care

- Neuro-Monitoring
  - EEG
  - aEEG
  - NIRS

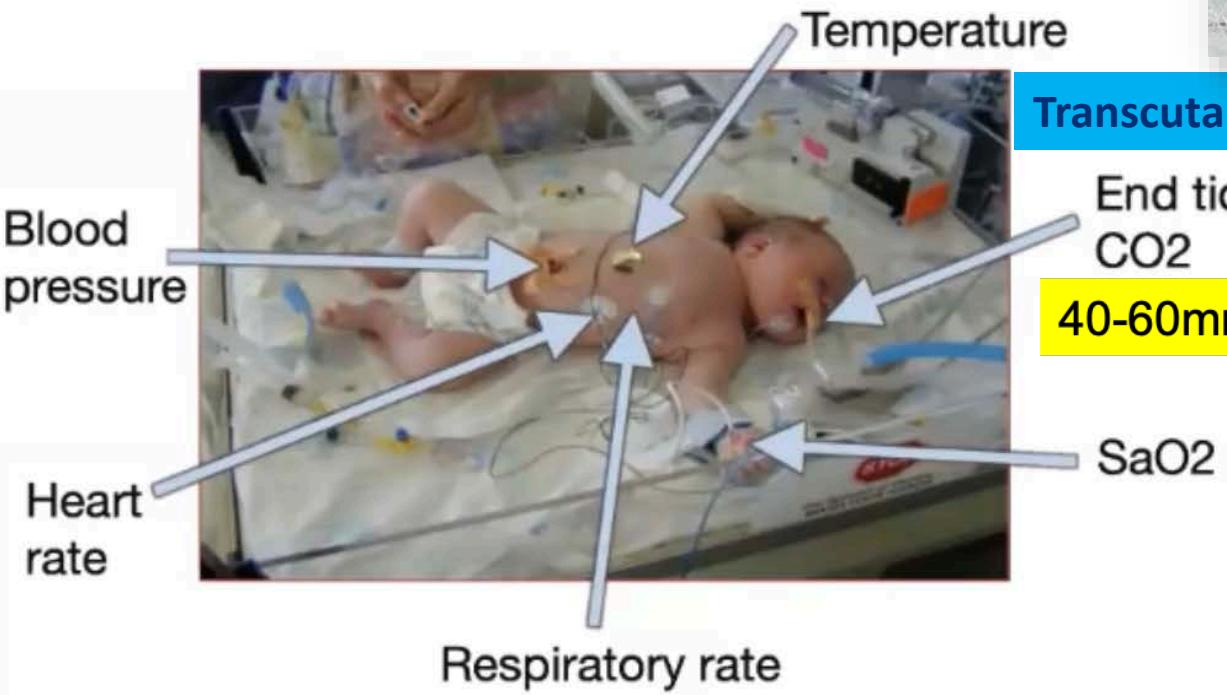
SomatoSensoryEvoked Potentials
VisualEvoked Potentials
BrainstemAuditoryEvokedPotentials

- Neuro-Protection
  - Cooling
  - Medications
  - IVH Bundles (Head position, etc..)

- Neuro-Development
  - Parents
  - Positioning
  - Sensory Environment
  - Sleep
  - Pain/Stress/Separation
  - Nutrition

Shukla et al 2022

What monitoring devices are used for sick neonates in the NICU?



Transcutaneous monitoring

40-60mmHg, pH≥ 7.25

What about the brain?

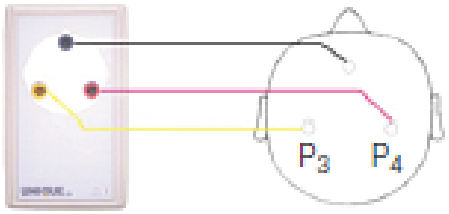
a-EEG
amplitude-integrated Electroencephalography
α-Ηλεκτροεγκεφαλογράφημα

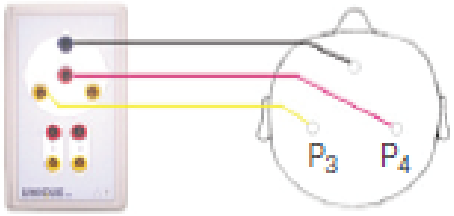
ΤΟΠΟΘΕΤΗΣΗ ΗΛΕΚΤΡΟΔΙΩΝ

6cm/h

Number of electrodes will vary from 3 – 5, dependant on the headbox chosen and aEEG channels to be displayed

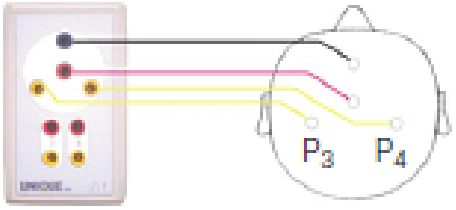
3 Electrodes for Single Channel recording





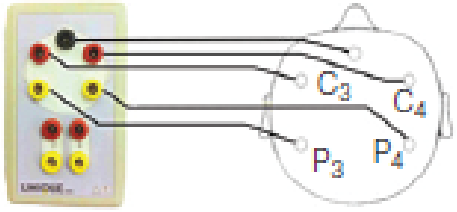
Ground (Black) electrode placed in midline in front of the fontanel. Reference (Red) and Active (Yellow) electrodes placed bi-parietal, 75mm apart evenly spaced from midline P_3/P_4.

4 Electrodes for Dual Channel & Unipolar recording



Ground (Black) electrode placed in midline in front of the fontanel (or shoulder). Reference (Red) electrode should be placed in midline in front of the fontanel. Active (Yellow) electrodes placed bi-parietal, 75mm apart evenly spaced from midline P_3/P_4.

5 Electrodes for Dual Channel & Unipolar recording



Ground (Black) electrode placed in midline front of the fontanel (or shoulder) Reference (Red) electrodes placed bi-parietal, 75mm apart evenly spaced from midline C_3/C_4. Active (Yellow) bi-parietal, 75mm apart evenly spaced from midline P_3/P_4.

Ενδείξεις χρήσης aEEG

ΠΟΙΑ ΝΕΟΓΝΑ;

- Παρακολούθηση και **πρόγνωση** σε **ΥΙΕ**
  - The time to normal trace (TTNT) has prognostic value and is a good predictor of neurodevelopment outcome in term infants with Hypoxic-Ischemic Encephalopathy (HIE) undergoing hypothermic treatment3
  - Monitor aEEG patterns to indicate the presence of sleep wake cycling in preterm infants, which is associated with better outcomes in HIE patients4 and may add value in developmental care

Prognostic value of EEG background during therapeutic hypothermia

The greatest prognostic value of EEG background was not achieved until mid-cooling, highlighting the importance of continuous monitoring or sequential EEGs

A burst-suppression or extremely low voltage EEG was not highly predictive for moderate-severe MRI injury until the second day of life, around the time of mid-cooling

- Νεογνά **μετά από καρδιακή ανακοπή, ανάνηψη**
- Παρακολούθηση και καταγραφή της συχνότητας και έντασης σπασμών
- Παροξυσμικά μη επιληπτικά φαινόμενα
- **Σοβαρή άπνοια** (ειδικά όταν επαναλαμβάνεται)
- Αποτελεσματικότητα **αντι-Ε θεραπείας**
- Τελειόμηνα με **παθολογική νευρολογική** εικόνα
- Εφαρμογή σε νεογνά **μετά το χειρουργείο**
- **Ωρίμανση εγκεφάλου**
- **Διερεύνηση** συγγενών **ανωμαλιών εγκεφάλου, Εμφρακτο**
  Συγγενείς καρδιοπάθειες, ΧΜΝ, δια-χές μεταβολισμού,
  Συγγενείς λοιμώξεις, IVH ±PHVD, NAS

Ictal apnea

- Rhythmic epileptic discharge
- Usually accompanied by other clinical manifestations (eye deviation, eye opening)
- Rarely associated with bradycardia
- Mesial temporal lesions (Deepa Sirsi et al., 2007; Hoogstraate et al, 2009)
- Occipital lesions (Castro Conde et al, 2012)

Variane et al 2023

Pisani F et al 2016

aEEG Measurements

Pattern Recognition:

- Continuous/discontinuous
- Sleep/wake cycles
- Burst Suppression
- Seizures

Measurements:

- Lower margin
- Upper margin
- Amplitude
- Distance between bursts

Always look at:

- Impedance – goodness of signal
- Raw Trace – artifact, seizures, burst suppression

Continuous
Normal
Voltage

> 10 AND > 5

Discontinuous
Normal
Voltage

> 10 AND < 5

Burst
Suppression

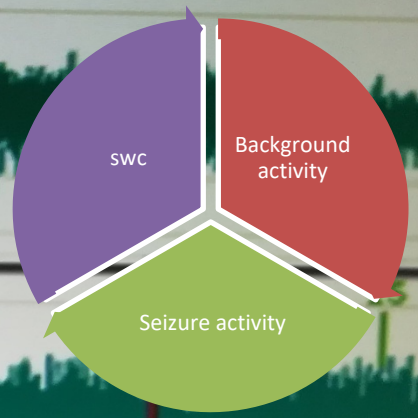
> 25 AND < 5

Continuous
Low
Voltage

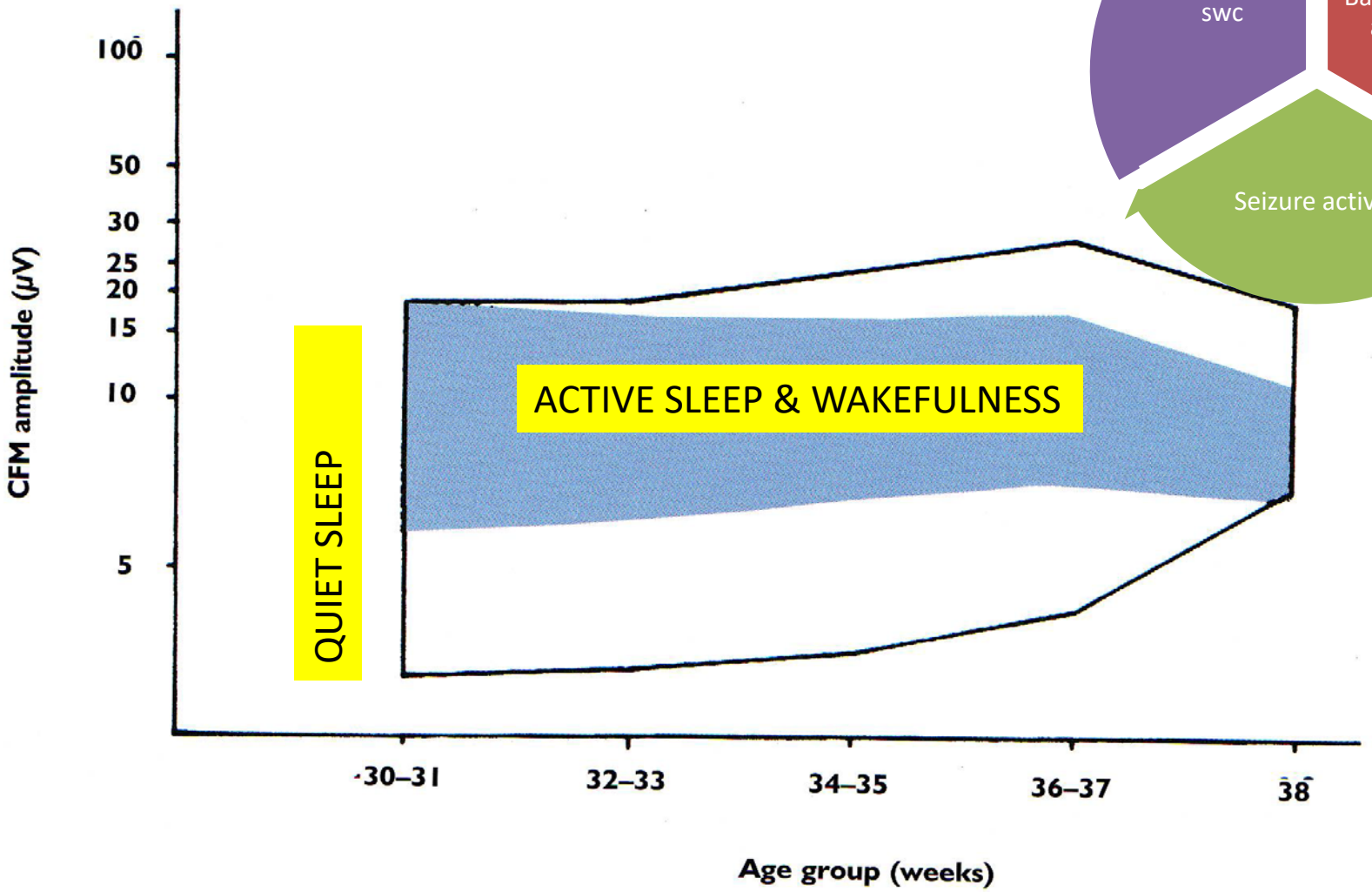
< 10 AND < 5

Inactive
Flat
Isoelectric

< 5 AND < 5



Normal variations in CFM amplitude in different age groups



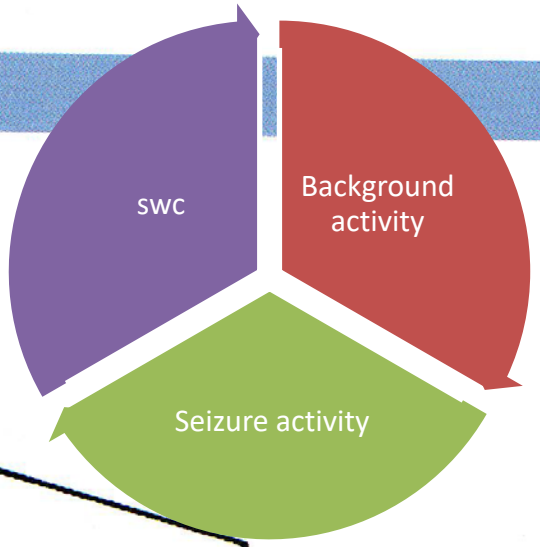
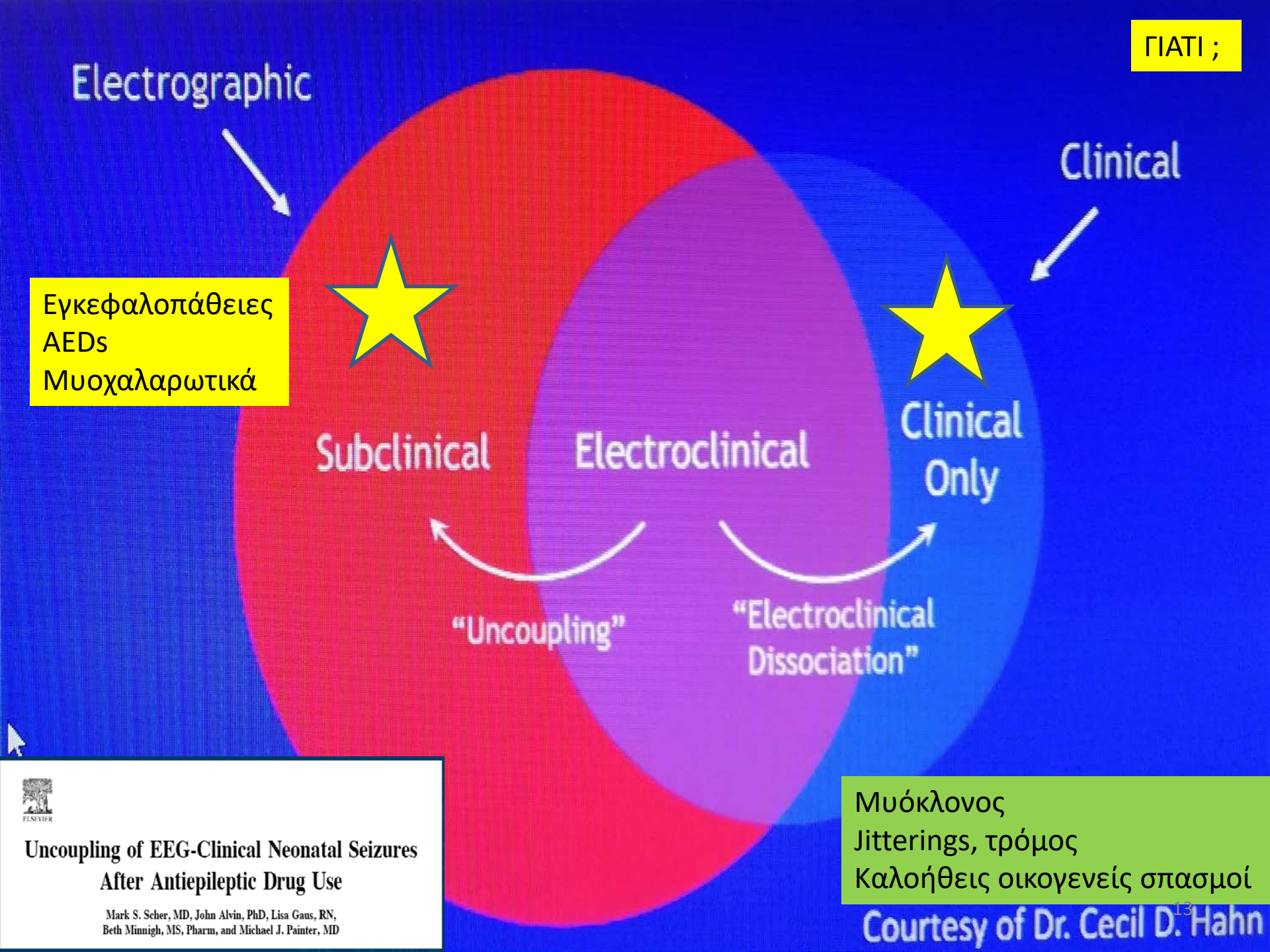


Figure 2.6 Normal variations in CFM amplitude in different age groups. The white area shows the variation of the broadest band width (corresponding to quiet sleep), the colored area the narrowest band width (corresponding to active sleep and wakefulness). From reference 38 with permission

ΓΙΑΤΙ ;



Εγκεφαλοπάθειες
AEDs
Μυοχαλαρωτικά

Μυόκλονος
Jitterings, τρόμος
Καλοήθεις οικογενείς σπασμοί

ELSEVIER

Uncoupling of EEG-Clinical Neonatal Seizures After Antiepileptic Drug Use

Mark S. Scher, MD, John Alvin, PhD, Lisa Gaus, RN, Beth Minnigh, MS, Pharm, and Michael J. Painter, MD

Courtesy of Dr. Cecil D. Hahn

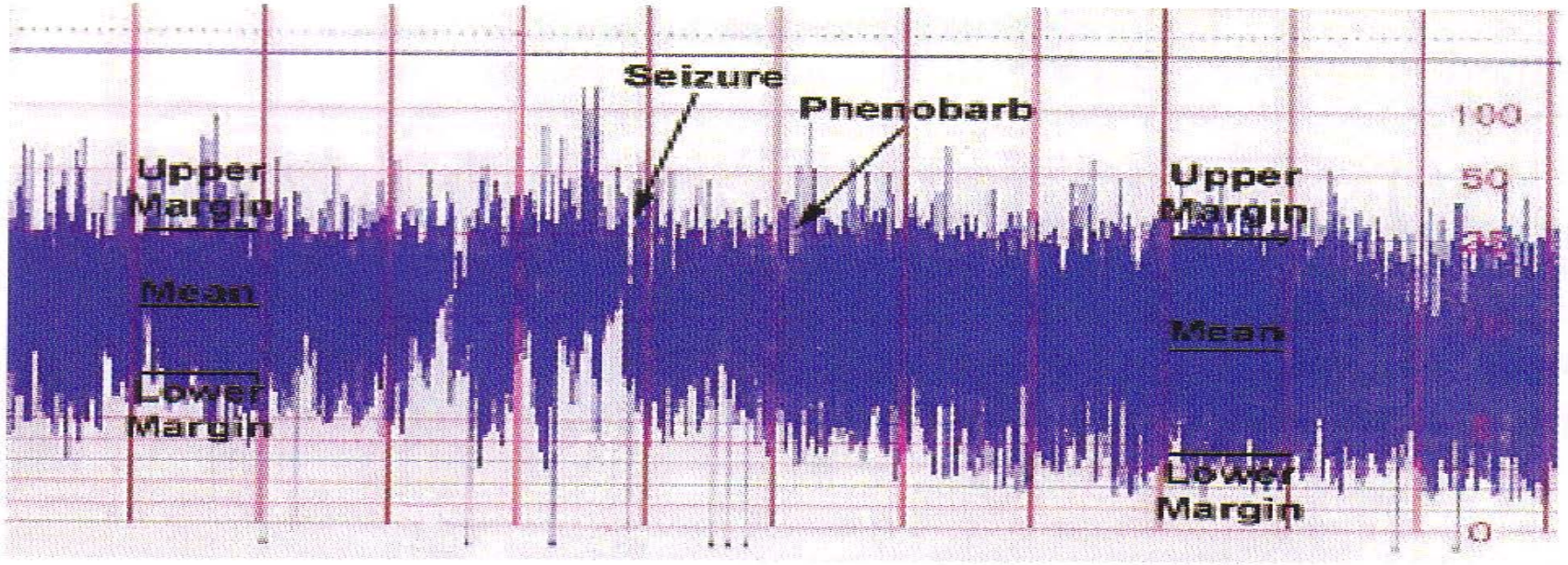


Figure 5. Moderately Abnormal with Seizures and Administration of Phenobarbital

Moderately Abnormal with Seizures and Administration of Phenobarbital

This trace shows a moderately suppressed background. There is no indication of sleep/wake cycling, but the lower margin is generally above 5 μvolts. There is evidence of occasional seizures. Note the expected decrease in the mean and lower margin after administration of phenobarbital.

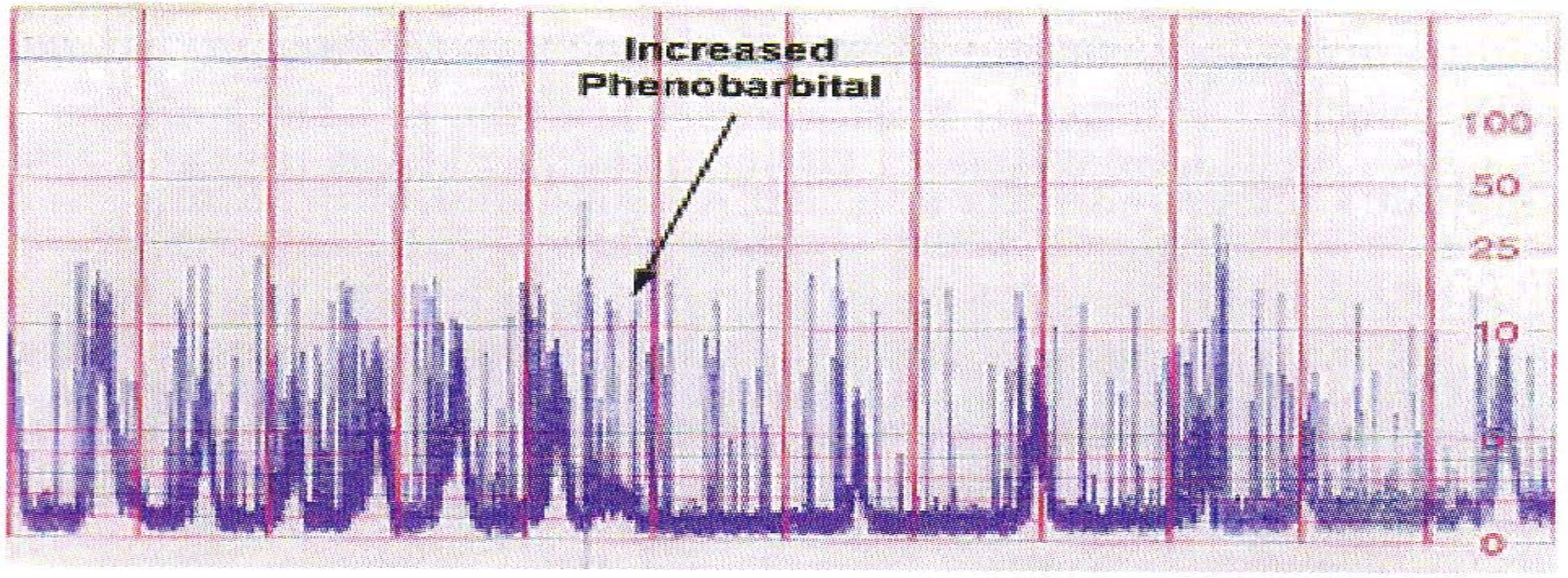


Figure 6. Severely Abnormal with Frequent Seizures

Severely Abnormal with Frequent Seizures and Administration of Phenobarbital

≥10 sec

An example of a severely suppressed background with frequent seizures. Note the decrease in the frequency of the seizure after an increase in the dose of phenobarbital. Due to the already severely suppressed background there is no noticeable effect on the amplitude.

α-ΗΕΓ & Σπασμοί

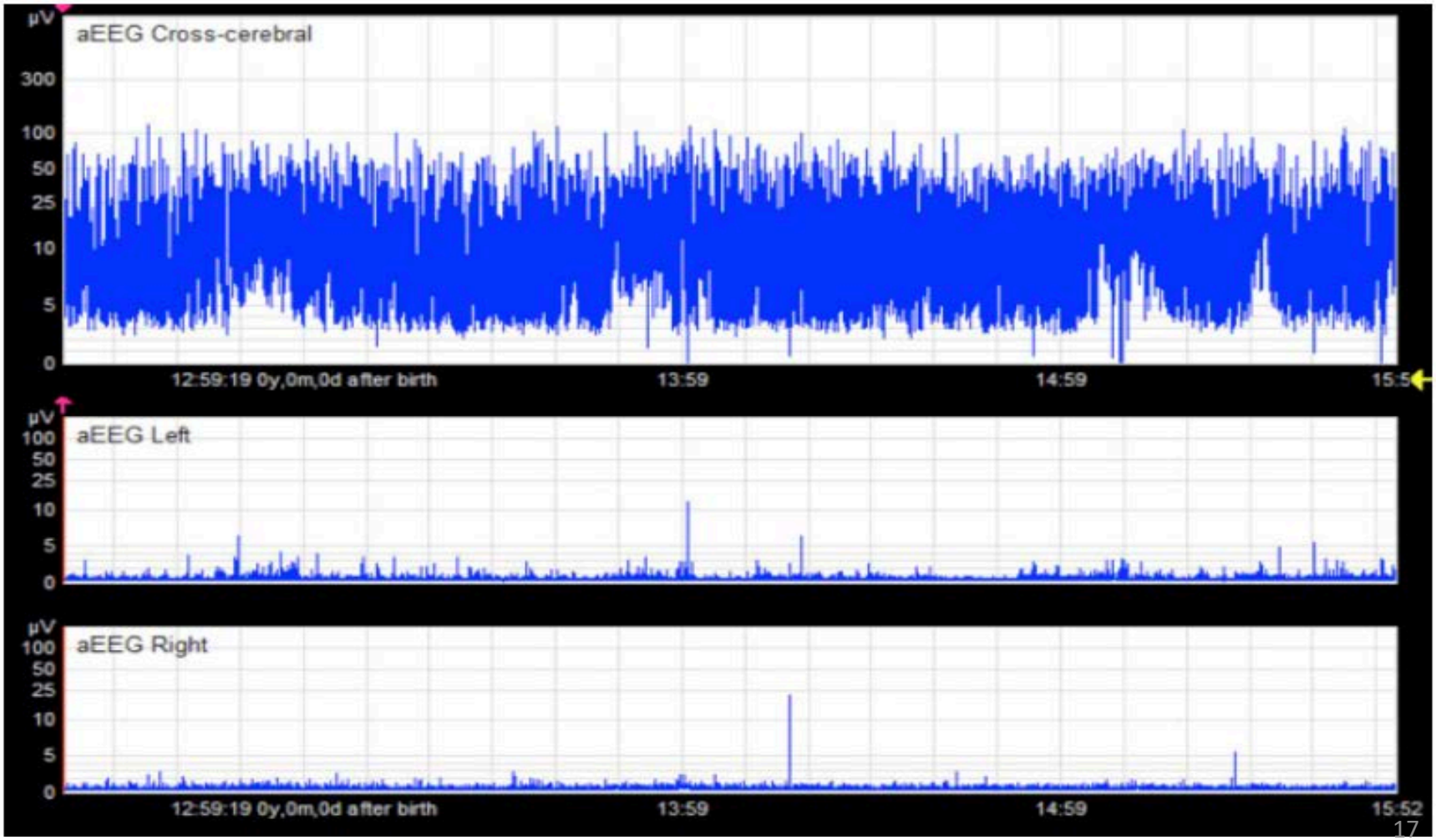
Εκτίμηση 1

- Εναρξη σπασμών
- Διασπορά
- Διάρκεια (seizure-burden, status epilepticus)
- Αποτελεσματικότητα φαρμάκων
- Φαινόμενο uncoupling

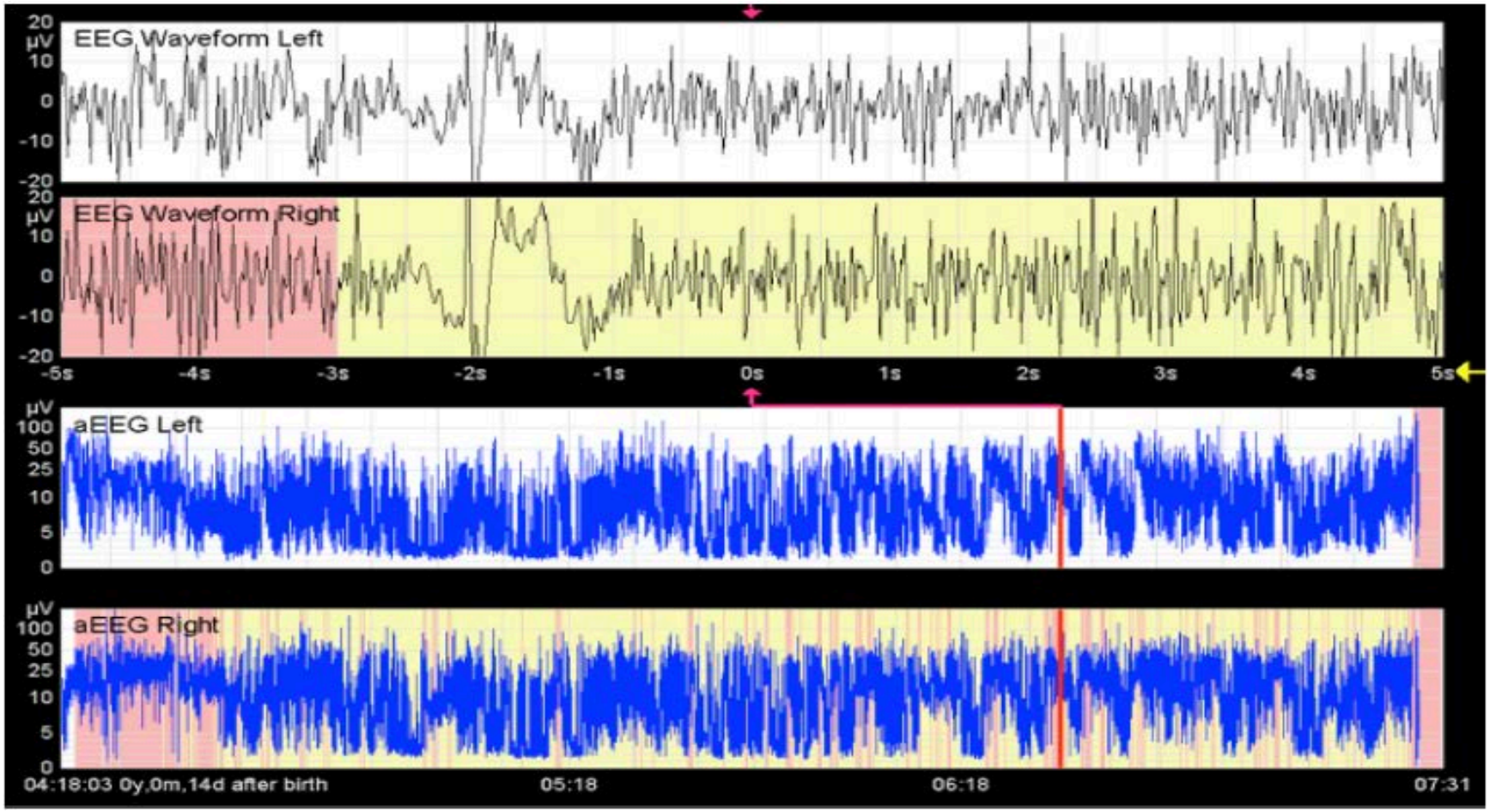
Εκτίμηση 2

- Προσδιορισμός ΚΝΣ βλάβης
- Εκτίμηση βαρύτητας ΚΝΣ βλάβης
- Προγνωστικός δείκτης

Flat trace > Ιδρώτας ή gel μεταξύ 2 ηλεκτροδίων



Υψηλή συχνότητα (frequency) & αύξηση εύρους (amplitude) : δίκην σπασμών !!> κίνηση μυών, HFOV



Bruns N et al. Jove 2017

ΓΙΑ ΠΟΣΟ ;

ACNS GUIDELINE

The American Clinical Neurophysiology Society's Guideline on Continuous Electroencephalography Monitoring in Neonates

Renée A. Shellhaas, Taeun Chang,† Tammy Tsuchida,† Mark S. Scher,‡ James J. Riviello,§ Nicholas S. Abend,‖ Sylvie Nguyen,¶ Courtney J. Wusthoff,# and Robert R. Clancy‖*

Recommendations

- Minimum of 24 hours
- If no seizures and EEG background is stable, stop after 24 hours of monitoring
- During Therapeutic Hypothermia full 72 hrs and rewarming

J Clin Neurophysiol, 2011

NDI:Νευροανάπτυξη

Φυσιολογική

- Continous background & presence of SWC within 1st wk of life

  Soubasi V et al 2012

Παθολογική

- Pathol Background activity & absence of SWC

  Variane GFT et al 2017, Shellhaas RA 2007, Patrizi S 2003, Kidokoro H 2012, Wikström S 2012

- Background +SWC+seizure activity > CUS

  Klebermass K 2011

- Higher seizure burden

  Kharoshankaya L 2011

All types of EEG monitoring will be ineffective if no one looks at the EEG regularly during the monitoring period .....

NIRS
Near Infrared Reflectance Spectroscopy

ΦΑΣΜΑΤΟΣΚΟΠΙΑ ΕΓΓΥΣ ΥΠΕΡΥΘΡΗΣ ΑΚΤΙΝΟΒΟΛΙΑΣ

Ανάγκη συνεχούς παρακολούθησης της εγκεφαλικής οξυμετρίας για την έγκαιρη θεραπευτική παρέμβαση με σκοπό τη βελτίωση της έκβασης των νεογνών

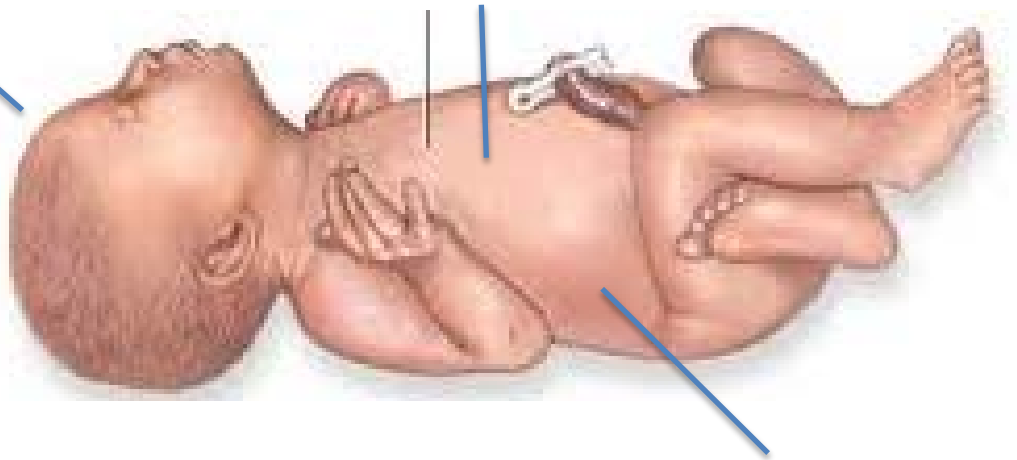
Clinical Application

Continous Real Time Bedside monitor of regional tissue oxygenation

Cerebral rSO_2:
High Flow/High O_2 extraction tissue
Typical range **60%-80%**

Abdominal rSO_2:
Variable flow/lower extraction tissue

Right or Left side of forehead



Right or Left lower quandrant

Posterior flank below costal margin & above iliac crest (T10-L2)

Peri-Renal rSO_2:
Variable flow/lower extraction tissue
Typical range **5% - 20%** > $CrSO_2$

Hoffman GM, et al. Semin Thorac Cardiovasc Surg Pediatr Card Surg Annu. 2005
Petrova A et al. Pediatr Crit Care Med. 2006
Dent CL. et al. J Thorac Cardiovasc Surg. 2005

ΕΝΔΕΙΞΕΙΣ ΧΡΗΣΗΣ NIRS

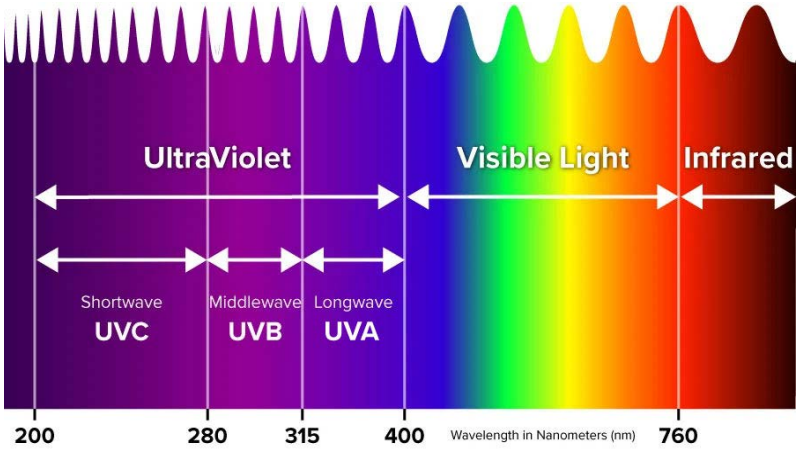
Indications for NIRS

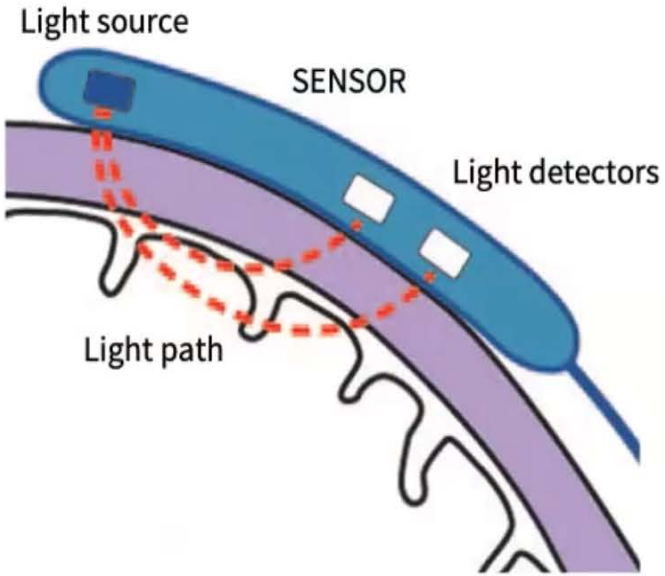
- HIE /NE
- PDA
- At risk for IVH
- Autoregulation (critical care)
- Post surgery

Glass H 2011

- **Προωρότητα < 28 εβδ** για τις πρώτες 72 ώρες ζωής (με επηρεασμένη εγκεφαλική αυτορύθμιση ?)
- **YIE, IVH** (για 72 ώρες μετά τη διάγνωση), **υδροκέφαλος** (για 72 ώρες μετά τη διάγνωση)
- **Συγγενής Καρδιοπάθεια** (αιμοδυναμικά σημαντική) πριν το χειρουργείο
- **Αιμοδυναμικά σημαντικός ΑΒΠ** για 48-72 ώρες (τοποθέτηση και στην νεφρική χώρα) >> πριν την θεραπεία 24ώρες, σε χειρουργική αντιμετώπιση ή τοποθέτηση καθετήρα 24 ώρες πριν -72 ώρες μετά
- **Νεογνά που λαμβάνουν ινότροπα, υδροκορτιζόνη** για υπόταση (τοποθέτηση και στην νεφρική χώρα)
- **Διεγχειρητικό /Μετεγχειρητικό στάδιο**
- **Υπογλυκαιμία, σπασμοί**

How does NIRS work?





- Placement of sensor on neonate's skin
- Light passes from light source to detectors after passage through underlying tissue
- Tissue oxygen saturation (rSO_2) reflects a ratio of arterial and venous blood (25%:75%) and the balance between oxygen delivery and consumption in underlying tissue

Adapted from Davie, et al. *Anesthesiol*, 2012.

rSO_2

% percentage of oxygenated hemoglobin / total hemoglobin

$$rSO_2 = \frac{HbO_2}{HbO_2+HHb}$$

↑ rSO2 : hyperoxia, red O2 utilization

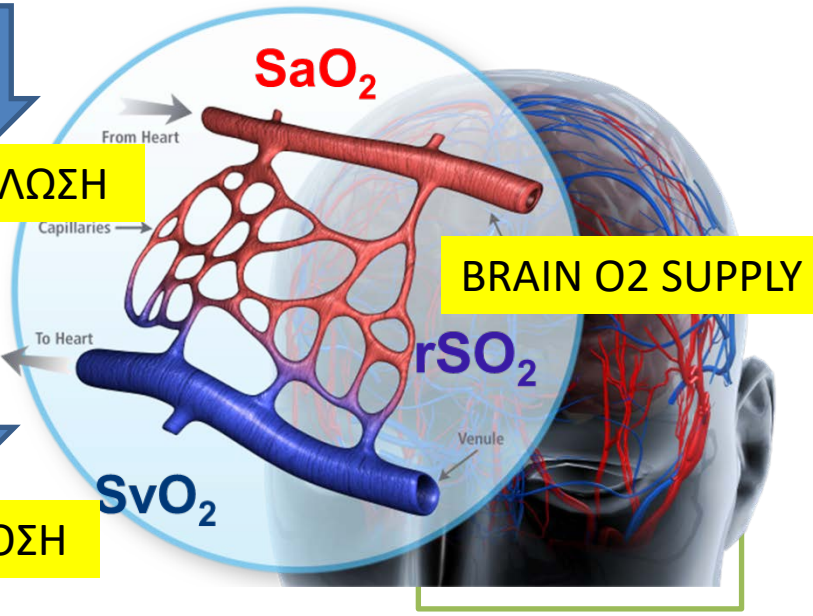
↓ rSO_2 : hypoxia, incr O2 utilization)

- indicates oxygen saturation: 70- 80% in venous blood
  20- 25% in arterial blood
  5% in capillaries
- considering arterial : venus blood is 15: 85

DELIVERY =ΜΕΤΑΦΟΡΑ

CONSUMPTION=ΚΑΤΑΝΑΛΩΣΗ

ΑΠΟΔΟΣΗ



BRAIN O2 SUPPLY

NIRS is a capillary level measurement of primary venous blood, reflecting the the perfusion status & oxygenation status of undelying BRAIN tissues

Leon et al 2019

MONITORS OXYGENATION & PERFUSION (ΟΞΥΓΟΝΩΣΗ & ΑΙΜΑΤΩΣΗ)

Target cerebral saturation ranges using NIRS

rSO2	Term	Preterm
Cerebral (%)	66-89	66-83
Renal (%)	75-97	64-87
Mesenteric (%)	63-87	32-66

Values differ by sensor type with neonatal sensors reading 10% higher

Alderliesten T, et al. Ped Res (2016)

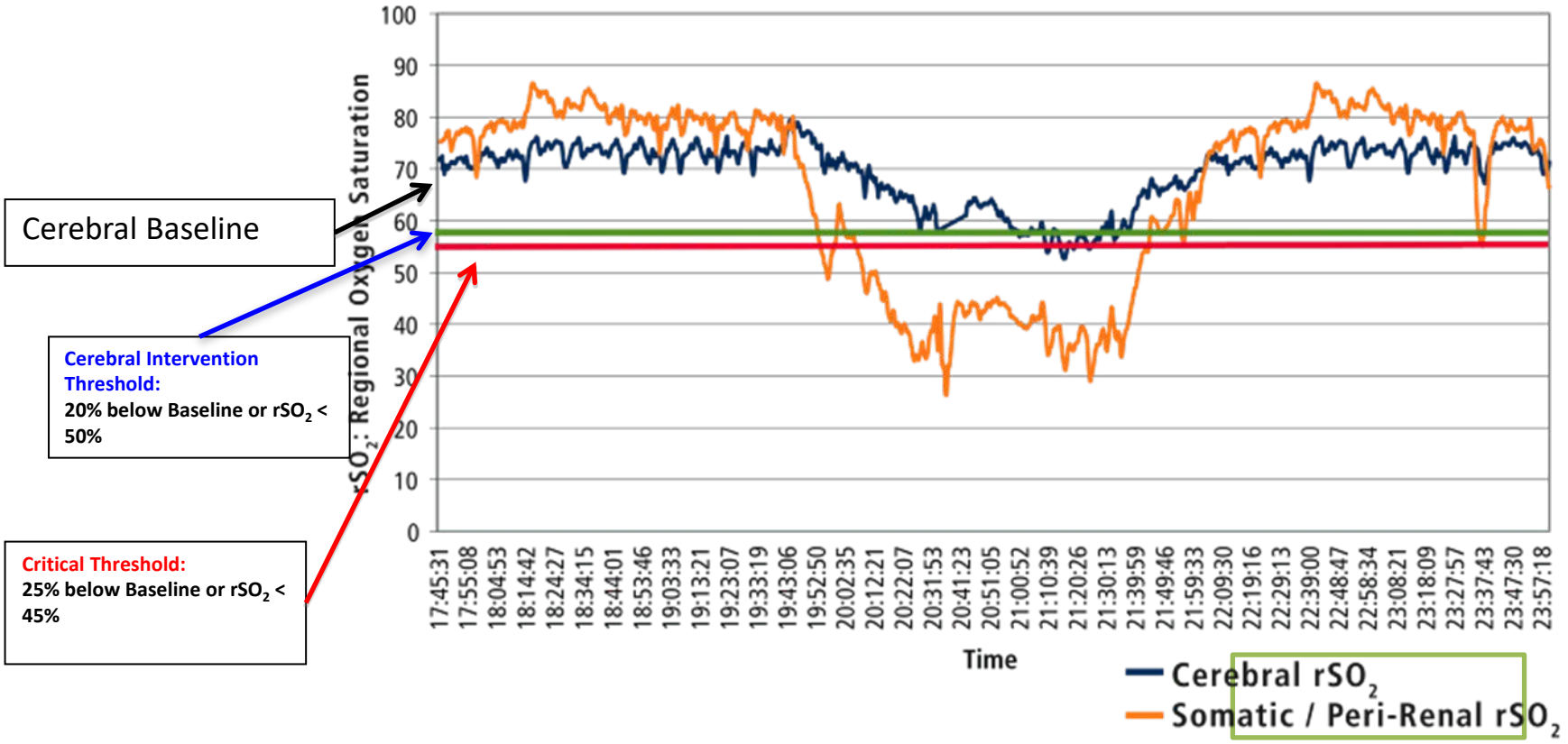
Algorithm for interventions for babies with rScO2 < 55%

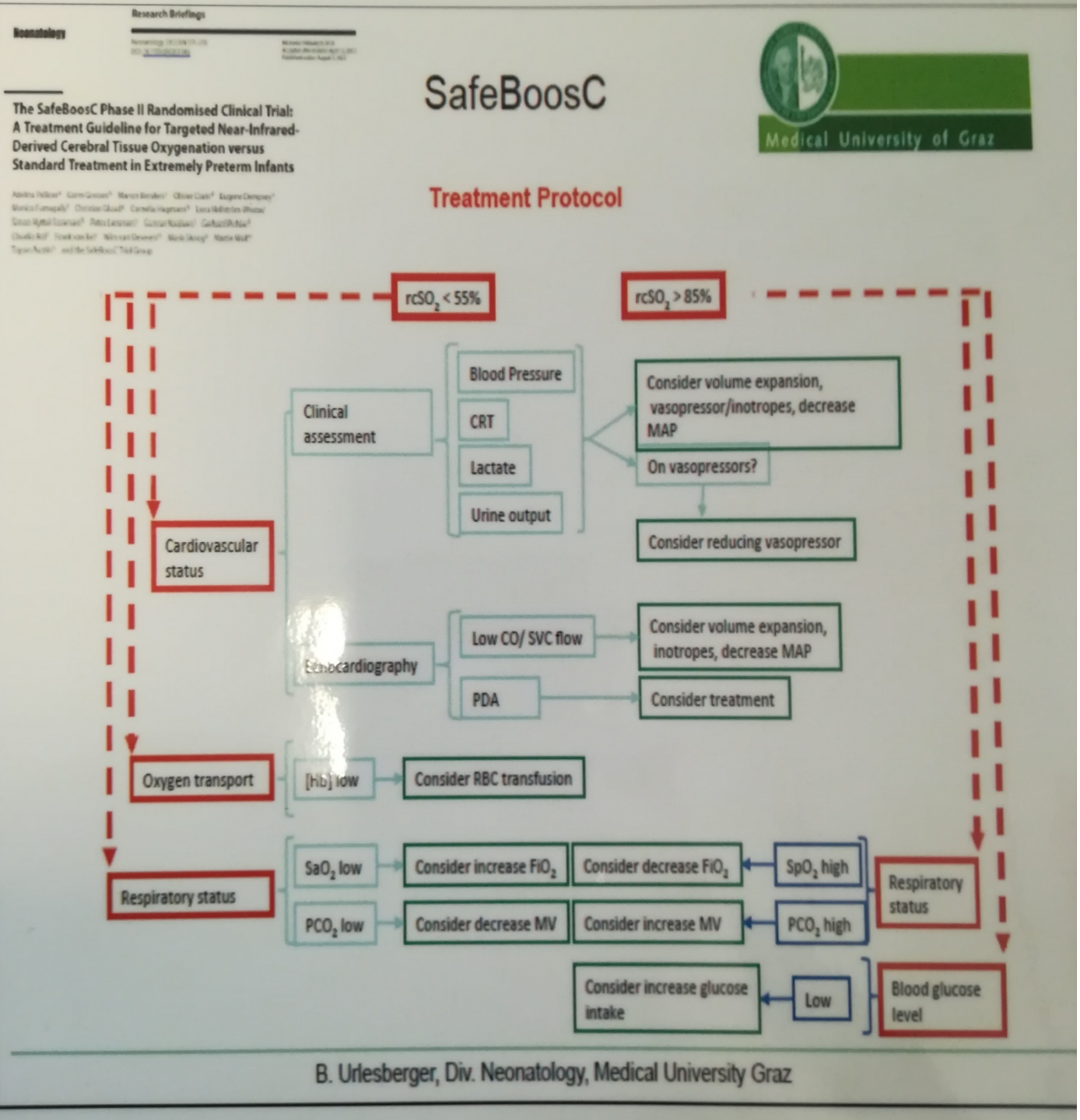
Dix *et al.*, *Pediatr Res* (2014);
Alderliesten *et al.*, *Pediatr Res* (2015)

Baselines and Thresholds

- **important to set patient's baselines before the initiation of recording**
- **peri-renal 5-20 points > cerebral rSO_2**

ΜΕΤΑΒΟΛΕΣ >15-20% > ΕΚΤΙΜΗΣΗ !!!





Παροχή O_2

- Συγκέντρωση Hb
- SaO_2
- Καρδιακή παροχή (HR, προφορτίο, συσταλτικότητα μυοκαρδίου, μεταφορτίο)

Ανάγκες O_2

- Αυξημένες: πυρετός, ρίγος, στρες υποθερμίας, λοίμωξη, σπασμοί, πόνος
- Μειωμένες: υποθερμία, καταστολή/παράλυση, μειωμένη απορρόφηση, περιγεννητική ασφυξία (δευτερογενής ενεργειακή ανεπάρκεια)

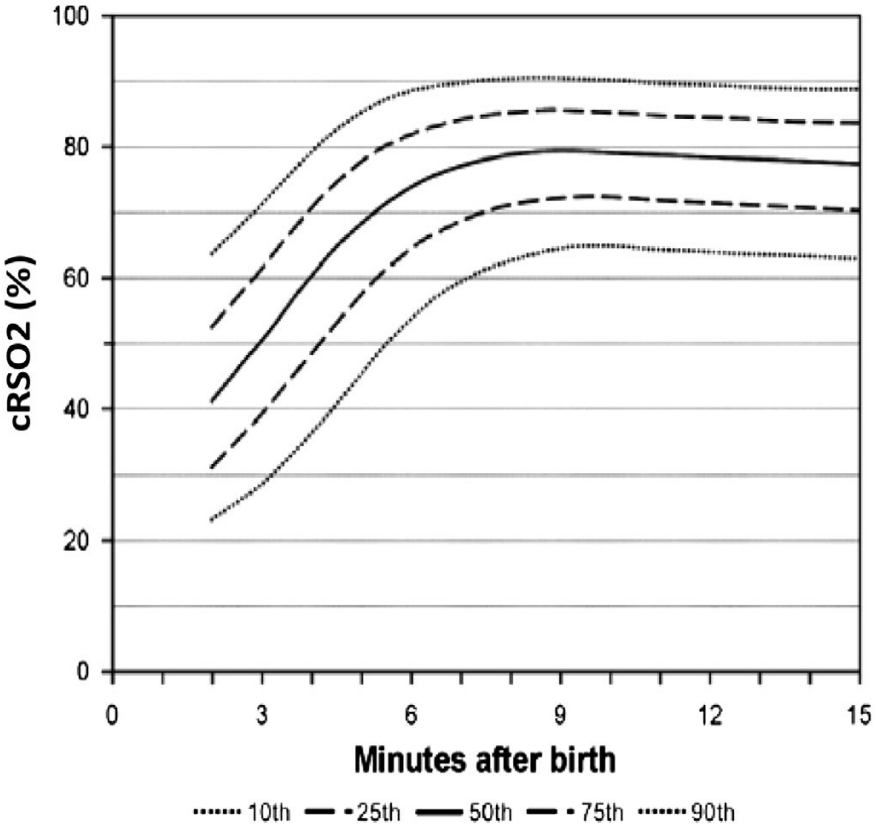
Practical approaches

- **Reference values**
- **Hemodynamically significant PDA**
- **Hypotension – hemodynamic instability**
  -Loss of cerebral autoregulation
- **Cardiac collapse**
- **PCO_2 fluctuations**
  -Severe RDS: high pressure support in mechanical ventilation

Transition after birth

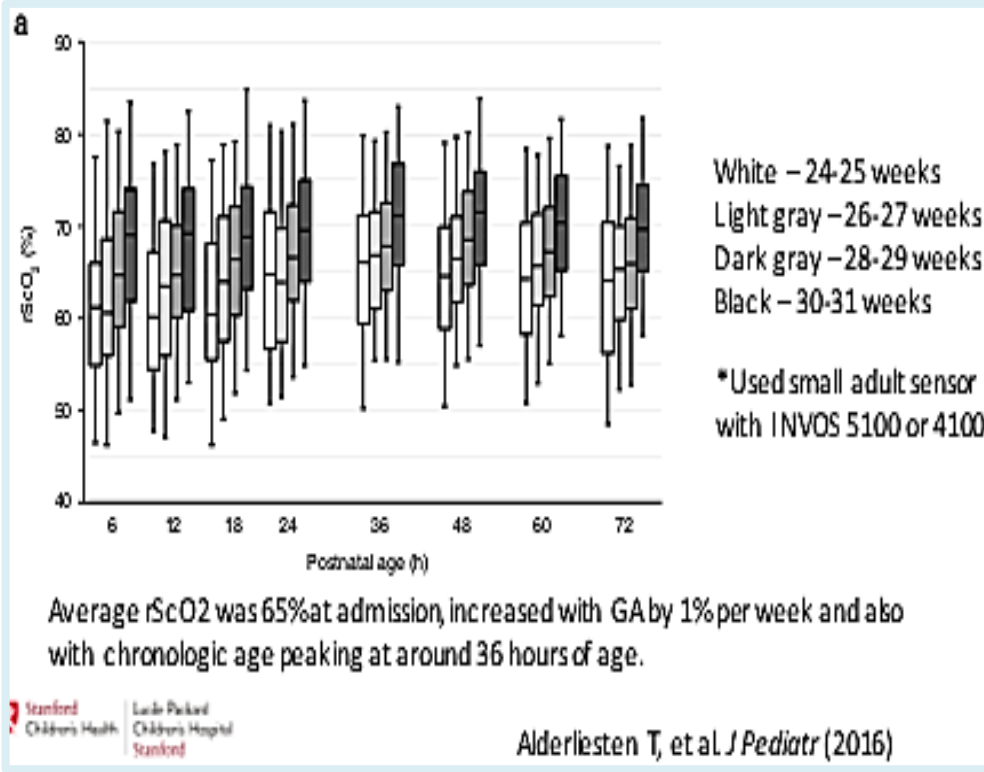
Cerebral regional oxygen saturation in term and preterm neonates requiring no medical support

CEREBRAL OXYGENATION DURING NORMAL TRANSITION



Pichler G. et al. Reference ranges for regional cerebral tissue oxygen saturation and fractional oxygen extraction in neonates during immediate transition after birth. J Pediatr 2013

CEREBRAL OXYGENATION BY GESTATIONAL AGE & TIME

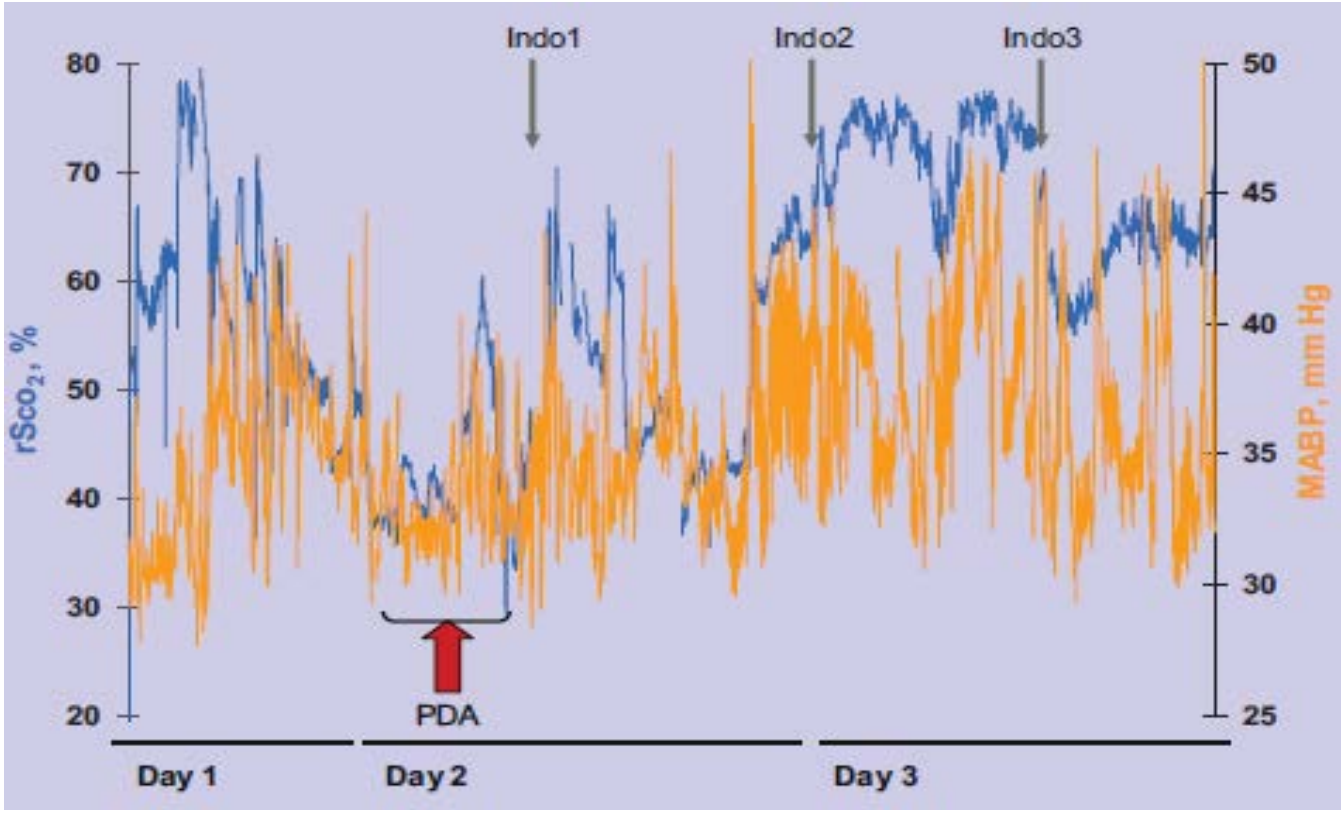


Patent ductus arteriosus

Improvement of cerebral oxygenation after PDA closure with indomethacin

In case of a PDA, SGA infants demonstrated a significantly larger fall in cerebral oxygenation, as compared to AGA infants

Cohen E. et al. Reduction in cerebral oxygenation due to PDA is pronounced in SGA neonates. Neonatology 2017



$rScO_2$

Επαναφορά σε φυσιολογικά όρια μετά από τη φαρμακευτική σύγκλιση

P.M.Lemmers et.al. Pediatrics 2008

Hypotension

0031-3998/11/6906-0548
PEDIATRIC RESEARCH
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Cerebral Tissue Oxygenation and Regional Oxygen Saturation Can Be Used to Study Cerebral Autoregulation in Prematurely Born Infants

ALEXANDER CAICEDO, DOMINIQUE DE SMET, GUNNAR NAULAERS, LIEVEKE AMEYE, JOKE VANDERHAEGEN, PETRA LEMMERS, FRANK VAN BEL, AND SABINE VAN HUFFEL

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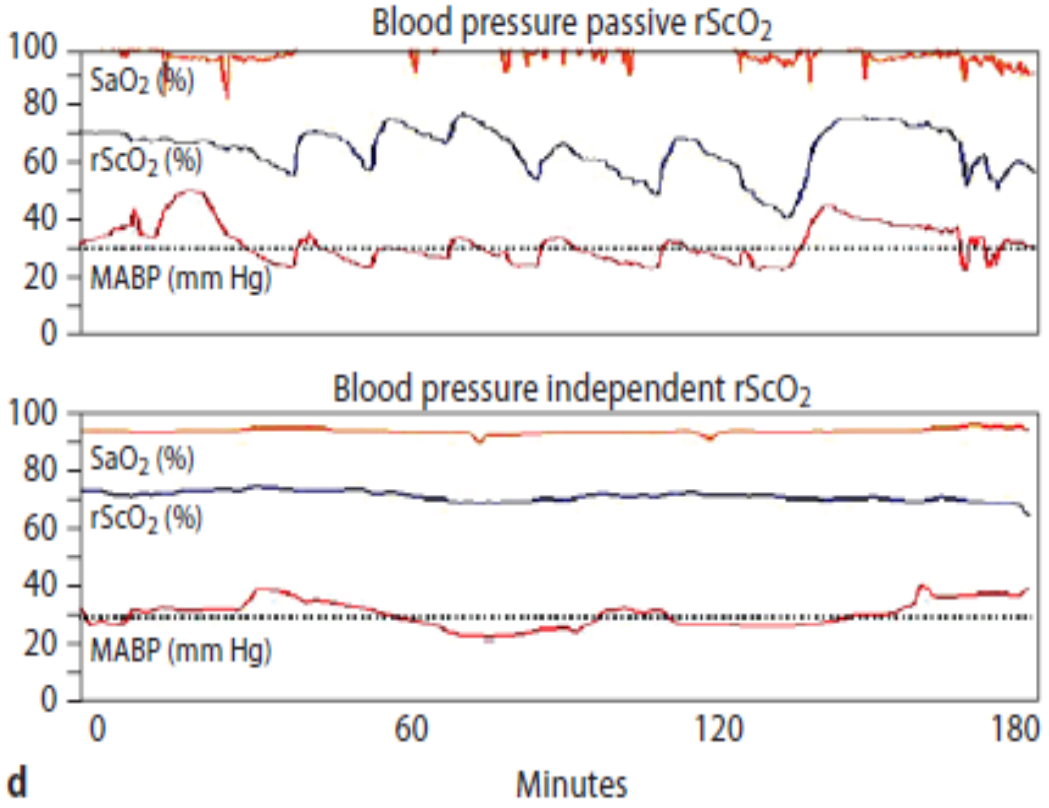
Impairment of cerebral oxygenation (lack of cerebral autoregulation)



Van Bel et al 2008

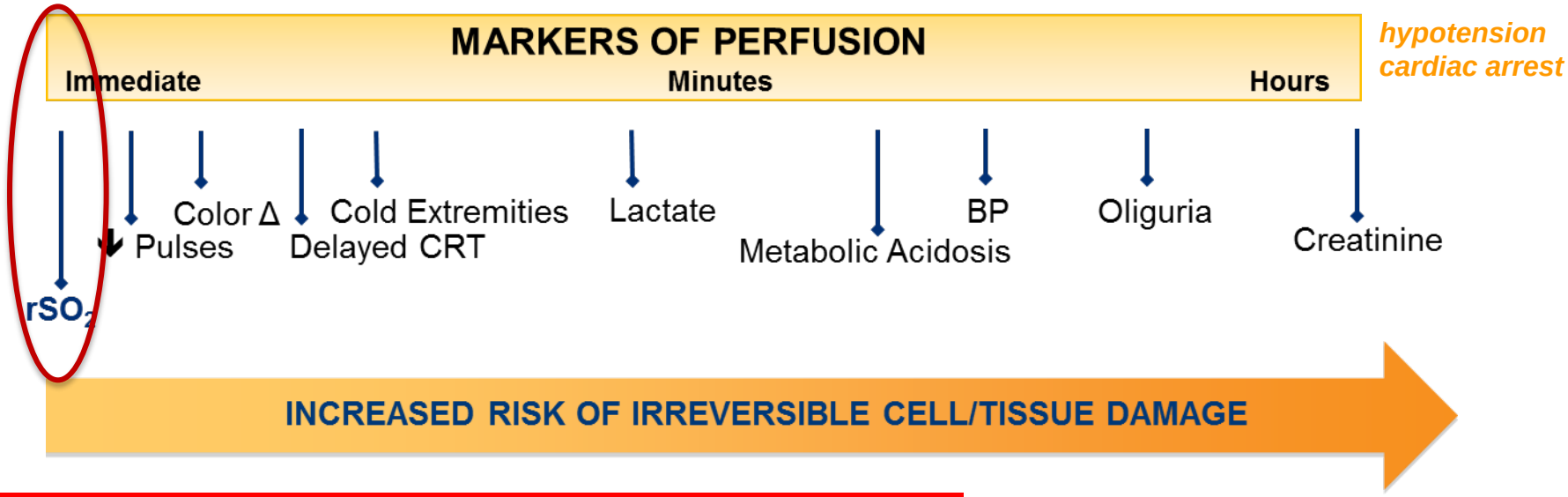
TOHOP study:
determine the stage at which hypotension treatment is warranted, based on ScO_2

ClinicalTrials.gov: NCT01434251

A.Caicedo et.al. Cerebral tissue oxygenation and regional oxygen saturation can be used to study cerebral autoregulation in prematurely born infants. Pediatr. Res. 2011

Cardiovascular collapse

Early detection of ischemia



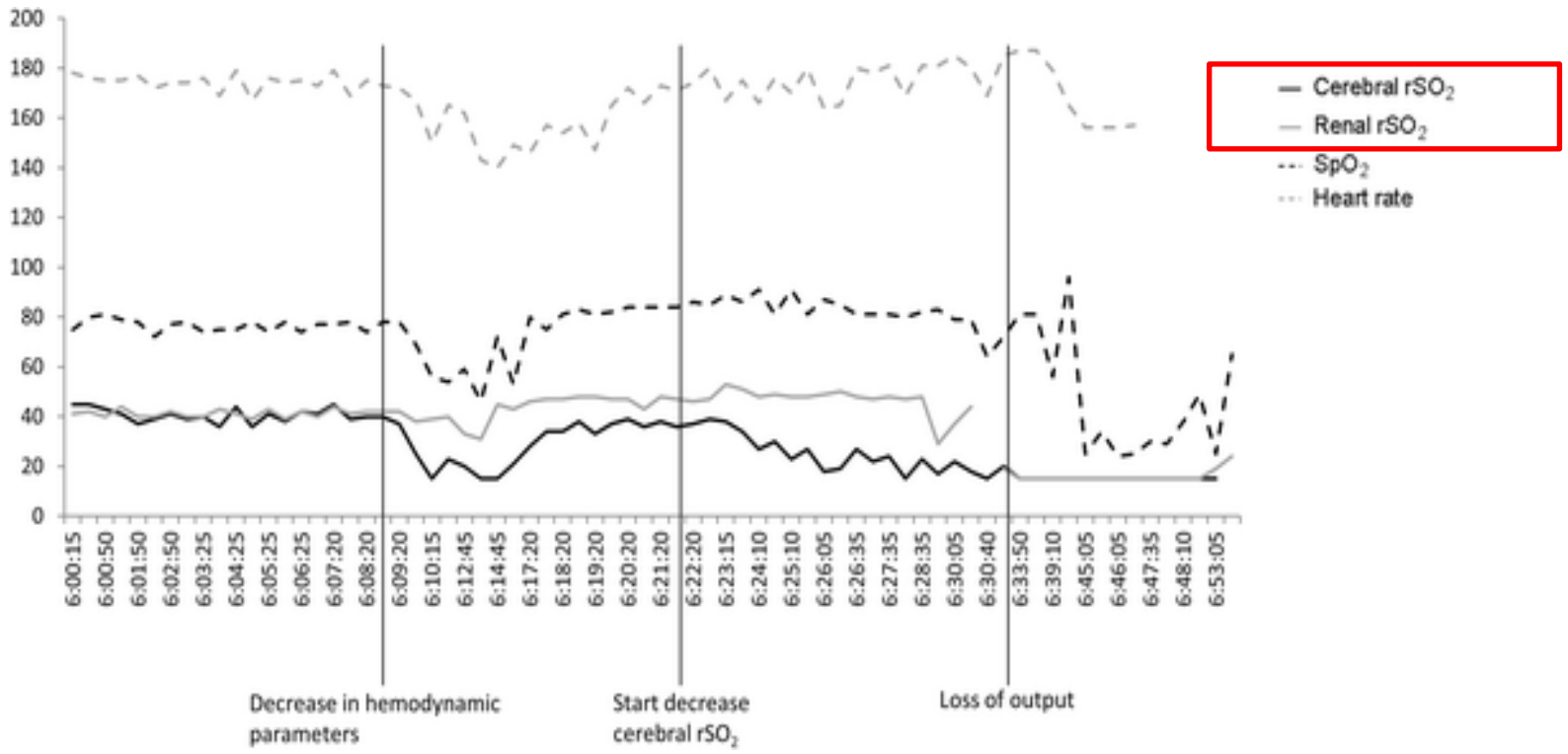
INDIRECT MEASUREMENT of PERFUSION-OXYGENATION

DIRECT MEASUREMENT ?

Blood Pressure, Heart Rate, satO2, Hb concentration, mixed venous oxygen saturation (SvO_2)

Sood B et al 2015

Cardiovascular collapse

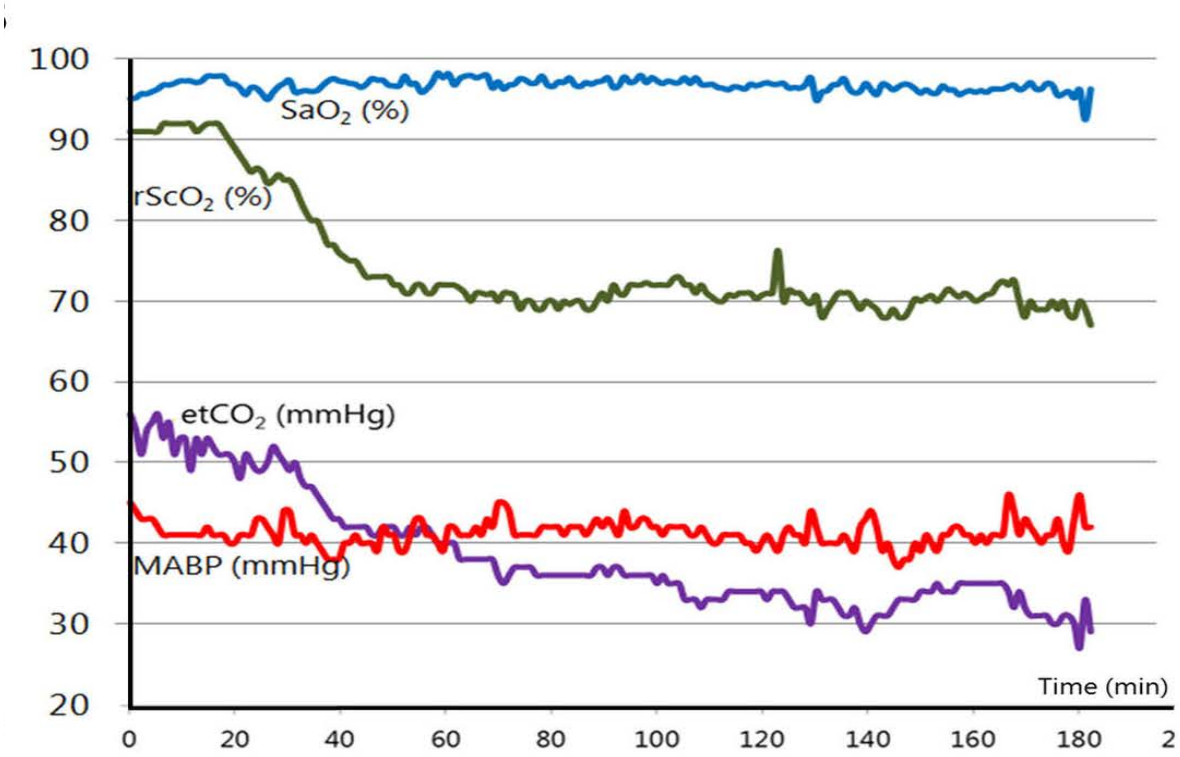


Conclusions: These two cases demonstrate that near-infrared spectroscopy might contribute to detecting a deteriorating clinical condition and might therefore be helpful in averting cardiopulmonary collapse and need for resuscitation in infants with congenital heart disease.

Pulmonary atresia with intact VS

NIRS as a predictor of clinical deterioration: a case report of two infants with duct-dependent congenital heart disease. Mebius MJ et al. BMC Pediatrics 2017

NIRS και αναπνευστική υποστήριξη

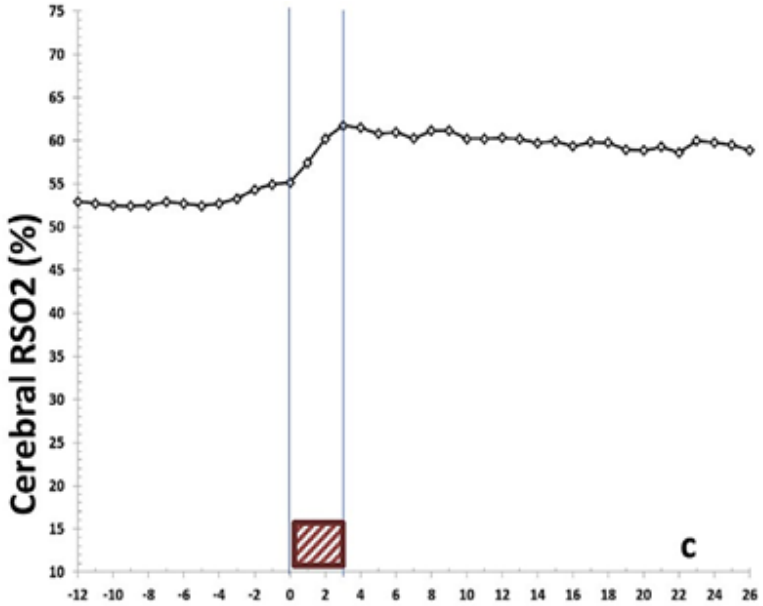


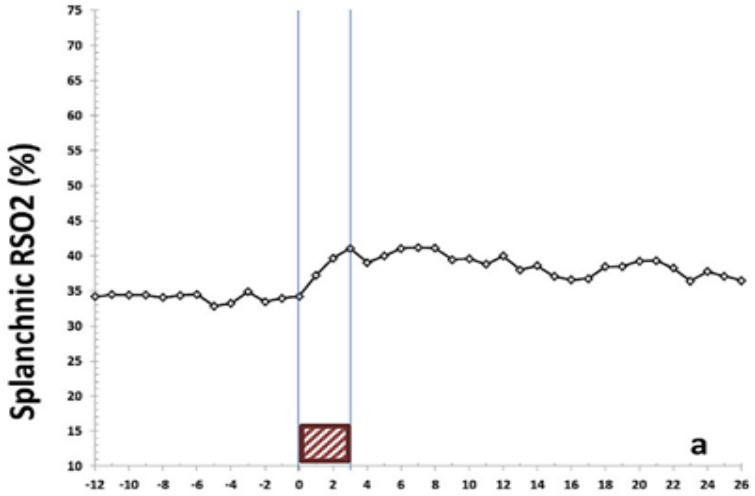
from Ref. (14). **(B)** Acute end-tidal CO_2 ($etCO_2$) decrease results in a subsequent reduction in $rScO_2$, on the contrary arterial oxygen saturation (SaO_2) remains stable. MABP, mean arterial blood pressure. **(C)** $rScO_2$ during hypothermia and after rewarming (rew) in two severely asphyxiated infants. The infant with an adverse

Dix et al 2017

ΜΕΤΑΓΓΙΣΕΙΣ

Improvement of splanchnic and cerebral oxygenation during red blood cell transfusion





rScO2 at risk when Hb< 9.7 gr/dl

Va Hoften JC et al 2010

- **improvement of splanchnic and cerebral oxygenation during red blood cell transfusion**

- $rScO_2$ και FTOE δείκτες αναγκαιότητας μετάγγισης >↑ $rScO_2$ και ↓FTOE μετά από μετάγγιση
- $rScO_2$, ιστική άρδευση και συμπτώματα βελτιώνονται αν $rScO_2$<55% vs $rScO_2$≥55%
- Δεν υπάρχει συσχέτιση του ύψους του $rScO_2$ και του Hct

- **$sRSO_2$ response can potentially be a biomarker to identify infants who are likely to develop NEC after red blood cell transfusion**

Sood BG et.al. Near Infared spectroscopy as a biomarker for NEC following red blood cell transfusion. J Near Infrared Spectrose 2014

NIRS+aEEG

Neuro-NICU eligibility and recommended neuromonitoring

Diagnosis	Monitoring
1. HIE/cooling	aEEG, cEEG
2. Seizures	aEEG and cEEG
3. ECMO/pre-ECMO	NIRS and consider aEEG
4. Grade III/IV IVH or PHVD	aEEG
5. Critical/unstable	NIRS and consider aEEG
6. Preterms <28 weeks	aEEG and NIRS
7. CNS anomalies cEEG	cEEG and/or aEEG
8. Metabolic disease	cEEG and/or aEEG
9. Cyanotic CHD	NIRS
10. CNS infection	cEEG and/or aEEG
11. Symptomatic PDA	NIRS
12. ALTE/BRUE	aEEG
13. Hyperbilirubinemia > 20 or hemolytic process	NIRS and consider aEEG

ALTE, apparent life-threatening event; BRUE, brief resolved unexplained events; CNS, central nervous system; ECMO, extracorporeal membrane oxygenation; PDA, patent ductus arteriosus.

Variane et al 2023
Van Meurs et al 2018

ΠΕΡΙΓΕΝΝΗΤΙΚΗ ΑΣΦΥΞΙΑ (Sarnat III)- Υποθερμία

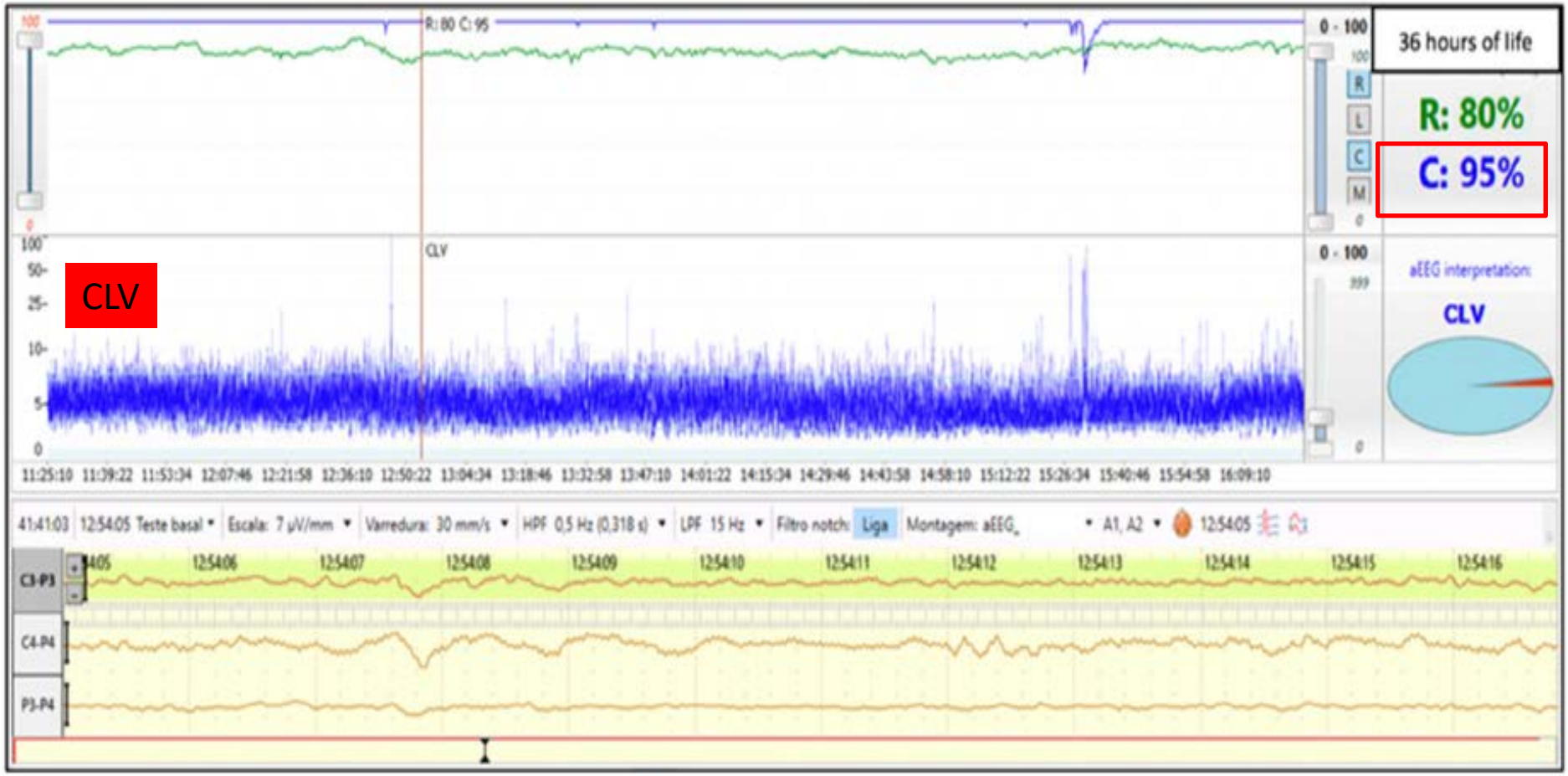


FIGURE 1 | Brain monitoring (aEEG and NIRS) in a term infant undergoing cooling for severe HIE (Sarnat stage III) shows a supranormal $rScO_2$ of ~95% while aEEG displays a continuous low voltage pattern.

ΑΙΜΟΔΥΝΑΜΙΚΗ ΑΣΤΑΘΕΙΑ (ΣΗΠΤΙΚΟ SHOCK)

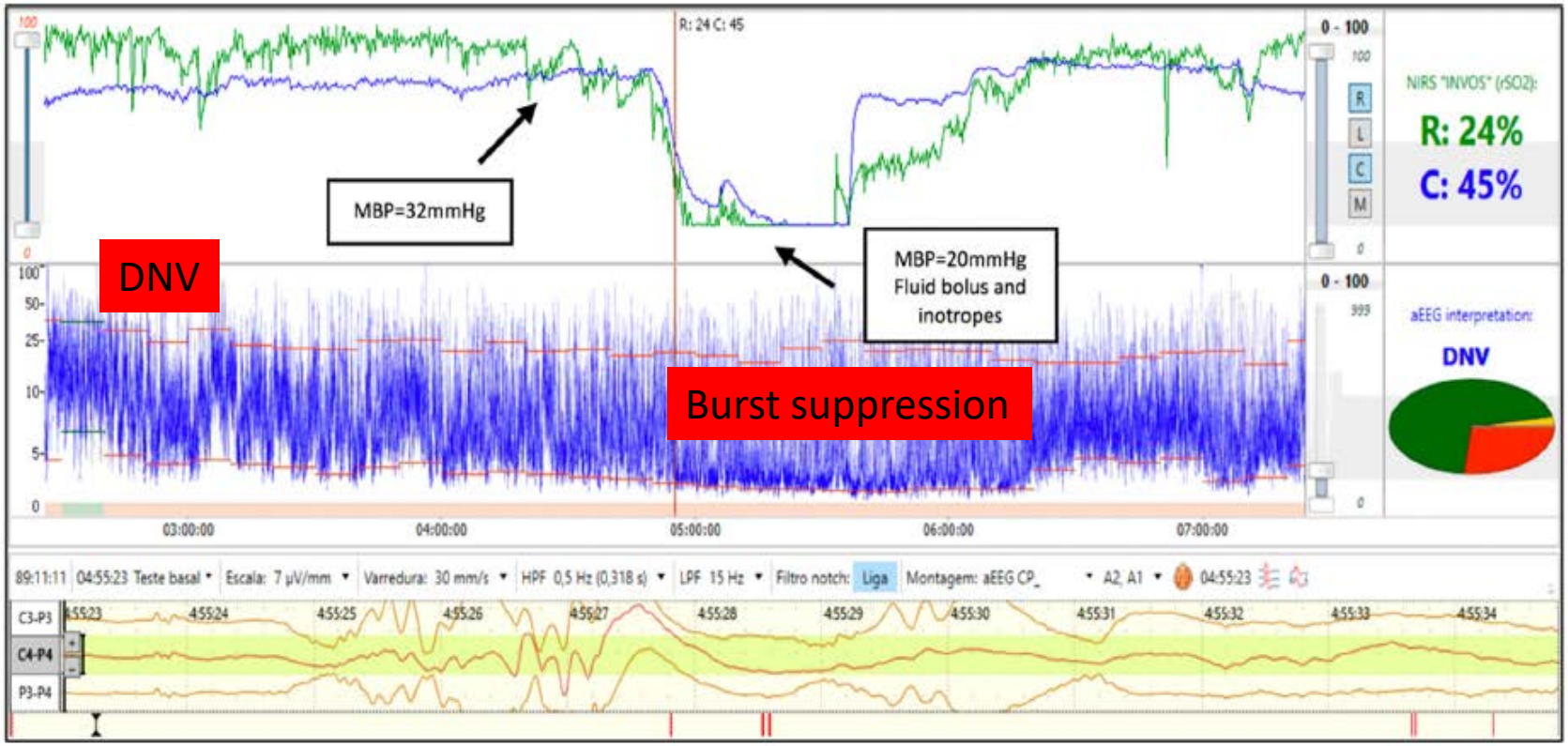
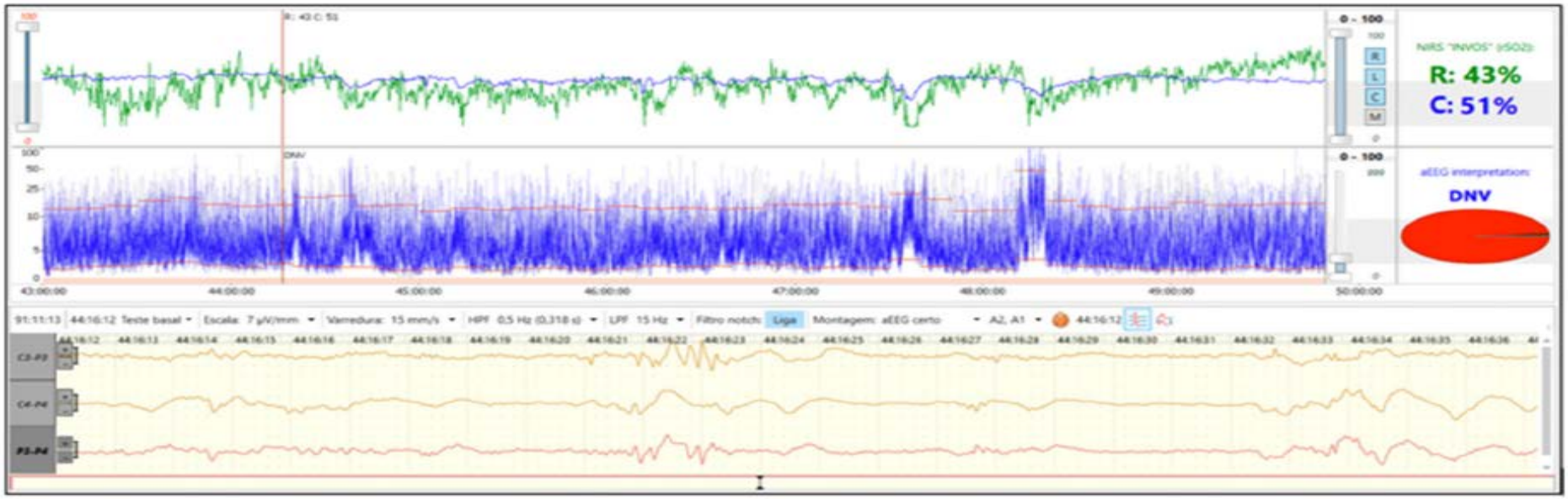
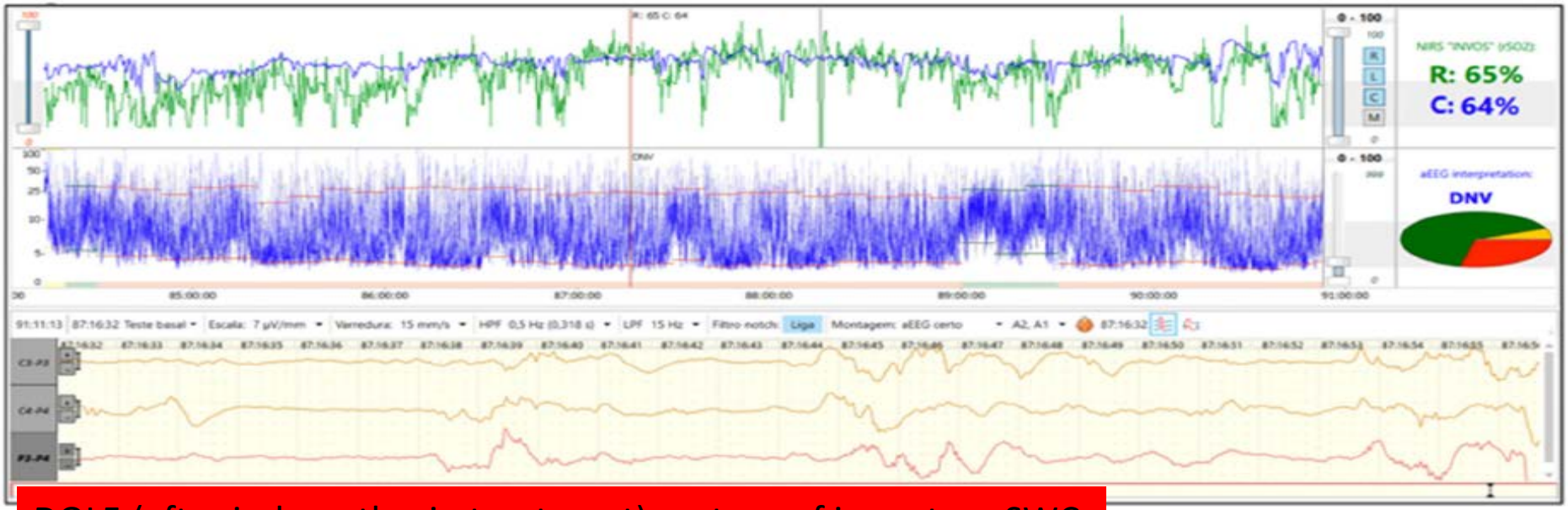


FIGURE 2 | Brain monitoring (aEEG and NIRS) in a preterm infant with septic shock. In this infant with hemodynamic instability an early decrease in $rSrO_2$ with normal mean blood pressure (32 mmHg) is seen followed by a decrease in $rScO_2$ and associated aEEG burst-suppression (BS) and low blood pressure. After fluid bolus and inotropes, a recovery of $rScO_2$ is noted and associated with recovery of background activity to discontinuous normal voltage (DNV).

DOL3 :DNV with loss of SWC, hsPDA

PDA 3rd DOL





DOL5 (after indomethacin treatment) : return of immature SWC

Variane G et al 2020

PDA closed 5th DOL

ΝΕΟΓΝΙΚΗ ΕΓΚΕΦΑΛΟΠΑΘΕΙΑ -ΣΠΑΣΜΟΙ

FIGURE 4 | Brain monitoring (aEEG and NIRS) in a preterm infant with severe anemia after placental abruption who had clinical seizures on 1st day of life. The aEEG demonstrates a flat tracing with seizure activity (arrow). Simultaneous NIRS tracing shows supranormal $rScO_2$ which transiently decrease during seizure activity.

Variane G et al 2020

ΣΥΜΠΕΡΑΣΜΑΤΑ

- Η συνεχής παρακολούθηση του ΚΝΣ (Neuromonitoring) δίπλα στον ασθενή είναι σημαντική κατά την **παρακολούθηση νεογνών υψηλού κινδύνου & σοβαρής νοσηρότητας**

- Η συνεχής παρακολούθηση του ΚΝΣ έχει βελτιώσει δραματικά την δυνατότητα **εκτίμησης** νεογνών υψηλού κινδύνου για πρόκληση εγκεφαλικής βλάβης , ως **προγνωστικό εργαλείο νευροεξέλιξης και νευροαποκατάστασης**

- Παθολογικά πρότυπα στην α-ΗΕΓ και παθολογικές τιμές στο NIRS **σχετίζονται με εγκεφαλική βλάβη** και κατ'επέκταση με την νευροανάπτυξη

- Ο συνδυασμός α-ΗΕΓ +NIRS , CUS +/- MRI ως πολυπαραγοντικό μοντέλο παρακολούθησης προσφέρει **σημαντικές πληροφορίες για την κατάσταση** του εγκεφάλου